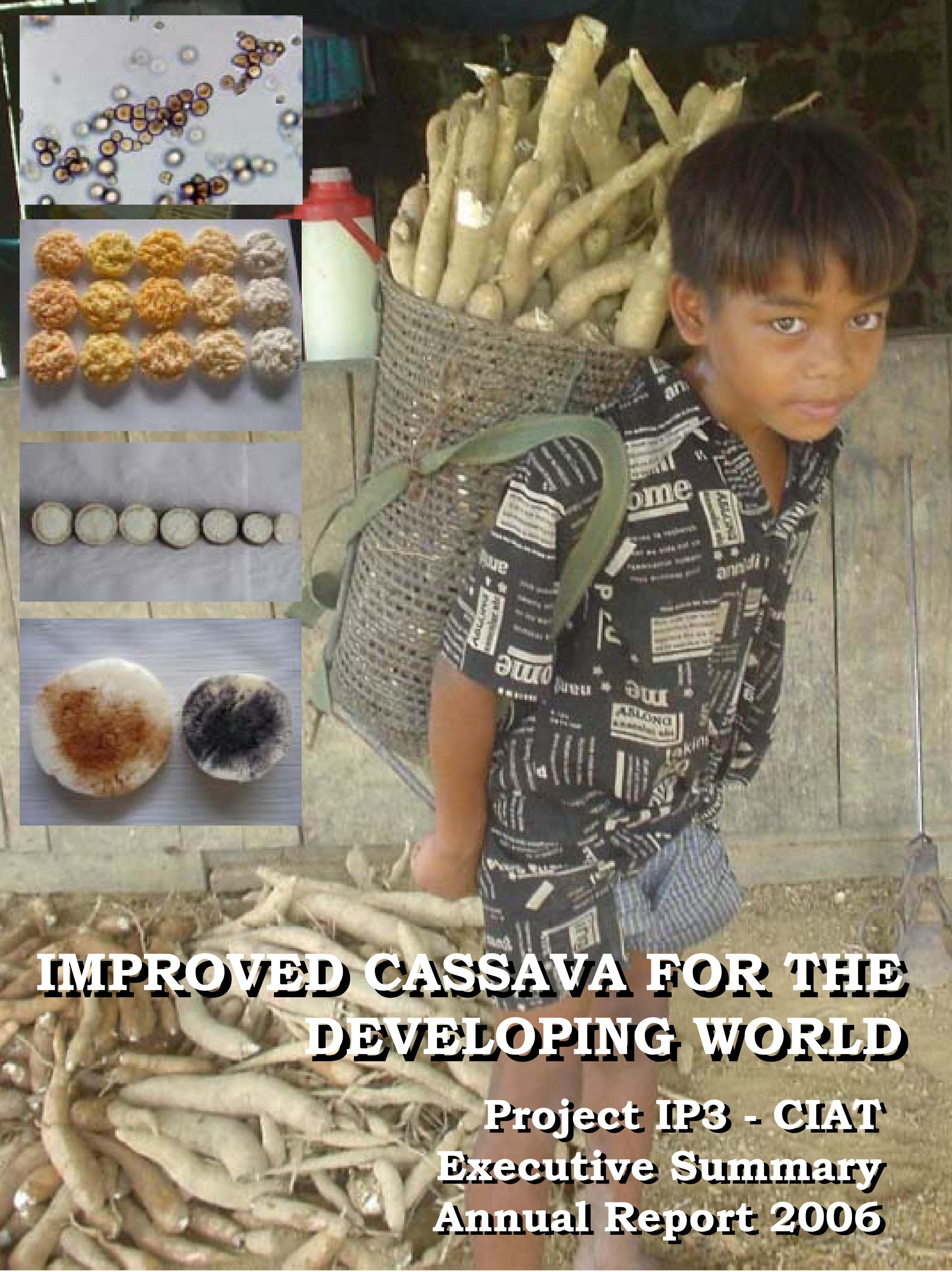

IMPROVED CASSAVA FOR THE DEVELOPING WORLD

Project IP3 - CIAT
Executive Summary
Annual Report 2006

1. LOGFRAME

Cassava outputs for the 2006-2008 period.

Output targets	Outputs	Intended users	Outcome	Impact
Output 1 Genetic stocks improved gene pools developed and transferred to national programs.				
2006, 2007, and 2008	Generation, identification and transfer to national programs of elite cassava germplasm with high and stable productivity	National research programs and cassava farmers and communities in Africa, Asia and Latin American and the Caribbean.	Consolidation and strengthening of cassava-based agriculture.	Increased and stable income of cassava farmers and processing facilities. Enhanced food security of rural communities that grow cassava. Rural development
2007	Identification, indexation and transfer to national programs of cassava clones identified with higher than normal protein levels.	National research programs, 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 the feed industry (in developing and developed countries) to incorporate cassava as source of energy in the diets but with the additional advantage of the reduced or no need for additional sources of protein.	Increased value and stronger markets for cassava products. Enhanced nutritional status of people consuming higher-protein roots. Alternative sources of raw material for the feed industry (different from maize and soybean).
2008	Identification, indexation and transfer to national programs of cassava clones identified particular starch quality traits.	National research programs, 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 the starch industry (in developing and developed countries) to incorporate cassava as source of raw material in their operations.	Increased value and stronger markets for cassava products. Higher income of cassava communities. Reduced environmental impact in the process of production of modified starches.

