CFC/ICCO/IPGRI Project on:

Cocoa Germplasm Utilization and Conservation: a Global Approach

Project Completion Report

Prepared by IPGRI, October 2004

The International Plant Genetic Resources Institute (IPGRI) is a centre of the CGIAR

FUTURE HARVEST

CFC/ICCO/IPGRI Project on Cocoa Germplasm Utilization and Conservation, a Global Approach

Project Completion Report

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APPENDIX: FINAL INDIVIDUAL INSTITUTE REPORTS (distributed separately)

1. PROJECT AND REPORT DATA

1.1. PROJECT TITLE	Cocoa Germplasm Utilisation and Conservation: a Global Approach
1.2. PROJECT NUMBER	ICCO/03 (CFC) and D08B (IPGRI)
1.3. PEA	The International Plant Genetic Resource Institute (IPGRI)
1.4. SB	The International Cocoa Organisation (ICCO)
1.5. PROJECT DURATION	01/04/98 (Starting Date) till 31/03/04 (Completion Date)

1.6. PROJECT FINANCING PLAN (ACCORDING TO THE APPRAISAL REPORT)°

Total Costs	US$ 9,985,940
of which:	
CFC Grant	US$ 2,942,000
Co-financing Contributions	US$ 1,940,480
Counterpart Contributions	US$ 5,104,231

1.7. PERIOD COVERED	April 1998 - March 2004
1.8. DATE OF REPORT	October 2004
1.9. AUTHORS OF REPORT	Albertus B. Eskes, project co-ordinator and Emmanuel Gonnord, financial officer

1.10.EXTENDED ABSTRACT

Introduction to the Completion Report

The first part of this Completion Report (Section 2) provides background information on the project objectives, project structure, financing and beneficiaries, as identified in the project proposal, presented in its final format to CFC in July 1996, and reproduced in the Project Appraisal Report. Sections 3 to 5 are based on the results reported in the final reports provided to IPGRI by all Collaborating Institutions between September 2003 and February 2004. These Final Individual Institute Reports are considered as an Appendix to this Completion Report. They were compiled by IPGRI in March 2004 and distributed as a separate document at the occasion of the Final Project Workshop held in Reading, UK, end March 2004. These reports contain information on all activities that were supported with CFC funding as well as with co-financing contributions from BCCCA and ACRI (now WCF). They also inform on the project teams that have been actively involved in the implementation of the activities at each of the Project Sites.

The original Completion Date of this five-year project (31 March 2003) has received a budget-neutral extension of one year from CFC. This was justified to complete certain project activities and to be able to organise and hold the Closing Project Workshop on 28-31 March 2004. During this Closing Workshop, the main project achievements as well as constraints and intended solutions were analysed. The presentations given and working documents produced at this workshop were distributed to all partners by July 2004 in the form of a CD-rom.

Main Project Achievements

The activities undertaken are characterization, evaluation and selection of cocoa genotypes (clones and hybrids), improvement and enhancement of germplasm populations, exchange of information and of selected germplasm accessions between project sites, and transfer and adoption of improved cocoa selection and breeding technologies. Emphasis in the evaluation and selection process has been on disease and pest resistance.

The project has achieved all major objectives and more activities were carried out than originally planned. In total, 94 ha of new variety trials (clones and hybrids) have been established at the different project sites, compared to 55 ha planned originally. These contain a total of 2775 clonal and 1647 hybrid varieties (compared to 1300 and 800, respectively, as originally planned).

Standardized ***Working Procedures*** for cocoa germplasm evaluation and selection, including disease and pest resistance screening methods, were agreed on and adopted by the project during the initial workshop held in January 1998. The publication resulting from this workshop was widely distributed (more than 400 copies).

The total number of evaluations of selection traits carried out on cocoa genotypes in collections and breeding trials in the project amounted to 37,848. The respective numbers are: 4,877 for vigour; 6026 for yield and other traits; 2385 for pod and bean traits; and 16,138 for resistance traits (11,354 to *Phytophthora* pod rot (Ppr), 3,259 to witches' broom, 630 to mirids, 480 to CSSV, 272 to VSD and 143 to *Ceratocystis*). The evaluation activities resulted in the identification of 2345 promising new selections, each containing one or more favourable traits.

The ***International Clone Trial*** was established at 10 sites in nine cocoa producing countries, permitting the evaluation of stability of economically important traits world-wide of 20 selected cocoa accessions distributed from intermediate quarantine centres. Resistance of the 'International Clones' to the three major species of *Phytophthora* proved to be generally stable in relation to more than 20 fungal isolates from the ten cocoa producing countries involved. Good resistance was identified for nine genotypes. The interactions between clones and fungal isolates, within and between *P. palmivora, P. capsici* and *P. megakarya*, as tested in leaf disc tests appeared to be relatively small

Local Clone Trials (LCT) and ***Local Clone Observation Plots*** (LCOP) were established in all 10 participating cocoa producing countries. In nine countries, 20-25 of the most interesting local clones have been planted in LCT's, with four to six replicates. At each site, between 50 and 300 other potentially interesting clones were planted in LCOP's, with one or two replicates. Many of the local clones have been screened in the project for resistance to Ppr, witches' broom or mirids. The most promising clones are already being used for further breeding and/or for testing in farmers' plots.

Local Hybrid Trials were established at five sites, as originally planned. These include between 24 and 92 new progenies per country. Results on early vigour, yield and disease resistance have already been obtained in most countries. These trials have great potential for accelerated selection of new "hybrid clones" within the next few years.

Population Breeding Programmes have been reinforced in Brazil and Côte d'Ivoire and were initiated in Ghana and Malaysia. The available knowledge about the local germplasm has been used to identify base populations for recurrent selection procedures, aiming at simultaneous improvement for several selection traits. In *Brazil*, the efforts undertaken

include evaluation of individual trees in segregating populations, establishment of new progenies and observation plots, screening for witches' broom and Ppr resistance, and testing of selected clones in regional on-farm trials. In *Côte d'Ivoire*, the first cycle of recurrent selection was concluded and a second cycle initiated, with as main selection criteria yield, Ppr resistance, bean size and yield efficiency. In *Ghana*, Ppr resistance has been evaluated for several hundred clones of the base populations. More than 500 crosses, within and between groups, were screened for CSSV and Ppr resistance Two hundred progenies were planted in field trials and 100 clones in observation plots. In *Malaysia*, base populations were evaluated for resistance to VSD and Ppr, as well as fat content. Sixty crosses between superior clones were established in hybrid trials and 97 selected clones in observation plots.

Germplasm Enhancement for resistance to *Phytophthora* pod rot (Ppr) has been successfully carried out in Trinidad and Tobago, using the genetic diversity present in the International Cocoa Genebank in Trinidad (ICG,T). Of a total of 960 accessions, 11% was classified as 'resistant' according to the detached pod test. Over a four-year period, 3486 seedlings from 96 bi-parental crosses between 136 clones were screened using leaf disc inoculations. The genetic gain by selecting 10% of the seedlings would result in a population with better average resistance than that of the resistant control clone (SCA6). In total, 856 selected seedlings have been established in the field during the last three years.

The large efforts carried out on cocoa ***Germplasm Conservation, Characterisation and Evaluation*** in the ICG,T included disease resistance reactions, molecular and biochemical marker studies (iso-enzymes, RAPDs and SSR markers), as well as bean and pod traits. These studies enabled the identification of the so-called 'CFC/ICCO/IPGRI Project Collection', which is an international working collection containing 110 accessions possessing valuable agronomic traits and wide genetic diversity. Distribution of this collection to the project partners and to other user-countries has been initiated through the intermediate quarantine facility at the University of Reading, UK.

The genetic identity of project clones was verified by comparing more than 200 DNA samples from different collections using micro satellite markers. The high level of mis-identification (30%) demonstrates the need for a continuous effort to verify identity of cocoa accessions. Within the project, photos of pods and flush leaves of more than 200 widely distributed clones were made. The photos, together with easily identifiable traits, were used by the University of Reading to elaborate a "Field Guide for Rapid Identification of Cocoa Clones".

Distribution of Germplasm has included the International Clones, which were provided to all project partners as well as to other interested parties. Exchange of selected germplasm has been carried out on a voluntary basis. Ppr resistant populations were provided by the CNRA (Côte d'Ivoire) to Cameroon and to Nigeria, and by the CCRI (PNG) to CIRAD. Resistant segregants of the PNG population identified by CIRAD were sent to the Reading quarantine centre, and distribution to interested user countries has been initiated. DNA analysis of this population, carried out also by CIRAD, demonstrated the presence of two significant QTLs for resistance to Ppr.

Indirect Benefits

Besides the above Outputs, the following indirect benefits of the project should be mentioned:

- Establishment of a world-wide collaborative network on cocoa conservation, evaluation and selection, involving private as well as public stakeholders;
- Enhanced attention worldwide on the need for developing and distributing better cocoa varieties;

- Increased collaboration between international and national cocoa conservation and breeding programmes;
- Increased multidisciplinary collaboration in cocoa breeding, involving breeders, geneticists, pathologists, entomologists and agronomists;
- Increased human capacity building;
- Transfer of several new technologies and methods in cocoa breeding; and
- More effective and coordinated use of limited resources.

Problems and Lessons Learned

Technical problems included extended dry periods that occurred in Africa in 2000 and 2001, causing a 1-2 year delay in the implementation of project field trials in Ghana and Nigeria. Flooding in Venezuela in 2000 caused losses of plant materials that were replaced in subsequent years. Low success of vegetative multiplication of clones caused delays in Cameroon, Côte d'Ivoire, Nigeria and Venezuela. This was partly overcome by replacing the hypocotyl budding method with the top-grafting method. Furthermore, relative low repeatability for some of the resistance testing methods was observed (witches' broom, mirids). This is a rather typical problem that is often faced by scientists when developing new screening methods. Despite increased efforts, including higher co-financing contributions, these latter problems could not be completely overcome.

Institutional reorganisation and modifications in the project teams have caused some delay during the first two years (e.g. Côte d'Ivoire, Malaysia and Nigeria). These delays were generally overcome by accelerated implementation of project activities at these sites in later years of the project.

Distribution of Results

Within the project, results were distributed through six-monthly "Individual Institute Reports", "General Progress Reports", as well as travel reports. Results were distributed outside the *project* through numerous presentations in international scientific meetings, through publication of 18 scientific papers, and through the publication of the "Working Procedures for Cocoa Germplasm Evaluation and Selection" in 2000.

The project results were analysed collectively firstly during the three mid-term Technical Meetings held in 2000 and 2001, with participation of all Collaborating Institutions, CFC, ICCO and Co-financiers. Agreed modifications in activities were presented in the reports of these meetings.

The project Closing Workshop was held at the University of Reading on 28-31 March 2004. The presentations given, including supporting documents, were widely distributed in the form of a CD-rom. A proposal was made for a Final Technical Report in the form of a scientific publication, with more than 20 papers presenting results that will be of further use in cocoa selection and breeding activities to be pursued by the project partners as well as by institutions in other countries. The "Field Guide for Rapid Identification of Cocoa Clones" will also be part of this final publication.

Supervision and Monitoring

Day-to-day monitoring has been carried out through frequent contacts between the PEA, SB and the CFC. Supervision was carried out by the ICCO through the analysis of the Project Progress Reports and other project documents and publications. ICCO presented and distributed summary reports on the pProject at the six-monthly council meetings to

representatives from all ICCO member countries. IPGRI has presented twice details on project implementation to the ICCO council.

ICCO and CFC participated actively to the three mid-term Technical Meetings. At the same occasions, CFC and ICCO representatives visited several Collaborating Institutions. A project review meeting was organised by IPGRI in Montpellier in May 2001, with participation of representatives of the CFC, the ICCO and of Co-financing Institutions. In addition, the project has been reviewed on an annual basis as it has been part of one of IPGRI's 20 institutional projects, that all undergo this internal peer review.

Resource Utilisation

Total ***CFC funds*** available for project implementation, excluding supervision and monitoring but including contingencies, amount to 2,863,250 USD. Total claims presented to date by IPGRI to the CFC amount to 2,834,242 USD (99% of available funds). The difference of 29,008 USD is the amount that is proposed to be reserved to pay for the final project publication and for the final audit. The high utilisation level of CFC funds is consistent with the large amount of activities carried out and outputs produced.

