PRESENTATION SUMMARIES

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1608 RHODE ISLAND AVE, NW • WASHINGTON, DC 20036
TELEPHONE: (202) 974-6287 • FAX: (202) 833-3419

PLANT SCIENCE: ENSURING THE SURVIVAL OF A FRAGILE CROP

UNIVERSITY OF CALIFORNIA, DAVIS • C/O UC WASHINGTON CENTER, 3RD FLOOR
1608 RHODE ISLAND AVE, NW • WASHINGTON, DC 20036
TELEPHONE: (202) 974-6287 • FAX: (202) 833-3419

Integrating genomics into an applied cacao breeding program.

R. J. Schnell[1], J. C. Motamayor[2], J. S. Brown[1], D. N. Kuhn[3], C. Cervantes-Martinez[1], C. T. Olano[1], R. C. Ploetz[4], and E. Rosenquist[5]

[1]USDA, ARS, SHRS, Miami FL, USA
[2]Mars Inc., Miami FL, USA
[3]Florida International University, Miami FL, USA
[4]University of Florida, TREC, Homestead FL, USA
[5]USDA-ARS, National Program Staff, Beltsville MD, USA

Abstract
Theobroma cacao L. is an under story tree from the Amazon basin that can be cultivated in a sustainable agro-forestry system, providing income to small farmers while maintaining biodiversity. During the seventeenth and eighteenth centuries, plants derived from a small number of parents were distributed to many tropical regions of the world, resulting in commercial plantings with a relatively narrow genetic base. Production of cacao in tropical America has been severely affected by three fungal pathogens causing diseases known as witches' broom (WB), frosty pod (FP) and black pod (BP). Currently, WB and FP are confined to Central and South America; however, commercial populations in West Africa and South Asia are highly susceptible to both diseases. Traditional cacao breeding programs have only been marginally successful in producing resistant material with suitable commercial characteristics. In 1999, the USDA-ARS in collaboration with Mars Inc. initiated a project to apply modern genomic techniques to cacao breeding. The objectives were to develop an international Marker Assisted Selection (MAS) breeding program focusing on disease resistance. Over 400 micro satellite and 50 candidate gene markers have been used to map families segregating for resistance to WB, FP, and BP diseases. Quantitative Trait Loci (QTL) has been identified for resistance to WB, FP BP and productivity traits. These are being employed in the newly developed accelerated MAS cacao breeding program using a two stage selection technique that greatly improves genetic gain in selection cycles. The application of new genomic technologies along with the accelerated MAS will result in significant cost savings and enhanced efficiency in the development of new cultivars. Large evaluation trials are located in Costa Rica, Ecuador, and Papua New Guinea with additional QTL evaluation studies in Ghana, Nigeria, Costa Rica, and Ecuador. All these projects are collaborations with national agricultural institutes in the respective countries. The accelerated MAS project is expected to produce new disease resistant cultivars by 2010. The utility of Association Mapping for productivity traits has been demonstrated to provide an alternative method to traditional mapping and allow the mining of current germplasm collections for novel alleles. Genetic stocks developed in this program will be distributed to areas currently free of WB and FP in anticipation of the arrival of these diseases. International collaboration and sharing of genetic resources will ensure that crop losses due to these pathogens are manageable and will contribute to stability in the supply of cocoa beans.

Reconstructing the natural history of *Theobroma cacao* L. geographic origins and domestication through molecular genetics and its consequences on modern breeding

Juan C. Motamayor[1], Jonathan K. Pritchard[2] , Nannette Langevin[3], Cuahtemoc Cervantes[2], Jay Wallace, Freddy Amores and Raymond Schnell[3]

[1]MARS Inc., 800 High Street, NJ 07840, USA
[2]Department of Human Genetics, University of Chicago, 920 East 58th Street, Chicago, IL 60637, USA
[3]National Germplasm Repository, US Department of Agriculture, Agricultural Research Service, Subtropical Horticulture Research Station, Miami, FL 33129, USA.
[4]CEPLAC/SUPOR (AMAZONIA), Rod. Augusto Montenegro Km 07, Belem-Pa, Brasil
[5]INIAP, Estacion Experimental Pichilingue, Km 5, Quevedo, Los Rios, Ecuador.

Traditionally, two main genetic groups, also called morphogeographic groups, have been defined within *Theobroma cacao* L. according to morphological traits and geographic origins. As a result of this division, some authors recognized two subspecies: *cacao* and *sphaeorocarpum*, corresponding to the morphogeographic or genetic groups Criollo and Forastero respectively. It was proposed that subspecies *cacao* evolved in Central America and subspecies *sphaeorocarpum* in South America. Cacao breeding schemes were developed to maximize genetic gain through hybridization between these two groups. A number of germplasm collecting expeditions have been accomplished over the past 50 years in several countries of South and Central America. The germplasm collected has had little impact on cacao breeding because its relationship with the exploited germplasm was not understood. Molecular genetic analysis has had a major influence on our understanding of the origin and domestication of many important crops. In cacao, a clonally propagated species, these types of studies have been problematic due to the low reliability of field maps and tagging systems used in germplasm collections. Clones collected decades ago and introduced after a long quarantine into different locations were often misidentified in the process. This problem of mislabeling has limited molecular studies in cacao as the geographic origin of the plants analyzed is not known or is wrong. With the goal of resolving the origin, classification and process of domestication of *Theobroma cacao* L., molecular analyses were performed on 1241 accessions covering a very large geographic sampling area from South and Central America. These included individuals from the most important collection trips. Using Bayesian statistics we identified and eliminated mislabeled samples and optimally performed subsequent analyses. Instead of two major genetic groups, at least 13 major ones were found by fingerprinting with 97 micro satellite markers. We propose a new classification of the germplasm that will enhance management, conservation and breeding. Our data clearly demonstrate that the germplasm present in Central America was introduced by humans, giving rise to a single cultivar, which corresponds to what is called Criollo. The origin of two other traditionally exploited cultivars, Nacional and Amelonado, is also discussed. The analysis revealed gaps in the current germplasm diversity and led to a new collecting expedition in the Ucayali river valley in Peru that yielded new, unique genetic resources. Important information for breeding was obtained, more specifically for the production of homogeneous hybrid seeds and for research on genetic gain through heterosis.

