GRO-Cocoa

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

Breaks with Tradition

Every 3 years the global cocoa community meets at the International Cocoa Research Conference (ICRC - see Box, Acronyms in this issue, p. 3) and associated satellite meetings. In October 2003, the meetings were held in Ghana. Besides the hot cocoa that brought welcome refreshment to participants, there were other novel features. The attendance of West African cocoa farmers brought a fresh perspective: they judged research a success if they could use the outputs. Farmer-centred initiatives are an obvious way in which scientists have adopted this yardstick, but even in the apparently more arcane areas of molecular and endophyte research (identified as emerging areas at this conference), the focus on producing results that will translate into something the farmer can use was evident.

Many speakers at the opening ceremony highlighted how limitations set by meagre resources of cocoa-producing countries have been overcome by international collaboration, through initiatives such as COPAL and regional research programmes. The framework for these is provided by the national research organizations. We present a snapshot of some research at CRIG to illustrate how it is geared towards improving the lot of the Ghanaian cocoa farmer.

The importance of supplying farmers with high quality planting material was a recurring theme. Great strides using molecular methods in understanding properties such as yield, resistance and quality may soon lead to molecular-based breeding. Pioneering methods of technology transfer now will allow future improvements to be delivered quickly to farmers. Uilson Lopez has kindly adapted his presentation, given at the opening ceremony to the INGENIC and INCOPED meetings, on how participatory approaches to breeding and multiplication are helping restore the Bahian cocoa industry post-witches' broom.

With biocontrol and particularly endophytes another hot topic, Gary Samuels has kindly summarized his thoughts on *Trichoderma*, the most widely known genus for cocoa disease control. He demystifies *Trichoderma* taxonomy, explains the pitfalls and prospects for this genus in biocontrol, and provides insights into different ways in which mycoparasites may contribute to disease control.

The 14th ICRC

The 14th ICRC took place in Accra, Ghana on 13-18 October 2003. The conference, with the theme 'Towards a sustainable cocoa economy - what strategies to this end?', was hosted by COCOBOD and organized by COPAL under the able management of their Secretary-General, Mr Hope Sona Ebaï. The 200-plus participants heard 86 oral presentations and viewed 93 posters selected from over 250 submitted abstracts.

Opening the conference, the President of Ghana, Mr John Agyekum Kufour, described challenges facing governments with fragile economies dependent on cocoa and how they had pooled resources to deal with constraints. He pointed to role of COPAL in producing the synergies necessary for survival in the international market. Taking up this theme, Mr Sona Ebaï spoke of the international cooperation demonstrated by the conference, and the importance of improving developing country research and providing support to cocoa-producing countries. The Chair of the Conference's National Organizing Committee, Dr S.E.A. Ntifo highlighted the importance of farmer participatory programmes, and initiatives to improve the sustainability of cocoa production and reduce reliance on pesticides.

An invited speaker, Mr Tony Lass (on behalf of Mr Hans Rysgaard, ICA), speaking on threats and opportunities for cocoa consumption, described the 'cocoa cycle', characterized by farmers planting when prices are high, but by the time the trees come into bearing, prices have fallen. He said the cocoa community needs to act now to counteract the next economic cycle and prevent recycling of past problems. This was one of six invited presentations at the conference; the others were: (1) Dr Jan Vingerhoets (ICCO) Influencing supply and demand for a sustainable cocoa economy. (2) Dr G.K. Owusu with Dr Beatrice Padi (CRIG) Increased productivity and quality through production and distribution of improved planting material and promotion of an IPM strategy (see: Cocoa research in Ghana, p. 4). (3) Prof. Reinhard Matissek Cocoa and chocolate research in Germany - an overview; and the Cocoa Atlas, 2002 edition - a milestone in cocoa and chocolate research in Germany. (4) Mr Bill Guyton (WCF) WCF cooperative strategy to support sustainable cocoa production. (5) Mr Hugo Hermelink (cocoa farmer) Modernizing cocoa farming in Costa Rica. The meeting considered a wide range of topics including genetics & breeding, agronomy, crop protection, technology transfer, socioeconomics, chemistry & quality, improving consumption and various cocoa products.

The field of cocoa genetics and breeding has seen a marked increase in molecular and cell biology research. This was one of two 'emerging areas' identified at the Conference. The sessions on quantitative genetics (13 papers) and molecular biology (7) indicated the remarkable progress made in mapping and understanding the cocoa genome. Some papers demonstrated how the tools and results of these new technologies are being made widely available in databases on the Internet, while others reported on field assessments of various traits. A common thread running through the conference was the need for 'deliverables' to farmers. Widespread sharing of results can increase the speed at which the new technologies filter through to farmers. Abdoulaye Traore

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Dragon Prints

ICRC participants talk to a custodian of Ghana's oldest cocoa farm.

and co-authors described cocoa somatic embryogenesis technology transfer in Cote d'Ivoire and Ghana as a method for effective delivery to farmers, which has been pioneered by CNRA, CRIG and Pennsylvania State University (USA).

One project merits special mention for showing the power of international collaboration. A paper presented by Bertus Eskes on behalf of co-authors and co-workers summarized the results of the 5-year project 'Cocoa Germplasm Utilization and Conservation, a Global Approach', funded by the CFC, supervised by ICCO, and coordinated by IPGRI in collaboration with CIRAD. These organizations worked with national research institutes in ten countries, the CRU (Trinidad) and the University of Reading (UK) on characterization, evaluation and selection of new cocoa genotypes for disease and pest resistance, improvement and enhancement of germplasm populations, exchange of information and selected germplasm accessions, and transfer and adoption of improved cocoa selection and breeding technologies. An international clone trial in nine countries evaluated the stability of economically important traits in 20 selected and diverse accessions worldwide. This produced, for example, clones with stable resistance to *Phytophthora* spp. and new sources of resistance to pests and diseases, which have in some cases directed germplasm enhancement efforts. A lasting achievement of the project is the CFC Project Collection, containing 110 accessions possessing valuable agronomic traits and wide genetic diversity, which are being distributed to countries through the intermediate quarantine facility at Reading. (See the INGENIC report, p. 4, for news of a follow up project.)

