CacaoNet/INGENIC Workshop on the Development of a

Collaborative Framework for Cacao Evaluation (CFCE)

The Penn Stater Hotel and Conference Centre, Room 107
215 Innovation Boulevard, State College, PA, 16803
Friday 3 June 2016

Contents

1. BACKGROUND, OBJECTIVES AND PROGRAMME OF THE WORKSHOP

The Global Network for Cacao Genetic Resources (CacaoNet[1]) published a Global Strategy for the Conservation and Use of Cacao Genetic Resources in 2012 (available on www.cacaonet.org). This Strategy is intended to be a roadmap towards building an efficient and effective global system to ensure that valuable genetic resources are securely conserved, and made available for use in developing the planting materials urgently needed by cocoa farmers to improve quality and productivity in the face of threats such as pest and diseases, climate change and soil contamination.. The future of the cocoa industry depends on these valuable resources but access to promising materials and sharing of information relating to their potential value in addressing these urgent threats needs to be improved and supported.

CacaoNet has been engaged for the past 6 months in the development of a global **Collaborative Framework for Cacao Evaluation (CFCE)**, in response to the urgent needs of the cocoa producing countries. CFCE is aiming at establishing the global collaboration that can be sustained for the long-term. This can only be achieved if all participate. CFCE also needs to link and complement current and on-going initiatives. We cannot afford to duplicate efforts.

CacaoNet is in contact with key research partners and a broad range of potential investors/donors from the private and public sectors. The feedback is positive. Bringing increased collaboration and building on on-going initiatives in line with a number of other complementary projects is crucial.

CacaoNet and The International Group for Genetic Improvement of Cocoa *(*INGENIC) took the opportunity of the Conference "Frontiers in Science and Technology for Cacao Quality, Productivity and Sustainability" organized by and at Penn State University (31 May – 2 June) to discuss the development of a Collaborative Framework for Cacao Evaluation with the cacao research community.

A summary description of the CFCE was sent out to all participants in advance of the discussion and is included in ***Annex A***.

Brigitte Laliberté, Bioversity International, welcomed all participate, provided background and presented the programme and objectives of the workshop below.

CacaoNet-INGENIC Workshop Objectives

- To review the proposal for the Collaborative Framework for Cacao Evaluation (CFCE)
- To discuss the key research questions
- To make recommendations on outputs deliverables
- To agree on the next steps for the development of the CFCE concept note and submission for funding

Workshop Programme:

- 09:30 – Welcome and introduction
- 10:00 - Presentation of the Collaborative Framework for Cacao Evaluation (CFCE)
- 11:30 – Group discussion

[1] *CacaoNet has benefitted from financial and in-kind contributions from many organizations, institutions and individuals who are interested in the global cocoa genetic resources effort. CacaoNet is coordinated by Bioversity International (Stephan Weise (Coordinator) and Brigitte Laliberté (Scientific Advisor) and the Secretariat, based at the Rome Office, is responsible for providing coordination and administrative support for the network. The current CacaoNet chairman is Martin Gilmour (Mars Global Chocolate UK) and the current CacaoNet secretary is Michelle End (Cocoa Research Association Ltd. UK, CRA Ltd).*

- *13:00 – Lunch*
- 14:00 – Status of where we are on the priority traits proposed – focus on Climate Change
- 16:00 - Next steps and agreed actions
- 17:00 – Closing of the CacaoNet/INGENIC workshop

The CacaoNet-INGENIC workshop included 48 participants listed in ***Annex B***. These represented the international cocoa research community with representatives from research institutes and universities in both cocoa-producing and consuming countries together with representatives from the industry, governmental and non-governmental organisations.

Since the participants included a number of researchers from the industry the following pre-competitive guidelines were presented at the start of the meeting, included in ***Annex C***.

Printed copies of the publication titled: Supplying new cocoa planting material to farmers: a review of propagation methodologies were available and for download from the Bioversity website: http://www.bioversityinternational.org/e-library/publications/detail/supplying-new-cocoa-planting-material-to-farmers-a-review-of-propagation-methodologies/

Michelle End, CRA Ltd UK informed the group about the recent publication from ECA/Caobisco/FCC titled: Cocoa Beans: Chocolate and Cocoa Industry Quality Requirements – that can be downloaded in English, French and Spanish at: www.cocoaquality.eu

Michelle End made a presentation of updates from the INCOCOA International Cocoa Research Groups and is in ***Annex D***.

2. Introduction to the Collaborative Framework for Cacao Evaluation (CFCE)

Brigitte Laliberté, on behalf of CacaoNet and Bioversity International, provided the background to the development of the Collaborative Framework for Cacao Evaluation (CFCE). The presentation titled *Improved Planting Materials of good Quality, Yield and Diverse Flavours: Tapping Cacao Diversity for Farmers, Manufacturers and Consumers* is in ***Annex E*** and key points on the CFCE are below:

What is the recommendation?

- International collaboration bringing key players in the public and private sectors to increase value of cacao diversity and optimize use in development of improved, diverse and locally-adapted cocoa varieties
- The international services of CATIE, CRC and ICQCR have to be optimised and contributing strategically to the materials research today, for the breeding pipeline producing the cocoa of tomorrow.
- Building on and learning from previous and current initiatives, assessing what worked and did not work
- Develop a Collaborative Framework for Cacao Evaluation – where each partner defines what they are interesting in getting out of the collaboration and what they are willing to put in and contribute.
- Stimulate, facilitate and support on-going and future breeding efforts.

Collaborative Framework for Cacao Evaluation - CFCE

- Each partner defines what they are interesting in getting out and willing to put in.
- Stimulate, facilitate and support on-going and future breeding efforts.

Goal:

- Optimize the use of cacao genetic diversity in development of improved, diverse and locally-adapted varieties through international collaboration, bringing together players in public and private sectors.

Outputs – focus on traits for:

- Climate Change adaptation – drought (water stress) and temperature
- BP (global), WBD and FP (Latin America), VSD and PB (Asia and Pacific), CSSV (Africa)
- Low uptake of soil contaminants - cadmium

Cross-cutting components:

- Identification and screening of potentially resistant materials
- Agreed common tool, methods and standards
- International and regional safe-movement
- Policy and legal frameworks agreed for the sharing of specific materials
- Evaluation of promising germplasm in a range of environments
- Efficient Collaborative Framework

Key Linkages

- It builds on the experience of the CFC/ICCO/Bioversity programme from 1998-2010 (2 phases), what worked well and lessons learnt.
  - First Phase - CFC/ICCO/IPGRI project on "Cocoa Germplasm Utilization and Conservation: a Global Approach" (1998-2004)
  - Second Phase - CFC/ICCO/Bioversity project on “Cocoa Productivity and quality improvement: a Participatory Approach” (2004-2010)
- Building on complementary initiatives such as: Climate Smart Agriculture (CSA) work with CIAT and others, CocoaAction, the Cocoa Africa Initiative and its new phase (CIRCLE), WCF, ICCO etc.

Summary circulated widely

- Bioversity, Costa Rica-Brigitte Laliberté, Allison Smith, Dietmar Stoian, Evert Thomas, Maarten van Zonneveld, Stephan Weise
- Barry Callebaut, Switzerland-Cinzia Anselmi and Lachlan Monsbourgh
- Bean and Co. – Johann Dahan
- ECA/Caobisco/FCC-Catherine Entzminger, Paula Byrne
- CATIE, Costa Rica-Wilbert Philips
- CEPLAC, Brazil-Uilson Lopes
- CIRAD, France-Selim Louafi, Philippe Bastide, Claire Lanaud
- CNRA, Cote d’Ivoire-Adiko Amoncho, Mathias Tahi, Désiré Pokou and Louise,
- CocoBod, CRIG, Ghana-Gilbert Anim Kwapong, Francis Padi, Stephan Opoku, Francis Oppong
- CRA Ltd, UK-Michelle End
- CRC, Trinidad and Tobago-Path Umaharan
- EuropeAid – Roberto Ridolfi
- ICCO – Laurent Pipitone
- ICCRI - Indonesia-Agung Wahyu Susilo
- ICQC,R, UK-Paul Hadley, Andrew Daymond
- International Fund for Agriculture Development – IFAD – Wafaa El Khrouy
- Lutheran World Relief LWR), Nicaragua-Jenny Wiegel
- Mars, UK-Martin Gilmour
- Mondelez International, UK-Nicholas Cryer
- Nestlé, Tours, France-Pierre Broun, Anne Buchwalder
- Penn State University, USDA-Mark Guiltinan and Siela Maximova
- Peru - ICT-Enrique Arevalo
- Peru - MINAGRI-Carmen Chavez
- Peru - UNAS-Luis García Carrión / Rolando Rios
- Tree Global-Greg Hess
- University of Arizona, USA-Judith Brown
- USAID – Jay Daniliuk
- USDA, Beltsville-Peter Bretting, Dapeng Zhang, Lyndel Meinhardt, Osman Gutierrez, Ricardo Goenaga
- WCF, Washing to-Virginia Sopyla

Feedback Received

- Very supportive – particularly the national research programmes from producing countries
- Aligned with current research efforts
- Need to build on what is currently being done – carry out an inventory
- Need to learn the lessons from CFC/ICCO/Bioversity – particularly regarding the multi-site evaluation of a set of clones
- Climate Change – URGENT - Lack of research on traits related to adaptation – drought and temperature – this topic can federate all the partners
- Priority on phenotypic characterisation of the core set of genotypes representing the diversity of *T. cacao* for all priority traits – including quality
- Need to carry out an inventory of who is working on what and what is the current status of research and key questions to be addressed

Main Concerns - Scope

- Should it include multi-site field evaluation trials?
- Is it mainly about supporting breeding efforts?
- Should it support the use of diversity directly to farmers' fields?
- How to directly link with delivery mechanism to farmers – seed systems?
    - E.g. For CSSV – CocoaAction can be the mechanism for application and CFCE the mechanism for screening and facilitating access to genetic diversity

Cacao Genetic Resources Research Community

- Social Network Analysis – Selim Louafi CIRAD and Andrew Meter, UMR AGAP, Montpellier, France
- Survey of current and past collaboration critical to support long-term efforts.
- All are asked to complete the survey that will be sent out by Selim Louafi in the coming weeks.

