EXECUTIVE SUMMARY

ANNUAL REPORT 2008

Outcome Line

SBA-2

Improved Cassava for the Developing World

CIAT

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TABLE OF CONTENTS PAGE NO.

SBA-2 Improved Cassava for the Developing World

1. Narrative Project Description

Rationale & Changes

Rationale:
Cassava is a very rustic crop that grows well under marginal conditions where few other crops could survive. Most cassava varieties are drought tolerant, can produce in degraded soils, and are resistant to the most important diseases and pests. The crop is naturally tolerant to acidic soils, and offers the convenient flexibility that it can be harvested when the farmers need it. These characteristics make this crop a fundamental food security component in marginal agriculture land. In addition to its important role in subsistence farming and food security, cassava is acquiring an increased role in rural development as raw material for many industrial applications. The most important industrial uses of cassava are as a source of energy in animal diets in the feed industry, for the starch industry and, more recently for the production of ethanol.

The main objective of the project has traditionally been for a high and stable productivity (through breeding and adequate cultural practices), which remains a fundamental goal for the varieties to be grown by resource-limited cassava farmers. However, there is an increasing interest in cassava as cash crop and its industrial uses, which do not only require high and stable productivity but also would benefit from specialty cassava with specific properties. Unfortunately, very little effort has been made to make a qualitative improvement of cassava to better fit the needs of the different industries. The globalization of economies and new technological breakthroughs are offering a unique opportunity for cassava never available to the crop before. Tropical production of maize is facing increasing problems in competition with maize from temperate regions. This situation has prompted government and private sectors of many tropical countries to turn to cassava as a competitive alternative to imported maize. In addition, advances in molecular biology, genetic engineering, plant-tissue culture protocols and starch technologies provide important tools that will allow bridging the main gaps between cassava and the cereals. There are three main approaches that have been implemented to face the new opportunities and challenges for cassava in the third millennium, which are described below.

1. *More efficient breeding scheme.* For cassava to remain competitive, a more efficient breeding scheme, particularly for low heritability traits such as yield, has been implemented. Changes introduced ranged from simple approaches such as the stratification of evaluation trials all the way to sophisticated molecular approaches such as marker -assisted selection for resistance to the Cassava Mosaic Disease, which is not present in the Americas.

2. *Qualitative traits.* In addition to changes for a more efficient breeding system for quantitative traits (≈ low heritability) we have shifted the objectives of the project to produce high-value cassava based on qualitative traits. In addition to high and stable productivity the project started to pay attention to quality of cassava roots. The HarvestPlus program will produce clones with enhanced nutritional value particularly

in relation to carotenoids, Fe and Zn. For the **animal feed industry** and human nutrition, increased protein content is the main objective. Clones with three times the normal levels of proteins have been identified. For the **starch industry** novel starch types are of huge economic relevance. Different strategies have been implemented to develop these novel types and a diversity of mutations have been identified, and among them, the long sought after mutation for a waxy cassava starch. For the production of **bioethanol** we are searching for a "sugary" cassava that will store molecules simpler-than-starch facilitating the fermentation process. Such mutations have been identified and we are trying to gain access to them, so they can be incorporated in the main breeding process. Other identified mutations (high amylose, small granule size, etc.) may reduce the costs of enzymes used in the fermentation process.

3. *Sustainable and competitive production.* Cassava cultivation can lead to negative impact to the environment because it is typically grown in marginal environments, which are more susceptible to degradation; because it is grown by resource-limited farmers that have little flexibility or capacity to introduce sound agronomic practices because the increase their production costs; and because of the scarcity of research in developed countries that may contribute to a more sustainable production of cassava. CIAT and the valuable intervention of CLAYUCA are conducting research to reduce the negative impact that cassava cultivation may have on the environment. This research has been particularly important in Asia where the introduction of contour hedgerows has been successful.

Changes:

The discovery of cassava germplasm with unique quality traits such as the high-protein roots, the waxy starch and different starch mutants resulted in increased emphasis in the creation, evaluation and sharing of genetic stocks related to Outputs 1 and 3. Because of the time involved in the transfer or introgression of high-value traits into mainstream gene pools there will be a heavier emphasis in these activities than anticipated. Departure of the molecular geneticist during 2008, along with financial constraints in that area of research has reduced the our capacity in that area of research.

CG System Priorities:

CIAT's cassava project is housed principally under Priority area 2 (Producing more and better food at lower cost through genetic improvements). All the priorities listed within this area are considered by the project: Maintaining and enhancing yields and yield potential of food staples; Improving tolerance to selected abiotic stresses (in our case particularly drought, low-fertility soils and acid soils); Enhancing nutritional quality and safety (specifically cassava roots with enhanced protein, carotenoids, Fe and Zn); and genetically enhancing selected high-value species. The last priority somewhat relates to the concept of high-value cassava such as the development of what is basically a "new crop" such as a clone whose starch contains almost no amylose (waxy starch).

The cassava project is also connected with Priority Area 4 (Promoting poverty alleviation and sustainable management of water, land and forest resources). The cassava project has conducted extensive research for the last decade and a half to promote sustainable production of cassava in Asia, particularly in sloped land. The main emphasis has been promoting adequate fertilization and the use of hedgerows to prevent soil erosion. These activities can be seen as related to priority 4D (Promoting sustainable agro-ecological intensification in low- and high-potential areas).

Our efforts to develop high-value clones relates to priorities Making international and domestic markets work for the poor (5B); Increasing income from livestock (3B), for instance through the development of clones with enhanced nutritional value; promoting conservation and characterization of staple crops (1A) and Promoting conservation and characterization of underutilized plant genetic resources (1B).

Impact Pathways:

Output 1: Maintenance and distribution of accessions from the germplasm collection.

This is an activity that is maintained by the Genetic Resources Unit of CIAT under the management of the curator of the germplasm collections. However, there is a close collaboration between the cassava-project and the Genetic Resources Unit. The several areas of collaboration include growing large number of accessions from the collection in the field for further phenotypic characterization, evaluations of the core collection across three contrasting environments (mid-altitude valleys, sub-humid environment and acid soil savannas), and the initiation of a process to obtain self-pollinated seed from each accession as a back-up conservation strategy (of genes, not genotypes). Related to this output is the interest to identify sources of stress tolerance and/or wide adaptation (Output 2) and high-value traits (Output 3) from the germplasm collection. The identification of useful sources of genes / traits within the germplasm collection has a direct benefit for the end users of these traits (the farmers) and an indirect effect justifying and highlighting the need for adequate conservation and screening of genetic resources in cassava and other crops.

Output 2: Genetic stocks adapted to the most common cassava growing environments and their abiotic stresses, with emphasis in drought.

This output involves the development of improved germplasm to be shared, typically through NARs and IITA, with cassava farmers. Because of the diversity of environments where cassava is grown and the frequency of different production constraints, this germplasm has to have specific traits that allows it to adapt to these conditions characterized by biotic and/or abiotic stresses. The main outcome for this Output is the consolidation and strengthening of cassava based agriculture by developing a germplasm that will allow for a high and stable productivity. A competitive production of cassava is a key factor to be able to compete with other commodities, typically (imported) maize. This output describes the traditional breeding activities conducted by the project. A significant change in this activity has been the recent introduction of high-value traits in the list of objectives and this creates a connection with several other Outputs. All these Outputs ultimately involve the same end-users but with varying emphases: national research programs; the processing sectors; cassava farmers and rural communities; and production chains. Whereas this is true for Asia and Latin America and the Caribbean, in the case of Africa, we have the additional presence of IITA

The competitiveness of cassava can be increased considerably with the introduction of high-value traits, which is the main objective of Output 3. The way germplasm is shared is through direct shipment of *in vitro* plants from outstanding clones identified in CIAT's breeding activities in the sub-humid, acid soils, or mid-altitude valleys environments. In addition CIAT routinely produces and ships thousands of botanical seeds to NARs and

IITA, who initiate evaluation and selection schemes with this seed. Assumptions for the successful delivery of these outputs include institutional and financial stability of partners, political stability, and institutional support. It is always a matter of concern the phytosanitary restrictions for the shipment of plants in vitro. The African Cassava Mosaic Disease is not present in the Americas. If the disease (or a similar one) appeared in Colombia, the shipment of germplasm in vitro would be greatly hampered. The role of CIAT is that of a primary research provider of the improved germplasm. It is important to emphasize that, at times, our role is of secondary research provider exploiting traits or elite germplasm developed (and generously shared) by NARs. *Manihot esculenta* originated and was domesticated in the region where CIAT is located. Consequently most pest and diseases have co-evolved with cassava in the region. This implies that CIAT has to be extremely cautious in the process of shipping germplasm outside the region by a thorough indexation process to prevent the shipment of pathogens and/or pests as well.

Otuput 3: Clones with high-quality traits for food, feed, starch and ethanol industries identified or bred.

This output relates with the previous two outputs. The end-users are national research programs; the processing sectors; cassava farmers and rural communities; and production chains. The emphasis, however, are the processing sectors and production chains. A new actor that is not as important for the other Outputs are Universities in developed and developing countries. A good example of the economic relevance of the outcomes of this output is when cassava is used as source of energy in animal feed. Its price cannot be higher than 70% of the price of maize. This is because of the lower protein content in the roots. A cassava clone with 8% protein in their roots (dry weight basis) would make the value of that root similar to that of maize. The immediate consequences of deploying such cassava germplasm would be that the income of farmers will increase; the feed industry will be more interested in incorporating cassava roots in their feeds; and because there is an intermediate process (drying the roots) which typically takes place near the production fields, there will be enhanced economic activity in rural communities as well. Assumptions for the successful delivery of these outputs include institutional and financial stability of partners, political stability, and institutional support. CIAT can be the primary research provider but also may act as secondary provider, if it was a partner who discovered the high-value trait. A key collaborator in this case is EMBRAPA-Brazil because of the wealth of genetic variation found in that country for *Manihot* species. This collaboration may result in a study case for the exploration, analysis and exploitation of Manihot species different from cassava because they have not been included as those with facilitated access in the International Treaty on Plant Genetic Resources for Food and Agriculture. The targeted end-users that will benefit from this Output are ultimately the actors of the production chains involved in the production of animal feed (higher nutritional value, particularly the high-protein trait); starches (novel types such as the waxy starch) and ethanol for vehicles (roots that store energy in molecules simpler than starch).

A significant development during 2008 has been the establishment of the nutritional quality laboratory at CIAT. This laboratory will enable the cassava-breeding project to initiate, at last, breeding activities for enhanced protein content in the roots. For several years CIAT has known the existence of several genotypes with higher-than-normal levels of protein in the roots. Whereas cassava roots have typically 2-3%, these clones can have up to 6-8%. However, these estimates are based on the traditional approach of measuring N through the Kjeldahl method. Unfortunately the N-to-protein conversion factor in the case of cassava roots may not be the standard 6.25. N quantification is expensive and slow, and would not provide any information regarding quality of the protein (i.e. amino acid composition). The nutrition laboratory will carryout an ambitious study to provide information relating N-content, with NIRs (near-infrared spectroscopy) readings, total soluble proteins for a set of about 600 segregating progenies and hopefully amino acids profiles from a selected group of genotypes.

Output 4: Management of pests and diseases, likely to cause acute problems in large areas planted with cassava.