In the agronomy session (7 papers), A.A. Afrifa (CRIG) and co-authors neatly summed up a major soil problem: in Ghana, cocoa was first planted in 1879 and over a hundred years later it is being grown in the same, exhausted soil. Different countries are researching the optimum levels of fertilizer for ecological and economic sustainability in these conditions, but the cost of repeated inputs does not make it an easy task. Further papers from West Africa highlighted the special problems of declining rainfall in the region. The discussions at the end of these sessions illustrated the farmers' demands for specific recommendations, which scientific results do not necessarily provide. One contributory factor - climatic variability - was tackled at the University of Reading through an assessment of how various simulated environments affected different cocoa genotypes. Making specific recommendations will remain difficult and perhaps the best hope is to equip farmers with the knowledge and tools to make their own decisions.

Of 24 papers delivered in the crop protection sessions, 19 were on phytopathology, demonstrating the importance of diseases as constraints to production. Nonetheless, insect pests remain significant in West Africa and Southeast Asia; CRIG research on insect pest IPM is described below (see: Cocoa research in Ghana, p. 4). Rodents are significant pests in all regions. A diverting paper by C.H. Lee (Malaysian Cocoa Board) described how encouraging barn owls to nest in cocoa plantations had reduced rodent damage. Encouraging bird predation has given good results in many crops in the Asian region, but is not necessarily part of IPM elsewhere. While the introduction of owls to new habitats would need careful thought (their introduction can have serious impacts on native biodiversity on islands), encouraging local birds of prey may have potential. The second 'emerging area' at the Conference was biocontrol, and particularly the use of endophytes for disease control. Papers on diseases covered their genetic diversity, containment and control including host plant resistance as well as biological control. In a *tour-de-force* chairing of one session, Gary Samuels (USDA) began with an entertaining presentation on *Trichoderma* which nonetheless contained serious messages (see, *Trichoderma*: a taxonomist reports, p. 6), while subsequent discussions indicated both the quantity of on-going endophyte research and the extent of international collaboration. News of progress with a commercial *Trichoderma* product (developed at CEPLAC/CEPEC) for controlling witches' broom caused by *Crinipellis perniciosa* was accompanied by reports of promise for *Trichoderma* (Pierre Tondje & co-workers, IRAD) and *Myrothecium verrucaria* (Marie-Claude Bon, EBCL) in controlling black pod in Africa caused by *Phytophthora megakarya*. Frosty pod (caused by *Crinipellis roreri*) is proving more intractable. Prakash Hebbar (USDA/Masterfoods) summarized key features for successful biocontrol with reference to research projects in Africa and the Americas. He identified three key requirements for a biocontrol agent: it must be economic, effective and user-friendly. He highlighted the importance of product quality, and discussed the need to integrate agents for sustainable control of the cocoa disease complex. He pointed to evidence that agents could become self-perpetuating in the field, making the technology sustainable both economically and ecologically.

The presentations in the chemistry, technology and quality session (8 papers) indicated the importance of geographical and post-harvest influences on cocoa quality. New projects such as the PRIMA Cocoa project in Sulawesi demonstrate that stakeholders are gaining a wider awareness of quality as a key factor in making cocoa production sustainable.

The session on transfer of technology & other research (8 papers) dealt with farmer-centred initiatives, including the SUCCESS and SUCCESS Alliance projects and CRIG Farmer Field School initiatives (see: Cocoa research in Ghana, p. 4). A paper by J.L. Battini (CIRAD/University of Legon, Ghana) described a West African regional research project (2001-05) in collaboration with CIRAD that aims to develop competitive and sustainable cocoa production by intervention at the level of the plot, the farm and the zone. Other presentations reported on surveys of farmers that focused on learning from them about what they did. Such approaches are becoming increasingly common as stakeholders acknowledge the importance of understanding farmer needs rather than imposing solutions. The final session on by-products & new and traditional uses (6 papers) included some innovative ideas for

ICRC participants discuss cocoa with staff at CRIG, Tafo-Akim.

cocoa use, neatly rounding off a conference that aimed to identify strategies for a sustainable cocoa economy.

Dr Martin Gilmour (Masterfoods) was elected Chairman of the International Organizing Committee for the 15th ICRC, with the theme: 'Cocoa production, quality, profitability, human health and the environment'. The location for this meeting is yet to be decided.

A field trip during the conference began at the Aburi Botanical Garden. Established in 1890, it subsequently became an agricultural station, supplying planting material to farmers; nowadays it is a tourist attraction but contains many of the country's germplasm resources. Next was a visit to the country's first cocoa farm, the Tetteh Quarshie Farm at Mampong Akwapim, also now a tourist site, where there was an opportunity to meet the Chief and the descendants of the man who introduced cocoa from Fernando Po. The penultimate stop was a 70-year-old cocoa farm owned by Opanin Philip M. Boakye, recently restored to profit following the adoption of agronomic methods developed at CRIG. Finally, participants visited CRIG's Tafo-Akim station, where a display of posters and exhibits gave a vivid summary of current research activities, while the seemingly effortless expertise of Ghanaian hospitality meant the visitors were treated to an exuberant programme of drumming and dancing and a feast of epic proportions.

