Issue 10
December
2006

GRO-Cocoa

Global Research On Cocoa - *working with and for farmers*

Research Post Costa Rica

The 15th International Cocoa Research Conference (ICRC), organized jointly by COPAL (Cocoa Producers' Alliance) and CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) in San José, Costa Rica in October 2006, gave researchers a chance to review progress. In his closing presentation, from which this article is drawn, Dr Martin Gilmour (Mars Inc.), Chairman of the International Organizing Committee, assessed the status of research and identified remaining gaps. This provides a framework, and a series of challenges, for cocoa research.

A sobering overview of the impact of pests and diseases demonstrated why they remain the major limitation and threat to cocoa production, and also highlighted the need for proper risk assessment. This was underlined by presentations on the relentless spread of frosty pod rot (FP; caused by *Moniliophthora roreri*) through Latin America, and of the movement of CSSV (cocoa swollen shoot virus) in West Africa and cocoa pod borer (CPB; *Conopomorpha cramerella*) in Southeast Asia, while a new and possibly significant pest in Cote d'Ivoire signalled continuing risk from emerging threats. Against this, what progress has there been?

Cherry picking, out of necessity, amongst the many crop protection presentations: pheromones are showing promise for mirid and CPB control; simpler, quicker assays for *Phytophthora* and *Ceratocystis*, and for potential biocontrol agents are being developed; research on biocontrol with *Trichoderma* species has reached the field trial stage for black pod (BP; caused by *Phytophthora* spp.), FP and witches' broom (WB; caused by *M. perniciosa*) in Cameroon, Costa Rica and Ecuador, respectively (and some species are being delivered to farmers in pilot projects) – nonetheless, biocontrol researchers generally complained of lack of sustained support for developing these technologies. The successes against pests and diseases of a national programme in Ghana has shown the potential of coordinated action. Whatever the reasons, many gaps in sustainable control options for pests and diseases worldwide were clear. Copper fungicides were shown to be still important for disease control in Bahia, and this was part of a wider recognition of the importance of chemicals, and pesticide research, in the absence as yet of robust alternatives.

How well are genetic resources being used? The importance of better coordination was recognised with the launch of CacaoNet (see p. 4). Reports of possible new sources of resistance to BP from French Guiana underlined that much genetic diversity may yet to be found. Promise is being shown by work, for example, at the International Cocoa Genebank, Trinidad (ICG,T) with selections showing tolerance to CPB (through hard pod walls), and with vascular streak dieback (VSD) and BP in Sulawesi and FP in Costa Rica. It emerged from these sessions that farmers are proving a useful source of resistant material (e.g. see p. 5).

In the field of molecular biology, research on the genetic structure of cocoa and the genetic diversity of disease pathogens can feed into breeding and other areas of research. Markers continue to be developed and there has been progress with quantitative trait loci (QTLs) for disease resistance. Genetic maps generated in different laboratories can now be joined using Expressed Sequence Tags (ESTs) containing microsatellites. An important output of the marker work has been recognition of the extent of mislabelling in collections, which is an important step towards managing and rationalising the collections based on sound genetic information.

What does the 15th ICRC say to the farmer about pest and disease control? Unfortunately it says there are large areas where research has not yet delivered.

Looking for the gaps for the main cocoa fungal diseases is revealing. For BP the picture looks quite good: while there are gaps in knowledge about the pathogen, much has been achieved in breeding for resistance, and there have also been advances in IPM; with adequate training farmers can control it. For WB the picture is less good: despite progress in understanding the biology and spread of the pathogen, and some advances in selecting tolerant varieties and developing a QTL for resistance, a robust IPM system still needs to be developed. Of most concern, however, is FP: despite much effort by a few researchers, little is known about the pathogen, there has yet to be a serious impact in breeding for resistance, and there is a long way to go to develop an adequate IPM system. In addition, although with exceptions, delivery of training to farmers for dealing with fungal diseases is poor: research outputs generally are not being applied where it really matters. Before leaving diseases, CSSV merits a mention: this potentially serious threat needs more attention.

For the two main insect pests, the current situation is also poor. Research on the biology, genetics and spread of mirids and

Martin Gilmour (Mars Inc.) (left), Chairman of the International Organizing Committee for the 15th International Cocoa Research Conference with Hope Sona Ebaï, Secretary-General of the Cocoa Producers' Alliance (COPAL). The conference, organized by COPAL in collaboration with CATIE, was held in San José, Costa Rica on 9–14 October 2006

In This Issue

CPB is insufficient, and little has been done on breeding for resistance to insect attack. (But while this may be a promising avenue of research for CPB, it is less likely to be useful for sap-sucking mirids). Definitive approaches for IPM control of insect pests still remain to be developed and while there have been several programmes to deliver CPB management tools to farmers in Asia, overall cocoa quality is still poor there. Notwithstanding the centrally organised spraying campaigns in West Africa, techniques for control of mirids by smallholders remain under development.

A feature of the conference was the reawakening interest in agronomy, indicated by the launch of a cocoa agroforestry specialist group, INAFORESTA, and reports on agroforestry systems appearing to offer benefits to sustainable cocoa production. Despite much work on cocoa–legume tree cultivation, cocoa agroforestry has still to define good models with economically valuable shade or companion trees. With regard to establishment and rehabilitation and the tendency to plant in drier areas, more needs to be known about the effects of soil moisture stress. The soil, an often neglected topic, was brought into the limelight with the first meeting of a Cacao Soils Group. The key questions here are the long term effects on soil fertility of cocoa cultivation, and how to manage soil fertility more sustainably.