Implications of Different Mechanisms by which endophytic fungi protect Theobroma cacao from pathogens

Edward Allen Herre

Smithsonian Tropical Research Institute

Abstract:

Cultivation of Theobroma cacao constitutes one of the most ecologically beneficial agricultural uses of tropical lands. However, losses due to pathogens undermine the economic incentives to maintain cacao where it is currently cultivated. Recent laboratory, greenhouse, and field studies indicate that naturally occurring endophytic fungi isolated from healthy T. cacao leaf tissues can be used to protect the host from pathogen damage. Further, we have evidence suggesting that different endophytic fungi protect the host via different mechanisms. I will discuss the very different ecological and applied implications of the different mechanisms that potentially underlie host protection.

Thoughts on *Crinipellis*: Defeating the Disease that Destroyed Brazil's Cocoa Crop

Júlio C M Cascardo[1], Abelmon S Gesteira[1], Fabienne Micheli[1,2], Nicolas Carels[1]; Gonçalo G A Pereira[3].
[1]UESC-DCB, Ilhéus, BA-Brazil; [2]CIRAD-CP, Montpellier, France; [3]UNICAMP-IB, Campinas, SP-Brazil.

Crinipellis perniciosa (Stahel) Singer is a fungus basidiomycete that causes witches' broom disease in members of the plant families *Sterculiaceae*, *Solanaceae*, and *Bixaceae*. The economic impact of the pathogen is mainly on *Theobroma cacao* L. Basidiospores infect meristematic tissues (shoots, flower cushions, single flowers, and developing fruits), inducing a range of symptoms depending on the organ infected and stage of development. Hypertrophy growth of infected buds ('brooms') is the most dramatic symptom. Flower cushion infection usually leads to the production of vegetative shoots and abnormal flower development. Pod infections can directly result in seed losses reaching up to 90% of potential annual production in some areas and seasons. Pod set is further reduced indirectly by the infection of flower cushions and the general debilitation of the tree. The life cycle of the pathogen is completed by the production of basidiocarps on necrotic brooms and dried pods releasing basidiospores, the unique source of inoculum. Since 1989, witches' broom disease, caused by *Crinipellis*, has spread throughout Brazil, destroying cacao tree plantations, and leading to important economical and social changes in specific areas such as the State of Bahia. In order to recover cacao plantations, numerous efforts have been made such as the development of new cacao varieties, use of cloned resistant plant material or biological control of the disease. Although these technical procedures have been efficient, they do not represent an adequate method of control. The variability of the fungus, associated with several possible genetic recombinations, in a short period of time, could break the cacao resistance, as observed for some cacao tree hybrids which contain the SCA-6 resistant parent. For many pathogenic systems in plants, study of gene interaction is a suitable approach to discover plant defense mechanisms. The identification of differential expressed genes between cacao trees susceptible and resistant to witches' broom disease is essential to understand biological events of the cacao x *Crinipellis* interactions.

For that purpose we generated two cDNA libraries corresponding to resistant (TSH1188) and susceptible (Catongo) cacao trees inoculated by a pool of *Crinipellis perniciosa* spores. The sequencing of 10,000 ESTs is completed. Fungus and cacao sequences could be discriminated according to their codon usage using a new bioinformatics tool developed in the LABBI (http://labbi.uesc.br). This algorithm is able to discriminate cacao from *Crinipellis* sequences with 95% confidentiality.

The libraries presented two distinct gene expression patterns, with the susceptible genotype undergoing a programmed cell death triggered by the pathogen and the resistant genotype expressing several defense related genes. We also found, in the susceptible library) key genes expressed by the fungus that are clearly related to the infection success and disease progression.

The collections of ESTs obtained are providing new data about the physiology of the interaction between *Theobroma cacao* and *Crinipellis perniciosa*. We are currently performing functional analyzes of some candidate genes. Validated genes could also be used for mapping, aiming to facilitate introgression strategies and to create new varieties resistant to *Crinipellis perniciosa.* These data may also be related to research on gene expression of cacao challenged with other pathogens, such as *Phytophthora* spp and *Monillia*.

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BIOMEDICAL SCIENCE: FLAVANOLA AND CARDIOVASCULAR HEALTH

UNIVERSITY OF CALIFORNIA, DAVIS • C/O UC WASHINGTON CENTER, 3RD FLOOR
1608 RHODE ISLAND AVE, NW • WASHINGTON, DC 20036
TELEPHONE: (202) 974-6287 • FAX: (202) 833-3419

COCOA FLAVANOLS, NITRIC OXIDE AND ENDOTHELIAL FUNCTION

Norman Hollenberg, M.D., Ph.D., Professor of Medicine,
Brigham and Women's Hospital, Howard Medical School

Diet patterns are widely recognized as contributors to hypertension. Widely studied potential contributors include intake of sodium, potassium, magnesium, calcium, soluble fiber, Omega-3 fatty acids, alcohol, protein, and calories. We add to that list the effect of dietary flavanols present in certain cocoas, which have sufficient activity on vascular nitric oxide to influence blood pressure control. Kuna Indians who live on islands near Panama have little age-related rise in blood pressure or hypertension. On migration to Panama City, blood pressure raises with age and the frequency of essential hypertension matches urban levels elsewhere. We have identified a specific food that probably makes an important contribution to cardiovascular status. Island-dwelling Kuna drink more than five cups of flavanol-rich cocoa per day and incorporate that cocoa into many recipes. Mainland Kuna ingest little cocoa and what they do take is commercially available and flavanol-poor. The flavanol-rich cocoa activates nitric oxide synthase in vitro and in intact humans in the doses that the Kuna employ. Island-dwelling Kuna have a 3-fold larger urinary nitrate: nitrite than do Mainland dwellers. As endothelial dysfunction is central to current thinking on cardiovascular pathophysiology, a food that enhances endothelial function could have broad implications. The list of candidate conditions that might be influenced is impressive, ranging from atherosclerosis and diabetes mellitus to hypertension and pre-eclampsia, to vascular dementias and end-stage renal disease. All share as a common feature endothelial dysfunction with loss of either production or action of nitric oxide.