COPAL On-line

For more about the Cocoa Producers' Alliance, see their website at: http://www.copal.org

INCOPED Seminar

The INCOPED 4th International Seminar in Accra (19-21 October 2003) had the theme, 'Dealing with pressing crop protection problems'. In the first session on quarantine G.K. Owusu and Boamah Adomako (CRIG), assessing Ghana's cocoa quarantine capacity, summed up the worries of many pest and disease experts by emphasizing the importance of ensuring that regulatory barriers are not overwhelmed. Owusu presented another joint paper describing how in-country quarantine was containing the spread of CSSVD in Ghana. Megan Fenn (University of Reading, UK) and co-authors explained the importance of intermediate country quarantine for containing regional pests and diseases in a climate where worldwide demand for germplasm is growing.

Subsequent sessions focused largely on IPM, and described the wide variety of chemical, cultural and biological options being assessed for pest and disease control. The most popular topic was disease biocontrol using endophytes and mycoparasites, with the relative merits of coevolved *vs* local isolates a point of discussion. For example, Ulrike Krauss (CABI Bioscience/CATIE) and co-authors and Alan Pomella (STRI) and co-authors presented work showing the potential of local pod and leaf isolates for frosty pod (*Crinipellis roreri*) and witches' broom (*C. perniciosa*) control, respectively, while Keith Holmes (CABI Bioscience) and co-authors described how natural enemies from the area of origin of frosty pod were a promising source of novel agents. However, a paper by Roy Bateman (CABI Bioscience) and co-authors comparing the performance of chemical and biological agents for frosty pod control emphasized the prime importance of optimizing delivery systems, and ensuring farmer understanding of this.

Papers by Beatrice Padi and co-authors summarized some of the extensive research behind CRIG's capsid (mirid) IPM package (see: Cocoa research in Ghana, p. 4). In a paper summarizing current knowledge on *Rosellinia*, Martijn ten Hoopen & Ulrike Krauss put out a call for more information on this little-known cocoa disease [email: cabi-catie@cabi.org].

Concerns that coconuts in Indonesia might harbour the same strain of *Phytophthora palmivora* as cocoa (which would have implications for intercropping) were scotched by A. Lolong (Research Institute for Coconut and Palmae, Indonesia) and co-authors. Pierre Tondje (IRAD) and co-authors outlined progress towards biocontrol of black pod (*Phytophthora megakarya*) in Cameroon. A paper by R.T. Awuah and M. Frimpong (Kwame Nkrumah University of Science and Technology, Kumasi, Ghana) confirmed earlier reports by A.Y. Akrofi and I.Y. Opoku (CRIG) that *Phytophthora* could be seedborne but not seed transmitted in contrast to a 1996 report by Kumi and co-workers that the pathogen is seed transmitted in cocoa. The resurgence of stemborers in the West African subregion and the potential for using virgin females and pheromones for their control were highlighted by R. Adu-Acheampong and co-workers (CRIG).

In the final session on technology transfer Mercy Asamoah spoke about CRIG's work in this field (see: Cocoa research in Ghana, p. 4), while Janny Vos (CABI Bioscience) described the importance of farmer access to tailor-made information, and the role in this of all stakeholders in the cocoa IPM knowledge system. The final presentation by Frances Bekele and co-authors (CRU), was on the red squirrel, a reminder that rodents remain one of the cocoa farmer's unsolved problems.

Dr Louis Pereira (CEPLAC/CEPEC, Brazil) indicated his wish to step down as Chairman of INCOPED. The meeting agreed Andrews Akrofi (CRIG) as the new Chairman, with Dr Pereira kindly agreeing to provide support during a hand-over period.

Acronyms in this Issue

BAC: Bacterial artificial chromosome
CABI-ARC: CAB International - Africa Regional Centre, Kenya
CATIE: Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica
CCRI: Cocoa and Coconut Research Institute, Papua New Guinea
CEPLAC/CEPEC: Comissão Executiva do Plano da Lavoura Cacaueira/Centro de Pesquisas do Cacau, Brazil
CFC: Common Fund for Commodities
CIRAD: Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France
CNRA: Centre National de Recherche Agronomique, Côte d'Ivoire
COCOBOD: Ghana Cocoa Board
COPAL: Cocoa Producers' Alliance
CRIG: Cocoa Research Institute of Ghana
CRU: Cocoa Research Unit, University of the West Indies, Trinidad and Tobago
CSSVD: Cocoa swollen shoot virus disease
EBCL: USDA European Biological Control Laboratory, France
FFS: Farmer Field Schools
HRI: Horticulture Research International, UK
ICA: International Confectioners Association
ICCO: International Cocoa Organization
ICRC: International Cocoa Research Conference
INCOPED: International Permanent Working Group for Cocoa Pests and Diseases
INGENIC: International Group for Genetic Improvement of Cocoa
IPGRI: International Plant Genetic Resources Institute
IRAD: Institut de Recherche Agricole pour le Développement, Cameroon
NRI: Natural Resources Institute, UK
STRI: Smithsonian Tropical Research Institute, Panama
SUCCESS: Sustainable Cocoa Extension Services for Smallholders project, Indonesia
USDA: US Department of Agriculture
WCF: World Cocoa Foundation

INGENIC Workshop

The 4th INGENIC Workshop in Accra (19-21 October 2003) entitled, 'Cocoa Breeding for Improved Production', commenced with an overview of cocoa production by Bertus Eskes (CIRAD) in which he emphasized, "cocoa breeders need to understand cocoa agronomy and production or they may lose their jobs." In Brazil, only 2-3% of cocoa trees in production are clonal cultivars while more than 95% are from open-pollinated seeds. He emphasized the need for better understanding of genotype × environment (G×E) interactions in cocoa and the effects of rootstock on clonal materials.