A major issue, at least for countries exporting to Europe, is pesticide residues (see next article). The cocoa supply chain needs to be responsive to new residue issues and be willing and able to take steps in each case to determine the entry point, and propose workable solutions to reduce levels.

In summary, having reached the end of the 15th ICRC, Dr Gilmour identified the main gaps in cocoa research, and the areas for which more resources are needed.

- Cocoa genetic resources (better coordination and collaboration needed)
- Fungal diseases and their spread (notably FP for which more IPM and breeding work is needed urgently)
- Insect pests and their spread (with more work needed on IPM of CPB and mirids in particular)
- CSSV (coordinated efforts to deal with the spread of this virus through West Africa are needed)
- Agronomy (cocoa–soil interactions [e.g. nutrient requirements, soil fertility] shade, establishment, appropriate agroforestry models and diversification all need more research)
- Residues (for pesticides, surveys and rational pesticide use need to be promoted; in general, farmer field schools need to be developed to manage residue reduction in the supply chain)

Minimising Impacts of EU Pesticide Regulation

Consumers in the European Union (EU) put pesticides top of their list of food safety issues. New EU harmonised pesticide residue legislation (EC No. 396/2005), which is likely to come into force in late 2007, applies for the first time to imported foods, including cocoa beans. The regulation introduces limits that could severely affect cocoa imports, and hence impact adversely on cocoa production, unless the cocoa sector as a whole acts quickly to ensure the appropriate maximum residue levels (MRLs) are in place (see Box for an explanation of terminology).

A project co-funded by the European Cocoa Association (ECA), the Association of the Chocolate, Biscuit & Confectionery Industries of the EU (CAOBISCO) and the Dutch Subsidy Scheme for the Sustainable Development of the Cocoa and Chocolate Sector aims to address pesticide residue issues throughout the cocoa chain.

The aim of the new regulation is to set a harmonised EU MRL or EU Import Tolerance for each pesticide/commodity combination. Until now EU member states have been able to set their own national MRLs (including Import Tolerances). Although commodities covered by legislation have been largely those grown in the EU, some member states have had national MRLs for some pesticides in cocoa, whereas others, such as the UK, have not. In countries with no cocoa MRLs, until now traders have had to comply with general food safety legislation – e.g. in the UK, under the general provisions of the Food Safety Act (1990), cocoa would be expected to comply with any current Codex MRLs (see next section), and/or MRLs set in the cocoa's country of origin (provided these incorporate an appropriate assessment of consumer safety).

Under the new legislation, temporary EU MRLs will be set for cocoa as a first step. The temporary MRLs will be based on existing EU member state national and/or Codex MRLs. Where there are none, the EU MRL will be the default limit of detection (LOD), set at 0.01 mg/kg unless an Import Tolerance is established.

There are thought to be many pesticides in use on cocoa that have no EU member state or Codex MRLs, and these will be assigned the default LOD MRL; any detected residue of such a pesticide would be considered illegal, although it might not necessarily pose a threat to consumer safety. Thus it is essential that EU MRLs and Import Tolerances are established for all pesticides likely to be encountered as residues on cocoa consignments, including new products coming onto the market in cocoa growing countries.

Pesticide Residues & Limits

In most countries, pesticides must be approved for use on a particular crop following trials to establish **Good Agricultural Practice (GAP)** and assessments for toxicology, dietary intake and environmental impact.

Acceptable Daily Intake (ADI): amount of an active ingredient (active) that can be consumed daily over a lifetime without harm, expressed in mg/kg body weight of the consumer, and based on toxiciological evaluation.

Acute Reference Dose (ARfD): estimate of amount of an active, expressed as above, that can be ingested over a short period of time (1 meal or 1 day) without appreciable health risk.

Maximum Residue Level (MRL): maximum concentration of pesticide residue likely to occur in or on a specific food commodity after the pesticide has been used under GAP. MRLs are not necessarily safety limits, but primarily a check that GAP is being followed and are intended to assist international trade in produce treated with pesticides.

Limit of Detection (LOD): lowest concentration of a pesticide residue that can be measured by routine analysis. Continuing progress in analytical methods means residues can be detected at ever smaller concentrations.

Import Tolerance: described in EC No. 396/2005 as an MRL set to meet the needs of international trade where either (a) the use of the active on a commodity is not authorised in the EU (for reasons other than public health), or (b) a different level is appropriate because the existing EU MRL was set for reasons other than public health.

The Risk Assessment Process

The toxicology and ecotoxicology of a potential active must be thoroughly evaluated before it can be approved for use in pesticides. Periodic reviews of existing actives ensure they meet modern standards. Evaluation is normally undertaken by panels of scientific experts and organised at national, regional or international level.

Active ingredient	MRL (mg/kg)
Endosulfan	0.1
Hydrogen phosphide	0.01
Metalaxyl	0.2

Table 1. Codex MRLs for cocoa beans.

Atrazine	Metalaxyl
Benomyl	Methyl parathion
Captafol	Monocrotophos
Carbaryl	Parathion methyl
Cartap	Permethrin
DDT	Promecarb
Diazinon	Propoxur
Dieldrin	Pyrifenox
Dioxacarb	Tetramethrin
Endosulfan	Thiazinon
Fenitrothion	Triadimefon
Fenvalerate	Zineb

Table 2. Actives of relevance to the cocoa sector already withdrawn from use in Europe (i.e. excluded from Annex 1, Directive 91/414/EEC).

