Review of the CFC/ICCO/Bioversity project on cacao germplasm evaluation (1998-2010)

November 2017

CONTRIBUTORS

This report was compiled by Viviana Medina, Nicole Demers and Brigitte Laliberte from Bioversity International, together with Andrew Meter from the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD).

ACKNOWLEDGEMENTS

The CFC/ICCO/Bioversity project was developed under the aegis of the International Cocoa Organization (ICCO), and funded by the Common Fund for Commodities (CFC). We thank the ICCO and the CFC for their important contributions. The ICCO played an important role in the establishment phase of the project and provided supervision and general support throughout the two phases of the project. The implementation of the project would not have been possible without significant co-financing and counterpart contributions from all partner institutions. We also recognize the important role played by Tony Lass (independent consultant) and Jan Engels (Bioversity International) in developing the initial project concept, together with ICCO staff.

Financial support for this review was provided by the World Cocoa Foundation (WCF) and its Feed the Future Partnership for Climate Smart Cocoa Program, through a grant to Bioversity International from the United States Department of Agriculture, Foreign Agricultural Service (USDA-FAS)[1]; the European Cocoa Association (ECA) / Association of the Chocolate, Biscuit and Confectionery Industries of Europe (CAOBISCO) / Federation of Cocoa Commerce (FCC) Joint Working Group on Cocoa Quality and Productivity and the CGIAR Research Program on Forests, Trees and Agroforestry (FTA).

We thank all those who contributed to the review of this document: Jan Engels, Vincent Johnson and Stephan Weise from Bioversity International; Michelle End (Cocoa Research Association Ltd UK); Tony Lass; and Bertus Eskes (project coordinator and currently an independent consultant). We are grateful to Elizabeth O'Keeffe for assisting with the copy-editing and layout of the document.

Finally, we would like to express our gratitude to all those individuals, project partners and collaborators who responded to the surveys, providing information that was essential for the development of this review.

[1] This publication was supported by FAS Number TA-CA-16-026, CFDA 10.960 from USDA. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of USDA.

Bioversity International is a global research-for-development organization.

We have a vision – that agricultural biodiversity nourishes people and sustains the planet. We deliver scientific evidence, management practices and policy options to use and safeguard agricultural and tree biodiversity to attain sustainable global food and nutrition security. We work with partners in low-income countries in different regions where agricultural and tree biodiversity can contribute to improved nutrition, resilience, productivity and climate change adaptation.

Bioversity International is a CGIAR Research Centre. CGIAR is a global research partnership for a food-secure future.

www.bioversityinternational.org

CGIAR Research Program on Forests, Trees and Agroforestry (FTA) is the world's largest research for development program to enhance the role of forests, trees and agroforestry in sustainable development and food security and to address climate change. CIFOR leads FTA in partnership with Bioversity International, CATIE, CIRAD, ICRAF, INBAR and TBI.

This work is supported by the CGIAR Fund Donors.

Citation: Medina, V., Meter, A., Demers, N. and Laliberte, B. 2017. *Review of the CFC/ICCO/Bioversity Project on Cacao Germplasm Evaluation (1998-2010)*. Bioversity International.

ISBN: 978-92-9255-077-6

Cover photo: Allan Mata, CATIE (2017)

ACRONYMS

ACD	Accelerated clone development
ACRI	American Cocoa Research Institute, USA (now WCF)
BCCCA	Biscuit, Cake, Chocolate and Confectionery Alliance, UK (now CRA Ltd)
BP	Black pod
CacaoNet	Global Network for Cacao Genetic Resources
CAOBISCO	Association of the Chocolate, Biscuit and Confectionery Industries of Europe
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica
CCI	Cocoa Coconut Institute, Papua New Guinea
CCRI	Cocoa and Coconut Research Institute, Papua New Guinea (now CCI)
CEPEC	Centro de Pesquisas do Cacau, Brazil
CEPLAC	Comissão Executiva do Plano da Lavoura Cacaueira, Brazil
CFC	Common Fund for Commodities, based in the Netherlands
CFCE	Collaborative Framework for Cocoa Evaluation
CGIAR-FTA	CGIAR Research Program on Forests, Trees and Agroforestry
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France
CIRAD-CP	Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Département des Cultures Pérennes, France
CNRA	Centre National de Recherches Agronomiques, Côte d'Ivoire
COPAL	Cocoa Producers Alliance, Nigeria
CPB	Cocoa pod borer
CRA	Cocoa Research Association Ltd., UK
CRC-UWI	Cocoa Research Centre, University of the West Indies
CRIN	Cocoa Research Institute of Nigeria
CSSV	Cocoa swollen shoot virus
ECA	European Cocoa Association
FCC	Federation of Cocoa Commerce
FONAIAP	Fondo Nacional de Investigaciones Agropecuarias, Venezuela (now INIA)
FUNDACITE	Aragua Fundación para el Desarrollo de la Ciencia y la Tecnología del Estado de Aragua, Venezuela
GCA	General combining ability
HT	Hybrid Trial
ICCO	International Cocoa Organization, based in the UK
ICG,T	International Cocoa Genebank, Trinidad
ICGD	International Cocoa Germplasm Database
ICQC,R	International Cocoa Quarantine Centre, Reading, UK
ICT	International Clone Trial
IE	Isozyme electrophoresis
IITA	International Institute of Tropical Agriculture, Nigeria
INGENIC	International Group for Genetic Improvement of Cocoa
INIA	Instituto Nacional de Investigaciones Agrícolas, Venezuela
INIAP	Instituto Nacional de Investigaciones Agropecuarias, Ecuador
INIBAP	International Network for the Improvement of Banana and Plantain, France

IPGRI	International Plant Genetic Resources Institute, Italy (now Bioversity International)
IRAD	Institut de Recherche Agricole pour le Développement, Cameroon
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
ITS	Internal transcribed spacer
LCOP	Local Clone Observation Plot
LCT	Local Clone Trial
MALMR	Ministry of Agriculture, Land and Marine Resources, Trinidad and Tobago
MCB	Malaysian Cocoa Board, Malaysia
MTA	Material transfer agreement
PBT	Population breeding trial
PCR	Polymerase chain reaction
Ppr	Phytophthora pod rot
QTL	Quantitative trait locus
RHVT	Regional Hybrid Variety Trial
SMTA	Standard Material Transfer Agreement
SSR	Simple sequence repeat
USDA-FAS	United States Department of Agriculture, Foreign Agricultural Service
UWI	University of the West Indies, Trinidad and Tobago
VSD	Vascular streak dieback
WB	Witches' broom
WCF	World Cocoa Foundation, USA

TABLE OF CONTENTS

FOREWORD

The ICCO Secretariat and Bioversity International have, for many decades, enjoyed a very strong and fruitful collaboration. At the time, distinctive destructive pests and diseases became widespread in many cocoa growing areas: witches' broom in Brazil; frosty pod in Central and South America; black pod in West Africa; and pod borer in Indonesia. Cocoa yields declined dramatically around the world and with them the living incomes of cocoa producers. An immediate response to this threat was warranted as a result of this formidable threat to the global cocoa supply chain.

To tackle this issue, Bioversity formulated an international, concerted response to develop more resilient cultivars tapping into the large biodiversity of the species Theobroma cacao. The idea appealed to many cocoa stakeholders and a project proposal followed. The Common Fund for Commodities (CFC) agreed to finance its implementation; and the ICCO Secretariat acting as a Project Supervisory Body appointed the International Plant Genetic Resources Institute (IPGRI, now Bioversity International) as the International Project Execution Agency. The project is the largest ever implemented by the ICCO and Bioversity as it covered fourteen institutions in Africa, Asia, Europe and Latin America and Caribbean. It was a typical example of how international cooperation can be harnessed to tackle global cocoa challenges.

This CFC/ICCO/Bioversity Project on Cacao Germplasm Evaluation had an overwhelming success. Over 2,300 new cocoa varieties, each containing one or more favourable traits against these global destructive pest and diseases, were identified.

To carry out such a large-scale assessment of cocoa germplasm, many cross-border, multidisciplinary organizational challenges had to be overcome. And the latter fuelled a momentum in fostering collaborative efforts in cacao breeding at international level. Indeed, new scientific and institutional partnerships were created; and these new promising cocoa varieties were then used directly by cocoa farmers.

Many lessons were learnt from the implementation of the CFC/ICCO/Bioversity Project on Cacao Germplasm Evaluation. It soon became clear that Bioversity not only identified successful new cocoa varieties but created a blueprint for the successful management of international, multidisciplinary collaborations aiming to achieve a common goal: the creation of standardized international working procedures and the strengthening formal and informal networks of cocoa stakeholders.

These spill-over effects can be instrumental to tackle the next global challenges faced by the world cocoa economy. How can we identify cocoa varieties resistant to prolonged drought, excessive rainfall extreme weather and rising temperature? Are there any cocoa varieties having reduced uptake of a specific chemical compound?

Through this report Bioversity International provides us with an account of a challenging journey to tackle a global threat to the sustainability of the world cocoa economy. I am proud to say that I was a part of this incredible journey, first as Project Officer, then as Director of the Economics and Statistics in the ICCO Secretariat. And I can only express my full confidence in the success of this and other ambitious initiative from Bioversity International.

Finally, I would like to express my sincere appreciation to all our partners, in particular, to the Common Fund for Commodities (CFC), and especially to Dr Bertus Eskes, for their efforts in making the CFC/ICCO/Bioversity Project on Cacao Germplasm Evaluation, the global success that it has become.

Dr Jean Marc ANGA
Executive Director

EXECUTIVE SUMMARY

The CFC/ICCO/Bioversity project on cacao (referred to hereafter as the project) was a global project on cacao germplasm evaluation that was funded by the Common Fund for Commodities (CFC) and the International Cocoa Organization (ICCO), with the International Plant Genetic Resources Institute (now Bioversity International), in response to an urgent need to revitalize cacao breeding and research globally for increasing resistance to pests and disease. It was developed as a way to incentivize and support cacao breeding through an international collaborative effort. It aimed to strengthen national cacao improvement programmes and increase international collaboration by carrying out joint evaluation, selection and breeding activities in ten cocoa-producing countries. It also aimed to enhance cacao germplasm utilization and conservation activities. The project was implemented in two phases – Phase I (1998- 2004) and Phase II (2004-2010).

To date, the project has been one of the most ambitious collaborative efforts in cacao breeding. Given its significant achievements, we can take into account the lessons learned from the project before embarking on similar collaborations of comparable global range, such as the Collaborative Framework for Cocoa Evaluation (CFCE), which is currently being developed by Bioversity International in collaboration with several partners from the public and private sectors.

Today, climate change is an emerging challenge that has generated the need for a new international collaborative effort within the cocoa community. Increased temperatures and unpredictable precipitation patterns are issues in many cocoa-producing regions. Further changes in climate are predicted to continue and perhaps worsen over the course of this century, with the progression of climate change placing the security of cocoa production at risk.

With an understanding that a similar global collaboration is needed to tackle the projected impacts of climate change on cacao production, this review was developed in response to a request from the cocoa industry and research partners to: (i) evaluate the effectiveness of the project and identify key lessons learned for the development and implementation of new international, inter-organizational multisite evaluation field trials, focused on increasing the resilience of cacao to the effects of climate change; and (ii) present updated information on the current status of the different trials that were established between 1998 and 2010 within the framework of the project.

This review first provides a full description of the project, including the justification, objectives, components and expected outputs of the project, and its general structure, partners, and financing. The achievements and key benefits are then summarized, together with the recommendations for improvement that were presented at the conclusion of the project. Results from two surveys carried out between 2016 and 2017, of institutes that participated in the project, are presented, providing information on the current status of field trials established as part of the project. In conclusion, the review discusses reported strengths and limitations based on the results of the two surveys, and provides suggestions for future joint initiatives, which are outlined here below:

***Trial design*:** The design of future field evaluation trials is where the foundation of success lies. To ensure well-structured and sustainable field trials, full agreement is required on the scientific experimental design, location, partners, and duration of the trials. An experimental set-up that has enough statistical power and knowledge of the possible limitations imposed by intrinsic cacao physiology must be discussed, evaluated and agreed upon by all participating institutions.

Trial duration: For several of the trials, the duration of the trial was not long enough to generate conclusive results. Factors such as sufficient funding to ensure trial length that is representative of cacao physiology, considerations of trial set-up time, and consistency in personnel in charge of trials, are critical for establishing a realistic duration that gives conclusive data for the traits in question.

Plant selection: Some of the plant material selected to be part of international trials did not have any resistance to local pathogens. As a result, many plants were lost. Survey respondents suggested that only varieties with a certain level of resistance to local pathogens should be used in future trials, to ensure the plants do not succumb to local disease pressures, and that experiments can take place effectively.

Exchange of plant genetic material: Although material exchange in the project occurred with relative ease, germplasm exchange can act as a significant bottleneck in global collaboration. Understanding the likely restrictions can help in better planning for material transfers, and facilitate appropriate scheduling of activities such as quarantine periods.

The lack of molecular fingerprinting of clones before establishment was one of the greatest concerns reported. Some researchers did not feel confident they were comparing like with like. Future trial layouts should include fingerprinting resources and funding prior to field establishment. Care must also be taken during propagation, as it could be a major source of plant error.

Working procedures. Establishing working procedures was very useful in principle, but in practice a number of institutes deviated. A checks and balances system must be incorporated to rapidly evaluate whether participating institutes are implementing the agreed upon protocols, and assess limitations early on as a way to secure data integrity and comparability. Developing a cacao ontology is essential for this step of ensuring comparability.

Collaboration and coordination: The complexity of the project's structure, the differences in capacities, and legal and administrative constraints of participating institutions, led to complications that in some cases undermined the efficiency of the collaboration. It is important to increase communication between participating institutes and the project coordinator with new ways of communication offered by evolving technologies.

Farmer benefits: Many of the institutes indicated that little of the work actually resulted in direct benefits for the farmer, possibly owing to the limited duration of the trials. Future projects must take extra steps to establish clear, defined and attainable goals that result in significant farmer benefits.

It is our aim that the scientific community will be able use the information presented in this report to reflect on those aspects of the project that worked best and those that must be improved on, and to identify the planting materials still in place in field trials that are available for future evaluation. The cacao research community will be able to use these lessons learned to be better prepared for, and more effective in, the execution of future collaborative research initiatives.

1 INTRODUCTION

After years of stagnation in the research and development of new cacao varieties, and in response to the continued loss of cacao genetic diversity, the Common Fund for Commodities (CFC), and the International Cocoa Organization (ICCO) funded a global project with the International Plant Genetic Resources Institute (IPGRI, now Bioversity International),[2] on the evaluation of cacao germplasm with the aim of revitalizing cacao breeding and research. During this time, destructive pests and diseases increased in many cacao-growing areas, such as *Moniliophthora perniciosa* (witches' broom) in Brazil (Bahia); frosty pod caused by *Moniliophthora roreri* in Central and South America; *Phytophthora megakarya* (Ppr, black pod) caused by many different *Phytophthora* spp. pathogens in West Africa; and *Conopomorpha cramerella* (pod borer) in Indonesia. In this context, the project emerged as a way to incentivize and support cacao breeding through an international collaborative effort that targeted a global challenge. The project was divided into two phases:

- Phase I (1998-2004) – 'Cocoa germplasm utilization and conservation: a global approach'
- Phase II (2004-2010) – 'Cocoa productivity and quality improvement: a participatory approach'[3].

Although both phases were successful and generated much interest and enthusiasm for other collaborations and initiatives, since the closing workshop in Bali in 2009[4], discussions and follow-up actions have dwindled. As a result, another recession in global cacao breeding efforts has taken place. Facing a new threat to global production, in particular caused by climate instability, there is an urgent need to regenerate international collaborative efforts towards the development of more resilient cultivars that better meet the present and upcoming challenges of climate change.

This review was developed in response to a demand from the cocoa industry and research partners to evaluate the status of the project and particularly that of the field trials as a way to prepare the ground for new collaborative initiatives in cacao genetics. Planting materials are already available in many countries, in the trials that were established as part of the project, offering the potential for genotype-environment evaluations of drought resilience or other physiological studies.

The main objectives of this review are to:

1. Evaluate the effectiveness of the CFC/ICCO/Bioversity project and analyse key lessons learned for the development and implementation of a new international collaborative framework, including multisite evaluation field trials focused at increasing cacao climatic resilience.
2. Assess the current status of the different field trials put in place between 1998 and 2010, within the framework of the CFC/ICCO/Bioversity project, that could be used immediately for continued and new evaluation.

This review was developed using information compiled from the two reports of the project (Eskes and Efron 2006; Eskes 2011a), as well as country reports and final workshop presentations (Eskes 2009; Weise 2009). Further data were generated from the results of two surveys sent out to institutes that participated in the CFC/ICCO/Bioversity trials in 2016 and 2017. The first survey, entitled 'Cacao genetic resources - survey of the conservation and use community', was sent out in April 2016, by the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) and the Global Network for Cacao Genetic Resources (CacaoNet), to 391 members of the international cacao genetic resources community, and included questions directed to participants of the project; a sample survey (2016) is included as Appendix 7.1, while results of the survey are available in Appendix 7.2. Part of the information collected through this 2016 survey was used as input for the design of a second survey that was sent out in April 2017 to individuals and institutes who implemented the field trials of the project; a sample survey (2017) is provided in Appendix 7.3.

[2] IPGRI changed its name to Bioversity International in 2006, during the second phase of this project.
[3] See Eskes and Efron (2006) for the report of Phase I; and Eskes (2011a) for the report of Phase II.
[4] 'Developments in cocoa genetics and breeding', 22-24 November 2009, Nusa Dua, Bali.

The 2017 survey aimed to identify lessons learned from the project, and to collect information on the current status of the field trials; results of the survey are available in Appendix 7.4.

The review presents the justification, objectives, components, expected outputs, and general structure of the project, and provides details of partners and financing. The achievements and key benefits, as reported at the end of the project, are described, and the current status of field trials established during the project is presented. Reported strengths and limitations are discussed, with suggestions and recommendations for a future joint initiative. By using the lessons learned from this global approach, the cacao scientific community will be better prepared for, and more effective in, the execution of future collaboration and multilocational trials.

2 PROJECT DESCRIPTION

2.1 Project justification and objectives[5]

The CFC/ICCO/Bioversity project was initiated in response to a sharp decline in cacao breeding efforts in the 1990s. During this hiatus, destructive diseases and pests (e.g. *Moniliophthora perniciosa*, *Moniliophthora roreri*, *Phytophthora megakarya* and *Conopomorpha cramerella*) spread across existing production areas and into new cacao-growing areas. In line with the goal of fostering and supporting cacao breeding globally, the project aimed to 'kick-start' cacao breeding activity, making use of existing diversity within the two international cacao *ex situ* collections at the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) in Costa Rica, and the Cocoa Research Centre at the University of West Indies (CRC/UWI) in Trinidad and Tobago. The further exploration, use and exchange of materials in these collections presented great opportunities to the global community. The project proposed to enhance the collaborative evaluation of cacao, and widen the genetic base of available germplasm for breeding in the different participating countries, through increased international collaboration and exchange, and enhanced conservation, screening and selection protocols. Consequently, the project was established on the assumption that a global approach would be most effective, considering the existing geographical distance and cultural divide between areas of cacao genetic diversity (Latin America in particular), cacao production (West Africa and Southeast Asia), and the processing/manufacturing of cocoa (Europe and North America). Thus, international collaboration was seen to be essential to conserve, characterize, select, improve and subsequently distribute cacao germplasm in a coordinated and sustainable manner.

The immediate objectives of Phase I (1998-2004) were:

- To strengthen national cacao improvement programmes and increase international collaboration by carrying out cooperative evaluation, selection and breeding activities in ten cacao-producing countries.
- To establish cost-effective and efficient conservation, characterization and distribution efforts of available cacao germplasm.
- To strengthen cacao germplasm utilization and conservation activities through scientific/technical backstopping, information exchange and capacity building. (Eskes 2006, p.5).

Phase II continued and intensified the on-station conservation and selection activities initiated in the first phase, while at the same time incorporating a farmer participatory approach. This approach included an on-farm survey of existing diversity and practices used, as well as the direct involvement of farmers in selecting outstanding trees on their farms and in the on-farm trials established between the second and fourth year of Phase I. Phase II focused on further capacity building of researchers, by (formally) linking research institutes (especially those engaged in conservation and breeding efforts) with one another, and through the organization of two project workshops in the Americas and in Africa, in the second and fourth years (1998-2002).

The overall objectives of Phase II (2005-2010) were:

- To validate promising cacao varieties in farmers' fields through participatory approaches, involving farmers directly in the evaluation and selection process.
- To increase sustainability in cacao crop improvement programmes through validation and dissemination of selected cacao varieties between project partners, through enhanced regional and international collaborative research and development activities, and through capacity building.
- To exchange information and disseminate results among all project partners and also outside the project.

[5] This section was adapted from the final reports of Phase I and Phase II: Eskes and Efron (2006), Eskes (2011a).

- To establish and maintain functional linkages between national cacao breeding programmes, international cacao genebanks and quarantine centres, and international cacao research and development efforts. (Eskes 2011b, p.1).

The combined and summarized objectives of both phases were:

- To strengthen coordinated cacao genetic resources conservation efforts across the world.
- To select improved varieties with increased yield capacity, resistance to major diseases and pests, and with good quality attributes.
- To reinforce regional and international collaboration in cacao breeding.
- To reinforce local breeding programmes.
- To directly involve farmers in the selection of new varieties through a participatory approach.
- To use the diversity present in international cacao genebanks to carry out germplasm enhancement to combat important diseases.
- To distribute selected germplasm through intermediate quarantine to user countries, and through exchange between partners (regional trials).
- To exchange information and build capacity.

2.2 Project structure, partners and financing[6]

Project structure

The structure of the project was based on a multi-stakeholder international collaborative model with CFC as the main sponsor, ICCO as the supervisory body, and Bioversity International as the project executing agency. ICCO, representing the cocoa-producing and cocoa-processing member countries, provided the political platform needed for both the initial project discussions, as well as for the evaluation of project objectives and achievements within its wider commodity development strategy. A technical working group and a co-financiers' working group were created during the first project workshop in 1998 to help steer the project and make inputs at the administrative and political levels.