This output has been an integral part of the cassava-breeding project at CIAT since its inception. The ultimate end-users of the results of this income are the farmers that grow cassava. However, the immediate beneficiary may be different. For the exploitation of genetic resistance to pests and diseases the breeding projects from CIAT, IITA and NARs are clearly the first one benefiting from these products. For approaches related to the biological control of diseases and pests NARs can promote their use but farmers can almost immediately benefit from implementing them. In addition to farmers rural communities benefit from the positive impact that these approaches have on the environment by preventing or reducing the uses of agro-chemicals. These technologies also have a direct impact on the production costs and/or the sustainability of cassava productivity. CIAT's role is as a primary (in some instances as secondary) research provider. An interesting impact from this Output could be a benefit to other crops grown in temperate regions. For instance, cassava is probably the only crop susceptible to white flies that offers a genetic resistance to this pest. It is conceivable that the source of the resistance can be identified, cloned and transferred to other crops so that an additional tool to control "*the pest of the century*" becomes available.

As cassava successfully becomes a source of raw material for different processing alternatives larger plantations will gradually emerge. When this happens, phytosanitary problems are likely to emerge. Of particular concern, are the current emerging insect problems in Asia (particularly in relation to the mealybug and the whiteflies), which could allow CIAT to reenact the successful story of introduction of agents for the biological control of the mealybug in Africa decades ago. The main mealybug and whiteflies species affecting cassava is Asia are different than those in the Neotropics or Africa, so this will be an excellent opportunity to test the efficiency of biological control and genetic resistance in these new set of circumstances.

Output 5: Organizational approaches, processing technologies and cultural practices for competitive and sustainable cassava production, processing and utilization systems.

Increasing the productivity of cassava in Asia using farmer participatory methods relate to this Output. Farmers are the ultimate end-users. The expected outcomes are improved yields and more sustainable production in target countries; increased and more stable income for farmers (for example through improved nutrition and health of farm animals fed with cassava roots and foliage especially during the dry season); and more alternatives for the use of cassava products open to farmers. A key activity is the promotion of adequate fertilization practices and the use of hedgerows to prevent soil erosion in sloped land. NARs are also beneficiaries because the participatory methodologies employed were introduced through this project and is now used for other purposes in the region. The focus of this Output has gradually changed over the years. Whereas prime agriculture areas (for cassava standards) of Thailand were the target ten years ago, now the project concentrates in more marginal environments and resource-limited farmers in Cambodia, Laos and East Timor. CIAT's role is as a primary (in some instances as secondary) research provider. Because of the very nature of this Output, CIAT's role can also be envisioned as an advocate or catalyst for the development and deployment of sound agricultural practices. Assumptions for the successful delivery of these outputs include institutional and financial stability of partners, political stability, and institutional support. In the particular case of our operations in Asia, we are through an inter-phase because the scientist that has been working in cassava research during the last 20 years is close to retirement and a replacement (and the resources required for the position) will soon be needed.

Because of emerging opportunities the research conducted in cassava has integrated with other production systems also promoted within CIAT research agenda by the Regional Office in Laos. Forages, cassava, animal nutrition, production chains, linking farmers to markets, bio-ethanol production for small scale, simple technologies at the village level, and erosion prevention measurements are frequently combined for the benefits or the rural communities where CIAT is working.

This output also relates to the activities conducted by CLAYUCA (Latin American and the Caribean Consortium on Cassava Research and Development). Therefore it does not originate on activities conducted by the cassava project itself, but it is the result of a productive and close collaboration between the two research groups. The main outcome related to the interaction between CLAYUCA and SBA-2 is the adaptation and/or promotion of technologies and products developed by SBA-2 efficiently done by CLAYUCA. The strategic positioning of CLAYUCA as a bridge between SBA-2 project and NARs associated with CLAYUCA has been of great help in making these technologies and products available to NARs. In this regard CIAT can be seen as a secondary research provider and in many ways as a beneficiary of CLAYUCA's activities. Very relevant is the progress during 2008 for the development of automatized fermenting units that will allow the efficient evaluation of "*fermentability*" of cassava roots aiming at the efficient production of bio-ethanol

Output 6: New breeding tools: genetic transformation, use of molecular markers, rapid multiplication and production of doubled-haploids.

This is an important Output, where CIAT has traditional played a leading role. For cassava to remain competitive, efficient breeding methods need to be developed and implemented. This output is related to Output 3 because these new breeding methods must facilitate the discovery and identification of useful, high-value traits. The intended users of this Output are mostly NARs involved in cassava breeding projects. Eventually a processing company may make the significant jump to start its own breeding project, as was the case for several years of a large company in Indonesia. The product of this output is knowledge, which is shared with the intended beneficiaries through scientific publications, training courses, conferences and presentations at scientific meetings. An important vehicle is personal communication through internet, including CIAT Webpage. The products of this Output range from the identification of traits to be selected for (i.e., leaf retention); methods for determining breeding values of parental lines; the use of selection indexes; the development of a protocol for the production of doubled-haploids; the introduction of inbreeding; the identification and use of molecular markers and, of course, genetic transformation, which is mainly conducted elsewhere in the structure of CIAT. The outcomes of this output will be more efficient breeding system that will allow cassava remain competitive in the global markets, but also a subtle consequence will be the stimulus for cassava breeders that a new era of advanced technologies has arrived for cassava. This is important because cassava is typically an undervalued crop within the NARs systems. The role of the cassava project at CIAT is mostly as primary research provider. Because of the strong links with partners there is a flow of information among us and, therefore, our role may also be of secondary research provider exploiting ideas developed by NARs. In the case of the activities related to the development of a protocol for the production of doubled-haploids there is an interaction with SIBS-ETH Shanghai Center for Cassava Biotechnology (National Key Laboratory of Plant Molecular Genetics, Institute of Plant Physiology and Ecology, Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences) and South China Botanical Garden (Chinese Academy of Sciences, Guangzhou) in China. CIAT role can also be seen as catalyser promoting the incorporation of new ideas into cassava genetic improvement. Doubled-haploids are a promising avenue for the rapid production of homozygous cassava, which offers many advantages (identification of useful recessive traits, elimination of genetic load, making possible the implementation of back-cross, facilitated shipment and exchange of germplasm, facilitated genetic studies, etc.) in the genetic improvement of cassava

The ultimate beneficiaries of this output are farmers and rural communities growing and processing cassava. However, our immediate contacts are the NARs in Africa, Asia and Latin America from countries where cassava is grown; but also Universities from developed and developing countries and private sector. This Output is closely related to the second one and, therefore, one of the expected outcomes is a more efficient breeding system. A subtle, but significant, outcome is that cassava will attract young scientists who will see cassava not as a neglected crop but as a promising alternative for tropical agriculture and a challenging opportunity for their professional development. CIAT's role is clearly as a primary research provider. Because many of the biotechnology tools are developed for other crops CIAT role, in some cases, can be seen as a secondary research provider when adapting these technologies to cassava. In some instances CIAT role can also be as facilitator or advocate for some of these technologies, frequently affected by proprietary rights, made available to cassava. Of particular relevance is the fact that we can now select in Colombia for germplasm that is resistant to a disease not present in the Americas (ACMD). This is very important because it facilitates greatly the flow of germplasm from CIAT to Africa, knowing in advance that it will possess a high frequency of clones with the critical trait for their survival in that target environment. Furthermore molecular markers facilitate the pyramiding of genes against the same disease or the accumulation of sources of resistance to different pests and diseases.

International Public Goods:

There are two main types of products developed by the cassava-breeding project at CIAT: knowledge and improved germplasm (including genes and DNA sequences). The project has been successful in writing a large number of research articles describing and sharing the knowledge and discoveries made in our project with the scientific community. The distribution of germplasm is cumbersome because of the phytosanitary restrictions imposed in the movement of in vitro vegetative tissues from country to country. Nonetheless CIAT has been generous and responsible in making the germplasm collection and improved clones available to NARs. CLAYUCA has played a fundamental role in the introduction of many elite clones to its member countries.

The existence of the world cassava germplasm collection at CIAT offers us a unique situation to screen the germplasm in search of useful traits. It has been from the collection that a unique source of resistance to white flies was found. The search of high-value traits finds the collection a valuable source of genetic variability as well. In most cases these traits are readily made available to partners and collaborators. For instance the high-protein trait has readily been shared with IITA, NARs and a new shipment will soon be made to EMBRAPA-Brazil. Because of the declining core resources for the genetic improvement of cassava in some cases CIAT may develop strategic alliances with the private sector for their access to specific traits. This has been the case for the development of a waxy cassava variety for Thai farmers with the financial support of Thai Tapioca Development Institute (TTDI). This kind of approaches has generated resources that allow us to continue the activities that are considered strategic but that, unfortunately, do not receive the necessary funds from the system.

Partners:

A key partner for SBA-2 project is CLAYUCA with whom it interacts on a day-to-day basis, complementing or benefiting from its work and presenting join research proposals. This document does not mention specifically all and each one of the activities where CLAYUCA and SBA-2 collaborate but the reader should be aware of this close partnership.

Africa. IITA in Nigeria is a key partner in the deployment of knowledge and germplasm developed by CIAT in Africa. Since it is another CG Center we prefer not to mention their contributions to the different partnerships. National Research Programs of Africa include those of **Tanzania** (0.5); **Uganda** (0.5); **Kenya**; **Ghana** (0.5); **Nigeria** (0.5); **Mozambique** and **South Africa**. These countries contribute with access to field and laboratory facilities and, within parenthesis, the time of scientists directly involved with collaborative special projects.

Asia. **Thailand**: Department of Agriculture (0.25), Field Crops Research Institute (1) Thai Tapioca Development Institute (2) and Kasetsart University (2). **Vietnam:** Thai Nguyen University (1); National Institute of Soils and Fertilizers; Hue University of Agriculture and Forestry (0.25); and Institute of Agric. Sciences (1). **China:** CATAS – Hainan (0.25). **Laos**: National Agric. and Forestry Research Institute (NAFRI) (1) and Provincial Agric. Forestry Offices (1). **Cambodia**: Cambodia Agric. Research and Developm. Inst. (CARDI) (1); Provincial Dept. Agric. For. Fish (1); CelAgric; C.J Cambodia Co. **India**: CTCRI (0.25). These countries contribute with access to germplasm, field and laboratory facilities and, within parenthesis, the estimated time of scientists directly involved with collaborative special projects.

Latin America and the Caribbean. **Brazil**: EMBRAPA-CNPMF (2); EMBRAPA-CENARGEN; IAC-Campinas. **Colombia**: CORPOICA (1); National University of Colombia (0.2);. **Venezuela**: Agropecuaria Mandioca (0.5); Universidad Central de Venezuela; INIA (0.5). **Cuba**: INIVIT (0.5); and CLAYUCA (2). These countries/institutions contribute with access to germplasm, field and laboratory facilities and, within parenthesis, the estimated time of scientists directly involved with collaborative special projects.

Advanced Laboratories in Developed Countries. Wageningen University in The Netherlands (0.25); ETH – Zurich, Switzerland (1); Ohio State University in USA; Danforth Center (0.5) in USA; Uppsala University in Sweden (0.25). Collaboration between CIAT and these Laboratories is in joint projects where a field worker or a post-doctoral fellow is involved.

Private Companies. National Starch Company (USA / UK). AVEBE Starch Company (The Netherlands); Corn Products (Colombia and Brazil) Cassava Starch Manufacturing Mill (South Africa); Nigeria Starch Mill (Nigeria); PETROTESTING (Colombia) (1); DESARGO Ltda (Colombia). In most cases, these companies have been supporting cassava research at CIAT and also benefiting from it. One assistant originally working under CIAT payroll is now paid by PETROTESTING to develop clones adapted to the acid soil environment specifically for the production of ethanol.