The international Codex Alimentarius Commission aims to protect consumer health, ensure fair trade practices in the food trade, and promote coordination of food standards work undertaken by international, governmental and non-governmental organisations. The Codex Commission and the Joint Meeting on Pesticide Residues (JMPR), administered by WHO/FAO (World Health Organization/Food and Agriculture Organization of the UN), together set suitable international standards for pesticide residues in food commodities. A JMPR panel evaluates data and sets an acceptable daily intake (ADI) and an acute reference dose (ARfD) for each active. Based on trial data, the panel estimates for each commodity the maximum residue that might occur when a pesticide is used according to Good Agricultural Practice (GAP). So long as intakes would be well within the ADI, these estimated MRLs are recommended to the Codex Committee on Pesticide Residues (CCPR) for adoption as Codex MRLs for each commodity/pesticide combination. These are indicative, and not legally binding for countries which have not implemented Codex standards into their national legislation, but can be used as guidance in the absence of other MRLs. However, there are very few current Codex MRLs for cocoa (Table 1); those for deltamethrin, fenitrothion and lindane were revoked in 2002 and 2003, and the limit for metalaxyl on cocoa will be considered for revocation in 2008.

Under a pre-set programme, the JMPR evaluated 21 actives in 2005 and ADI/ARfDs were established for a number of pesticides used on cocoa (benalaxyl, glyphosate, malathion and pyrethrins) and the potential methyl bromide alternative, sulfuryl fluoride. No data were submitted from cocoa trials and there were no estimates for residues from GAP for this crop; consequently no cocoa MRLs were recommended. Over the next 3 years, the JMPR will be carrying out evaluations of more actives used on cocoa (endosulfan, λ-cyhalothrin, benalaxyl, permethrin, fenitrothion and carbaryl).

A review of actives in plant protection products within the EU was begun in 1992, and since 1993 risk assessments have been undertaken by the European Food Safety Authority (EFSA), which makes recommendations to the EU. If a compound is shown to be without unacceptable risk to people or the environment, it can be included in a positive list of actives: 'Annex I' to EC Directive 91/414. If a compound is excluded from this list, pesticides containing it must be withdrawn within a specified period. This programme has resulted in the banning for use in Europe of a number of actives known to be used, or thought to have been in recent use, on cocoa and/or in cocoa producing countries (Table 2).

Import Tolerances

Applications for Import Tolerances may be submitted by any interested party and follow a similar procedure to other applications for MRLs. A dossier of information is submitted to the EU member state assigned responsibility for the active substance. This would normally include a comprehensive overview of the data on toxicology, metabolism, and analytical methods together with the GAP applying to the specific use of the active. However, the assessment might include reference to relevant publicly available data, particularly when the active has already been evaluated under EC Directive 91/414/ or where a codex MRL has been established.

Actions to Minimise Impact on the Cocoa Sector

ECA and CAOBISCO have invited representatives from cocoa producing countries, research institutes and the European Pesticide Manufacturers Association to join them to form a Pesticides Working Group. This Working Group has entered into discussions with the EC (Directorate General for Development and Directorate General for Health and Consumer Affairs) to explain how these changes in legislation will affect the cocoa sector. The pesticide manufacturers experience in the process of submitting data packages for pesticide approvals/Import Tolerances will be invaluable. Contact has also been made with the COLEACP (Europe-Africa-Caribbean-Pacific Liaison Committee), an organisation set up by the EC to provide information and advice for the horticultural sector in ACP (African/Caribbean/Pacific) countries. COLEACP is implementing an EU-funded Pesticide Initiative Programme (PIP) set up to enable ACP countries to comply with EU food safety and traceability requirements. Although the original COLEACP mandate did not include cocoa, it is hoped that our sector can benefit from their experience. The International Cocoa Organization (ICCO) has launched an Action Programme on Pesticide Residues and is collating data on pesticide usage by its member countries which will be very helpful in negotiations with the EC.

As outlined at the beginning, ECA/CAOBISCO are co-funding a project entitled the 'Safe cocoa, sustainable production: a concerted programme by the cocoa and chocolate industries to understand and address market changes regarding pesticide acceptability' with support from the Ministry of Agriculture, Nature and Food Quality of the Netherlands via the Dutch Subsidy Scheme for the Sustainable Development of the Cocoa and Chocolate Sector. The project will be led by CABI working in conjunction with the national cocoa programmes of Ghana, Nigeria, Côte d'Ivoire and Cameroon. Mirroring the legislation, the project will tackle the complete supply chain, from origin to processing (including transit, warehousing, etc.), focusing on West Africa since this is the main source for the European cocoa–chocolate industry. Participants will gather information on current pesticide usage on cocoa in each of these countries and conduct an analysis of pesticide residues in cocoa beans so that critical points for contamination in the supply chain are identified. It will provide support for producer countries in raising awareness of pesticide issues in their farming communities, including operator safety, in eliminating illegal use of non-approved pesticides and in developing and establishing viable alternatives. It is anticipated that the work will be closely linked with other initiatives in the region including the Sustainable Tree Crops Programme (STCP) and the CropLife International Training of Trainers programme aimed at raising awareness of safe pesticide use and IPM.

Clearly there is a great deal to be done, but by working together, researchers, extension organisations and authorities in producing countries, pesticide manufacturers and the cocoa industry can ensure any pesticides used in cocoa production are used safely and effectively.

This will contribute to the sustainability of the whole cocoa chain, thus securing the future for cocoa farmers and ensuring the quality our industry depends on.

This article is based on a presentation made at the 15th ICRC by the ECA/CAOBISCO Pesticides Working Group.