Yoel Efron (CCRI) explored some of the reasons why the genetic potential of *T. cacao* has not been fully utilized, citing the emphasis of breeding for disease resistance, lack of true varieties on plantations, lack of use of current breeding technologies and unsustainability or discontinuity of cocoa breeding programmes. He also saw the need for the integration of disciplines.

The meeting proceeded looking at different factors affecting yield in cocoa. It was noted that 72% of young cocoa pods were lost through cherelle wilt and that pods are most vulnerable in their first 12 weeks. Yoel also explored the measurement of yield in cocoa with the introduction of the concept of Harvest Efficiency (yield over a period of time divided by the increase in trunk cross sectional area over the same period). He presented results indicating that it was a better indicator of yield than the Harvest Index (yield/vegetative growth), a destructive means of yield estimation used in annual crops.

The second day dealt with the use of rootstocks in cocoa. Chris Atkinson (HRI) expounded on the use of scion length, root pruning and restriction as means to achieve dwarfing in apple with the potential to achieve the same effect in cocoa. Rob Lockwood noted that rootstocks have been reported, shown in some cases, to modify harvest efficiency, improve resistance to pests and diseases and improve quality. He cited the use of rootstocks for virus indexing in West Africa and for resistance to *Ceratocystis* wilt in other cocoa-producing countries as examples of successes. However, in some countries the effectiveness of rootstocks was less convincing. He found rootstocks had no significant effect on quality. In his view, selecting for dwarfing scions in cocoa would be more beneficial than using rootstocks. There were two presentations on mutations in cocoa with dwarfing effects, of which the more promising, presented by Yoel's group, exhibited apparent cytoplasmic inheritance showing a 1:1 ratio of normal:dwarf progeny in crosses between dwarf female × normal male and all normal progeny when the male was the dwarf - investigations are continuing.

The meeting closed with the announcement of funding approval for the new ICCO/CFC project 'Cocoa productivity and quality improvement, a participatory approach'. This 5-year project, expected to commence in January 2004, will unite cocoa researchers from cocoa-producing countries in Africa, Latin America and Southeast Asia and international research institutions in Europe and the USA. The highlight of the closing ceremonies came when Bertus Eskes was recognized with a plaque and highly commended by the cocoa community for his unwavering efforts for the advancement of cocoa research.

Cacao Genomics Group

In a pre-Workshop meeting (18 October 2003), a new coordinating committee for this group was established with Mark Guiltinan (Pennsylvania State University, USA) as chairman. This group was voted in as a sub-group of INGENIC. Two main outputs were:

- A two-prong approach to characterizing cocoa germplasm, establishing (as far as possible) the original genotype for each accession (spearheaded by Paul Hadley, University of Reading, UK), and standardization of SSR allele calling or sizing between laboratories and over sequencing methodologies.
- Availability and accessibility of BAC libraries was discussed and the new database CocoaGen-DB was introduced which bridges the ICGD (International Cocoa Germplasm Database at http://www.icgd.rdg.ac.uk) and TropGENE (Tropical Crop database at http://tropgenedb.cirad.fr). CocoaGen-DB is intended to complement not replace the ICGD and TropGENE databases.

By: Lizz Johnson, CABI-CATIE- USDA, Laboratorio de Biotecnología, CATIE 7170, Turrialba, Costa Rica
Email: ljohnson@catie.ac.cr

Cocoa Research in Ghana

The importance of cocoa in Ghana was clear during the 14th ICRC. Opening the conference, the President of Ghana paid homage to the country's cocoa farmers who built the nation with "cutlasses and hoes", but pointed out that the average Ghanaian cocoa farmer is 57 years old and the challenge was to attract the young. He noted that the modern farmer needed education and technical know-how to succeed. The importance of cocoa in Ghana was reiterated by the Chief Executive of COCOBOD, Mr Kwame Sarpong, who said cocoa, first introduced in 1879, remained the backbone of the country's economy.

Pod speckling, characteristic of mirid damage (G. Oduor)

CRIG is at the centre of the drive to equip cocoa farmers with the necessary methods and knowledge. Its mandate is to undertake research into all problems relating to the production, processing and utilization of cocoa (and other mandated crops).

Papers given by CRIG staff during the 14th ICRC and the INCOPED and INGENIC meetings, together with a field visit to CRIG's station at Tafo-Akim, gave other participants insights into how the national cocoa research programme is geared towards the farmer. There are five research divisions at CRIG (Agronomy and Soil Science; Entomology, Physiology/Biochemistry; Plant Breeding; Plant Pathology) and two units (Social Science and Statistics; New Products Development). However, research is organized into multidisciplinary thrusts: cocoa establishment, cocoa management, cocoa improvement, cocoa insect management, cocoa swollen shoot virus, cocoa fungal diseases, and new products. Here we look at just two research areas.

Capsid IPM Strategy

A major achievement in recent years, developing an IPM strategy for capsids (mirids), was described by Beatrice Padi at the 14th ICRC and the INCOPED 4th International Seminar. Some 25-30% of Ghana's cocoa acreage is affected by capsids. The ultimate goal for developing and applying IPM methods is to provide a safer capsid control strategy that will also help generate a satisfactory income for the small cocoa farmer.