Presence of the project in the world:

As described in the introductory paragraph the activities of the cassava improvement project can be broadly divided into three large categories around breeding, production practices and processing. It is acknowledged that not all these activities can be directly conducted by the project, nor that there is a need for this approach. The project benefits from the collaboration with other key institutions such as CLAYUCA and IITA. Below is a brief description of how the SBA-2 project interacts with different partners to address these objectives and to maximize the probabilities of having a positive impact.

	LAC	Asia	Africa
Breeding	Direct and through collaboration with partners.	Through collaboration with key partners	Direct and through strong collaboration with IITA
Production	Through a leadership by CLAYUCA	Direct work supported by NIPPON foundation and through collaboration with partners.	Activity mostly conducted by IITA but certain specific work done by CLAYUCA under contracts with private sector.
Processing	Through a leadership by CLAYUCA and collaboration with partners	Through collaboration with key partners, particularly in the private sector	Through collaboration with key partners in the private sector and through the leadership by IITA

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (actual)	2007 (actual)	2008 (actual)	2009 (plan)
US Dollars (millions)	3.356	3.145	2.747	2,671	To be defined

CIAT PROJECT SBA-2: IMPROVED CASSAVA FOR THE DEVELOPING WORLD (2008-2010)

Targets	Outputs	Intended users	Outcome	Impact
Output 1: Maintenance and distribution of accessions from the germplasm collection.				
2008, 2009, and 2010	Accessions from the cassava germplasm collection maintained, made available, distributed to users following international standards (including certification to be free of frog skin disease) and screened in search of useful traits.	Cassava scientists, breeders, geneticists, cassava networks and consortia, from both public and private sectors, interested in using cassava germplasm directly or in breeding or in other studies	Cassava genetic resources are maintained for the future. Genetic resources are better known and used. High-value traits identified and exploited. Training in conservation and exploitation of genetic resources.	Useful traits identified and exploited for the benefit of farmers and processors. Through genetic resistances to abiotic and biotic stresses, less negative impact on farm environment (less pesticides, less fertilizers). Benefits of sharing germplasm support the International Treaty.
Output 2: Genetic stocks adapted to the most common cassava growing environments and their abiotic stresses, with emphasis in drought.				
2008, 2009 and 2010	Transfer of at least 300 CMD resistant, early dry matter yield, delayed PPD and/or high and stable productivity under drought, acid soils and/or highlands cassava genotypes to National programs in LAC, Africa and/or Asia.	National research programs and cassava farmers and communities in Nigeria, Uganda, Tanzania, Ghana, and India. IITA Breeding Project	Increased productivity of cassava production systems from the introduction of elite cassava varieties from South America with CMD resistance. Most important mechanisms for drought tolerance in cassava established	Improved food security and processing opportunities for rural communities that depend on cassava. Improved cooperation between CIAT and IITA. CIAT germplasm more useful to cassava breeding projects in Africa and India. Increased and stable income of cassava farmers and processing facilities.
Otuput 3: Clones with high-quality traits for food, feed, starch and ethanol industries identified or bred.				
2008 and 2009	30 genotypes with crude protein 2 standard deviations above the mean. Shipment to Africa of at least 50 genotypes combining high carotene or protein in the roots with CMD resistance. Shipment of botanical seed of high-protein genotypes to LAC and Asia. Production of new high-carotenoids clones.	Cassava breeding project in IITA. Scientists from national programs and universities in developing and developed countries. Feed industry. Farmers that use cassava on farm for animal feeding	Availability of high nutritional status cassava germplasm for evaluation of its agronomic and nutritional value Shift in breeding objectives and methods at NARs. Protein quality in these high-protein clones determined. Enhanced human capacity through training.	Improved nutritional status of communities in target countries that rely on cassava as a staple Enhanced industrial uses of the crop. Stronger markets for cassava. Rural development in cassava growing communities and reduction of poverty. Alternative sources of financing cassava research in Africa, Asia and LAC.

Targets	Outputs	Intended users	Outcome	Impact
2009	Identification and characterization of at least three new mutants for starch and/or root quality traits from the different strategies implemented. At least 500 new crosses made and evaluated to produce high-amylose clones.	NARs, private sector, processing companies and cassava farmers in Africa, Asia and Latin American and the Caribbean. Universities and advanced laboratories in developed countries.	Enhanced interest of different processing industries in cassava.. Appreciation of the high-value traits concept Specialization of cassava farmers. First steps for exploiting high-value traits through designed crosses	Enhanced industrial uses of the crop. Stronger markets for cassava. Rural development in cassava growing communities and reduction of poverty. Enhanced health of people consuming “resistant starches”, particularly those affected by diabetes.
Output 4: Management of pests and diseases, likely to cause acute problems in large areas planted with cassava.				
2008 and 2009	Crosses no less than 7 wild *Manihot* species to introgress genetic variability in search of resistance genes for insects and diseases and development of at least one molecular marker for resistance to white flies.	Breeders, entomologists and pathologists from national programs, IITA and universities in developing and developed countries. Cassava farmers.	Better understanding and exploitation of the genetic variability in the *Manihot* gene pool. Justification for the need of exploration & conservation of genetic resources.’ Interaction with scientists working with other crops.	Proof of concept for cassava of the value represented by related *Manihot* species. South-to-south collaboration Improved health and productivity of cassava result in increased and more stable income of cassava farmers and processing facilities. Reduction in the negative impact on the environment from the use of pesticides.
2010	Identification of the pathogen(s) and insect vector(s) responsible for the frog skin disease (FSD) and clones resistant to the disease.	Curators of germplasm banks, breeders, pathologists and entomologists from national programs, and universities in developing and developed countries. Farmers.	Molecular tools for detection. Bioassays for transmission developed & implemented. DartT markers on genome-wide basis for QTL mapping for molecular breeding. QTL analysis of mapping populations for FSD resistance. Diagnostic kits for the detection of FSD	Healthier cassava grown by farmers. Enhanced exchange of germplasm. Increased and more stable income of cassava farmers.
Output 5: Organizational approaches, processing technologies and cultural practices for competitive and sustainable cassava production, processing and utilization systems.				

Targets	Outputs	Intended users	Outcome	Impact
2008 and 2009	Validation, under commercial conditions, of at least three productions systems for the production and exploitation of cassava foliage, including the evaluation of at least five outstanding clones. Systematic evaluation of 20 elite clones to East Timor, Laos, Cambodia	Cassava agro-industrial projects in Asia, Africa and LAC. IITA Research and extensionists from NARs, cassava farmers and/or small scale processors in East Timor, Cambodia and Laos.	Cassava foliage consolidated as a raw material for animal feeding systems. Improved yields and more sustainable production of cassava in Laos, Cambodia, East Timor and Indonesia. Promotion of balanced fertilization for cassava.	Higher income for cassava farmers. Enhanced food security. South-to-south cooperation Reduction of the negative impact on the environment of cassava cultivation, particularly in marginal sloped land.
2010	Development, testing and dissemination of at least one decentralized approach to produce ethanol, based on enhanced participation of small-holder farmers in the value chain, two new mutants and at least 30 elite clones combined with at least 5 new enzymatic processes.	Smallholder farmers, Universities and NGOs in LAC, Asia and Africa Private sector industries Cassava projects for the production of ethanol (from cassava and other starch crops) in Colombia and other countries in the world. IITA scientists	Enhanced engagement of farmers in all phases of the field-to-fuel value chain Conversion rates from root to ethanol of at least 30 elite clones, including two starch mutations of reduction in production costs determined. Enhanced human resources through training.	Improved capacity of smallholder farmer organizations to participate in bio-ethanol production chains Reduced environmental impact Rural development at village level Market diversification for farmers. Enhanced equity in the value chain Higher economic value for cassava production systems.
Output 6: New breeding tools: genetic transformation, use of molecular markers, rapid multiplication and production of doubled-haploids.				
2008	Identification of at least one root promoter for genetic transformation using genes to be expressed in the roots.	Molecular breeders from national programs and universities in developing and developed countries.	Cassava roots are its more important economic product, identification and cloning of root promoters are fundamental for the genetic transformation of the crop with genes affecting root quality traits.	Improved nutritional conditions of communities where cassava is an important component in the diet. More efficient breeding methods lead to faster and more consistent genetic gains. Root promoters found in cassava can help other root and tuber crops, as well. Enhanced economic value of cassava.
		Field and molecular	Cost-effective markers aid breeding for the transfer of	

Targets	Outputs	Intended users	Outcome	Impact
2009	Development of markers associated with protein content and delayed PPD, from wild Manihot sp. Generation of 30,000 unigene full length cDNA collection that covers more than 50% of genes in cassava and development of cassava genomic database.	breeders from national programs, IITA. Scientists from Advanced Research Laboratories. Ultimately farmers benefiting from more efficient breeding approaches	root quality traits identified in wild relatives of cassava. Enhanced identification of genes and genomic region for more efficient molecular breeding tool development Better understanding of cassava genome and more efficient breeding Enhanced human resources through training.	Improved nutritional status of rural and urban populations that rely on cassava as a staple Cassava varieties with improved target traits by more efficient molecular breeding tool for people that rely on cassava as a staple Faster and cost effective cassava breeding process by MAS and transgenic approach
2010	Production of at least 3 lines of homozygous tissue in the process of developing a protocol for the production of doubled haploids.	Field and molecular breeders from national programs, IITA and universities in developing and developed countries.	Introduction of inbreeding in cassava is a key step for a more efficient breeding. Enhanced human resources through training.	More efficient breeding methods leads to faster and more consistent genetic gains. Increased and more stable income of cassava farmers and processing facilities. Enhanced food security.

2. Results associated with 2008 project output targets

CIAT Project SBA-2: Improved Cassava for the Developing World (2008-2010)

Targets	Outputs	Intended users	Outcome	Impact	Achieved 08 (yes or no)	Proof of achievement (list documentation)
Output 1: Maintenance and distribution of accessions from the germplasm collection.						
Output targets 2008, 2009, and 2010	Accessions from the cassava germplasm collection maintained, made available, distributed to users following international standards (including certification to be free of frog skin disease) and screened in search of useful traits.	Cassava scientists, breeders, geneticists, cassava networks and consortia, from both public and private sectors, interested in using cassava germplasm directly or in breeding or in other studies	Cassava genetic resources are maintained for the future. Genetic resources are better known/used. High-value traits identified and exploited. Training in conservation and exploitation of genetic resources.	Useful traits identified and exploited for the benefit of farmers and processors. Through genetic resistances to abiotic and biotic stresses, less negative impact on farm environment (less pesticides, less fertilizers). Benefits of sharing germplasm support the International Treaty.	YES	Courier shipping documents. Phytosantiary certificates. Scientific article accepted for publication in Starch/Stärke
Output 2: Genetic stocks adapted to the most common cassava growing environments and their abiotic stresses, with emphasis in drought.						
Output targets 2008, 2009, and 2010	Transfer of at least 300 CMD resistant, early dry matter yield, delayed PPD and/or high and stable productivity under drought, acid soils and/or highlands cassava genotypes to National programs in LAC, Africa and/or Asia.	National research programs and cassava farmers and communities in Nigeria, Uganda, Tanzania, Ghana, and India. IITA Breeding Project	Increased productivity of cassava production systems from the introduction of elite cassava varieties from South America with CMD resistance. Most important mechanisms for drought tolerance in cassava established	Improved food security and processing opportunities for rural communities that depend on cassava. Improved cooperation between CIAT and IITA. CIAT germplasm more useful to cassava breeding projects in Africa and India. Increased and stable income of cassava farmers and processing facilities.	YES	Courier shipping documents. Phytosantiary certificates. Adoption of varieties
Otuput 3: **Clones with high-quality traits for food, feed, starch and ethanol industries identified or bred.**						