Contact/further information: Dr Michelle End, c/o CAOBISCO, 1 Rue Defacqz – B-1000 Brussels, Belgium

Email: Michelle.End@BCCCA.org.uk

CacaoNet: Establishing a Global Genetic Resources Network

Cocoa has long been an 'orphan' crop with little multilateral donor support for research. Only a few 'global' projects deal with cocoa genetic resources conservation and use, but none of them addresses squarely the urgent need for secure long-term conservation and the continued availability of this germplasm to users. CacaoNet was launched during the recent COPAL 15th International Cocoa Research Conference (ICRC) in Costa Rica as a global network with the aim of contributing to the safe conservation and the ready availability of cocoa genetic resources. During the establishment phase of CacaoNet the International Plant Genetic Resources Institute (IPGRI), now called Bioversity International ('Bioversity'), played a coordinating role. Why, the cocoa community might well ask, do we need another international 'player' in cocoa, and what does Bioversity offer? We hope this article will answer those questions.

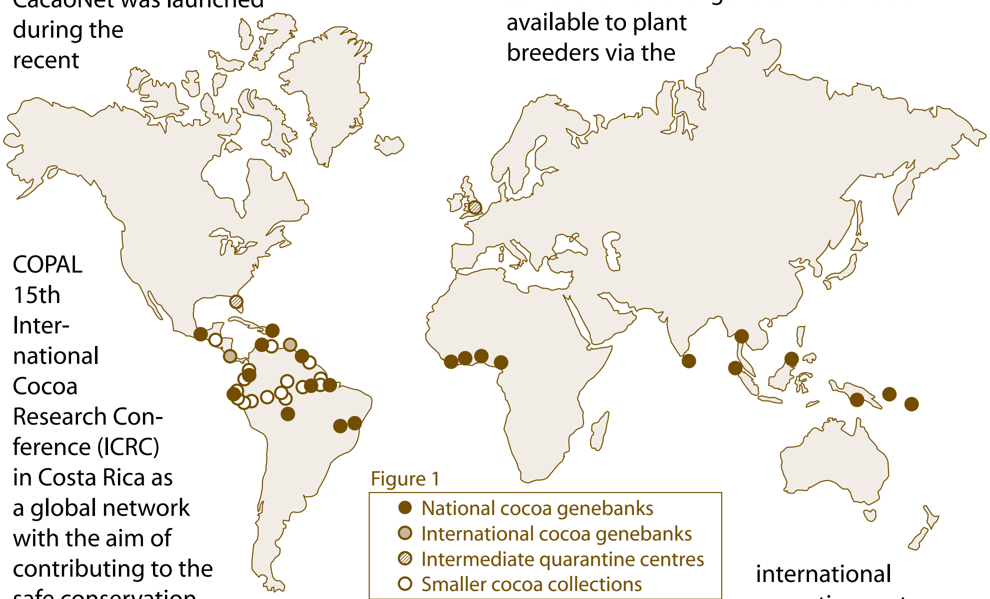

Figure 1

Status of Cocoa Genetic Resources

There is currently no globally coordinated genetic resources conservation and use effort for cocoa, or indeed any assured long-term support. However, in the 1970s and 1980s the International Board for Plant Genetic Resources (IBPGR, as IPGRI was previously known) established a 'Registry of Base Collections'. Both the Cocoa Research Unit of the University of the West Indies (CRU) in Trinidad and the Centro Agronómico Tropical de Investigación y Enseñanza in Costa Rica (CATIE) concluded agreements with IBPGR some 20 years ago to maintain a global collection of cocoa genetic resources for the long-term and to make the germplasm freely available to any professionally qualified institution or individual. Although these two collections – the International Cocoa Genebank, Trinidad (ICG,T) and the CATIE International Cacao Germplasm Collection – are complementary, they do not capture the entire variability of cocoa. National collections in some 28 cocoa-producing countries extend the holdings of global genetic resources, in particular in Latin America, but there is undeniably other cultivated and wild material yet to find a place in any collection – especially material as-yet still undiscovered in the Amazon basin (Fig. 1).

The material currently held in international and national genebanks is made available to plant breeders via the international quarantine centres in Miami, Florida, USA (for the western hemisphere and the USA including Hawaii and Puerto Rico) and at the University of Reading, UK, who operate worldwide (Fig. 1).

The genebanks are currently supported by usually insufficient and sometimes unreliable national and bilateral public funding, while part of the support to the international collections and the quarantine centres comes from industry. It is this inadequate, frequently fragmented and uncoordinated financial support for the (long-term) conservation of cocoa genetic resources and its continued availability to users that prompted the cocoa community to establish CacaoNet.

Although plant breeders have access to a considerable range of cocoa germplasm through international genebanks, quarantine facilities and in some cases, national genebanks (Fig. 1), lack of both coordination and secure funding is hindering rational and secure long-term genetic resources conservation efforts and thus improvements in cocoa productivity and sustainability. Loss of genetic diversity with the destruction of the Amazonian rainforests and continued genetic erosion in the genebanks are serious problems that must be addressed with urgency. For example, 60% of a unique collection of Amazonian cocoa held at the INIAP (Instituto Nacional Autónomo de Investiga-

CacaoNet Scope & Objectives[1]

Scope

- Germplasm collecting
- Conservation of public domain germplasm
- Information and database management
- International and regional quarantine
- Characterization (molecular and morphological)
- Evaluation and germplasm enhancement

Objectives

- To ensure cost-effective long-term conservation and management of cocoa genetic resources (GR) in the global public domain
- To facilitate the utilization of cocoa GR for breeding, through effective characterization, evaluation and pre-breeding efforts
- To provide a platform for the co-ordination and implementation of cocoa GR related research, breeding and use related to cocoa GR
- To prioritize and implement collecting missions to ensure conservation and access to poorly-known gene pools, especially where threatened
- To develop priorities for, and coordinate regional approaches to, cocoa GR conservation, exchange and utilization
- To ensure effective management and exchange of information on cocoa GR
- Through effective quarantine, facilitate access to useful germplasm for breeding programmes and other users
- To promote access to, and the adoption of, superior cocoa cultivars by farmers
- To enhance and strengthen capacity in national programmes in cocoa GR management and improvement

[1] *Not presented in any order of priority.*

ciones Agropecuarias) Napo genebank in Ecuador has been lost over the last decade owing to lack of funding for adequate maintenance. The wild cocoa growing in this area would have co-evolved with endemic diseases such as witches' broom, which is currently a major threat to the industry; indeed a partial characterisation and evaluation of the surviving accessions has revealed some resistant types which could be of great value in breeding programmes. Strategies to collect, conserve and share genetic diversity are urgently needed by the cocoa community.