Project partners

As the supervisory body, ICCO played a crucial role in securing the funds for the project, and in monitoring and conducting mid-term evaluations of the project's progress. CFC was actively engaged in the mid-term evaluations of the project through participation in regional technical meetings, and through visits of the CFC project officer (PO) to several project sites. The main implementing partners of the project comprised fourteen institutes, coordinated by Bioversity International (Bioversity). Project partners are listed here below:

- Common Fund for Commodities (CFC), the Netherlands - main financing institution
- The International Cocoa Organization (ICCO), United Kingdom - supervisory body
- Bioversity International (formerly IPGRI) - project executing agency and Co-Financer
- Co-financing organizations:
  - Biscuit, Cake, Chocolate and Confectionery Alliance (BCCCA), United Kingdom; now the Cocoa Research Association Ltd. (CRA Ltd.)
  - American Cocoa Research Institute (ACRI), USA; now the World Cocoa Foundation (WCF)
  - Centre de Coopération Internationale en Recherche Agronomique pour le Développement/Département des Cultures Pérennes (CIRAD-CP), France.
- National research organizations:

[6] Adapted from Eskes (2006), p.8-10.

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

- International agricultural research organizations:
  - Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica
  - Cocoa Research Centre of the University of the West Indies, Trinidad and Tobago (CRC/UWI); formerly the Cocoa Research Unit (CRU).

Project financing

At the end of the project, total expenditure amounted to US$ 11,175,387. CFC was the main sponsor, providing a grant of approximately US$ 10 million. Co-financing contributions (in cash and in kind) were provided by the BCCCA, CIRAD-CP, ACRI, Guittard, Mars Inc., the United States Department of Agriculture (USDA), and Bioversity International. Contributions from ACRI were directed mainly towards the evaluation of witches' broom resistance at the Centro de Pesquisas do Cacau/Comissão Executiva do Plano da Lavoura Cacaueira (CEPEC/CEPLAC) in Brazil, and at CRC/UWI in Trinidad and Tobago. Co-financing resources from the BCCCA were allocated to accelerated germplasm conservation, characterization and evaluation activities at CRC/UWI, the safe movement of cacao accessions selected for use in the project at the International Cocoa Quarantine Centre in Reading (ICQC,R) and testing for resistance to witches' broom. CIRAD-CP gave co-financing support by providing scientific staff to reinforce the germplasm characterization and evaluation activities at CRC/UWI, conduct population breeding activities at CNRA and carry out the technical coordination of the project, through an agreement with Bioversity. Co-financing contributions from Bioversity involved project preparation, technical backstopping and overall project management.

2.3 Components and expected outputs of Phase I (1998-2004)[7]

Component 1: International and local clone trials

Expected outputs:

- Interesting new cacao clones were to be evaluated and distributed; superior clonal varieties were to be selected; and genetic stability of economically important traits was to be assessed through multilocational clone trials (referred to as 'international clone trial') in ten cocoa-producing countries.
- Twenty cacao clones, supplied by intermediate quarantine centres, were to be compared with 20 local clones in ten different countries for all economically important traits, including disease and pest resistance.
- Stability of clones to fungal isolates (pod rot from *Phytophthora* species or Ppr and witches' broom diseases) was to be studied using standardized early screening methods.
- 100-150 trees were to be selected in each country through early screening methods, and these trees were to be planted in field observation plots.

Component 2: Internationally coordinated hybrid trials

Expected outputs:

- Roughly 40 hybrid progenies were to be produced in each of five countries through crosses between locally selected superior clones, which were part of the clone trials of Component 1.
- Superior hybrid varieties were to be selected.
- Value of parental clones with their progenies was to be compared, and individual trees within these hybrids were to be selected for use in further breeding.

Component 3: Population breeding

Expected outputs:

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

Component 4: Germplasm enhancement

Expected outputs:

- More heritable economic traits were to be evaluated at the International Cocoa Genebank, Trinidad (ICG,T), managed by the Cocoa Research Unit (CRU, now CRC/UWI), especially resistance to Ppr and witches' broom diseases, through the identification of more resistant seedlings within crosses between selected resistant clones.
- Transfer of selected clones and/or populations to user countries was to be initiated.

[7] Taken from Eskes (2006), p.6-8.

Component 5: Germplasm conservation, characterization and preliminary evaluation

Expected outputs:

- Genotypes of interest to breeders in international and local collections were to be identified, with a view to establishing ‘core collections’.
- Selected material in the ICG,T was to be characterized to evaluate the genetic diversity present in such a core collection (also referred to as the ‘CFC/ICCO/Bioversity project collection’).
- Existing and newly obtained characterization and evaluation results were to be incorporated into the national and international databases.
- Opportunities for collection and conservation of material from interesting new areas were to be explored.

Component 6: Distribution and quarantine of interesting genotypes

Expected outputs:

- Interesting genotypes, identified during the project, to be distributed to participating countries following the internationally agreed ‘Technical guidelines for the safe movement of cacao germplasm’ (End, Daymond and Hadley 2014). These genotypes were to include, specifically, the accessions of the international clone trial, the project core collection to be identified at CRC-UWI, and improved populations.

Component 7: Exchange of information and workshops

Expected outputs:

- Exchange of information between project partners was to be achieved through the exchange of working documents and the preparation of information sheets, including photographs, on clones included in the international clone trial and on other widely distributed clones.
- All the data collected on genotypes were to be entered into the International Cocoa Germplasm Database.
- Notes on project development and achievements were to be published in newsletters and presented at international conferences, and relevant data introduced into existing databases. A compendium of the results was to be published as a final project publication.
- Two project workshops were to be implemented: one at the beginning of the project and one at the end of the project. During the first workshop, standardized procedures for the evaluation and selection of cocoa genotypes in project trials were to be adopted, and the planned collaborative activities between participants were to be established. During the closing workshop, project results were to be presented and possibilities for project continuation were to be discussed. Regional technical meetings were to be held in the third year of the project.

Component 8: Coordination and scientific/technical backstopping

Expected outputs:

- A project coordinating unit was to be established at Bioversity International (at its office in Montpellier, France) to provide the participating institutions with the means and procedures to communicate with each other and cooperate in the various activities.
- The coordinating unit was to provide liaison between the project partners to ensure efficient implementation of the activities, and that results were internationally comparable.
- Human capacity in the various disciplinary areas of cacao breeding and conservation was to be strengthened through the visits of the coordinator to project sites, as well as through workshops and regional technical meetings.

Component 9**: **Management, supervision and evaluation

Expected outputs:

- Day-to-day management of the project was to be the responsibility of Bioversity International, the project executing agency, while ICCO was the supervisory body. Project evaluation was to be based on six-month progress and financial reports.
- General mid-term evaluations were to be organized in the third project year.

2.4 Components and expected outputs of Phase II (2004-2010)[8]

Component 1: Farmer participatory approaches to cacao selection and breeding

Expected outputs:

- Criteria to be used by farmers for choosing new planting materials were to be identified through farmers' surveys.
- Cacao varieties with good potential for high yield, quality and resistance traits were to be selected by breeders and distributed to farmers for validation in their fields and comparison with their own preferred materials.
- Farmers' selections were to be established in observation plots at research centres for back-up evaluation on economically important traits.
- Best procedures for dissemination and validation of promising new varieties on-farm were to be determined through workshops with national extension services and other stakeholders.

Component 2: International collaborative approaches in cacao breeding

Expected outputs:

- Cacao varieties in existing collaborative variety trials and germplasm enhancement programmes were to be selected for yield, resistance and quality traits.
- The best selections were to be disseminated through intermediate quarantine to all participating cocoa-producing countries, to be established in Local and Regional Variety Trials or in local germplasm collections (as a resource for future variety development).
- Methods for screening of resistance to major diseases and pests (witches' broom, monilia and mirids) were to be improved to allow rapid selection process.

[8] This section was compiled with information from the final project report for Phase II (Eskes (2011a), the project agreement (Common Fund for Commodities 2004), and the final completion report (Bioversity 2010; see Appendix 7.5a in this review).

- DNA markers were to be utilized for identification of varieties used in the project and to find associations of these markers with economically important traits (QTLs).

Component 3: Exchange of information and dissemination of results

Expected outputs:

- Best procedures to involve farmers in the validation and distribution of new varieties were to be identified by representatives of implementing institutions, co-financiers, CFC and ICCO, through a workshop organized at the beginning of the meeting.
- Proceedings and results of the initial workshop were to be published and widely distributed to all project partners and main stakeholders.
- A final workshop was to be organized and attended by the participants of the project and other stakeholders, including non-participating countries.
- Overall results of the project were to be published through proceedings.
- Publications of various sorts were to be developed, and data were to be inserted into databases, during the lifetime of the project.

Component 4: Coordination, supervision and management

Expected outputs:

- A project coordination unit was to be set up by Bioversity for the efficient management of the project.
- A technical working group, comprising representatives from Bioversity and technical coordinators from national participating institutions, was to be established to ensure satisfactory implementation of the project and to decide on appropriate best procedures.
- Technical coordinators from each of the regions were to meet twice during the project (in the second and fourth year) and attend the first and final project workshops.

3 PROJECT ACHIEVEMENTS

3.1 Main achievements of Phase I (1998-2004)[9]

Phase I achieved most of the expected outputs; several additional activities that were not included in the original plan were also carried out. In total, an estimated 94 hectares (ha) of new variety trials were established at the different project sites (55 ha were originally planned). These trials contained a total of 2,775 clonal and 1,647 hybrid varieties (1,300 clones and 800 varieties were originally planned).

Standardized working procedures for cacao germplasm evaluation and selection, including methods of screening for resistance to pests and diseases, were agreed upon and adopted by the project during the initial workshop held in February 1998 (Eskes, Engels and Lass 2000).

The total number of evaluations carried out on cacao genotypes in collections and breeding trials in the project has been estimated to be 34,576, distributed per trait (or group of traits) as follows: 4,877 for vigour; 6,026 for yield and related traits; 5,000 for self-compatibility; 2,385 for pod and bean traits; 150 for fat content; and 16,138 for resistance traits – 11,354 to Ppr, 3,259 to witches' broom, 630 to mirids, 480 to cacao swollen shoot virus (CSSV), 272 to vascular streak dieback disease (VSD), and 143 to *Ceratocystis* wilt). The evaluation activities resulted in the identification of 2,345 promising new cacao varieties, each containing one or more favourable traits. Part of the above results reported were, however, still preliminary, as cacao varieties need to be observed for at least five years in the field before meaningful selections can be made efficiently.

The final report of Phase I also highlighted the following indirect benefits from the project:

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

Detailed results for each of the nine components of Phase I can be found in the final report (N'Goran and Eskes 2006, p.13-16).

3.2 Main achievements of Phase II (2004-2010)[10]

Based on the positive achievements of Phase I and lessons learned, the partners of Phase I (together with several additional partners) extended their collaboration into a second phase to continue the momentum, establish partnerships in new areas, and begin to exploit the promising materials identified in the first phase, this time with the direct participation of the farmers. Recommendations made during the mid-term project meetings of Phase I were incorporated into the

---

[9] Adapted from the final project report for Phase I (Eskes and Efron 2006).
[10] Adapted from the final report for Phase II (Eskes 2011a).

proposal for Phase II, which aimed to build on the achievements of Phase I, including the distribution and validation of the most promising selections in farmers' fields. Following a comparison between the expected outputs and the main results detailed in the final report of Phase II, the majority of the expected outputs were achieved.

Detailed results of Phase II are described in the final report and were presented during the closing workshop of the project. A table summarizing the achievements of Phase II, as compared to the five-year work plan, and a list of publications generated as a result of the project, are available in Appendix 7.5. The achievements and benefits listed below are based on the results described in the final report (Eskes 2011b, p.5):

- Reinforcement of existing cacao breeding programmes in eleven countries.
- Selection of 55 new candidate varieties for distribution to farmers in Brazil, Ecuador, Nigeria, Papua New Guinea (PNG) and Trinidad and Tobago.
- Selection of numerous varieties to be used in further breeding (all cocoa-producing countries).
- Adoption of a farmer participatory approach in cacao breeding by incorporating farmers' knowledge of their planting materials in the selection of interesting trees and establishment of on-farm trial plots.
- Establishment of two Regional Variety Trials aimed at sharing varieties with disease resistance: one in the Americas (Brazil, Venezuela, Peru, Costa Rica, and Trinidad and Tobago); and another in Africa (Ghana, Côte d'Ivoire, Cameroon, and Nigeria).
- Evaluation of stability of cacao traits through the International Clone Trial, using similar evaluation methods.
- Enhanced awareness on methods of testing for resistance. Methods of testing for Ppr resistance produced positive results, whereas less consistent results were obtained for methods used for other diseases and pests.
- Pre-breeding for resistance to Ppr pod rot and witches' broom disease carried out using the international cacao collection at CRC/UWI, Trinidad.
- Initiation of distribution of germplasm (from the so-called CFC Collection) through the ICQC,R to user countries, especially African countries.
- Sensory profiling of liquors and independent organoleptic evaluations conducted by industry partners on chocolates made using beans from the Local Clone Trial and the International Clone Trial
- Unprecedented cooperation achieved among research institutions in the cocoa-producing countries, regional and international institutions, and the private sector.
- Reinforcement of ongoing breeding programmes, with positive impacts on cacao breeding programmes.
- Identification of 1,500 promising trees using a farmer participatory approach.
- Safe distribution of 100 selected genotypes to participating countries.
- Capacity building through the organization of four regional workshops, and exchange of results (publications, project reports).
- Use of data generated in the project in studies for three PhD degrees in Africa, and several MSc and undergraduate degrees elsewhere.
- Initiation of new projects in cacao breeding and other cacao research areas by several institutes, as a spin-off of the project.

3.3 Additional achievements/impacts of the project

Aside from those detailed in the two project reports (Eskes and Efron 2006; Eskes 2011a), the following additional project impacts, which include those listed in survey responses, have been identified:

Oversight

Essential, complementary co-financing arrangements were made through collaboration between public organizations and the private sector, i.e. chocolate manufacturers' associations. ICCO played a key role in guaranteeing access to funds; CFC and counterpart financing was mainly devoted to the improved utilization of cacao germplasm; while the private sector directed its co-financing contributions largely towards conservation, characterization and evaluation efforts.

CFC was actively engaged in the mid-term evaluation of the project, through participation in the regional technical meetings and visits of the CFC project officer to several project sites. The project officer also actively participated in project steering committee meetings organized by Bioversity to discuss aspects of project implementation together with ICCO and co-financing institutions. Bertus Eskes coordinated all of these activities; his knowledge as an experienced breeder was essential for the effective and successful coordination of the project.

Engagement and collaboration within and between institutes

Effective collaboration within institutes, between breeders, pathologists, entomologists and agronomists, fostered a multidisciplinary approach towards achieving the common goals set by the project. Partner institutes put to the test their capacity to fulfil their respective roles in coordinating trials, organizing activities, providing scientific input and capacity building, and distributing genetic material. The project also achieved a significant level of collaboration in the exchange of resources (data, genetic material, knowledge and experiences). Collaboration between CATIE-Costa Rica, CRC/UWI-Trinidad, and ICQC,R, facilitated not only the exchange of genetic material, but also the establishment of a CFC/ICCO/Bioversity collection, which is still held at the ICQC,R. The collaboration between those institutes and research institutes of cocoa-producing countries, provided operational links for more efficient conservation, evaluation, distribution and use of cacao germplasm.

Establishment or strengthening of formal and informal networks

The project led to the creation or enhancement of formal and informal networks at international and regional level, some of which are still ongoing, such as the International Group for Genetic Improvement of Cocoa (INGENIC) of the INCOCOA groups, the African Cocoa Breeders Working Group, the Asia-Pacific Cocoa Breeders Working Group, the South American Cocoa Breeders Working Group, and (indirectly) CacaoNet – an informal network of those interested in cacao genetic resources evaluation and use. Additionally, results of the Bioversity/CacaoNet/INGENIC survey conducted in 2017, indicated that the project is considered by most participating institutes to have strengthened national networks and their collaboration with government agencies, the private sector and producers (see Appendix 7.4a). Most institutes that responded to the 2017 survey listed several institutes with which they had started collaborating as a result of their participation in the project (see Appendix 7.4b).

Creation of an international cacao breeding community

One of the greatest benefits of the project for all the participating institutions was the exchange of information between scientists, breeders and institutions through meetings, workshops and reports.

These exchanges, motivated by the common goal of developing varieties that could sustain production given the prevalent threats, led to the creation of a global cacao breeding community. This allowed institutions that had a greater level of resources and research to train scientists from other participating institutions. Such exchanges raised the profile of many of the participating institutions, bringing their work to the attention of external collaborators and allowing for new partnerships to be formed.

Broadening of genetic diversity within countries

The enhancement and widening of the genetic base of cacao germplasm was observed at each of the participating institutions, as a result of their engagement with the project. The exchange of specifically selected plant material transferred to and from the ICQC,R allowed for diversification and expansion of the genetic base available for future breeding. Furthermore, it enhanced awareness on the germplasm available, thereby increasing interest in and demand for material from the ICQC,R. The germplasm introduced and the crosses generated, eventually led to commercial cultivars being released by CCI-PNG, CRC/UWI-Trinidad, CRIN-Nigeria, and INIAP-Ecuador. A researcher from CCI-PNG shared the following particular story that highlights the impacts of the CFC/ICCO/Bioversity trials:

'After the CPB [cacao pod borer] incursions in 2006, many farmers lost hope in cocoa and were shifting focus to other crops. Some farmers continued with cocoa but with some level of uncertainty. After the release of the ten new clones in 2013, new interest in cocoa resurfaced. Through the support from the CFC/ICCO/Bioversity project, CCI was able release ten new clones to the cocoa industry. The clones were released at a time when the industry was contracting. Interest has since grown and so support has also increased from government, non-government agencies and other important partners both local and international (personal communication, 2017)'.

Documentation

Bioversity International, as project executing agency, prepared all project documents required for the efficient implementation of the project. The project coordinator visited all partners on a yearly basis, which was essential for the exchange of information and to harmonize the work plans and their details among project partners. Official arrangements with the project partners were made through individual memoranda of understanding (MoUs) and annual letters of agreement (LoAs), which included five-year work plans, and annual work plans and budgets. Project coordination activities significantly strengthened human capacity in the various disciplinary areas of cacao breeding and conservation through the exchange of information. Biannual regional workshops were also held, at which protocols and results were discussed and decisions made. This 'coaching' of project partners was made possible because the project coordinator was an experienced cacao breeder who had practical knowledge in the field.

Standardized working procedures

In collaborating at the international and regional levels, participating research institutes successfully implemented standardized trials and procedures, exchanging resources such as information and germplasm globally, despite institutional and legal constraints – mobilizing internal resources, national partnerships and coordinating multidisciplinary teams in the process. Some of the working procedures are still used today, as cited by several of the respondents.

Establishment of an international cacao quality competition

Efforts to characterize flavours of cacao of different origins, and to set up an annual award system for identifying outstanding cocoa samples of diverse origins, were of particular importance. These efforts resulted in the establishment of the Cocoa of Excellence Programme and the International Cocoa Awards in 2008, a global competition coordinated by Bioversity, which recognizes the work of cacao farmers and celebrates the diversity of cocoa flavours around the world.

4 PROJECT TRIALS: IMPACTS AND CURRENT STATUS

In 2017, a survey developed by Bioversity/CacaoNet/INGENIC was sent out to institutes participating in the project, to gather information on the current status of the trials implemented during the CFC/ICCO/Bioversity project. Despite our best efforts, we did not receive any response to the questionnaire from CEPEC-Brazil or CRC/UWI-Trinidad. Information from INIA-Venezuela is also missing. The results are presented below.

4.1 International Clone Trial and Local Clone Trials

The International Clone Trial (ICT) and Local Clone Trials (LCTs) were established between 1999 and 2004 in nine countries: CEPLAC-Brazil, IRAD-Cameroon[11], CNRA-Côte d'Ivoire, INIAP-Ecuador, CRIG-Ghana, CRIN-Nigeria, MCB-Malaysia, CCI-PNG, CRC/UWI-Trinidad, and INIA-Venezuela. The main objectives were to evaluate selected clones as future candidates to be used as clonal planting material for farmers, and also in the development of new improved hybrid varieties, with an emphasis on high yield, resistance to Ppr and CSSV, and minimal susceptibility to insect pests such as capsids. In addition, the ICT facilitated the distribution of interesting new cacao clones, while assessing the genetic stability of economically important traits, under contrasting climatic conditions. Most of the clones were selected from the ICG,T at CRC/UWI, and sent to ICQC,R, from where they were distributed to the different research institutes. For the LCTs, 20-25 of the most interesting local clones were planted for further evaluation.

A range of physiological parameters (e.g. canopy light transmission, canopy shape, leaf size, flowering and flushing intensity) were measured in the ICT, typically over the course of two years at six locations: CEPLAC-Brazil, INIAP-Ecuador, CRC/UWI-Trinidad, INIA-Venezuela, CNRA-Côte d'Ivoire and CRIG-Ghana (Daymond and Hadley 2011). International clones were generally found to be lower yielding than the best local clones (in LCTs), this was due to resilience to local pests and diseases present in local clones, but not in those recently imported (Eskes 2011b).

The flavour attributes of cocoa liquors prepared using cacao samples from CEPLAC-Brazil, CNRA-Côte d'Ivoire, INIAP-Ecuador, CRIG-Ghana, MCB-Malaysia, CCI-PNG, CRC/UWI-Trinidad and INIA-Venezuela, were evaluated over two years for seven main flavour traits to examine individual and combined clonal and environmental effects, and ensure the quality of future selections (Sukha et al. 2011). Evaluation of sensory quality was carried out on the international clones between 2007 and 2009. Cocoa liquors of approximately 200 cacao bean samples were prepared by Guittard Chocolate Co. and distributed to three panel members from CIRAD, CRC/UWI and Guittard/Mars Inc. Analysis of the data generated over the two years revealed environmental effects for cocoa flavour, acidity and astringency, and clone effects for floral flavour. (Suhkha et al. 2011, p.4).

Impact of the ICT

The ICT had a significant impact on all the participating institutions. The greatest impact was the addition of new plant materials, expanding the genetic base of many locations, some of which had a narrow genetic diversity. As a result of the addition of this new genetically diverse material, selections that meet the institutes' requirements have been made. Most of the institutes indicated that the selection of improved plant materials for future breeding projects was carried out from the ICT. Criteria for selection focused on resistance to pests and disease, vigour, growth habit and bean

---

[11] IRAD-Cameroon initially participated in the ICT trial but due to low budding success, ICT clones could only be established as an LCT.

characteristics, amongst others. At CRIG-Ghana, three ICT clones, namely MAN 15-2, MO 20 and T85/799, produced the highest yields, while at MCB-Malaysia several clones (such as PBC 123) recorded low values in the disease severity index in relation to VSD and black pod (BP), compared to the controls. Observations from Côte d´Ivoire were different, with T79/501, C151-61, MAN 15-2, GU 255-V and PA150 proving to be promising clones for yield, and EET59 and Mocorongo showing low rates of pod rot.