Targets	Outputs	Intended users	Outcome	Impact	Achieved 08 (yes or no)	Proof of achievement (list documentation)
Output targets 2009, and 2010	30 genotypes with crude protein 2 standard deviations above the mean. Shipment to Africa of at least 50 genotypes combining high carotene or protein in the roots with CMD resistance. Shipment of botanical seed of high-protein genotypes to LAC and Asia. Production of new high-carotenoids clones.	Cassava breeding project in IITA. Scientists from national programs and universities in developing and developed countries. Feed industry. Farmers that use cassava on farm for animal feeding	Availability of high nutritional status cassava germplasm for evaluation of its agronomic and nutritional value Shift in breeding objectives and methods at NARs. Protein quality in these high-protein clones determined. Enhanced human capacity through training.	Improved nutritional status of communities in target countries that rely on cassava as a staple Enhanced industrial uses of the crop. Stronger markets for cassava. Rural development in cassava growing communities and reduction of poverty. Alternative sources of financing cassava research in Africa, Asia and LAC.	YES	Results of evaluation of harvest in March 2009. A scientific manuscript to be submitted as result of this harvest. About 600 high protein clones to be evaluated in March 2009.
2009	Identification and characterization of at least three new mutants for starch and/or root quality traits from the different strategies implemented. At least 500 new crosses made and evaluated to produce high-amylose clones.	NARs, private sector, processing companies and cassava farmers in Africa, Asia and Latin American and the Caribbean. Universities and advanced laboratories in developed countries.	Enhanced interest of different processing industries in cassava.. Appreciation of the high-value traits concept Specialization of cassava farmers. First steps for exploiting high-value traits through designed crosses	Enhanced industrial uses of the crop. Stronger markets for cassava. Rural development in cassava growing communities and reduction of poverty. Enhanced health of people consuming “resistant starches”, particularly those affected by diabetes.	YES	Journal of Agricultural and Food Chemistry 56(16): 7215-7222 Characterizarion of a sugary genotype to be reported in 2009. More than 21,000 botanical seed including starch quality mutants made in 2008. New source of PPD tolerance.
Output 4: **Management of pests and diseases, likely to cause acute problems in large areas planted with cassava.**						
	Crosses no less than 7 wild *Manihot*	Breeders,	Better understanding and exploitation of	Proof of concept for cassava of the value represented by	Partially accomplished	M.Sc. and Ph.D. theses at National University

Targets	Outputs	Intended users	Outcome	Impact	Achieved 08 (yes or no)	Proof of achievement (list documentation)
Output targets 2008 and 2009	species to introgress genetic variability in search of resistance genes for insects and diseases and development of at least one molecular marker for resistance to white flies.	entomologists and pathologists from national programs, IITA and universities in developing and developed countries. Cassava farmers.	the genetic variability in the *Manihot* gene pool. Justification for the need of exploration & conservation of genetic resources.' Interaction with scientists working with other crops.	related *Manihot* species. South-to-south collaboration Improved health and productivity of cassava result in increased and more stable income of cassava farmers and processing facilities. Reduction in the negative impact on the environment from the use of pesticides.	(floods in 2008 affected crossing block and crosses from four wild relatives could be made).	of Colombia. Molecular markers identified and available for validation
2010	Identification of the pathogen(s) and insect vector(s) responsible for the frog skin disease (FSD) and clones resistant to the disease.	Curators of germplasm banks, breeders, pathologists and entomologists from national programs, and universities in developing and developed countries. Farmers.	Molecular tools for detection. Bioassays for transmission developed & implemented. DartT markers on genome-wide basis for QTL mapping for molecular breeding. QTL analysis of mapping populations for FSD resistance. Diagnostic kits for the detection of FSD	Healthier cassava grown by farmers. Enhanced exchange of germplasm. Increased and more stable income of cassava farmers.	Work on progress as expected	Scientific publication on the viral origin of FSD. Diagnostic kit developed for testing FSD in germplasm collection. Results of a "blind test" to assess the methodologies (to be initiated in 2009)
Output 5: **Organizational approaches, processing technologies and cultural practices for competitive and sustainable cassava production, processing and utilization systems.**						
	Validation, under commercial conditions, of at least three productions	Cassava agro-industrial projects in Asia, Africa and LAC.	Cassava foliage consolidated as a raw material for animal feeding systems.	Higher income for cassava farmers.	Partially Accomplished	Scientific publications on foliage production system. A drastic change in the

Targets	Outputs	Intended users	Outcome	Impact	Achieved 08 (yes or no)	Proof of achievement (list documentation)
2008 and 2009	systems for the production and exploitation of cassava foliage, including the evaluation of at least five outstanding clones. Systematic evaluation of 20 elite clones to East Timor, Laos, Cambodia	IITA Research and extensionists from NARs, cassava farmers and/or small scale processors in East Timor, Cambodia and Laos.	Improved yields and more sustainable production of cassava in Laos, Cambodia, East Timor and Indonesia. Promotion of balanced fertilization for cassava.	Enhanced food security. South-to-south cooperation Reduction of the negative impact on the environment of cassava cultivation, particularly in marginal sloped land.	(Thailand shifted drastically its interest on bioethanol against foliage production: no commercial plantings in 2008 to validate)	priorities of cassava grown in Thailand away from foliage in favor of ethanol production prevented validations at the commercial level Report writted to ACIAR on the Cassava Project in East Timor and Indonesia
2010	Development, testing and dissemination of at least one decentralized approach to produce ethanol, based on enhanced participation of small-holder farmers in the value chain, two new mutants and at least 30 elite clones combined with at least 5 new enzymatic processes.	Smallholder farmers, Universities and NGOs in LAC, Asia and Africa Private sector industries Cassava projects for the production of ethanol (from cassava and other starch crops) in Colombia and other countries in the world. IITA scientists	Enhanced engagement of farmers in all phases of the field-to-fuel value chain Conversion rates from root to ethanol of at least 30 elite clones, including two starch mutations of reduction in production costs determined. Enhanced human resources through training.	Improved capacity of smallholder farmer organizations to participate in bio-ethanol production chains Reduced environmental impact Rural development at village level Market diversification for farmers. Enhanced equity in the value chain Higher economic value for cassava production systems.	Work on progress as expected	A fully automized pilot plant for testing the "fermentability" will be operational in 2009 at CIAT's HQ. The plant will be used to ferment cassava roots to provide the information to be published in a scientific article in 2010.
Output 6: **New breeding tools: genetic transformation, use of molecular markers, rapid multiplication and production of doubled-haploids**						

Targets	Outputs	Intended users	Outcome	Impact	Achieved 08 (yes or no)	Proof of achievement (list documentation)
2008	Identification of at least one root promoter for genetic transformation using genes to be expressed in the roots.	Molecular breeders from national programs and universities in developing and developed countries.	Cassava roots are its more important economic product, identification and cloning of root promoters are fundamental for the genetic transformation of the crop with genes affecting root quality traits.	Improved nutritional conditions of communities where cassava is an important component in the diet. More efficient breeding methods lead to faster and more consistent genetic gains. Root promoters found in cassava can help other root and tuber crops, as well. Enhanced economic value of cassava.	**YES**	Different root promoters have not only been identified but evaluated in cassava and carrots modified genetically for increased carotenoids content in the roots. CIAT Annual Reports and scientific presentations H+ Report
2009	Development of markers associated with protein content and delayed PPD, from wild Manihot sp. Generation of 30,000 unigene full length cDNA collection that covers more than 50% of genes in cassava and development of cassava genomic database.	Field and molecular breeders from national programs, IITA. Scientists from Advanced Research Laboratories. Ultimately farmers benefiting from more efficient breeding approaches	Cost-effective markers aid breeding for the transfer of root quality traits identified in wild relatives of cassava. Enhanced identification of genes and genomic region for more efficient molecular breeding tool development Better understanding of cassava genome and more efficient breeding Enhanced human resources through training.	Improved nutritional status of rural and urban populations that rely on cassava as a staple Cassava varieties with improved target traits by more efficient molecular breeding tool for people that rely on cassava as a staple Faster and cost effective cassava breeding process by MAS and transgenic approach	Work on progress as expected	Departure of the cassava geneticist has delayed deliveries in this regard. PPD tolerance has been indeed identified. Collaborative work to be done with Bath University and BioCassavaPlus. M.Sc. degree theses Scientific publications

Targets	Outputs	Intended users	Outcome	Impact	Achieved 08 (yes or no)	Proof of achievement (list documentation)
2010	Production of at least 3 lines of homozygous tissue in the process of developing a protocol for the production of doubled haploids.	Field and molecular breeders from national programs, IITA and universities in developing and developed countries.	Introduction of inbreeding in cassava is a key step for a more efficient breeding. Enhanced human resources through training.	More efficient breeding methods leads to faster and more consistent genetic gains. Increased and more stable income of cassava farmers and processing facilities. Enhanced food security.	Work on progress as expected	Scientific publications on the progress of doubled haploids technology. Scientific publications on inbreeding. Inbred lines developed Reports to donors

3. RESEARCH HIGHLIGHTS IN 2008

3.1) LAUNCHING OF THE PROJECT TO DEVELOP WAXY-STARCH CASSAVA FOR THAILAND

As a result of the discoveries related to Output 3 several starch mutants have been identified. An agreement was signed in 2008 with Thai Tapioca Development Institute to develop a waxy (amylose-free) starch cassava variety for Thailand. This is the first time that an organization representing the processing sector invests in cassava breeding. This important financial contribution implies a non-traditional donor investing in cassava research and a very promising interaction between public and private institutions. Similar agreements are currently underway for Brazil and Colombia. The discovery of these mutations also represents a solid evidence of the vision of the cassava team (to define relevant research objectives) and its technological capacity (to achieve them). In addition to TTDI, colleagues from Kasetsart University have been involved in this collaborative effort and local institutions will be involved for Brazil and Colombia. Two set of crosses have been made and the 20,000 resulting seed will be shipped by April 2009. It is impossible to predict the ultimate economic impact of this outcome at this point. Huge interest has already been demonstrated by many important cassava starch producing (multinational and national) companies, who will soon start conducting their own research regarding the specific industrial applications of these unusual starch types. Impact relates to new donors for cassava research, demonstration of the suitability of breeding approaches used by CIAT (and now imitated by partners) and a drastic change in the way cassava is envisioned by the processing sector. A large multinational company has decided to initiate a cassava-breeding project of its own and has contacted CIAT to train a person that will lead this project.

3.2) A NEW MUTATION ON PLANT TYPE

As part of the systematic process of self-pollination of cassava germplasm several members of an S_1 family showed a very distinctive phenotype with petioles leaves and very reduced or no branching at all. The most immediate use of this type of plant would be for the production of dried cassava foliage. One of the bottlenecks for this new market is the costs involved in the harvesting of the foliage. The only practical approach is a mechanical harvest that would also carry a considerable amount of young stems and petiole tissue. The mutation should facilitate foliage harvest. The result would be a reduce cost of harvest and, because the reduced proportion of petiole and young stems, a better quality of the foliage with reduced fiber content. This last characteristic would be fundamental for the use of dried foliage in the composition of diets for the poultry industry. A second important potential application of this mutation would be the possibility of drastically increasing plant densities in commercial planting of cassava. It should also be easy to accept the idea that this new plant type could allow for higher plant densities in cassava fields. Perhaps as many as 30,000 plants per hectare could be used. This concept is important because most of the genetic gains achieved through the last century relates to modifications in plant architecture. The use of semi-dwarf wheat and rice varieties lead to the highly successful green revolution. In the case of maize, if there is a single characteristic that can explain the consistent gains observed after the first introduction of commercial hybrids is reduced plant height with increased tolerance to higher plant densities. Today modern hybrid maize is planted at much higher densities than 40-50 years ago. So, this mutation observed in cassava may lead to a new plant type and, perhaps, a green revolution for this crop. It should be mentioned that the petioles mutation had been known in cassava for a long time. There are few accessions in the collection with this trait (in addition to the progenitor which does not have the mutation in homozygous condition, MVE332 shows the petioles phenotype). What this mutation brings in is the certainty of the genetic nature of this mutation, the reasonable hypothesis that it is the result of a single recessive mutation and, more importantly, the combination of the petioles trait with short plant height and non-branching architecture.