Steps and Timeframes

- February-March 2016 – Involvement of partners and donors in the development of the Concept Note
- End of April 2016 - Draft Concept Note revised with input from partners
- Early May 2016 – Consultation with key investors
- End of May 2016 - Presentation at the third World Cocoa Conference in the Dominican Republic, 22-26 May 2016
- 3rd June - Consultation at the Cocoa Research Symposium, Penn State University, 31 May – 3 June 2016 – 40 participants
- June-July 2016 – Develop a 6-month workplan to establish the workpackages's teams and plans and specific consultations
- June to October 2016 – Revised concept note for submission to specific donors and calls and Secure funding
- 2017 – Start Collaborative Framework implementation – first phase of 5 years

3. GROUP DISCUSSION ON THE CFCE IN GENERAL

CFCE particularly builds on the experience of the two Phases of the CFC/ICCO/Bioversity funded programme between 1998 and 2010 coordinated by Bertus Eskes.

- First Phase - Report of the CFC/ICCO/IPGRI project on "Cocoa Germplasm Utilization and Conservation: a Global Approach" (1998-2004) available at: http://www.bioversityinternational.org/e-library/publications/detail/global-approaches-to-cocoa-germplasm-utilization-and-conservation/
- Second Phase - Report of the CFC/ICCO/Bioversity project on "Cocoa Productivity and quality improvement: a Participatory Approach" (2004-2010) available at: http://www.bioversityinternational.org/e-library/publications/detail/collaborative-and-participatory-approaches-to-cocoa-variety-improvement/

Following the presentation of the CFCE, a general group discussion made the following points:

- It is essential to keep in mind the current needs of the farmers as well as the longer term needs of the whole cocoa sector in ensuring sustainable cocoa production in a changing environment. The modernization of cocoa farming will require a change to a much more yield-efficient cocoa plant, so that more cocoa can be produced from a given area of land and amount of resources (water, nutrients, etc). Nevertheless, it will be important to maintain diversity in flavor attributes in some planting materials to satisfy the market for specialty cocoas and overall genetic diversity in the planting materials to avoid a monocrop situation with all the risks that entails. Farmers should not bear the burden of maintaining this genetic diversity if it has a negative impact on farm economics and the industry can play an important role in supporting genebanks to conserve this diversity.

- Improvement in yield efficiency will involve gaining a better understanding of the physiology of the cocoa plant and its response to its environment, knowledge of the agronomic and genetic bases of these responses and breeding work to develop and disseminate the improved planting materials. A thorough understanding of seedling establishment and growth/yield under different environmental conditions will also be needed to help breed cocoa varieties capable of performing well in areas affected by local or global climate change. Breeding improved varieties, though essential for the long term sustainability of cocoa production, will take time and there may be information on Good Agricultural Practices (GAP) and planting materials available now that could contribute to addressing immediate issues and improving farmers' profitability in the short-term. It is also important to recognize that there will be regional and even local differences in farming systems (agroforestry vs high density planting, clonal v seedling planting materials etc), including pests and diseases and soil contaminant issues and quality requirements for specific markets. Consequently, priorities and approaches may vary according to region and the current farming systems in place.

To address all these needs, the approach should include multiple partners and be multi-disciplinary, including socio-economic and extension services to help farmers adopt new materials and practices, as well as genetics, pathology, soil science, agronomy, etc and take place over a long-time scale.

It may be a challenge to raise sufficient funding to support such a large all-encompassing project and may be more realistic to narrow the focus and keep in mind the possibilities for linkages with other activities. Various approaches could be envisaged including a large project focused on a specific topic and set of evaluation traits through to a consortium set-up to pool resources and manage smaller projects with a view to achieving a common goal. The importance of building on existing projects and collaborative activities and the need to coordinate with new initiatives was stressed as a way to

maximize use of limited resources. Therefore a status report on existing activities and planned new initiatives is urgently required as the starting point for further development of the CFCE.

Much of the discussion focused on the learnings from the CFC/ICCO/Bioversity projects which were large-scale and including several partner and which had been very successful in improving collaboration between research institutions and had led to the creation of regional breeders working groups for West Africa and Asia-Pacific.

However, several members of the group had also positive experiences of multi-partner initiatives using a consortium approach to strengthen collaboration. This approach had worked well for example for the International Cocoa Genome Sequencing Consortium and the consortia established by the National Science Foundation. Once appropriate rules and criteria have been agreed, this approach could allow a number of smaller projects with a similar focus to benefit from coordination.

One of the challenges is the time-span for projects: cocoa is a perennial tree crop, and thus trials often require more than five years to generate meaningful results. However, it is often very difficult to secure funding for periods longer than three years. Therefore strategies to maximize outputs can take into account:

- Existing facilities (e.g. greenhouse facilities or open-top chambers for climate change studies).
- Existing expertise, tools and research capacities which can be shared with members of the group.
- Existing trials (e.g. CFC/ICCO/Bioversity clonal/regional trials and other breeding trials) which through their design or location (genotypes included, climatic and edaphic conditions etc) offer potential for studies of genotype x environment effects, drought resilience and other physiological studies. However, verification of the identity of materials in the trials through genetic fingerprinting would be needed and consideration given to factors such as competition effects in interpreting results.
- For multi-location trials, genotypes that are already available in multiple countries (after identity verification) or at least already available in the post-quarantine collection.
- Genotypes that have been well characterized, evaluated for at least some traits and/or for which genomic information is available.
- Activities focused on sharing, collating and interpreting existing data (for example, pedigree information, curated phenotypic data, transcriptomic data and improving access through databases etc).

However, at the same time, activities should look to the future and include the following:

- Training and capacity building.
- Investigating traits that have not been the focus of previous studies (including uptake of soil contaminants such as cadmium, yield efficiency, traits associated with resilience to climate change, CSSV etc).
- Establishment of new trials with the genetic composition and design most appropriate for traits to be evaluated.
- Investigating new sources of diversity and under-exploited genetic diversity, especially where there is a serious risk that this diversity will be lost due to de-forestation or replacement of traditional varieties.

4. FEEDBACK ON THE CFC/ICCO/BIOVERSITY PROGRAMME (1998-2010) AND RECOMMENDATIONS

The 2 phases of the programme have been very successful in fostering collaboration and building research capacity in the many research institutes involved. The projects had resulted in the establishment of clonal and regional hybrid trials aimed at sharing varieties with disease resistance. The second phase (2004-2010) included farmer-participatory breeding with on-farm trials and the evaluation of farmers' selections. Research had also been undertaken on developing and using resistance screening methods for diseases including *Phytophthora* Black Pod Rot and those caused by *Moniliophthora spp*. (Witches' Broom and Frosty Pod diseases). Although the project did include some evaluation of physiological characteristics and CSSV resistance, the results obtained were rather limited. Discussion points raised included:

- The importance of trial design appropriate to the traits being evaluated. For example the CFC/ICCO/Bioversity trial designs are not robust enough for physiological studies due to strong competition effects favouring overly vigorous clones at the expense of less vigorous but potentially more yield efficient clones. In other cases, the material included in the trials did not show enough resistance to local disease pressures for good establishment. Although existing trials may give some useful data, it may be necessary to set up new trials to reliably evaluate some traits.
- Further consideration should be given to multi-location trials since these can be useful in determining genotype x environment effects, including performance against multiple strains of diseases for example, but care must be taken that the same genotypes are used and the same methodologies are followed for setting up trials, collecting and analyzing data. Although the CFC/ICCO/Bioversity project established protocols, it is likely that a further review of at least some of these will be needed to ensure they are appropriate, standardized and implemented in the same way in the different institutions
- There is a need for data collection over a long period of time for reliable results. Data collection was terminated in several of the institutes at the end of the CFC/ICCO/Bioversity project when many of the trials were only just coming into bearing. Mechanisms are needed to ensure that trials continue to be maintained and evaluated with ongoing coordination to maximize the outputs.
- The regional breeders groups formed during the CFC/ICCO/Bioversity project have enabled some coordination to be maintained between the institutes but there is potential for more integration of regional breeding efforts and support is needed to ensure that trials are maintained. This has often been lacking and is importa*nt in ensuring continuity.
- There is a need to survey the trials that are still in place and assess the condition and confirm the identity of individual trees, status of data collection and possibilities to commence evaluation of other traits of interest.
- There is a need to consider whether further analysis of existing data may be useful in determining future trial design as well as in identifying promising types for confirmation trials and/or use in further breeding work.
- New materials are available for evaluation such as the USDA clones which were selected for Witches' Broom and Frosty Pod resistance. These are currently passing through the international cocoa quarantine at Reading and will soon be available for those interested in evaluating their response to CSSV.
- Countries which were not involved in the CFC/ICCO/Bioversity project, such as Colombia, have been isolated from the international cocoa breeding community and are now seeking opportunities to collaborate, especially with research institutes in the Latin America region. The institutes are looking

for active involvement of their researchers rather than just supplying genetic resources for analysis elsewhere.