Status of the ICT

The ICT plots established as part of the projects are still in place in six out of the nine participating institutes, mainly with yearly maintenance. The number of clones still present in the plots varies significantly depending on the organization, as several of the ICT clones did not have resistance to local pathogens and diseases and thus succumbed to pathogenic attacks. This was the case in CEPLAC-Brazil and CCI-PNG. In CCI, although the ICT itself has been terminated, superior clones that adapted to the local conditions were selected from the ICT and were later used in new crossing programmes. For those that have indicated the ICT plots are still available, none have been fingerprinted yet to corroborate authenticity. The focus of the data collected is mostly on disease resistance and yield components. Appendix 7.4c comprises a list of clones still available in individual institutes, while Appendix 7.4d provides a list of clones that are common to several institutes.

4.2 Local Clone Observation Plots

Seven Local Clone Observation Plots (LCOPs), were established, containing mainly clones from the germplasm collection, distributed via the ICQC,R and used as parents in population breeding progeny trials in the different project countries. The participating institutes were CEPLAC-Brazil, IRAD-Cameroon[12], INIAP-Ecuador, CRIG-Ghana, MCB-Malaysia, CRIN-Nigeria and CCI-PNG. The accessions used in the LCOPs belonged to the main genetic groups used in the population breeding trials. A smaller number of clones in the LCOPs comprised single-tree selections made within the best hybrid progenies selected from recently finalized hybrid trials. The LCOPs also aimed at identifying promising new clones within superior hybrid progenies, in farmers' fields or local germplasm collections. Depending on the country, between 50 and 300 other potentially interesting clones were planted in the LCOPs, with one or two replicates only. The main objective was to maintain collections of on-farm and on-station cacao selections under field and lab evaluation, enabling the identification of the more promising clones for the composition of new large-scale evaluation trials, or for the recommendation of planting materials for establishment in small-scale trials.

Impacts of LCOPs

The LCOPs were of value to several of the institutes, particularly INIAP-Ecuador, MCB-Malaysia, CRIN-Nigeria and CCI-PNG, where improved plant material was selected for future efforts in disease tolerance breeding developments. However, the sharing of these selections was not foreseen; only MCB-Malaysia and CRIN-Nigeria stated that they shared this improved material. Although most institutes indicated that the trial had an impact on farmers, none specified that farmers were able to access these improved varieties, stating instead that important information was generated to create future varieties.

Status of LCOPs

The LCOPs are still in place and data are being actively recorded in the majority of the locations where they were established (INIAP-Ecuador, CCI-PNG, MCB-Malaysia, and CRIN-Nigeria). Of those that are still active, data are available on yield and yield components, plant vigour, growth habit, pod and bean characteristics (sensorial), and on the rate of incidence of BP, VSD and other

[12] The ICT of IRAD-Cameroon had to be transformed into an LCOP due to the susceptibility of the international clones to local diseases.

diseases. Due to disease infection, the plots had to be removed in CRIG-Ghana, while only a few of the original 374 trees are still present in CCI-PNG. Only CRIN-Nigeria has fingerprinted the plant material to corroborate authenticity of the local clones (see Appendix 7.4e).

4.3 Hybrid trials

Hybrid trials (HTs) were established to select improved hybrid varieties and to increase knowledge of trait inheritance by comparing the performance of parental clones with progenies in IRAD-Cameroon, CNRA-Côte d'Ivoire, INIAP-Ecuador, CRIN-Nigeria, INIA-Venezuela and CCI-PNG. Approximately 40 hybrid progenies were to be produced in each of the six participating countries by making crosses between locally selected superior clones, almost all of which were also part of the LCT. These crosses and subsequent observations would permit the 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. Data were collected on early vigour, yield and disease resistance. In the end, between 24 and 92 new hybrid progenies were produced in the different participating countries: IRAD-Cameroon, INIAP-Ecuador, CRIN-Nigeria, CCI-PNG and INIA-Venezuela. The dry period of December 2001 to March 2002 was quite severe in some places in Africa, resulting in one hybrid trial lost in CRIN-Nigeria and another trial lost in the Bechem area of CRIG-Ghana.

Impacts of HTs

All participating institutions indicated they had selected improved material for further breeding efforts. Most of them concentrated on disease pressure, and yield data. The HTs were most successful at INIAP, where two commercial, highly productive, fine flavour and aromatic clones were released for the central regions of Ecuador. Selection of these clones was mostly based on disease resistance, yield and productivity indexes, and sensorial evaluations. Nonetheless, only CRIN-Nigeria shared its improved selected material with others, both at the national and regional levels.

It is important to also note that INIAP-Ecuador had additional governmental funding that allowed them to continue the trials even after the completion of the CFC/ICCO/Bioversity project. The additional funding made it possible for them to continue evaluating the planting material and release the newly produced commercial cultivars in 2016, six years after the completion of the project. Other participants indicated that due to funding scarcity, they were not able to continue with evaluation and subsequent selections.

Status of HTs

Many of the HT plots are still available in one way or another, although none reported to have fingerprinted the material to corroborate their authenticity. At CCI-PNG, disease pressure eradicated much of the planting material. The level of management varied from country to country: CRIN-Nigeria has not collected any data from the plots but indicated that a high level of maintenance is provided. INIAP-Ecuador has recently completed data collection, while IRAD-Cameroon and Côte d´Ivoire continue to collect yield data (see Appendix 7.4e).

4.4 Population Breeding Trials

Population Breeding Trials (PBTs) were established in four major cocoa-producing countries: CEPLAC-Brazil, CNRA-Côte d'Ivoire, CRIG-Ghana, and MCB-Malaysia, with the aim of long-term improvement of economically important traits. The available knowledge on local germplasm was to be used to identify base populations for initiation of recurrent selection procedures.

Impacts of PBTs

Improved material was only selected at MCB-Malaysia, where the trials are still ongoing and data are being collected for the long-term evaluation of traits. Thus far, several planting materials have demonstrated good levels of disease tolerance, especially for VSD and BP, as well as good yield potential and acceptable bean quality. New planting materials developed at MCB-Malaysia are: MCBC 12 and MCBC 13. These have been shared with other institutes at national level.

Status of PBTs

The PBTs at CRIG-Ghana were discontinued due to severe disease pressure, specifically CSSV. The trials at CNRA-Côte d'Ivoire and MCB-Malaysia have continued, with the majority of the data collected related to yield, quality (fat content), disease pressure and tree structure. No information was received from CEPLAC-Brazil (see Appendix 7.4e).

4.5 Regional Hybrid Variety Trials

Two Regional Hybrid Variety Trials (RHVTs) were established between 2005 and 2006: one in the Americas (Brazil, Venezuela, Peru, Costa Rica, and Trinidad and Tobago), and another in Africa (Ghana, Côte d'Ivoire, Cameroon, and Nigeria). The objective was to exchange hybrid varieties with good yield potential and with resistance to diseases among the respective countries (Ppr in Africa, and frosty pod and witches' broom in the Americas). The theory behind the RHVTs is that countries in one region are geographically closer to each other, and thus face similar limiting constraints, such as pest and diseases, so they could therefore work together towards finding and sharing solutions.

Impacts of RHVTs

In Costa Rica, the RHVT facilitated the selection of cultivars with resistance to monilia (infection rate of 10-50 % observed); two hybrids in particular had a very low rate of infection. This selected material was not shared with others, but has been continually evaluated for further selection and future distribution (Wilbert Phillips, personal communication, 2017).

Crosses made at CNRA-Côte d'Ivoire resulted in clones with superior yield and quality traits, whereas in CRIG-Ghana and Cameroon crosses were made aimed at achieving resistance to black pod disease, and promising materials were generated. IRAD-Cameroon reported to have made their best parental lines available for farmers in farmer seed gardens. Researchers at CRIN-Nigeria indicated that they had produced CSSV-tolerant and high yielding selections, and that they had subsequently shared the improved materials at both regional and national levels.

Status of RHVTs

Most of the RHVT plots established during the CFC/ICCO/Bioversity project are still in place in IRAD-Cameroon, CRIN-Nigeria, CNRA-Côte d'Ivoire and CATIE-Costa Rica, but only researchers at IRAD-Cameroon still collect data and have fingerprinted some of the material. In Ghana, the trial did not establish well and was thus terminated, but some potentially resistant progenies still remain and are being evaluated for yield and resistance to CSSV (see Appendix 7.4e).

4.6 Participatory Trials

As Phase II continued and intensified the on-station selection activities that had been established during Phase I, it adopted a participatory approach. This approach included a farm survey and the direct involvement of farmers in selecting outstanding trees on their farms to be used in participatory trials (PTs) – on-farm and on-station farm selection observation plots.

In Phase I, approximately 2,000 farms were surveyed in ten different countries. The farmers' knowledge of their planting materials was documented, and the results were presented at international meetings on cocoa (e.g. INGENIC workshop in 2006). As planned, approximately 2,000 trees were identified as having interesting traits for yield or for low incidence of pests and disease. Early screening for Ppr resistance carried out in African countries and in Trinidad showed that several of the farmers' selections were highly resistant to the disease. This was consistent with farmers' knowledge of trees that were identified as less susceptible in farmers' fields (Efombagn et al. 2008; Pokou et al. 2008).

Approximately 1,500 selections from farmers' fields were established in on-station observation plots or on-farm trial plots in eight countries. Some of the selections from farmers' fields appeared to be as good as or better than the local control varieties. Through a co-financing agreement involving the International Institute of Tropical Agriculture (IITA), the genetic diversity of approximately 2,000 varieties sampled in farmers' fields in Africa were analysed using simple sequence repeat (SSR) markers. The results showed a large genetic variation in the on-farm population selected from farmers' fields, which was mainly of hybrid origin, with important contributions of the Amelonado, Trinitario and Upper Amazon parental genomes (Eskes 2011b, p.3).

Many of the PT trials suffered from drought in Africa, and from neglect by some of the farmers. Consequently, the total number of plots that were still actively being observed when the project ended had therefore reduced to between 120 and 150 plots – the exact number was difficult to identify due to lack of corroborating information.

Impacts of PTs

Impact on institutions

Through the surveys of farms, research institutions gained insights into farmers' knowledge, practices, and selection criteria utilized for selecting improved cacao varieties. The surveys informed institutions on the status of the material planted in farmers' fields, allowing them to measure the impact of their breeding efforts, based on the popularity of the improved varieties among farmers. Interesting material was found in farmers' fields, some of which outperformed improved varieties from research institutes. In at least four countries – Ecuador, Malaysia, Nigeria and Papua New Guinea – improved materials were eventually selected from the participatory trials. In CCI-PNG, INIAP-Ecuador and MCB-Malaysia, selected materials were subsequently used in institutional breeding projects. MCB-Malaysia, CRIN-Nigeria and CCI-PNG indicated that they shared some of these materials with other institutes at national level; some specific examples are provided here below:

- CCI-PNG selected materials from the PTs based on the following traits: potential yield; production stability; tolerance to vascular-streak dieback, black pod, longicorn (*Glenea aluensis*), and cocoa pod borer; and vigour and bean characteristics.
- INIAP-Ecuador selected materials from the PTs based on the following traits: pod size, healthy pod number, fresh and dry bean weight, pod and bean index, disease incidence, sensorial characteristics and auto-compatibility.
- MCB-Malaysia selected materials from the PTs based on the following traits: yield, pod and bean quality, and disease resistance.

Impact on farmers

Direct benefits to farmers included technology transfer, training and sharing of new propagation methods, as well as the transfer of and/or increased access to new and improved genetic materials. Participatory activities, such as the selection of farmers' accessions, on-farm trials, field days and meetings, strengthened collaboration between researchers, extension officers and farmers, as well as between the farmers themselves. Some institutes reported that the farmers were enthusiastic about the trials and the prospect of participating in the development of improved varieties. In some cases, farmers involved in the trials showed increased interest in the research process, and willingness to participate in further participatory activities; some specific examples are provided here below:

- At CCI-PNG, ten new clones were selected in 2013 from the on-farm trials and released to the cocoa industry. The clones are being taken up by many farmers and demand is very high. They have also been included in the various roll-out programmes sponsored by government and non-government agencies. Five new hybrids were selected from farmers' field trials and are in the process of being evaluated to see whether they can be used to replace the more susceptible commercial varieties currently available. The inclusion of the five new hybrids broadens the genetic base for the commercial hybrids available to farmers.
- At INIAP-Ecuador, a farmer's collection field was established with superior selections to be used in future breeding trials.
- MCB-Malaysia reported that farmers had access to planting material with improved yield, bean quality and disease tolerance.

Status of PTs

In all but three countries (CRIG-Ghana, CCI-Papua New Guinea and UNAS-Peru), at least parts of the trials are still in place, mostly with yearly maintenance. Of those trials with plant material still available – IRAD-Cameroon, CNRA-Côte d´Ivoire, INIAP-Ecuador, MCB-Malaysia, CRIN-Nigeria and CCI-Papua New Guinea (partially available) – only the materials at MCB-Malaysia have been fingerprinted. Most of the current data collected relate to productivity and disease infection. Several survey respondents stated that some of the data still being recorded today may be used in screening for tolerance to drought or high temperature in several countries, e.g. MCB-Malaysia and IRAD-Cameroon (see Appendix 7.4e).

4.7 Conclusion on the status of all field trials

Out of all the trials established in the different participating countries, the majority of trial plots are still in place seventeen years after their inception. Although the collection of experimental data from some of the plots may have ceased, much of the planting material is still alive, and some of the progeny from initial trials are still under investigation (see Appendix 7.4e). This reflects the value that the project had and continues to have in many of the participating institutes. The survey results revealed that much of the plant material that was distributed as part the project is still available for future trials. The materials that are still available and of use vary depending on location; see Appendix 7.4c for details.

5 SUGGESTIONS, KEY RECOMMENDATIONS AND LESSONS LEARNED

The overall collaborative structure of the project and design of the trials resulted in numerous achievements, and in the identification of areas for improvement in specific trials.

5.1 Suggestions for future collaboration

At the closing project workshop in 2009, additional ideas were presented, including the need to provide long-term support for international collaborative breeding approaches, and to continue pre-breeding programmes for distributing and establishing resistant materials.

During the workshop, suggestions were made in favour of continuing the following collaborative activities[13]:

- Support for on-farm variety trials to overcome drought problems and neglect by farmers.
- Further evaluation of the Regional Variety Trials, including quantitative trait loci (QTL) studies on two progenies distributed for this purpose in the Americas and in Africa, as these were not completed.
- Establishment and/or reinforcement of regional selection and breeding activities in all regions.
- Continuation of the International Clone Trials.
- Further evaluation of material for quality and flavour.
- Continuation of pre-breeding and breeding activities using selected germplasm accessions in the international collections at CATIE-Costa Rica, and CRC/UWI-Trinidad.
- Further distribution of selected germplasm (through intermediate quarantine).
- Ongoing characterization, evaluation, documentation and information sharing among partners, to maximize the value of the improved germplasm.

Suggestions were also made to initiate collaborative activities in new areas, such as[14]:

- Improve access to well-trained breeders in order to address major ongoing challenges.
- Create and support a regional cacao breeders' working group and breeding programme in the Americas (this group was created in 2014).
- Reinforce the regional breeding activities in Africa and Asia.
- Forge/strengthen links with the Global Network on Cacao Genetic Resources Conservation and Use (CacaoNet) as a framework for continued collaboration.
- Provide/solicit support for the international collections at CATIE-Costa Rica and CRC/UWI-Trinidad as part of the global genetic resources conservation and use strategy.
- Establish the adaptability of elite selections/improved varieties under varying environmental conditions through collaborative research.
- Generate genetic profiles of the improved varieties to facilitate future identification and utilization.
- Select and breed for quality aspects; evaluate the feasibility of early testing for quality and flavour.
- Conduct studies on the optimal management of selected varieties; for example, on the level of pruning required to optimize disease control and bearing potential, and on the use of suitable nutrient management and integrated pest management (IPM) practices, etc.

[13] Suggestions made by A.B. Eskes in a presentation at the final project workshop 'Developments in cocoa genetics and breeding', 22-24 November, Nusa Dua, Bali (Eskes 2009).
[14] Suggestions made by S. Weise in a presentation at the final project workshop in Bali (Weise 2009).

- Assess the potential impact of climate change on the performance of the elite types. This will require future research on factors such as physiological traits that would foster tolerance to drought and adaptation to high irradiance, for example.

5.2 Lessons learned and key recommendations

Key lessons learned from Phases I and II of the project, based on the results of the 2016 and 2017 surveys, are detailed below.

Scope

While the project fostered a shared perception of belonging to a global cacao community for participating organizations, some non-participating organizations felt excluded. Future initiatives that take a global approach, such as that of the CFC/ICCO/Bioversity project, will not be able to involve every organization, and those organizations that are not included may feel at a disadvantage in terms of research and of belonging to a cacao community.

The issue of inclusiveness versus efficiency was raised by many participants. Some felt that the project was ‘over-inclusive’, pointing out the adverse effects of including too many participants with limited capacity to efficiently cooperate – e.g. to implement certain standardized procedures, ensure the quality of their results, or exchange germplasm. Other participants were in favour of more inclusive, overarching aims. Some participants also indicated the convenience of collaborating at a regional level, since institutions in the same region share more common goals and issues – e.g. pests and diseases pressures. New international collaborations should first decide on what scope they want to target, and then identify common ground where both visions are complementary to the main goal of the project.

Trial design

The design of future field evaluations is where the foundation of success lies: this has and always will be critical to success. To ensure well-structured and sustainable field trials, full agreement is required on the scientific experimental design, location, partners, and duration of the trials. Based on the lessons learned in the project, the following key areas for improvement in trial design have been identified, and should be considered in the planning phase of future trials:

Experimental layout

Decisions on the layout and experimental design of the trial should be made with the full understanding of cacao physiology and behaviour, so that issues like competition with border trees do not have an impact on the reliability of the data recorded. For the ICT, there were strong concerns about field spacing and distribution. Border trees outgrew the experimental trees, causing significant competition between them. As a result of this observed competition, which favoured overly vigorous clones over less vigorous but potentially more yield-efficient clones, physiological studies were limited in their scope. Future trials must implement experimental designs that have been thoroughly evaluated, and whose limitations are anticipated and understood by all involved. Data on climatic conditions and soil characteristics, and on the local management practices used in the trial, should be incorporated into the data evaluation process in order to facilitate the best interpretation of the results, and reduce the level of ‘experimental noise’ as much as possible. Although a meeting was set up to discuss experimental design at an early stage in the project, according to the survey responses not everyone was convinced by the design. In future, all experimental designs in such international collaborative projects should be discussed and agreed upon by all participating partners.

Farmer participation

Use of farmer participatory approaches is recommended, with clear guidelines for farmers' consideration, including the different markets for the beans, diversity present in famers' fields, and the involvement of extension workers. After exploring ways of motivating farmers and involving the extension service at an early stage, future trials must select farmers that have a real enduring interest in participating in such trials.

Duration and funding

There should be full agreement on the funding required to cover the duration of a trial, which ensures that the data gathered are representative of cacao physiology and can provide conclusive results on the traits in question. Some participants mentioned the short duration of trials as an impediment for more conclusive results.

Given the lengthy period required for establishment of perennial crops, trial duration is always an issue in breeding programmes. While many donors, including on occasions CFC, have specific administrative limits on the duration of any funded project, these factors need to be part of the guiding principles determining project length and funding allocation. Such constraints can generate conflict in the consideration of funding for tree crops breeding projects.

The planned duration for some of the CFC/ICCO/Bioversity trials, such as the PBT, seemed to be sufficient. Yet, for trials such as the ICT and RHVT, the designated trial period was insufficient to generate conclusive data representative of cacao behaviour, as data collection ceased just when many of the trees were starting to bear. Some institutes were able to continue with the trials, generating valuable data after the official end of the projects, because they had other sources of funding. Perhaps a way of dealing with this limitation could be to make it a necessity for participating organizations to 'institutionalize' the trials, i.e. include the trials in their main breeding programmes, and thus to continue the trials beyond the period covered by the initial funding, rather than regarding them as 'project based'. This will ensure that sufficient data are collected that are representative and conclusive of the traits in question. Mechanisms are needed to ensure that future trials continue to be maintained and evaluated with ongoing coordination to maximize the outputs.

Initial setup period

For several of the scientists managing the trials in these projects, this was the first time that they were responsible for leading a breeding or selection trial. All these trials had an initial setup period, which transpired to be a sharp learning curve for several of the trial leaders; in some cases, the leaders required more time, thus reducing the effective data collection period in some locations. When discussing the funding and duration of trials in future projects, time needed for the initial setup must be included.

Changes in personnel

Some institutes changed the personnel in charge of the trials several times over the course of the trial, and the time needed to adjust negatively impacted the success of the trial. These changes delayed the planting and establishment of some trials, and on occasions jeopardized the implementation of the agreed protocols. Consistency in personnel is key for effective trial data management and collection.

Material selection and exchange

Selection of plant materials for international collaboration

Plant material selected to be part of the trials should have some level of resistance to local pathogens, as well as potential for high yield and good quality. The ICT depended mainly on primary germplasm available at ICQC,R. In relation to much of the germplasm that was sent, there was a lack of detailed knowledge on agronomic or disease resistance traits. This was one of the main reasons why most ICT clones yielded considerably less than the LCT clones in several of the countries evaluated. The RHVTs were a better success, as the countries accepted to share hybrid seed of well-known interesting clones with some level of tolerance to shared pests and diseases (Bertus Eskes, personal communication, 2017).

Plant density and the effect of border trees

Another issue was the observed effect of border rows on experimental trees. In order to avoid inter-plot interactions, plant density is a critical aspect that should be considered when establishing clones of diverse canopy characteristics. Thus, future selections must be based on known physiological and phonological information on all the selected plant materials intended for use as both experimental and border trees.

Exchange of plant genetic material

Material exchange in the project occurred without difficulty thanks to the participation and availability of two international genebanks in the project; however, germplasm exchange can act as a significant bottleneck in global collaboration. Any future initiative should involve an assessment of the import and export limitations of each of the possible country partners. Understanding the likely restrictions can help in better planning for material transfers, and facilitate appropriate scheduling of activities such as quarantine periods, allowing for a more accurate assessment of the trial duration. These assessments should be conducted as soon as the trial design phase commences.

Although the transfer of plant material can be much more challenging than the transfer of seed, in the project, plant materials were exchanged with relative ease between the ICQC,R and receiving institutions. However, some participants noted that while the material made it into the country, it was sometimes held at customs for long periods, resulting in the death of the plant or loss of material. In CCI-PNG, the main problem experienced was the internal quarantine process, which did not allow them to access the clones until after a period of six to twelve months; some clones were lost as a result. Similarly, UNAS-Peru was able to receive material from CRC/UWI-Trinidad, CEPLAC-Brazil and CATIE-Costa Rica, but not from INIAP-Ecuador or INIA-Venezuela due to customs limitations at the border. Researchers at IRAD-Cameroon reported that import permits were difficult to obtain for importing germplasm from the ICQC,R. Country import/export limitations must be evaluated before finalizing a list of participating countries. Exchange should be facilitated through material transfer agreements (MTAs), such as the Standard Material Transfer Agreement (SMTA) of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) used by Bioversity, ICQC,R and the project. Such agreements involve governments, set out conditions for benefit sharing, and specify legal constraints for exchange.