3.3) ADDITIONAL SOURCES OF DELAYED POST HARVEST PHYSIOLOGICAL DETERIORATION (PPD)

Manihot walkerae has been reported to be a source of tolerance to PPD previously. This source of tolerance was first introgressed into cassava and then backcrossed again using a different cassava cultivar. However this approach implies introduction of large number of undesirable alleles from *M. walkerae*. At least two cassava genotypes offer good levels of tolerance to PPD. AM 206-5 was evaluated in a ad hoc replicated experiment and proved to have very low levels of PPD even three weeks after harvest. GM 905-66 proved to have very good levels of tolerance to PPD. Two roots from the later evaluated two months after harvest and maintained at room temperature showed no symptoms of PPD. A third source of tolerance to PPD will be evaluated in April 2009 when large number of roots from three different M_2 genotypes (from mutagenized populations) will be evaluated and their reaction to PPD properly assessed.

3.4) INITIATION OF STUDIES OF POLLEN FLOW IN CASSAVA

Several transgenic cassava events are already available. However, biosafety and regulatory issues required for the legal deployment of transgenic cassava will most likely require knowledge on the risk of the transgene moving into landraces and wild relatives of cassava. During 2008 CIAT initiated studies to assess the risk of such undesirable event taking place. Because of the peculiarities of cassava flowering biology and the relative fitness of plants developing from botanical seed compared with those originating in the vegetative cuttings planted by the farmers the answer to this question requires very specific type of studies. Extrapolations from results measured in other crops such as maize are irrelevant. Different studies were planned and some of them initiated during 2008 to assess the distance and frequency cassava pollen goes from one variety to another in the field. Different approaches have been considered from the use of male sterile genotypes to the use of starch markers to assess the frequency of cross pollinations. Individual volunteer plants (from botanical seed) have been identified in two farmers' fields and will be monitored through the harvest. The survival rate of these seedlings, the possibility of the stems they eventually produce being mixed with the stock of standard planting material combined with the frequency of cross pollination would provide a estimation in the field for the possibility of the transgene contaminating non-transgenic cassava stocks.

3.5) IDENTIFICATION OF NEW POTENTIALLY USEFUL SOURCES OF BIOLOGICAL CONTROL FOR WHITEFLIES

Five new parasitoid *Eretmocerus* species were found affecting whiteflies feeding on cassava. This genus showed a great potential for the control of whiteflies worldwide. However, the generalized lack of knowledge on the native species makes their analysis, assessment of their potential and actual utilization difficult. Future work can assess the potential of the new knowledge of the parasitic capacity of these five species in the management of the many whitefly species that can seriously affect cassava production worldwide.

3.6) SUCCESSFUL TRAINING COURSE FOR CASSAVA RESEARCHERS IN ASIA

For two weeks an intensive training course for young cassava scientists took place at Rayong Field Crops Research Center and at the Thai Tapioca Development Institute. A total of 59 trainees coming from ten different countries participated in this course that combined lectures and field visits. A group of eighteen leading cassava researchers shared their knowledge and experiences. As a result of this course valuable training material (printed chapters and visual aids have been produced and will be published in 2009. Training of a new generation of scientists was considered a key activity to take advantage of the old generation of scientists that have already or will son retire.

3.7) ORGANIZATION OF A HARVEST SEMINAR ON STARCH AND ROOT QUALITY MUTANTS.

As a result of the recent discoveries of high-value starch and root quality mutations a "*Harvest Seminar*" took place in March 2008. During this event the high-value mutants were harvested and starch extracted and analyzed. A group of about 30 people from NARs, advanced research laboratories and private processing sector (Belgium, Brazil, Colombia, Thailand, The Netherlands and USA) attend. The main objective of this event was to promote the mutations, demonstrate the methodologies that CIAT used for their identification so that NARs can benefit, and allow for a dynamic exchange of ideas on how best exploit and deploy them and what else the processing sector needs.

4. PROJECT OUTCOME:

For several years the cassava-breeding project at CIAT has collaborated with Grupo GPC (previously Petrotesting) to develop cassava varieties adapted to the harsh environmental conditions of open acid-soil savannas in the Puerto López County (Meta Department, Colombia). The objective was the production of bio-ethanol. Collaboration involved the development of germplasm; pest and diseases management approaches, techniques for rapid multiplication of planting material, mechanization of planting and harvest and proper fertilization. CIAT helped GPC to identify cassava varieties that perform well in these environments and to gradually increase the area planted with the best performing ones. Early in 2009 the initiation of bio-ethanol production (20,000 liters per day) was announced in Colombian journals (El Tiempo: Tierras y Ganados and Portafolio: Agronegocios). Although the initial phase included only 2000 ha of cassava, it is expected that production will expand to 1,05 million liters/day requiring more than 45,000 hectares. Three cassava varieties developed by CIAT (Cantaclaro 1, 2 and 3) have been identified and were used for the current planting. For a competitive productivity of raw material, a combination of adequate varieties and suitable package of cultural practices needed to be developed. The close interaction between CIAT and GPC provided the needs for this success. This is the first modern initiative n the Americas to produce ethanol from cassava, which complements ongoing initiatives in Asia. The varieties developed offer good and stable productivity. However, to sustain the competitiveness of this initiative CLAYUCA has developed a pilot plant that will become operational in 2009. This pilot plant will allow the development of cassava varieties with qualitative characteristics which will reduce the costs of conversion from roots to ethanol. So there was a plan to satisfy immediate needs but also prepared for future opportunities. The construction of CANTACLARO has been important to demonstrate the feasibility of bio-ethanol production from cassava roots (although the economic changes by mid-2008 have altered the competitiveness of this industry).

This outcome combines contributions from several outputs in the (2007-2009) MTP: Genetic stocks improved gene pools developed and transferred to national programs; Research on the industrial uses of cassava and elite germplasm produced; Breeding for insect and other arthropods and disease resistance and development of alternative methods for their control; and Latin American and the Caribbean Consortium on Cassava. The last output included the "results of studies to produce ethanol out of cassava roots."

This outcome is important because, as explained in the press releases, up to 8000 direct jobs will be created (when the plant is at full operational capacity) in an area affected by poverty and where employment is scarce. It is also important because it represents a pilot experience that can be repeated in Colombia and elsewhere, and because it represents a new type of alliance between the research and processing sectors. Both, products (i.e. varieties) and information (i.e. pest management approaches) were generated by CIAT who also learned from GPC's experiences in rapid multiplication approaches.

<u>Financial support:</u> Another outcome of this research is the serious commitment from the private processing sector to finance cassava research in the acid soils savannas. This is also important for CIAT to better understand and define needs of the processing sector.

<u>Visibility for CIAT</u>: There has been a public awareness created by the official inauguration of CANTACLARO's operations through the most important printed press in Colombia. The press reports made an explicit recognition of CIAT's role in this endeavour.

5. List of 2008 Publications

Refereed and non-refereed journal articles

Papers published in English Refereed Journals:	16
Papers published in Spanish Refereed Journals:	7
Papers published in Thai Refereed Journals:	1
TOTAL	**24**

Proceedings, posters, abstracts, others

Conferences in English:	52
Conferences in Spanish:	2
TOTAL	**54**

Other publications (Divulgation brochures, databases, etc.)

Publications in English:	0
Publications in Spanish:	1
TOTAL:	**1**

Awards and public recognition

The Colombian Association for the Advance of Science awarded Hernán Ceballos the 2008 National Award for the Scientific Contributions in the area of Technological Innovation.

5.1 Refereed Journals

1. Alvarez, E.; Loke, J.B.; Trujillo, R. 2007. Avances en la caracterización patogénica de *Phytophthora* spp. Asociado al complejo pudrición de cogollo en palma africana *Elaeis guineensis* Jacq. Fitopatología Colombiana 31(1): 15-28.
2. Alvarez, E.; Llano, G. A.; McAdam, E. L. 2008. Controlling cassava root rots with the participation of Tukano communities in the Mitú area of the Colombian Amazon. Gene Conserve No. 28: 426-455.
3. Alvarez, E.; Castillo, F.; Gómez, E.; Llano, G.A. 2008. Mejoramiento del manejo nutricional de la rosa para el control preventivo de *Peronospora sparsa* Berkeley, causante de mildeo velloso. Revista Asocolflores 71:19-29.
4. Alvarez, E.; McGee, Denis C.; Harrington, T. 2008. Molecular variation and pathogenicity of isolates of *Fusarium* spp. affecting corn seed quality. Fitopatología Colombiana 32(1): 11-17.
5. Alvarez, E.; Gómez, E.A.; Llano, G.A.; Castillo, F. 2007. Utilización de fosfitos de potasio en el control de *Peronospora sparsa*, causante de Mildeo velloso de rosa. Fitopatología Colombiana 31(2): 49-52.
6. Arenas, A.; Alvarez, E.; Afanador, L.; Mejía, J.F. 2007. Especies de *Colletotrichum* asociadas con la antracnosis de la mora de castilla (*Rubus glaucus* Benth) en el Valle del Cauca. Fitopatología Colombiana 31(1):7-14.
7. Aye, T. M.; Hedley, M.J.; Loganathan, P.; Lefroy, R.D.B.; Bolan, N.S. 2009. Effect of organic and inorganic phosphate fertilizers and their combination on maize yield and phosphorus availability in a Yellow Earth in Myanmar. Nutrient Cycling and Agroecosystem Journal. Vol. 83:111-123.
8. Baiyeri, K. P.; Edibo, G. O.; Obi, I. U.; Ogbe, F. O.; Egesi, C. N.; Eke-Okoro, O. N.; Okogbenin, E.; Dixon, A. G. O. 2008. Growth, yield and disease responses of 12 cassava genotypes evaluated for two cropping seasons in a derived savannah zone of south-eastern Nigeria. Agro-Science 7(2):162-169.