Total ***Co-financing and Counterpart Contributions*** are estimated as 2,423,548 USD and 5,917,597 USD, respectively, which represents 125 and 116% of the originally budgeted amounts. This confirms the strong commitment that the co-financing and collaborating institutions have maintained throughout the project duration with its full implementation.

The ***Total Project Costs***, excluding Supervision and Monitoring, amount to 11,175,387 USD, which is 13% higher than originally budgeted in the Appraisal Report (9,907,961 USD). The relative participation of CFC funding, co-financing and counterpart contributions has become 25.5%, 21.6% and 52.8%, respectively, of total project costs, compared to the original distribution of 28.6%, 19.4% and 51.1%, respectively.

Limitations

Despite the significant benefits obtained, it should be recognised that the project has certainly not been able to cope with all constraints in cocoa breeding. Some of the urgent needs that could not be addressed at all, or only insufficiently, in the current project are:

- The urgent need for more formal training opportunities for young scientists in practical cocoa breeding;
- The continuous need for high-yielding resistant varieties with good quality (though the current project has provided important inputs to obtain such varieties in the medium term);
- The defective or non-existent systems of distribution to farmers of improved varieties, where these exist;
- Lack of long-term support for cocoa conservation and breeding activities.

Conclusions and Recommendations

The project has significantly increased national and international collaborative efforts on evaluation, selection and conservation of cocoa germplasm with the aim of producing better cocoa varieties. The implementation of the CFC/ICCO/IPGRI project activities has been satisfactory at most project sites. The achievements are in general equal or superior to the planned outputs. The quantity of work carried out is impressive and the numerous new cocoa selections made represent an invaluable tool for further and future cocoa breeding. These achievements have also resulted in a better effort to conserve the cocoa genetic

resources maintained in the countries. The achievements are in agreement with the high level of resource utilisation observed, which is nearly 100% for the CFC funding, 125% for the co-financing and 113% for the counterpart contributions. It should be emphasised that the counterpart contributions have made up the larger part (53%) of the total project costs, which confirms the continuous commitments made by the collaborating institutions during the entire project life.

The direct and indirect benefits are expected to enhance sustainability of cocoa breeding programs. The achievements in the current project will permit the partners to foster further international collaboration and to involve the farmers directly in the process of developing new varieties.

Recommendations made during the Mid-Term Technical Meetings were incorporated in the proposal for a new CFC/ICC/IPGRI project on "Cocoa Productivity and Quality Improvement, a Participatory Approach", that was accepted by CFC for financing in October 2003 and April 2004, and that is operational from 1 June 2004 onward. This project will be able to build on the achievements obtained in the "Germplasm" project, including the distribution and validation of the most promising selections in farmers' fields.

Recommendations were made during the Closing Workshop on the content of the final technical paper to be produced with the project results. IPGRI, with the help of all collaborating institutions and in close contact with ICCO and CFC, expects to publish this final publication within the next 12 months.

Despite the progress obtained in the current "Germplasm" project, it is important to realise that important constraints continue to prevent good new cocoa varieties from becoming widely available to the farmers. It is hoped that, besides the new CFC/ICCO/IPGRI "Productivity" project, alternative funding mechanisms can be found to help to address these constraints.

2. BACKGROUND AND CONTEXT OF THE PROJECT

2.1. SUMMARY OF PROJECT PROPOSAL

The project was set up with the aim of obtaining more sustainable production of cocoa at lower cost by making better use of cocoa germplasm. An internationally co-ordinated effort was proposed in screening, selecting and breeding of improved cocoa genotypes. Selection for resistance to some of the major diseases and pests, which are important destabilizing factors in many producing countries, was a priority objective. The project focused on establishing functional links between germplasm conservation, evaluation and selection activities in a joint effort to increase the genetic potential of cocoa germplasm. The project should contribute over the medium and long-term to significantly improving the quality of planting material available to cocoa growers.

The following outputs were planned:

- Multilocational clone and hybrid trials, containing introduced and locally available genotypes, established at 10 different sites with a view to selecting superior genotypes, assessing their breeding value as well as their genetic stability for economically important traits;
- Population breeding activities initiated or reinforced at four sites, aiming at sustainable improvement of cocoa;

- Internationally conserved germplasm characterized and evaluated to strengthen germplasm enhancement programmes;
- Selected genotypes from the international collections distributed to interested user countries.

Project Collaborating Institutions were cocoa research institutes in 10 cocoa producing countries (see Section 2.6.1) and three international research institutions (CIRAD, CRU, University of Reading). Co-financiers in the project were British and American chocolate and biscuit manufacturing associations (BCCCA, ACRI), CIRAD and IPGRI.

It was envisaged that the project would require efficient co-ordination, training and scientific/technical backstopping. All collaborating institutions were visited by the project coordinator during the preparatory year (1997) to finalise their work plans and budgets. Two workshops were planned, one at the beginning of the project (1998), to decide on working procedures to be applied in the project, and one at the end of the project duration, to analyse and disseminate results. During the first project workshop it was proposed that mid-term Regional Technical Meetings should be organised in Asia, Africa and America.

The proposed conservation and characterization activities would be supported through counterpart contributions and co-financing, especially by associations of cocoa processors and chocolate manufacturers as well as by CIRAD. Selection, breeding and project co-ordination depended largely on CFC financing, on counterpart contributions (national institutions) and, to a lesser extent, on co-financing. To achieve success the project would require excellent liaison conditions between all participants.

In view of the long-term nature of cocoa breeding it was anticipated that a further phase would be required to consolidate the achievements of the present project.

2.2. COMMODITY ISSUES ADDRESSED BY THE PROJECT

Average world-wide cocoa yields are about 400 kg/ha, varying between countries from 150 to about 800 kg/ha. The main production constraints of cocoa are diseases and pests. The most important diseases are *Phytophthora* pod rot (Ppr), witches' broom, vascular streak dieback (VSD), monilia and the cocoa swollen shoot virus (CSSV). The most important pests are cocoa mirids in Africa and the cocoa pod borer (CPB) in Asia. Together, diseases and pests are responsible for about 35% losses in production of cocoa worldwide.

Diseases and pests continue to spread to new areas. For example, the most destructive form of the Ppr disease (*Phytophthora megakarya),* that causes crop losses up to 70% in Central Africa, continues to spread westwards in Ghana and has entered Côte d'Ivoire, the world's largest cocoa producing country. Monilia spread within Central America and into the Peruvian Amazon region in the 1980s and 1990s. Witches' broom spread from the Amazon Region of Brazil to the State of Bahia, being largely responsible for the 50% reduction in the total amount of cocoa produced by the country in the 1990s. In South-East Asia, CPB is spreading within newly established cocoa growing areas in Indonesia (Sulawesi, Sumatra) and is threatening Papua New Guinea.

Chemical control of diseases or pests is often not possible (VSD, witches' broom, CSSV, CPB) and expensive as frequent spraying is required (CPB, black pod). The existing genetic variation for resistance in cocoa collections should be exploited for the development of varieties with effective resistance to pests and diseases.

It can be concluded that the extensive way of growing cocoa is directly related to the production structure, dominated by smallholders. With such a structure, it is difficult to introduce technological changes that depend on increased financial inputs. The introduction and use of improved varieties is therefore one of the most cost-effective and environmentally friendly technological changes that can be proposed to overcome the major cocoa production constraints.

Seventy percent of the cocoa planting materials used world-wide are still made up of unselected varieties. However, based on knowledge on genetic diversity for all important traits, especially for yield and disease resistance, the potential of improved varieties is considered to be large. Important advances have been made in the 1990s in developing more reliable early screening tests for resistance to diseases and pests, especially for the black pod and witches' broom diseases.

Many cocoa producing countries have been unable to maintain effective long-term breeding activities because of their limited financial resources, especially during the period of low cocoa prices in the 1990's. In addition, many breeders lack training and operate under isolated conditions, thus international co-operation in cocoa breeding is needed. This is the main reason why in 1993 the International Group for the Genetic Improvement of Cocoa (INGENIC) was created. INGENIC was closely consulted during the development of the project proposal.

Against the aforementioned background information the project has been justified as follows:

a) Cocoa is, and for a considerable time, expected to continue to be a predominantly extensively grown crop produced mostly by smallholders;
b) One of the most efficient ways to enhance sustainable cocoa production is through the creation and use of improved varieties. This technology is easily transferred to smallholders compared to other technologies that require higher inputs;
c) Currently grown cocoa varieties show low resistance to major diseases and pests;
d) Genetic progress to overcome major production constraints can be expected through adequate application of proven breeding techniques as well as by additional evaluation of germplasm;
e) Clone selection as well as population breeding strategies appear to be the most appropriate strategies to obtain rapid short-term progress and sustainable long-term genetic progress, respectively;
f) Application of germplasm enhancement procedures (pre-breeding), aiming at improvement of specific traits in breeding populations, is complementary to local breeding efforts in overcoming some of the major cocoa production constraints, like losses due to diseases. Such a procedure would benefit from additional evaluation studies carried out on germplasm; and
g) International collaboration will be essential to conserve, characterize, select and improve cocoa germplasm in a co-ordinated manner, and to subsequently distribute it. Because of the existing geographic "division" between areas with cocoa genetic diversity, the cocoa producing areas and the processing/manufacturing countries, only a global approach will be meaningful.

2.3. ICCO STRATEGY

A major objective of international co-operation between cocoa producers on one hand and cocoa consumers on the other, has been, and continues to be, the avoidance of strong fluctuations in world cocoa bean prices caused by the boom-bust syndrome. On the production side, the ICCO strategy calls for direct co-operative action among cocoa producers to adjust world cocoa production, taking account of medium- and long-term market trends and bearing

in mind the basic aim of stable and remunerative prices that are consistent with high and rising levels of consumption. This would involve, among other things, the ability to control changes in production capacity within a reasonable time, measures to increase productivity and facilitate the orderly transfer of resources into and out of cocoa; the direct exposure of production decisions to market forces; the promotion of transparency in marketing arrangements; the conservation and improvement of cocoa genetic materials and the defence of the competitiveness of cocoa *vis à vis* other agricultural crops, through quality improvements and stable prices.

Overall, the main focus of the current global strategy for cocoa is on the need to increase the flexibility with which cocoa production responds to changes in price levels in both the short- and long-term. If it is successful, it should contribute significantly to an avoidance of the boom-bust cycle for cocoa and enhance the prospects for a prosperous world cocoa economy.

2.4. OBJECTIVES AND EXPECTED OUTPUTS

2.4.1. Objectives Identified

The ***wider development objective*** is to contribute to the welfare of the large number of smallholders cultivating cocoa through higher and sustainable productivity levels of good quality cocoa at lower production costs by making optimal use of available cocoa genetic resources.

The ***intermediate project objective*** is to make available improved cocoa planting material with good yield and quality capacity, with resistance to diseases and pests, and which is well adapted to local conditions.

The ***immediate project objectives*** are:

a. *To strengthen national cocoa improvement programmes and increase international collaboration by carrying out co-operative evaluation, selection and breeding activities in ten cocoa producing countries;*
b. *To establish cost effective and efficient conservation, characterization and distribution efforts of available cocoa germplasm; and*
c. *To strengthen cocoa germplasm utilization and conservation activities through scientific/ technical backstopping, information exchange and human capacity building.*

2.4.2. Project Components and Outputs

The project Components and Outputs related to the immediate project objectives were identified as follows:

Component 1: International Clone Trials

Multilocational clone trials will be established in 10 cocoa producing countries, aiming at distribution and evaluation of interesting new cocoa clones, selection of superior clonal varieties and assessment of the genetic stability of economically important traits. Twenty cocoa clones, supplied by intermediate quarantine centres, will be compared with 20 local clones in 10 different countries for all economically important traits, including disease and pest resistance. For the black pod and witches' broom diseases, "ring tests" will be carried out, applying standardised early screening methods, to study stability of these clones to fungal isolates from different geographical origins. In addition, 100-150 interesting trees will be selected in each country by applying early screening methods. These trees will be planted in field observation plots.