Output 2 New methods for cassava breeding developed				
2007	First systemic study of inbreeding depression in cassava conducted and published.	Scientists from national programs and universities in developing countries.	Proof of concept that inbreeding of cassava facilitates its genetic improvement. Sustained and faster genetic gains for cassava to compete with other crops like maize.	Increased and more stable income of cassava farmers and processing facilities. Enhanced food security of rural communities that grow cassava.
2008	First evaluation of hybrids from partially inbred parental clones. By defiinition these parents have reduced genetic load and are better parents than those currently used.	Breeders from national programs and universities in developing countries. Scientists working with other crops n developing and developed countries.	Better hybrids will lead to increased and more stable income of cassava farmers and processing facilities.	Increased and more stable income of cassava farmers and processing facilities. Enhanced food security of rural communities that grow cassava. Sustained and faster genetic gains for cassava to compete with other crops like maize.
Output 3 **Research on the industrial uses of cassava and elite germplasm produced**				
2006	Stability of high- and low-amylose traits evaluated in contrasting clones. Similar study for high-protein.	Scientists from national programs and universities in developing and developed countries. Starch industry.	Cassava breeding projects in Asia, Africa and LAC shift their objectives towards the development of high-value cassava clones.	Stronger markets for cassava. Rural development in cassava growing communities. Reduced poverty.
2007	Field evaluation of S1 plants from mutagenized cassava and results of TILLING	Scientists from national programs and universities in developing and developed countries.	Identification of commercially useful cassava mutants. Proof of concept of novel technologies.	A range of useful traits that cannot be predicted at this point (i.e. apomixis, acyanogenesis, novel starch types, etc.) with high scientific value on one hand and, eventually, large economic impact.
2008	Field evaluation of first cycle of recurrent selection for high- or low-amylose starch.	Scientists from national programs and universities in developing and developed countries.	Cassava breeding proejcts learn to interact with processing sector and deliver products better suited for their needs. Shift in breeding objectives and methods at NARs.	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.

Output 4 **Development and use of biotechnology tools for cassava improvement**				
2006	Results from first generation of germplasm introduced into Africa using molecular marker for ACMV consolidated.	Scientists from national programs and universities in developing and developed countries. Cassava farmers in Africa	Deployment of a new approach to introduce cassava germplasm in Africa	Improved cassava health and productivity, particularly in Eastern African Countries.
2007	Development of markers for high beta-carotene, protein, and/or dry matter content in cassava roots. Results from the first field-evaluation of transgenic cassava. Validation of MAS in cassava-breeding at NARs.	Scientists from national programs and universities in developing and developed countries.	Cassava is no longer a *neglected* crop: biotechnology tools have been adapted and contribute in its genetic improvement. More efficient genetic improvement of cassava	Increased and more stable income of cassava farmers and processing facilities. Enhanced food security of rural communities that grow cassava, particularly in Africa.
2008	Identificiation of root promoters 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.	Enhanced economic value of cassava. Improved nutritional conditions of communities where cassava is an important component of diet. More efficient breeding methods will lead to faster and more consistent genetic gains. Root promoters found in cassava can help other root and tuber crops as well.
Output 5 **Breeding for insect and other arthropods and disease resistance and development of alternative methods for their control**.				
2007	Significant progress in identifying and eventual cloning of the resistance gene(s) for	Field and molecular breeders and entomologists from national programs and universities in developing countries.	Combined with resistance to the African Cassava Mosaic Virus a stable and effective solution to	Improved health and productivity of cassava. Sustainable production, particularly in AFrica. Potential benefit to other crops in developed countries (e.g.

	white flies found in cassava germplasm (MECU 72)		ACMV problem in Africa can be obtained.	tomato in Europe) leading to a reduction in the use of pesticides.
2008	Introgression of genetic variability from wild *Manihot* species in search of resistance genes for insects and diseases.	Breeders, entomologists and pathologists from national programs and universities in developing and developed countries. Cassava farmers.	Better understanding and exploitation of the genetic variability in the *Manihot* gene pool. Scientific justification for the need of exploration and conservation of genetic resources.	Improved cassava health and productivity. Increased south-to-south collaboration between Brazilian and African research institutions.
Output 6 **Increasing the productivity of cassava in Asia using farmer participatory methods.**				
2006	On-station research on cassava leaf production, preparation of root and leaf silage and more productive pig and goat feeding. Value adding of cassava roots through small-scale processing. Training in cassava production, animal feeding and farmers' participatory research (FPR)	Researchers and extensionists from national programs, cassava farmers and/or small-scale processors. Cassava breeding project at HQ and NARs in Africa. Households involved swine production, particularly the women that typically are in charge of feeding them.	Improved nutrition and health of farm animals fed with cassava roots and leaves, especially during the dry season. Enhanced research capacity of NARs.	Increased and more stable income for farmers. Enhanced research capacity in countries that urgently need it. Improved conditions of women who typically are responsible of feeding pigs in households in many different countries.
2007	FPR trials on newly introduced clones and balanced fertilizer use established in Cambodia, East Timor (ET) and Laos. Collection and evaluation of local varieties in these countries.		Improved yields and more sustainable production of cassava in Laos, Cambodia, Indonesia and ET	Increased and sustainable income for farmers. Reduction of the negative impact on the environment of cassava cultivation, particularly in marginal and slopped land.

2008	Increasing adoption of improved varieties, balanced fertilization, soil conservation practices and use of cassava roots and leaves for on-farm feeding.		Improved yields and more sustainable cassava production in target countries. Increased and more stable income for farmers. More alternatives for the use of cassava products open to farmers.	Increased and stable income of farmers. Protection to the environment. Poverty alleviation.
Output 7 **Latin American and the Caribbean Consortium on cassava (CLAYUCA)** NOTE: The following are contributions that CLAYUCA and IP3 will be having during the next three years. CLAYUCA's work is complementary in some areas to the IP3's agenda.				
2006	Consolidation of technological packages for cassava production systems based on mechanization of planting and harvesting.	Cassava agro-industrial projects with emphasis in Colombia, Venezuela, Ecuador, Mexico, Nigeria, South Africa, National Research Programs.	Sustainable cassava production systems in the region. Alternatives for a significant reduction in production costs and enhanced productivity of cassava.	Higher income for cassava growers and processors. Enhanced food security for cassava growers and processors. Rural development in cassava growing and processing countries and regions.
2007	Evaluation of germplasm with enhanced nutritional value in farmer-managed conditions in three regions of Colombia and research on different processing approaches.	Cassava agro-industrial projects in Colombia and other countries in the region.	High-value cassava germplasm available for agro-industrial projects, national research programs, cassava producers and processors.	Higher economic value for cassava production systems. Rural development in cassava growing communities.
2008	Cassava foliage productions systems validated under commercial conditions and improved cassava germplasm for foliage production identified.	Cassava agro-industrial projects in Colombia and other countries in the region.	Cassava foliage consolidated as a raw material for animal feeding systems.	Higher income for cassava farmers. Enhanced food security. South-to-south cooperation.