9. Calvert, L.A.; Cuervo, M.; Lozano, I.; Villarreal, N.; Arroyave, J. 2008. Identification or three strains of a virus associated with cassava plants affected by Frogskin Disease. Journal of Phytopathology 156(11/12):647-653.
10. Ceballos, H.; Sánchez, T.; Denyer, K.; Tofiño, A. P.; Rosero, E. A.; Dufour, D.; Smith, A.; Morante, N.; Pérez, J. C.; Fahy, B. 2008. Induction and identification of a small-granule, high-amylose mutant in cassava (*Manihot esculenta* Crantz). Journal of Agriculture and Food Chemistry 56(16):7215-7222.
11. Chávez, A. L.; Ceballos, H.; Rodríguez-Amaya, D.B.; Pérez, J.C.; Sánchez, T.; Calle, F.; Morante, N. 2008. Sampling variation for carotenoids and dry matter contents in cassava roots. Journal of Root Crops 34(1). 43-49.
12. Da G., Dufour D., Marouzé C., Le Thanh Mai, Maréchal P.A. 2008. Cassava Wet Starch Processing at Small-Scale in North Vietnam. Starke/Starch 60 (7): 358 – 372.
13. Ojulong, H.; Labuschagne, M.T.; Fregene, M.A.; Herselman, L.. 2008. A cassava clonal evaluation trial based on a new cassava breeding scheme. Euphytica 160:119-129.
14. Okogbenin, E.; Marín, J.; Fregene, M.A. 2008. QTL analysis for early yield in a pseudo F2 population of cassava. African Journal of Biotechnology (Kenya) 7(2):131-138.
15. Reddy, B. V. S.; Ramesh, S.; Ashok Kumar, A.; Wani, S.P.; Ortiz, R.; Ceballos, H.; Sreedevi, T.K. 2008. Bio-fuel Crops Research for Energy Security and Rural Development in Developing Countries. BioEnergy Research 1:248-258.
16. Tangphatsornruang, S.; Sraphet, S.; Singh, R.; Okogbenin, E.; Fregene, M.; Triwitayakorn, K. 2008. Development of polymorphic markers from expressed sequence tags of Manihot esculenta Crantz. Molecular Ecology Resources 8(3):682-685.
17. Tofiño R., A.P.; Romero, H.M.; Ceballos, H. 2007. Efecto del estrés abiótico sobre la síntesis y degradación del almidón. Una revisión = Effect of abiotic stress on starch synthesis and degradation. A review. Agronomía Colombiana 25(2):245-254.
18. Tofiño, A.P.; Cabal, D.; Romero, H.; Ceballos, H. 2008. Caracterización morfológica de una población M1 de yuca (*Manihot esculenta* Crantz) derivada de semillas irradiadas. Fitotecnia Colombiana 8(1):39-55.
19. Tofiño, A., Ceballos, H.; Romero, H.M. 2008. Posibilidades de expansión del cultivo de yuca (*Manihot esculenta* Crantz) en el Caribe seco colombiano a partir de investigación multidisciplinaria. Acualidades Biológicas 30(88): 15-27.
20. Watananonta, W.; Atchara Limsila; Peaingpen Sarawat; Howeler, R.H. 2008. Cassava variety selection for optimizing the production of leaves to be used as a protein source for animal feed. Thai Agric. Research J. 26(2): 117-129 (in Thai with English abstract)
21. Wisser R.J.; Murray, S.C.; Kolkman, J.M.; Ceballos, H.; Nelson, R.J. 2008. Selection mapping of loci for quantitative disease resistance in a diverse maize population. Genetics 180:583-599.
22. Pérez Velásquez, Juan Carlos, Cláudio Lopes de Souza Jr., Luis . A. Narro, Shivajy. Pandey, and Carlos de León. 2008. Genetic Effects for Maize Traits Under Acid and Non-Acid Soils. Genetics and Molecular Biology. 31(1):89-97.
23. Aye, T.M., M.J. Hedley, P. Loganathan, R.D.B. Lefroy and N.S. Bolan. 2009. Effect of organic and inorganic phosphate fertilizers and their combination on maize yield and phosphorus availability in a Yellow Earth in Myanmar. Nutrient Cycling in Agroecosystems 83(2): 111-123.
24. Watananonta, W., Atchara Limsila, Peaingpen Sarawat and R.H. Howeler. 2008. Cassava variety selection for optimizing the production of leaves to be used as a protein source for animal feed. Thai Agric. Research J. 26(2): 117-129 (in Thai with English abstract)

NON-REFEREED JOURNALS

1. Alvarez, E., Mejía, J.F., Llano, G.A., Loke, J. 2008. Enfermedades limitantes de la yuca: Cartilla. Centro Internacional de Agricultura Tropical (CIAT); Instituto Colombiano Agropecuario (ICA), Seccional Quindío, Cali, CO. 24 p.

5.3 PROCEEDINGS, POSTERS, ABSTRACTS AND OTHERS

1. Howeler, R.H. (ed.). 2008. Integrated cassava-based cropping systems in Asia: Working with farmers to enhance adaption of more sustainable production practices: Proceedings of the workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam, Oct. 27-31, 2003. Centro Internacional de Agricultura Tropical (CIAT), Cassava Office for Asia, Bangkok, TH. 252 p.
2. Aye, T. M.; Khanthavong, P.; Howeler, R.H. 2008. Improving the productivity and Sustainability of cassava in small farmer holding in Lao PDR. International Seminar on: "Sustainable Agriculture Development in Response to Global Climate Change". Sofitel Racha Orchid Hotel, Khon Kaen, Thailand. June 6-7, 2008. pp.11-12.
3. Ceballos, H.; Sánchez, T.; Rosero, A.; Tofiño, A.P.; Denyer, K.; Smith, A.; Dufour, D.; Morante, N.; Pérez, J.C.; Fregene, M.; Egesi, C. 2008. High-value cassava: from a dream to a concrete reality. In: 8th Asian Cassava Research Workshop. Vientiane, LAO PDR. 20-24 Oct. 2008. Lecture.
4. Ceballos, H.; Fregene, M.; Debouck, D.; Dufour, D.; Tohme, J.; Sánchez, T.;
5. Mafla, G.; Morante, N.; Pérez, J.C. 2008. High-value cassava germplasm: a reality that will open markets to cassava farmers. In: First Scientific Meeting of the Global Cassava Partnership GCP-1. "*Cassava: meeting the challenges of the new millennium*", 21-25 July, IPBO, Ghent University, Belgium. Lecture, p 113.
6. Charoenrath, S.; Srisura, A.; Klakhaeng, K.; Watananonta, W. 2008. Working together for success in Thailand: A case study of khut kook ¨cassava development village. In: Howeler, R.H. (ed.). Integrated cassava-based cropping systems in Asia: Working with farmers to enhance adaption of more sustainable production practices: Proceedings of the workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam, Oct. 27-31, 2003. Centro Internacional de Agricultura Tropical (CIAT), Cassava Office for Asia, Bangkok, TH. p. 88-91.
7. Da, G.; Dufour, D.; Giraldo, A.; Moreno, M.; Sánchez T.; Marouze, C. 2008. A comparison between cassava processing at small-scale in Vietnam and in Colombia. In: First Scientific Meeting of the Global Cassava Partnership GCP-1. "*Cassava: meeting the challenges of the new millennium*", 21-25 July, IPBO, Ghent University, Belgium.
8. Díaz, A.; Torres, A.M.; Alvarez, E.; Fernández, A.; Dufour, D. 2008. Influencia varietal del plátano en los procesos de deshidratación osmótica y fritura. In: J.S. Borja ; C. Nogales ; C. Orrantia ; R. Paladines ; V. Quimi and L. Tazan (eds.).CD-Proceedings, Acorbat 2008, XVIII International Meeting, November 11-14/2008, Guayaquil, Ecuador, 8 p.
9. Doanh, L.Q.; Loan, T.T.O.; Ngoan, T.N.; Tuan, H.D.; Hung, N.V.; Chien, D.H.; Tat, H.V.; Thanh, L.Q.; Minh, D.Q. 2008. Integration of Northern upland program with farmer participatory research for sustainable cassava production in North Vietnam. In: Howeler, R.H. (ed.). Integrated cassava-based cropping systems in Asia: Working with farmers to enhance adaption of more sustainable production practices: Proceedings of the workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam, Oct. 27-31, 2003. Centro Internacional de Agricultura Tropical (CIAT), Cassava Office for Asia, Bangkok, TH. p. 157-160.

10. Dufour, D.; Dufour, E.; Escobar, A.; Giraldo, A.; Sánchez, T. 2008. Evaluation of Altitude Cassava for the Starch Production in Colombia. In: First Scientific Meeting of the Global Cassava Partnership GCP-1. "*Cassava: meeting the challenges of the new millennium*", 21-25 July, IPBO, Ghent University, Belgium. Lecture, p 96.
11. Howeler, R.H. 2008a. Background and general methodology used in the Nippon Foundation Project. In: Howeler, R.H. (ed.). Integrated cassava-based cropping systems in Asia: Working with farmers to enhance adaption of more sustainable production practices: Proceedings of the workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam, Oct. 27-31, 2003. Centro Internacional de Agricultura Tropical (CIAT), Cassava Office for Asia, Bangkok, TH. p. 5-32.
12. Howeler, R.H. 2008b. Results, achievements and impact of the Nippon Foundation cassava project. In: Howeler, R.H. (ed.). Integrated cassava-based cropping systems in Asia: Working with farmers to enhance adaption of more sustainable production practices: Proceedings of the workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam, Oct. 27-31, 2003. Centro Internacional de Agricultura Tropical (CIAT), Cassava Office for Asia, Bangkok, TH. p. 161-209.
13. Howeler, R.H.; Fahrney, K. 2008. Cassava production and utilization in Asia and its potential as a bio-fuel. Paper presented at Nex Gen Bio-Ethanol Conference, held in Bangkok, Thailand. April 22-24, 2008.
14. Howeler, R.H. 2008. Does cassava cultivation degrade the soil? Paper presented at First Scientific Meeting of the Global Cassava Partnership (CCP-1), held in Gent, Belgium, July 21-25, 2008.
15. Lyons, Graham H.; Ceballos, Hernán; Genc, Yusuf; Liu, Fang; Graham, Robin D. 2007. Agronomic biofortification of cassava zinc and other micronutrients to improve human health . In: Zinc Crops 2007: Improving crop production and human health, 24-26 May 2007, Istanbul, Turkey . International Zinc Association; International Fertilizer Industry Association (IFA), Brussels, BE. p. [1-3]
16. Nguyen, T.H.L.; Dao, T.P.; Le, V.P.; Le, V.A.; Howeler, R.H. 2008. The FPR cassava project and its impact of the use of ensiled cassava roots and leaves for on-farm pig feeding in Central Vietnam. In: Howeler, R.H. (ed.). Integrated cassava-based cropping systems in Asia: Working with farmers to enhance adaption of more sustainable production practices: Proceedings of the workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam, Oct. 27-31, 2003. Centro Internacional de Agricultura Tropical (CIAT), Cassava Office for Asia, Bangkok, TH. p. 130-139.
17. Sánchez, T., Ceballos, H.; Debouck, D.; Mafla, G.; Calle, F.; Pérez, J.C.; Dufour, D.; Morante, N.; Tohme, J. 2008. Variation in starch and root quality traits in cassava. In: First Scientific Meeting of the Global Cassava Partnership GCP-1. 21-25 July, Ghent, Belgium. Poster presentation, p 111.
18. Trinh, T.P.L.; Thai, P.; Hoang, V.T.; Dao, H.C.; Nguyen, H.; Nguyen, T.B.; Howeler, R.H. 2008. The FPR cassava project and its impact in Ha Tay, Hoa Binh and Thanh Hoa Provinces of North Vietnam. In: Howeler, R.H. (ed.). Integrated cassava-based cropping systems in Asia: Working with farmers to enhance adaption of more sustainable production practices: Proceedings of the workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam, Oct. 27-31, 2003. Centro Internacional de Agricultura Tropical (CIAT), Cassava Office for Asia, Bangkok, TH. p. 113-123.
19. Vankaew, B.; Petpraphai, P.; Watananonta, W.; Vongkasem, W.; Howeler, R.H. 2008. The use of a farmer participatory approach in cassava technology transfer in Thailand. In: Howeler, R.H. (ed.). Integrated cassava-based cropping systems in Asia: Working

with farmers to enhance adaption of more sustainable production practices: Proceedings of the workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam, Oct. 27-31, 2003. Centro Internacional de Agricultura Tropical (CIAT), Cassava Office for Asia, Bangkok, TH. p. 74-77.