The success of the multi-disciplinary approach is evident in the IPM initiative's achievements so far:

- Neem-based products have been developed and field-tested in collaboration with farmers (see below).
- Pheromones have been identified and synthesized in collaboration with NRI, and sticky traps assessed for a lure-and-trap system.
- Isolates of *Beauveria bassiana* are being assessed for biocontrol of capsids at CRIG in collaboration with CABI-ARC.
- Ghana is among a number of countries that has identified different genotypes showing some resistance/tolerance to capsid attack under the CFC/ICCO/IPGRI global project on cocoa germplasm utilization and conservation (see 14th ICRC report, p. 1).

For the moment conventional insecticides continue to be the most effective method for controlling capsids in Ghana and research on them focuses on both lessening environmental and health impacts and reducing costs to farmers, e.g.:

- Long-term studies on the ecology and phenology of capsids have been completed, which will help with optimization of spray application methods and timing.

CRIG adapts its research to meet the changing needs of cocoa farmers. While capsids are long-recognized pests in West Africa, new pests and diseases continue to emerge. The cocoa stem borer *Eulophonotus myrmeleon* is recognized to be inflicting increasing damage in the region. Research into IPM solutions initiated in 1998 gave promising results in large-scale on-farm trials in 2 consecutive years.

Listening to Farmers

Working with farmers is increasingly seen as the key to improving farmer adoption of research outputs. Although primarily concerned with developing technologies, CRIG has stepped up its extension activities to meet the information needs of farmers.

Farmers choose not to use cocoa research technology because of perceived high input costs and the long interval between implementation and observable benefits, which represents a failure in extension. CRIG's activities to redress this have included media campaigns, FFS, involvement in the government cocoa pest and disease control programme, on-farm studies and socioeconomic surveys. At the 14th ICRC, Francis Baah and co-authors described the challenges in adapting the FFS approach to Ghana's cocoa sector and the activities planned. FFS were developed in annual crops and have been successfully implemented in the Ghanaian vegetable sector. Using the approach in cocoa means adapting the curriculum to a perennial tree crop. Beatrice Padi, at the INCOPED seminar, outlined the use of socioeconomic surveys in evaluating costs and methods for manufacturing and applying botanicals against capsids. Speaking at the INCOPED seminar, Mercy Asamoah described efforts by CRIG to improve research-farmer linkages and make research findings more meaningful and acceptable to farmers. Baah and Asamoah described at the 14th ICRC how talking to men and women individually in three cocoa farming communities has provided insights into gender issues in cocoa production in Ghana, which may help researchers to be more gender sensitive when developing production technologies.

The potential of farmer-based research is illustrated by one initiative where CRIG scientists worked with farmers to design a mistletoe pruner. This tool, on show during the visit to CRIG, was developed from indigenous technology through a participatory process. It is able to cut through larger-diameter stems than the imported pruner, and the jagged teeth of the cutting edge were perfected through discussions with farmers about their traditional tools and trials of various models. The new 'homegrown' pruner performs better, and is cheaper, than the imported pruner.

CRIG, P.O. Box 8, New Tafo-Akim, Ghana
Email: crig@crig.org
Fax: +233 027 609901

Fostering the Bahian Phoenix

The introduction of witches' broom (caused by *Crinipellis perniciosa*) to Bahia in 1989 led to the collapse of cocoa production. The disease ran rampant through 600,000 ha of continuous cultivation of what proved to be largely susceptible cocoa cultivars. Bahia formerly produced some 80% of Brazil's cocoa, but annual production fell from an average of 350,000 tonnes to 100,000 tonnes in 10 years. The economic disaster was accompanied by social problems, as destitute farmer and farm-worker families migrated to the cities leaving 'ghost farms' behind. Environmental degradation also followed as farmers who were struggling to hold onto their livelihoods chopped shade trees for saleable wood, causing intensive deforestation in the remnants of one of Brazil's most important rainforests, the Atlantic forest.

This article describes how CEPLAC/CEPEC

A witches' broom on a flower cushion (Roy Bateman)

tackled the crisis. Witches' broom is one of several invasive fungal diseases threatening cocoa production around the world, and the experiences in Bahia provide lessons for any country facing threats from these diseases.

Resistance was seen as the foundation for an IPM strategy, but initially no resistant clones were available. It was recognized that a new strategy for fast development and deployment of productive and resistant varieties to farmers was crucial to restoring Bahian cocoa. A participatory approach was developed, which included:

- Surveying for and selecting resistant genotypes on private farms
- Propagating resistant varieties in on-farm clonal gardens
- Forming farmers' associations to facilitate technology transfer and multiplication of selected varieties

On-Farm Selection

Paradoxically, the extent of the devastation wrought by witches' broom helped the search, because trees showing resistance became quickly apparent under high disease pressure. In addition the climate, although ideal for epidemics, promoted year-round pod bearing which meant farmers harvested frequently and were well-placed to notice resistant trees.

Surveys for trees showing resistance were conducted between June 1993 and December 1998 on farms identified by CEPLAC extension agents in areas where the disease was extremely severe. Each visit included a breeder and an extension agent, and began with a discussion with the farmer to explain what the survey was for. Farmers were at first unable to recognize either disease symptoms or signs of resistance because the disease was new to them, but their knowledge subsequently increased. Although 90% of preliminary on-farm selections were later discarded, by December 1998 some 1200 were being evaluated. These were initially called VB (*Vassoura de bruxa*, or witches' broom) selections, a name that stuck. Evaluation consisted of (usually) three visits per year

Farm Demonstrates Success

The participatory nature of the field evaluations was originally necessary because CEPEC stations had low witches' broom disease incidence. Mrs Maria Rosalina Moura Pinto, owner of the Rainha do Sul farm, in an area of high disease incidence, gave land for planting and testing resistant strains. The farm covers an area of 160 ha all planted with cocoa. Before the introduction of witches' broom it produced 180 tonnes per year, but by 1995, 6 years after the disease arrived, it produced 4.5 tonnes.