Component 2: Internationally Co-ordinated Hybrid Trials

Approximately 40 hybrid progenies will be produced in each of five countries by making crosses between locally selected superior clones, which are part of the clone trials of Component 1. This would permit for selection of superior hybrid varieties, comparison of the value of the parental clones with their progenies and selection of individual trees within these hybrids to be used in further breeding. The use of crossing designs will permit genetic analysis of the results to advance knowledge on inheritance of traits.

Component 3: Population Breeding

Population breeding programmes will be initiated or reinforced in four major cocoa producing countries, aiming at long-term improvement of economically important traits, including disease resistance. The available knowledge about the local germplasm is to be used to identify base populations for initiation of recurrent selection procedures. Exchange of basic breeding material (parental genotypes or seed progenies) is to be promoted between countries, which face similar production constraints, thus stimulating regional/international approaches to cocoa breeding.

Component 4: Germplasm Enhancement

More heritable economic traits will be evaluated at the International Cocoa Genebank maintained by CRU in Trinidad (ICG,T), especially resistance to black pod and witches' broom diseases. Germplasm enhancement consists of identifying more resistant seedlings within crosses between selected resistant clones. This approach explores the large genetic variation present in this collection to create improved populations. During the project life, a start will be made to transfer selected clones or populations to user countries.

Component 5: Germplasm Conservation, Characterisation and Preliminary Evaluation

This component aims at co-ordinated and intensified characterization and evaluation of germplasm by identifying genotypes in international and local collections which are of interest to breeders and make up so-called core collections. Selected material in the ICG,T will be characterised to evaluate the genetic diversity present in such a core collection (called CFC Project Collection). Incorporation of existing and newly obtained characterisation and evaluation results in the national and international databases will be done. Furthermore, opportunities for collection and conservation of material from interesting new areas will be explored. Funding for these activities will be by existing or complementary counterpart and co-financing contributions.

Component 6: Distribution and Quarantine oflinteresting Genotypes

This component aims at the distribution to participating countries of interesting genotypes identified in the project, following the internationally agreed Technical Guidelines for the Safe Movement of Cocoa Germplasm, published by FAO and IPGRI. This includes specifically the clones of the International Clone Trials, of the project core collection to be identified at CRU and of improved populations. Exchange of cocoa germplasm between the participating institutions is stimulated by mutual interests and agreements.

Component 7: Exchange of Information and Workshops

Exchange of information between project partners is to be achieved through exchange of working documents and through preparation of information sheets, including photographs, on

clones which are included in the international clone trials and of other widely distributed clones. All the data collected on genotypes will be entered into the International Cocoa Germplasm Database. Notes on project development and achievements will be presented in Newsletters, at International Conferences, and relevant data introduced into existing databases. A compendium of the results will be published as a final project publication.

Two project workshops are scheduled; one at the beginning of the project and one at the end of the project. During the first workshop, standardised procedures for evaluation and selection of cocoa genotypes in project trials will be discussed and adopted and the planned collaborative activities between participants established. During the second workshop, project results will be presented and possibilities for project continuation discussed. During the first workshop, Regional Technical Meetings were proposed to be held in the third project year.

Component 8: Co-ordination and Scientific/Technical Backstopping.

This component provides the means and procedures to the participating institutions to communicate with each other and co-operate in the various activities. A Project Coordinating Unit will be established at IPGRI's banana centre, INIBAP, at Montpellier, dealing with technical and administrative matters. This Unit is to carry out the liaison between the project partners, needed for efficient implementation of the activities and to ensure that results are internationally comparable. Working visits of the project co-ordinator to all project sites are carried out at regular intervals. Through the exchange of information, through technology transfer, through the visits of the co-ordinator to project sites, through the workshops and Regional Technical meetings, inputs will be made into the strengthening of human capacity in the various disciplinary areas of cocoa breeding and conservation.

Component 9: Management, Supervision and Evaluation

Day to day management of the project will be done by IPGRI, the Project Executing Agency, whereas ICCO is the Supervisory Body. Project evaluation will be based on 6-month Progress and Financial Reports. A general Mid-term Evaluation should be organised in the third project year.

2.4.3. Milestones Identified

Identified milestones in the project implementation were:

- Standardized working procedures discussed and approved (1st year).
- 25 selected clones transferred from quarantine centres to user countries (1st and 2nd year).
- Internationally co-ordinated clone and hybrid trials planted in 10 countries (2nd and 3rd year)
- Genotypes with increased disease resistance identified in base collections (1st to 3rd year).
- Segregating populations created and early selection applied for disease resistance in the germplasm enhancement and population breeding activities, (2nd to 5th year).
- Newly selected genotypes or seed populations transferred to interested user countries (2nd to 5th year).
- International coordination mechanisms established.
- Information on cocoa clones exchanged and stored in international databases.
- Transfer of technology and training activities implemented.

Quantified project Outputs are presented under Section 3, where they are compared with the actual results obtained.

2.5. BENEFICIARIES AND ESTIMATED BENEFITS

The selection and creation of improved varieties will be of great benefit to the cocoa growers in many countries. This will be especially so for the smallholders, who rely almost entirely on the supply of improved planting material from outside. It is expected that this approach will lead to more sustainable systems of cocoa cultivation, to the use of less land for similar production levels of cocoa, to less losses because of diseases and pests and other biotic stresses. The potential decrease in the need for chemical pest and disease control resulting from cultivation of more resistant varieties should diminish environmental pollution, the risk of exposure of labourers to harmful pesticides and presence of residues.

The proposed international approach to cocoa improvement should benefit cocoa researchers, especially breeders, through the distribution of relevant genotypes, through the provision of funds to execute evaluation and breeding activities, and through increased collaboration between cocoa producing countries as well as with international germplasm and quarantine centres leading to improved efficiency in the research processes. The co-operation between cocoa research institutes in the developing countries and in developed countries will facilitate the transfer of technology and allow human capacity building, especially in the producing countries. This improved collaboration is seen as a very important benefit of the project and by the formation of an active network that is expected to be long-lasting.

Intensified and improved international contacts are expected to facilitate access to the conserved germplasm and thus to strengthen indirectly the operations of the National and International Cocoa Genebanks. Furthermore, this international co-operation will enhance the efficiency of the conservation of cocoa germplasm at national and international levels, through increased use and distribution of genotypes from these collections. It is hoped that this will create conditions leading to more sustainable management and funding.

In conclusion, as a result of this project, all cocoa producing countries will be able to incorporate broader genetic diversity into their improvement programmes and, thereby encourage more productive and environmentally-friendly cultivation. The consumers of the cocoa products will benefit through more stable access to products at affordable prices and better quality.

2.6. PROJECT STRUCTURE AND FINANCING PLAN

2.6.1. Project Structure

The project has been implemented as a joint initiative of cocoa research institutes, chocolate manufacturers organizations, ICCO and IPGRI. National research institutes in Brazil, Cameroon, Côte d'Ivoire, Ecuador, Ghana, Malaysia, Nigeria, Papua New Guinea, Trinidad and Tobago, and Venezuela participate in the project, as well as CIRAD-CP, CRU and the University of Reading. ICCO is the Supervisory Body (SB) and IPGRI the Project Executing Agency (PEA). IPGRI has established a Project Coordinating Unit at INIBAP's headquarters, Montpellier, France; and technical coordination is done through a collaborative agreement with CIRAD. Local Technical and Administrative Coordinators have been nominated by each participating institute and a Technical Working Group and a Co-financiers Working Group were created during the first Project Workshop to help steering the project.

The participating institutions are:

National agricultural research institutions (NARS)

- Cocoa & Coconut Research Institute (CCRI, now CCI), Papua New Guinea
- Cocoa Research Institute of Nigeria (CRIN), Nigeria
- Cocoa Research Institute (CRIG), Ghana
- Comissão Executiva do Plano da Lavoura Cacaueira (CEPLAC), Brazil
- Centre National de Recherche Agronomique (CNRA), Côte d'Ivoire
- Fundación para el Desarrollo de la Ciencia y la Tecnología del Estado de Aragua (FUNDACITE-Aragua) and the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP, now INIA), Venezuela
- Institut de Recherches Agronomiques pour le Développement (IRAD), Cameroon
- Instituto Nacional de Investigaciones Agropecuarias (INIAP), Ecuador
- Malaysian Cocoa Board (MCB), Malaysia
- Ministry of Agriculture, Land and Marine Resources (MALMR), Trinidad and Tobago
-

International agriculture research institutes (IARI)

- Centre de Coopération Internationale en Recherches Agronomiques pour le Développement/Département des Cultures Pérennes (CIRAD-CP), France
- Cocoa Research Unit (CRU) of the University of the West Indies, Trinidad and Tobago
- University of Reading, UK

Co-financing organisations

- American Cocoa Research Institute (ACRI, now World Cocoa Foundation or WCF), USA
- Biscuit, Cake, Chocolate and Confectionery Alliance (BCCCA), UK
- CIRAD, France
- International Plant Genetic Resources Institute (IPGRI), Italy

Supervisory Body

- International Cocoa Organization (ICCO), London, UK

Project Executing Agency

- IPGRI, Italy

Main Financing Institution

- Common Fund for Commodities (CFC), Amsterdam, The Netherlands

The project teams that have been responsible for implementing the activities at the different project sites are indicated in the Final Individual Institute Reports, which were distributed to all partners at the occasion of the Final Project Workshop, held in Reading end March 2004.

2.6.2. Project Financing

The accepted project budget, amounting to about 10 million dollars (see Section 1), is made up of about 30% CFC funding, 50% counterpart funding from all participating institutions, and 20% co-financing from ACRI, BCCCA, CIRAD and IPGRI. The details on the planned contributions of each institution are given in the tables on resource utilization (see Section 3).

2.6.3. Co-ordination and Project Management

Day to day management of the project has been done by IPGRI, the Project Executing Agency, through the Project Coordinating Unit established at IPGRI's banana center (INIBAP), at Montpellier. This Unit was composed of the Project Coordinator (workload estimated as

70%), a Programme Assistant (workload estimated as 50%) and a financial officer (workload estimated as 20% of total working time). This Unit was created to carry out the liaison between the Project partners, needed for efficient implementation of the activities and ensures that results are internationally comparable. Regular visits of the Project Coordinator to all Project sites were planned.

IPGRI established Memoranda of Understanding (MoU) with all Collaborating Institutions, including the Five-Year Work Plans and Budgets for each of these institutions. Furthermore, IPGRI established annual Letters of Agreement (LoA) with all partners, including the agreed annual work plans and budgets. Another task of IPGRI was the distribution of the funds received from CFC according to the MoU and LoAs.

General Progress Reports were prepared by IPGRI and the Individual Institute Reports to be agreed, compiled and distributed at six-month interval. IPGRI was also in charge of the organization of the two Workshops and the three Regional Technical Meetings (proposed during the first project workshop).

3. PROJECT IMPLEMENTATION AND RESULTS ACHIEVED

3.1. PROJECT IMPLEMENTATION

3.1.1. Structure and Rationale of Project Implementation

The structure of the CFC/ICCO/IPGRI project (hereinafter referred to as the 'project') reflects a multi-stakeholder international collaborative model to achieve a common objective, i.e. making available better cocoa planting materials to the farmers. The project brought together important parties in the cocoa production, research and development as well as manufacturing and consumption sectors.

The project has been set up as a joint initiative of:
- National research institutes in ten cocoa producing countries,
- International agricultural research institutes,
- International cocoa genebanks and quarantine centres,
- The International Plant Genetic Resources Institute (IPGRI).
- Chocolate manufacturers organizations,
- The International Cocoa Organisation (ICCO), and
- The Cocoa Producers Alliance (CPA),

Collaboration between public organisations and the private sector, *i.e.* chocolate manufacturers associations, has been fundamental for obtaining the necessary co-financing arrangements. While CFC and counterpart funds are mainly devoted to the improved utilization of cocoa germplasm, the co-financing contributions from the private sector are supporting largely the conservation, characterization and evaluation efforts.