If restoration of nitric oxide production can be achieved by ingestion of flavonoid-rich cocoa, as commonly it can, does this improve natural history? We reduced blood pressure with medications not to make the numbers nicer but because doing so reduces morbidity and mortality. The same logic applies to treatment of high blood cholesterol or a high blood sugar. Does restoration of nitric oxide production improve natural history in these conditions? Only a partial answer is available, but it is very promising. We are at the stage where epidemiology usually plays a crucial role. In the case of flavonoids, efforts to use epidemiology have been limited by the variability in the content of flavonoids in foods, largely representing processing or handling. Grapes grown in the same vineyard have a very different flavonoid content in different years, and so does the red wine produced from these grapes. When an individual eats applesauce or apple pie, he or she rarely knows whether the skin of the apple was included. Essentially all of the flavonoids in apples come from the skin. Flavonoid content in chocolate and cocoa is equally or even more variable. In the island-dwelling Kuna, conversely, cocoa intake is very high, and the cocoa is always rich in flavonoids. Thus, the indigenous Kuna provide an opportunity to address this issue. In data obtained from death certificates, mainland Panama residents who died had disease of the circulation as the most common cause and cancer as a close third. The frequency of these two problems was much lower in the San Blas where the indigenous Kuna live. Indeed, the relative risk of death from heart disease on the Panama mainland was 1,280% of that in the island, and a cancer death was 630%. Thus, the preliminary data available indicate that flavonoid-rich foods may provide an extraordinary benefit in the management of the two most common causes of death in today’s world.

Cocoa Flavanols: Bioactive Nutrients Beyond Antioxidants?

Hagen Schroeter[*], Christian Heiss[§], Carl L. Keen[*], Malte Kelm[‡]
[*] Department of Nutrition, University of California Davis, One Shields Avenue, 3150E Meyer Hall, Davis, CA 95616, USA; [§] Division of Cardiology, University of California San Francisco, 513 Parnassus Ave Room S-1136, San Francisco, CA 94143-0124; [‡] Medical Clinic I, Division of Cardiology, Pulmonology, Vascular Medicine, University Hospital RWTH Aachen, Germany

Previous studies, as well as epidemiological and medical anthropological investigations suggest that the consumption of flavanol-rich cocoa is associated with cardiovascular health benefits. In order to further investigate the biomedical properties of cocoa we aimed at identifying specific, bioactive cocoa constituents, and at elucidating potential mechanisms that underlie the effects on the cardiovascular system that are associated with certain cocoas. We show that the ingestion of flavanol-rich cocoa leads to enhanced vascular function as demonstrated by an increased flow-mediated dilation (FMD) response of conduit arteries, and an augmented microcirculation. Applying previously established causality criteria we demonstrate that: 1) certain cocoa flavanols are absorbed following ingestion, and the kinetics of their appearance in plasma temporally parallels the vascular effects observed. 2) The circulating concentrations of specific flavanols in plasma are sufficient to mediate *ex vivo* vasodilation in isolated aortic rings, mimicking a physiological function of the endogenous mediator acetylcholine. 3) The ingestion of pure (-)epicatechin, a flavanol abundant in certain cocoas, by humans closely and quantitatively mimics the vascular effects of flavanol-rich cocoa consumption. 4) The increase in plasma flavanol concentration after consumption of flavanol-rich cocoa is paralleled by increases in plasma levels of the vasodilator nitric oxide (NO). Furthermore, the direct inhibition of the NO-producing enzyme, nitric oxide synthase (NOS), in humans, and in isolated aortic rings, abolishes the vascular effects related to the consumption of flavanol-rich cocoa. 5) The concept that a chronic intake of high-flavanol diets is associated with prolonged, augmented NO synthesis and cardiovascular health is supported by data from the Kuna Indians that indicate a correlation between the chronic consumption of a cocoa flavanol-rich diet and the augmented urinary excretion of NO metabolites. 6) Data obtained in endothelial cell culture models *in vitro* demonstrate that (-) epicatechin, and (-)epicatechin-related cocoa flavanol metabolites increase cellular NO production by modulating the activity of NOS.
In addition, data from *in vitro* studies, and results obtained following the ingestion of flavanol-rich cocoa by human subjects indicate that the efficacy of cocoa flavanols in the context of cardiovascular function is not solely dependent on antioxidant effects.

The Potential of Flavanols as a "Value-Added" Nutrition Component: Implications for Agriculture and Public Health

Joseph T. Spence, Ph.D., Deputy Administrator, Nutrition, Food Safety and Quality, Agricultural Research Service, U. S. Department of Agriculture.

Consumers are becoming more interested in the foods that they consume, and to a certain extent, are willing to pay for products that offer added value. Health claims related to foods are more common and more food producers are seeking to make such claims for their products. Consumers now have an expanding variety of so-called "functional foods" to consider as well as many enhanced products. Consumers typically will pay for immediate health benefits but have been reluctant to pay for anticipated delayed benefits. Consumers, understandably, make a judgment between the increased cost of a product and the value of any benefits they perceive.

In the past, the focus of production agriculture and the food industry has been on increased yields. More recently, there is a growing emphasis is on increased nutritional content and beneficial characteristics of foods to increase health and reduce the risk of chronic diseases. With regard to traditional nutrients, their importance has been well documented and a lack of these food components results in associated deficiency symptoms. While classical nutritional deficiencies have become much less frequent, they do occur. At the same time, we suffer from an excess of easily available and very affordable foods; the problem of over nutrition and obesity and the associated health impacts is an increasing challenge to society. But what can we say about the emerging newer nutrients? The literature contains many examples of foods that are rich in components such as phytonutrients and this raises a need to look at nutrition in a new light. What are the active components in foods? Do all individuals require all of these nutrients or is there a wide range of requirements for some of the components? What endpoints do we need to examine to accept a food component as a legitimate nutrient? How much will the consumer pay for value added products? Are there other food components that an effect on efficacy? Even the definition of a nutrient needs to be reexamined.

A key issue is determining the economic benefits to farmers and the food industry to the development of foods that meet the demand for functional foods. Flavones and other components in cocoa, based on the emerging evidence of their benefits, are an excellent study of the issues related to agricultural production, consumer acceptance, and public health benefits. A database of these important compounds in foods has been released and the availability of this information has opened up the scientific exploration of the importance of these compounds through some well designed epidemiological studies. By fully demonstrating the value of the nutrition components, consumers can decide their individual disease risk and the benefits of consuming these foods. The producers benefit from the added value to their crops and products, and the additional income they can generate and knowing that they are benefiting society with the new products.