Fingerprinting trial progeny prior to planting

One of the greatest concerns reported was the lack of molecular fingerprinting of the clones before establishment, which created a level of uncertainty concerning the data they were collecting. As part of the CFC project, a field identification guide of the ICT materials was produced, complete with photos and morphological data, so that participants could visually check their materials and prioritize any apparent off-types for genetic fingerprinting/removal. During the trials, several institutes voiced concerns that a number of the cacao trees visibly differed in physical traits such as pod colour and shape, to those that were expected based on the field guide (Tony Lass, personal communication, 2017). As a result, some institutes did not feel confident they were comparing like with like, and no financial resources were available to carry out fingerprinting of all the materials exchanged. As such, one of the most important and fundamental requirements for future trial layouts should be that individual trees must be fingerprinted prior to field establishment, and funding should be made available for such validations.

Methods, protocols and working procedures

Working procedures were reported as generally useful in outlining the processes by which each set of data should have been collected and subsequently analysed, which is particularly important when individuals have different technical skills and experience and are managing trials in a variety of locations.

Management practices for reducing errors in propagation

Effective multiplication of varieties is just as important as fingerprinting to ensure reproducibility and accurate identification. Some researchers indicated that errors can be created during propagation and multiplication, and these errors can lead to major issues once the trees are established and off-types have been observed. Thus, there is a need for very tight nursery management to ensure the material is correctly labelled throughout the entire process before going to the field, with the possibility of genetically fingerprinting the trees actually planted.

Checks and balances

Despite the engagement of the project coordinator in the day-to-day operation of the project, and the establishment of experimental norms at the initiation stage of the project, a number of variations were introduced at local level on the ground. Although many institutes indicated that they used and implemented the agreed protocols, several institutes said that they did not use all of them, and others stated that they modified some of the procedures, or had to implement their own approaches due to lack of resources. Some of these changes were necessary, but others were just short-cuts that compromised the comparability of the data collected.

The physiological data collected from the ICT varied significantly according to location, despite the protocol stating specific requirements for data collection. As can be observed in data presented in the final project report, in some cases, one institute would record data on a particular trait 13 times during the experimental window, while another would record data on the same trait just once (Daymond and Hadley 2011). Not only does this pose a risk to the overall scientific quality of the results, it may also create mistrust, impacting on collective action and problem solving. It is also worth mentioning that some institutes may have used data collection methods and analyses from previous years/trials to compare the data with their own results from previous or ongoing work. Simple issues, such as the lack of specific equipment, impeded full homogeneity within the implementation of working procedures. One institute cited not being able to complete the established protocol owing to the lack of appropriate refrigeration at the institute. Notwithstanding these issues, the procedures were generally useful for outlining the methods by which each set of data should have been collected and subsequently analysed - with many still being used today.

In any future international collaborative project, the establishment of protocols should as far as possible take into account the technical or administrative limitations faced by the participating institutes. Those that agree to participate need to be fully aware of their own restrictions and impediments, and those who cannot fully implement the agreed protocols should be excluded from this type of trial. A checks and balances system must be incorporated to rapidly evaluate whether participating institutes are implementing the agreed upon protocols, and assess limitations early on as a way to secure data integrity and comparability. In addition, it is the responsibility of the coordinators to attend any related meetings; if others must attend in their place, they must brief the coordinators afterwards. Technological advances such as video conferences and smartphone communication apps will facilitate such interventions.

Cacao ontology

Definitions for terms such as cumulative, annual, potential and actual yield should be identified consistently and correctly to be able to compare data between sites. The most effective way to do this would be to implement a validated ontology for cacao, thus ensuring the eventual scientific quality of the work achieved, but also maintaining and fostering trust between participants by avoiding classic collective action problems.

Coordination, collaboration and communication

Given the level of collaboration in cacao breeding prior to 1998, the project set an ambitious goal in the development of a global collaborative initiative, challenging the ability of the participating institutions to overcome the constraints posed by such an endeavour. The complexity of the project's structure and the differences in capacity, legal and administrative constraints between participating institutions led to complications that, in some cases, undermined the efficiency of the collaboration.

Many participants pointed out shortcomings concerning coordination and collaboration. Some expressed a general feeling that coordination remained complex or too centralized, and that collaboration was generally limited or lacking. Reported issues and constraints were quite diverse, some were very specific[15], linked to technical and administrative issues that impeded collaboration, while others questioned essential aspects of the design of the collaborative framework. Specific examples of participants' comments in relation to the perceived shortcomings of the project can be found in Appendix 7.2b. Although the project faced considerable constraints that were not always overcome, the emergence of informal and formal networks that are still active today shows the long-lasting impact of the project on collaboration.

Reflecting on these issues and understanding what worked and what did not is crucial to the development of future collaborative initiatives. Ensuring efficient coordination and collaboration within the framework of a global initiative involved many challenges, such as the lack of implementation of working procedures, or a failure to share the best materials. Such challenges could be resolved by increasing communication between participating institutes, and through more effective project coordination. Many years have passed since the project was finalized, and new ways of communication are now available. These new technologies should be exploited to facilitate enhanced coordination and collaboration, and support the sharing of knowledge and information between all partners. However, this will still not guarantee that partners will be willing to share the information; that is another issue that must first be addressed. Nevertheless, a generous budget should be earmarked for the coordination of activities (including expenses related to travel and project workshops, and to the establishment of a communication platform). As in the CFC/ICCO/Bioversity project, the coordinator of a future collaborative initiative must have the right skill set, motivation, qualifications and allocation of adequate time for this very important and time-consuming role. Ineffective coordination may well lead to comparably poor results.

Farmer benefits

Many of the institutes indicated that little of the work actually resulted in direct benefits for the farmer, possibly owing to the limited duration of the trials. The institutes that indicated direct farmer benefits – INIAP-Ecuador, CRC/UWI-Trinidad, CRIN-Nigeria and CCI-PNG – noted that these benefits were mainly obtained through the release of commercial cultivars years after the project had ended. Future projects must take extra steps to establish clear, defined and attainable goals that result in significant farmer benefits. Thus, funding must be secured for an adequate duration that can result in the release of superior cultivars, or projects must be institutionalized for continued evaluation.

[15] For instance, for CCI-PNG, the main constraints on collaboration were problems with communicating by email, as well as the limited budget available for costly air travel to the several cacao-growing island provinces of Papua New Guinea.

5.3 Conclusion

A new collaborative initiative on cacao is urgently needed to address the serious challenges that are currently affecting cocoa production. Important lessons were learned from the evaluation of the CFC/ICCO/Bioversity project on cacao, which will be essential for the success of future collaborative projects, whether they are at regional or international level. The key to success is to consolidate efforts, resources, and intelligence, in order to explore and evaluate the whole gamut of cacao genetic resources available. It is hoped that the main recommendations and conclusions presented in this review will be able to guide future efforts for more effective cacao research initiatives that help advance our understanding of cacao, and lead to the development of more resilient cacao cultivars.

6 REFERENCES

Bioversity International. 2010. 'CFC/ICCO/Bioversity project on cocoa productivity and quality improvement: a participatory approach', *Final completion report. 1 June 2004 – 30 November 2009. July 2010*. Compiled by Bioversity International. Project funded by the Common Fund for Commodities (CFC).

Common Fund for Commodities. 2004. 'Cocoa productivity and quality improvement: a participatory approach', *Project agreement between the International Cocoa Organization, the International Plant Genetic Resources Institute and the Common Fund for Commodities*. (Bioversity International, internal document).

Daymond, A. and Hadley, P. 2011. 'Analysis of physiological data from the international clone trial (ICT) at the University of Reading', in Eskes, A.B. (ed.) *Collaborative and participatory approaches to cocoa variety improvement. Final report of the CFC/ICCO/Bioversity project on 'Cocoa productivity and quality improvement: a participatory approach' (2004-2010)*. Amsterdam: CFC, London: ICCO, Rome: Bioversity International. pp.142-149. Available at https://www.bioversityinternational.org/e-library/publications/detail/collaborative-and-participatory-approaches-to-cocoa-variety-improvement/ (accessed 24 September 2017).

Efombagn, M.I.B., Motamayor, J.C., Sounigo, O., Eskes, A.B., Nyasse, S., Cilas, C., Schnell, R., Manzanares-Dauleux, M.J. and Kolesnikova-Allen, M. 2008. 'Genetic diversity and structure of farm and genebank accessions of cacao (*Theobroma cacao* L.) in Cameroon revealed by microsatellite markers', *Tree Genetics and Genomes,* 4(4): 821-831.

End, M.J., Daymond, A.J. and Hadley, P. (eds.). 2014. *Technical guidelines for the safe movement of cacao germplasm*. Revised from the FAO/IPGRI Technical Guidelines No. 20 (Second Update, August 2014). Global Cacao Genetic Resources Network (CacaoNet), Bioversity International, Montpellier, France. Available at https://www.bioversityinternational.org/e-library/publications/detail/technical-guidelines-for-the-safe-movement-of-cacao-germplasm/ (accessed 24 September 2017).

Eskes A.B. (ed.). 2011a. *Collaborative and participatory approaches to cocoa variety improvement. Final report of the CFC/ICCO/Bioversity project on 'Cocoa productivity and quality improvement: a participatory approach'* (2004-2010). Amsterdam: CFC; London: ICCO; Rome: Bioversity International. Available at https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Collaborative_and_participatory_approaches_to_cocoa_variety_improvement_1444.pdf (accessed 24 September 2017).

Eskes, A.B. 2011b. 'Summary of project results and benefits', in Eskes, A.B. (ed.) *Collaborative and participatory approaches to cocoa variety improvement. Final report of the CFC/ICCO/Bioversity project on 'Cocoa productivity and quality improvement: a participatory approach' (2004-2010).* Amsterdam: CFC, London: ICCO, Rome: Bioversity International. pp.142-149.

Eskes, A.B. 2009. *Results from collaborative and participative approaches to cocoa variety selection and breeding*. [Presentation]. Final project workshop 'Developments in cocoa genetics and breeding', 22-24 November 2009, Nusa Dua, Bali.

Eskes, A.B. 2006. 'Project justification, objectives, structure and expected outputs', in Eskes, A.B. and Efron, Y. (eds.). *Global approaches to cocoa germplasm utilization and conservation. Final report of the CFC/ICCO/IPGRI project on 'Cocoa germplasm utilization and conservation: a global approach' (1998-2004)*. Amsterdam: CFC; UK: ICCO; Rome: IPGRI.

Eskes, A.B. and Efron, Y. (eds.). 2006. *Global approaches to cocoa germplasm utilization and conservation. Final report of the CFC/ICCO/IPGRI project on 'Cocoa germplasm utilization and conservation: a global approach' (1998-2004)*. Amsterdam: CFC; UK: ICCO; Rome: IPGRI. Available at https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Global_approaches_to_cocoa_germplasm_utilization_and_conservation_1172.pdf (accessed 24 September 2017).

Eskes, A.B., Engels, J.M.M. and Lass, R.A. 2000. 'Working procedures for cocoa germplasm evaluation and selection', *Proceedings of the CFC/ICCO/IPGRI project workshop*, 1- 6 February 1998, Montpellier, France. Available at http://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/Working_procedures_for_cocoa_germplasm_evaluation_and_selection_1998.pdf (accessed 24 September 2017).

N'Goran, J.A.K. and Eskes, A.B. 2006. 'Outline of the CFC/ICCO/IPGRI project achievements', in Eskes, A.B. and Efron, Y. (eds.). *Global approaches to cocoa germplasm utilization and conservation. Final report of the CFC/ICCO/IPGRI project on 'Cocoa germplasm utilization and conservation: a global approach' (1998-2004)*. Amsterdam: CFC; UK: ICCO; Rome: IPGRI.

Pokou, N.D., N'Goran, J.A.K., Kebe, I., Eskes, A., Tahi, M. and Sangare, A. 2008. 'Levels of resistance to Phytophthora pod rot in cocoa accessions selected on-farm in Cote d'Ivoire', *Crop Protec*, 27: 302-309.

Sukha, D., Seguine, E., Assemat, S., Butler, D.R., Cilas, C., Ribeyre, F., Seni, G., Cros, E., Davrieux, F. and Eskes, A.B. 2011. 'Comparative organoleptic evaluations of cocoa (*Theobroma cacao* L.) accessions from the international clone trial by three sensory panels over two years', in Eskes, A.B. (ed.) *Collaborative and participatory approaches to cocoa variety improvement. Final report of the CFC/ICCO/Bioversity project on 'Cocoa productivity and quality improvement: a participatory approach' (2004-2010)*. Amsterdam: CFC; London: ICCO; Rome: Bioversity International. pp.128-141.

Weise, S. 2009. *International collaboration in cocoa germplasm utilization, variety selection and breeding: looking beyond the CFC/ICCO/Bioversity projects*. [Presentation]. Final project workshop 'Developments in cocoa genetics and breeding', 22-24 November 2009, Nusa Dua, Bali.

Additional background documents

Anonymous. 2016. *CacaoNet/INGENIC workshop on the development of a collaborative framework for cacao evaluation (CFCE): report,* 3 June 2016, Penn Stater Hotel and Conference Centre, Pennsylvania. CacaoNet, INGENIC, Bioversity International, CGIAR.

Bioversity International. 2010a. 'CFC/ICCO/Bioversity project on cocoa productivity and quality improvement: a participatory approach', *Final individual institute reports, 1 June 2004 - 30 November 2009. Volume 1.* CATIE, Costa Rica; CEPLAC, Brazil; INIA, Venezuela; INIAP, Ecuador; UNAS, Peru; CRC-UWI and MALMR, Trinidad. Compiled by Bioversity International. Project funded by the Common Fund for Commodities (CFC).

Bioversity International. 2010b. 'CFC/ICCO/Bioversity project on cocoa productivity and quality improvement: a participatory approach', *Final individual institute reports, 1 June 2004 - 30 November 2009. Volume 2*: CNRA, Cote d'Ivoire; CRIG, Ghana; CRIN, Nigeria; IRAD, Cameroon; CCI, Papua New Guinea; MCB, Malaysia; CIRAD, France; University of Reading, U.K. Compiled by Bioversity International. Project funded by the Common Fund for Commodities (CFC).

Eskes, A.B., Adu-Ampomah, Y., Aikpokpodion, P.O., Butler, D.R., Amores, F., Daymond, A.J., Efombagn, M.I.B., Engels, J.M.M., Gonzalez, V.V., Iwaro, D., Garcia, L., Gilmour, M., Maharaj, P., Motamayor, J.C., Marfu, J., Monteiro, W.R., N'Guessan, K.F., Paulin, D., Phillips, M. and Seguine, E.S. 2010. 'Results from collaborative and farmer participatory approaches to cocoa variety selection and breeding', in *Proceedings of the 16th International Cocoa Research Conference: towards rational cocoa production and efficient use of a sustainable world cocoa economy*. 16-21 November 2009, Bali.

Eskes, A.B., Efron, Y., End, M.J. and Bekele, F. (eds.). 2009. *Proceedings of the international workshop on cocoa breeding for farmers' needs*. 15 -17 October 2006, San Jose, Costa Rica. UK: INGENIC; Costa Rica: CATIE. Available at http://www.incocoa.org/data/ingenic_workshop_5_proceedings_2006.pdf (accessed 24 September 2017).

Meter, A. 2016. *Network collaboration in science for the global genetic resources commons. A study of the global collaboration in the cacao genetic resources community*. Master's thesis. CIRAD. Available at https://web.supagro.inra.fr/pmb/opac_css/doc_num.php?explnum_id=3171 (accessed 24 September 2017).

7 APPENDICES

7.1 CIRAD/CacaoNet sample survey (2016)

This survey is part of a research conducted by Selim Louafi (CIRAD) on existing collaboration patterns in the Cacao resources community. This study is conducted in the context of the Marie Curie Fellowship project ISCOBRA (Institutional Structures, Constraints and Outcomes of Bio-based Research in Agriculture) that investigates how global rules and regulations for the exchange and use of genetic materials and data are implemented and addressed in global science programs for agricultural development.

An important focus of our study is on the collaboration and exchange relationships that are part of Cacao resources community. The following questions ask you about specific types of interactions with people you collaborate with. The data collected in these questions are critical for understanding collaboration relationships in the cacao GR environment.

This survey is a first step to obtain an overview of current collaboration structure and potential constraints for future collaboration. In this context, the Global Network for Cacao Genetic Resources (CacaoNet) is keen to learn from the success of previous collaboration programmes and relationships to strengthen the development of future initiatives. CacaoNet and CIRAD are therefore pleased to work together in this objective.

<u>The purpose of this survey</u> is to:

- map out the cacao genetic resources community;
- identify collaboration relationships within this community;
- gather views and experiences on past or existing projects;

The survey should take about 20 minutes to complete.

<u>Personal data – Privacy policy:</u> We will process your personal information in accordance with the French Act n°78-17 of January 6th, 1978 on data processing, data files and individual liberties. Under this law, you have the right to access to personal data relating to you (as respondent) and to require personal data to be corrected if inaccurate or to be deleted. If you wish exercising such rights, you should notify Selim Louafi by e-mail to the following address: selim.louafi@cirad.fr.

<u>Your responses are confidential:</u> Before the data are examined and analyzed, your name and all personal identifiers will be removed and replaced with unique numbers to protect your confidentiality.

<u>Your participation is very valuable</u>.

There are 23 questions in this survey

GR use

Definition of genetic resource

For the purpose of this survey, the term "genetic resources" includes all biological materials that contain functional units of heredity (DNA/RNA) used in your area of expertise. Genetic resources include for example trees seeds, pollen, in vitro/cryo plants, cuttings, bud wood, graftings, rootstock, genomic sequences. You may work with only one or a subset of these.

Are you interested in cacao genetic resources for your professional activity?
Please choose **only one** of the following:
○ Yes
○ No

Projects

Could you mention up to 5 cacao genetic resources projects (full title and acronym) in which you are or have been involved recently (in the last three years) and indicate your role in these projects?

	Scale	Your role
1		
2		
3		
4		
5		

Click on [+] to add new project.

Acronym
Please write your answer(s) here:
1
2
3
4
5

Full title name of the project
Please write your answer(s) here:
1
2
3
4
5

Participation to CFC.ICCO/Bioversity initiative

Did you take part in the CFC/ICCO/Bioversity project (1998-2004) on Global Approaches to Cocoa Germplasm Utilization and Conservation and the second phase (2004-2009) on Cocoa Productivity and Quality Improvement: a Participatory Approach?
Please choose **only one** of the following:
○ Yes
○ No

CFC strength

What are according to you the most important achievements of the CFC/ICCO/Bioversity project?
Only answer this question if the following conditions are met:
Answer was 'Yes' at question '5 [participation]' (Did you take part in the CFC/ICCO/Bioversity initiative (1998-2010)?)
Please choose **all** that apply:
☐ Reinforcement/re-initiation of cocoa breeding programmes in selected countries
☐ Selection of new candidate varieties for distribution to farmers
☐ Adoption of a farmers' participatory approach through use of farmers' knowledge in selecting promising trees in farmers' fields, and establishment of on-farm trials
☐ Establishment of Regional Variety Trials in Africa, Asia and in the Americas, aiming at sharing germplasm with disease resistance
☐ Evaluation of stability of selection traits through the International Clone Trial established in eight different countries
☐ Insights gained in resistance testing methodologies

☐ Use of the International Cocoa Collection at the Cocoa Research Centre in Trinidad and Tobago to enhance germplasm for black pod and witches' broom resistance
☐ Initiation of distribution of selected germplasm through the International Cocoa Quarantine Centre at Reading to user countries
☐ Sensory profiling and independent industry organoleptic evaluations of cocoa liquors made with clones of the International Clone Trial
☐ Human capacity building through regular regional and international project workshops and use of project data to obtain university degrees
☐ Cooperation among research institutes in the cocoa-producing countries, regional and international cocoa research institutes as well as the private sector
☐ The creation of an effective informal research network
☐ Increased availability of funding for research on cacao genetic diversity
☐ Increased availability of funding for conservation of cacao genetic diversity

CFC weakness

What were the major shortcomings of the CFC/ICCO/Bioversity project?
Only answer this question if the following conditions are met:
Answer was 'Yes' at question '5 [participation]' (Did you take part in the CFC/ICCO/Bioversity initiative (1998-2010)?)
Please write your answer here:

CFCE benefit

As a follow-up to the CFC/ICCO/Bioversity projects between 1998-2010 that had a global scope, new global collaborative initiatives are being discussed in the context of the Global Network for Cacao Genetic Resources – CacaoNet and other organizations. Do you think that your own activities on cacao GR would benefit from the establishment of such global/interregional initiatives?

Please choose **only one** of the following:
○ Strongly agree
○ Agree
○ Neither agree or disagree
○ Disagree
○ Strongly disagree
Comment

CFCE involvement
If a new collaborative framework for cacao genetic resources is established, how would you like to be involved?
Please choose **only one** of the following:
○ Low involvement: receiving newsletters and joining a mailing-list
○ Medium involvement: participating to yearly meetings
○ High involvement: being an active member of the initiative
Collaborations
Could you mention people you mostly collaborate with (within and outside your own organization) on issues related to Cacao genetic resources in the past two years?
As a reminder, your completion of this survey is completely confidential and the people you identify will not know that you have named them in a survey. Moreover, when we analyze these data, all individual names will be anonymized so that individuals will not be identifiable.

	First name	Last name	Current organization
1			
2			
3			
4			
5			

Frequency
How long have you known the individuals you identified?
Please choose the appropriate response for each item:
- Only answer this question for the items you selected in question collaborators ('Based on your own contacts and experience in current and previous initiatives, who are the persons involved in the conservation and use of cacao genetic resources whose contribution could be valuable for any future global initiative?')
- Only answer this question for the items you did not select in question collaborators ('Based on your own contacts and experience in current and previous initiatives, who are the persons involved in the conservation and use of cacao genetic resources whose contribution could be valuable for any future global initiative?')