Research institutes in the ten cocoa producing countries, representing approximately 80% of world cocoa production, together with the international agricultural research institutes, were the main project implementing agencies (through use of CFC funds, counterpart and co-financing contributions). Within these institutes, the project has promoted collaboration between breeders, pathologists, entomologists and agronomists allowing for integration between these disciplines for obtaining common goals.

The collaboration between the project partners has promoted international and/or regional approaches to deal with major research and development objectives, such as obtaining varieties with resistance to diseases and pests. The collaboration between the international cocoa genebank (ICG in Trinidad), the intermediate quarantine centres in the UK and France and the research institutes in the ten cocoa producing countries provided the necessary operational links for more efficient conservation, evaluation, distribution and use of cocoa germplasm.

ACRI's (now WCF) co-financing contributions went mainly to evaluation of witches' broom resistance in Brazil (CEPLAC) and Trinidad (CRU). Co-financing support of BCCCA went to accelerated germplasm conservation, characterization and evaluation activities in Trinidad (CRU), to quarantine of cocoa accessions selected for use in the project at the University of Reading, and for witches' broom resistance testing (Reading and Trinidad). CIRAD-CP has provided important co-financing support by providing scientific staff to reinforce the germplasm characterization and evaluation activities in Trinidad (CRU), the population breeding activities in Côte d'Ivoire (CNRA) and to technical project coordination through an agreement with IPGRI. IPGRI's co-financing support has involved project preparation, technical backstopping and project management.

ICCO, representing cocoa producing and consuming countries, has provided the political platform needed for evaluation of the project objectives and achievements within its wider commodity development strategy. Furthermore, as the Supervisory Body, ICCO has played an important role in the monitoring and Mid-Term Evaluation of the project progress.

CFC has actively participated in the mid-term evaluation of the project through the attendance of the Regional Technical meetings and visits of the Project Officer (PO) to several project sites. The PO also participated actively in project steering meetings, organised by IPGRI to discuss project implementation aspects together with the SB and co-financing institutions.

IPGRI, as PEA, has prepared all project documents required for efficient implementation of the project. The Project Coordinator has visited all project partners on a nearly yearly basis, which was essential for exchange of information and to harmonise the work plans between project partners. Official arrangements with the project partners were made in the form of MoU and annual LoAs including, respectively, five-year and annual work plans and budgets. The Project Coordination Unit created by IPGRI, with support of CIRAD, has also provided the technical platform for exchange of information and for human capacity building, where required.

A 'Technical Working Group' and a 'Co-financiers Working Group' were created during the first Project Workshop in 1998 to help steering the project.

3.1.2. *Modus Operandi* of Proposed Project Activities

The project Outputs were subdivided into nine project components as indicated in Section 2.4.2. These can be classified into three type of activities: 'collaborative activities', 'reinforcement of local germplasm evaluation and breeding efforts', and 'coordination and management' of the project.

Collaborative Activities

International Clone Trial
Twenty to 25 genetically diverse cocoa clones with interesting traits were supplied by intermediate quarantine centres (University of Reading and CIRAD-CP) to each of the ten cocoa producing countries participating in the project. These clones were multiplied and

planted in replicate clone trials together with local control clones. Field evaluation of these clones was initiated in these countries for all economically important traits including yield, resistance to diseases and pests and quality. For the Ppr and witches' broom diseases "ring tests" have been devised, applying standardized early screening methods decided among project scientists, to compare the stability of reaction of these clones to fungal isolates from different geographical origins. The best clones are candidates for further use in breeding in each of the countries.

Germplasm enhancement (pre-breeding)
More heritable and economically important traits have been evaluated at the International Cocoa Germplasm Collection site at CRU in Trinidad (ICG,T), with emphasis on resistance to Ppr and witches' broom diseases. Germplasm enhancement is being carried out by firstly identifying resistant accessions in the ICG,T followed by selecting seedlings within these crosses by applying an early screening test. This approach explores the large genetic variation present in this collection to create improved populations. The project has been specially effective in identifying sources of resistance to Ppr and using these to obtain improved populations. During the project life, a start was made to transfer selected clones and populations to user countries.

Germplasm conservation, characterization and preliminary evaluation
This collaborative activity aimed at co-ordinated and intensified characterization and evaluation of germplasm by identifying genotypes, in international and local collections, which are of interest for cocoa breeding. In the course of the project, the ICG,T collection was evaluated and characterized to obtain a selection of 110 clones containing wide genetic diversity and useful agronomic or resistance traits. This population, called the 'CFC/ICCO/IPGRI Project Collection', was introduced into intermediate quarantine towards the end of the project life for subsequent distribution to users countries. Opportunities for collection and conservation of new material were also explored. Funding for these activities was mainly through counterpart and co-financing contributions.

Distribution, identification and quarantine of interesting genotypes
Interesting genotypes identified in the project were distributed, following the internationally agreed Technical Guidelines for the Safe Movement of Cocoa Germplasm, published by FAO and IPGRI in 1986. This includes the clones of the International Clone Trials, of the CFC/ICCO/IPGRI Project Collection and of improved breeding populations. The identity of the 'International Clones' distributed from quarantine has been compared to similarly named clones growing in the different countries by using DNA markers. Exchange of cocoa germplasm between the participating institutions was stimulated according to mutual interest and agreements. Germplasm maintained in the international collections is available on request to all bona fide users.

Exchange of information and organization of workshops
Exchange of information between project partners was done through exchange of working documents, through preparation of information sheets, including photographs, of the clones included in the International Clone Trial and in the CFC/ICCO/IPGRI Project Collection as well as of other widely distributed clones. The data collected on the genotypes studied in the project were entered into the ICGD. During the first Project Workshop, held in February 1998, standardized procedures for evaluation and selection of cocoa genotypes were adopted. The organization of Mid-term Regional Technical Meetings in the third project year to evaluate progress and constraints has also been proposed during the first Project Workshop. A final workshop was held at the end of the project (March 2004) to analyse results and prepare a final project publication.

Reinforcement of Local Selection and Breeding Activities

Local Clone Trial and Observation Plots
In each of the ten participating cocoa producing countries, 20-25 interesting local clones were multiplied and planted in replicate field trials, and another 50-150 potentially interesting trees in 'Clone Observation Plots', the latter with two replicates only. The use of control clones will make comparison possible between the 'international' and local clones. These local clones were evaluated for resistance to *Phytophthora*, witches' broom or insects by using available early screening tests (depending on the country, as applicable). Selections made are candidates for further use in breeding or for selection in farmers' plots.

Hybrid selection trials
Twenty to 40 hybrid progenies were produced in each of five of the participating cocoa producing countries (Cameroon, Ecuador, Nigeria, Papua New Guinea and Venezuela) by making crosses between locally selected superior clones, which are often part of the Local Clone Trial. This should permit selection of superior hybrid varieties, studies on parent-offspring relationships and selection of individual trees for use in further breeding. The crossing designs used will permit genetic analysis of the results to increase knowledge on inheritance of traits.

Population breeding
Population breeding programmes were initiated or reinforced in four countries (Brazil, Côte d'Ivoire, Ghana and Malaysia), aiming at improvement of all economically important traits but with emphasis on disease resistance. The available knowledge about the local germplasm has been used to identify base populations for initiation of recurrent selection procedures in each of these countries. The base populations are made up of clones belonging to genetically distinct populations, allowing to exploit general and specific combining ability, or of any type of superior clones, in which case mainly general combining ability for specific traits will be exploited. Parental genotypes were inter-crossed and index selection applied to the resulting populations to identify superior hybrids and clones to be tested as new varieties or as parents for the next selection cycle. Exchange of basic breeding material (parental genotypes or seed progenies) was promoted between countries that face similar production constraints, thus stimulating regional collaborative approaches to cocoa breeding.

Project Co-ordination and Management by the PEA

Day to day management of the project has been done by IPGRI through the Project Coordinating Unit established at IPGRI's banana centre, INIBAP, at Montpellier. The Coordination Unit carried out the liaison between the project partners, needed for efficient implementation of the activities and ensures that results are internationally comparable. Information and technology transfer (methods used in the project) was enhanced by regular visits of the project coordinator to all project sites. IPGRI prepared General Progress Reports and compiled the Individual Institute Reports that were distributed at six-monthly interval. IPGRI also organized two Project Workshops and three Regional Technical Meetings.

Project Co-ordination at National level

Each Collaborating Institution has nominated a Local Technical Coordinator and a Local Administrative Coordinator. These were the key persons for coordinating all activities carried out by the local project teams, for technical and financial reporting as well as for publications.

3.1.3. Project Monitoring and Supervision

ICCO has carried out the supervision of the project. ICCO has participated in the preparation of official project documents (Project Appraisal Report, Project Agreement). It has received and analysed all progress reports and presented summary reports to the six-monthly ICCO council meetings. ICCO participated in the initial and final project workshops. It has been an active partner also in the mid-term Technical meetings aimed at evaluation of progress and problems encountered and to proposing remedial actions, where required. ICCO has supported remedial actions proposed to the CFC for correcting exchange rate losses incurred by the project due to the USD-SDR fluctuations. This has resulted in an effective use of the total CFC contributions in USD currency instead of in SDR.

The CFC has actively carried out the monitoring and management of the project by a series of interventions required for smooth implementation of the project. These included:

- Disbursement of project funds, based on analyses of financial claims presented by the PEA;
- Analyses of requests for modifications in the use of CFC funds, such as required to overcome unforeseen circumstances or technical problems;
- Participation in both project workshops and in the mid-term technical meetings,
- Visits to several project sites;
- Participation in a project review meeting organised by the PEA in May 2001.

3.1.4. Resource Utilisation

CFC Contributions

Total CFC contributions available for project operations

The total contribution of CFC according to the Project Agreement is 2,048,376 SDR (including Contingencies and Supervision/Monitoring costs), which was equivalent to approximately 2,942,000 USD at the date of acceptance of the project by the Executive board of the CFC (October 1996). Due to the devaluation of the SDR in relation to the USD during the first 4 years of the project (1998-2002), IPGRI has twice requested and obtained authorisations from the Executive Board of the CFC to compensate for the losses due to variations in the SDR-USD exchange rate. The authorisations received from the CFC mean, in practice, that the actual working budget for the project is in the USD currency amount as indicated in the Project Agreement and Appraisal Report.

The total amount of CFC funds to be managed by the PEA amounts therefore to 2,863,250 USD, which includes the Contingencies (5%) but excludes the budgeted amount for Monitoring and Supervision (78,750 USD). The amount of 2,863,250 USD is reproduced in Tables 1 to 3 as the total CFC contribution available for project operations managed by the PEA.

Total amount claimed to CFC

In total, IPGRI has presented 16 claims to CFC between December 1997 and October 2004. CFC has reimbursed a total of 2,451,355 USD relative to the claims 1 to 15. Claim 16 represents a total of 382,887 USD. The total amount claimed by IPGRI to the CFC is therefore 2,451,355 + 382,887 = 2,834,242 USD.

Reservation of funds for the Final Project Publication and for the Final Audit

The difference between the total amount available and claimed is 29,008 USD. In the letter accompanying the final claim, IPGRI has requested the CFC to reserve this amount largely for payment of the final audit (carried out in September 2004, with estimated cost of 7,200 USD) and for the final project publication (with estimated cost of 20,000 USD).

Utilisation of CFC Contributions by Cost Site

The utilisation of the CFC contributions by Cost Site for the entire project duration, including the budget-neutral extension of 12 months, is presented in Table 1. The total expenditures carried out at the 14 different Cost Sites and claimed to the CFC, including the claim number 16 presented in October 2004, represents 99.0 % of the total amount available for project implementation (including Contingencies).

The breakdown of expenditures by Cost Site (Table 1) shows that the total expenditures incurred by the Collaborating Institutions varied from 87.3% (MCB) to 123.2% (INIAP) of the amounts as budgeted in the Appraisal Report (without Contingencies). For all 13 Collaborating Institutions, this percentage is on average 105%.

Deviations from the 100% utilisation of budgeted amounts for each of the Collaborating Institutions were incurred mainly as a consequence of the following:

- Modifications of activities, as adopted at the Mid-Term Technical Meetings,
- Extension of the project duration by 6 to 12 months depending on the needs of the Collaborating Institution to complete project activities.
- Climatic problems (*e.g.* droughts in Africa, flooding in Venezuela),
- Technical/administrative problems, and
- Exchange rate fluctuations.