Conservation of Genetic Resources of Major Food Crops as a Model

The situation with regard to the world's major food crops is more ordered and coordinated, largely thanks to international efforts coordinated by the Consultative Group on International Agricultural Research (CGIAR), and it is the belief that a global network closely associated with the existing global network of *ex situ* collections could bring some of these benefits to cocoa.

These genetic resources are held 'in trust' under the auspices of the United Nations Food and Agriculture Organization (FAO), predominantly at CGIAR research centres as part of the International Network of *Ex Situ* Germplasm Collections. This Network is one of the supporting components of the International Treaty on Plant Genetic Resources for Food and Agriculture (IT) that entered into force in June 2004. The formal placement of genetic resources collections under the auspices of FAO ensures that designated germplasm remains essentially in the public domain, is safely conserved for the long-term according to international standards and remains readily available to plant breeding programmes and other *bona fide* users – arrangements in full compliance with the Convention on Biological Diversity. Agreements between the Governing Body of the IT and the CGIAR centres as well as CATIE to formalise the above legal status of these public domain collections were signed on 16 October 2006 in Rome.

An important aspect of the IT is the establishment of a so-called multilateral system of access and benefit-sharing for species listed in Annex I of the Treaty. Cocoa is not one of the 35 food crops listed in this Annex, as food security and interdependency of countries were the two important selection criteria in establishing the list. In addition, cocoa is not one of the traditional 'mandate species' in the conservation agenda of the CGIAR but several centres, including the International Institute of Tropical Agriculture (IITA) and Bioversity are directly involved in research activities on it. The close association of CacaoNet with the CGIAR, through Bioversity, will facilitate the development of a legal framework for cocoa genetic resources to match those of the CGIAR collections, and also bring benefits from the arrangements under the IT.

Cocoa Ripe for a New Initiative

Historically, efforts to coordinate cocoa conservation activities have stumbled over political obstacles, resulting in fragmented approaches, and compounded by the lack of long-term funding. But on-going efforts, in particular those co-financed by the Common Fund for Commodities (CFC), industry and research institutes such as Centre de Cooperation Internationale en Recherche Agronomique (CIRAD), France and Bioversity, and dealing with the conservation and distribution of cocoa germplasm that is well-characterised and documented, are much appreciated by the cocoa community and have contributed to a number of successful breeding programmes. The spirit of cooperation that has developed between the 14 cocoa research institutes participating in the CFC/ICCO/IPGRI cocoa germplasm projects, the improved prospects for long-term funding, and the experience brought by Bioversity from the establishment and coordination of a global genetic resource network for coconut (COGENT, www.ipgri.cgiar.org/networks/cogent/CGRDatabase.htm), all enhance the prospects for a new and well-coordinated conservation approach for cocoa.

In May 2005, IPGRI tabled an outline proposal to set up a network for cocoa germplasm related activities, which was enthusiastically welcomed by the cocoa research and genetic resources community. An Interim Steering Committee of 16 stakeholders was created, representing research and related institutions from many cocoa-consuming and -producing countries, from the International Group for the Genetic Improvement of Cocoa (INGENIC) and from the chocolate industry. A series of stakeholder conference calls, email contacts and a 'brainstorming' workshop held in Montpellier, France in August 2005 followed, culminating in the formation of a small IPGRI coordinated Task Force and the first face-to-face meeting of the Interim Steering Committee in October 2005 in Washington DC, where the scope and objectives (see Box p. 4) and operating principles of CacaoNet were agreed, although it was also agreed that a wide consultation should be carried out to establish the function, roles and structure of CacaoNet. The US Department of

Jan Engels, Coordinator-elect of CacaoNet, explains the objectives of the network at the 15th ICRC

Agriculture, the World Cocoa Foundation (WCF) and Mars Inc. contributed financially to this effort, BCCCA (Biscuit, Cake, Chocolate and Confectionery Association) made substantial in-kind inputs into activities so far, whereas IPGRI agreed to coordinate the establishment phase of CacaoNet. WCF also endorsed the original concept and subsequent proposals on how to proceed, with bi-annual meetings in Brussels and Washington DC.

A presentation on CacaoNet was given at the 15th ICRC and the so-called San José Declaration, indicating the importance of establishing CacaoNet and signed by key institutions worldwide, was read out. During a Stakeholders' meeting, the key components of CacaoNet were discussed and strong support for the ideas behind these was voiced. Two Working Groups, on cocoa quarantine procedures and cocoa genetic resources information management, were established and INGENIC agreed to contribute to the development of a long-term cocoa conservation strategy.

For more information visit the new (temporary) CacaoNet website:
www.cacaonet.org/new/index.php

And/or contact the author: Jan Engels, Genetic Resources Management Adviser, IPGRI, Rome, Italy
Email: j.engels@cgiar.org

Lessons for Participatory Researchers

Since 2001 Australian and Indonesian researchers have been working with Sulawesi smallholder cocoa farmers under the Australian Centre for International Agricultural Research (ACIAR) Project CP/2000/102 (see *GRO-Cocoa* No 3 for an introduction to the project).