The farm subsequently became important as a centre for training and motivating farmers, extension personnel, government officials and politicians. Its location close to a federal highway made access easy, and the resistant selections were planted close to the farm entrance, making the better performance of the selections immediately apparent to visitors.

From 1997 to 2002, hundreds of visitors, from farm workers to the provincial governor, visited the farm. It gave hope to farmers on the point of abandoning cocoa, and convinced politicians that witches' broom could be overcome using resistant varieties, which led to credit being made available to farmers to replant.

Farmers visiting one of the demonstration areas, Rainha do Sul Farm (U. Lopes)

to the 'mother' tree, together with inoculation studies on seedlings grown from seed (where found) and studies on budwood grafted seedlings planted in observation plots and evaluated under uniform conditions. Some 600 selections were chosen for on-farm field trials (see Box 'Farm Demonstrates Success').

The success of the VB project meant that farmers were trained to identify resistant trees and eager to continue. Guidelines were written and widely distributed*. Farmers expanded their surveys into neighbouring abandoned farms, and between 1997 and 2002 they pre-selected more than 5000 trees, of which a fair number survived. Stimulated by CEPEC, the best selections were exchanged between farmers, both to make them more widely available, and to test them under different environmental conditions. The best farmer selections are now grown in clonal gardens on most farms in the region, and many are widely planted.

In 1998, CEPEC downgraded its own surveying activities, relying instead on the stream of farmers' pre-selections. The drawback to this was that data were sometimes inadequate. Nonetheless, CEPEC today holds about 300 farmer selections, and some 70 are being assessed in multi-location on-farm trials (see below).

Propagation and Distribution

The production of large quantities of planting stock at low cost was achieved though decentralized clonal gardens on (mostly large) private farms, which distributed to small farmers. About 100 gardens were established with five clonal varieties recommended by CEPEC (TSH-516, TSH-565, TSH-1188, CEPEC-42 and EET-397), and 20 of the best VB selections were also planted in most of them (see also Box 'Finding Mixed Resistance'). Farmers established many other gardens, using not just the above varieties but 500-1000 selections that had been interchanged between them. A drawback to this enthusiasm was that these were often distributed and planted widely before they had been properly evaluated.

A further challenge was to engage more small farmers. CEPEC encouraged the formation of associations, so groups of farmers could be trained to produce their own propagation material. Where farmer poverty precluded the establishment of clonal gardens, CEPEC encouraged local government to provide start-up funds.

On-Farm Testing

In 2000-2001, 24 clonal trials were established on farms to evaluate some 150 chupon-grafted clones (from CEPEC and farmer selections), covering most if not all environments of the region and pathogen populations (as identified by molecular markers). Farmers are trained to collect data for several traits for usually some 700-800 trial plants. The information is collated by CEPEC, which reports back to each farmer.

Conclusion

In the 10 years since the programme began, more than 1000 trees have been pre-selected by CEPEC and more than 5000 by farmers, and highly productive and resistant clones have been found. The best 20-30 VB selections are widely planted on most farms in Bahia.

Out of the disaster of witches' broom, the Bahian cocoa sector has re-emerged as more diverse, better trained, better coordinated and more prepared for facing future challenges. The participatory approach adopted by CEPEC allowed it to establish strong links with the local community and to reach many farmers. Importantly, for the regeneration of the industry, this approach has expanded beyond the farmers. Success has attracted politicians, and consequently more resources have been provided for CEPEC and the cocoa farmers.

Finding Mixed Resistance

Although some VB selections were Scavina, the best-known source of resistance to witches' broom, others were not. Isozyme analysis, at the time the only marker technique available at CEPEC, suggested that of the 39 selections tested, the most likely parentage was Scavina for 18 selections, IMC-67 for five and Pa-150 for 3, while a single antecedent was not identifiable for the remainder.

It was decided to avoid trees with obvious (phenotypic or genetic) Scavina parentage to increase the chances of selecting other genes for resistance. While observed diversity is not a guarantee that different resistance genes exist, incorporating this into a breeding programme is a sensible approach in the absence of better (genetic) information. Since then, use of other molecular markers has shown that wide variability indeed exists among the selections. The next step is to use markers associated with witches' broom resistance to identify its genetic components.

* Pinto, L.R.M. & Pires, J.L. (1998) *Seleção de plantas de cacau resistentes à vassoura-de-bruxa*. CEPLAC/CEPEC, Ilhéus, Bahia, Brazil. Boletim Técnico No..181, 34 pp.

Adapted from Lopes, U.I., Monteiro, W.R., Pires, J.L., da Rocha, J.B. & Pinto, L.R.M. (2003) On farm selection for witches' broom resistance in Bahia, Brazil - a historical retrospective. Presented at the Opening Ceremony to the INGENIC and INCOPED meetings (19-21 October 2003, Accra, Ghana) by:

Uilson Lopes, SEGEN/CEPEC/CEPLAC, Rod. Ilhéus-Itabuna, km 22. Itabuna, Bahia, 45.600-000, Brazil
Email: uilson@cepec.gov.br

Trichoderma: a Taxonomist Reports

My presentation at the 14th ICRC began with a stark warning: *Trichoderma* taxonomy is very tricky, so don't believe what you read. Why? This genus presents few morphological highlights, so defining and identifying species is difficult. From its first description in the early 19th century until

1969, it contained no more than nine species, and at one point these were reduced to one (which made identification very easy but left the observant user unfulfilled!), although a later worker recognized 35 species. It was not until the mid 1990s when DNA sequence analysis was first applied to *Trichoderma* taxonomy that better understanding was possible. Today, DNA sequence analysis is absolutely essential for the description and characterization of *Trichoderma* species. It is possible that *Trichoderma* is the only genus for which every species is represented in GenBank, the international database of DNA sequences, by at least one partially sequenced gene and many species are represented by sequences of two or more genes.