	I have never collaborated with this person	< 1 year	1 to 5 years	> 5 years
{collaborators_SQ01_SQ001} {collaborators_SQ01_SQ002}	○	○	○	○
{collaborators_SQ02_SQ001} {collaborators_SQ02_SQ002}	○	○	○	○
{collaborators_SQ03_SQ001} {collaborators_SQ03_SQ002}	○	○	○	○
{collaborators_SQ04_SQ001} {collaborators_SQ04_SQ002}	○	○	○	○
{collaborators_SQ05_SQ001} {collaborators_SQ05_SQ002}	○	○	○	○
{collaborators_SQ06_SQ001} {collaborators_SQ06_SQ002}	○	○	○	○
{collaborators_SQ07_SQ001} {collaborators_SQ07_SQ002}	○	○	○	○
{collaborators_SQ08_SQ001} {collaborators_SQ08_SQ002}	○	○	○	○
{collaborators_SQ09_SQ001} {collaborators_SQ09_SQ002}	○	○	○	○
{collaborators_SQ10_SQ001} {collaborators_SQ10_SQ002}	○	○	○	○
{collaborators_SQ30_SQ001} {collaborators_SQ30_SQ002}	○	○	○	○

Relationship
Could you specify what you exchange with the persons you have listed in the past two years? Check all that apply.
Only answer this question for the items you selected in question collaborators ('Based on your own contacts and experience in current and previous initiatives, who are the persons involved in the conservation and use of cacao genetic resources whose contribution could be valuable for any future global initiative?')
Only answer this question for the items you did not select in question collaborators ('Based on your own contacts and experience in current and previous initiatives, who are the persons involved in the conservation and use of cacao genetic resources whose contribution could be valuable for any future global initiative?')

	Sharing of Germplasm	Sharing of advice, information	Sharing of data, results	Sharing equipment, technologies	Training, mentorship	Access to networks or projects
collaborators_SQ01_SQ001 collaborators_SQ01_SQ002	☐	☐	☐	☐	☐	☐
collaborators_SQ30_SQ001 collaborators_SQ30_SQ002	☐	☐	☐	☐	☐	☐

Other
Please write your answer(s) here:
{collaborators_SQ01_SQ001} {collaborators_SQ01_SQ002}
{collaborators_SQ02_SQ001} {collaborators_SQ02_SQ002}
{collaborators_SQ30_SQ001} {collaborators_SQ30_SQ002}

Other collaborations

Other than the people you mostly collaborate with and named so far, from which other people have you requested or sent Cacao genetic material and/or associated information over the past two years?

	First Name	Last Name	Current organization
1			
2			
30			

About you

Your full name (first name, last name):
Please write your answer(s) here:
First name
Last name
Name of your institution:
Please write your answer here:

Your professional experience in Cacao genetic resources:
Please choose **only one** of the following:
◯ Less than one year
◯ Between one and five years
◯ Between five and ten years
◯ More than ten years

Your current position
Please choose **all** that apply:
☐ Director or senior administrator
☐ Project/Program Manager
☐ Research scientist
☐ Technician
☐ Production/processing engineer
☐ Other (please specify):

What is your highest level of education?
Please choose **only one** of the following:
◯ PhD

○ Master
○ Bachelor
○ Other (please specify)

Please indicate the academic discipline of your highest degree:
Please write your answer here:

In which of the following sectors is your primary current employment?
Please choose **only one** of the following:
○ University or college
○ Research institute
○ Government organization or agency
○ Private industry including trade associations
○ Non-profit (not government or university)
○ Other (please specify)

Which of the following describes the organisation you work for?
Please choose **all** that apply:
☐ Research lab or center
☐ Academic department
☐ Extension office
☐ Farm (includes greenhouse, nursery, field)
☐ Breeding facility
☐ Manufacturing or processing facility
☐ Administrative or management office
☐Other (please specify):

Panel
Thank you for your participation in this survey.

Would you accept to be surveyed/interviewed again in the future (once a year maximum) to share your perception on the evolution of the new collaborative framework for cacao genetic resources?
Please choose **only one** of the following:
○ Yes
○ No

If you have any additional comments, please write them to Sélim Louafi at selim.louafi@cirad.fr
Thank you for participating in this survey!

Submit your survey.
Thank you for completing this survey.

7.2 Results of the CIRAD/CacaoNet survey (2016): main achievements and weaknesses of the CFC/ICCO/Bioversity project

7.2a Main achievements of the CFC/ICCO/Bioversity project

WHAT ARE ACCORDING TO YOU THE MOST IMPORTANT ACHIEVEMENTS OF THE CFC/ICCO/BIOVERSITY PROJECT? PLEASE CHOOSE ALL THAT APPLY: SEE ALL 14 OPTIONS BELOW.	PERCENTAGE OF RESPONDENTS WHO CHOSE THIS OPTION (N=37)
INSIGHTS GAINED IN RESISTANCE TESTING METHODOLOGIES	76%
SENSORY PROFILING AND INDEPENDENT INDUSTRY ORGANOLEPTIC EVALUATIONS OF COCOA LIQUORS MADE WITH CLONES OF THE INTERNATIONAL CLONE TRIAL	76%
INCREASED AVAILABILITY OF FUNDING FOR CONSERVATION OF CACAO GENETIC DIVERSITY	76%
INCREASED AVAILABILITY OF FUNDING FOR RESEARCH ON CACAO GENETIC DIVERSITY	71%
ADOPTION OF A FARMERS' PARTICIPATORY APPROACH THROUGH USE OF FARMERS' KNOWLEDGE IN SELECTING PROMISING TREES IN FARMERS' FIELDS, AND ESTABLISHMENT OF ON-FARM TRIALS	66%
HUMAN CAPACITY BUILDING THROUGH REGULAR REGIONAL AND INTERNATIONAL PROJECT WORKSHOPS AND USE OF PROJECT DATA TO OBTAIN UNIVERSITY DEGREES	66%
SELECTION OF NEW CANDIDATE VARIETIES FOR DISTRIBUTION TO FARMERS	63%
EVALUATION OF STABILITY OF SELECTION TRAITS THROUGH THE INTERNATIONAL CLONE TRIAL ESTABLISHED IN EIGHT DIFFERENT COUNTRIES	63%
USE OF THE INTERNATIONAL COCOA COLLECTION AT THE COCOA RESEARCH CENTRE IN TRINIDAD AND TOBAGO TO ENHANCE GERMPLASM FOR BLACK POD AND WITCHES' BROOM RESISTANCE	58%
THE CREATION OF AN EFFECTIVE INFORMAL RESEARCH NETWORK	53%
ESTABLISHMENT OF REGIONAL VARIETY TRIALS IN AFRICA, ASIA AND IN THE AMERICAS, AIMING AT SHARING GERMPLASM WITH DISEASE RESISTANCE	50%
INITIATION OF DISTRIBUTION OF SELECTED GERMPLASM THROUGH THE INTERNATIONAL COCOA QUARANTINE CENTRE AT READING TO USER COUNTRIES	42%
COOPERATION AMONG RESEARCH INSTITUTES IN THE COCOA-PRODUCING COUNTRIES, REGIONAL AND INTERNATIONAL COCOA RESEARCH INSTITUTES AS WELL AS THE PRIVATE SECTOR	42%
REINFORCEMENT OR RE-INITIATION OF COCOA BREEDING PROGRAMMES IN SELECTED COUNTRIES	37%

7.2b Shortcomings of the CFC/ICCO/Bioversity project

**The content of these statements may have been subject to minor modifications (spelling mistakes, spaces between words, hyphens between sentences).*

Groupings by topics	Respondents' answers to question: 'What were the major shortcomings of the CFC/ICCO/Bioversity project?'
Lack of funding and sustainability	*Research funding decreased*
	Work stopped when funding stopped
	The regional variety trial did not go to completion
	Data collection/trial maintenance often ceased at the end of the project. lack of long term support for breeding activities and the process of getting improved materials into the hands of farmer's
	A follow-up effort on regional basis to share the outcome (research tangibles) after the end of the project was lacking. Example: if black pod resistant materials were identified in country a, how was this shared for countries within the sub-region and vice versa
	Follow up of projects
	Lack of provision for follow-up activities that would have maximised the output of the project: maintenance and evaluation of enhanced and selected genotypes over the requisite timeframe was not assured
	Lack of sustainability and follow-up
	The absence of a next project proposal to continue the activities in a sustainable way
	No ongoing follow through and plan for sensory skill development and maintenance in the participating countries
Complexity of coordination and lack of cooperation	*Complex coordination*
	The informal networking depended heavily on the project coordinator and the host institute Bioversity
	Trial design somewhat compromised by need to accommodate interests/needs of various institutes
	Lack of continuity-sometimes seemed like a collection of separate, but related projects rather than one unified project with a common approach
	Lack of focus
	Cooperation among research institutions was low; commitment of governments was low
	Lack of international collaboration among different regions and countries
	Collaboration in south east Asia may be strengthened
	A follow-up effort on regional basis to share the outcome (research tangibles) after the end of the project was lacking. Example: if black pod resistant materials were identified in country a, how was this shared for countries within the sub-region and vice versa"
	Screening protocols were not standardized, learnt and adopted
	Whilst a common set of methodologies was set out at the start in practice these were not all adhered to.
	The development and exchanges of protocols for testing cocoa disease resistance and data produced by regional trials on different cocoa traits (but not completely put available for all, and synthetized)
Design of clone trials	*Design of trials*
	The design of the international clonal trial could have been better
	Trial design somewhat compromised by need to accommodate interests/needs of various institutes

Lack of attention given to sensory quality	*The project was not sufficiently interested in the sensory quality characteristics of improved planting material* *No ongoing follow through and plan for sensory skill development and maintenance in the participating countries*
Other statements	*Enlarging the national germplasm collection establishment of informal working group in the region* *For farmers' selections they should stress more the issue of needed large number of clones to be tested to get any good candidates. It is a number game* *In my humble opinion, a weakness of this project was not to consider the variety protection regulation* *Meetings* *The capacity to do DNA and molecular analysis in finger printing of germplasm, clone identification etc, not being done at our organisation… urgent need for our organisation* *The duration of the project* *The overall scientific quality is relatively low* *Too many to list in a document like this and without a great deal of fore-thought* *La biodiversidad genetica es una herramienta clave para obtener estabilidad productiva y corrientes de calidad, es importante recurso frente a los cambios climaticos y una oportunidad para optimizar productores y mercados especiales*

7.3 Bioversity/CacaoNet/INGENIC sample survey (2017)

CFC/ICCO/Bioversity Project (1998-2010) Review Survey

April 20, 2017

This survey aims to review the CFC/ICCO/Bioversity projects from 1998 to 2010. It is intended for the institutes that participated in the research activities of the projects. The aim is to specifically collect in-depth information on the germplasm evaluation trials, including logistics, management and collaboration to understand what worked well and what should be improved, and the current status of the field trials (what is still in place and research carried on the germplasm).

The information gathered will enable us to draw key lessons to aid in the establishment and coordination of future global initiatives.

This survey also seeks to collecting information on ongoing research focusing on drought and heat tolerance related to climate resilience.

The survey is divided in three main parts:

- ***i.*** Information about the institutions responding
- ***ii.*** Information about the specific field evaluation trials the institutions have participated in
- ***iii.*** General information concerning the CFC/ICCO/Bioversity projects

Since we need to collect information for each type of trials, some questions are repeated for each trial type. If some questions are not clear to you – please feel free to comment where you deem appropriate.

The results of the review of the CFC/ICCO/Bioversity projects will be published by Bioversity and available to all. We are therefore grateful for your important contribution towards this review that will inform future international collaboration in this area.

We kindly ask that you return the completed survey by May 3rd to:

Viviana Medina (PhD)

Scientist, Cacao Genetic Diversity and Climate Change
Bioversity International, c/o CATIE 7170 Turrialba, Costa Rica

Email v.medina@cgiar.org | Tel: + (506) 8321-622

Institution responding to the survey

Name of respondent:	
Position:	
Name of institution:	
City:	
Country:	
Phone number:	
Email:	

The table below summarizes basic information we have gathered concerning the trials in which your institute has participated during the CFC/ICCO/Bioversity projects[16]. Please correct the information below if needed in the *comments* column.

	Participated	Comments
ICT - International Clone Trial – 1998-2004)	**Yes**	
LCOP - Local Clone Observation Plots - (1998-2004)	**No**	
HT - Hybrid trials - (1998-2004)	**Yes**	
PBT - Population Breeding Trials - (1998-2004)	**Yes**	
RHVT - Regional Hybrid Variety Trials - (2004-2010)	**Yes**	
PT - Participatory Trials - (2004-2010)	**Yes**	

In the following section, questions will be repeated for each trial your institute has participated in (based on the information above).

In depth questions on the CFC/ICCO/Bioversity evaluation field trials

International Clone Trial (ICT)

Current status:	
ICTQ. 1	Are plots from the **ICT** still in place?
	☐Yes ☐No
ICTQ. 1.1	If **NO**, Why have the trials been discontinued?
ICTQ. 1.2	If **YES**, What is the current level of management (i.e. pruning, fertilizing, harvesting) of the site and plant material of the **ICT**?
	☐ Low (less than once) ☐ Medium (every year) ☐ High (every other month or more)
ICTQ. 1.3	If **YES**, This is a list of materials that your institution received from the **ICT**, please indicate their status by placing an X on the pertinent box in the table.

**List of materials specific to institutions were listed.*

[16] For more information on these different trials, see Eskes (2011), and Eskes and Efron (2006).

ICTQ. 1.4	If **YES**, in general, what traits are being evaluated?
ICTQ. 1.5	If **YES**, Can the data be used for drought or high temperature tolerance?
ICTQ. 1.6	If **YES**, Has the plant material from the **ICT** been fingerprinted to corroborate authenticity?
	☐Yes ☐No
ICTQ. 2	What were the most significant observations/conclusions from the **ICT**?
ICTQ. 3	Was improved plant material selected from the **ICT** for future breeding projects?
	☐Yes ☐No
ICTQ. 3.1	If **YES**, what traits were used for selection?
ICTQ. 3.2	If **YES**, was the improved plant material selected shared with other institutions?
	☐Yes ☐No
ICTQ. 3.3	If Yes and **improved plant material was shared**, at what level? ☐National ☐Regional ☐International
ICTQ. 4	Please list the reports and academic papers that were generated from the trials (communications, scientific papers, reports, ext).
Benefits for farmers	
ICTQ. 5	Has the information generated in these trials translated to benefits for farmers through access to improved planting material or improved management practices?
	☐Yes ☐No
ICTQ. 5.1	If **YES**, Please describe the main benefits and if **NO**, the main reasons

Hybrid Trials (HT)

Current status:	
HTQ. 1	Are plots from the **HT** still in place?
	☐Yes ☐No
HTQ. 1.1	If **NO**, Why have the trials been discontinued?
HTQ. 1.2	If **YES**, What is the current level of management (i.e. pruning, fertilizing, harvesting) of the site and plant material of the **HT**?

	☐ Low (less than once) ☐ Medium (every year) ☐ High (every other month or more)
HTQ. 1.3	If **YES**, What traits are being evaluated?
HTQ. 1.4	If **YES**, Can the data be used for drought and high temperature tolerance?
HTQ. 1.5	If **YES**, Has the plant material from the **HT** been fingerprinted to corroborate authenticity?
	☐Yes ☐No
HTQ. 2	Are there current trials evaluating progeny from the **HT**?
	☐Yes ☐No
HTQ. 2.1	If **YES,** What traits are being evaluated?
HTQ. 2.2	If **YES,** how many breeding cycles have the progeny from the trials gone through?
HTQ. 3	What were the most significant observations/conclusions from the **HT**?
HTQ. 4	Was improved plant material selected from the **HT** for future breeding projects?
	☐Yes ☐No
HTQ. 4.1	If **YES**, what traits were used for selection?
HTQ. 4.2	If **YES**, was the improved plant material selected shared with other institutions?
	☐Yes ☐No
HTQ. 4.3	If YES and **improved plant material was shared**, at what level? ☐National ☐Regional ☐International
HTQ. 5	Please list the reports and academic papers that were generated from the trials (communications, scientific papers, reports, ext).
Benefits for farmers	
HTQ. 6	Has the information generated in these trials translated to benefits for farmers through access to improved planting material or improved management practices?
	☐Yes ☐No
HTQ. 6.1	If **YES,** Please describe the main benefits and if **NO**, the main reasons

Population Breeding Trials (PBT)

Current status:

PBTQ.1	Are plots from the **PBT** still in place?
	☐Yes ☐No
PBTQ.1.1	If **NO**, why have the trials been discontinued?
PBTQ.1.2	If **YES**, What is the current level of management (i.e. pruning, fertilizing, harvesting) of the site and plant material of the **PBT**?
	☐ Low (less than once) ☐ Medium (every year) ☐ High (every other month or more)
PBTQ.1.3	If **YES**, what traits are being evaluated?
PBTQ.1.4	If **YES**, can the data be used for drought and high temperature tolerance?
PBTQ.1.5	If **YES**, has the plant material from the **PBT** been fingerprinted to corroborate authenticity?
	☐Yes ☐No
PBTQ.2	Are there current trials evaluating progeny from the **PBT**?
	☐Yes ☐No
PBTQ.2.1	If **YES,** what traits are being evaluated?
PBTQ.2.2	If **YES,** if YES, how many breeding cycles have the progeny from the trials gone through?
PBTQ.3	What were the most significant observations/conclusions from the **PBT**?
PBTQ.4	Was improved plant material selected from the **PBT** for future breeding projects?
	☐Yes ☐No
PBTQ.4.1	If **YES**, what traits were used for selection?
PBTQ.4.2	If **YES**, was the improved plant material selected shared with other institutions?
	☐Yes ☐No
PBTQ.4.3	If **improved plant material was shared**, at what level? ☐ National ☐ Regional ☐ International
PBTQ.5	Please list the reports and academic papers that were generated from the trials (communications, scientific papers, reports, ext).

Benefits for farmers	
PBTQ.6	Has the information generated in these trials translated to benefits for farmers through access to improved planting material or improved management practices?
	☐ Yes ☐ No
PBTQ.6.1	If **YES,** Please describe the main benefits and if **NO**, the main reasons

Regional Hybrid Variety Trials (RHVT)

Current status:	
RHVTQ. 1	Are plots from the **RHVT** still in place?
	☐Yes ☐No
RHVTQ. 1.1	If **NO**, Why have the trials been discontinued?
RHVTQ. 1.2	If **YES**, What is the current level of management (i.e. pruning, fertilizing, harvesting) of the site and plant material of the **RHVT**?
	☐ Low (less than once) ☐ Medium (every year) ☐ High (every other month or more)
RHVTQ. 1.3	If **YES**, What traits are being evaluated?
RHVTQ. 1.4	If **YES**, Can the data be used for drought and high temperature tolerance?
RHVTQ. 1.5	If **YES**, Has the plant material from the **RHVT** been fingerprinted to corroborate authenticity?
	☐Yes ☐No
RHVTQ. 2	Are there current trials evaluating progeny from the **RHVT**?
	☐Yes ☐No
RHVTQ. 2.1	If **YES,** What traits are being evaluated?
RHVTQ. 2.2	If **YES,** If YES, how many breeding cycles have the progeny from the trials gone through?
RHVTQ. 3	What were the most significant observations/conclusions from the **RHVT**?
RHVTQ. 4	Was improved plant material selected from the **RHVT** for future breeding projects?
	☐Yes ☐No
RHVTQ. 4.1	If **YES**, what traits were used for selection?
RHVTQ. 4.2	If **YES**, was the improved plant material selected shared with other institutions?

	☐Yes ☐No
RHVTQ. 4.3	If **improved plant material was shared**, at what level? ☐National ☐Regional ☐International
RHVTQ. 5	Please list the reports and academic papers that were generated from the trials (communications, scientific papers, reports, ext).
Benefits for farmers	
RHVTQ. 6	Has the information generated in these trials translated to benefits for farmers through access to improved planting material or improved management practices?
	☐Yes ☐No
RHVTQ. 6.1	If **YES,** Please describe the main benefits and if **NO**, the main reasons

Participatory Trials (PT)

Current status:	
PTQ. 1	Are plots from the **PT** still in place?
	☐Yes ☐No
PTQ. 1.1	If **NO**, Why have the trials been discontinued?
PTQ. 1.2	If **YES**, What is the current level of management (i.e. pruning, fertilizing, harvesting) of the site and plant material of the **PT**?
	☐ Low (less than once) ☐ Medium (every year) ☐ High (every other month or more)
PTQ. 1.3	If **YES**, What traits are being evaluated?
PTQ. 1.4	If **YES**, Can the data be used for drought and high temperature tolerance?
PTQ. 1.5	If **YES**, Has the plant material from the **PT** trial been fingerprinted to corroborate authenticity?
	☐Yes ☐No
PTQ. 2	What were the most significant observations/conclusions from the **PT** trial?
PTQ. 3	Was improved plant material selected from the **PT** trial for future breeding projects?
	☐Yes

	☐No
PTQ. 3.1	If **YES**, what traits were used for selection?
PTQ. 3.2	If **YES**, was the improved plant material selected shared with other institutions?
	☐Yes ☐No
PTQ. 3.3	If **improved plant material was shared**, at what level? ☐National ☐Regional ☐International
PTQ. 4	Please list the reports and academic papers that were generated from the trials (communications, scientific papers, reports, ext).
Benefits for farmers	
PTQ. 5	Has the information generated in these trials translated to benefits for farmers through access to improved planting material or improved management practices?
	☐Yes ☐No
PTQ. 5.1	If **YES**, Please describe the main benefits and if **NO**, the main reasons

General questions on the CFC/ICCO/Bioversity projects (1998-2010)

GQ.1	Does your institute manage a cacao germplasm collection?
	☐Yes ☐No
GQ.1.1	If **YES**, Has the use of the cacao collection at your institution increased as a result of your participation in the CFC/ICCO/Bioversity Project?
	☐Yes ☐No
GQ.1.2	If **YES**, What types of studies are currently being done to evaluate the diversity contained in the cacao collection?

Working procedures of the CFC/ICCO/Bioversity field evaluation trials[17]

GQ.2	Did your institution find the working procedures to be useful?
	☐Yes ☐No

[17] See A.B. Eskes, J.M.M Engels, R.A. Lass; Working procedures for cocoa germplasm evaluation and selection - Proceedings of the CFC/ICCO/IPGRI project workshop 1-6 February 1998, Montpellier, France. Available at http://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/Working_procedures_for_cocoa_germplasm_evaluation_and_selection_1998.pdf.