2. Output targets for 2006

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

Output 1:
Genetic stocks improved gene pools developed and transferred to national programs.
Target:
Generation, identification and transfer to national programs of elite cassava germplasm with high and stable productivity

A total of 783 genotypes from the germplasm bank have been shared as in vitro planting material until December 2006. Of these 71 genotypes were shipped to partners in Latin America (a total of 319 in vitro plantlets), 224 to partners in Asia (represented by 657 in vitro plants), 41 to partners in Africa (including IITA, for a total of 174 in vitro plants) and 447 genotypes to advanced laboratories Europe and USA, including those where planting material is indexed for certification to be disease-free prior to their introduction to Africa (a total of 524 plantlets). In addition, a total of 176 families (as botanical seed) were shipped to different countries. Of these, 71 families (represented by 4329 botanical seeds) went to Latin American countries and the remaining 105 families (represented by 7083 botanical seeds) to Asia. In addition a total of 1087 CIAT improved varieties and advanced breeding lines have been shipped to Africa, after screening for resistance to the CMD disease using the molecular marker described in Output 4. In addition 198 genotypes in vitro were shipped to Sweden and 35 to Brazil as part of collaborative work with the Generation Challenge Program. In addition a total of 546 in vitro plants from six different elite cassava germplasm was sent to Austria to be irradiated with different doses of gamma rays and repatriated to CIAT for phenotyping and in search of useful mutations.

Of relevance is the recent shipment of 21high-protein clones (a total of 126 in vitro plants) to Africa. These genotypes are the result of a shift in the objectives of the cassava-breeding project at CIAT to identify clones with high-value traits.

This target was achieved and as evidence the different documents for the courirer company that delivered the germplasm to the different recipients are available at CIAT administration.

Output 2:
New methods for cassava breeding developed.
Target:

First study of inbreeding depression in cassava conducted and published.

Although this target was planned to be delivered in 2007 the data necessary for this target has already been produced and a preliminary publication made during the 14th Triennal Symposium of International Society for Tropical Root Crops held in Kerala State, India during November 2006. Proper citation in the proceedings of such meeting is: Pérez, J.C., J. López , H. Ceballos and N. Morante. "*Introduction of inbreeding and analysis of inbreeding depression in eight S_1 cassava families*". In addition two Masters Degree theses are being conducted and will be finished during 2007.

Output 3:
Research on the industrial uses of cassava and elite germplasm produced
Target:
Stability of high- and low-amylose traits evaluated in contrasting clones. Similar study for high-protein.

A trial involving high- and low-amylose, as well as high- and low-protein clones was planted and harvested in four different locations. One of these locations (CIAT-Palmira) was affected by the flooding of the fields that killed the plants in large sections of the nurseries and was not included. This complex evaluation trial also included planting and harvesting the materials at different ages and in addition to the traits mentioned above high and low carotenoids, high and low Fe and high and low Zn were also included. Three genotypes were used for each class (i.e. three high-amylose clones and three low-amylose clones). Data are available and is currently under analysis for publication in a peer-reviewed journal. In addition samples were analyzed at Waite Analytical Services Laboratory at Adelaide University, Australia.

A significant event changed the whole strategy for this Output. In March 2006 a cassava mutation that results in starch to be amylose-free ("waxy" starch) was discovered as an outcome of Output 2 ("New methods for cassava breeding"). The mutation was found as a result of the introduction of inbreeding in cassava. Amylose-free cassava has been a constant request from the starch industry that saw this characteristic as a key trait to enhance the competitiveness of cassava as a raw material for starch. In a way, this mutation renders the idea of producing cassava germplasm with low amylose content in the starch from their roots through recurrent selection useless. There is no need for further breeding to achieve this goal because a single-gene mutation has already been found. The economic relevance of this discovery is difficult to be overemphasized.

Moreover, as a result of the mutagenesis work (a Target for 2007) a few mutations from self-pollinated (M_2) mutagenized plants (M_1) have already been discovered. Of relevance is the "small granule" mutation that doubles the amount of amylose is the roots of these cassava plants. In other words with few days of difference mutations that result in starch free of amylose or with twice the normal level of amylose have been found. Therefore, the long-term recurrent selection scheme originally planned is outdated and unnecessary in light of these new discoveries.

The discovery of the different mutants makes 2006 a turning point year for cassava. The long term objectives of this activity have already been achieved during 2006, and this means that the future Targets for this Output will have to be modified so that the commercial advantages of these mutations can be fully exploited.

Output 4:
Development and use of biotechnology tools for cassava improvement

Target:

Stability results of the first generation of germplasm introduced into Africa using molecular marker for ACMV consolidated.

Molecular marker-assisted breeding of resistance to the cassava mosaic disease (CMD), using the dominant *CMD2* gene, at CIAT has led to the development of CMD resistant genotypes derived from a wide range of elite Latin American parental lines. A total of 503 CMD resistant genotypes were shipped to NARs of Tanzania, Nigeria, Uganda, and India beginning November 2004 until April 2005. Subsequent field evaluations (conducted in the second semester of 2005 through 2006) revealed 70% of the germplasm was resistant across all sites. Two cycles of evaluations in a single location in Nigeria led to the selection of 14 genotypes that combine CMD resistance and high yield. Three of the most promising genotypes were included in regional trials in preparation for on-farm adaptive trials and eventual release by the Nigeria's Plant Varietal Release Committee in late 2008. In Tanzania, 80 genotypes, with excellent resistance to CMD and good harvest index, were selected and used as parents in crosses with local cassava varieties to combine resistance to CMD with resistance to the cassava brown streak disease (CBSD). A total of 36,077 sexual seeds were obtained from these crosses and 60% of seeds established in a seedling trial to evaluate resistance to CMD and CBSD. Similarly in Uganda and India selections of CMD resistant lines have been made and incorporated into a multi-stage selection programs. As evidence of the progress made, the results have been reported in two peer-reviewed journal papers:

Fregene M. Morante N., Sanchez T., Marin J., Ospina C., Barrera E., Gutierrez J., Guerrero J., Bellotti A., Santos L., Alzate A., Moreno S., and Ceballos H (2006). Molecular Markers for the Introgression of Useful Traits from Wild *Manihot* Relatives of Cassava; Marker-Assisted Selection of Disease and Root Quality Traits. Journal of Root Crops, Vol 32, No.1, pp 1-31.