20. Vongkasem, W.; Klakhaeng, K.; Srakaew, K.; Sevatasai, R.; Watananonta, W.; Howeler, R.H. 2008. Farmer participatory research (FPR) and extension (FPE) methodologies used in Thailand. In: Howeler, R.H. (ed.). Integrated cassava-based cropping systems in Asia: Working with farmers to enhance adaption of more sustainable production practices: Proceedings of the workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam, Oct. 27-31, 2003. Centro Internacional de Agricultura Tropical (CIAT), Cassava Office for Asia, Bangkok, TH. p. 65-73.
21. Watananonta, W.; Klakhaeng, K.; Vongkasem, W.; Howeler, R.H. 2008. Adoption of new technologies and their impact on cassava production in Thailand. In: Howeler, R.H. (ed.). Integrated cassava-based cropping systems in Asia: Working with farmers to enhance adaption of more sustainable production practices: Proceedings of the workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam, Oct. 27-31, 2003. Centro Internacional de Agricultura Tropical (CIAT), Cassava Office for Asia, Bangkok, TH. p. 78-87.
22. Dixon, A. and H. Ceballos (2008). Megabreeding of cassava for African rural development: where do we stand? First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P19
23. Morillo, A. C., Y. Morillo, A. L. Chávez, M. Fregene and H. Ceballos (2008). Identification of regions of the cassava genome involved in carotene synthesis and accumulation in cassava. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P40
24. Egesi, C., C. Guambe, A. Rosero, T. Sánchez, N. Morante, H. Ceballos and M. Fregene (2008). Controlling delayed post harvest physiological deterioration (PPD) in cassava. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P45
25. Kim, H., N. V. Ngai, R. Howeler and H. Ceballos (2008). Current situation of cassava in Vietnam and its potential as a biofuel. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P54
26. Simmons, A., H. Ceballos and C. M. Fauquet (2008). Cassava root proteome landscape available for gene discovery. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P70
27. Sánchez, T., H. Ceballos, D. Dufour, K. Denyer, A. Smith, M. Fregene, J. C. Pérez, N. Morante, A. Rosero and A. Tofiño (2008). Characterization of amylose-free and high-amylose starch mutations. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P93
28. Ceballos, H., J. C. Pérez, F. Calle, J. I. Lenis, N. Morante, M. Fregene, T. Sánchez, and A. L. Chávez (2008). Recent progress in cassava breeding technologies. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium.p106
29. Fukuda, W. M., V. Santos, L. Oliveira, M. Pereira, H. Ceballos, M. Nutti, J. Carvalho and M. Dita (2008). Breeding cassava for enhancement of carotenoids, iron and zinc contents. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium.p106
30. Rosero, A., C. Cuambe, C. Egesi, H. Ceballos and M. Fregene (2008). Controlling delayed post-harvest physiological deterioration (PPD) in cassava. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P119
31. Duque, L., T. Setter, H. Ceballos, M. Fregene and A. Alves (2008). Evaluation of drought tolerance in contrasting cassava varieties genotypes under field controlled

water stressed environments. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium.p143

32. Changhu W., E. Tabares, M. Quintero, H. Ceballos and Z. Lentini (2008). Development of doubled-haploids through isolated microspore culture can greatly benefit cassava breeding and other applications. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium.p160
33. Adeyemo, O. S., S. J. Davis, P. Chavarriaga, J. Tohme, H. Ceballos and M. Fregene (2008). Strategies for enhancing flowering in cassava using molecular tools: towards a more efficient breeding program. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P51
34. Fukuda, W., L. Oliveira, V. Santos, H. Ceballos, M. Nutti, and J. L. Carvalho (2008). Development of cassava cultivars with high iron and zinc contents in roots. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium.p111
35. Calle, F., J. I. Lenis, J. C. Pérez, G. Mafla, D. Debouck, H. Ceballos, J. Tohme and N. Morante (2008). Variation in starch and root quality traits in cassava. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P111
36. Calle, F., J. I. Lenis, J. C. Pérez, G. Mafla, D. Debouck, H. Ceballos, J. Tohme and N. Morante (2008). Multilocation evaluation of the cassava core collection from CIAT. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P88
37. Morillo, Y., A. L. Chávez, T. Sánchez, N. Morante, J. C. Pérez, F. Calle and H. Ceballos (2008). Heritability estimates of carotenoids content in cassava roots. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium.p112
38. Ceballos, H., M. Fregene, D. Debouck, D. Dufour, J. Tohme, T. Sánchez, G. Mafla, N. Morante, and J. C. Pérez (2008). High-value cassava germplasm: a reality that will open markets to cassava farmers. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium.p113
39. Changhu W., E. Tabares, M. Quintero, H. Ceballos, C. Sautter, Z. Peng and Z. Lentini (2008). Development of the microspore in cassava (*Manihot esculenta*, Crantz) and androgenesis. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium.p167
40. Chávez, A.L., M. Ishitani, T. Sánchez, M. Dominguez and H. Ceballos (2008). Reliability of freezing carontenoids extracts for an efficient tandem selection of high β-carotene in cassava. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P37
41. Chávez, A. L., Morillo, Y., T. Sánchez, N. Morante, M. Dominguez, J. Tohme and H. Ceballos (2008). Enhancing the nutritional quality of cassava roots to improve the livelihoods of farmers in marginal agriculture: vitamin A. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium.p.37
42. Kim, H., N. V. Bo, R. Howeler and H. Ceballos (2008). Current situation of cassava in Vietnam n the selection of cassava doubled haploids (dh) lines derived from CIAT. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P. 63
43. Kim, H., N. V. Ngai, R. Howeler and H. Ceballos (2008). New progress of cassava research and extension in Vietnam. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P. 60
44. López, D., J. Beltrán, M. C. Duque, H. Ceballos, P. Zhang, W. Gruissem, P. Chavarriaga and J. Tohme (2008). Transgenic plants carrying an isopentenyl transferase (ipt) gene of Agrobacterium, under the control of a senescence-inducible promoter from Arabidopsis, increased foliage under field conditions. First Scientific Meeting of the Global Cassava Partnership GCP-1. Ghent, Belgium. P. 131
45. Sánchez, T., A. Rosero, A. P. Tofiño, K. Denyer, A. Smith, H. Ceballos, N. Morante, and J. C. Pérez (2008). Induction and identification of useful mutations for root quality traits in cassava. FAO/IAEA International Symposium on Induced Mutations in Plants. Vienna, Austria. P.107

46. Ceballos, H., K. Fahrney, R. Howeler and B. Ospina (2008). Cassava potential for bioethanol Soils Science, Agronomy and Crop Science Societies of America Joint Meeting. Houston, USA. p.308
47. Ceballos, H., T. Sánchez, A. Rosero, A. P. Tofiño, K. Denyer, A. Smith, D. Dufour, N. Morante, J. C. Pérez, M. Fregene and C. Egesi (2008). High-value cassava: from a dream to a concrete reality. 8th Asian Cassava Research Workshop. Vientiane, LAO PDR. P.5
48. Bo N. V., H. Kim, N. V. Ngai, T. N. Ngoan, H. Ceballos and R. Howeler (2008). New developments in the cassava sector in Vietnam. 8th Asian Cassava Research Workshop. Vientiane, LAO PDR. P. 9
49. Kim, H., N. Phuong, T. C. Khan and Hernán Ceballos (2008). Recent progress in cassava breeding and varietal adoption in Vietnam. 8th Asian Cassava Research Workshop. Vientiane, LAO PDR. P. 13
50. Okogbenin, E., M. Fregene, L. G. Santos, C. Ospina, P. Hurtado, I. Moreno, H. Ceballos, J. Tohme, C. Egesi, K. Ogundapo, S. Hahya, C. Mba, E. Okai, H. Gomez and C. de Vicente (2008). The use of molecular markers to identify and breed for resistance to African and Indian Cassava Mosaic Disease. 8th Asian Cassava Research Workshop. Vientiane, LAO PDR. P. 47
51. Ceballos, H. (2008). Yuca industrial con énfasis en la producción de etanol para regiones estratégicas de Colombia. 1er Foro de socialización de la investigación para la agricultura en Colombia. Bogotá, Colombia. Proceeding in a CD
52. Ceballos, H. (2009). Shaping the Future for Tapioca: Innovations in Genetic Improvement. World Tapioca Conference. Bangkok, Tailandia.
53. Calari, A., Paltrinieri, S., Duduk, B., Mejía, J.F., Álvarez, E., Carraro, L., Bertaccini, A. 2008. Genomic variability within conserve genes of 16SrIII phytoplasma strains in micropropagated periwinkles and in naturally infected host plants. Abstract presented at the Proc of the 17th Congress of the International Organization for Mycoplasmology, held in Tianjin, China, on 6–11 July 2008.
54. Alvarez, E. 2008. Cassava Diseases in Latin America Africa and Asia. In: 8th Asian Cassava Research Workshop. Vientiane, LAO PDR. October 20-24, 2008. Lecture.
55. Aye, T.M. 2008. Cassava production and utilization in Myanmar. *In:* 8th Regional Cassava Workshop, held in Vientiane, Lao PDR. Oct 20-24, 2008.
56. Aye, T.M. and R.H. Howeler. 2008. The way forward in cassava collaboration in Asia. *In:* 8th Regional Cassava Workshop, held in Vientiane, Lao PDR. Oct 20-24, 2008.
57. Howeler, R.H. 2008. Does cassava degrade soils? *In:* First Scientific Meeting of the Global Cassava Partnership (GCP-1), held in Gent, Belgium. July 21-25, 2008.
58. Howeler, R.H. and K. Fahrney. 2008. Cassava production and utilization in Asia and its potential as a bio-fuel. *In:* NexGen Bio-ethanol Conference, held in Bangkok, Thailand. April 22-24, 2008.
59. Howeler, R.H. and K. Fahrney. 2008. Cassava production and utilization in Asia and its potential as a feedstock for bio-fuel. *In:* EU-Asia Biofuel Workshop, held in Bangkok, Thailand. Nov 2-4, 2008.
60. Howeler, R.H. 2008. Cassava in Asia: A potential new green revolution in the making. *In:* 8th Regional Cassava Workshop, held in Vientiane, Lao PDR. Oct 20-24, 2008.
61. Howeler, R.H. 2008. Does cassava production degrade or improve the soil? *In:* 8th Regional Cassava Workshop, held in Vientiane, Lao PDR. Oct 20-24, 2008.
62. Howeler, R.H. 2008. Technology adoption and impact as a result of the Nippon Foundation cassava project in Thailand, Vietnam and China. *In:* 8th Regional Cassava Workshop, held in Vientiane, Lao PDR. Oct 20-24, 2008.

5.4 CHAPTERS IN BOOKS

1. Howeler, R.H. 2008a. Background and general methodology used in the Nippon Foundation Project. *In:* R.H. Howeler (Ed.). Integrated Cassava-based Cropping Systems in Asia. Working with Farmers to Enhance Adoption of More Sustainable Production Practices. Proc. Workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam. Oct 27-31, 2003. pp. 5-32.

2. Howeler, R.H. 2008b. Results, achievements and impact of the Nippon Foundation cassava project. *In:* R.H. Howeler (Ed.). Integrated Cassava-based Cropping Systems in Asia. Working with Farmers to Enhance Adoption of More Sustainable Production Practices. Proc. Workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam. Oct 27-31, 2003. pp. 161-223.