A key recommendation was to have stronger farmers' participatory approaches that would include the following:

- Develop guidelines for participatory plant breeding taking into consideration the diversity used by famers, including the involvement of extension workers and keeping in mind the different markets and consumers.
- Efficient coordination to ensure standard protocols are agreed and used and good quality data collection.
- Increase access to good quality locally adapted planting materials and ensure that strengthen linkages between regions on promising materials through the ICQCR.
- Need to conserve native genetic resources and support *in situ* conservation and participatory approach to use native materials with breeders particularly for specialty cocoas. Local selection could be evaluated in a number of countries for climate change and other priority traits.
- If the results are not in the hand of the farmers, the industry is not going to benefit. But there is a need to increase adoption of materials by farmers. The second phase of the CFC/ICCO/Bioversity Programme had demonstration plots and farmers days.
- Farmers' participatory selection of the most promising local selection adapted to local practices is key and we need to keep in mind that maximizing farmers' income is the ultimate goal. And this may not be only about yield but also maintaining diversity on farms to lower some risks.

Sharing information and knowledge is a key part of any collaborative activity. Issues to consider are how to motivate people to share their data and to maximise the value of shared information. One of the problems historically has been the level of misidentification of germplasm in collections and trials. Efforts are underway at CATIE and CRC to re-analyse the characterisation and evaluation data of the international collections in the light of SNP fingerprinting data to ensure better linkage of data to verified clones. This information will be used to overwrite the existing data in the ICGD (and flagged to show where information has changed). Going forward, the development of a cacao trait ontology with clearly defined standard methodologies will help ensure that data originating from different sources can be interpreted with more confidence. Where new traits are to be measured, including the physiological traits associated with the yield efficiency/abiotic stress resilience, it should be possible to ensure that those participating in multi-location trials are using the same methodologies, providing appropriate capacity is present or developed through training and supply of meteorological and other equipment.

An important next steps is to agree on the overall vision including what cocoa production needs and the direction it should go, taking into consideration the different needs and situations. The goal is to develop the tools for breeding to develop the diversity of planting materials that are needed. Quality and flavour need to be included and not only focusing on productivity.

5. STATUS OF WHERE WE ARE ON THE PRIORITY TRAITS PROPOSED: CLIMATE CHANGE AS AN EXAMPLE

A brief report on the status of research and suggestions for collaboration was put together as a basis for broader discussion and is included in the following Annexes:

- ***Annex F.*** Brief report on Status of Research on Drought / Physiological Attributes – Paul Hadley, Andrew Daymond, Fiona Lahive, University of Reading, UK
- ***Annex G.*** Brief Report on Status of Research for Black Pod - Bryan A. Bailey, Sustainable Perennial Crops Laboratory, USDA/ARS, Beltsville, Maryland, USA
- ***Annex H.*** Brief report on Status of Research on Cadmium bioaccumulation levels – Path Umaharan, CRC, Trinidad and Tobago
- ***Annex I.*** Brief report on Status of Research on Frosty Pod - Wilbert Phillips, CATIE, Costa Rica
- ***Annex J.*** Brief report on Status of Research on CSSV - Andy Wetten, University of Reading, UK

NOTE: These draft proposals were put together for the purpose of broader discussion during the workshop and do not constitute final proposals. CacaoNet/INGENIC is grateful to the people listed above for having taken the time to do this at a short notice in order to guide the group discussions.

In the interest of time, one global topic was proposed for more in-depth discussion – climate change adaptation and focus on drought and physiological attributes. Paul Hadley introduced the topic and status which includes the following:

<u>The most significant advances in recent years</u>

- The Reading Cocoa Groups are currently completing a five year programme to study the impact of climate change on contrasting clonal genotypes. The outputs of this project include quantitative response on vegetative and reproductive growth of contrasting cocoa genotypes to combined effects of changes in long-term water status and elevated carbon dioxide.
- The groups are also surveying the materials held in the International Cocoa Quarantine Centre, University of for key physiological attributes associated with yield efficiency and resilience to abiotic stress.
- INDIA- Drought resistance traits incorporated into breeding/ selection work
- Dos Santos *et al*[2] paper

<u>Proposed focus of research for the next 3-5 years</u>

- Linking physiological phenotypic measurements with gene expression studies e.g. those reported by Dos Santos et al.
- Collaborative research using multi-location trials in cocoa growing countries under contrasting environmental and management conditions to evaluate the growth, development and yield of a subset of elite cocoa genotypes available at ICQC,R. The focus of this research would be to identify an Ideotype for high yielding cocoa based on physiological attributes e.g. high assimilate rates, water use efficiency, yield partitioning. A secondary focus will be to screen for drought tolerance particularly in relation to plant establishment

[2] *Santos dos, I.C., Anhert, D., Conceicaoda, A.S., Pirovani, C.P., Pires, J.L., Valle, R.R., Baligar, V.C., Almeidade, F.A. 2014. Molecular, physiological and biochemical responses of Theobroma cacao L. genotypes to drought. PLoS One. 9(12):e115746. DOI:10.1371/journal.pone.0115746.*

- The establishment of a multisite open top chamber system to study climate change variables in cocoa growing countries.
- Below ground studies on root architecture to improve understanding of tolerance to water stress/flooding.
- Studies on the amelioration of climatic extremes through shade management.
- Use of rootstocks for improved performance and yield, including under environmental stresses.

Proposed specific research questions to be addressed

- What are the traits that underlie drought tolerance?
- What is the genetic variation in tolerance to high temperature stress?
- Which physiological traits are associated with high yield efficiency (harvest index)?
- Building our knowledge base on the effects of climate change variables on yield determinants

Any other information that may be useful to share with the research group

- Need to agree a set of traits to measure for adaptability to abiotic stresses and future climates, such as photosynthetic responses, stomatal regulation and water use efficiency.

The key research partners in this area

- The University of Reading has a long history of studying physiological attributes in cocoa.
- Facilities include a large, 6 compartment greenhouse specifically designed for research on the environmental physiology of cocoa in general and specifically climate change.
- The facilities enable long-term responses of pod bearing cocoa trees to carbon dioxide, temperature, water availability and nutrient status.
- The group also has access to the Crops and Environment Laboratory which includes 32 controlled environment growth cabinets and walk-in rooms.
- The International Cocoa Quarantine Centre (ICQC,R) is also based at Reading and includes over 400 accessions maintained under closely controlled environmental conditions which are being evaluated for physiological characteristics including light saturated photosynthetic rate, stomatal conductance and intrinsic water use efficiency.

Other key research partners with interest in studying drought/physiological attributes include:

- Brasil - CEPLAC
- Colombia - CORPOICA
- CORAF funded programme in Cote d'Ivoire, Ghana and Cameroun – completed now
- Cote d'Ivoire - CNRA
- Ecuador INIAP
- France - CIRAD
- Ghana CRIG,
- India - CPCRI
- Indonesia ICCRI,
- MARS, Brazil and Indonesia
- Mondelez
- Nestle, Tours France
- Nigeria CRIN,
- Peru
- Trinidad and Tobago - Cocoa Research Centre, University of West Indies
- USDA-ARS

Group Discussion and Proposed Actions

Although Paul Hadley had been asked to consider "Climate Change" as the focus, the traits to be evaluated are associated with yield efficiency and abiotic stress tolerance which are just as relevant for current production, especially in cocoa producing areas already experiencing challenging conditions for establishing cocoa and prolonged dry seasons, or prolonged flooding, due to local changes to climate.

Studies on the effects of environment on the three phases of growth (establishment, time to flowering and yield partitioning) should be considered.

Trials design needs careful consideration to avoid compounding effects of plant size on results. For example, pot-based experiments using a simple water-regime to induce water-stress favour smaller plants which will not use the water supplied as quickly as larger ones. Rain shelter approaches can be used successfully to study drought resilience in cocoa-producing countries.

It would be important to link studies of physiological traits and crop modelling with a genomic approach to develop and share the markers needed for accelerated breeding

A phenotyping platform approach, as used to screen for drought tolerance for a number of other crops at CIRAD-Agropolis Montpellier, was mentioned as a good way to generate data though it would be expensive to establish.

It may also be possible to use existing trials established in drier regions to generate some useful data. A number of possible trial sites were mentioned including experimental sites and commercial farms in Brazil, Cameroun and Ecuador. However, it was noted that commercial farms are likely to be unwilling to restrict irrigation if there is a risk to their production. Sites where high shade levels are being maintained with a view to mitigating occasional drought conditions due to La Nina in Indonesia could provide useful sources of data. There could also be useful data collection for example in areas of the international cocoa collection at CRC-Trinidad affected by occasional drought.

It was suggested to collect complement data from existing trials in the short-term, with more tailored data which would be generated over the longer-term by new trials with an appropriate design and composition. New trials could target evaluation of clones already known for their yield performance and other materials which have contrasting water-use efficiency characteristics.

Many tree crops use rootstocks to improve yield efficiency and/or stress resilience but little work has been done on this area for cocoa. Preliminary studies indicate a rootstock x scion effect on establishment ability and a PhD is underway to study rootstock effects at the University of Florida. Further trials to investigate rootstock/scion effects on stress resilience and yield efficiency may generate useful information. There is also interest in looking for rootstocks that could reduce uptake of cadmium from soils whilst maintaining the quality attributes of the scion.

Expeditions targeted at collecting materials along rain gradients and from farmers' fields established in areas with unusual climatic conditions might be an interesting way to conserve materials with adaptations to different environments.

In addition to the longer-term research towards improved varieties, it is important to also consider measures that farmers could implement now to improve stress resilience including mulching and appropriate shading.

The Regional Breeders Groups are important platforms for sharing knowledge, data and materials. Common tools and protocols need to be developed including models to understand the yield component impacted by climate change.

It may be useful to look at how other crops such as mango and citrus are managing these aspects of research. And there may be a need to define "drought-tolerance" in cacao, considering this is a humid-tropic crop.

There are a lot of activities going on and there are short-term answers and questions for long-term research. The first step is to agree on the goal proposed which is to continue to grow cocoa in the marginal areas where it is growing now and to have an interdisciplinary approach.