E. Okogbenin, M.C.M. Porto, C. Egesi, C. Mba, E. Espinosa, L.G. Santos, C. Ospina, J. Marín, E. Barrera, J. Gutiérrez, I. Ekanayake, C. Iglesias, and M.A. Fregene (2007). Marker-Assisted Introgression of Resistance to Mosaic Disease into Latin American Germplasm for the Genetic Improvement of Cassava in Africa. Crop Science (In press).

Output 6:
Increase the productivity of cassava in Asia using farmer participatory methods.

Target:
On-station research on cassava leaf production, preparation of root and leaf silage, and more productive pig and goat feeding. Value-adding on cassava roots through small-scale processing. Training in production, animal feeding and farmers' participatory research (FPR) methodologies.

Farmers in three provinces in Lao PDR and Cambodia, in five provinces of Indonesia, and in three districts of East Timor have evaluated both local and introduced varieties during field days organized at time of harvest of the trials. These evaluations are the basis for selecting the varieties that farmers will test in FPR trials on their own fields the following year. In 2006 a total of 147 FPR trials were established in Lao PDR, 19 in Cambodia, 36 in Indonesia and 17 in East Timor.

Cassava germplasm banks have been established at Naphok Agric. Research Center in Laos, at CARDI in Cambodia and at Maliana, Betano and Hare experimental sites in East Timor (Indonesia already has a large cassava germplasm collection). In Laos we now have about 10 local varieties and over 30 introduced ones, which are currently being incremented and evaluated. In Cambodia there are basically 2-3 local varieties and about 20 introduced ones, and in East Timor we have about 70 local varieties (with many duplicates) and 40 introduced ones. Photo books with digital photos of each variety, including leaves, shoot, stem and roots are being prepared. Three training courses were held in Indonesia, East Timor and Cambodia in Jan, Feb and March 2006, respectively.

Silage making and animal feeding trials have been conducted at Nam Xuang Center in Laos, at CelAgrid in Cambodia and at Brawijaya University in Indonesia; farmer-training courses on silage making were organized in seven districts of East Timor by MAFF. Farmer training courses on silage making have also been organized in Oudomxay by PRDU and by the Nippon Foundation Project in Luang Prabang and Xiang Khouang provinces of Lao PDR.

Collaborators at BPTP-East Java located in Malang, Indonesia are working on value-addition of cassava roots, through small-scale processing. They have set up three farmer groups in central and south Malang district and have taught farmers how to make various cassava-based produces for sale, such as *kripik*, *krupuk* and many other products that contain cassava. BPTP also organized a field trip for 19 researchers and farmers from those three groups to visit Gunung Kidul district of Yogyakarta and Pati district in Central Java to learn about the making of new cassava products in those provinces. They have produced a booklet with 31 recipes in Indonesian language and the farmer groups are now making some of the new products for sale in Malang, East Java.

The transfer in the form of tissue culture plants of about 600 clones from CIAT's core collection to Thailand's Rayong Field Crops Research Center was completed in 2005. These vitro-plants have been sub-cultured and multiplied, hardened and planted out in the field. There are now about 2-3 ha of various types of evaluations being conducted on this material at Rayong Center. See paper by Prapit Wongtiem *et al*. presented at the 14th Symposium of the Intern. Soc. Tropical Root Crops in India in Nov 2006. In addition, the transfer in the form of tissue culture plants of 100 local varieties from Indonesia to CIAT was completed in 2005. These have been sub-cultured in CIAT, and entered into the cassava germplasm bank in 2006.

Overall the Targets for this project have been fulfilled. Progress reports with experimental details have been submitted to the Nippon Foundation and ACIAR.

Output 7:
Latin American and the Caribbean Consortium for Cassava Research and Development (CLAYUCA).
Target:
Consolidation of technological packages for cassava production systems based on mechanization of planting and harvesting.

Mechanization of cassava planting and harvesting components of a cassava production technology has become a sine-qua-non condition to achieve the level of price competitiveness required for the cassava crop to enter as raw material in industrial markets (ethanol, starch, flour, animal feeding). CLAYUCA has continued the work in this area. Additional companies and prototypes have been identified, mainly in Brazil and Colombia. Cassava-based projects in Venezuela, Nigeria, and Colombia are now using these prototypes. Other countries such as Ghana, Ecuador, Costa Rica are in the process of acquiring the machinery.

Overall the Targets for this project have been fulfilled. The evidence of the progress can be found in the Report that CLAYUCA prepares for its stakeholders.

3. Research highlights from 2006

3.1 First Highlight

The massive application and adoption of marker assisted selection for resistance to the *Cassava Mosaic Disease* and other biotic stresses (i.e. green mite) has been a major development for the project during 2006. MAS for this viral disease (but also green mites) is now a standard technology with proven capacity to provide useful results. CIAT developed AR (combined resistance to CMD and green mite) or CR (only resistance CMD) germplasm pre-selected for resistance to these biotic stress factors using molecular markers. Tanzania, Nigeria, Uganda, India, Ghana, and South Africa have grown this germplasm with excellent results. This is the first time that germplasm from CIAT can be directly used in breeding nurseries because most of it was resistant to CMD. Previous shipments were plagued with susceptibility and of little use. A total of 60,000 seed from 300 families derived from crosses between AR or CR germplasm and local clones (farmers preferred and/or resistant to cassava brown streak virus disease, the other prevalent disease in Eastern Africa) at ARI-Mickocheni (Tanzania). This large population is currently screened for resistance to CMD using the three markers identified at CIAT. This is the first example of successful MAS in cassava.