3. Huang Jie, Li Kaimian, Ye Jianqiu, Liu Guodao and R.H. Howeler. 2008. The FPR project in Hainan province of China. *In:* R.H. Howeler (Ed.). Integrated Cassava -based Cropping Systems in Asia. Working with Farmers to Enhance Adoption of More Sustainable Production Practices. Proc. Workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam. Oct 27-31, 2003. pp. 33-46.

4. Nguyen Thi Hoa Ly, Dao Thi Phuong, Le Van Phuoc, Le Van An and R.H. Howeler. 2008. The FPR cassava project and its impact on the use of ensiled cassava roots and leaves for on-farm pig feeding in Central Vietnam. *In:* R.H. Howeler (Ed.). Integrated Cassava-based Cropping Systems in Asia. Working with Farmers to Enhance Adoption of More Sustainable Production Practices. Proc. Workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam. Oct 27-31, 2003. pp. 130-139.

5. Trinh Thi Phuong Loan, Thai Phien, Hoang Van Tat, Dao Huy Chien, Nguyen Hue, Nguyen Thi Bong and R.H. Howeler. 2008. The FPR cassava project and its impact in Ha Tay, Hoa Binh and Thanh Hoa provinces of north Vietnam. *In:* R.H. Howeler (Ed.). Integrated Cassava-based Cropping Systems in Asia. Working with Farmers to Enhance Adoption of More Sustainable Production Practices. Proc. Workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam. Oct 27-31, 2003. pp. 113-123.

6. Vankaew, B., P. Petpraphai, W. Watananonta, W. Vongkasem and R.H. Howeler. 2008. The use of a farmer participatory approach in cassava technology transfer in Thailand. *In:* R.H. Howeler (Ed.). Integrated Cassava-based Cropping Systems in Asia. Working with Farmers to Enhance Adoption of More Sustainable Production Practices. Proc. Workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam. Oct 27-31, 2003. pp. 74-77.

7. Vongkasem, W., K. Klakhaeng, K. Srakaew, R. Sevatasai, W. Watananonta and R.H. Howeler. 2008. Farmer participatory research (FPR) and extension (FPE) methodologies used in Thailand. *In:* R.H. Howeler (Ed.). Integrated Cassava-based Cropping Systems in Asia. Working with Farmers to Enhance Adoption of More Sustainable Production Practices. Proc. Workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam. Oct 27-31, 2003. pp. 65-73.

8. Watananonta, W., K. Klakhaeng, W. Vongkasem and R.H. Howeler. 2008. Adoption of new technologies and their impact on cassava production in Thailand. *In:* R.H. Howeler (Ed.). Integrated Cassava-based Cropping Systems in Asia. Working with Farmers to Enhance Adoption of More Sustainable Production Practices. Proc. Workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam. Oct 27-31, 2003. pp. 78-87.

5.5 Edited books

1. Howeler, R.H. 2008. Integrated Cassava-based Cropping Systems in Asia. Working with Farmers to Enhance Adoption of More Sustainable Production Practices. Proceedings of a Workshop on the Nippon Foundation Cassava Project in Thailand, Vietnam and China, held in Thai Nguyen, Vietnam. Oct 27-31, 2003. 252 p.

2. Howeler, R.H. (Ed.). 2009. The Use of Cassava Roots and Leaves for On-farm Animal Feeding. Proceedings of a Regional Workshop, held in Hue city, Thua Thien Hue province, Vietnam. January 17-19, 2005. 256 p.

6. LIST OF SPECIAL PROJECTS

6.1. New proposals submitted during 2008

Title	Donor	Funding period	Total Amount (US $)	Amount to Partners (US $)	Available in 2009 (US$)
Development of a waxy-starch variety for Brazil	Fadel – Halotek and National Starch Company	2008-2012	750,000	0	200,000
Development of high-value cassava varieties for Colombia	Industrias del Maíz Andina; Grupo GCP and COLCIENCIAS	2008-2012	250,000	0	125,000
Use of DArT (Diversity Array Technology), as markers for resistance to frog skin disease	COLCIENCIAS	2008–2009	148,000,000 Colombian pesos		
Harnessing water-use efficient bio-energy crops for enhancing livelihood opportunities of smallholder farmers in Asia, Africa and Latin America	IFAD	2008-2010	139,000	126,200	77,000
Desarrollo y evaluación de un programa de manejo integrado de microorganismos asociados con la enfermedad de cuero de sapo en yuca en la zona caribe Colombiana	MADR	20082011	860,000	29,012	94,503
NIPPON Foundation proposal for cassava research and development in Asia.	NIPPON Foundation	2009-2013	US$ 2,106,000		US$ 421,200

6.2. New proposals approved in 2008

Title	Donor	Funding period	Total amount	Amount to Partners (US $)	Available in 2009 (US$)
Use of DArT (Diversity Array Technology), as markers for resistance to frog skin disease	COLCIENCIAS	2008–2009	148,000,000 Colombian pesos	0	US$ 62,000
NIPPON Foundation proposal for cassava research and development in Asia.	NIPPON Foundation	2009-2013	US$ 421,200	0	US$ 421,200

6.1.3 List of ongoing special projects in 2008

Title	Donor	Funding period	Total Amount (US $)	Amount to Partners (US $)	Available in 2008 (US$)
Doubled-Haploids	Rockefeller Foundation	2006-2008	600,000	36,667	220,971
Improved nutritional quality of cassava	HarvestPlus	2003-2009	1,193,703	63,999	327,325
Harnessing water-use efficient bio-energy crops for enhancing livelihood in Asia, Africa and Latin America	IFAD	2008-2010	299,134	30,000	76,989
Production of a waxy starch variety for Thailand	TTDI	2008-2012	750,000	-.-	200,000
Improving Livelihoods of Smallholders Upland Farmers in Lao PDR	NIPPON Foundation	2004 - 2008	812,500	43,500	463,600
Development of low-cost technologies to pyramiding useful genes from wild relatives of cassava into Elite progenitors	Generation Challenge Program	2005-2007	894,906	30,000	25,259
Combating Hidden Hunger in Latin America: Biofortified crops with improved Nutritional Quality	CIDA	2006-2010	651,386	0	81,998
Integrated disease management practices in cassava with special emphasis on frog skin disease	MADR	2006-2008	361,040	29,770	96,969
A Cassava Breeding Community of Practice in Africa: Production of Farmer-Preferred Cassava Varieties	Generation Challenge Program Commissioned	2008	189,900	99,600	90,300
Improvement of the Nutritional Value of Cassava: High Storage Protein Content, No Cyanide Liberating Toxins	KVL	2006-2009	133,718	15,250	45404
BioCassava plus program	Ohio State Univ.-Danfourt	2005-2010	287,237	0	45,497
Improved Cassava Production and Utilization Systems in Indonesia and East Timor	ACIAR	2004-2008	308,799	0	2,846
Development of an in vitro protocol for the production of cassava doubled haploids and its use in breeding	ZIL – ETH	2004 – 2008	193,883	0	38,699
High value cassava clones- PCTA	COLCIENCIAS	2004 –08	110,425	0	27,000
Integrated Crop Management (ICM) Componet of the Training Objective of the Great Lakes Cassava Initiative (GLCI)	CRS	2008-2009	26,000	0	26,000
Cassava Productivity in Sub-Saharan: Characterizing and Combining New Resistance to Cassava Mosaic Disease	Rockefeller Foundation	2005-2008	53,673	0	17,000
Master Agreement Regarding the Provision of Genotyping Services	GCP Competitive	2005-2008	84,200	0	55,000
International Program in the Chemical Sciences	IPICS	2000-2008	172,837	0	6,677
Swine feeding based on cassava	MADR	2006-2008	82,497	0	52,069
Identifying the Physiological and Genetic Traits that Make Cassava One of the Most Drought Tolerant Crops. D485gcp	GCP Competitive	2005-2009	258,837	0	2,030
Sustainable production of cassava. Evaluation of cassava clones	IICA	2005-2008	126,936	0	42,312
Design and builgind of a pilot plant for the production of bio-ethanol	MADR	2007-2008	46,423	0	23,200
New waxing alternatives for the preservation of cassava roots.	Universidad del Valle	2007-2010	75,250	0	10,010
Evaluation of two vegetable fibers: Kenaf	Productora de Papeles S.A	2008-	54,500	0	21,800

(*Hibiscus Cannabinus* L) and Roselle (*Hibiscus Sabdariffa* L) for the paper making industry	(PROPAL)	2009			
TOTALS			**6,872,878**	**288,786**	**2,103,778**

7. Problems encountered and their solution

- During 2008 two international recruited scientists collaborating with the project decided to leave CIAT: Martin Fregene (Molecular Geneticist) and Zaida Lentini (Tissue Culture expert). Their departure affected the work in several projects related to molecular markers and to the protocol for the production of doubled haploids. Several remaining staff at CIAT have involved themselves in covering the activities of these two departing scientists. Hopefully CIAT will replace these positions in the near future.

- Departure of Martin Fregene left the budgets of the different activities under his coordination with a large deficit and several commitments made by CIAT which were left without resources. Accounting, outcome leaders and the projects office personnel become aware of the deficiencies in the system and have developed approaches to avoid this kind of problems in the future.

- The retirement of Anthony C. Bellotti as the leader of cassava entomology research has left a team of capable research assistants without a leadership. CIAT has hired a new entomologist that will start working sometime during 2009. This new person will hopefully take advantage and benefit from the vast capital human capacity, experience, products and knowledge that had been generated and accumulated over the years in the area of cassava entomology. There may be, however, problems to deliver on time some of the outputs as originally planned for instance in the identification of vectors for FSD, originally expected to happen in 2010.

8. Staff List (including % time assignment)

8.1 Staff at Headquarters

Hernán Ceballos, PhD, Cassava Breeding and Pre-breeding, Project Manager (**70% SBA-2**, **30% SB-2**)
Martin Fregene, PhD, Molecular Breeder and Cassava Geneticists (**60% SB-2, 40% SBA-2**) Left CIAT during 2008
Elizabeth Alvarez, PhD, Plant Pathologist (**80% IP-1, 20% PE-1**)
Bernardo Ospina, M.Sc. Director CLAYUCA (**100% SBA-2**)

8.2 Staff posted in Africa or asia

Reinhardt Howeler, Ph.D, Cassava Agronmist **(75% SBA-2).**
Tin M.Aye, Post-doctoral Fellow **(100% SBA-2)**
Emmanuel Okogbenin Post-doctoral Fellow **(100% SBA-2)**

Outcome Line SBA-2: Cassava

SOURCE	Cassava Project			Total US$	(%)
	HQ + LAC	Asia & Africa	URG + Biotech		
Unrestricted Core	188,149		156,401	344,550	6%
Restricted Core C.E + Japan	732,190			732,190	12%
Sub-total Core	**920,339**	**-**	**156,401**	**1,076,740**	**18%**
Restricted					
Special Projects	1,583,091	591,173	1,004,081	3,178,346	52%
Generation Challenge Program	181,672		254,592	436,264	7%
Harvest Plus	285,864		429,099	714,964	12%
Sub Total Restricted	**2,050,627**	**591,173**	**1,687,773**	**4,329,573**	**71%**
Direct Expenditures	**2,970,966**	**591,173**	**1,844,173**	**5,406,313**	**89%**
Non Research Cost	382,481	76,107	237,418	696,007	11%
Total Expenditures	**3,353,448**	**667,281**	**2,081,592**	**6,102,320**	**100%**

(1) Excluding Non Operational expenses: Phase-out and Fixed Assets adjustment.