Teasing out *Trichoderma* Taxonomy

Trichoderma species are common in soils around the world. Most reports of fungi used in the biocontrol of fungal diseases refer to one of three species: *T. harzianum*, *T. virens* and *T. viride*. However, DNA sequence analysis has permitted us to uncover some misidentifications in this literature, for example:

- *T. viride* has long been known as THE species of *Trichoderma* that has globose and warted conidia and, as such, is easily identified. Elke Lieckfeldt and her collaborators examined cultures identified as *T. viride* and found a correlation between DNA sequences and the type of warts, which were more or less conspicuous depending on the strain. They separated *T. asperellum* from *T. viride*. Currently, the soil fungus *T. asperellum* is being evaluated against black pod disease caused by *Phytophthora megakarya* in Cameroon (see below).
- *T. stromaticum* is the heart of the commercial biocontrol product TRICHOVAB®, which is reducing the inoculum of *Crinipellis perniciosa* (cause of witches' broom disease) in eastern Brazil. This was reported in the literature as first *T. viride* and then *T. polysporum*. A combined study of morphology and DNA sequence analysis in our lab revealed it to be a new species. There are indications that it is becoming established in eastern Brazil and that sexual reproduction, with possible genetic recombination, is taking place. Prakash Hebbar and Jorge T. de Souza, at USDA-Beltsville and Masterfoods, are investigating this.

Cocoa pod with frosty pod infection (light area) colonized by Trichoderma *(overlying dark patch on left-hand side) (Keith Holmes)*

Another 'source' of new species of *Trichoderma* is the DNA-based phylogenetic analysis itself.

- *T. koningii* is representative of a common morphology in *Trichoderma* sect. *Trichoderma* shared by at least four species, of which three are undescribed. In the light of sequence analysis, *T. koningii* can be defined in a strict sense by the length/width ratio of its conidia and its growth rate. One of these *T. koningii* morphological species is being evaluated for biocontrol of frosty pod rot (caused by *Crinipellis roreri* [formerly *Moniliophthora roreri* and *Monilia roreri*]), in Ecuador. It has been isolated as an endophyte from trunks of *Theobroma* species in Brazil, Ecuador and Brazil and its *Hypocrea* sexual stage has been found in Cuba, Puerto Rico and the USA (Kentucky).

The bottom line is that one must view reports of identified species of *Trichoderma* with some scepticism. While *Trichoderma* species can be identified using the microscope and cultural characters, the most secure way for most people to identify a species of *Trichoderma* is through DNA sequences. Keys to the identification of most species of *Trichoderma* described up to the year 2000 are available in printed form and an interactive key is available at:

http://nt.ars-grin.gov/taxadescriptions/keys/trichodermaIndex.cfm

With the phylogeny of *Trichoderma* being revealed at a great pace, it becomes possible to ask whether some kinds of biological activity might be phylogenetically based. One of the first volatile antifungal compounds isolated from a *Trichoderma* species was 6-pentyl-α-pyrone (6PAP), a non-toxic compound with the distinctive coconut odour that characterizes *T. viride* and its relatives (*Trichoderma* sect. *Trichoderma*). (Although production of 6PAP has been attributed to *T. harzianum*, which is not a member of the *viride* group, we have never had a culture of true *T. harzianum* that has the coconut odour.) As 6PAP has been shown inhibit some disease-causing species, assays of the many members of *Trichoderma* sect. *Trichoderma* for enhanced ability to produce 6PAP could prove fruitful.

Author and collaborators examining fungi on a rotten branch during field surveys in West Africa (H.C. Evans)

Trichoderma from Trees

A previously unexplored niche is the tissue of healthy cocoa trees where *Trichoderma* species are found as endophytes. Harry Evans and his team (CABI Bioscience) are using 'classical biological control' techniques in searching for biocontrol agents in the area of origin of the crop and/or pathogen. They have isolated endophytic fungi from asymptomatic cocoa and cocoa relatives (*Theobroma* and *Herrania* species) in the upper Amazon region, which is where cocoa is thought to have evolved along with one of its major American pathogens *Crinipellis perniciosa* and in the western Andes where the second major pathogen, *C. roreri*, evolved on its original forest host *T. gileri*.

Coevolved antagonists of *Phytophthora megakarya* have been sought in the Korup National Park of western Cameroon where the pathogen is thought to have evolved in association with *Cola*, a relative of cocoa. We have taken soil samples from the Korup Forest in the hope of finding more effective strains of *T. asperellum* than currently being used in Cameroon by Pierre Tondje. Keith Holmes and Harry Evans have also isolated endophytes from trunks of *Cola* species in the Korup National Park. Species found include both well-known species, such as *T. harzianum*, and a high proportion of new species.