3.2 Second Highlight

A long standing member of the cassava team currently based in Asia received during 2006 two international recognitions for his outstanding research and extension work in the areas of agronomy. Reinhardt Howeler received the following awards:

Royal decoration in the third class of the “Most Exalted Order of the White Elephant” by the Thai government for significant contributions to Thai cassava research and development - May 2006.

Recipient of 2006 “International Service in Agronomy Award” by the American Society of Agronomy, for outstanding contributions to Thai and Vietnamese cassava production through a team effort - Nov 2006.

This is a recognition to the excellence, commitment and dedication that Reinhardt Howeler demonstrated in his work for cassava in Asia. It is this work that prompted the Nippon Foundation to continue supporting our work in Asia as a second phase of a previous project, a rather seldom event in the Foundation’s tradition.

3.3 Third Highlight

The progress to increase the nutritional quality of cassava roots during 2006 provided very relevant information. During the year we demonstrated the usefulness of the NIRs for a rapid, reliable and inexpensive method to screen simultaneously for protein, carotenoid pigments, β-carotene, cyanogenic potential and dry matter content. In the area of proteins content evidence that higher N-content (the indirect method universally used for measuring proteins in living organisms) is independent of cyganogenic potential and, indeed related to increased amino-acid contents. We conducted the first experiment to measure genotype by environment interaction. Proteomics work is currently underway in collaboration with Danforth Center in the USA. Further understanding of the relationship between total carotenoids and β-carotene contents has been reached. This is important because it facilitates screening on one hand and supports the working hypothesis that current β-carotene content levels can be further increased. Ongoing progress and the evidence that molecular markers provide regarding multiple allelism in the genes involved in β-carotene synthesis further justifies continuing the work to increase the content of pro-vitamin A carotenoid pigments in cassava roots through traditional breeding. In addition to this the first transgenic plants for increased carotenoids content have been produced.

4. Research Outcome

Processing cassava is important to alleviate poverty. To meet the request from the starch industry, cassava-breeding activities at CIAT shifted its objectives and methodologies few years ago hoping to find mutations that would increase the commercial value of cassava, making this tropical source of starch more competitive. In 2006 two different mutations were found:

An amylose-free (waxy) starch mutation: a long time a request from the starch industry. Multinational companies invested in the development of a transgenic waxy cassava. However the regulatory issues have prevented this investment to prosper. Waxy maize starch is 30% more valuable that normal starch.

A small starch-granule mutation: that, in addition, has twice the normal levels of amylose in the starch. This mutation is thought to be equivalent to the ae_1 mutation in maize.

These two natural mutations have commercial applications for the starch and bio-ethanol industries and, therefore, provide high-value trait for this crop. They will have large impact in cassava starch and ethanol producing countries (i.e. Thailand and Brazil). So important are these mutations that multinational starch companies, as well as, NARs are interested in investing, for the first time, in the cassava breeding project at CIAT. In summary the outcomes of these discoveries are:

1. Traits that increase the commercial value of cassava and its products have been identified.
2. The efficiency of new breeding approaches demonstrated and adopted by NARs and IITA.
3. New sources of financial support for CIAT’s cassava project.
4. For the first time, a clear interest by large multinational starch companies to invest in cassava-germplasm enhancement.
5. Prompted the interest within NARs to consider the issue of proprietary rights for cassava improved germplasm.

This outcome (result of Outputs 2 and 3) is happening at EMBRAPA (Brasilia), TTDI (Bangkok) and National Starch (Bridgewater, USA).

5. Publications

5.1 PEER-REVIEWED JOURNALS (underlined are authors from NARs)

1. Alvarez, E., Mejia, J.F., Loke, J., Llano, G. 2006. Detection and characterization of a phytoplasma associated with cassava frogskin disease. **Fitopatología Colombiana** 29(2):69-76
2. Cach T.N., J.I. Lenis, J.C. Perez, N. Morante, F. Calle and H. Ceballos (2006). Inheritance of relevant traits in cassava (*Manihot esculenta* Crantz) for sub-humid conditions. **Plant Breeding** 125(2):177-182.
3. Castelblanco W. and Fregene M. (2006). SSCP-SNP based markers as conserved orthologous set (COS) markers for comparative genomics in cassava (*Manihot esculenta* Crantz). **Plant Molecular Biology Reporter** 24:229-236