6. SETTING UP A RESEARCH FUND FOR CACAO GENETIC RESOURCES AND BREEDING

The group discussed the approach of getting the work done and proposed to look into the development of a long-term research fund for cacao genetic resources and breeding. This fund could invite proposals for competitive grants.

A Consortium Advisory Committee could coordinate the network of researchers (CacaoNet and the IN-Groups) and support the sharing of knowledge, expertise, information, tools and technologies. There are consortium models to support research for other crops such as citrus, pine and sugar cane. In the latter case the industry supports biotechnology research via a fund generated from a 3% check-off collected from producers of the commodity programme. Others, such as the National Science Foundation (NSF) are funded by a mix of private and public funds.

Mechanisms would be needed to ensure that the call for proposals is accompanied by appropriate guidance and support, so that it does unduly favour organisations which already have the capacity to develop good proposals. Moreover, the Consortium would define criteria to select proposals, possibly limiting the number of projects awarded to any specific institute.

The ICCO is considering possible mechanisms to generate a Fund to support sustainable cocoa. The recent World Cocoa Conference[3] in DR however concluded that it is still too early to decide on the establishment of a Cocoa Sustainability Fund. Further investigation is needed into the priority purpose of such a Fund, based on the objectives of the Global Cocoa Agenda. It has to be decided whether a new Fund – as opposed to intensifying the use of existing financing mechanisms – would be an appropriate and feasible mechanism to meet the identified needs. The ICCO Consultative Board should decide at the meeting in spring 2017 whether a Fund is appropriate and feasible. If affirmative, the Board should set the next World Cocoa Conference in March 2018 as the deadline for designing the Fund.

In the absence of a large fund for cocoa research, it was suggested that funds should be sought at least to strengthen current networks and coordination. It is important not to lose sight of the immediate goal which is how best to exploit and add value to cacao genetic resources to support farmers and widen the genetic base for breeding.

[3] *The information is from the Bavaro Declaration of the closing session of the 3rd World Cocoa Conference in Bavaro, Dominican Republic.*

7. NEXT STEPS AND AGREED ACTIONS

The following activities are proposed as next steps in moving forward with the CFCE concept:

- Carry out an inventory of who is doing what in the proposed priority areas (existing activities and planned new initiatives). This should include a status report on the CFC/ICCO/Bioversity trials in each of the project partner countries (what is still in place and assessment of conditions for continued evaluation). This process will clarify the priorities and possibilities for the immediate next steps. This could include preparatory work towards agreement on the establishment of new trials, methodologies, standards and models.
- Develop a 6-month workplan including inviting proposals from interested partners to better define specific collaborative research.
- Review the approach for the funding mechanism and the options of one programme vs a collection of projects under a global consortium.

Bioversity International on behalf of CacaoNet will coordinate the development of the proposal, contact the research community and discuss with potential donors.

ANNEX A. COLLABORATIVE FRAMEWORK FOR CACAO EVALUATION (CFCE) – IN BRIEF – DRAFT *DATED 21 MAY 2016*

Title: Collaborative Framework for Cacao Evaluation (CFCE): ***Increasing Value of Diversity through International Evaluations***

Timeframe: A first Phase of 5 years from January 2017 to December 2021 is proposed. The aim to establish a Collaborative Framework of on-going research on cocoa quality and productivity with subsequent phases of 5 years, addressing specific issues, building on the tool, methods and standards developed as part of the first Phase.

Goal: Increased sustainable cocoa productivity and quality by optimizing the use of the genetic diversity in the development of improved, diverse and locally-adapted cocoa varieties through international collaboration, bringing together key players in the public and private sectors.

Purpose: Understand the value of cacao diversity through its further research, characterisation and support global, regional and national evaluations. The Collaborative Framework for Cocoa is about solving today's problems via vis priority diseases in each producing region, soil contaminants and climate resilience, and building a framework for global collaboration for the future.

Scope: The Collaborative Framework will focus on adding value to the existing cacao diversity to facilitate use in breeding. The scope would start with the information and genetic resources that are currently available in the 2 international collections at CATIE and CRC/UWI and at the International Cocoa Quarantine Centre at Reading (ICQCR) and those available for research in the national collections. It will enable new germplasm that is currently available to feed into national programmes. Materials from countries with diversity would be screened to generate knowledge and possibly transferred based on specific agreements specifying conditions and restrictions. This will enable the selection and breeding activities and reaching farmers which is outside of the scope of the Collaborative Framework. The Collaborative Framework however acknowledges that providing support to some urgent collecting of threatened materials of priority for screening and support to some initial breeding may provide incentives for some partners to participate. But generally speaking the scope would focus on understanding the current diversity available and useful for supporting the breeding efforts.

Outputs:

- Identification and screening of materials with potential for Climate Change adaptation – with focus on drought (water stress) and high temperature tolerance.
- Identification and screening of materials with potential resistance for pests and diseases – with focus on:
  - Black Pod (BP) (global issue)
  - Witches Broom disease (WBD) and Frosty Pod (FP) (Latin America)
  - Vascular Streak Dieback (VSD) (Asia and Pacific) and Pod Borer (PB)
  - Cocoa Swollen Shoot Virus (CSSV) (Africa)
- Identification and screening of materials for uptake of soil contaminants and nutrients – with focus on cadmium.
- And the following cross-cutting outputs setting up the global and regional frameworks
  - Agreed common tool, methods and standards for screening and evaluating traits
  - Bioinformatics tools to provide access to trait information for selection of germplasm for breeding
  - International and regional safe-movement of cacao germplasm to support research and evaluation
  - Evaluation of locally-adapted and quality germplasm evaluated in a range of environments
  - Policy and legal frameworks agreed for the sharing of specific materials

- Collaborative Framework / Programme Coordination for addressing research priority and global and regional collaboration over the long-term

Linkages: The Collaborative Framework is building on past and current complementary initiatives such as the Climate Smart Cocoa Initiative of the WCF, the Climate Smart Agriculture (CSA) work with CIAT and others, CocoaAction, the Cocoa Africa Initiative and its new phase (Plant, Services and Performance – PSP), ICCO and the Global Cocoa Agenda etc.

It uses the model of the 2 phases of the CFC/ICCO/Bioversity programme from 1998-2010, building on what worked well and also the many lessons learnt. And the working procedures for cocoa germplasm evaluation and selection, developed in 1998, proceedings of the CFC/ICCO/IPGRI Project Workshop, 1-6 February 1998, Montpellier, France.

Proposed Partnerships: The following key institutes are invited to partner in the Collaborative Framework *(indicative list to be completed*):

1. Bioversity International – Coordinator of the Global Network for Cacao Genetic Resources - CacaoNet
2. Barry Callebaut, Switzerland
3. Brazil – CEPEC-CEPLAC - Comissão Executiva do Plano da Lavoura Cacaueira/Centro de Pesquisas do Cacau
4. Cargill
5. CATIE - Centro Agronómico Tropical de Investigación y Enseñanza - International cocoa collection, Costa Rica
6. CCAFS - CGIAR Research Program on Climate Change, Agriculture and Food Security
7. CIAT - International Center for Tropical Agriculture, Colombia
8. CIRAD – Centre de coopération internationale en recherche agronomique pour le développement
9. Cocoa Research Association, Uk Ltd (CRA)
10. Colombia – CasaLucker
11. Colombia - CORPOICA - Corporación Colombiana de Investigación Agropecuaria
12. Colombia – FEDECACAO - Federacion Nacional de Cacaoteros de Colombia
13. Cote d'Ivoire – CNRA - Centre national de recherche agronomique
14. Cote d'Ivoire –CCC - Conseil Café Cacao
15. CRC/UWI – the Cocoa Research Centre of the University of the West Indies - International cocoa collection
16. ECOM Agrotrade Limited
17. Ecuador – INIAP - Instituto Nacional Autónomo de Investigaciones Agropecuarias
18. European Industry Cocoa Research Outreach Group: European Cocoa Association (ECA), Association of the Chocolate, Biscuits and Confectionery Industries of Europe (CAOBISCO), and the Federation of Cocoa Commerce Limited (FCC)
19. Ferrero
20. Ghana – CRIG - Cocoa Research Institute of Ghana - CocoBod
21. Hershey Company
22. Honduras – FHIA – Fundación Hondureña de Investigación Agrícola
23. ICCO – International Cocoa Organization
24. ICQCR, The International Cocoa Quarantine Centre, Reading University, UK
25. IDH, Netherlands
26. Indonesia - ICRRI - Indonesian Cocoa and Coffee Research Institute
27. INGENIC – International Group for Genetic Improvement of Cocoa
28. IT-PGRFA - International Treaty on Plant Genetic Resources for Food and Agriculture
29. Malaysia – MCB - Malaysian Cocoa Board
30. Mars Global Chocolate
31. Mondelez International
32. Nestle
33. Penn State University
34. Peru – INIA - Instituto Nacional de Innovación Agraria
35. Peru – ITC - Instituto de Cultivos Tropicales
36. Peru – La Cooperativa Agraria Norandino
37. Peru – UNAS - Universidad Nacional Agraria de la Selva
38. Peru – UNSAAC - Universidad Nacional de San Antonio Abad del Cuzco
39. USAID - United States Agency for International Development
40. USDA/ARS – United States Department of Agriculture, Agricultural Research Service, Tropical Agriculture Research Station, Beltsville, Miami and Puerto Rico
41. WCF – World Cocoa Foundation, Washington

ANNEX B. LIST OF WORKSHOP PARTICIPANTS

Participants	Organization	Email Address
1. Agung Wahyu Susilo	ICCRI, Indonesia	soesiloiccri@yahoo.com
2. Albert Ling	Malaysian Cocoa Board	albert@koko.gov.my
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4. Andrew Daymond	ICQC,R, UK	a.j.daymond@READING.AC.UK
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47. Tom Adkins	TreeGlobal, New York, USA	tom.adkins@treeglobal.com
48. Uilson Lopes	CEPLAC, Brazil	uvlopesbr@gmail.com
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ANNEX C. PRE-COMPETITIVE GUIDELINES

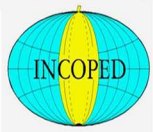
- The Workshop on the Development of the Collaborative Framework for Cacao Evaluation (CFCE), held at Penn Stater Hotel 3rd June 2016, has the objectives to discuss and critically review the proposed concept and deliverables of the CFCE.
- The Participants invited are from the range of stakeholders including representatives of national and international research organisations, the cocoa industry and trade associations.
- While the goal of the Consultation will be to encourage a free and inventive discussion in relation to the Consultation Objectives, for the avoidance of doubt, all Participants will at all times refrain from discussing any information which is confidential to their company and/or which is likely to affect the commercial strategy or activities of their company. The participants are in the best position to judge what is, and what is not, commercially sensitive or confidential and so responsibility lies with the Participants in the first place.
- Failure to follow these guidelines may bring with it serious consequences for the Participants as individuals, the companies and the trade associations.
- The results of the Consultation will be put into the public domain via the revision of the CFCE concept note and circulation to partners and potential funders.
- The Consultation will be chaired and facilitated by Bioversity International.