We tested methodologies for on-farm selection and trialling of cocoa genotypes with the aim of improving pest and disease control, and cocoa yield and quality on smallholdings in South and Southeast Sulawesi. As the project nears it end, we reflect on our experiences with participatory approaches to cocoa improvement.

Problems were approached from the farmers' standpoint. How could farmers and local institutions improve production and quality of cocoa and what resources did they have? One resource is the widely spread network of government extension and research services but these have limited funding. In line with ACIAR's aims, some project funding was allocated for training and capacity building, including almost full-time employment of two Indonesian government officers. A second resource is the considerable diversity of cocoa on Indonesian farms, owing to introductions of various genotypes over a long period of time and hybridisations between them. A third resource is the local knowledge of farmers: most can identify their best yielding trees and, in many cases, individual trees that appear resistant to particular pests or diseases.

The project's main activity was to develop a methodology whereby farmers and local institutions could select promising genotypes from among the great diversity. We established trials of selected (and some imported) clones on farms and have begun to evaluate them. Later on, we expect that farmers will be able to retest the most promising clones on their own farms. Overall, we hope the project will help demonstrate basic methods of statistically sound research to Sulawesi researchers and farmers. We hope to show that low-tech methods, basic science and local human resources are enough to conduct productive and rewarding research.

The ACIAR project involved the cooperation of farmers from selection through to retesting. This has not been without its problems, especially as farmers are very diverse in terms of ability and commitment. We discuss below our successes and failures, and the lessons we learned from them.

On-Farm Selection of Genotypes

Selection of promising local genotypes was done with the farmers. Project personnel visited farms affected by one or more severe pest/disease problems. Farmers were asked to identify trees that yielded well and/or were comparatively resistant to CPB, PPR or VSD (see Box). Particularly susceptible clones were used as controls. The aim was to find clones with both resistance and good yields to recommend to farmers, while clones with resistance only could be used in breeding activities.

Budwood was collected from the trees, propagated by side-grafting onto adult cocoa trees and tested in trials established on farms. Although the results were mixed in terms of the farmers' predictions, e.g. some clones selected as CPB resistant were mediocre in performance, there were successes (Table 1).

- Some clones farmers identified as CPB resistant showed significantly higher resistance than other clones. The average infestation rate among clones tested exceeded 80% and in some clones over 40% of pods were severely infested with CPB, but one farmer-selected genotype had an average infestation rate of 63% with only 5% severely infested (Table 1).
- A number of the farmers' CPB resistant clones had moderate–high rates of average infestation but very low rates of severe infestation, meaning most beans escaped severe damage and could be sold.
- Clones farmers identified as very susceptible to CPB (included as controls) were among the most susceptible in the trial.

In general, CPB resistance is hard to identify since nearly every cocoa genotype becomes infested, especially in the low pod season when infestation rates are highest. More success was met with local selections for PPR and VSD resistance.

- Two local selections had a level of PPR resistance comparable to clones widely recognised for resistance.
- A genotype selected on-farm for VSD resistance was as resistant as two international clones, including one of the most resistant to emerge from the severe VSD epidemic in Papua New Guinea in the 1960s.
- Again, the susceptible controls for both diseases were among the most susceptible in the trial.

Some farmers but not all could identify trees for general productivity as well as pest or disease resistance.

Sulawesi's Pests & Diseases

CPB: cocoa pod borer (*Conopomorpha cramerella*) causes huge crop losses, has a detrimental effect on bean quality, and is thus regarded by buyers and processors in Indonesia as the main problem facing the Sulawesi cocoa industry.

PPR: Phytophthora pod rot caused by the fungus *P. palmivora* can, in particularly wet areas, cause losses exceeding even those from CPB.

VSD: vascular-streak dieback caused by the fungus *Oncobasidium theobromae* can severely affect cocoa trees, especially in prolonged dry spells.

SUCCESS Alliance farmer group setting up a trial under the guidance of the ACIAR project (Peter McMahon)

Establishing Trials on Farms

The project began by establishing two major trials on farms in South and Southeast Sulawesi, with some smaller trials added later on. The large trials consist of 20 replicate blocks, each containing one representative of each test clone. Budwood from about 50 selected genotypes was side-grafted onto 800–1000 mature cocoa trees in each trial. Farmers were asked to progressively prune back the root-stock (mother) trees as the side-grafts developed to allow ample light and other resources to reach the graft. Farmers were compensated for the losses in production expected until the grafts developed fully.

Establishing these early trials was fraught with problems. Firstly, difficulties were encountered in the logistics of long-distance transport of grafting material, sometimes from island to island. Even though budsticks were kept as fresh as possible by sealing the ends with wax and wrapping them in moist banana leaves or foam, there was still high graft mortality largely because it took at least 3 days from collection of material to grafting at the trial sites. We recommend that in future