4. Ceballos H., T. Sánchez, A.L. Chávez, C. Iglesias, D. Debouck, G. Mafla and J. Tohme (2006). Variation in crude protein content in cassava *(Manihot esculenta* Crantz) roots. **Journal of Food Composition and Analysis** 19:589-593
5. Ceballos, H., M. Fregene, Z. Lentini, T. Sánchez, Y.I. Puentes, J.C. Pérez, A. Rosero and A.P. Tofiño (2006). Development and Identification of High-Value Cassava Clones. **Acta Horticulturae** 703:63-70.
6. Chávez, A.L., T. Sánchez, H. Ceballos, D.B. Rodriguez-Amaya, P. Nestel, J. Tohme, M. Ishitani (2007). Retention of carotenoids in cassava roots submitted to different processing methods. **Journal of the Science of Food and Agriculture** 87(3):388-393.
7. Checa, O., H. Ceballos and M.W. Blair (2006). Generation mean analysis of climbing ability in common bean (*Phaseolus vulgaris* L.). **Journal of Heredity** 97(5)456-465.
8. Fregene M. Morante N., Sanchez T., Marin J., Ospina C., Barrera E., Gutierrez J., Guerrero J., Bellotti A., Santos L., Alzate A., Moreno S., and Ceballos H (2006). Molecular Markers for the Introgression of Useful Traits from Wild *Manihot* Relatives of Cassava; Marker-Assisted Selection of Disease and Root Quality Traits. **Journal of Root Crops**, Vol 32, No.1, pp 1-31
9. Holguin, C.M., A. Carabali, A.C. Bellotti. 2006. Tasa intrínseca de crecimiento de la población de *Aleurotrachelus socialis* Bondar en Yuca *Manihot esculenta* Crantz. **Revista Colombiana de Entomolgia** (32)2: 140-144.
10 Howeler, R.H., W. Watananonta, W. Vongkasem, K. Klakhaeng and Ngoan Ngoc Tran. 2006. Working with farmers: the key to achieving adoption of more sustainable cassava production practices on sloping land in asia. **Acta Horticulturae** 703: 79-88.
11. Kizito E., Chiwona-Karltun L., Egwang T., Fregene M., Westerberg A. (2006). Genetic diversity and variety composition of cassava on small scale farms in Uganda: an inter-disciplinary study using genetic markers and farmer interviews. **Genetica**. Published online September 2006.
12. Lenis, J.I., F. Calle, G. Jaramillo, J.C. Pérez, H. Ceballos and J. Cock (2006). Leaf retention and cassava productivity. **Field Crops Res.** 95(2-3):126-134.
13. Okogbenin, E.; Jaime Alberto Marin, and Martin Fregene (2006). A SSR marker based Genetic Map of Cassava. **Euphytica** 147:433-440.
14. Posada, C.A., A. López-G. and H. Ceballos (2006). Influencia de harinas de yuca y de batata sobre pigmentación, contenido de carotenoides en la yema y desempeño productivo de aves en postura. **Acta Agronómica** 55(3):47-54.
15. Tofiño, A., M. Fregene, H. Ceballos and D. Cabal (2006). Regulación de la biosíntesis del almidón en plantas terrestres: perspectivas de modificación. **Acta Agronómica** 55(1):1-
16. Watananonta, W., S. Tangsakul, S. Katong, S. Jantawat, N. Samuthong and R. Howeler. 2006. Effect of land preparation methods on root yields of four cassava varieties in Thailand. **Thai Agric. Research J**. 24(1): 2-19. (in Thai with English abstract)
17. Watananonta, W., S. Tangsakul, S. Katong, P. Pretprapai, S. Jantawat, N. Samuthong and R.H. Howeler. 2006. Effect of methods of land preparation on the yields of four cassava cultivars in Thailand. **Acta Horticulturae**. 703: 225-232.

5.2 CHAPTER IN BOOKS AND OTHER SCIENTIFIC PUBLICATIONS (underlined are authors from NARs)

1. Melo, M., E.L.; C.A. Ortega O.; A. Gaigl; A. Koppenhöfer; A.C. Bellotti. 2006. Evaluación de patogenicidad e infección de la nueva especie *Steinernema scarabaei* Stock & Koppenhöfer (Rhabditida: Steinernematidae) sobre la chisa rizófaga *Phyllophaga* pos. Bicolor. **In:** Nematodos entomoparásitos: Experiencia y perspectivas. Eds. J.C. Parada, J.E. Luque Z, W de J. Piedrahita C. Universidad Nacional de Colombia. Conciencias, Colombia. Pp. 127-136.

2. Melo, M., E.L.; C.A. Ortega O.; A. Gaigl; A.C. Bellotti. 2006. Evaluación de cinco aislamientos de nematodos entomoparásitos, nativos e introducidos, para el manejo de chisas rizófagas (Coleoptera: Melolonthidae) de tercer instar. **In:** Nematodos entomoparásitos: Experiencia y perspectivas. Eds. J.C. Parada, J.E. Luque Z, W de J. Piedrahita C. Universidad Nacional de Colombia. Conciencias, Colombia. Pp. 156-165.
3. Melo, M., E.L.; C.A. Ortega O.; A. Gaigl; R. Ehlers; A.C. Bellotti. 2006. Parasitismo de dos cepas de entomonematodos, una nativa (*Steinernema feltiae,* cepa Colombia) y otra introducida (*Heterorhabditis bacteriophora* cepa E-Nema®), sobre los seis estados de desarrollo de *Cyrtomenus bergi* Froeschner (Heteroptera: Cydnidae) en condiciones de laboratorio. **In:** Nematodos entomoparásitos: Experiencia y perspectivas. Eds. J.C. Parada, J.E. Luque Z, W de J. Piedrahita C. Universidad Nacional de Colombia. Conciencias, Colombia. Pp. 175-183.
4. Melo, M., E.L.; C.A. Ortega O.; A. Gaigl; A.C. Bellotti. 2006. Evaluación de concentraciones de *Heterorhabditis bacteriophora* (Italia) sobre larvas de segundo instar de *Phyllophaga menetriese* (Coleoptera: Melolonthidae). **In:** Nematodos entomoparásitos: Experiencia y perspectivas. Eds. J.C. Parada, J.E. Luquez Z, W de J. Piedrahita C. Universidad Nacional de Colombia. Conciencias, Colombia. Pp. 184-191.
5. Rejane Nunez Farias, A.; A.C. Bellotti. 2006. Pragas e seu controle. **In**: Aspectos socioeconômicos e agronômicos da mandioca. Eds. L.S. Souza, A. Rejane N. F., P.L.P. de Mattos, W.M. G. Fukuda. EMBRAPA, Mandioca e Fruticultura Tropical. Cruz das Almas, BA, Brazil, 2006. Pp. 591-671.

6*. Setter T. and Fregene M. (2006). Cassava. **In**: Matthew A. Jenks, Paul M. Hasegawa, and S. Mohan Jain (Eds.). Advances in Molecular-breeding toward Drought and Salt Tolerant Crops. Springer, Berlin. **26 pp**

7*. Thottappilly G., Fregene M., Makeshkumar T., Calvert L.A. and Cuervo M. (2006). Cassava. **In:** Loebenstein G. and Carr J. (eds). Natural Resistance Mechanisms of Plants to Viruses. CAB Publishers, London. **19 pp**

8*. Lokko Y., Okogbenin E., Mba C., Dixon A., Raji A. and Fregene M.(2006). Genome Mapping and Molecular Breeding in Cassava. **In:** Kole C. Genome Mapping and Molecular Breeding. Springer, Berlin. **17 pp**

9*. Ceballos, H. Introduction to quantitative genetics. **In:** Cassava Breeding (C. Hershey Ed.). FAO Publishing.

(*) Chapters for which we do not have access to hard copies yet.