Harry Evans' team has also found an endophytic strain of *T. stromaticum* in Ecuador that is more effective against witches' broom, in *in-vitro* studies, than the one currently used in TRICHOVAB. The finding of *Trichoderma* - and other soil fungi such as *Clonostachys rosea* (formerly *Gliocladium roseum*, a species often used in biological control) - living endophytically within asymptomatic cocoa trees is surprising. Endophyte literature tends to emphasize leaves of dicotyledonous plants and not stems, and the fungal endophytes of leaves tend to be species that, outside of the leaf, are found on decaying leaves or as twig, leaf and fruit, but not soil, inhabitants. We are in the process of describing several new *Trichoderma* species that are endophytic within trunks of *Theobroma* species. Keith Holmes has been able to reinfect cocoa seedlings with some of them and could re-isolate many from the shoot meristem of the cocoa seedlings. At least one, a new species, inhibited radial growth of *Crinipellis roreri* in vitro. It also persisted on the surface, and within the tissues, of cocoa pods in the field for at least 10 weeks.

In Conclusion

Trichoderma species are effective in biocontrol of fungus-induced plant disease. The study of endophytic fungi in stems and leaves from a biocontrol perspective, especially when combined with exploration in areas of diversity of hosts and their pathogens, holds the promise of finding new or more effective biocontrol agents (and not just in the genus *Trichoderma*). The study of the interaction between host plants and their endophytes, especially at a molecular level, will certainly give new insights into the resistance of plants to disease-causing fungi. It's all very exciting at this point!

By: Gary J. Samuels, USDA-ARS, Systematic Botany and Mycology Lab., Rm. 304, B-011A, Beltsville, MD 20705, USA
Email: gary@nt.ars-grin.gov

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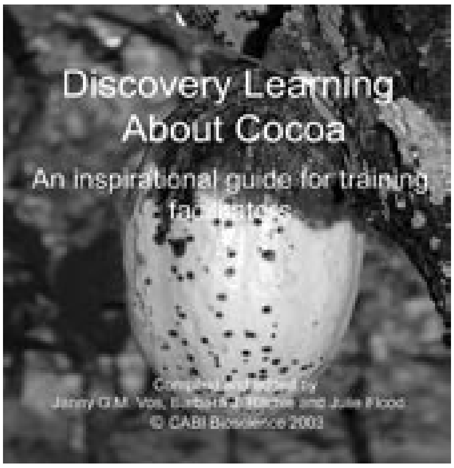
New Resources



Discovery Learning Manual

This sourcebook for trainers was developed with funding from the CAB International Partnership Facility, and printed and translated thanks to funding from Masterfoods.

Section 1 explains why sustainable cocoa production is needed, and how the discovery-based exercises in section 3 contribute to building an understanding of the principles and methods of its various components. Section 2 includes data sheets on ten of the world's main cocoa pests, diseases and parasitic plants. Section 3 contains 22 exercises, beginning with an appraisal of cocoa production and going on to deal with:

- Introduction to discovery-based learning: monitoring, agroecosystem analysis, cooperation, standardization.
- Agronomic practices: top-grafting, pruning, shade and humidity, compost, fertilizer.
- Pests and diseases: insect 'zoos' to observe biocontrol, symptom development and life cycles; disease 'zoos' for infection studies and symptom development; soil and disease spread; insects and virus spread; disease resistance.
- Pesticide use: contamination, pesticide specificity, pesticide resistance.
- Economics for crop management decision making.

The manual is available in English and will shortly be available in French, with other translations in the pipeline. The editors hope it will inspire further cocoa IPM training curricula development, such as regionally tailored editions.

Vos, J.G.M.; Ritchie, B.J.; Flood, J. (*eds*) (2003) Discovery learning about cocoa. An inspirational guide for training facilitators. Egham, UK; CABI Bioscience. Pbk 110 pp and CD-ROM.

Contact: Babara J. Ritchie, CABI Bioscience, Bakeham Lane, Egham, Surrey TW20 9TY, UK
Email: b.ritchie@cabi.org
Fax: +44 1491 829100
Website: http://www.cabi-commodities.org

Cocoa Atlas

This CD-ROM is the output of a University of Hamburg-based project, initiated and funded by the German Chocolate and Cocoa Foundation. A summary of cocoa biology and cocoa statistics is followed by the results of analyses of cocoa beans from 21 countries. The 122 tests performed give information on the levels of many compounds that contribute to cocoa flavour and quality, including caffeine, flavonoids, organic acids, polyphenols, amino acids and fatty acids.

German Chocolate and Cocoa Foundation (2002) The cocoa atlas - 2002 edition. CD-ROM. Price incl. p&p: €30.00 (includes CD-ROM: 'The making of one of life's pleasures, from cocoas tree to chocolate').

Email: order@infozentrum-schoko.de
Fax: +49 214 31255 29
Website: http://www.infozentrum-schoko.de

Phytophthora Book

Phytophthora palmivora is the most serious worldwide disease of cocoa, while containing the spread of and damage from *P. megakarya* in Africa presents enormous challenges. This book provides the international cocoa community with the knowledge and tools for breeding cocoa trees with greater resistance to *Phytophthora*. It covers pathogen diversity, epidemiological knowledge, the genetic parameters of resistance observed in the field, and practical breeding. Breeding is a field where methods are advancing rapidly and guidance is invaluable, so wide coverage of the use of different screening tests involving artificial inoculation and of molecular markers for the selection of resistant material adds value to the book.

Cilas, C.; Despréaux, D. (*eds*) (2003) Improvement of cocoa tree resistance to *Phytophthora* diseases. Montpellier, France, CIRAD, 184 pp. Price: €23.00 + p&p. ISBN: 2 87614 562 6

Contact: Librairie du CIRAD, TA 283/04, Avenue Agropolis, 34398 Montpelier Cedex 5, France
Email: librairie@cirad.fr
Fax: +33 4 67 61 55 47
Website: http://www.cirad.fr

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CABI *Commodities*, an initiative of CABI *Bioscience*, 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 Julie Flood

Send correspondence, contributions and enquiries to:

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

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

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