ANNEX D. INCOCOA - INTERNATIONAL COCOA RESEARCH GROUPS UPDATES – PRESENTATION BY MICHELLE END

- Informal groups with a common interest in aspects of cocoa research
- Workshops to coincide with COPAL International Cocoa Research Conferences
- Working Groups, websites and email lists to promote sharing of information and collaborative activities
- Some support and in-kind contributions from industry, research institutions, and other sponsors allow secretariats to function and to support workshops

www.incocoa.org

The International Group for the Genetic Improvement of Cocoa



The International Permanent Working Group for Cocoa Pests and Diseases

Sustainable Cocoa Production in Agroforestry Systems

<u>Status Update – New "IN" groups</u>

- New group "INCOSOM" for soil management forming following discussions at Asia Pacific Regional Workshop held in Philippines Oct 2015
- Developing mailing list
- Workshop planned
- Possibilities for links to new quality group

<u>Status Update - Communications</u>

- Improving Communications: Chris Turnbull/ME continuing to work on website/email lists
- Areas of interest include:
    - Sub-sections/password protected access to pages for working groups to share data etc
    - Improved literature search capabilities: links to other sources of cocoa information, possibilities to improve access to "grey" literature (conference and workshop proceedings, annual/internal reports etc)
    - Updates to mailing lists – adding new contacts and developing system to allow users to choose which groups to subscribe to
    - Possibilities for other social media

… More suggestions welcome!

<u>Status Update – International Research Conference</u>

- Strong interest from secretariats of INCOCOA groups in opportunities for an international conference in absence of COPAL ICRC
- Excellent news that ICCO planning to address this need
- Possible role for INCOCOA groups in helping planning, and depending on proposed format, possibilities for workshops

ANNEX E. CFCE BACKGROUND PRESENTATION BY BRIGITTE LALIBERTÉ

Improved Planting Materials of good Quality, Yield and Diverse Flavours
Tapping Cacao Diversity for Farmers, Manufacturers and Consumers
Presentation by Brigitte Laliberté, 3rd June 2016, Penn State, USA

What is needed?

- Farmers' access to good planting materials as part of a package of measures to increase productivity and improve overall economy of their farms.

How?

- Replace ageing trees with high-yielding and disease-resistant planting materials.
- Superior planting materials incorporating flavour traits to gain higher premiums.
- Increasing productivity

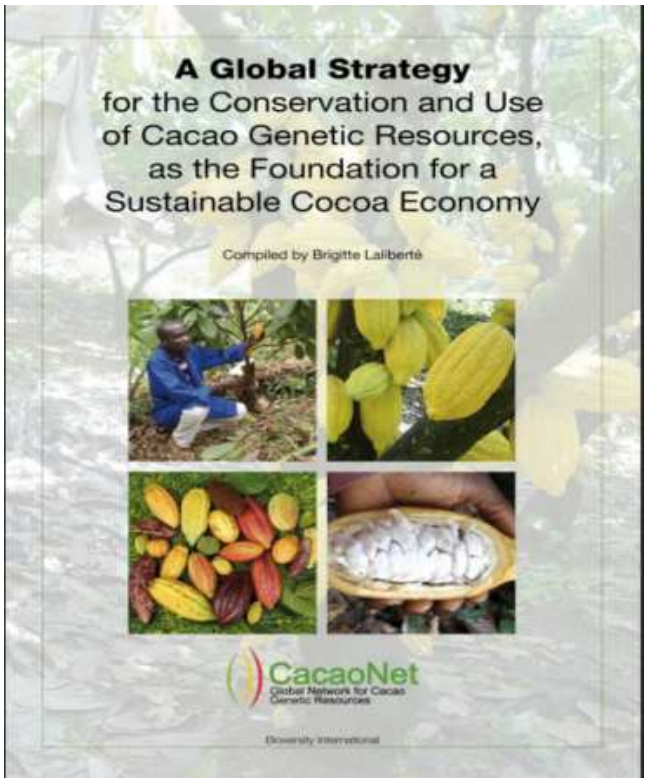
Several ways of increasing cocoa productivity and quality to benefit farmers' livelihoods and ensure consumers continue to enjoy cocoa products:

- Good agricultural practices (GAP) to realise the full potential of the materials currently grown – in specific sites and climates – including post harvest processes.
- Production in the most optimum agroforestry systems to ensure sustainable income for the farmers and his/her family.
- Growing the optimum planting materials (or combination of) for the farm's environmental and soil conditions and tailoring the country/region market opportunity.

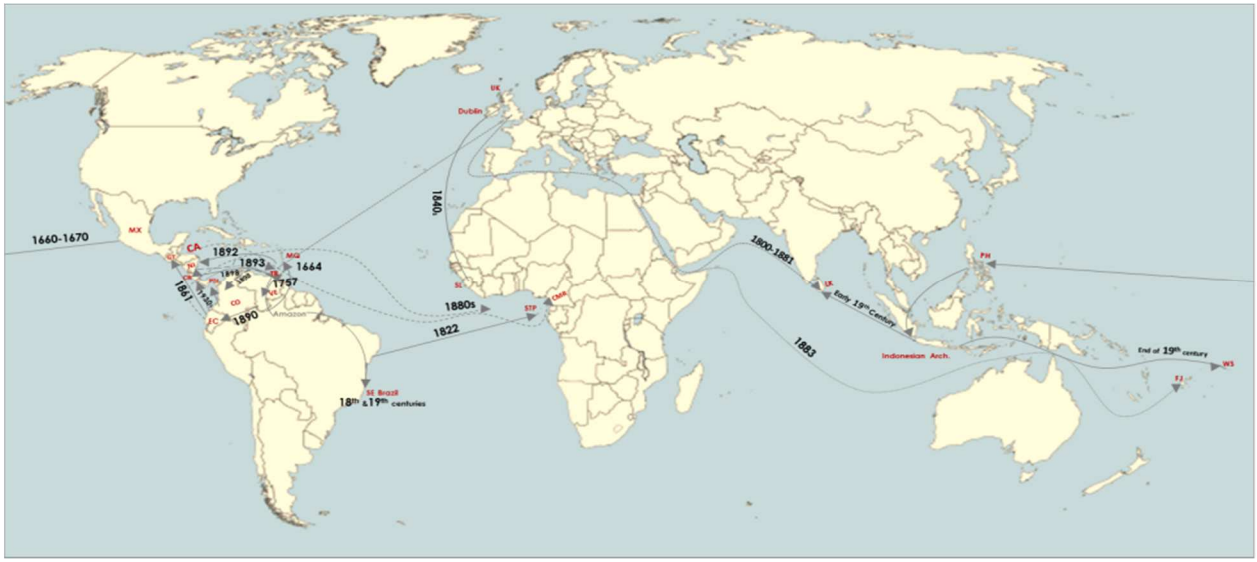
How can this be done?

Global Strategy for the Conservation and Use of Cacao Genetic Resources - Finalised in October 2012

- Result of a consultation process, drawing upon the global cocoa community's expertise in all aspects of cacao genetic resources
- Over 75 individuals from 26 institutes contributed
- Framework to secure funding for the most urgent needs to ensure that cacao diversity provides direct benefits to the millions of small-scale farmers around the world.
- Detailed and booklet versions available for download at: www.cacaonet.org



The Cocoa Route – how it moved around the world – Ref. Bartley 2005



- 1660-1670 - Mexico to the Philippines
- 1664 - Amazon to Martinique
- Philippines to Indonesian Archipelago
- 1757 - Amazon to Trinidad
- Early 19th century - Indonesian Archipelago to Ceylon
- 18th &19th centuries - Amazon to Southeastern Brazil
- 1822 - Brazil to Principe
- 1840s - Dublin to Sierra Leone
- 1861 - Ecuador to Guatemala
- 1880-1881 - Trinidad (via England) to Sri Lanka
- 1883 - Trinidad (via England) to Fiji
- 1892-1893 - Trinidad to Nicaragua. Nicaragua to Trinidad.
- 1898 - Trinidad to Costa Rica and Colombia
- 1890 - Venezuela to Ecuador
- 1930s - Ecuador to Costa Rica and Panama
- 1880s - Trinidad, Venezuela and Ecuador to Sao Tome
- 1899 - Trinidad, Venezuela, Ecuador and Central America to Cameroon
- End of 19th century - Indonesian Archipelago to Samoa