5.3 SCIENTIFIC PRESENTATIONS IN CONFERENCES

1. Alvarez, E. 2006. Pudriciones radiculares en cultivos tropicales: Pudrición de raíz en yuca (*Manihot esculenta* Krantz) causada por *Phytopthora* spp. Memorias. Segundo Curso Internacional de Riesgos fitosanitarios para la agricultura colombiana. Palmira Colombia, Nov 14-16 2006. pags 159 -167.
2. Alvarez, E., Llano, G., Loke, J.B. 2006. Efecto de dos especies de *Trichoderma* sobre el rendimiento y control de pudrición de raíces de yuca. XLVI Annual Meeting American Phytopatholo society (APS) Caribbean Division, XXVII Congreso de ASCOLFI (Asociación Colombiana de Fitopatologia), Annual Meeting III UMNG Internacional Phytopathology Workshop.
3. Bellotti, A.C.; M. Fregene. 2006. Low-cost Technologies for pyramididng useful genes from wild relatives of cassava into elite progenitors. Generations Challenge Program 2006 Annual Research Meeting. Sep. 12-16, Sao Paolo, Brazil.
4. Carabali, A.; A.C. Bellotti; J. Montoya-Lerma. 2006. Potencial demográfico del biotipo B de *Hemisia tabaco* (Homoptera: Aleyrodidae) sobre genotipos africanos de

Manihot esculenta Crantz [poster]. Resúmenes XXXIII Congreso Sociedad Colombiana de Entomología, SOCOLEN. Julio 26-28, Manizales, Colombia. P.32.
5. Caicedo, A.M.; A. Valencia; J. Montoya-Lerma; A.C. Bellotti. 2006. Respuesta inmune de *Cyrtomenus bergi* Froeschner (Hemiptera: Cydnidade) en presencia de Trypanosomatidae en órganos y hemocelo. Resúmenes XXXIII Congreso Sociedad Colombiana de Entomología, SOCOLEN. Julio 26-28, Manizales, Colombia. p. 37.
6. Ceballos, H., J.C. Pérez, N. Morante, Sánchez, T, A.L. Chávez and F. Calle (2006). Strategies to develop and identify cassava clones with high-protein content in the roots. 14TH Triennal Symposium of International Society for Tropical Root Crops. Kerala, India.
7. Ceballos, H. (2006). HarvestPlus: A Global Research Alliance. 14TH Triennal Symposium of International Society for Tropical Root Crops. Kerala, India.
8. Ceballos, H. and W. Fukuda (2006). HarvestPlus: Breeding for nutritional quality in cassava – Research emerging from CIAT, IITA and EMBRAPA 14TH Triennal Symposium of International Society for Tropical Root Crops. Kerala, India.
9. Holguin C.M.; C.J. Herrera; A.C. Bellotti. 2006. Diagnóstico de moscas blancas (Homoptera: Aleyrodidade) en yuca *Manihot esculenta* de la zona cafetera de Colombia. [poster]. Resúmenes XXXIII Congreso Sociedad Colombiana de Entomología, SOCOLEN. Julio 26-28, Manizales, Colombia. P.125.
10. Howeler, R.H. and H. Ceballos (2006). CIAT initiatives on cassava improvement in Aisa. 14TH Triennal Symposium of International Society for Tropical Root Crops. Kerala, India.
11. Loke, J. 2006. Innovación en la Producción de bioetanol: Una oportunidad para Asociaciones de Agricultores. 22 sept. 2006. Fería de Yuca, Espinal, Tolima, Colombia.
12. Loke, J., Álvarez, E., González, S., Ospina, B., Cardona J., Ríos, D. de los, López, R. N., Galema, T., Llano, D., Llano, G., Pabón, C. and R. van Eck. 2006. *Innovación en la Producción de Combustibles Biológicos:* Crear Acceso para Asociaciones de Agricultores a Mercados Ilimitados. Congreso Nacional de Ingeniería Agrícola. 3 Noviembre 2006. Neiva, Huila, Colombia. 6 p.
13. Pérez, J.C., J. López, H. Ceballos and N. Morante (2006). Introduction of inbreeding and analysis of inbreeding depression in eight S_1 cassava families. 14TH Triennal Symposium of International Society for Tropical Root Crops. Kerala, India.
14. Sánchez, T, N. Morante, H. Ceballos, J.C. Pérez and F. Calle (2006). Strategies to develop and identify cassava clones with novel starch types. 14TH Triennal Symposium of International Society for Tropical Root Crops. Kerala, India.
15. Watananonta, W., S. Tangsakul, P. Pretprapai, S. Jantawat, N. Samuthong and R.H. Howeler. 2006. Effect of methods of land preparation on the yields of four cassava varieties in Nakhon Ratchasima and Chachoengsao provinces. *In:* Proc. 44th Annual Scientific Meeting of Kasetsart University, Bangkok, Thailand. pp. 32-41. (in Thai with English abstract)
16. Watananonta, W., N.N. Tran and R.H. Howeler. 2006. A participatory approach to cassava production in Thailand and Vietnam. *In:* R. Bourgeois, L. Svensson and M.L. Burrows (Eds.). Farming a Way Out of Poverty, Forgotten Crops and Marginal Populations in Asia and the Pacific. Proc. Regional Workshop on "Rural Prosperity and Secondary Crops: Towards Applied Pro-Poor Research and Policies in Asia and the Pacific", held in Bogor, Indonesia. Dec 6-9, 2005. CAPSA Monograph No. 48. pp. 231-254.

5.4 OTHER SCIENTIFIC PUBLICATIONS

1. Alvarez E., Mejía J.F., Llano G., Loke J., Pineda B. y Huertas C. 2006. Enfermedades limitantes de la yuca. CIAT, CLAYUCA. 20 pp.