These factors have led to relatively low utilisation of available CFC funds at a few Cost Sites (carry-forwards from one year to the next) and increased financial requirements at other Cost Sites.

In order to be able to obtain optimal implementation for the project as a whole, the PEA has adjusted, at several occasions, the CFC funds allocated to the different Institutions. Substantial modifications were applied only after consultation with the CFC and with the ICCO and were reflected in the annual General Progress Reports provided by IPGRI to the CFC, to ICCO and to all Collaborating Institutions.

The utilisation of CFC funds by the PEA included the management, technical and financial coordination, technical backstopping and exchange of information (workshops and other technical meetings). The total amount used corresponds to 103.8% of the budgeted amount for the IPGRI Cost Site (excluding Contingencies and projected costs for the final Audit and Final Publication). The higher than planned costs were due to the following factors:

- Up-front costs involved in the full preparation of the project documents during 1997 (50,000 USD of which were accepted by the CFC to be included in the first claim);
- Organisation of the three mid-term Regional Meetings in 2000 and 2001, as proposed during the first Project Workshop in February 1998, and approved by the CFC (additional costs of about 36,000 USD);
- Additional costs incurred for auditing of the project account (approximately 30,000 USD) that were not foreseen in the Appraisal Report; and
- Additional costs incurred for coordination of the project during the extension period (April 2003 to March 2004).

Utilisation of CFC Contributions by Budget Category

The breakdown of the utilisation of CFC funds according to Budget Categories is presented in Table 2. This breakdown is based on the presentation of all claims by IPGRI to CFC and excludes again the costs for Supervision and Monitoring.

The percentage of total expenditures in relation to the allocated budget (without Contingencies) for each of the Budget Categories varies from 62.5% (Duty Travel) to 113.2% (Personnel). The higher than expected Personnel Costs are partly due to increased personnel requirements to cope with unforeseen problems (such as climatic disorders and technical problems), which made it necessary to repeat certain activities over time. Institutional changes have lead to the presentation of revised budgets by three Institutions (CNRA, MALMR and MCB) in the third project year, which were accepted by CFC. In the case of CNRA, the revision included a significant increase of Personnel Costs (due to the impossibility of CNRA to hire staff) and lower needs for travel costs (due to the fact that most of the staff was moved from Abidjan to Divo). Lower travel expenditures are further explained by increased use of counterpart funds for travelling and by savings made by IPGRI for the travelling costs involved in the coordination of the project.

Total Resource Utilisation by Cost Site and Funding Source

Table 3 summarizes the total resource utilisation by Cost Site and Financing Source. This is based on the estimates of the Co-financing and Counterpart Contributions that have been provided to IPGRI on a regular basis by the institutions involved.

The **Total Project Costs**, excluding Supervision and Monitoring, amount to 11,175,387 USD instead of 9,907,961 USD as budgeted in the Appraisal report. The difference of 1,267,426 USD (12.8% of the budgeted amount) is mainly due to the increases of 481,068 USD in Co-financing Contributions and of 813,366 USD in Counterpart Contributions. This brings the relative participation of CFC funding, Co-financing and Counterpart contributions to 25.5%, 21.6% and 52.8%, respectively, of total project costs, from an original distribution, as reflected in the Appraisal Report, of 28.6%, 19.4% and 51.1%, respectively.

The Collaborating Institutions presenting the highest total costs are CEPEC, CIRAD, CNRA, CRIG, CRU and the University of Reading. This reflects the large amount of activities planned and carried out at these sites. In two cases, it also reflects the higher USD costs of activities carried out in Europe.

The estimate of the total **Co-financing Contribution** (in-kind or in cash) for the entire project duration amounts to 2,423,548 USD, which is 24.7% more than originally budgeted. The contributions of CIRAD, BCCCA, ACRI (now WCF) and IPGRI were, respectively, 11%, 22%, 37% and 153% higher than originally budgeted. These increases can be largely ascribed to:

- Initiation of co-financed activities before the official start of the project (*e.g.* the multiplication of clones for the International Clone trials with BCCCA and CIRAD funding and of project preparation activities by IPGRI);
- Increased co-financing during the project (e.g. increased financing of ACRI and BCCCA to support witches' broom resistance evaluations in Trinidad and in Reading, respectively; increased co-financing for project coordination by CIRAD); and
- Increased duration of co-financing contributions, including 6 or 12 extra months during the extension period (April 2003 to March 2004).

The estimate of the total **Counterpart Contribution** (in kind) for the entire project duration amounts to 5,909,252 USD, which is 16% more than originally budgeted. The contributions expressed as a percentage of the originally budgeted contributions vary between 77% and 186%. Most of the institutions spent more than originally budgeted. The institutions that spent relatively less than budgeted are CNRA, INIAP and Fundacite/INIA. Institutions that spent considerably more than budgeted are CIRAD, CRIG and IPGRI. These variations in estimated USD Counterpart Contributions reflect generally genuine increases in Counterpart

efforts, but may also be caused by longer project duration (6 or 12 months extension, depending on the Institution), exchange rate fluctuations and modifications in the Institute's staff composition (Personnel is generally the main component of co-financing). In the case of CNRA and IRAD, the lower than planned counterpart contribution appears to be largely due to involvement of less staff in the project activities than planned (due to a ban on recruiting for the larger part of the project duration) and lower conversion rate of local salaries into USD due to the relative high USD value against the local currencies.

Conclusions on Resource Utilisation

The **CFC funds** available at the start of the project, including Contingencies, have been nearly entirely utilised by the formal Completion Date of the project (30 March 2004), except for paying the final project publication and the final audit. The CFC contribution represents 26% of the total costs. The high utilisation level is consistent with the large amount of activities carried out and Outputs produced. Furthermore, the high level of utilisation was also affected by approved additional activities, which were not budgeted for in the original Appraisal Report, such as coordination costs incurred before the official start of the project, costs of the mid-term Technical meetings, and auditing costs.

The budget-neutral extension, for 12 months, authorised by CFC in 2003, has been very useful to complete most of the planned activities. This was possible due to a carry-forward of approximately 60,000 USD of CFC funds in April 2003. These were re-distributed among the project partners aiming to complete activities at sites that, for diverse reasons, had lagged behind in project implementation. It implied that the remaining resources by April 2003 were effectively and fully used until March 2004.

However, the CFC contributions have not been sufficient to cover all the expenses related to the above-mentioned approved modifications. Especially, the more intense than planned coordination requirements needed complementary support from other sources. This applied to the coordination carried out by IPGRI during the preparatory phase, during the entire five-year implementation and during the extension period. The limitation of funds for these activities was compensated by increased co-financing contributions of CIRAD, in support of the technical coordination of the project, and of IPGRI, for general coordination and management costs.

The **Co-financing Contributions**, which have been considerably higher than planned (+25%), represent 22% of total project costs. This confirms the commitment that the co-financiers have shown during the entire project duration to the effective and full implementation of the project activities.

The main source of financing of the project activities has been through the **Counterpart Contributions**. These finally represent 53% of the total project costs incurred (compared to 51% as originally planned). This confirms the high level of commitment shown by the project partners to implement the project.

3.2. PROJECT RESULTS ACHIEVED

3.2.1. Qualitative Analysis of Results

A full qualitative analysis of results achieved should become available in the final project publication. Hereafter, a summary of major results is presented.

Component 1: International and Local Clone Trials (ICTs and LCTs, 11 sites)

Field trials with 20 clones, distributed from intermediate quarantine centres in the UK and in France, were established in nine countries between 1999 and 2004. In PNG the trial was planted at two sites to be able to evaluate correctly resistance to VSD. In Cameroon, due to low budding success, the ICT clones could only be established as a Local Observation Plot. Evaluation for important traits has been initiated at most sites. In Papua New Guinea and Ecuador significant amounts of data were already collected on vigour, early yield and field resistance.

Resistance of the 20 "International Clones" to Ppr has been evaluated by leaf disc inoculation in nine countries, as well as in Montpellier, France, using isolates from the same countries. Good resistance was often observed for PA150, IMC47, PA120, PA107, SCA6, P7, AMAZ15-15, Mocorongo and T85/799. In France, the interactions between clones and fungal isolates, within and between *P. palmivora, P. capsici* and *P. megakarya*, appear to be relatively small. However, in Brazil and in Venezuela, most clones, except SCA6, showed low resistance to *P. citrophthora* and *P. palmivora*, respectively. In Papua New Guinea, the results of the detached pod test appeared to give more reliable results than that of the leaf disc test, carried out on grafted nursery plants.

Resistance of clones of the ICT to isolates of the witches' broom fungus was assessed at the University of Reading. Confirmation of isolate-specific resistance was obtained for the Sca6 clone. The level of infection of a series of other clones inoculated with an isolate from Trinidad was quite well correlated with field results from Ecuador.

In nine countries, 20-25 of the most interesting local clones have been planted in LCT's, with four to six replicates. Between 50 and 300 other potentially interesting trees were planted in Local Clone Observation Plots (LCOP's), with one or two replicates only. Use of control clones will make comparisons possible between these local clones and the 'international clones'. Many of the local clones have been screened in the project for resistance to Ppr, witches' broom or mirids. The most promising clones are to be used for further breeding or for testing in farmers' plots.

Component 2: Internationally Coordinated Hybrid Selection Trials (5 sites)

Between 24 and 92 new hybrid progenies have been produced in Cameroon, Ecuador, Nigeria, Papua New Guinea and Venezuela. The crosses involve mainly locally selected superior clones, which are also part of the Local Clone Trial. This permits selection of superior hybrid varieties, studies on parent-offspring relationships and selection of individual trees for use in further breeding. Results on early vigour, yield and disease resistance have already been obtained in most countries. Full results can only be expected after three to five more years of observation.

Component 3: Population Breeding

Population breeding programs have been reinforced or initiated in Brazil, Côte d'Ivoire, Ghana and Malaysia. The aim is simultaneous improvement for economically important traits. The available knowledge about the local germplasm has been used to identify base populations for recurrent selection procedures in each of these countries.

In Brazil, accumulation of genes for resistance to witches' broom and good yield in crosses between genetically diverse populations is the most important objective. The large efforts undertaken include evaluation of individual trees in segregating populations, establishment of observation plots, screening for witches' broom and Ppr resistance, and testing of selected clones in regional on-farm trials.

In Côte d'Ivoire, the first cycle of recurrent selection was concluded and a second cycle initiated (Lachenaud *et al.*, 2002). The base populations used are Lower Amazon (plus Trinitario) and Upper Amazon. Selection criteria are yield, Ppr resistance, bean size and yield efficiency. Early screening for Ppr resistance and for attractiveness to mirids was carried out in base populations and for Ppr resistance also in the crosses for the second cycle of recurrent selection (Kebe *et al.*, in press; Lachenaud *et al.*, 2002; N'Guessan and Eskes, in press). Several selections from French Guiana (clones GU) appeared promising for Ppr and mirid resistance. Several hundred promising trees, including selections made in farmers' fields, are being established in observation plots for further selection.

In Ghana, base populations are IMC, NA, PA and T clones. Ppr resistance has been evaluated for several hundred clones of these populations. More than 500 crosses, within and between groups, were screened for CSSV and Ppr resistance (Adu-Ampomah *et al.*, in press; Opoku *et al.*, in press). Two hundred progenies were planted in field trials and 100 clones in observation plots.

In Malaysia, base populations were evaluated for resistance to VSD and Ppr, as well as fat content. Sixty crosses between superior clones were established in variety trials and 97 selected clones in observation plots. Early screening for fat content and for Ppr resistance has been carried out on a number of promising progenies.

Component 4: Germplasm Enhancement

A germplasm enhancement program aiming at accumulation of genes for Ppr resistance, was initiated using the large diversity in the International Cocoa Genebank, Trinidad (ICG,T). Results were presented in detail by Iwaro *et al.* (in press). Of a total of 960 accessions, 11% was resistant according to the detached pod test, more so in Forastero (14%) than in Refractario (8%) or in Trinitario (6%). Over a four-year period, 3486 seedlings from 96 bi-parental crosses between 136 clones were screened using leaf disc inoculations. Transgressive segregation for resistance was frequently observed but no immunity. Estimates of heritability suggested that the genetic gain in selecting 10% of the seedlings would result in a population with better average resistance than that of the control (SCA6). In total, 856 selected seedlings have been established in the field during the last three years. A second selection cycle is proposed and the most promising genotypes should then be available to cocoa breeding programs worldwide.