COCOA:
ITS PLACE IN THE SOCIOECONOMIC AND ECOLOGICAL LANDSCAPE

UNIVERSITY OF CALIFORNIA, DAVIS • C/O UC WASHINGTON CENTER, 3RD FLOOR
1608 RHODE ISLAND AVE, NW • WASHINGTON, DC 20036
TELEPHONE: (202) 974-6287 • FAX: (202) 833-3419

Ecological, economic, and social perspectives on cocoa production worldwide

M. Franzen and M. Borgerhoff Mulder

Cocoa is a crop grown largely by smallholder farmers in the lowland tropics, including parts of Latin America, West Africa, and Indonesia. Research suggests that it has the potential to provide biodiversity benefits when grown under certain shade conditions, especially when compared with alternative land uses such as annual food crops and pasture. The primary literature on cocoa production in the developing world reveals a range of objectives for improvement of cocoa production on small farms. These objectives are sometimes in direct opposition to each other, for example, increasing productivity through shade removal and chemical inputs, and the desire to increase biodiversity benefits. These opposing goals demonstrate some real trade-offs faced by cocoa producers who experience fluctuating prices and the challenges of controlling disease on their farms. We summarize the current literature, drawing attention to some of these trade-offs and highlighting important ecological, economic, and social considerations for inclusion in the policy discussion. We make two primary recommendations. First, we suggest that outreach focusing on farm diversification may be the most effective way of optimizing ecological, economic, and social outcomes. Our review of the literature suggests that the alternative approach of increasing cocoa productivity on small farms may not necessarily lead to economic security of farmers as intended. Increasing productivity through shade reduction and chemical inputs not only causes negative biodiversity effects but also results in dependence on those inputs. Farmers appear to be caught in a cycle of overproduction, falling prices, and cocoa abandonment, followed by new forest conversion when prices improve. Outreach focusing on farm diversification may provide an effective means of achieving improved farmer security and reduce the impulse of farmers to abandon or plant cocoa according to price fluctuations, thus reducing the use of new forest areas in cocoa production. Secondly, price premiums associated with fair trade and high quality shade-grown cocoa may increase economic benefits while simultaneously providing incentives to farmers to maintain shade in production. We recommend continued research into the outcomes associated with such programs. Our paper ends by identifying some potential areas of new research for further informing policy in this arena.

Cultivating diversity: The role of cacao agroforestry systems in rural economic growth and conservation of biodiversity.

A.J. Simons, G. Schroth, M. van Noordwijk, R.R.B. Leakey, H. Shapiro and D.P. Garrity

Cacao (*Theobroma cacao*) is the most widely planted, neotropical, rainforest tree covering more than 7 million hectares globally. More than 85% of these plantings are outside of its native range, and most expansively in West Africa. In general, these plantings constitute an un-shaded, or shaded, monoculture of 200 to 2000 trees per hectare rather than a heterogeneous system. In contrast, the natural ecology is defined by a mixed-forest habitat where 1 to 10 cacao trees occur in the low- and mid-canopy strata. From more than 100 years of experience of cocoa plantations in both native and exotic locations, it is clear that mono-cropping is both a high-input and a fragile practice. The fragility is most pronounced with respect to pests and diseases, but also with regard to soils and climatic variability. Furthermore, with fluctuating world prices the real and perceived returns to growers are questionable. For cacao production to be sustainable several commentators have identified agroforestry systems as the best opportunity. Such sustainability will be underpinned firstly, but not exclusively, by stable and profitable returns. Complementary and supplementary agro-enterprises will equally be important for sustainable cacao production in agroforestry systems. The real key to sustainability, however, will be in balancing ecosystem function and integrity of farms and adjacent forests with economic benefits to ensure that viable populations and communities of cacao-associated biota continue to regenerate. A compilation of experiences and opportunities with cacao agroforestry systems and forest landscape management from throughout the tropics are presented. From a synthesis of these experiences, recommendations are made on options that farmers, communities, local authorities, governments and industry may employ to develop more sustainable supplies of cacao, as well as more diverse and stable cacao-associated landscapes. In this way, it is hoped we can let the buyer, seller and consumer be aware of, and not beware, a new cacao agroforestry paradigm.

Cocoa Farming Made More Profitable through the Sustainable Tree Crops Program

James Gockowski and Stephan Weise

International Institute of Tropical Agriculture, Humid Forest Ecoregional Center (IITA-HFC),
P.O. Box 2008, Messa, Yaoundé-Cameroon, Email: j.gockowski@cgiar.org and s.weise@cgiar.org

Traditional smallholder tree crop systems, which are part of an export-oriented cash economy, can play an important role in stimulating the rural economy and contribute significantly to increasing welfare by providing a stable platform for new investments and partnerships in the agricultural sector overall. Over the past decades, under-investment in the tree crop sector, combined at times with weak policy support and market failures, has meant that this potential has not been realized. The Sustainable Tree Crops Program (STCP) was launched in May 2000 to pull together a concerted effort towards the improvement of smallholder tree crop systems in West and Central Africa. At the core of this regional program is a public-private partnership, which includes farmers and producer organizations, the global chocolate industry and cocoa trade, donors and development agencies, the public sector and policymakers, national governments, and national and international research institutes. Together, this first-of-a-kind partnership with an initial focus on cocoa is identifying technologies, approaches and mechanisms to enhance the economic and social well-being of smallholders and the environmental sustainability of tree crop farms. Program activities to augment the productive base of farmers, increase their access to markets, and develop the necessary institutional and policy environment to support this process have to date been carried out in Cameroon, Nigeria, Côte d'Ivoire, and Ghana – and the results are encouraging.

A curriculum has been developed and Farmer Field Schools (FFS) have been instituted during the past three years to address challenges related to integrated crop and pest management (ICPM). Across the four countries, STCP has directly trained approximately 13,000 cocoa farmers and an additional 26,000 farmers have benefited through facilitated farmer-to-farmer diffusion of knowledge. In Ghana, the program's FFS experience has been credited with bringing about average productivity gains of 14% among participating farmers. In Nigeria, farmers who successfully transmitted FFS knowledge to their sharecroppers saw 17% increases in cocoa yields and required the application of 12% less fungicide. STCP has also been working to strengthen collective actions in marketing through training and technical support with interventions particularly successful in Cameroon and Cote d'Ivoire where efforts have led to farmers receiving 5-15% higher farm-gate prices for their cocoa. In Cameroon, households who sold all their cocoa collectively and participated in FFS training are estimated to have increased cocoa income in 2004 by approximately 200,000 Fcfa (US$ 370) or 55%. In Cote d'Ivoire the increase in per household cocoa income in 2004 as a result of combined STCP production and marketing interventions was estimated at approximately 70,000 Fcfa (US$ 130) per farmer, which is a 23 percent increase in cocoa incomes relative to non-program farmers.

Insights have also been gained as to where additional advances can be achieved. Credit market failures in Cameroon and Nigeria are estimated to have reduced cocoa revenues significantly. In Cameroon, the minority of producers with access to credit increased their purchased inputs by 20% and subsequently their gross output by 5%. Quality discounts due to poorly dried beans in Cameroon averaged 4% on approximately half of all sales in two of

the main growing regions. Currently, there appears to be little government regulation of weights and standards in West African agricultural markets. An STCP study found that the scales of itinerant buyers under-weighed the typical 85 kg bag traded in Cameroon by an average of 6 kilograms.