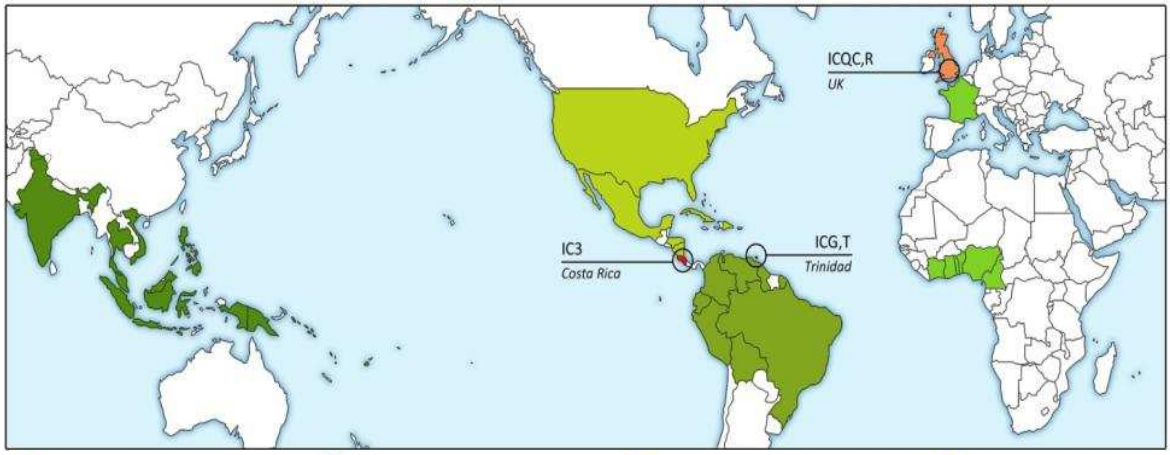
How to increase the exchange of diversity?

- A range of cacao genetic diversity is maintained in national and international genebanks
- Access is restricted by the lack of clear institutional legal and policy frameworks for exchange of materials or pest and diseases affecting its safe movement.
- Issues of access and benefit-sharing, security of the material and ownership of collections are the subject of continuing debate.

Policy and Legal Frameworks impacting on cacao

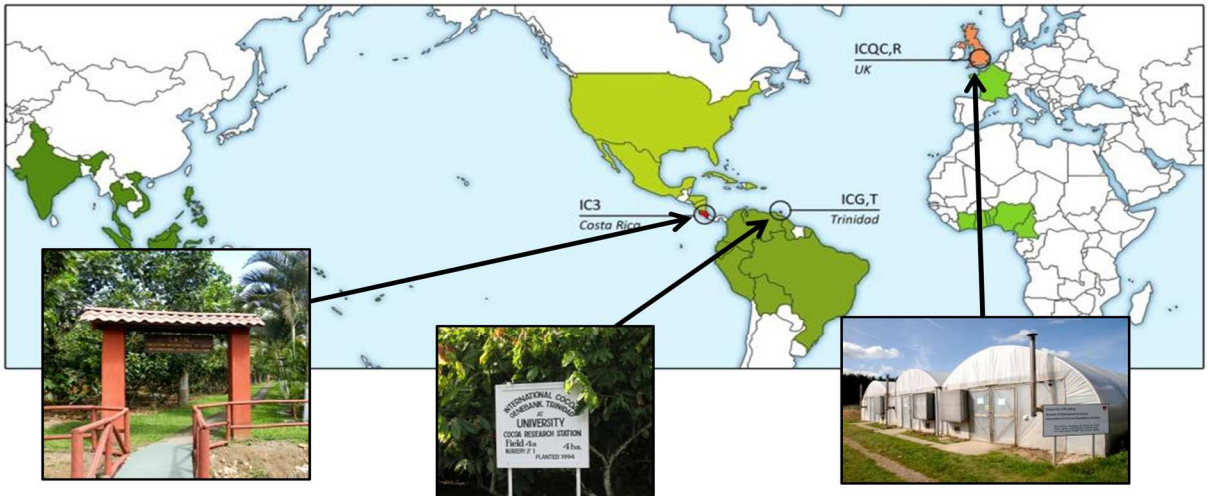
- Convention on Biological Diversity – CBD – 1992 – nations are sovereign on providing access and sharing biological resources within their boundaries
- International Treaty on Plant Genetic Resources for Food and Agriculture – ITPGRFA - 2004
- Nagoya Protocol (CBD) - Access to Genetic Resources and Fair and Equitable Sharing of Benefits – 2014
- More information – report of CacaoNet Consultation on policy for exchange of cacao genetic resource - 2015

Where is cacao diversity conserved?



Fiji	Dobuilevu	*Costa Rica*	IC3 (International)	*Bolivia*	El Ceibo Cooperative	*Benin*	CRA-SB
India	CPCRI	*Cuba*	EIC-ECICC	*Brazil*	CEPEC	*Cameroon*	IRAD
Indonesia	Bah Lias	*Dominican Republic*	IDIAF		SUEPA	*Côte d'Ivoire*	CNRA
	ICCRI	*Honduras*	FHIA		SUERO	*Ghana*	CRIG
Malaysia	MCB	*Mexico*	INIFAP		ICA	*Nigeria*	CRIN
Papua New Guinea	PNGCCI	*Nicaragua*	UNAN	*Colombia*	*ICA*	*Togo*	CRAF
Philippines	USMARC/PICRI	*Trinidad & Tobago*	ICG,T (International)	*Ecuador*	*CORPOICA*		
Solomon Islands	BPCU	*USA*	USDA	*French Guiana*	INIAP	*France*	CIRAD
Thailand	Chumphon			*Guyana*	CIRAD	*UK*	ICQC,R (Quarantine)
Vanuatu	VARTC			*Peru*	MHOCGA		
Vietnam	Nong Lam University				CEPICAFE		
					ICT		
					UNAS		
					UNSA		
				Venezuela	INIA		

How it is safely exchanged?



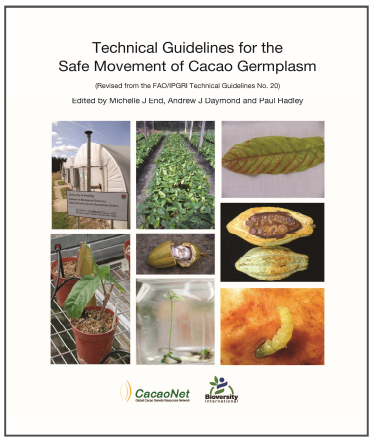
Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica

Cocoa Research Centre of the University of the West Indies (CRC/UWI), Trinidad and Tobago

International Cocoa Quarantine Centre (ICQC), UK

Sharing Genetic Resources

Guidelines for the Safe Movement of Cacao Germplasm – 2014 – available in English, French and Spanish from www.cacaonet.org



- Legal and Policy expertise in the fair and equitable sharing of genetic resources
  - International Treaty for Plant Genetic Resources for Food and Agriculture
  - Convention on Biological Diversity – Nagoya Protocol

What is the recommendation?

- International collaboration bringing key players in the public and private sectors to increase value of cacao diversity and optimize use in development of improved, diverse and locally-adapted cocoa varieties
- The international services of CATIE, CRC and ICQCR have to be optimised and contributing strategically to the materials research today, for the breeding pipeline producing the cocoa of tomorrow.
- Building on and learning from previous and current initiatives, assessing what worked and did not work
- Develop a Collaborative Framework for Cacao Evaluation – where each partner defines what they are interesting in getting out of the collaboration and what they are willing to put in and contribute.
- Stimulate, facilitate and support on-going and future breeding efforts.

Collaborative Framework for Cacao Evaluation - CFCE

- Each partner defines what they are interesting in getting out and willing to put in.
- Stimulate, facilitate and support on-going and future breeding efforts.

Goal - Optimize the use of cacao genetic diversity in development of improved, diverse and locally-adapted varieties through international collaboration, bringing together players in public and private sectors.

Outputs – focus on traits for:

- Climate Change adaptation – drought (water stress) and temperature,
- BP (global), WBD and FP (Latin America), VSD and PB (Asia and Pacific), CSSV (Africa)
- Low uptake of soil contaminants - cadmium

Cross-cutting components:

- Identification and screening of potentially resistant materials
- Agreed common tool, methods and standards
- International and regional safe-movement
- Policy and legal frameworks agreed for the sharing of specific materials
- Evaluation of promising germplasm in a range of environments
- Efficient Collaborative Framework

Key Linkages

- It builds on the experience of the CFC/ICCO/Bioversity programme from 1998-2010 (2 phases), what worked well and lessons learnt.

    - First Phase - CFC/ICCO/IPGRI project on "Cocoa Germplasm Utilization and Conservation: a Global Approach" (1998-2004)
    - Second Phase - CFC/ICCO/Bioversity project on “Cocoa Productivity and quality improvement: a Participatory Approach” (2004-2010)

- Building on complementary initiatives such as: Climate Smart Agriculture (CSA) work with CIAT and others, CocoaAction, the Cocoa Africa Initiative and its new phase (CIRCLE), WCF, ICCO etc.