Component 5: Germplasm Conservation, Characterisation and Preliminary Evaluation

This Component contains characterisation and evaluation activities of internationally available germplasm. This activity included mainly the ICG,T managed by CRU in Trinidad and also studies carried out in several national collections. The studies at CRU involved evaluation of resistance to the Ppr and witches' broom diseases (field studies and studies done by artificial inoculation), studies on genetic markers (isozymes and RAPD), and on pod and bean traits. The number of accessions studied for each of these traits during the five-year project period varied between 500 and 1000. The results were introduced into the International Cocoa Genetic Database (ICGD) by the University of Reading and were compared to results obtained elsewhere to identify the "CFC/ICCO/IPGRI Project Collection".

The aim of the CFC/ICCO/IPGRI Project Collection is to make available to cocoa breeders diverse germplasm that is enriched for important traits, e.g. resistance to diseases, bean weight and pod index (Sounigo *et al.*, in press). The data obtained by CRU over the last 5-10 years was completed with data from other research institutes to identify this collection of 110 genotypes. Molecular marker studies at CRU helped to guarantee the genetic diversity

of the collection (Sounigo *et al.,* 2001). Most of the selected accessions are part of the ICG,T. By 2004, 40 of the accessions were already available at the quarantine facility at Reading, and distribution to project partners has been initiated at the occasion of the Final Project Workshop at Reading, in April 2004.

The genetic identity of approximately 30 project clones was verified by using microsatellite markers (Risterucci *et al.,* 2001). Over 200 DNA samples from different collections were compared with "control" samples from the intermediate quarantine centres (Reading, UK, and Montpellier, France). On average, 30% of the DNA samples proved to be different among each other or from the control samples. This high level of mis-identification demonstrates the need for a continuous effort to verify identity of cocoa accessions. CRU in Trinidad is already carrying out routine verifications of identity in the ICG,T.

Furthermore, as part of the project, photographs of pods and flush leaves of more than 200 widely distributed clones were made. These have been used by the University of Reading to elaborate a "Field Guide for Rapid Identification of Cocoa Clones". This Guide was presented by the University of Reading at the Final Workshop in March 2004. The printing and distribution of this guide will be done together with the final project publication.

Component 6: Distribution and Quarantine of Interesting Genotypes

This Component included the maintenance and multiplication of project clones at the intermediate quarantine centres managed by the University of Reading, UK, and by CIRAD, in Montpellier, France. The clones that were part of the ICT were distributed to all project Partners mainly during the first three years of the project. Distribution to other interested Institutions was carried out at several occasions.

Exchange of selected germplasm between project sites was carried out based on mutual agreement. Four crosses with resistance to *P. palmivora* were provided by CNRA, Côte d'Ivoire, to Cameroon and to Nigeria. Leaf inoculation tests showed that these varieties are more resistant to *P. megakarya* than resistant control clones selected in Cameroon (Nyassé *et al.*, 2003). The four crosses are currently being validated in farmers' fields in Cameroon and in a variety trial in Nigeria. Four hundred seedlings of a cross between two resistant and productive clones were made available by CCRI, Papua New Guinea, to CIRAD, France, where they have been screened for resistance to several *Phytophthora* species. The thirty most resistant seedlings were sent to the Reading quarantine centre, and are shortly to become available for distribution to interested user countries.

Component 7: Exchange of Information and Workshops

Exchange of information between project partners was achieved through exchange of working documents and through preparation of information sheets, including photographs, on clones which are included in the international clone trials and of other widely distributed clones. All the data collected on genotypes were entered into the International Cocoa Germplasm Database. Notes on project development and achievements will be presented in Newsletters, at International Conferences, and relevant data introduced into existing databases. A compendium of the results will be published as part of the final project publication.

Two project workshops were carried out; one at the beginning of the project and one at the end of the project. The first workshop was held in January 1998 in Montpellier, France, and was attended by 50 participants. Standardised procedures for evaluation and selection of cocoa genotypes in project trials were adopted and the planned collaborative activities between participants established at this workshop. The proceedings of this workshop were

published and widely distributed in 2000 as "Working Procedures for Cocoa Germplasm Evaluation and Selection" (Eskes *et al.*, 2000).

During the First Project Workshop, it was decided to organise mid-term Regional Technical Meetings. These were organised in 2000 by CCRI in PNG (for Asia), and in 2001 by CRU in Trinidad (for the Americas) and by CNRA in Côte d'Ivoire (for Africa). These were attended mainly by project scientists, but also by representatives of co-financing institutions, CFC, ICCO and IPGRI. The progress obtained and problems encountered were analysed, and recommendations made on further project implementation.

The Final Project Workshop, held in Reading in March 2004, was attended by approximately 100 persons representing project partners, co-financing institutions, ICCO, CFC, IPGRI and other interested parties. Project results were summarised and analysed. The Final Individual Institute Reports, compiled by IPGRI in February 2004, were distributed to all partners at the same occasion. A CD-rom with all presentations given and documents distributed at the workshop has been sent in large number of copies to all project partners in June 2004.

Component 8: Co-ordination and Scientific/Technical Backstopping.

The Project Coordinating Unit, established at IPGRI's banana centre (INIBAP, Montpellier, France) dealt with technical and administrative matters. This Unit carried out the liaison between the project partners, needed for efficient implementation of the activities and ensured that results are internationally comparable. Visits of the Project Co-ordinator to all project sites were carried out at regular intervals. Through the exchange of information, through technology transfer, through the visits of the Co-ordinator to project sites, through the workshops and Regional Technical meetings, inputs were made into the strengthening of human capacity in the various disciplinary areas of cocoa breeding and conservation.

Besides the above direct project achievements, the following indirect benefits of the project should be highlighted:

- Establishment of a world-wide collaborative network on cocoa conservation, evaluation and selection, involving private as well as public stakeholders;
- Enhanced attention worldwide on the need for developing and distribution of better cocoa varieties;
- Increased collaboration between international and national cocoa conservation and breeding programmes;
- Increased multidisciplinary collaboration in cocoa breeding, involving breeders, geneticists, pathologists, entomologists and agronomists;
- Increased human capacity building;
- Transfer of several new technologies and methods in cocoa breeding; and
- More effective and coordinated use of limited resources.

3.2.2. Quantitative Analysis of Results Compared to Planned Outputs

A quantitative analysis of the work carried out and results obtained is presented in Tables 4 to 7.

Table 4 shows the large number of activities carried out. Clone multiplication (budding/grafting) was most intensively done at CRIN and at IRAD. In fact this reflects the initial problems occurring at these sites with budding success. Pollinations were highest at CRIG, where all crosses for the Population Breeding were repeated each year to be able to carry out infilling and disease resistance evaluations.

A total of 11,354 evaluations for resistance to Ppr were carried out, mainly by using the leaf disc test but also increasingly by using the detached pod test. The high number of evaluations at CRU reflects the work that has been done for the Germplasm Enhancement programme. Resistance evaluations for witches' broom included field observations as well as artificial inoculations. Low success was obtained for clone testing at three sites (CEPLAC, INIAP and Reading). This reflects the problems incurred with clonal inoculations (low infection rate).

Fewer tests were carried out on resistance to mirids, as the methods used are still quite laborious. At CNRA, field observations were carried out in the Divo collection. VSD observations included artificial inoculation of callus (MCB) as well as field observations (CCRI and MCB).

Field observations were initiated at most sites. These included observations on already established plots of adult trees, as well as observations on new trials planted with support of the CFC project. Other observations included, among others, molecular marker studies (for diversity and identity studies), observations on morphological traits, CSSV resistance testing (CRIG), and self-compatibility studies carried out at CEPLAC.

Table 5 shows the total number of hectares of trials planted or observed with support of the project. In total 93.5 ha of new trials were planted, compared to 50 ha originally planned. The increase is mainly due to CEPLAC (where the breeding programme is facing the urgent need to identify witches' broom selections), to CRIG (larger than planned Population Breeding programme) and to CCRI and INIAP (larger programme carried out than planned).

Table 6 shows the total number of genotypes planted in field trials. These amount to 4,422 clonal or hybrid varieties, compared to 2,100 originally planned. Major efforts were carried out at CEPLAC, CCRI, CNRA, CRIG and CRU.

Table 7 indicates the number of promising selections as a result of the observations carried out. The total number of selections is 2,195. The project partners that were most successful in identifying promising selections were CEPLAC (yield and witches' broom resistance in new clone observation plots), CRU (Germplasm Enhancement selections and the Project Collection), CCRI (multiple traits) and IRAD (Ppr resistance). It is recalled here that , according to the Project Agreement, *"selections distributed through the quarantine centres (Reading, Montpellier) are in the public domain and may be used by any bona-fida user. Locally available cocoa germplasm included in project trials shall be made available to any project partner on mutually agreed terms, in compliance with the provisions of the Convention of Biological Diversity".*

3.2.3. Extent of Impact on Beneficiaries

The above quantitative results are of very significant and direct benefit to the cocoa breeders community, which now has available numerous new selections for further cocoa breeding. The final beneficiaries will be the cocoa producers, although it should be realised that the new selections will not be immediately available, as further confirmation of these selections in the current and in new variety trials need to be carried out. Many of the selections will however be used in on-farm trials in the new CFC/ICCO/IPGRI project on "Cocoa Productivity and Quality Improvement, a Participatory Approach".

3.3. DISSEMINATION OF PROJECT RESULTS

Within the project, results were distributed through six-monthly "Individual Institute Reports", "General Progress Reports", as well as travel reports. Results were distributed outside the project through numerous presentations in international scientific meetings, through

publication of more than 15 scientific papers (see Section 3.4), and through the publication of the "Working Procedures for Cocoa Germplasm Evaluation and Selection" in 2000.

The project results were analysed collectively firstly during the three mid-term Technical Meetings held in 2000 and 2001, with participation of all Collaborating Institutions, CFC, ICCO and Co-financiers. Agreed modifications in activities were presented in the reports of these meetings.

The project Closing Workshop was held at the University of Reading on 28-31 March 2004. The presentations given, including supporting documents, were widely distributed in the form of a CD-rom. A proposal was presented at this workshop (see Section 3.5) for a Final Technical Report in the form of a scientific publication, with more than 20 papers presenting results that will be of further use in cocoa selection and breeding activities to be pursued by the project partners as well as by institutions in other countries. The "Field Guide for Rapid Identification of Cocoa Clones" will also be part of this final publication.

3.4. PROJECT PUBLICATIONS

The following publications at international level were made containing results from project activities:

ADU-AMPOMAH Y., F. AMORES, K. BADARU, Y. EFRON, J. ENGELS A.B. ESKES, E. FRISON, V. GONZALEZ, P. HADLEY, D. IWARO K. LAMIN, R.A. LASS, K. MAHARAJ, W. MONTEIRO, J. N'GORAN, S. NYASSÉ AND D. PAULIN. In press. Results and benefits of the CFC/ICCO/IPGRI project on 'Cocoa Germplasm Utilization and Conservation, A Global Approach'. *In* Proc. 14th Int. Cocoa Research Conf., 13-17 October 2003, Accra, Ghana. Cocoa Producers' Alliance, Lagos, Nigeria.

ADU-AMPOMA Y., L.A.A. OLLENNU AND B. ADOMAKO. In press. Sources of resistance to the cocoa swollen shoot virus disease. *In* Proc. 14th Int. Cocoa Research Conf., 13-17 October 2003, Accra, Ghana. Cocoa Producers' Alliance, Lagos, Nigeria.

AIKPOKPODION P.O., K. BADARU AND A. ESKES. (2003). Improving brown budding efficiency in cacao, Theobroma cacao L.: effects of twig manipulation and some control treatments of fungal infection on new sprouts. Crop Protection 22: 1-6.