Clone[1]	Putative characteristic	% total CPB[2]	% severe CPB[2]	% total PPR[2]
Darwis-3 (L)	CPB resistance	71.8	14.4 bc	9.5 ab
VSD-1Ldg (L)	VSD susceptibility	83.1	31.2 cd	2.8 a
Amelonado (IC)	Quality	89.5	32.4 cd	30.7 cd
418A (IC)	Quality	86.9	20.1 bc	11.8 ab
VSD-2Ldg (L)	VSD resistance	85.8	34.9 cd	17.8 b
Catongo (IC)	Yield	75	14.3 b	13 b
KKM-22 (IC)	Yield	85.9	18.3 bc	15.1 bc
Sca-12 (IC)	PPR resistance	79.7	12.5 b	26.7 cd
BR-25 (IC)	Yield, CPB resistance	77.5	15.3 b	39.9 d
Sugeng (L)	Yield, PPR susceptibility	81.7	29.8 c	35.3 d
RCC-72 (L)	N. Sumatra, yield	90.4	41.8 d	11.7 b
PBK-1Ldg (L)	CPB susceptibility	77.8	44.1 d	19 bc
KA2-106 (IC)	PNG, VSD resistance	95.2	19.3 bc	26.5 cd
Aryadi-2 (L)	CPB resistance	63.1	4.9 a	12.5 ab
Aryadi-5 (L)	PPR resistance	88.1	31.5 cd	8 ab
PhytLdg (L)	PPR susceptibility	86.9	26 c	27 cd

[1] *L: Local clone, IC: international clone.*
[2] *Different letters within a column indicate significant difference ($p < 0.05$; Mann Whitney tests).*

Table 1. Incidence of total and severe CPB and PPR in a few of the clones tested in a farm-based trial in Southeast Sulawesi. Ripe pods were harvested and evaluated each fortnight for 18 months. Most local clones (L) were selected on Indonesian farms with the assistance of the farmer.

the emphasis should be on testing local materials in smaller trials in collection areas. Other mortality factors included the skill of the grafters, the condition of the rootstock trees (especially trunk infection with *Phytophthora* canker), infection of grafts with *O. theobromae* or *P. palmivora*, blight and weather conditions. We thus also recommend exploring other propagation methods (see below).

Secondly, although the single-tree replicate design is useful for trials planted on cleared land, in our trials where budstock was side-grafted onto existing cocoa trees, replicates were widely dispersed and sometimes difficult to locate for evaluation. Furthermore, single-tree replicates lack any demonstration value because visitors (e.g. farmers) cannot easily compare the performance of different clones. In later trials we overcame these shortcomings by establishing plots of 6+ trees for each clone, replicated in three blocks.

Thirdly, we found that establishing on-farm trials requires sensitivity to farmers' expectations and needs, and clarity on what is expected of them from the outset. Although the owner-farmers agreed in principle to the trials and the compensation payment, they later proved reluctant to prune back the mother trees to allow grafts to develop. At one location in South Sulawesi, where this remains a problem and grafted clones are yielding very few pods, the reason became clear when it transpired that the trial was established not just on the land of the farmer with whom agreements were made, but on neighbours' land too – all of one of these farmers' trees had been side-grafted. The trees here were also weakened by two major flooding events, which increased graft mortality and decreased fruiting. In Southeast Sulawesi, the farm manager – coincidentally the son-in-law of the owner – refused to prune back the rootstock trees, contrary to the agreement made with the owner. The owner, one of the wealthier farmers in the area, stepped in and made sure the trial trees were pruned properly. He is particularly keen on research, but as he owns a large acreage of farms, he is risking less than the owner-farmers in South Sulawesi.

Our experience indicates that it is crucial to consider social aspects when designing on-farm cocoa research; questions to ask include: Who are the main decision-makers? What risks are they taking by allowing trials on their farms? Who else would be affected by the proposed research (family members, itinerant labourers)? What is their level of understanding of the research objectives?

We applied the lessons we had learned when we established three smaller trials, coordinated by the extension service Dinas Perkebunan, at different locations in Southeast Sulawesi in collaboration with farmer groups formed through SUCCESS Alliance (see *GRO-Cocoa* No. 1) and found a high level of enthusiasm among the farmers, with often whole families becoming involved. We plan to involve farmer groups in the collection of basic data at the evaluation stage. Through these research trials these groups are adding participatory research to the participatory education method used by SUCCESS Alliance. It is hoped that this will help encourage them to employ local clone selection and testing, and also enhance dissemination of the approach to other farmers. Such participation encourages farmers to think independently rather than rely on external help.

Conclusion

Farmers are understandably wary about research that might risk cocoa production on their farms. In our project, the heavy pruning of mother trees created a very negative perception of the research as it involved destruction of existing cropping potential. Research perceived by farmers as adding value to their farms will be better received in farming communities. One way to solve the problem we encountered would be to bud-graft clones onto seedlings in nurseries and plant these out in gaps where trees have died (from disease, age, storm damage, etc.) in cocoa farms chosen as trial sites. Such an approach has other advantages: more plants can be produced from a given quantity of budwood (one bud/seedling, compared to the 2–3 budsticks each with 2–3 buds often used for side-grafting) and graft mortality is lower; also, easier and more uniform nurturing will give more uniform grafted material.

We found farmers are generally enthusiastic and keen to learn about new methods. Farmer groups set up by extension organisations such as SUCCESS Alliance are particularly committed. Some of our collaborating farmers have already side-grafted portions of their farms with locally-selected genotypes. However, caution does have to be preached: it is crucial to warn farmers never to graft significant numbers of their trees with a clone that has not been proven in a replicated field trial – the high yield component is particularly easy to misinterpret from one-tree selections. Our results indicate the importance of evaluating clones in local environments both to confirm farmers' observations, and to determine whether any can be recommended to other local farmers as high-yielding in the presence of local pest and disease pressure. It is also crucial farmers understand the advantages of improved planting materials, and learn how to make clone selections and test them properly – and also, given that levels of skills and commitment vary greatly between farmers, the problems and work involved.