Another set of opportunities is presented by the biodiverse cocoa agroforests of southern Cameroon and Nigeria. An important reason farmers maintain this biodiversity is because it provides an avenue for diversifying income beyond cocoa. In Nigeria sales of oil palm, cola nuts and citrus grown in association with cocoa annually contributed an additional 8,300 naira (US$ 60) per ha representing 15% of cocoa gross revenues. Cocoa farmers also actively manage timber in their cocoa farms for both personal need and market sales. However, in most of West Africa timber belongs to the state which can sell the right to harvest to timber companies. A recent inventory of cocoa agroforests in Cameroon estimated the average amount of exploitable timber to have a FOB value of US$ 2,350 per ha, while farmers receive US$ 115 in the local illegal market.

The Sustainable Tree Crops Program has been able to show that public-private partners working together across the supply chain can bring a variety of unique assets to bear. Successes to date will be scaled up by working closely with development institutions and governments. Identified opportunities will be pursued further towards improving the welfare of smallholder tree crop farmers.

ABSTRACT: Cocoa and Chocolate During the American Revolution Era.

Louis Grivetti, Professor of Nutrition, University of California, Davis

(Office: 530-752-2078; legrivetti@ucdavis.edu)

The Chocolate History Research Group was formed in September, 2004. Our research team consists of approximately 80 scholars/scientists working in North America and abroad that represent four cooperating units: Colonial Williamsburg, Virginia; Fort Ticonderoga, New York; Mars, Incorporated; and the University of California, Davis, Department of Nutrition.

OBJECTIVES: 1) Determine how, when, and where chocolate products were introduced and dispersed throughout North America from 1565 and the foundation of St. Augustine, Florida, to the early industrial age of 20th century America; 2) Trace the development of chocolate-related technology in North America; 3) Identify the culinary, cultural, economic, and dietary-health uses of chocolate in N. America from the Colonial Era into the early 20th century; 4) Develop a chocolate-research web portal for students, teachers, and scholars, and 5) Present chocolate-related findings via popular and scholarly journals and through local, national, and international symposia.

DATA SOURCES: Our primary data sources have included documents from: archives/libraries, art (lithographs/paintings), diaries/travel accounts, government resources (Library of Congress and other depositories), hospital records, ledgers/account books, literature (novels/poetry), medical texts, menus, military records, museum holdings, newspapers and magazines (articles/advertisements), religious archives, shipping manifests, and selected digitized resources.

THEMES INVESTIGATED: We concentrated on eight primary themes/sub-themes in our research on the history of North American chocolate: 1) **culinary** (recipes; preparation and serving equipment); 2) **culture** (art; literature; music; religious and social uses); 3) **health and medicine** (health maintenance and treatment); 4) **economics** (import/export; manufacturing; advertising, marketing and pricing; and sales; production personnel; division of labor); 5) **education** (accounts in 18th century North American schoolbooks); 6) **legal issues** (cacao/chocolate-related crimes and trial accounts); 7) **military uses** (rations and commissary reports; hospital accounts); and 8) **political** (government debates; tariffs; and taxation).

SELECTED FINDINGS: Chocolate consumed primarily as a beverage was a key food throughout North America during the Colonial Era. The types and names of ships, identities of ship Masters/Captains and associated cargoes can be traced from specific South and Central American ports through the Caribbean to North American and western European ports. North American auctioneers, brokers, manufacturers, merchants, and other associated with the chocolate trade may be identified by name and street address, and advertisement dates allow analysis for price changes through time and geographical location. Pre-, Revolutionary, and Post-War Eras are rich with chocolate-related documentation: sales of chocolate by both Torrey and Revolutionary supporters can be identified; British soldiers purchased chocolate on credit available from Boston merchants; chocolate “houses” were opened where male patrons read imported newspapers and drank their favorite beverage; chocolate merchants relocated their shops and goods from central Boston to outlying areas during 1765 smallpox outbreak; chocolate was regularly drunk (or sold) by Period notables among them: Ethan Allan, Zebadiah Boylston, Benjamin Franklin, King George III, Alexander Hamilton, John Hancock, Thomas Jefferson, Benjamin Rush, George Washington, and Noah Webster. Period military documents reveal that Revolutionary War chocolate rations were 6 pounds per company, per week; an inventory taken in August, 1776 noted 800 pounds of chocolate were stored at Fort Ticonderoga, New York; Colonel Anthony Wayne reported on

December 19th, 1776, that chocolate and sugar were distributed to patients recuperating at the Fort Ticonderoga hospital; the diary of Moses Greenleaf, written at Fort Ticonderoga contains an entry for Sunday, April 27th, 1777, with the notation that he "breakfasted on chocolate, dined on peas and beef, and supp'd [sic.] on tea." Importation of chocolate mills into North America began in the 18th century, followed by North American chocolate-manufacturing inventions. Especially notable was a chocolate-grinding machine developed in Massachusetts (1767). Potential risk of fire in chocolate manufacturing was great and towns sometimes established zoning ordinances that restricted the location of large chocolate mills. Colonial Era chocolate recipes – coupled with economic data – permit analysis for cost and suggest that most Colonial Era North Americans could rarely afford drinking chocolate in any quantity. Colonial Era chocolate was used to treat illnesses such as asthma, cholera, dysentery, smallpox, typhus, and yellow fever. The medical importance of chocolate also is documented through Colonial Era apothecary shop advertisements that list chocolate among the various "healing" products for sale. From the late 18th into the early 19th centuries, references to chocolate appeared in childhood educational tracts on subjects as diverse as: arithmetic, ethics/morality, geography, and spelling. Cacao beans, cocoa, and manufactured chocolate were high-priced commodities/product and attracted more than their share of criminal behavior as evidenced by chocolate-related crimes such as: attempted murder, burglary, forgery, shoplifting, and theft (simple; grand larceny; sometimes with violence). The association of chocolate with religious and secular holidays has a long history: our researchers identified chocolate associated with 4th of July celebrations (1791) and chocolate-related gifts associated with Christmas (1792). Our most important finding, however, has been the identification of prominent Jewish merchants involved in the cacao/chocolate trade especially in New Amsterdam/New York and New England. Among these merchants may be counted Aaron Lopez, Isaac Navarro, and Nathan Simpson. Summaries of our findings are displayed on three project posters located in the Academy Rotunda where our project chocolate research portal (under construction) will be demonstrated.