ESKES A.B. (2002). Collaborative activities on cocoa germplasm utilization and conservation supported by the CFC/ICCO/IPGRI Project. *In* Proc. of the 13th Int. Cocoa Research Conf., 9-14 October 2000, Kota Kinabalu, Sabah, Malaysia. Cocoa Producers' Alliance, Lagos, Nigeria.

ESKES A.B., J. ENGELS AND R.A. LASS. (1998). The CFC/ICCO/IPGRI project: a new initiative on cocoa germplasm utilization and conservation. Plantations Recherche Développement 5:412-422.

ESKES A.B., J.M.M. ENGELS AND R.A. LASS, Editors. (2000). Working Procedures for Cocoa Germplasm Evaluation and Selection. *In* Proc. of the CFC/ICCO/IPGRI Project Workshop, 1-6 February 1998, Montpellier, France. International Plant Genetic Resources Institute, Rome, Italy. 200. 176 pp.

ESKES A., J. ENGELS, T. LASS AND E. FRISON. (2001). An operational model of international collaboration on utilization of cocoa genetic resources: the CFC/ICCO/IPGRI project. *In:* Proc. of "The Future of Perennial Crops" Conference, 5-9 November 2001, Yamoussoukro, Côte d'Ivoire. CD-rom. CIRAD, France.

IWARO A.D., S. BHARATH, F.L. BEKELE, D.R. BUTLER AND A.B. ESKES. (In press). Germplasm enhancement for resistance to black pod disease: strategy and prospects.

In Proc. 14th Int. Cocoa Research Conf., 13-17 October 2003, Accra, Ghana. Cocoa Producers' Alliance, Lagos, Nigeria.

KEBE I.B., G.M. TAHI, P. LACHENAUD, J.A.K. N'GORAN AND A.B. ESKES. In press. Genetic improvement in resistance of cocoa to black pod disease in Côte d'Ivoire. *In* Proc. 14th Int. Cocoa Research Conf., 13-17 October 2003, Accra, Ghana. Cocoa Producers' Alliance, Lagos, Nigeria.

LACHENAUD PH., A. ESKES, J. A. K. N'GORAN, D. CLEMENT, I. KEBE, M. TAHI AND C. CILAS. (2002). Premier cycle de sélection récurrente en Côte d'Ivoire et choix des géniteurs du second cycle. *In* Proc. 13th Int. Cocoa Research Conf., 9-14 October 2000, Kota Kinabalu, Sabah, Malaysia. Cocoa Producers' Alliance, Lagos, Nigeria.

N'GUESSAN K.F. AND A.B.ESKES. (In press). Study on the resistance of cocoa trees to mirids in Côte d'Ivoire: classification of major groups by their level of resistance/sensitivity. *In* Proc. 14th Int. Cocoa Research Conf., 13-17 October 2003, Accra, Ghana. Cocoa Producers' Alliance, Lagos, Nigeria.

NYASSÉ S., I.B. EFOMBAGN M., E. BOUAMBI, M. NDOUMBE-NKENG AND A.B. ESKES. (2003). Early selection for resistance to *Phytophthora megakarya* in local and introduced cocoa varieties in Cameroon. Trop. Sci. 43: 96-102.

OPOKU I.Y., A.Y. AKROFI, A. ABDUL-KARIMU AND Y. ADU-AMPOMAH. In press. Selection of cocoa genotypes as parents for resistance to *Phytophthora megakarya* and *Phytophthora palmivora*. *In* Proc. 14th Int. Cocoa Research Conf., 13-17 October 2003, Accra, Ghana. Cocoa Producers' Alliance, Lagos, Nigeria.

PADI B., Y. ADU-AMPOMAH AND P. KUDEKOR. (2002). Evaluation of local clone materials for resistance/tolerance to capsid attack under laboratory and mimicked field conditions. *In* Proc. of the Third Int. Seminar on Cocoa Pests and Diseases. 16-17 October 2000, Kota Kinabalu, Sabah, Malaysia. Published by INCOPED.

PAULIN D., M. DUCAMP, K. VEZIAN-BONNEMAIRE AND A.B. ESKES. (In press). Evaluation par le test d'inoculation sur feuille du niveau de résistance de trente clones vis-à-vis de plusieurs espèces de Phytophthora. *In* Proc. 14th Int. Cocoa Research Conf., 13-17 October 2003, Accra, Ghana. Cocoa Producers' Alliance, Lagos, Nigeria.

RISTERUCCI A-M., A.B. ESKES, D. FARGEAS, J-C. MOTAMAYOR AND C. LANAUD. (2001). Use of microsatellite markers for germplasm identity analysis in cocoa. *In* Proc. of the INGENIC Workshop on "New Technologies and Cocoa Breeding". 15-17 October 2000, Kota Kinabalu, Sabah, Malaysia. INGENIC, London.

SOUNIGO O., F. BEKELE, A.D. IWARO, G. BIDAISEE, R. UMAHARAN, M. BOCCARA, D.R. BUTLER AND A.B. ESKES. (In press). Description of the CFC/ICCO/IPGRI Project Collection. *In* Proc. 14th Int. Cocoa Research Conf., 13-17 October 2003, Accra, Ghana. Cocoa Producers' Alliance, Lagos, Nigeria.

SOUNIGO O., Y. CHRISTOPHER, S. RAMDAHIN, R. UMAHARAN AND A. SANKAR. (2001). Evaluation and use of the genetic diversity present in the International Cocoa Genebank (ICG,T), in Trinidad. *In* Proc. of the INGENIC Workshop on "New Technologies and Cocoa Breeding". 15-17 October 2000, Kota Kinabalu, Sabah, Malaysia. Pp 65-71. INGENIC, London.

UMAHARAN R., J-M THÉVENIN AND D.R. BUTLER. (In press). Identification of resistance to Witches' Broom disease in the International Cocoa Genebank, Trinidad. *In* Proc. 14th Int. Cocoa Research Conf., 13-17 October 2003, Accra, Ghana. Cocoa Producers' Alliance, Lagos, Nigeria.

3.5. PROPOSAL FOR THE CONTENTS OF THE FINAL PROJECT PUBLICATION

At the Closing Workshop of the project, the following chapters to be contained within a Final Technical Publication were agreed:

Selection and Breeding

1. Population Breeding Approaches applied in the project (Brazil, Côte d'Ivoire, Ghana and Malaysia)
2. Description of the CFC/ICCO/IPGRI project Collection
3. Description of the Field Guide for Rapid Identification of Project Clones (the full Guide will be published separately)
4. Methods for Multiplication of Clones
5. Accelerated Hybrid Clone Selection Scheme
6. Visual Assessment of Yield Potential in Selection Trials

Phytophthora *Resistance Studies*

1. Studies on Validation of Testing Methods
2. List of Promising Clones Identified
3. Review of Working Procedures
4. Interaction Studies between ICT Clones and Pathogen Isolates (Montpellier)
5. Ring Test for Resistance to *Phytophthora* (multi-site trials)
6. Molecular Studies Related to *Phytophthora* Resistance (CIRAD study)

Mirid Resistance Studies

1. Resistance and Tolerance Studies Carried Out (Cameroon, Côte d'Ivoire, Ghana)
2. Review of Working procedures

Witches' Broom Resistance Studies

1. Resistance and Studies Carried Out in Trinidad
2. IsolatexClone Intercation Studies Carried Out by the University of Reading
3. Resistance Studies Carried out in Brazil
4. Resistance Studies Carried out in Ecuador
5. Review of Working Procedures

VSD Resistance Studies

1. Resistance Studies in Malaysia
2. Resistance Studies in PNG

CSSV Resistance Studies Carried out in Ghana

4. LESSONS LEARNT

4.1. RESEARCH AND DEVELOPMENT LESSONS

The project has yielded a series of lessons learnt from technical problems. Small experiments carried out to overcome these problems have often produced significant results.

Budding versus top-grafting

In several countries the hypocotyl budding technique recommended at the onset of the project has shown to produce very low success rates (Cameroon, Nigeria, Venezuela). In

Nigeria, a series of experiments were done to reduce infection of budded plants with opportunistic fungi, and Benomyl at 5% appeared to be quite effective. Despite this result, the use of top-grafting has subsequently been applied in most countries in order to obtain higher average success rate. This method is suited for Clone Observation Plots and may be increasingly applied in the future by farmers, even in Africa, to multiply preferred clones on their own farm. The top-grafting is however less suited than hypocotyl budding for the establishment of clonal collections (due to the higher chances of sprouting from the rootstock with top-grafted plants).

Clonal multiplication of seedlings

Budding of seedlings has been carried out for accelerated hybrid clone selection in PNG and in Malaysia. Success of budding has been low in Malaysia, which appears to be due to dormancy of the young orthotropic buds and thus low sprouting of the scion. Results from PNG and also from Nigeria suggest that sprouting of the dormant buds can be overcome by eliminating the growing point, thus breaking apical dominance. Top-grafting of seedlings may also be an interesting alternative to seedling budding. Experiments carried out in Malaysia have shown very good results for the bud-break of top-grafted materials in relation to budded seedlings.

Damage due to drought

The dry period of December 2001 to March 2002 was quite severe in some places in Africa. One hybrid trial was lost in Nigeria and also one in the Bechem area in Ghana. These trials could be partially replanted with new seedlings during the reporting period. A small trial carried out at CRIN using reduction of the leaf surface by 50% before the dry period starts has not given conclusive results. It appeared that overhead shade was a more important factor to promote seedling survival than reduction of the leaf surface. In Côte d'Ivoire, CNRA put in place a large trial in 2002 to evaluate the effect of leaf surface reduction on survival during the dry period. The results also failed to show any beneficial effect of the leaf surface reduction treatment.

Evaluation of resistance of clones to witches' broom.

At CRU, Trinidad, several treatments were undertaken to improve infection rate of inoculations of clones. Manual spraying or drop inoculations of buds appeared to give more regular results than the automised belt spray method. This effect could be due to partial drying-up of inoculum between spraying and incubation of the plants. Results from Reading suggest that latency period may be correlated with infection rate, but also that latency period can be affected significantly by the environment. On the other hand, the weight and length of the brooms did not appear to be affected by the clone, and hence would be less valuable traits to be evaluated.

However, there were other technical problems in the project that could not be solved adequately. The main problem remains relative unsatisfactory results from screening for resistance to certain diseases and pests, mainly witches' broom, CSSV and mirids. Resistance testing methods will therefore receive special attention again in the new CFC/ICCO/IPGRI "Productivity" project.

4.2. OPERATIONAL LESSONS

The project has suffered relatively little from administrative and operational problems. A very important element is the effective liaison that is to be ensured for a large project with many partners, as was the case with this project. This liaison was possible thanks to the Coordination Unit put in place by IPGRI and thanks to the regular visits of the Coordinator to the project sites.

The nomination by each Collaborating Institute of an Administrative and a Technical Coordinator for the project helped to clarify the liaison for administrative/financial aspects and for technical aspects, respectively.

The organisation of the Mid-Term Technical Meetings, which was proposed during the Initial Workshop of the project, was also a crucial element to analyse the progress obtained and to propose remedial actions where needed.

It was also very important that the CFC budget could be dealt with in a more or less flexible way. This made it possible to make adjustments where necessary to obtain the maximum results for the project as a whole.

Furthermore, the use of the Contingencies was a very important aspect to cover necessary but unforeseen expenses, i.e. the losses in the SDR/USD exchange rate, additional coordination cost for the preparatory (1997/98) and extension years (2003/04), organisation of the mid-term meetings and the costs of the audits.

The project has also benefited from the creation of the Co-financiers Working Group (CWG) and the Technical Working Group (TWG), representing the Co-financiers and the Collaborating Institutions, respectively. The chairman of the CWG (Mr. Tony Lass) has actively participated in the elaboration of the project documents, in the two Project Workshops, in one Mid-Term Review Meeting (Trinidad) and in some of the technical publications. This demonstrated the very active involvement of the CWG in the preparation and in the implementation of the project.

During the final project workshop, the role of the TWG was analysed by the Technical Coordinators of the project at the different sites. Although the chairman and all members of this Group have been in regular contact (through e-mail and telephone contact) on technical matters with the Project Coordination Unit, it was felt that the TWG as a Group has not been able to be very active. It was suggested that resources would need to be made available in future projects for a more effective participation of this Group in the project implementation and in project review meetings.