GQ.2.1	If **YES**, How so?
GQ.3	Did your institution find that aspects of the standardized working procedures could have been improved?
	☐Yes ☐No
GQ.3.1	If **YES**, Can you provide recommendations to improve the standardized working procedures?
GQ.4	Were the standardized working procedures relatively easy to implement globally (within all participating institutions)?
	☐Yes ☐No
GQ.4.1	If **NO**, Can you list them and explain why they were difficult to implement globally?
GQ.5	Did the CFC/ICCO/Bioversity projects, allow for a smooth and straightforward exchange of plant material with other countries (receiving and/or sending plant material)?
	☐Yes ☐No ☐Some of both
GQ.5.1	Please explain

Community building

GQ.6	Did your institution initiate new collaborations with organizations as a result of its participation in the CFC/ICCO/Bioversity projects?
	☐Yes ☐No
GQ.6.1	If **YES**, Please list the names of these organizations.
GQ.7	During the CFC/ICCO/Bioversity projects, did your institution experience constraints in cooperating with other participants?
	☐Yes ☐No
GQ.7.1	If **YES**, Please explain.
GQ.8	Which collaboration network did the CFC/ICCO/Bioversity projects strengthened the most? You may comment below.
	☐National ☐Between national research, government and business institutes ☐Between national research and producers ☐Both ☐Regional ☐International
	Comments:

CFC/ICCO/Bioversity Project Funding

GQ.9	Were you satisfied with the level of funding provided by the CFC/ICCO/Bioversity project(s) for your participation?
	☐Not satisfied ☐Satisfied ☐Very satisfied
GQ.9.1	If ***not satisfied***, why?

CFC/ICCO Bioversity Projects impacts and limitations

GQ.10	What was the greatest impact of the CFC/ICCO/Bioversity Projects within your institution?
GQ.11	What was the greatest limitation your institution faced when participating in the CFC/ICCO/Bioversity Projects?

Suggestions for future collaboration initiatives

GQ.12	What are your suggestions for future international, multisite cacao germplasm evaluation trials (i.e. duration, participants, plant material, funding etc.)?

7.4 Results of Bioversity/CacaoNet/INGENIC survey (2017)

7.4a Table of collaborative networks strengthened during the project

Responses from participating institutes to the question: 'Which collaboration network did the CFC/ICCO/Bioversity project strengthen the most?'

INSTITUTE	NATIONAL	BETWEEN NATIONAL RESEARCH, GOVERNMENT AND BUSINESS INSTITUTES	BETWEEN NATIONAL RESEARCH AND PRODUCERS	REGIONAL	INTERNATIONAL
CCI	x	x	x		
INIAP	x	x	x		x
MCB	x	x			
IRAD	x		x		
CRIN	x	x	x	x	x
CATIE				x	
UNAS	x	x		x	

7.4b List of new collaborations strengthened during the project

A list of new collaborations established as a result of the project, according to survey responses.

Institute	Collaboration strengthened
CCI	ACAI World Bank World Vision International University of Natural Resources and Environment, PNG Cocoa Board of PNG Government institutions including provincial governments Farmers' groups and cooperatives
INIP	USDA-Miami USDA-Washington CIRAD
IRAD	CRIG CNRA CRIN
UNAS	CATIE; USDA-Agricultural Research Service (ARS) CIRAD CRC-UWI CEPLAC
CRIN	Multitrex Federal Ministry of Agriculture and Rural Development, Nigeria

7.4c List of ICT clones available

List of the clones sent according to institute, and those still available today (Where ✗ = received but not available; ✓ = received and still available; - = did not receive). The clones that are still available in the different countries can similarly be identified. For example, AMAZ15-15 is still available for use in CRIG-Ghana, MCB-Malaysia, CRIN-Nigeria and CCI-PNG.

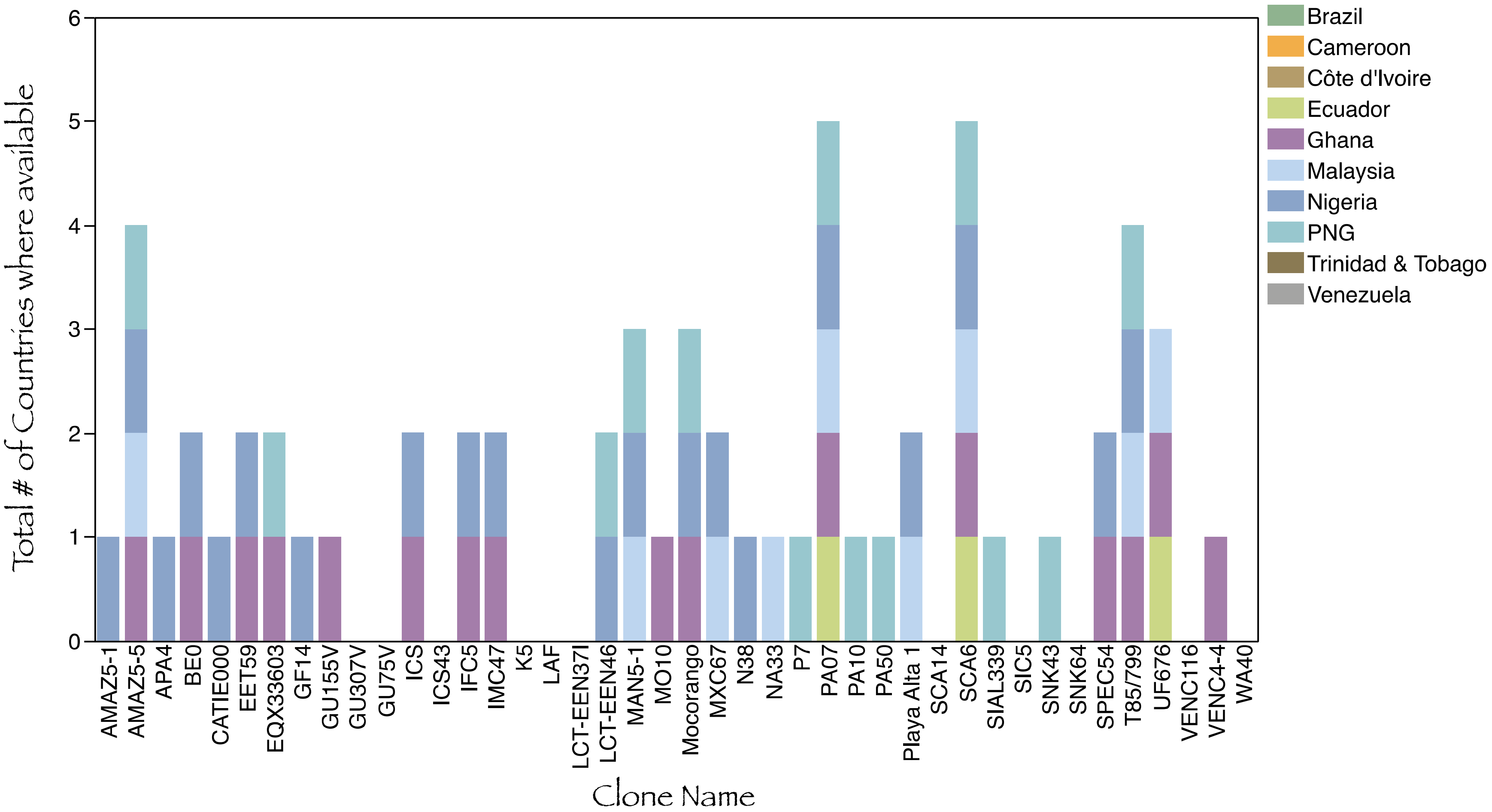
Clone name	Institute (country)									
	CEPEC CEPLAC (Brazil)	IRAD (Cameroon)	CNRA (Côte d'Ivoire)	INIAP (Ecuador)	CRIG (Ghana)	MCB (Malaysia)	CRIN (Nigeria)	CCI (PNG)	CRC/UWI (Trinidad & Tobago)	INIA (Venezuela)
AMAZ15-15	✗	✗	✗	✗	✓	✓	✓	✓	✗	✗
AMAZ5-2	✗	-	✗	-	✗	-	✓	✗	-	-
APA4	✗	✗	✗	-	✗	✗	✓	-	-	✗
BE10	✗	✗	✗	✗	✓	✗	✓	✗	✗	✗
CATIE1000	✗	✗	✗	✗	✗	✗	✓	-	✗	✗
EET59	✗	✗	✗	✗	✓	✗	✓	-	✗	✗
EQX33603	✗	✗	✗	✗	✓	✗	✗	✓	✗	✗
GF24	-	✗	✗	-	✗	✗	✓	✗	-	-
GU175V	✗	✗	-	-	✗	-	✗	✗	-	-
GU255V	✗	✗	✗	-	✓	✗	✗	-	-	-
GU307V	✗	✗	-	-	✗	-	✗	✗	-	-
ICS1	✗	✗	✗	-	✓	✗	✓	-	✗	-
ICS43	-	✗	-	✗	-	✗	-	-	-	-

Clone name	Institute (country)									
	CEPEC CEPLAC (Brazil)	IRAD (Cameroon)	CNRA (Côte d'Ivoire)	INIAP (Ecuador)	CRIG (Ghana)	MCB (Malaysia)	CRIN (Nigeria)	CCI (PNG)	CRC/UWI (Trinidad & Tobago)	INIA (Venezuela)
IFC5	-	✗	✗	-	✓	✗	✓	✗	✗	✗
IMC47	✗	✗	✗	✗	✓	✗	✓	-	✗	✗
K5	-	✗	✗	-	✗	✗	✗	-	-	-
LAF1	✗	-	-	✗	-	-	-	✗	✗	✗
LCT-EEN37I	✗	-	-	-	-	-	-	✗	-	-
LCT-EEN46	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗
MAN15-2	✗	✗	✗	✗	✗	✓	✓	✓	✗	✗
MO20	✗	✗	-	-	✓	-	-	✗	-	-
Mocorango	✗	-	✗	-	✓	-	✓	✓	-	-
MXC67	✗	✗	✗	✗	✗	✓	✓	✗	✗	✗
N38	-	✗	✗	✗	✗	✗	✓	-	✗	✗
NA33	-	✗	✗	-	✗	✓	✗	✗	✗	✗
P7	✗	-	✗	✗	✗	-	-	✓	-	-
PA107	✗	✗	✗	✓	✓	✓	✓	✓	✗	✗
PA120	✗	-	-	-	-	-	-	✓	-	-
PA150	✗	-	-	-	-	-	-	✓	-	-
Playa Alta2	✗	✗	✗	✗	-	✓	✓	✗	✗	✗
SCA24	-	-	-	-	-	-	-	✗	-	-

Clone name	***Institute (country)***									
	CEPEC CEPLAC (Brazil)	***IRAD (Cameroon)***	***CNRA (Côte d'Ivoire)***	***INIAP (Ecuador)***	***CRIG (Ghana)***	***MCB (Malaysia)***	***CRIN (Nigeria)***	***CCI (PNG)***	***CRC/UWI (Trinidad & Tobago)***	***INIA (Venezuela)***
SCA6	✗	✗	✗	✓	✓	✓	✓	✓	✗	✗
SIAL339	-	-	-	-	-	-	-	✓	-	-
SIC5	-	✗	-	-	-	✗	✗	✗	-	-
SNK413	-	✗	✗	✗	✗	✗	✗	✓	✗	✗
SNK64	-	✗	✗	-	✗	✗	✗	-	-	✗
SPEC541	✗	✗	✗	✗	✓	✗	✓	✗	✗	✗
T85/799	-	✗	✗	✗	✓	✓	✓	✓	✗	-
UF676	-	✗	-	✓	✓	✓	-	-	✗	-
VENC226	✗	-	-	-	✗	-	✗	✗	✗	✗
VENC4-4	✗	-	-	✗	✓	-	-	✗	✗	✗
WA40	-	-	✗	-	-	✗	-	-	✗	✗
Total received	28	30	28	21	32	28	30	30	24	23
Total still available				3	16	9	20	13		
Percentage available				**14%**	**50%**	**32%**	**67%**	**43%**		**n/a**

7.4d Clones common between institutions/countries

Graph highlighting location of specific clones still available for use, and where there is overlap per clone.



7.4e. Summary of trial status

Country	*Organization*	*Trial still in place*	*Current level of management*	*Traits being evaluated*	*Data of use for tolerance to drought or high temperature*	*Fingerprinting of plant material*
International Clone Trial (ICT) ** Information missing from CRC/UWI, CEPEC/CEPLAC and INIA*						
Ghana	CRIG	Yes	Medium	No data collected	No data collected	No
Côte d'Ivoire	CNRA	Yes	Low	Yield, bean quality and the rate of rotting pods	No	No
Papua New Guinea	CCI	Yes	Medium	Yield and yield components, vigour, growth habit, bean characteristics, disease	Maybe	No
Malaysia	MCB	Yes	Medium	Yield, pod and bean quality, VSD and BP	Maybe	No
Ecuador	INIAP	Yes	Medium	Morphological characterization	Maybe	No
Nigeria	CRIN	Yes	High	No data collected	No data collected	No
Cameroon	IRAD	No	Reason for termination**:** This trial was burnt down. However, most of the clones are in a germplasm collection (one or two rows of five grafted trees/clones) and have been fingerprinted			
Local Clone Observation Plots (LCOPs) ** Information missing from CEPEC/CEPLAC*						
Papua New Guinea	CCI	Yes	Low	Yield and yield components, plant vigour, growth habit, pod and bean characteristics, black pod, VSD, longicorn	No	No
Malaysia	CCI	Yes	Low	Yield, pod and bean quality, diseases (VSD and BP)	Maybe	No

Country	*Organization*	*Trial still in place*	*Current level of management*	*Traits being evaluated*	*Data of use for tolerance to drought or high temperature*	*Fingerprinting of plant material*
Nigeria	CRIN	Yes	High	No data collected	No data collected	No
Ecuador	INIAP	Yes	Medium	Disease infection, fresh and dry weight of beans, pod index, sensorial characteristics, and auto-compatibility	Maybe	No
Ghana	CRIG	No	Reason for termination: Disease infection terminated the trial.			
Cameroon	IRAD	No	Reason for termination: This trial got burnt down. However, most of the clones are in a germplasm collection (1 or 2 rows of 5 grafted trees/clone) and have been fingerprinted.			
Hybrid Trials (HTs) * *Information missing from INIA*						
Cameroon	IRAD	Yes	Low	Yield	No	No
Nigeria	CRIN	Yes	High	No data collected	No data collected	Yes
Côte d´Ivoire	CNRA	Yes	Medium	Yield, bean quality and the rate of rotting pods	No	No
Ecuador	INIAP	Yes	Medium	Disease infection, fresh and dry weight of beans, pod index, sensorial characteristics, and auto-compatibility evaluations.	Maybe, due to normal presence of prolonged dry periods	No
Papua New Guinea	CCI	No	Reason for termination: The trial was severely affected by heavy pruning during an operation to eradicate CPB in 2006/2007, in which many trees were lost/died. It became too expensive to maintain the trial and so termination was requested. Yield data and other related data from the trial during the first CFC project are available. Potential genetic materials from the trial were consolidated and maintained.			

Country	Organization	Trial still in place	Current level of management	Traits being evaluated	Data of use for tolerance to drought or high temperature	Fingerprinting of plant material
Regional Hybrid Variety Trials (RHVTs) * Information missing from INIA CEPEC/CEPLAC, and CRC/UWI						
Cameroon	IRAD	Yes	Medium	Yield (number of pods per tree), precocity, resistance to black pod, and auto-compatibility	Yes, meteorological data were recorded on the research station	Only on five full/sub progenies out of the 26
Côte d´Ivoire	CNRA	Yes	Medium	Vigour, Yield, pod weight, quality traits and the rate of rotting pods	No	No
Nigeria	CRIN	Yes	High	No data collected	No data collected	No
Costa Rica	CATIE	Yes	Low	No data collected	No data collected	No
Peru	UNAS	Yes	Medium	Productivity and disease resistance (WB and MO)	No	No
Ghana	CRIG	No	Reason for termination: Trial established poorly			
Participatory Trials (PTs) * Information missing from INIA, CEPEC/CEPLAC and CRC/UWI						
Papua New Guinea	CCI	Yes	Medium	Potential yield, production stability, VSD and black pod, longicorn (Glenea aluensis)	No	No
Ecuador	INIAP	Yes	Medium	No data collected	No data collected	No
Malaysia	MCB	Yes	Medium	Yield, pod and bean quality, VSD and BP	Maybe	Yes
Côte d´Ivoire	CNRA	Some	Low	Yield and rate of rotting pots		
Cameroon	IRAD	Yes	Medium	Yield, vigour, pod and bean traits and tolerance to mirids	Maybe	No
Nigeria	CRIN	Yes	High	No data collected	No data collected	No

Country	*Organization*	*Trial still in place*	*Current level of management*	*Traits being evaluated*	*Data of use for tolerance to drought or high temperature*	*Fingerprinting of plant material*
Ghana	CRIG	No	Plots established poorly			
Papua New Guinea	CCI	No	There were four activities included under the participatory research trials. One of the activities (1.3.1) was terminated due to issues with CPB and Longicorn as in the other trials			
Peru	UNAS	No	Not enough funding to support full establishment of trials			

7.5 Phase II: Summary of achievements and publications generated

7.5a Summary of Phase II achievements as compared to the five-year work plan[18]

Project output	Project activity	Planned activities (five-year work plan)	Implementation during five-year period	Degree of achievement
Component 1. Selection and validation of promising trees on-farm through a participatory approach				
1.1	***Survey on farmers' use and knowledge of planting materials***			
	1.1.1 Farm surveys (Brazil, Cameroon, Côte d'Ivoire, Ecuador, Ghana, Malaysia, Nigeria, Trinidad, Venezuela)	Farm surveys (in total 2,000 farms planned to be visited)	***Africa:*** Planned surveys finalised including visits to 2300 farms. Complementary interviews with farmers were carried out in Cameroon (400 as part of a PhD study), Ghana (1500) and Côte d'Ivoire (1000).	More than planned.
			Americas: Surveys including visits to 200 farms were mostly finalised already in Year 2 and in Year 3 in Brazil (Amazon region)	As planned
			Asia*:* In addition to earlier surveys including 85 farms, in Malaysia 12 promising trees for CPB tolerance were identified in farmers' fields.	As planned
	1.1.2. Identification, description and collection of promising trees (countries as above)	Description and collecting of 2,000 farm selections	***Africa:*** Collecting of 1600 promising trees finalised before Year 3. Publication of farm survey results has been done mainly in the Proceedings of the Fifth INGENIC Workshop (2009).	As planned
			Americas: In total, 350 promising trees were selected and collected. In Brazil, six new selections with witches' broom resistance were made in the Amazon. In Ecuador, the farm survey in Esmeraldas generated so much interest that new collections have been carried out. Publication of farm survey results (Trinidad, Ecuador) was carried out in the INGENIC workshop proceedings.	More than planned
			Asia: In Malaysia 74 promising trees for yield and CPB tolerance were collected. No activities were foreseen in PNG.	As planned

1.2	***Distribution to farmers and validation of promising planting materials on-farm***			
	1.2.1	A total of 200 on-farm trial plots were planned. Activities	***Africa:*** A total of 206 plots have been established: 36 in Côte d'Ivoire, 42 in Ghana, 19 in Nigeria and 109 in Cameroon. Due to high mortality during the severe dry season	As planned

[18] Annex 1 of Bioversity International (2010).

	Establishment of on-farm trials (Brazil, Cameroon, Côte d'Ivoire, Ecuador, Ghana, Malaysia, Nigeria, PNG, Trinidad, Venezuela)	varied between sites according to work plans and prior activities.	of 2006/07 and to farmers' neglect, the number of active plots has been reduced to 27, 0, 9 and 74, respectively, totalling 110 plots that are still maintained and observed.	
			Americas: A total of 38 trial plots were included in this activity: 15 in Brazil (mainly already established multi-location trial plots), 5 in Ecuador, 15 in Venezuela and 3 in Trinidad. Due to farmers' neglect, the number of active plots in Venezuela decreased to 10.	As planned
		Activities planned vary according to work plans and prior activities.	***Asia:*** Total number of plots effectively established is 14, with 8 plots in Malaysia and 6 plots in PNG. Due to lack of funding, the number of active plots in Malaysia decreased to 2.	As planned
	1.2.2 Evaluation and selection of planting materials on-farm	Activities planned vary according to work plans and prior activities.	***Africa:*** Observations on mortality and vigour were initiated in plots established in 2005-2008. CRIG and CNRA selections appear more vigorous than local farm selections.	As planned
			Americas: Evaluations of on-farm trial plots were initiated in Venezuela and Ecuador**.** In Brazil, two large on-farm trials established between 2001 and 2003 have been concluded and a simplified observation system has been put in place with 28 farms.	As planned
			Asia: In West New Britain (PNG), the already established on-farm trail plots before the start of the project have yielded valuable new selections. Yield observations have resumed after the CPB eradication campaign and compatibility was assessed on 60 clones. In Malaysia, early observations showed that some farm selections yielded as well as the local control clone PBC123.	As planned
	1.2.3 Dissemination to neighbouring farms	Planned for by the end of the project	High demand for improved varieties by neighbouring farmers has been met where possible. Dissemination of any new varieties to be identified in the on-farm trials will happen only after these trials have provided full results.	Activity below planning level, as on-farm trials not yet fully explored.