By: Peter McMahon[a] (p.mcmahon@latrobe.edu.au), Suntoro[b], Abdul Wahab[c], Agus Purwantara[d], Agung Susilo[e], Smilja Lambert[f], David Guest[g] & Philip Keane[a]

[a] Department of Botany, La Trobe University, Bundoora, 3086, Victoria, Australia
[b] Dinas Perkebunan, Kendari, Sulawesi Tengarrah, Indonesia
[c] BPTP SULTRA, Kendari, Sulawesi Tengarrah, Indonesia
[d] Biotechnology Research Institute for Estate Crops, Bogor 16151, Indonesia
[e] Indonesian Coffee and Cocoa Research Institute, Jember, Indonesia
[f] Masterfoods Australia/NZ, Ring Road, Ballarat, 3350, Victoria, Australia
[g] School of Horticulture, The University of Sydney, Sydney, Australia

Mycorrhizas and Cocoa Agroecosystems in Brazil

In many countries during recent years, agricultural management systems have become characterised by reduced utilisation of synthetic inputs along with the adoption of soil conservation practices. However, the role of microorganisms in sustainable agriculture has been neglected although these organisms could play a significant part in integrated crop management, crop rotations, strategies associated with soil conservation and fertility, and plant disease control including biological control.

Mycorrhizas are symbiotic associations between fungi and plant roots. The majority of plants have them; they are frequently important and sometimes essential to the plant. One group, the arbuscular mycorrhizal (AM) fungi, are often fundamental to efficient nutrient absorption by plants, and thus to plant development and production. The fungal hyphae extend into the soil, facilitating exploration of a larger soil volume than the plant roots alone. In addition, the large hyphal surface areas and their efficient absorption mechanisms facilitate mineral nutrient uptake even where these are in short supply or are relatively immobile in the soil. In this way they are capable of supplying more water and nutrient to meet the needs of the plant host. Under drought conditions, AM fungi are critical for the plant to obtain water and nutrients, and they have also been implicated in protecting plants against pathogens. But mycorrhizas are very fragile and are intolerant of disturbance. AM fungi seem to be obligate symbionts: they cannot grow or be grown in the absence of their host plant.

Brazilian coastal tableland soil profile: the knife marks the boundary between topsoil and compact subsoil 'coeso' layers (Quintino R. de Araújo)

The current research focus on agroenvironmental processes provides opportunities for developing biological alternatives for crop management, based on utilisation of mycorrhizas, for example. Such approaches could be particularly beneficial in areas of socioeconomic deprivation and poor soils. Cocoa is typically grown in acid soils in which phosphorus availability is reduced owing to chemical retention processes in the soil. Could there be a way of enhancing or manipulating AM fungal mycorrhizas in cocoa to improve uptake of nutrients such as phosphorus and zinc by the plants? If so, this could ultimately enhance plant growth and cocoa production.

Biodiversity of both macro- and micro-organisms is essential for terrestrial ecosystem stability. In the Coastal Tableland of Bahia, Brazil, in extensive areas previously occupied by Atlantic Forest, subsoil compaction caused by anthropogenic or natural processes has led to a high density layer, locally known as the coeso, which poses a great challenge to crop production. Agricultural productivity and environmental quality could be greatly improved if the role of mycorrhizas in the coastal tableland soils were better understood. Nutrient capture, and thus plant biodiversity and productivity, could be increased significantly by increasing AM fungal species.

There appears to have been limited work on AM fungi in relation to cocoa. Recent research in Panama and earlier work in Malaysia, Sri Lanka and Venezuela all indicated AM fungi could have a growth-promoting role. It was also reported from Panama, where strains were characterised using molecular techniques, that populations of mycorrhizas (of all kinds) seemed to be lower in cocoa plantations than in forest soils.

A field experiment conducted in Bahia looked at the abundance of AM fungi in four other land-use systems in the Coastal Tableland: natural forest, a rubber tree plantation, pasture and annual crops. Natural forest soil (phosphorus concentration 0.00 mg/kg) had the lowest number of AM fungal spores while pasture soil (phosphorus concentration 3.75 mg/kg) had the highest. Improvement to the nutrient status of the coastal tableland dystrophic (nutrient impoverished) soils may promote higher levels of mycorrhizal associations. In turn, increasing AM fungal activity and population diversity in these soils, especially in the coeso layers, appears to be an important consideration in reducing the edaphic limitations associated with those layers.

Collaborative research is now underway at CEPLAC (Comissão Executiva do Plano da Lavoura Cacaueira) and the Universidade Estadual de Santa Cruz (Ilhéus, Bahia) in Brazil and the University of Florida (Gainesville) and US Department of Agriculture – Agriculture Research Service (Beltsville, Maryland) in the USA to evaluate the role of mycorrhizas in improving nutrient recovery efficiency in cocoa and the use of mycorrhizas as biological indicators of soil health.

By Quintino R. Araújo[a] and V.C Baligar[b]
[a] CEPLAC/CEPEC and UESC, CP 07, 45600-970, Itabuna, Bahia, Brazil
Email: quintino@cepec.gov.br
[b] USDA-ARS Sustainable Perennial Crops Lab, Beltsville, Maryland, USA
Email: vbaligar@asrr.arsusda.gov

Global Research On Cocoa (GRO Cocoa) is produced biannually (June and December) with financial assistance from the US Department of Agriculture (USDA) by:

CABI, Bakeham Lane, Egham, Surrey TW20 9TY, UK

Email: cabi-commodities@cabi.org
Fax: +44 1491 829100
Website: http://www.cabi-commodities.org

Editors: Mrs Rebecca Murphy
Dr Keith Holmes

Send correspondence, contributions and enquiries to:

Rebecca Murphy,
CABI, Silwood Park, Buckhurst Road, Ascot, Berks. SL5 7TA, UK

Email: r.murphy@cabi.org
Fax: +44 1491 829123

www.cabi.org