Last but not least, the five-year duration of the project is relatively short for its main goal, which is developing new cocoa varieties. Therefore, the acceptance by CFC of the new CFC/ICCO/IPGRI project is of fundamental importance for the full exploitation of the trials put in place and for testing the most interesting selections in farmers' fields.

5. CONCLUSIONS AND RECOMMENDATIONS

The project has significantly increased national and international collaborative efforts on evaluation, selection and conservation of cocoa germplasm with the aim of producing better cocoa varieties. The implementation of the CFC/ICCO/IPGRI project activities has been satisfactory at most project sites. The achievements are in general equal or superior to the

planned Outputs. The quantity of work carried out is impressive and the numerous new cocoa selections made represent an invaluable tool for further and future cocoa breeding. These achievements have also resulted in a better conservation effort of the cocoa genetic resources maintained in the countries.

Other valuable benefits are:

- knowledge generated on germplasm evaluation and breeding with emphasis on disease and pest resistance,
- publication of results and introduction of data into international databases,
- human capacity building, the agreement and subsequent adoption and transfer of methodologies between project partners,
- the more effective and coordinated use of limited resources,
- reinforcement of links between cocoa conservation and breeding efforts, and
- reinforcement of multidisciplinary teams working towards the same goal of obtaining better cocoa varieties.

The direct and indirect benefits are expected to enhance sustainability of cocoa breeding programs. The achievements in the current project will permit the partners to foster further international collaboration and to involve the farmers directly in the process of developing new varieties. It also allows studies on cocoa genetic mapping (QTL studies) to advance, by using selected progenies segregating for interesting traits.

Recommendations made during the Mid-Term Technical Meetings were incorporated in the proposal for a new CFC/ICC/IPGRI project on "Cocoa productivity and Quality Improvement, a Participatory Approach", that was accepted by CFC for financing in October 2003 and April 2004, and that is operational from 1 June 2004 onward. This project will be able to build on the achievements obtained in the "Germplasm" project, including the distribution and validation of the most promising selections in farmers' fields.

Despite the significant benefits obtained, it should be recognised that the project has certainly not been able to cope with all constraints in cocoa breeding. Some of the urgent needs that could not be addressed, or only insufficiently, in the current as well as in the new project are:

- The urgent need for more training opportunities for young scientists in practical cocoa breeding;
- The need for more large-scale rapid clone selection programmes applying the "accelerated hybrid clone selection scheme";
- The defective or non-existent multiplication and distribution systems for improved varieties, in countries where such varieties are available; and
- Lack of stable long-term support for cocoa germplasm conservation and breeding activities.

It is important that other resources be made available to address these shortcomings in cocoa germplasm conservation and utilisation.

The project achievements are in agreement with the high level of resource utilisation observed, which is about 100% for the CFC funding, 125% for the co-financing and 113% for the counterpart contributions. It should be emphasised that the counterpart contributions have made up the larger part (53%) of the total project costs, which confirms the continuous commitment made by the Collaborating Institutions during the entire project life. This has been the basic pillar for the results obtained.

Recommendations were made during the Closing Workshop on the content of the Final Technical Paper to be produced with the project results. IPGRI, with the help of all Collaborating Institutions and in close contact with ICCO and CFC, expects to publish this final publication within the next 12 months.

Table 1. CFC Resource Allocation and Utilisation by Cost Site (in US $) for the Total Project Duration (December 1997 to March 2004, compared with the Appraisal Report)

Cost Site (project partner)	Budgets in Appraisal Report (AR)	Total claimed to CFC*	Purchases carried out by IPGRI on behalf of project partners	Total expenditures by Cost Site	Total spending related to AR (%)
CCRI (PNG)	90 888	105 959	0	105 959	116.6%
CEPEC (Brazil)	200 000	206 190	1 757	207 947	104.0%
CIRAD (France)	115 000	110 314	0	110 314	95.9%
CNRA (Côte d'Ivoire)	200 000	195 129	15 465	210 594	105.3%
CRIG (Ghana)	199 850	203 193	3 831	207 024	103.6%
CRIN (Nigeria)	90 000	78 021	1 814	79 835	88.7%
CRU (Trinidad)	243 000	251 962	50	252 012	103.7%
Fundacite (Venezuela)	94 000	103 754	379	104 133	110.8%
INIAP (Ecuador)	89 082	109 616	111	109 727	123.2%
IPGRI (Italy, France)	982 800	1 044 772	(24 713)	1 020 059	103.8%
IRAD (Cameroon)	90 000	107 711	961	108 672	120.7%
MALMR (Trinidad)	50 000	50 002	0	50 002	100.0%
MCB (Malaysia)	144 690	125 992	345	126 337	87.3%
Un. Reading (UK)	137 690	141 627	0	141 627	102.9%
Contingencies (5%)	136 250	-	-	-	-
Total budget managed by PEA	2 863 250	2 834 242	0	2 834 242	99.0%
Supervision and Monitoring (ICCO, CFC), incl. Contingencies	78 750	0	0	0	
Total budget (AR)	2 942 000	-	-	-	

* Excluding projected costs for the final audit and for the final project publication

Table 2. CFC Resource Utilization by Budget Category (in US$) for the Total Project Duration, compared with the Appraisal Report

Budget Categories	Total Allocated in Appraisal Report	Total Expenditures by Category	Spending as percentage of Allocated Budget
I Equipment	157 650	155 135	98.4%
II Civil Works	29 000	31 171	107.5%
III Materials and Supplies	511 223	537 866	105.2%
IV Personnel	1 132 347	1 281 407	113.2%
VI Duty Travel	285 975	178 825	62.5%
VII Exchange of Information	174 000	176 986	101.7%
VIII Operational Costs	436 004	472 852	108.5%
Contingencies (unallocated)	137 051	-	-
TOTAL (funds through PEA)	2 863 250	2 834 242	99.0%
Supervision and Monitoring (incl. Cont.)	78 750		

Table 3. Total Resource Utilisation by Cost Site and Funding Source (US $) for Total Project Duration, compared with the Appraisal Report

Collaborating Institute/ Project Site	CFC Funding	Co-financing Contributions				Counterpart Contributions			Total Project Costs per Site
		CIRAD	BCCCA	ACRI	IPGRI	Actual expenditures	Original AR budget	As % of AR	
CCRI, PNG	105 959					303 246	276 575	110%	409 205
CEPEC, Brazil	206 190			279 430		660 485	566 693	117%	1 146 105
CIRAD, France	110 314	243 000				579 500	312 000	186%	932 814
CNRA, Ivory Coast	195 129	582 675				256 390	332 200	77%	1 034 194
CRIG, Ghana	203 193					600 321	408 100	147%	803 514
CRIN, Nigeria	78 021					137 390	125 000	110%	215 411
CRU, Trinidad	251 962	539 550	150 000	252 659		1 813 342	1 650 000	110%	3 007 513
Fundacite, Venezuela	103 754					115 646	135 000	86%	219 400
INIAP, Ecuador	109 616					145 157	171 360	85%	254 773
IPGRI, Italy	1 044 772				252 704	489 203	275 000	178%	1 786 679
IRAD, Cameroon	107 711					107 395	117 500	91%	215 106
MALMR, Trinidad	50 002					82 333	64 000	129%	132 335
MCB, Malaysia	125 992					115 646	127 440	91%	241 638
Un. of Reading, UK	141 627		123 530			511 543	543 363	94%	776 700
Total expenditures	2 834 242	1365 225	273 530	532 089	252 704	5 917 597			11 175 387
Total budget as in AR (excl. Supervision + Monitoring)	2 863 250	1 227 750	223 530	389 200	100 000	5 104 231			9 907 961
Expenditures as % of AR budget	99%	111%	122%	137%	253%	116%			113%

* Co-financing and Counterpart Contributions as estimated by the Co-financiers and Collaborating Institutions

Table 4. Quantification of Work Carried Out by Project Site

Project partner	Budding/ Grafting	Pollinations	Resistance traits evaluated (No. of genotypes)				Field observations		Other
			Black pod	Mirids	Witches' broom	VSD	Growth	Yield/ other	
CCRI	15 800	8 600	1 250			109	1 209	3 189	
CEPLAC	16 578	4 320	1 304		1 448		698	1 023	143 (*Ceratocystis*) 5000 (Self compatibility)
CIRAD	600		1 264						150 (Anova), 200 (DNA markers), 200 (Shipment budwood)
CNRA	17 500	5 300	745	418			857	1 170	328 (Morph. Traits) 695 (gen. markers)
CRIG	12 000	25 000	715	122			911		480 (CSSV resistance)
CRIN	70 000	3 500	143				77	49	20 (Budding treatments)
CRU	22 300		4 921		951				803 (RAPD), 577 (Isozymes) 67 (SSR), 2057 (morph. traits)
INIA	15 400	5 675	170		110		299	60	60 (Insect resistance)
INIAP	7 692	1 625			610		453	302	
IRAD	25 000	4 000	630	90			90	30	
MALMR	5 000		40		40		120	40	
MCB	2 250	4 950	172			163	163	163	150 (Fat content)
Un. Reading	1 000				100				500 (Shipments budwood)
Total	**211 120**	**62 970**	**11 354**	**630**	**3 259**	**272**	**4 877**	**6 026**	**11 430**

Table 5. Number of Hectares of Field Trials Planted or Observed (old):

Project partner	Trials						Total (new)
	ICT	LCT	LCOP	HT	Population breeding (new)	Population breeding (old)	
CCRI	2.7	2.7	3.6	3.4			12.4
CEPLAC	0.8	2.5	12.9		5.0	8.0	21.2
CNRA	0.8	0.7	1.3		7.1	5.6	9.9
CRIG	1.5	1.0	2.5		11.8		16.8
CRIN	1.0	0.6	0.3	2.8			4.7
CRU					2.5		2.5
INIA	0.9	0.9	1.0	3.0			5.8
INIAP	1.5	1.4	1.5	3.8			8.2
IRAD	0.6		0.5	2.1		0.6	3.2
MALMR	0.6	0.6	0.5				1.7
MCB	1.2		0.8		5.1	1.0	7.1
Total	**11.6**	**10.4**	**24.9**	**15.1**	**31.5**	**15.2**	**93.5**
Total planned	**8.0**	**8.0**	**10**	**10**	**19**	**15.2**	**55**

ICT = International Clone Trial, LCT = Local Clone Trial, LCOP = Local Clone Observation Plot, HT = Hybrid Trials

Table 6. Number of Genotypes Planted in Field Trials or Observed in Adult Field Trials (old)):

Project partner	Trials						Total (new)
	ICT	LCT	LCOP	HT	Population breeding (new)	Population breeding (old)	
CCRI	54	55	374	100			583
CEPLAC	29	58	675		216	186	978
CNRA	24	20	502	10	244	310	800
CRIG	25	25	165		362	300	577
CRIN	26	16	25	60			127
CRU					400		400
INIA	25	25	189	60			299
INIAP	24	28	27	92			171
IRAD	30		177	42			249
MALMR	20	20	35				75
MCB	23		79		61		101
Total	280	247	2 248	364	1 283	796	4 422
Total planned	200	200	500	200	1 000	796	2 100

ICT = International Clone Trial, LCT = Local Clone Trial, LCOP = Local Clone Observation Plot, HT = Hybrid Trials

Table 7. Estimated Number of Promising Genotypes Identified at Project Sites

Project Site	Selection Traits						Total no. of selections
	Black pod resistance	Mirid resistance	Witches' broom resistance	VSD resistance	Multiple traits (yield and other)	Other	
CCRI	22				157		179
CEPLAC	112		22		750	1 (Ceratocystis))	885
CNRA	100	50			85		235
CRIG	70	10				10 (CSSV)	90
CRIN	35				19		54
CRU	464					103 (Project Collection)	567
INIA			10				10
INIAP					22		22
IRAD	100	9					109
MALMR	8		9				17
MCB	9			18			27
Total	**920**	**69**	**41**	**18**	**1 033**	**114**	**2 195**