1.3	***Establishment and evaluation of farmers' selections on-station***			
	1.3.1 Multiplication of farm selections and planting on-station in Farm Selection	Establishment of on-station FSOPs	***Africa:*** In Years 2 and 3, 1153 selections were established in FSOPs on 5.5 ha. An FSOP established in Côte d'Ivoire in 2006 had to be replanted in 2007 due to soil problems (1.7 ha).	As planned
			Americas: A total of 250 farm selections were planted in FSOP's. INIAP introduced a total of 122 farm selections to be planted in a collection on-station. In	As planned

	Observation Plots (FSOP's)		Brazil, four FSOP with Amazon farm selections were planted. UNAS established 48 more farm-selections in the nursery (totalling 97 selections).	
			Asia: Three FSOP's were established in Malaysia with 62 farm selections and 3 control clones. No FSOP's were planned for PNG.	As planned
	1.3.2 Preliminary nursery and field evaluation of farmers' selections	Early screening for black pod resistance, where applicable.	***Africa:*** Ppr resistance evaluations have been carried out in Côte d'Ivoire, Nigeria, Ghana and Cameroon. Several accessions were as resistant as the resistant control clones showing potential of farm selections. Filed observations carried out in Ghana and Côte d'Ivoire recorded higher mortality rates and less vigour for farm accessions compared to breeders' selections.	As planned
		Field evaluation in established FSOPs	***Americas:*** Field observations on FSOPs established before 2004 have been carried out in Brazil (5 ha) and in Venezuela (1 ha).	As planned
			Asia: Evaluation in PNG of advanced Trinitario x Amazon crosses indicated several crosses with 10-50% higher yield than the control varieties. An advanced Trinitario clone trial that suffered severely from insect attack and CPB eradication activities was evaluated for pod wall hardness, showing large variation. Field evaluations of FSOP in Malaysia were initiated.	Advanced (PNG) and as planned (Malaysia).
	1.3.3 Characterisation of farm accessions	Molecular characterisation dependent on related projects or co-financing.	***Africa*:** More than 2000 accessions were characterized by molecular markers, through co-financing arrangements. Publications on molecular data were carried out for the Cameroon, Côte d'Ivoire and Nigeria data.	More accessions characterised than planned. Publication behind in Ghana
			***Americas*:** DNA analyses on 154 clones carried out in Venezuela. Additional DNA analyses of farm accessions could not be carried out in time (delayed co-financing arrangements).	Delayed

1.4	***Stakeholder participation and capacity building***			
	1.4.1. a National stakeholder meetings and annual field days	Organisation of national stakeholder meetings with farmers, extension workers, breeders, and private sector. Activity implemented according to local situation.	***Africa:*** Activity finished in Year 2 in Ghana and in Côte d'Ivoire. In Nigeria, a stakeholder meeting was held in August 2007.	Activity implemented less than planned
			Americas: A stakeholder meeting was held in Ecuador in November 2007. Further meetings with farmers were organised in Venezuela and Trinidad.	As planned
			Asia: No stakeholder workshops planned.	
	1.4.1. b Annual field days (on-farm trials)	Field days organised where on-farm trials are established	Annual field days and discussions with the participating farmers have taken place during the regular visits by the researchers of the collaborating institutions to the on-farm trials.	As planned

	1.4.2 Exchange of scientists for participatory selection activities	Participation in stakeholder meetings in neighbouring countries	Nigerian and Côte d'Ivoire scientists participated in the Ghana stakeholder workshop.	Activity less than planned. This activity was partly replaced by participation to the four Regional Project Meetings

Component 2. Validation and dissemination of promising varieties through enhanced international collaboration				
2.1	***Selection and validation of varieties in ongoing collaborative trials***			
	2.1.1 Evaluation and selection of varieties in trials established with support of the "Germplasm" Project	Maintenance and field observations of clone and hybrid trials (totalling 85 ha) carried out (mainly with counterpart funding).	***Africa:*** Observations on vigour, yield and disease resistance have been carried out at all sites. Ghana presents results on early yield of clones in the ICT and LCT, while analyses of population breeding trials appear to confirm the value of parental clones currently being multiplied to establish new seed gardens. Results obtained in Nigeria on the Hybrid Trial 1 have been used to establish new seed gardens to be able to disseminate the best hybrids (special local funding). Detailed results on mirid resistance and tolerance studies on ICT, LCT and hybrid trial progenies have been obtained. In Côte d'Ivoire, analyses of the Recurrent Selection trials resulted in new selections and new crosses to evaluate new hybrid output.	As planned
			Americas: Observations on vigour, yield and disease resistance carried out. Best clones of the ICT and LCT are reported by INIAP, INIA and MALMR. Several clones out yield the local control clones.	As planned
			Asia: Observations on vigour, yield and disease resistance have been carried out. IN PNG, outstanding new hybrids and clones were identified.	As planned
		Evaluation of quality traits in the ICT and LCT.	Fermented and dried bean samples were prepared during two years at seven sites. One hundred and ninety cocoa liquor samples were prepared by Guittard for sensory evaluation by three panels (CRIAD, CRC-UWI and Guittard). Data analyses show the large environmental influence on sensory traits. Cocoa pulp evaluations were carried out in Peru and Ecuador. Results suggest a weak relationship between pulp and cocoa liquor flavours (except possibly for floral flavour).	As planned (except for PNG where the ICT has been terminated)

		Evaluation of ICT clones for physiological traits.	The protocol prepared by the University of Reading has been applied at six sites. Results were analysed and presented at the Final Project Workshop.	As planned, but data not always good for in depth analyses.
		New selections made during project life span.	Numerous individual tree selections have been carried out in hybrid trials in Nigeria, Ghana, Côte d'Ivoire, Brazil, Ecuador, Venezuela and Peru. CEPLAC selected 19 interesting clones in on-farm trials.	As planned

2.2	**Germplasm enhancement for resistance to *Phytophthora* pod rot (Ppr), witches' broom (WB) and monilia**			
	2.2.1 Germplasm enhancement for Ppr resistance in Trinidad	Maintenance, field observations and detached pod test on 1,000 genotypes selected in the Germplasm Project.	* Maintenance and field evaluation for disease incidence (3 ha) has been carried out. * Detached pod test applied to 766 trees, 68% of which confirmed to be R or MR. This compares to 35 % R or MR accessions in the base population. * Pod and bean traits evaluated on 762 trees. * Approximately 1000 seedlings of 24 second cycle crosses were tested with the leaf disc test; 41% proved to be resistant.	As planned. Some delay in Year 4 due to problems with sporulation of the *Phytophthora* isolate
	2.2.2 Evaluation and selection for witches' broom (WB) resistance in Trinidad	Evaluation of accessions in the ICG,T (with WCF co-financing). Establishment of crosses between most resistant accessions and screening of individual seedling progenies.	* A total of 181 promising accessions were mass-screened for WB resistance by using spray inoculation and 42 accessions of these proved to be resistant by using the agar-droplet inoculation method. * Crosses between promising accessions made during the first 3 years yielded a total of 3974 seedlings that were inoculated with the agar droplet method between year 2 and year 5. A total of 1480 seedlings (37%) proved to be resistant or moderately resistant to WB. However, narrow sense heritability appeared to be relatively low (0.11-0.15) for the resistance traits observed with the year 1 seedlings. * A total of 176 seedlings from 28 crosses were selected for resistance to WB as well as to Ppr. * A total of 134 resistant seedlings selected in 28 crosses were planted in the field, together with 55 susceptible control seedlings and grafts of two control clones. * Field observations on WB attack were initiated in Year 5.	As planned. Some delay in Year 4 due to problems with sporulation of the *Phytophthora* isolate
	2.2.3 Selection for monilia and black pod resistance at CATIE, Costa Rica	Selection for resistance to monilia and black pod (CATIE activity mainly supported by WCF and USDA funding).	Approximately 400 genotypes (4895 pods inoculated from germplasm accessions or interesting trees) were tested for monilia resistance and 900 for Ppr resistance (8880 pods). Several accessions were identified with high levels of resistance to Ppr and fewer with relative good resistance to monilia. These findings open the scope for further breeding for monilia and Ppr resistance.	As planned

2.3	**Dissemination of selected germplasm through intermediate quarantine to user countries**			
	2.3.1 Quarantine and dissemination of selected germplasm	Reception of accessions at the intermediate quarantine facility at Reading (UK), virus-indexing, quarantine for 2 years and distribution to user countries.	*Reading University:* * The entire CFC/ICCO/Bioversity collection of 112 accessions was introduced into quarantine and nearly all accessions are now released from quarantine and available for distribution to interested user countries. * Twenty-five seedlings from PNG with resistance to Ppr were maintained and made available for distribution. * A total of 222 budwood samples of the CFC/ICCO/Bioversity collection were distributed to 8 project partners. * A total of 115 budwood samples from PNG materials were distributed to 7 project partners. *CATIE:* * Catie made available selected germplasm (budwood or seeds) on a total of 76 occasions during the project lifespan to Reading quarantine and to Costa Rican or other Central American users.	As planned, with some delay due to initial failure of transfer of materials from Trinidad to Reading.
	2.3.2 Establishment of transferred germplasm in user countries	Nursery grafting and establishment of accessions from Reading.	Large quantities of budwood were introduced into Côte d'Ivoire, Ghana and Malaysia. This activity has been underdeveloped in most other countries.	Distribution of recommended clones from Reading is delayed by about one year.
	2.3.3 Development of pollen conservation methods	Improving methods for collecting, drying and conservation of cocoa pollen. Re-hydration tests.	Success is reported with pollinations using desiccated pollen kept for up to 12 months at -18°C. No differences were observed between genetic groups of pollen donors.	As planned

2.4	**Improvement, validation and use of rapid resistance screening methods**			
	2.4.1 Early screening tests for witches' broom (WB) and monilia	Starting of activities in 2006 planned in Brazil, Costa Rica, Ecuador, Venezuela and Trinidad.	* The agar-droplet method for WB resistance testing is routinely adopted by CRC-UWI. More consistent results were obtained with the broom base diameter (BBD) variable than with incubation period. A significant coefficient of correlation of 0.70 with field results (2006) was obtained for BBD observed on open pollinated seedlings. No infection success was obtained with inoculations of young fruits (cherelles). * CEPLAC has reported some positive results with inoculation of young fruits with WB spores, but this method need further improvement * Inoculation of vegetative tissues with monilia spores carried out in Peru and Costa Rica has been abandoned as results have been negative. * Germination of spores on leaves looks promising (results from INIAP) but not at CATIE.	The complexity of the testing methods proposed made it impossible to carry out all experiments at all sites.
	2.4.2 Early screening for resistance to cocoa mirids in Côte d'Ivoire, Ghana and Cameroon	a. Application and validation of mirid resistance and tolerance evaluation methods in Cameroon, Côte d'Ivoire and Ghana. CRIN decided to join this activity.	* Results were reported for antixenosis and tolerance of ICT, LCT or hybrid accessions in Côte d'Ivoire and Nigeria. Antixenosis appeared related with cumulative mirid damage in Côte d'Ivoire. * Field resistance evaluations provided interesting results in Côte d'Ivoire, Nigeria and Ghana. * Indirect evaluation of mirid tolerance by mechanical damage has been tested in Côte d'Ivoire and Nigeria, with inconclusive results.	As planned, with exception for Ghana. The complexity of working with mirids has often lead to inconclusive or non-repeatable results.
		b. Fungi associated with mirid damage isolated, identified and pathogenicity demonstrated.	* Isolation of mirid-damage associated pathogens suggests combined presence of other pathogens than *Lasiodiplodia* in Cameroon and combined action of *Fusarium* spp. and *Lasiodiplodia* in Nigeria. * Pathogenicity tests with *Lasiodiplodia* isolates are ongoing in Cameroon (IRAD) and France (CIRAD). Results have been inconclusive.	As planned. However, results showed to be rather inconclusive when using *Lasiodiplodia* pathogenicity studies.
	2.4.3 Validation and application of new resistance screening methods	Validation and routine application of existing screening methods in national breeding programmes.	* Active evaluation for disease resistance with validated methods (mainly for Ppr and monilia resistance) has been carried out at several sites. * Application of new methods has been limited, due to the inconsistent results obtained with these methods.	As planned

2.5	**Identification of project materials by DNA markers and development of marker assisted selection methods**			
	2.5.1 Verification of genetic identity of project materials	Identity studies of accessions in collections planned at USDA, Miami and at CRC-UWI, Trinidad. This activity is co-financed.	* At USDA, Miami, more than 250 leaf samples from ICT clone accessions were characterised with SSR markers. Some off-types were identified, that were eliminated from the analyses. * In Venezuela, identity of some 150 local accessions has been carried out.	As planned
	2.5.2 Dissemination of elite progenies for QTL analysis and selection	Five “elite” progenies to be established each in two countries: Côte d’Ivoire, Ghana, Brazil, Ecuador and Costa Rica.	* Three QTL progenies have been established and are being evaluated for phenotypic traits in Ecuador, Costa Rica, Côte d’Ivoire and Ghana. * Severe drought has reduced the QTL progeny in Ghana to 111 surviving trees and has also reduced the original number of 480 trees in Côte d’Ivoire.	Reduction of five to three progenies.
	2.5.3 Identification of QTLs	Phenotypic observations and molecular analyses of field populations (co-financed activity).	* Phenotypic observations are ongoing at all sites. * Molecular studies on the Almirante progeny are ongoing at the UESC university in Bahia and in the USDA laboratory in Miami. * No other molecular studies have yet been initiated.	Phenotypic and molecular studies could not be carried out.
2.6	**Exchange of scientists between sites and training**			
	2.6.1 Exchange of scientists	Planned according to identified training needs and opportunities.	* In total, three scientists profited from exchange visits to neighbouring countries. * The exchange of scientists was compensated for by the organisation of regular regional workshops (see 3.1.1.b)	Less than planned. This activity was replaced by the four regional project workshops.
	2.6.2 Operational support for formal training of scientists	Planned according to identified needs and opportunities.	* Bruno Efombagn (IRAD), Peter Aikpokpodion (CRIN) and Désiré Pokou (CNRA) have elaborated their PhD	As planned

			thesis (French scholarship), using results from the project. Stephen Opoku (Ghana) also used the data for obtaining a MSc degree. * The project has allowed for numerous undergraduate studies to be completed using project materials. This was especially the case in Ecuador, but also in Venezuela and Costa Rica.	

Component 3. Exchange of information and dissemination of results outside the project				
3.1	**Organisation of project meetings, analyses of data and dissemination of results**			
	3.1.1 Project workshops and meetings	a. Project launching workshop.	a. The workshop was held in Reading University in March 2004. The presentations were disseminated on a CD-Rom to all project partners	a. As planned
		b. Regional African Project Meetings (Year 2 and Year 4). Co-financed by USDA.	b. The Year 2 workshop was co-organised by IRAD (Cameroon) and Bioversity. It was held in Yaoundé in November 2005. The Year 4 workshop has been prepared jointly by Bioversity and CNRA and was held in Abidjan from 18 to 22 February 2008. Conclusions and presentations of these workshops were distributed on CD-Rom to all project partners.	b. Additional activity made possible through increased co-financing from USDA
		c. Regional American Project Meetings (Year 2 and Year 4). Partially co-financed by USDA.	c. The first regional American Project workshop was held in Miranda, Venezuela, in February 2006. The regional American project workshop was organised by INIAP and Bioversity in Guayaquil from 20 to 25 August 2007. The theme of the workshop has been enlarged to include progress on cocoa breeding also in countries that are not participating in the project (Dom. Republic, Mexico and Colombia). Conclusions and presentations of these workshops were distributed on CD-Rom to all project partners.	c. Additional activity made possible through increased co-financing from USDA
		d. Elaboration of Project Working Procedures Manual (outcome of project workshops)	d. Project Working Procedures have been proposed and discussed at the four regional project meetings. These related mainly to disease and pest resistance testing methods. Because of the inconsistent results obtained with these procedures, it was decided not to elaborate a specific manual for the project working procedures.	d. Compilation of working procedures has been abandoned
	3.1.2 Data analyses and publications	a. Analyses of project data from collaborative trials.	a. Data analyses of common project activities have been carried out at CIRAD. These include the analyses of hybrid trials in Ecuador and Ghana, and the data on sensory evaluation of the clones in the ICT.	a. As planned, with delays due to the passing away of Didier Paulin (CIRAD collaborator)

		b. Project publications	b. A total of 86 articles were published that include results obtained partially through support of the project.	b. On schedule
	3.1.3 Databases	Introduction of data into the International Cocoa Germplasm Database (ICGD)	Data introduction into databases has not been carried out. This will be possible once all the data have been compiled in the Final Project progress reports.	Activity delayed until the end of the project.

Component 4. Project Coordination, Supervision and Management *(only BIOVERSITY activities are reported here)*				
4.1.	**Coordination, Supervision and Management**			
	4.1.1 Project Coordination (BIOVERSITY Coordination Unit)	a. Elaboration of annual Letters of Agreement (LOA) with collaborating institutions.	a. Annual letters of Agreement (LOAs) for Years 1 to 5 were signed by all collaborating institutions. These include the annual work plan and budgets.	a. As planned
		b. Annual Work Plans and Budgets.	b. The Work Plans and Budgets for Year 1-5 were received and verified for each of the collaborating institutions. Bioversity compiled and sent these to CFC and to ICCO before the end of the ongoing project year.	b. As planned
		c. Visits of the Project Coordinator to collaborating institutions (Years 1, 3 and 5).	c. The international Project Coordinator has visited most project partners during project Years 1, 3 and 5. Mr. Paulin (CIRAD scientist) visited Côte d'Ivoire and Cameroon in 2005as part of the additional support that CIRAD provided to the project coordination.	c. As planned, except for year 5 when no visits could be carried out to Malaysia, PNG, Nigeria and Ghana (due to health reasons).
		d. Administrative and financial coordination activities (BIOVERSITY Coordination Unit), including organisation of annual audits of the Project Account.	d1. CFC funds for implementation of project activities in Years 1-5 were made available based on the Annual Project Work Plans and Budgets and according to the LOA's for Years 1-5. d2. The Years 1-5 financial reports of all collaborating institutions for the respective reporting periods were requested and verified. d3. Bioversity presented financial claims to CFC at annual basis. d4. Bioversity also claimed for the USDA contribution to the costs of the Regional Project Workshops.	d. As planned

Component 4 (Continued). Project Coordination, Supervision and Management *(only BIOVERSITY activities are reported here)*				
4.1	4.1.2 Exchange of information within the project	Elaboration and distribution of travel and progress reports.	* Travel reports of the visits of the Coordinator and of Mr. Paulin to collaborating institutions were elaborated and distributed. * The six-monthly and annual progress reports were analysed by the Coordinator and used to elaborate the General Progress Reports for Years 1-5. The Individual Institute Progress Reports (compiled in the Appendix) were distributed together with the General Progress Reports.	As planned.
	4.1.3 Project management and supervision	Interaction with CFC and with ICCO on project arrangements and financing.	* The Project Coordinator interacted with CFC to obtain authorisation for compensations for increased operational costs and losses due to exchange rate fluctuations in the Year 2-5 project budgets. These concerned 7 project sites (IRAD, CRIN, CCI, INIAP, MCB, UNAS and CNRA). CFC has accepted the requested modifications in the use of the CFC funds. The additional funds were made available from the Project Contingencies. * The Project Coordinator organised a joint visit of Mr. Abubakar (ICCO) and of Mr. Cromme (CFC) and himself to Malaysia and to PNG as part of the mid-term evaluation of the project.	As planned

7.5b Publications generated by the project[19]

CRIN, Nigeria

Aikpokpodion P.O., J.C. Motamayor, V.O. Adetimirin, Y. Adu-Ampomah, I. Ingelbrecht, A.B. Eskes, R.J. Schnell and M. Kolesnikova-Allen, 2009. Genetic diversity assessment of sub-samples of cacao, *Theobroma cacao* L., collections in West Africa using simple sequence repeats marker. *Tree Genetics and Genome* 5:699-711Aikpokpodion, P. O., V. O. Adetimirin, M. J. Guiltinan, A. B. Eskes, J-C. Motamayor, R. J. Schnell and M. Kolesnikova-Allen 2010. Population structure and molecular characterization of Nigerian field genebank collections of cacao, *Theobroma cacao* L. *Silvae Genetica* (In press).

Anikwe, J.C., A.A. Omoloye, P.O. Aikpokpodion, F.A. Okelana and A.B. Eskes, 2009. Evaluation of resistance in selected cacao genotypes to the brown cocoa mirids Sahlbergella singularis Haglund in Nigeria. Crop Protection 28:350-355.

Okeniyi, M. O., S. O. Afolami, A. O. Fademi and P. Aikpokpodion, 2009. Evaluation of cacao (*Theobroma cacao* L.) clones for resistance to root-knot nematode *Meloidogyne incognita* (Kofoid & White) Chitwood. *Journal of Applied Biosciences* 17:913-921.

IRAD, Cameroon

M.I.B Efombagn, O. Sounigo, A.B. Eskes, J.C. Motamayor, M.J. Manzanares-Dauleux, R. Schnell and S. Nyasse (2009) Parentage analysis and outcrossing patterns in cacao (*Theobroma cacao* L.) farms in Cameroon. *Heredity* Vol. 103 (1), 46-53.

M.I.B Efombagn, O. Sounigo, S. Nyasse, M.J. Manzanares-Dauleux and A.B. Eskes (2009) Phenotypic variation of cacao (*Theobroma cacao* L.) on farms and in the genebank in Cameroon. *Journal of Plant Breeding and Crop Science*, Vol. 1 (6), 258-264.

M.I.B Efombagn, Juan C. Motamayor, Olivier Sounigo, Albertus B. Eskes, Salomon Nyassé, Christian Cilas, Ray Schnell, Maria J. Manzanares-Dauleux, Maria Kolesnikova-Allen (2008). Genetic diversity and structure of farm and genebank accessions of cacao (*Theobroma cacao* L.) in Cameroon revealed by microsatellite markers. *Tree Genetics and Genome* Vol. 4, 821-831.

M.I.B Efombagn, S. Nyassé, O. Sounigo, M. Kolesnikova-Allen and A.B. Eskes (2007). Participatory cocoa Selection in Cameroon: *Phytophthora* pod rot resistant accessions identified in farmers' field. *Crop Protection Journal*, Vol 26 (10), 1467-1473.

M.I.B. Efombagn, O. Sounigo, S. Nyassé, M. Manzanares-Dauleux, C. Cilas, A.B. Eskes and M. Kolesnikova-Allen (2006) Genetic Diversity in cocoa germplasm of southern Cameroon revealed by simple sequences repeat (SSRs) markers. *African Journal of Biotechnology*, Vol 5 (16), 1441-1449.

M.I.B. Efombagn, K.D. Vevonge, N. Nkobe, O. Sounigo, S. Nyassé and A.B. Eskes. 2009. Assessment of cocoa farmers' knowledge and preferences as regards planting material in Cameroon. Pp 104-114 *in* Proceedings of the Sixth INGENIC Workshop. 15-17 October 2006, San José, Costa Rica. INGENIC and CATIE, UK and Costa Rica.

CNRA, Côte d'Ivoire

N'Guessan K.F., J.A.K. N'Goran and A.B. Eskes. 2008. Resistance of cacao (*Theobroma cacao* L.) to *Sahlbergella singularis* (Hemiptera: Miridae): investigation of antixenosis, antibiosis and tolerance. International Journal of Tropical Insect Science 28 (4): 201–210.

N'Guessan F. K., A. B. Eskes et P. Lachenaud. 2006. Résistance des principaux groupes génétiques de cacaoyer (Theobroma cacao) aux mirides (*Sahlbergella singularis*) en Côte d'Ivoire. Sciences et Nature 3 (1): 19-27.

N'Guessan, K. F, Ph. Lachenaud, J.A.K. N'Goran, and A. B. Eskes. 2009. Antixenosis as a mechanism of cocoa resistance to the cocoa mirid, *Sahlbergella singularis* (Hemiptera: Miridae). Proceedings of the 16th International Cocoa Research Conference, Denpasar, Bali, Indonesia. 16 - 21 November 2009.

Pokou N.D., J.A.K. N'Goran, A.B. Eskes and A. Sangaré. 2009. Cocoa farm survey in Côte d'Ivoire. Pp 26-30 *in* Proceedings of the Sixth INGENIC Workshop. 15-17 October 2006, San José, Costa Rica. INGENIC and CATIE, UK and Costa Rica.

[19] Taken from Bioversity International (2010), Annex 2.