Summary circulated widely

- Bioversity, Costa Rica-Brigitte Laliberté, Allison Smith, Dietmar Stoian, Evert Thomas, Maarten van Zonneveld, Stephan Weise
- Barry Callebaut, Switzerland-Cinzia Anselmi and Lachlan Monsbourgh
- Bean and Co. – Johann Dahan
- ECA/Caobisco/FCC-Catherine Entzminger, Paula Byrne
- CATIE, Costa Rica-Wilbert Philips
- CEPLAC, Brazil-Uilson Lopes
- CIRAD, France-Selim Louafi, Philippe Bastide, Claire Lanaud
- CNRA, Cote d’Ivoire-Adiko Amoncho, Mathias Tahi, Désiré Pokou and Louise,
- CocoBod, CRIG, Ghana-Gilbert Anim Kwapong, Francis Padi, Stephan Opoku, Francis Oppong
- CRA Ltd, UK-Michelle End
- CRC, Trinidad and Tobago-Path Umaharan
- EuropeAid – Roberto Ridolfi
- ICCO – Laurent Pipitone
- ICCRI - Indonesia-Agung Wahyu Susilo
- ICQC,R, UK-Paul Hadley, Andrew Daymond
- International Fund for Agriculture Development – IFAD – Wafaa El Khrouy
- Lutheran World Relief LWR), Nicaragua-Jenny Wiegel
- Mars, UK-Martin Gilmour
- Mondelez International, UK-Nicholas Cryer
- Nestlé, Tours, France-Pierre Broun, Anne Buchwalder
- Penn State University, USDA-Mark Guiltinan and Siela Maximova
- Peru - ICT-Enrique Arevalo
- Peru - MINAGRI-Carmen Chavez
- Peru - UNAS-Luis García Carrión / Rolando Rios
- Tree Global-Greg Hess
- University of Arizona, USA-Judith Brown
- USAID – Jay Daniliuk
- USDA, Beltsville-Peter Bretting, Dapeng Zhang, Lyndel Meinhardt, Osman Gutierrez, Ricardo Goenaga
- WCF, Washing to-Virginia Sopyla

Feedback Received

- Very supportive – particularly the national research programmes from producing countries
- Aligned with current research efforts
- Need to build on what is currently being done – carry out an inventory
- Need to learn the lessons from CFC/ICCO/Bioversity – particularly regarding the multi-site evaluation of a set of clones
- Climate Change – URGENT - Lack of research on traits related to adaptation – drought and temperature – this topic can federate all the partners
- Priority on phenotypic characterisation of the core set of genotypes representing the diversity of *T. cacao* for all priority traits – including quality
- Need to carry out an inventory of who is working on what and what is the current status of research and key questions to be addressed

Main Concerns - Scope

- Should it include multi-site field evaluation trials?
- Is it mainly about supporting breeding efforts?
- Should it support the use of diversity directly to farmers’ fields?
- How to directly link with delivery mechanism to farmers – seed systems?
    - E.g. For CSSV – CocoaAction can be the mechanism for application and CFCE the mechanism for screening and facilitating access to genetic diversity

Cacao Genetic Resources Research Community

- Social Network Analysis – Selim Louafi CIRAD and Andrew Meter, UMR AGAP, Montpellier, France
- Survey of current and past collaboration critical to support long-term efforts.
- All are asked to complete the survey that will be sent out by Selim Louafi in the coming weeks.

Steps and Timeframes

- February-March 2016 – Involvement of partners and donors in the development of the Concept Note
- End of April 2016 - Draft Concept Note revised with input from partners
- Early May 2016 – Consultation with key investors
- End of May 2016 - Presentation at the third World Cocoa Conference in the Dominican Republic, 22-26 May 2016
- 3rd June - Consultation at the Cocoa Research Symposium, Penn State University, 31 May – 3 June 2016 – 40 participants
- June-July 2016 – Develop a 6-month workplan to establish the workpackages's teams and plans and specific consultations
- June to October 2016 – Revised concept note for submission to specific donors and calls and Secure funding
- 2017 – Start Collaborative Framework implementation – first phase of 5 years

ANNEX F. BRIEF REPORT ON STATUS OF RESEARCH ON DROUGHT / PHYSIOLOGICAL ATTRIBUTES

Drought/physiological attributes - Paul Hadley, Andrew Daymond, Fiona Lahive, University of Reading, UK

***NOTE**: draft proposal put together for the purpose of broader discussion during the workshop and does not constitute a final proposal.*

With the aim of improving the development of improved planting materials for cacao farmers in the coming years:

1. Who are the key research partners in this area?

The University of Reading has a long history of studying physiological attributes in cocoa. Facilities include a large, 6 compartment greenhouse specifically designed for research on the environmental physiology of cocoa in general and specifically climate change. The facilities enable long-term responses of pod bearing cocoa trees to carbon dioxide, temperature, water availability and nutrient status. The group also has access to the Crops and Environment Laboratory which includes 32 controlled environment growth cabinets and walk-in rooms. The International Cocoa Quarantine Centre (ICQC,R) is also based at Reading and includes over 400 accessions maintained under closely controlled environmental conditions which are being evaluated for physiological characteristics including light saturated photosynthetic rate, stomatal conductance and intrinsic water use efficiency.

Other key research partners with interest in studying drought/physiological attributes include:

- Cocoa Research Centre, University of West Indies.
- CEPLAC, Brazil
- ICCRI, Indonesia
- USDA-ARS
- MARS, Brazil and Indonesia
- Nestle, Tours France
- Modelez
- CRIG, Ghana
- CRIN, Nigeria
- CPCRI, India
- CNRA, Cote d'Ivoire
- CORAF funded programme in CI, Ghana and Cameroun – completed now
- CIRAD
- CORPOICA
- INIAP Ecuador
- Brazil
- Peru – north

2. What have been the most significant advances in recent years?

- The Reading Cocoa Groups are currently completing a five year programme to study the impact of climate change on contrasting clonal genotypes. The outputs of this project include quantitative response on vegetative and reproductive growth of contrasting cocoa genotypes to combined effects of changes in long-term water status and elevated carbon dioxide.
- The groups are also surveying the Reading Cocoa Quarantine Collection for key physiological attributes.
- INDIA- Drought resistance traits incorporated into breeding/ selection work
  - Dos Santos paper

3. Where is or might be the focus of research for the next 3-5 years?

- Linking physiological phenotypic measurements with gene expression studies e.g. those reported by Dos Santos

- Collaborative research using multi-locational trials in cocoa growing countries under contrasting environmental and management conditions to evaluate the growth, development and yield of a subset of elite cocoa genotypes available at ICQC,R. The focus of this research would be to identify an ideotype for high yielding cocoa based on physiological attributes e.g. high assimilate rates, water use efficiency, yield partitioning. A secondary focus will be to screen for drought tolerance particularly in relation to plant establishment
- The establishment of a multisite open top chamber system to study climate change variables in cocoa growing countries.
- Below ground studies on root architecture to improve understanding of tolerance to water stress/flooding.
- Studies on the amelioration of climatic extremes through shade management.
- Use of rootstocks for improved performance and yield, including under environmental stresses.

4. What are the specific research questions to be addressed?

- What are the traits that underlie drought tolerance?
- What is the genetic variation in tolerance to high temperature stress?
- Which physiological traits are associated with high yield efficiency (harvest index)?
- Building our knowledge base on the effects of climate change variables on yield determinants

5. Any other information that may be useful to share with the research group

Need to agree a set of traits to measure for adaptability to abiotic stresses and future climates, such as photosynthetic responses, stomatal regulation and water use efficiency.

ANNEX G. BRIEF REPORT ON STATUS OF RESEARCH FOR BLACK POD

Bryan A. Bailey, Sustainable Perennial Crops Laboratory, USDA/ARS, Beltsville, Maryland, USA

***NOTE**: draft proposal put together for the purpose of broader discussion during the workshop and does not constitute a final proposal.*

With the aim of improving the development of improved planting materials for cacao farmers in the coming years:

1. Who are the key research partners in this area?

Since Black Pod Rot is an issue globally, all institutions willing to contribute through basic research, screening, selection, breeding and/or germplasm distribution must be considered key partners. Of particular importance due to their potential for distributing germplasm are the quarantine facilities at Reading University and ARS, Miami. Secondly, are the major sources of germplasm diversity maintained in collections, new or historical? Materials such as those in the French Guyana collections, and more recent collections such as those collected on the Amazon in Brazil, Peru, and elsewhere must be evaluated and therefore their controlling/managing organizations should be considered.

2. What have been the most significant advances in recent years?

- Defining the germplasm diversity. In general, validating clone identity is the starting point of making advances in cacao.
- Potential sources of resistance/tolerance such as those from French Guyana have been distributed to new groups/areas and their evaluations are advancing.
- Increased knowledge on the biology of *P. megakarya and P. palmivora*: origin, genetic diversity, and biology.
- A basic understanding of the biology of disease tolerance mechanisms in cacao continues to develop. The importance of secondary compounds/phenolics and cell wall development processes including lignin/cutin needs continued study.
- Several QTL mapping studies of disease resistance point us towards the basic set of cacao genes controlling disease tolerance/resistance. With the acquisition of the cacao genome sequence and associated SNP panels, we should be poised to exploit marker assisted selection extensively in the coming years.

3. Where is or might be the focus of research for the next 3-5 years?

- Each producing country having its own collection should be seeking to increase the diversity held in their collections.
- Germplasm exchange is a must. Only a small portion of the total cacao genetic diversity is being used extensively in current breeding programs. All the distinct populations of cacao, as recently described, should be shared and incorporated into breeding programs around the globe.
- The quarantine facilities should be identifying and carrying new sources of disease tolerance through quarantine. Due to capacity limitations, this requires significant coordination to identify priorities.
- The evaluation of a greater diversity of disease tolerant clones under varying conditions using a uniform set of screening tools. It is important to expose new materials to different populations of *P. megakarya and P. palmivora*. Many screening methods exist. A basic set of repeatable methods with reproducible results should be agreed on.
- From the literature, indications are that tolerance to one *Phytophthora* species contributes to tolerance to all *Phytophthora* species. Is this true of newer germplasm sources? If so, this suggests, in most cases, tolerance is multigenic involving similar components regardless of the germplasm source. The many QTL studies carried out to date support this idea. This can be tested.

- Increased knowledge on aspects from the biology of *Phytophthora* species causing disease on cacao. Why is *P. megakarya* able to displace *P. palmivora*? Why do losses to *P. palmivora* vary so much between locations? Is it due to environment or pathogen genetic diversity?