KEY WORDS: Cocoa, Chocolate, Colonial America, History of Medicine, North America.

The African Research Infrastructure: Is there a role for cocoa research?

Christophe KOUAME[1], Jules KELI[1], Joe COBBINAH[2] and Tony SIMONS[3]

[1] Centre National de Recherche Agronomique 01 BP 1740 Abidjan 01 ; Tel (225) 23 47 24 24, Fax (225) 23 47 24 11, Email : christophe.kouame@cnra.ci
[2] Forestry Research Institute of Ghana, KNUST Box 63, Kumasi, Ghana (Tel (233)-51-60121, 60122,
E-mail : jcobbinah@yahoo.com
[3] International Centre for Research in Agroforestry; PO Box 30677 Nairobi, Kenya tel: 254-20-7224151 fax:254-20-7224255 Email: T.SIMONS@CGIAR.ORG

Half a century after independence, the agricultural sector remains the principal engine of economic development and welfare of Subsaharan African countries. The sector contributes directly to GDP, employment and export earning. However, the performance of African agriculture has not kept pace with population growth, resulting in hunger and circle of poverty. In the new vision of Africa development, Heads of African states have set a target of 6% growth a year for the next twenty years. The vision suggests a rapid increase of the productivity and the competitiveness of African agriculture through a consistent investment in agricultural research, extension and the education system. In West Africa, cocoa is one of the most important export crops. Introduced near the end of the 19th century, cocoa ranks first as export commodity of West Africa, with a production level of over 2 millions tons in 2004. It is estimated that about 10 million West Africans depend on cocoa for their livelihood. In Cameroon, Cote d'Ivoire and Ghana, cocoa contributes more than 40% of the GDP. The role of agricultural research has been significant in this rapid development. Improved hybrids/clones and application of appropriate management techniques have resulted in increase production of cocoa. In Côte d'Ivoire, cocoa yield potential rose from 0.5 t/ha in 1962 to 3.0 t/ha in 2003. Although remarkable progress has been made in less than a century, the cocoa sector still faces many challenges – crop losses due to diseases and pests, poor crop diversification and limited marketing systems. Research capacity in addressing current challenges is limited by political, institutional, funding, governance and micro-economic instability. Research institutions in West Africa are mainly government funded public institutions. With the hard economic conditions public research funding is reduced and uncertain. The challenge of cocoa science and technology has become of utmost importance to sustained cocoa industry. The paper analyzes the cocoa research infrastructure in West Africa and discusses the sustainable production strategy to assure cocoa quality and productivity while preserving the natural resources. The contribution of the stakeholders, the private sector and the international research organization is analyzed as well as the development of strategic alliance to sustain the cocoa industry.

Cocoa Agroforestry and Tree Domestication in a Landscape Matrix

Tchoundjeu, Z; Mbile, P. and Asaah, E.

Cocoa has traditionally been a source of cash income for both local communities and Government's in the cocoa growing belt of West and Central Africa.
Incidentally, within this belt we also find the ecologically important Guinea-congolian and Upper-guinea forest landscapes. Reconciling these need for income and biodiversity have consequently been a major pre-occupation of the World Agroforestry Center (ICRAF).
From extensive patches with few interspersed indigenous trees, to small clearings within largely forested landscape matrices, cocoa agroforests have been linked to landscape fragmentation, habitat discontinuities and asymmetries in the transfers of genes across landscape corridors.
Tree domestication (TD) involving bringing tree species into wider cultivation, through a farmer-driven and market-led process, represents one method being used by ICRAF to modify the composition, structure and function of cocoa agroforests. TD has been shown to help maintain the productivity of cocoa agroforests as well as minimize their negative impact on landscape components.

Seeing the people for the trees: the social impacts of the Sustainable Tree Crops Program (STCP) in West African cocoa farming communities

Sonii David
International Institute of Tropical Agriculture, Sustainable Tree Crops Program, Regional Office
P.O. Box 135, Accra, Ghana, Email: s,david@cgiar.org

Abstract

The goal of the Sustainable Tree Crops Program (STCP), operating in Cote d'Ivoire, Ghana, Nigeria, Cameroon and Liberia, is to improve the economic and social well-being of smallholders and environmental sustainability of tree crop farms. Recent studies show that STCP's farmer training programs on integrated crop and pest management and support to farmer organizations have increased cocoa productivity and household income. This paper reports on the social impacts of STCP activities.

STCP implements farmer field schools (FFS), an experiential learning approach, to teach cocoa farmers how to make sounds decisions based on improved knowledge and observations, enabling them to become "experts" on their own farms. A 2005 survey that investigated the impact of FFS on farmer empowerment among 64 Cameroonian farmer field school graduates showed positive results (David, forthcoming). Nearly 60% of surveyed farmers had improved their observational skills, making observations on their cocoa farms before taking farm management decisions. A third experimented more with cocoa and other crops than prior to the FFS. Sixty three percent of FFS graduates reported having learned how to arrive at group consensus, while 47% had become more confident public speakers. Forty one percent of farmers reported a greater appreciation of group learning and work as a result of their experience in the FFS. FFS also improved social capital, with 67% of participants continuing to meet regularly with other former participant after the FFS, mainly to work on each other's farms (61%).

The paper highlights the impact of child labour sensitization through farmer field schools. A 2005 survey recorded significant reductions in the hazardous employment of children among Ghanaian farmer field school participants (Gockowski, Asamoah et al., 2005). Among the 2,800 cocoa farmers sensitized in 2003 in Atwina District, it is estimated that there are now 540 fewer children employed in heavy field transport, 440 fewer children employed in clearing fields with machetes and 170 fewer children employed in pesticide application. Based on the above results, sensitizing 50,000 cocoa producers in the Ashanti Region of Ghana on the hazards of child labour in cocoa production would result in a predicted 9,700 fewer children in heavy load transport, 7,900 fewer children in clearing fields with machetes and 3,000 fewer children employed in pesticide application.

Findings of a 2005 survey in Cote d'Ivoire and Ghana suggest that the impacts of cooperative development activities on social welfare are mixed (Calkins and Ngo, 2005). While cooperative members in both countries had higher per capita income compared with non-members, no significant difference was observed between the two groups in the health status of household members, gender equity in household decision-making and school attendance of girls. However, children in households belonging to cooperatives experienced less malnutrition compared with those in non-member households, although children in a control group living closer to clinics tended to have better health status than either group. The paper concludes by suggesting that multiple strategies need to be developed for improving the social welfare of cocoa farmers.