6 Funded proposals

Project Name	Donor	Activity	Budget USD	Total Partners	Total CIAT
HarvestPlus Challenge Programm	W.B. / HarvestPlus	Enhance nutritional quality of cassava roots for carotenoids, Fe and Zn.	302,369	87,432	214,937
Inbreeding in Cassava Breeding	RF / Rockefeller Foundation	Development and use of inbred lines in cassava breeding	295,994	172,500	123,494
Commissioned Research-GCP Program	Generation Challenge	Travel-commissioned research-GCP consortium members	3,440	0	3,440
Pyramiding Useful Genes from Wild Relatives	Generation Challenge	Low-cost technologies for pyramiding useful genes from wild relatives of cassava into elite progenitors	239,834	157,405	82,429
Traits related to drought tolerance in cassava	Generation Challenge	Identifying the physiological and genetic traits that make cassava one of the most drought tolerant crops	64,997	0	64,997
Competitiveness of cassava for ethanol production in Colombia	MinAgric - Colombia	Competitividad de producción de etanol carburante	65,581	0	65,581
High-value cassava.	COLCIENCIAS	Upgrade of root quality laboratory	19,396	0	19,396
Over-Expression of flowering genes	Rockefeller Foundation	Over-expression of known genes that allow breeders to control the timing and extent of flowering	50,536	0	50,536
New Sources of Resistance to CMD	Rockefeller Foundation	Increased productivity in Sub-Saharan Africa through new sources of resistance to cassava mosaic disease	20,165	0	20,165
Roadmap for cassava in Africa for year 2020	Rockefeller Foundation	Conference held in Bellagio, Italy to define the roadmap for cassava in Africa in the year 2020	8,325	0	8,325
MAS for cassava in Tanzania	Rockefeller Foundation	Applying MAS and FPR to the production of new disease- and insect-resistant cassava in Tanzania	33,878	0	33,878
M.Sc Training for NARs Scientists from Mozambique	Rockefeller Foundation	Graduate level (M.Sc) training in plant breeding for NARs scientists from Mozambique	52,009	47,009	5,000
Various	Rockefeller Foundation	Health Insurance and other expenses from different projects	958	0	958
Quantitative and Molecular Genetic Analysis	Rockefeller Foundation	Quantitative and Molecular Genetic Analysis of Important Agronomic Traits in Cassava	11,800	0	11,800
Biotechnologh and nutritional quality	BioCassava Plus	Biotechnology tools to improve nutritional quality of cassava roots.	111,826	0	111,826
Ethanol Production in Nigeria	Accenture/NNPC	To conduct a feasibility study for the establishment of a cassava plantation for fuel ethanol production in Nigeria	95,892	41,748	54,144

Cassava in East Timor and Indonesia	ACIAR Australia	Enhancing the adoption of improved cassava production and utilization systems in Indonesia and East Timor	83,038	45,954	37,084

Funded Proposals (cont.)

Project Name	Donor	Activity	Budget USD	Total Partners	Total CIAT
Improving Livelihoods in Lao PDR	The Nippon Foundation	Research and extension to promote adequate production practice and alternative uses for cassava products.	318,656	68,390	250,266
Genetic Mapping of Two Cassava Genes	DANIDA	Genetic Mapping of Two Cytochrome P450 Genes (CYP79 D1 and CYP79 D2) in Cassava	29,388	0	29,388
IPICS-Cassava molecular div. Network	International Program in the Chemical Sciences (IPICS)	Cassava molecular diversity network	31,203	0	31,203
Improvement of the nutriotional value of Cassava	KVL University Denmark	Improving the nutritional value of cassava: high storage protein content, no cyanide liberating toxins	30,060	10,296	19,764
Cassava Biotechnology Network III	Ministry of Foreign Afairs, Holland	MFA-CBN-Small Grant-Yoel Beovides-INIVIT	3,545	0	3,545
Mutagenesis of Cassava	IAEA / Universidad Nacional	Mutagenesis in cassava for the generation of novel traits with commercial advantages	10,000	0	10,000
Production of cassava in Eastern Savannas of Colombia	PETROTESTING	Production packages for bio-ethanol production based on cassava in the Eastern Savannas of Colombia	20,000	0	20,000
Starch quality traits in roots.	Corn Products	Development of high-value cassava clones for Colmbia	15,000		15,000
Total Special Projects 2006	**Various**	**Various**	**1,917,890**	**630,734**	**1,287,156**

7 Problems Encountered and Their Solution.

Certainly the most difficult problem faced by the cassava project at CIAT during 2006 was the flooding of the experimental station that rotted many roots, preventing us from obtaining valuable data. In general the plants suffered considerably and flowers and fruits in crossing nurseries aborted. The crosses program, therefore, was delayed by six months at least. Fortunately not many plants died and vegetative cuttings could be obtained for re-planting. So the ultimate problem was a delay in a year for delivering expected products (planting material or information).

8. Staff list and dedication to IP3 project

Alvarez, Elizabeth – Pathologist (50%)
Aye, Tin Maung – Agronomist (Postdoctoral position in Asia, 100%)
Bellotti, Anthony C. - Entomologist (50%)
Ceballos, Hernán - Field Breeder/Project Coordinator (60%)
Dufour, Dominique – Starch and Food Technologist (CIRAD)
Fregene, Martin – Molecular Breeder (40%)
Howeler, Reinhardt - Agronomist (75%)
Ospina, Bernardo – Cassava Processing/CLAYUCA (75%)
Dufour, Dominique – Starch and Food Technologist (CIRAD)

9. Financial statement

SOURCE	AMOUNT US$	PROPORTION (%)
Operations at CIAT Headquarters		
Unrestricted Core	315,324	14%
Restricted Core: Japan	70,000	3%
Sub-total Core (Colombia)	**385,324**	**17%**
Special Projects	1,436,377	63%
Generation Challenge Program	440,410	19%
Subtotal Special Projects (Colombia)	**1,876,787**	**100%**
Operations at CIAT Asia		
Unrestricted Core	0	0%
Restricted Core: Japan	0	0%
Sub-total Core (Asia)	**0**	**0%**
Special Projects	393454	100%
Sub-total Special Projects (Asia)	**393454**	**100%**
Summary of combined operations in Colombia and Asia		
Sub-total Core	385,324	**12.7%**
Subtotal Special Projects	2,272,241	**87.3%**
TOTAL BUDGET (Colombia and Asia)	**2,655,564**	**100%**