4. What are the specific research questions to be addressed?

- What is the molecular/biochemical basis for tolerance to black pod? Significant clues/indications exist concerning the answer to this question exist in the literature. If the indicated traits can be directly linked to the genes involved in their action, molecular breeding techniques can be better exploited. This connection is currently missing.
- There appears to be significant diversity among sources of tolerance to black pod rot. Is this true or do they all involve allelic forms of the same genes or are they derived from the same historical sources? What percentage of available sources is actually being used in breeding materials?
- With new sources of tolerance, does tolerance to one species of *Phytophthora* contribute to tolerance against all species of *Phytophthora* causing disease on cacao?
- The importance of *P. citrophthora* and *P. capsici/tropicalis* needs to be better defined. Although they are discussed in the literature, gaining access to data concerning these pathogens in the field is difficult.
- Is it disease tolerance and controlled by many or a few genes with minor effects or is it resistance controlled by one or two genes with major effects, or a combination depending on source. This is why we need to have a more complete understanding of the original sources of resistance.
- Some concept of potential stability of disease tolerance/resistance in the field must be developed.
- What is the genetic basis for penetration resistance versus post-penetration resistance?

5. Any other information that may be useful to share with the research group

The SPCL and collaborators, including PSU, are preparing to public release the genome sequences of *Phytophthora megakarya* and *Phytophthora palmivora*, as soon as the associated manuscript is submitted and accepted for publication. We are happy to share access to these sequences under appropriate conditions so that research can proceed/advance. Contact Bryan A. Bailey (bryan.bailey@ars.usda.gov) if you have questions.

ANNEX H. BRIEF REPORT ON STATUS OF RESEARCH ON CADMIUM BIOACCUMULATION LEVELS

Path Umaharan, CRC, Trinidad and Tobago

***NOTE**: draft proposal put together for the purpose of broader discussion during the workshop and does not constitute a final proposal.*

With the aim of improving the development of improved planting materials for cacao farmers in the coming years:

1. Who are the key research partners in this area?

The Cocoa Research Centre of the University of the West Indies is executing a three-year project on the above topic supported by ECA/CAOBISCO/FCC/CASA LUKER. It has also been involved in another study previously which examined the distribution of cadmium in Trinidad and Tobago soils and the relationship between soil cadmium and bean cadmium levels as well as the partitioning of cadmium within the plant organs and parts of the pod and bean. Potential key research partners with interest in studying cadmium bioaccumulation include:

- The University of Reading, UK.
- USDA-ARS, Beltsville
- NESTLE, Tours, France and Nestle, Ecuador
- Corpoica, Colombia
- CASALUKER, Colombia
- CEPLAC?
- FHIA, Honduras
- Peru?

2. What have been the most significant advances in recent years?

The Cocoa Research Centre has:

1. Published several papers on cadmium with regards to distribution in Trinidad and Tobago and partitioning into plant parts.
2. We have developed robust methodologies to determine soil and plant cadmium.
3. We have screened 100 accessions representing the various genetic groups with replications at a single moderately high cadmium site (ICGT) and have identified significant genetic variation in cadmium bioaccumulation levels.
4. It has also studied the interrelationships between cadmium and other metal elements
5. It has also testing several ameliorants in the greenhouse and field experiments for their efficacy
6. It is also testing several agronomic variables that can reduce the levels of cadmium bioaccumulation.

3. Where is or might be the focus of research for the next 3-5 years?

1. It will be useful to have a regional meeting involving cocoa growing countries in the LAC region to understand the degree of the problem, share information and discuss strategies to address the problem.
2. It will useful to test combination interventions in several sites with cadmium levels and various geological, edaphic and climatic conditions across Latin America and the Caribbean.
3. It will be extremely useful to understand the molecular and biochemical basis of cadmium bioaccumulation and partitioning so that other interventions can be developed and implemented.
4. It will be useful to screen additional varieties and conduct GWAS so that potential component genes involved in cadmium bioaccumulation of cocoa could be identified. This will allow potentially not only rapidly screening genotypes in the genebank but also allowing for accumulation of cadmium lowering genes in an enhanced population for distribution to Latin American Countries.

4. What are the specific research questions to be addressed?

- What is the molecular and biochemical basis of cadmium bioaccumulation?
- What is the genetic basis of cadmium bioaccumulation and can these genes be accumulated through breeding?
- What are the factors (edaphic, climatic, geology and management) that contribute to cadmium bioaccumulation in cocoa.
- Can cadmium bioaccumulation be mitigated through the use of low cadmium bio-accumulating rootstocks?
- How can this understanding used to mitigate cadmium levels in the cocoa beans?
- What are the genes that mitigate against cadmium bioaccumulation and can they be mapped and accumulated in breeding programmes?

Any other information that may be useful to share with the research group

ANNEX I. BRIEF REPORT ON STATUS OF RESEARCH ON FROSTY POD

Wilbert Phillips, CATIE, Costa Rica

***NOTE**: draft proposal put together for the purpose of broader discussion during the workshop and does not constitute a final proposal.*

With the aim of improving the development of improved planting materials for cocoa farmers in the coming years:

1. **Who are the key research partners in this area?**

CATIE is the only institution with a continuous program for selecting resistant varieties to FPR, which has been developed uninterruptedly during the last 20 years. This it is part of a holistic approach for the generation of high yielding, disease resistant and high quality varieties. Developing of durable resistance genotypes by accumulating resistant genes in single varieties is other important activity of the program.

INIFAP (Mexico) and FHIA (Honduras) are developing FP resistant varieties by using base information and materials received from CATIE. INIAP in Ecuador is developing a breeding program focusing on yield, quality and resistance to Witches´ broom and with a minor emphasis FPR. Other institutions in Latin America such as Corpoica and Fedecacao in Colombia, INIA in Venezuela and the *Instituto de Cultivos Tropicales* in Peru are selecting resistant genotypes from farmer´s fields and/or local collections.

USDA-ARS in Beltsville and the University of Purdue are performing studies on the biology *of M. roreri* with relevance in the future selection of resistant genotypes. USDA-ARS and MARS project in Miami has also developed genetic studies involving FPR, particularly QTL studies.

2. **What have been the most significant advances in recent years?**

- Identification of resistant genotypes from different genetic pools of T. cacao.
- Generation of resistant varieties combining resistance to FPR and Black pod with high yields and good quality profiles.
- Releasing of resistant varieties in a considerable geographic area (from Panama to Mexico), where they are showing a successful behavior.
- Generation of genotypes with double resistance: FPR and black pod rot.
- Transference of resistant parents to the Intermediate Quarantine Station at Reading, Brazil and USA for preventive breeding.
- Increased knowledge on the biology of M. roreri: origin, genetic diversity, biogeography and taxonomic affinities.

3. **Where is or might be the focus of research for the next 3-5 years?**

- Selection of superior varieties combining FPR resistance with as many as possible favorable traits of agronomic relevance.
- Developing of disease resistant durable varieties.
- Multilocation trials for determing GxE interactions and the effect of adverse environments on the performance of the materials. Exposition of the varieties to different genetic pools of M. roreri will be very relevant.
- Development of double and triple resistant varieties, paying more attention to moniliasis/witches´ broom resistant genotypes. This will need a joint effort among research institutions.
- Increased knowledge on aspects from the biology of M. roreri having important connections with the control of the disease.

4. **What are the specific research questions to be addressed?**

- What is the impact of climate change on the selected varieties?

- Which genetic groups and selected varieties are more resilient to the new conditions imposed by climate change?
- How the new scenarios will affect the spread and impact of diseases and pests?
- How can we improve the propagation and distribution among farmers of improved planting material?
- How can we improve the acceptance of these materials by the farmers?

5. **Any other information that may be useful to share with the research group**

ANNEX J. BRIEF REPORT ON STATUS OF RESEARCH ON COCOA SWOLLEN SHOOT VIRUS - CSSV

Andy Wetten, University of Reading, UK

***NOTE**: draft proposal put together for the purpose of broader discussion during the workshop and does not constitute a final proposal.*

With the aim of improving the development of improved planting materials for cocoa farmers in the coming years:

1. **Who are the key research partners in this area?**
   - West African cocoa farmers (once they have adequate information re visual recognition of CSSVD-symptomatic cacao), W African-based cocoa research institutes (CNRA, CRIG, CRIN, ICRAF etc) and universities (eg. University of Calabar, University of Cape Coast).
   - CIRAD, University of Reading, University of Arizona, USDA
   - Curators of cacao germplasm collections (CATIE, ICG,T, ICQC etc)
   - Research sponsors/Industrial partners: Mars, Nestle, Mondelez, WCF, Caobisco/ECA etc

2. **What have been the most significant advances in recent years?**
   - Increasing recognition of the actual extent of CSSVD in the W African crop
   - Progress on characterisation of the genetic diversity of CSSV and mapping of that diversity
   - Use of this knowledge for more effective quarantine screening
   - Characterisation of CSSV vector (mealybug) virus transmission efficiency and mapping of those vectors in the region

3. **Where is or might be the focus of research for the next 3-5 years?**
   - Establish an effective means of clearing CSSVD-affected areas before replanting and use a social science approach to identify how to engage farmers effectively with such cacao rehabilitation
   - Optimisation of methodology for screening for CSSV resistance and application of that screen (see below)

4. **What are the specific research questions to be addressed?**
   - Is there any CSSV-resistance within existing cacao germplasm collections and does that resistance functions across multiple CSSV genotypes and multiple vector species?
   - What is the mechanism of that resistance?
   - Characterisation of cacao's molecular response to vector attack and virus transmission
   - Characterise diurnal/seasonal activity of key CSSV vectors – can this be exploited for control purposes through an Integrated Pest Management approach (including eg. biological control, sex pheromone-based mating disruption etc)?
   - Establish efficacy of pesticide treatments for vector control (can they work without tainting of beans and do they impact on pollinators?)

5. **Any other information that may be useful to share with the research group**