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THE COCOA LANDSCAPE: HOW POLICY, TREE DIVERSITY AND COMMUNITY MANAGEMENT IS CHANGING THE USE OF CACOA IN GHANA

ABSTRACT

The paper reviews policy changes and drivers of change from that of the "controlled liquidation" of commercial trees within the cocoa landscape (up to 1985) through "compensatory plantings" (1985-2000) to sustainable tree management within the cocoa landscape (from 2000). Changes on policy goals from a technological approach to the restoration of degraded cocoa landscapes to a livelihood-based approach in recent years are discussed. A comparative analysis of changes in policy on benefit sharing of cocoa cultivation and commercial tree crops within the cocoa landscape and their impact on landscape conservation is done. The impact of structural reforms and the current Poverty Reduction Strategy (PRS) process on the cocoa landscape is outlined.

The paper also notes that succeeding Governments have addressed the issue of managing trees within the cocoa landscape primarily in relation (i) to the development of a revenue base for Government and Chiefs or Traditional Authorities with very little focus on the cocoa farmer (ii) maximization of the utilization of timber trees on secondary forest lands prior to conversion to cocoa farms. The paper observes that in furtherance of this policy of direct state control over commercial forest tree resources and maximisation of timber resources within the cocoa landscape, the Government has since 1962 vested all timber trees have been vested in the President.

The paper also outlines how the rural sector looks at the landscape to protect their cocoa and landscape. The issue of how farmers have been changing their landscapes through integration of trees within the cocoa landscape is addressed. The significance of cocoa fallows in biodiversity conservation and also the role it plays in fragmented forest connectivity within the cocoa landscape is outlined.

The report gives an indication on linkages between farmer tree preferences, farm cultural practices and its impact on biodiversity conservation and extinction of valuable timber trees. The report concludes with a review of the UNDP-GEF project on South-West Ghana biodiversity conservation within the cocoa landscapes and reviews how the project is changing the use of cocoa in Ghana.

The surprising biodiversity of the cocoa farm in southern Cameroon.

Denis J. Sonwa[1], S. Weise[1], A.B. Nkongmeneck[2], M. Tchatat[3], A. Adesina[4], M.J.J. Janssens[5]

1. International Institute of Tropical Agriculture, Humid Forest Ecoregional Center (IITA-HFC),
P.O. Box 2008, Messa, Yaoundé-Cameroon, Email: dsonwa@cgiar.org or desonwa@yahoo.com

2. Department of Plant Biology, University of Yaoundé I, P.O. Box 812 Yaoundé-Cameroon.

3. Institut de recherche Agricole pour le Développement (IRAD), B.P. 2067 Yaoundé-Cameroun

4. The Rockefeller Foundation, Agricultural Sciences Division, 420 Fifth Avenue, New York, NY 10018-2702, USA

5. Institute of Horticulture, University of Bonn, Auf-dem-Huegel 6, D-53121 Bonn, Germany

Cocoa is a species which traditionally grows in the forest. As the demand for the beans it produces has increased, its cultivation has shifted over time to a more “intensive” agricultural system. It can be cultivated under open sun or shaded systems. Both these approaches are used in West and Central Africa. But few studies in the past have tried to evaluate the biodiversity inside cocoa agroforests or orchard systems of this region. This study investigates the plant diversity inside cocoa agroforests of southern Cameroon.

Instead of removing the whole forest cover to produce cocoa beans in an “intensive” manner, Cameroonian farmers have succeeded in building a system where cocoa trees are intimately managed with associated plants. Overall over 201 species were found in cocoa agroforests. Each cocoa farm on average contained 21 species associated with cocoa: 6 species (on average) are edible, 2 are used primarily for medicinal purposes, 7 are timber species and another 6 are mainly retained to provide shade for cocoa. However, ecological and socio-economic conditions surrounding the cocoa field impact on this plant composition. Plant diversity is reduced in cocoa agroforests located in more intensively managed landscapes where pressure on the natural resources is higher. Thus the development and promotion of approaches for the sustainable management and conservation of plant diversity inside cocoa agroforests needs to be actively pursued or the biodiverse cocoa farms of southern Cameroon may be threatened.

Key words: Cocoa agroforest, biodiversity, socio-economic and ecological conditions, West and Central Africa, Cameroon

"What Happens When Disease Takes Out a Key Export Crop? Bahia in the 1990s"

Keith Alger, Vice President, Human Dimensions Program, Center for Applied Biodiversity Science, Conservation International

Demand for cacao products has grown steadily since 1950, but cacao itself originates from ever shifting locations across the globe. The science of tropical agriculture is racing to catch up with the complexity of tropical ecosystems to allow for sustainable production at existing production sites. But in the meantime, plant disease and economic change undermine cacao's older tropical frontiers while subsidies from nature attract production into newer tropical frontiers. The catalyst for these shifts is not simple, and in the case of Southern Bahia, Brazil, Witches Broom disease arrived at a stage in Brazil's global comparative advantage that was already making wage labor production on large plantations obsolete. The social and environmental costs left in the wake of agricultural decline in Bahia are evidenced by a population decline of 156,000 rural people from the 45 municipalities producing cacao in the 1990s and continued loss of the last fragments of natural forest. The renewal of a sustainable cacao economy in Bahia depends on scientific advance in production technology, the evolution of land tenure and technical assistance to family-scale production and conservation. But for cacao production to become globally sedentary, a global partnership will be necessary to recognize and compensate landowners and communities for environmentally sustainable production and protected areas commensurate with the costs incurred to maintain the valuable biodiversity and ecosystem services produced together with chocolate's raw material.

Cocoa, companion trees, households and environment

Eduardo Somarriba
CATIE, Turrialba, Costa Rica
January 18, 2006

Unlike many other important crops that are grown in large monocultures, cocoa (*Theobroma cacao*) is grown in close proximity with other plants, named “companion or neighbour plants” that share with cocoa trees the growing space and resources of the site (solar radiation, water and nutrients). Because of their stature and life form (trees, palm trees, giant herbs such as bananas and bamboos) companion plants constitute the shade canopy of the cocoa plantation, which if properly managed, can provide goods (timber, fruits, firewood, fiber, resins, etc.) and services (ameliorate the microclimate-shade, wind- within the plantation to favor the growth and yield of cocoa and to hamper pests and diseases, cultural, aesthetic and ornamental value, soil, water and biodiversity conservation, carbon sequestration, etc.) for home consumption and sale, to both the farm household and society. However, despite its potential, most cocoa shade canopies have sub-optimal design and management: 1) The botanical compositions that may not optimally provide the goods and services required by the household, 2) Tree densities may be either too high or too low for the shade needs of cocoa and tree cover may be un-evenly distributed over the plot resulting in gaps with no shade and patches with excessive shade and 3) The structural complexity of the cocoa plantation (botanical diversity, temporal and spatial arrangements of cocoa and companion plants) may be too simple and thus provide environmental services well below its full potential.