Pokou N.D., J.A.K. N'Goran, A.B. Eskes, J-C Motamayor, R. Schnell, M. Kolesnikova-Allen and A. Sangaré. 2009. Genetic diversity of selected cocoa (*Theobroma cacao L.*) in farmers' fields in Côte d'Ivoire. Pp 53-60 *in* Proceedings of the Sixth INGENIC Workshop. 15-17 October 2006, San José, Costa Rica. INGENIC and CATIE, UK and Costa Rica.

Tahi, G. M., Ph Lachenaud, J.A.K. N'Goran, I.B. Kébé, D. Paulin, K.F. N'Guessan and A. B. Eskes. 2009. Second recurrent cocoa (*Theobroma cacao* L.) selection cycle in Côte d'Ivoire: halfway stage report and proposals varietal output. Proceedings of the 16th International Cocoa Research Conference, Denpasar, Bali, Indonesia. 16 - 21 November 2009.

Tahi, G.M., J.A.K. N'Goran, O. Sounigo, Ph. Lachenaud and A.B. Eskes. 2007Efficacy of simplified methods to assess pod production in cocoa breeding trials. INGENIC Newsletter 11:7-11.

Tahi, G.M., J.A.K. N'Goran, G.K. N'Da, and A.B. Eskes. 2007. Comparison of methods to obtain twin seedlings by splitting of cocoa seeds. INGENIC Newsletter 11:20-22.

INIAP, Ecuador

Agama J., F. Amores, A.B. Eskes, A. Vasco and J. Zambrano. 2009. Estudio base de acercamiento y implementación de investigación participativa para la selección de clones superiores de cacao en tres áreas productoras tradicionales de Ecuador. Pp 31-40 *in* Proceedings of the Sixth INGENIC Workshop. 15-17 October 2006, San José, Costa Rica. INGENIC and CATIE, UK and Costa Rica.

Agama, J. 2005. Selección de progenies y plantas élites de cocoa (*Theobroma cacao L.*) mediante la evaluación de características agronómicas y de resistencia a las enfermedades. Quevedo-Los Ríos. Tesis de Ingeniero Agrónomo. Quito, EC. Universidad Central del Ecuador. 112 p.

Del Pozo, P. 2006. Comparación de métodos para la evaluación temprana de escoba de bruja (*Crinipelis perniciosa*) en cocoa (*Theobroma cocoa L*). Quevedo-Los Ríos. Tesis de Ingeniero Agrónomo. Quito, EC. Universidad Central del Ecuador.

Zambrano, J.; Amores, F.; Eskes, B.; Vasco, A. y Peña, G. 2006. Productividad y sanidad de un grupo de genotipos de cocoa (*Theobroma cacao L.*) introducidos al Ecuador y evaluados en la zona de Quevedo. Presentado en la 15va Conferencia Internacional de Investigaciones en Cocoa. San José, Costa Rica, 9 al 14 de Octubre del 2006.

Sanchez, V. 2007. Caracterización Organoléptica del cocoa (*Theobroma cacao L.*), para la selección de árboles híbridos con perfiles de sabor de interés comercial. Tesis Ing. Agr. Quevedo, Ecuador. Universidad Técnica Estatal de Quevedo. 82 p.

López, O. 2007. Determinación de grados de resistencia a la Moniliasis en varios genotipos de cocoa mediante la inoculación artificial de las mazorcas con *Moniliophthora* rorer*i.* Tesis Ing. Agr. Quevedo, Ecuador. Universidad Técnica Estatal de Quevedo. 43 p.

Angamarca, M. 2008. Determinación del comportamiento de cultivares de cocoa tipo Forastero *(Theobroma cocoa L)* frente al ataque del hongo *Ceratocystis fimbriata* a nivel de laboratorio y campo. Quevedo-Los Ríos. Tesis de Ingeniero Agrónomo. Quito, EC. Universidad Central del Ecuador.

Vera, J. 2008. Estudio de la respuesta fenológica, sanitaria y productiva del cocoa *(Theobroma cocoa L.)* frente a la aplicación de diferentes intensidades de poda. Tesis Ing. Agr. Guayaquil, Ecuador. Universidad Agraria del Ecuador. 76 p.

Montaño, N. 2008. Caracterización fenotípica y agronómica de cocoa (*Theobroma cocoa L.*) Tipos Nacional y Criollo en las zonas de Atacames y Muisne de la provincia de Esmeraldas. Tesis Ing. Agr. Esmeraldas, Ecuador. Universidad Técnica de Esmeraldas Luis Vargas Torres. 188 p.

Francis, T. 2008. Caracterización morfológica y agronómica del cocoa (*Theobroma cocoa L.*) tipo Criollo y Nacional, en el norte de Esmeraldas parroquia Colón Eloy. Tesis Ing. Agr. Esmeraldas, Ecuador. Universidad Técnica de Esmeraldas Luis Vargas Torres. 143 p.

Castillo, C. 2009. Evaluación agronómica de 23 genotipos de cocoa tipo Nacional vs. Ocho de cocoa tipo Criollo en el norte de Esmeraldas, Colón Eloy. Tesis Ing. Agr. Esmeraldas, Ecuador. Universidad Técnica de Esmeraldas Luis Vargas Torres. 96 p.

Ortiz, P. 2009. Evaluación del comportamiento agronómico de 31 genotipos de cocoa tipo Nacional (*Theobroma cocoa L.*) de la colección EET-Pichilingue y centro sur de Esmeraldas. Tesis Ing. Agr. Esmeraldas, Ecuador. Universidad Técnica de Esmeraldas Luis Vargas Torres. 60 p.

Quinaluisa, C. 2009. Estudio de la compatibilidad de árboles preseleccionados por productividad y sanidad en un grupo de progenies híbridas provenientes de ces entre cocoa (*Theobroma cocoa L.*) Nacional y otros orígenes genéticos. Tesis de Ing. Agr. Quevedo, Ecuador. Universidad Técnica Estatal de Quevedo. 70 p.

Baño, S. 2009. Evaluación y selección organoléptica de progenies y arboles híbridos de cocoa tipo Nacional en base a la degustación en pulpa fresca y licor. Tesis de Ing. Agr. Quevedo, Ecuador. Universidad Técnica Estatal Quevedo. 67p.

Revelo, S. 2010. Ajuste de Metodologías de evaluación temprana para la búsqueda de resistencia a *Moniliopthora perniciosa*. Quevedo-Los Ríos. Tesis de Ingeniero Agrónomo. Quito, EC. Universidad Central del Ecuador.

Montoya, J. 2009. Comparación de un grupo de clones de cocoa tipo Nacional vs el CCN-51 bajo condiciones de secano en la zona de Quevedo. Tesis de Ing. Agr. Guayaquil, Ecuador. Universidad Agraria del Ecuador. 61p.

Amarilla, J. 2010. Estudio de la productividad, sanidad y perfiles organolépticos de clones internacionales de cocoa (*Theobroma cocoa L*) introducidos en la zona de Quevedo. Quevedo-Los Ríos. Tesis de Ingeniero Agrónomo. Quevedo, EC. Universidad Técnica Estatal Quevedo (en preparación avanzada).

MALMR, Trinidad

Maharaj K., P. Maharaj and D. Ramnath. 2009. Farm practices, knowledge and use of cocoa planting material in Trinidad, a survey report. Pp 41-52 *in* Proceedings of the Sixth INGENIC Workshop. 15-17 October 2006, San José, Costa Rica. INGENIC and CATIE, UK and Costa Rica.

CRC, Trinidad

Bekele, F.L. and Bidaisee, G.G. (2006) Characterization of germplasm in the International Cocoa Genebank, Trinidad. Global approaches to cocoa germplasm utilization and conservation. *Final report of the CFC /ICCO/IPGRI project on "Cocoa germplasm utilization and Conservation: a global approach" (1998-2004)* (eds Eskes, A.B. and Efron, Y.), CFC, Amsterdam, The Netherlands/ICCO, London, UK/IPGRI, Rome, Italy. P 58-66.

Boccara, M., Zhang, D., Mischke, S., Motilal, L.A., Sankar, A.A, and Butler, D.R. (2009) Verification of clone identity in the International Cocoa Genebank, Trinidad using molecular markers. Presented at: *The 15th International Cocoa Research Conference*. San José, Costa Rica. 9-14 October 2006. (in press).

Butler, D.R. and Sukha, D.A. (2004). Transfer of clones from the Barbados Cocoa Quarantine Station. Annual Report, 2003. Cocoa Research Unit, U.W.I. St. Augustine, Trinidad. P 12.

Deberdt, P., Holder, A., Jadoo, V. and Thévenin, J.-M. (2008) Focusing on early-screening methods of Witches' Broom resistance. Annual Report 2007, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. 47-51.

Deberdt, P., Holder, A., Jadoo, V. and Thévenin, J.-M. (2007) Progress in germplasm enhancement for Witches' Broom resistance. Annual Report 2006, Cocoa Research Centre, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 63-69.

Holder, A., Deberdt, P., Jadoo, V. and Thévenin, J.-M. (2009) An update on the germplasm enhancement for Witches' Broom disease programme. Annual Report 2008, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 75-77

Holder, A., Deberdt, P., Jadoo, V. and Thévenin, J.-M. (2008) Pre-breeding of cacao for resistance to Witches' Broom and Black Pod diseases. Annual Report 2007, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 65-68.

Holder, A., Thévenin, J.-M., Boccara, M., Jadoo, V. and Solomon, F. (2006) Germplasm enhancement for resistance to Witches' Broom disease. Annual Report 2005, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 68-72.

Iwaro, A.D., Bharath, S., Bekele, F.L. and Butler, D.R. (2009) Assessment of genetic gain in a germplasm enhancement programme for resistance to black pod disease. *Proceedings of the 15th International Cocoa Research Conference*. San José, Costa Rica. 9-14 October 2006. P 33-39.

Iwaro, A.D., Bekele, F.L., Butler, D.R., Singh, V., Holder-John, A., Bharath, S., Umaharan, R., Surujdeo-Maharaj, S., Thévenin, J.-M., Deberdt, P. and Bidaisee, G.G. (2008) Recent progress in breeding for specific traits in cocoa to meet challenges to production. Presented at: *The International Congress on Overcoming Challenges to Developing Sustainable Agri-Food Systems in the Tropics*. Port of Spain, Trinidad. 30 November – 5 December 2008.

Iwaro, A.D., Singh, V., Bharath, S. and Butler, D.R. (2008) Germplasm enhancement for resistance to Black Pod disease: progress achieved in ten years. Annual Report 2007, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 60-64.

Iwaro, A.D. and Singh, V. (2006) Progress report on germplasm enhancement for resistance to Black Pod disease. Annual Report 2005, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 63-67.

Iwaro, A.D., Bharath, S., Bekele, F.L., Butler, D.R. and Eskes, A.B. (2006) Germplasm enhancement for resistance to black pod disease. *Global approaches to cocoa germplasm utilization and conservation: Final report of the CFC/ICCO/IPGRI project on "Cocoa germplasm utilization and conservation: A global approach"* (1998-2004), (A. Eskes & Y. Efron, eds.), Amsterdam: CFC, 47-57.

Iwaro, A.D., Thévenin, J.-M., Butler, D.R. and Eskes, A.B. (2006) Validation studies on the detached pod test and leaf disc inoculation method for the assessment of cocoa resistance to *Phytophthora* infection. *Global approaches to cocoa germplasm utilization and conservation: Final report of the CFC/ICCO/IPGRI project on "Cocoa germplasm utilization and conservation: A global approach"* (1998-2004), (A. Eskes & Y. Efron, eds.), Amsterdam: CFC, P 108-115.

Iwaro, A.D., Butler, D.R. and Eskes, A.B. (2005) Sources of resistance to *Phytophthora* pod rot at the International Cocoa Genebank, Trinidad. *Genetic Resources and Crop Evolution.* 53: 99-109.

Iwaro, A.D., Thévenin, J.-M., Butler, D.R. and Eskes, A.B. (2005) Usefulness of the detached pod test for assessment of cacao resistance to *Phytophthora* pod rot. *European Journal of Plant Pathology*. 113: 173-182.

Iwaro, A.D. and Singh, V. (2005) Enhancing cacao germplasm for resistance to Black Pod disease. Annual Report 2004, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 49-52.

Khan, N., Motilal, L.A., Sukha, D.A., Bekele, F.L., Iwaro, A.D., Bidaisee, G.G., Umaharan, P., Grierson, L.H. and Zhang, D. (2008) Variability of butterfat content in cacao (*Theobroma cacao* L.): combination and correlation with other seed-derived traits at the International Cocoa Genebank, Trinidad. *Plant Genetic Resources: Characterization and Utilization.* 6(3): 175-186, DOI 10.1017/S1479262108994132

Motilal, L.A., Khan, N., Sukha, D.A., Bekele, F.L., Iwaro, A.D., Bidaisee, G.G., Umaharan, P., Grierson, L.H. and Zhang, D. (2009) Cocoa (*Theobroma cacao* L.) bean traits for the identification of superior accessions for germplasm enhancement. Proceedings of the 15th International Cocoa Research Conference. San José, Costa Rica. 9-14 October 2006. Vol. I, 533-538. (in press).

Motilal, L.A., Umaharan, P. and Zhang, D. (2009) Accession and plot heterogeneity at the ICG,T Annual Report 2008, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. 24-28. Motilal, L.A., Umaharan, P., Zhang, D., and Boccara, M. (2008) Fingerprinting cacao trees in the International Cocoa Genebank, Trinidad with microsatellites. Annual Report 2007, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 22-29.

Motilal, L.A., Zhang, D., Umaharan P., Mischke, S., Boccara, M., and Pinney, S. (2008) Increasing accuracy and throughput in large-scale microsatellite fingerprinting of cacao field germplasm collections. Tropical Plant Biology. DOI 10.1007/s12042-008-9016-z

Motilal, L.A., Umaharan, P. and Zhang, D. (2006) Identifying marker-trait association in a cacao germplasm collection: a research plan. Annual Report 2005, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 17-24.

Motilal, L.A., Zhang, D., Umaharan, P. and Mischke, S. (2006) Association Mapping for Butterfat Content in the Tree Crop Theobroma cacao L. Poster presentation in: From Functional Genomics of Model Organisms to Crop Plants for Global Health. Arthur M. Sackler Colloquia, National Academy of Sciences Building, Washington DC, 3-5 April 2006.

Motilal, L.A. (2005) Validation and optimisation of SSR-PCR and SSR detection in agarose gels. Annual Report 2004, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 14-21.

Motilal, L.A. (2004) Tree identification by simple sequence repeats: a synopsis for 2000-2003. Annual Report 2003, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 13-21.

Motilal, L.A. and Boccara, M. (2004) Screening and evaluation of SSR primers in gel systems for the detection of off-types in cocoa field genebanks. INGENIC Newsletter. 9: 21-26.

Motilal, L.A., Sounigo, O., Butler, D.R. and Mooleedhar, V. (2004) Misidentification within global cacao germplasm collections. In vitro culture, transformation and molecular markers for crop improvement. A.S. Islam (ed). Science Publishers Inc., New Hampshire, USA. P 121-129.

Roberts, R.P., Wimmers, L., Jonnalagadda, K., Campbell, S., Butler, D.R., Sukha, D.A., Bekele, F.L. and Saunders, J.A. (2007) Detection of misidentified plants in *Theobroma cacao* germplasm collections in Trinidad. Poster presented at: *World Cocoa Foundation Partnership Meeting*. Washington, DC., 24 October 2007.

Sounigo, O., Bekele, F.L., Iwaro, A.D., Thévenin, J.-M., Bidaisee, G., Umaharan, R., Sankar, A., Sukha, D.A., Motilal, L.A., Butler, D.R. and Eskes, A. (2006) Description of cocoa clones proposed for the “CFC/ICCO/IPGRI project collection. Global approaches to cocoa germplasm utilization and conservation: Final report of the CFC/ICCO/IPGRI project on “Cocoa germplasm utilization and conservation: A global approach” (1998-2004), (A. Eskes & Y. Efron, eds.), Amsterdam: CFC, P 67-81.

Sounigo, O., Bekele, F.L., Iwaro, A.D., Thévenin, J.-M., Bidaisee, G., Umaharan, R., Sankar, A., Sukha, D.A., Motilal, L.A., Butler, D.R., and Eskes, A. (2004) Cocoa germplasm improvement: global and participatory approaches. [CD-ROM] Rome: IPGRI. CFC/ICCO/IPGRI Projects Workshop, Reading, UK. 28 March–3 April 2004.

Thévenin, J.-M., Holder, A., Butler, D., Cilas, C., Eskes, A.B. (2009) Application of an early screening test for Witches’ Broom resistance in cocoa progenies. *Proceedings of the 15th International Cocoa Research Conference*. San Jose, Costa Rica. 9-14 October 2006. 575-584. (in press).

Thévenin, J.-M., Umaharan, R. and Butler, D.R (2006) Review of resistance screening of cocoa seedlings and clones to witches’ broom disease: methods, problems and correlation with field results. The experience of the Cocoa Research Unit, Trinidad. Global approaches to cocoa germplasm utilization and conservation: Final report of the CFC/ICCO/IPGRI project on “Cocoa germplasm utilization and conservation: A global approach” (1998-2004), (A. Eskes & Y. Efron, eds.), Amsterdam: CFC, P 137-145.

Thévenin, J.-M., Umaharan, R., Surujdeo-Maharaj, S., Latchman, B., Cilas, C., Butler, D.R. (2005) Relationships between Black Pod and Witches’ Broom diseases in *Theobroma cacao*. *Phytopathology*. 95 (11): 1301-1307.

Umaharan, R. (2009) Evaluation of cocoa germplasm for resistance to Witches’ Broom disease. Annual Report 2008, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 52-56.

Umaharan, R. and Surujdeo-Maharaj, S. (2007) Evaluation of cocoa germplasm for resistance to Witches’ Broom disease. Annual Report 2006, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 60-61.

Umaharan, R., Thévenin, J.-M., Holder, A. and Bhola, J. (2005) Evaluation of cocoa germplasm for resistance to Witches’ Broom disease. Annual Report 2004, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 44-47.

Umaharan, R., Thévenin, J.-M., Holder, A. and Bhola, J. (2004) Evaluation of cocoa germplasm for resistance to Witches’ Broom disease under controlled conditions. Annual Report 2003, Cocoa Research Unit, The University of the West Indies, St. Augustine, Trinidad and Tobago. P 37-41.

Zhang, D., Boccara, M., Mischke, S., Motilal, L.A., Kolesnikova-Allen, M., Cryer, N., Turnbull, C., Lanaud, C., Philips-Mora, W., and Butler, D.R. (2009) Detection of mislabelled germplasm in cocoa collections using DNA fingerprinting with SSR markers. *Proceedings of the 15th International Cocoa Research Conference*. San José, Costa Rica. 9-14 October 2006.

Zhang, D., Boccara, M., Motilal, L., Butler, D.R., Umaharan, P., Mischke, S., Meinhardt, L. (2007) Microsatellite variation and population structure in the “Refractario” cacao of Ecuador. Conservation Genetics. 9 (2): 327-337. DOI 10.1007/s10592-007-9345-8

Zhang, D., Boccara, M., Motilal, L., Butler, D.R., Umaharan, P., Mischke, S., Meinhardt, L. (2007) Population structure and chocolate trees in Ecuador. Poster presentation in: Mid-Atlantic Plant Molecular Biology Society 24th Annual Meeting. Patuxent National Wildlife Refuge, Beltsville, Maryland.16-17 August 2007.

CRIG, Ghana

Opoku, SY, Bhattacharjee R., Kolesnikova-Allen M., Motamayor, JC., Schnell R., Ingelbrecht I., Enu-Kwesi L., Adu-Ampomah Y. 2007. Genetic diversity in cocoa (Theobroma cacao L) germplasm collection from Ghana. Journal of Crop Improvement 20: 73-87.

Adomako B., Padi F.K., Dadzie M. A., Opoku S. Y., Adu-Ampomah Y. 2009. Evaluation of yield and black pod incidence in selfed, intra-group and inter-group progenies of four upper Amazon cocoa populations. The 16th International Cocoa Research Conference, 16 – 21 November, Bali, Indonesia.

Opoku S. Y., Adomako B., Padi F.K., Dadzie M. A., Adu-Ampomah Y. 2009. Analysis of variation in bean yield components in a cocoa progeny trial. The 16th International Cocoa Research Conference, 16 – 21 November, Bali, Indonesia.

Adu-Ampomah Y., E.G. Asante and S. Y. Opoku. 2009. Farmers’ knowledge, attitudes and perceptions of innovation in cocoa production and implications for participatory improved germplasm development. Pp 11-25 *in* Proceedings of the Sixth INGENIC Workshop. 15-17 October 2006, San José, Costa Rica. INGENIC and CATIE, UK and Costa Rica.

Opoku, SY, R. Bhattacharjee, M. Kolesnikova-Allen, E.G. Asante, M.A. Dadzie and Y. Adu-Ampomah. 2009. Profile and genetic diversity of planting materials in Ghana cocoa farms. Pp 61-72 *in* Proceedings of the Sixth INGENIC Workshop. 15-17 October 2006, San José, Costa Rica. INGENIC and CATIE, UK and Costa Rica.

CCI, Papua New Guinea

Marfu J., Y. Efron and P. Epaina. 2009. Selection of new cocoa varieties through multilocation on-farm testing in Papua New Guinea. Pp 115-122 *in* Proceedings of the Sixth INGENIC Workshop. 15-17 October 2006, San José, Costa Rica. INGENIC and CATIE, UK and Costa Rica.

CEPLAC, Brazil

Monteiro, W. R.; Lopes, U. V. and Pires, J. L. 2003. Relatedness and Inbreeding in a Cacao Breeding Population. 14th International Cocoa Research Conference, in Ghana.

Lopes, U. V.; Monteiro, W. R.; Gramacho, K. P and Pires, J. L., 2003. Inheritance of the Resistance of Cocoa to Witches’ Broom (Herança da Resistência do Cacaueiro à Vassoura-de-Bruxa). 2nd Brazilian Plant Breeding Congress, 2003, in Porto Seguro, Bahia, Brazil.

Bioversity International

Eskes, A.B., Y. Adu-Ampomah, P. Aikpokpodion, D. Butler, F. Amores, A.J. Daymond, M.I.B. Efombagn, J.M.M. Engels, V. V. Gonzalez, R., D. Iwaro, L. Garcia C., M. Gilmour, P. Maharaj J-C Motamayor, F. K. Lamin, J. Marfu, W. Monteiro, F. K. N’Guessan, D. Paulin, W. Phillips M. and E.S. Seguine. In press. Results from collaborative and farmer participatory approaches to cocoa variety selection and breeding. In Proceedings of the 16th International Cocoa Research Conference, 16 – 21 November 2009, Bali, Indonesia. COPAL, Nigeria.