Why most farmers do not properly design and manage their cocoa shade canopies? I can only speculate on some of the reasons, but my first-hand candidates would be: 1) Most research and development effort has been centered on the cocoa plant and its crop, not paying enough attention to the fact that to most farmers cocoa is just a part (sometimes not even the most important one) of the household livelihood strategy; 2) Within the cocoa plantation, it is the combination of cocoa and companion plants, and not only the cocoa crop, that render the entire production system ecologically, socially and financially sustainable, 3) Public concern for the environmental impacts of agricultural production is very recent; 3) Agroforestry science (the analysis and management of the interactions between woody perennials and other components of the production system) is also recent (25 years); cocoa agroforestry research is at its infancy and current knowledge is fragmentary and disperse. There is an urgent need to objectively collate and evaluate the interactions between cocoa, trees and forest to develop guidelines for research, development, policy and funding on this important, yet unrealized potential of cocoa production systems.

Study on Bioactivity of a Purified Cocoa Flavanol

Wei-yu Zhang, Hua-qing Liu, Ke-qiang Xie, Lin-lin Yin, Yu Li, Catherine L. Kwik-Uribe, Dongmei Chen, Xing-zu Zhu

Department of Pharmacology II, Shanghai Institute of Materia Medica, Shanghai Institutes of Biological Sciences, Chinese Academy of Sciences, Shanghai 201203, P.R. China

Cocoa and chocolate have a rich history for their use as traditional medicines to combat numerous ailments including inflammation and pain. In addition to being a rich source of essential minerals, cocoa and some chocolates can also be a rich source of the monomeric flavanols (–)-epicatechin and (+)-catechin and oligomeric procyanidins formed from these monomeric units. Previous investigations have shown that these monomeric and oligomeric flavanol components of cocoa can be potent modulators of immune and inflammatory responses. As abnormally elevated levels of cyclooxygenase-2 (COX-2) are implicated in the pathogenesis of inflammation and other conditions such as cancer, cardiovascular disease and neurodegenerative disease, we investigated the effect of the predominant procyanidin in cocoa, M00002, on the expression and activity of COX-2. In the present study, we found that pretreatment of the procyanidin M00002 reduced COX-2 expression induced by the endotoxin lipopolysaccharide (LPS) in differentiated human monocytic cells (THP-1) in culture. To further elucidate the underlying mechanism of COX-2 inhibition by procyanidin, we examined their effects on the activation of extracellular signal–regulated protein kinase (ERK), Jun-terminal kinase (JNK) and p38 mitogen-activated protein kinase (MAPK), which are upstream enzymes known to regulate COX-2 expression in many cell types. Pretreatment with procyanidin M00002 decreased the activation of ERK, JNK and p38 MAPK. In addition, procyanidin M00002 suppressed the NF-κB activation through stabilization of IκB proteins, suggesting that these signal-transducing enzymes could be potential targets for procyanidin M00002. By affecting the expression rather than the activity of COX-2, these in vitro data strongly suggest that procyanidin M00002 may serve as a novel anti-inflammatory in vivo.

The Role of the World Bank in Supporting Agriculture in Asia:
"The Place for Technology and Innovation"

Institutional and Technical Innovation for Cocoa in Indonesia

Richard H Chisholm[1] , Josef Toledano [2] and M. Noureddine Benali [3]

Background

In pursuing its mission of poverty reduction, the World Bank recognizes the pivotal role of technology and innovation, particularly in rural areas where most poverty in Asia is now located. In Indonesia, the World Bank has a long history of assistance to research and extension, focused on direct service delivery to the poor through better access to information and funding for small demonstration activities. The Farmer Empowerment Through Agricultural Technology and Information (FEATI) project, now under preparation, exemplifies this approach and includes a component for public private partnership in the cocoa industry.

Why partnerships?

The changing nature of agriculture in East Asia, particularly as a result of low food crop prices, resulting diversification and an emphasis on aspects of marketing and product quality is placing new demands on the nature of agricultural cooperation between multilateral and bilateral development agencies and recipient governments. Increasingly, assistance must combine the traditional production oriented skills of the public sector with business and marketing skills of private sector. Moreover, countries such as Indonesia, which are only now emerging from the economic shocks of the late1990s can benefit through engagement with mainstream commerce as the major driver of poverty reduction.

The public private partnership component of FEATI seeks to address these challenges by piloting a public private partnership approach to provide a wider array of technical and financial resources, particularly in areas such as international business skills and marketing which can be difficult and expensive to obtain.

Why the Cocoa Industry?

The Cocoa industry in Eastern Indonesia has been identified as offering sound prospects for spearheading a model for development of public private partnerships for larger scale agricultural industries in Indonesia for several reasons(i) the size and economic importance of the industry; which involves some 500,000 smallholders nationwide and has a gross production value of some US$700 million (ii) scope for substantial improvements in sector performance- the industry is currently losing some $300 million annually from a combination of yield losses and quality discounts by buyers (averaging $280/ton or about 20% of international prices) due to Cocoa pod borer (iii) the willingness of commercial partners to be involved- the partnership already involves substantial in- kind contributions of international consultancy from Mars Inc. and private plantation owners. and (iv) potential for an immediate start under bridging arrangements with IFC and AusAID. (vi) the large potential benefits from relatively small investments. The estimated NPV of the initiative for cocoa under FEATI has been estimated at $139 million based on five years experience with pilot projects funded by USAID, Mars Inc and the Netherlands Government.

The Public Private Partnerships Cocoa Sub-Component

The cocoa PPP will have the following elements:

- A Cocoa Coordinating Commission (CCC) which will be the governing body for the PPP initiative and would comprise representatives from farmers, traders, processors and relevant public and private institutions. The CCC would play a particular role in industry advocacy worldwide to demonstrate Indonesia's commitment to better quality cocoa.
- A CCC Management Team to conduct day-to-day management of the PPP including administration of the proposed FEATI funding.
- An applied Cocoa Research Field Station to be located in South Sulawesi, and Operational Centers to be located in each of the 15 most important Cocoa Districts; and
- Activities linking the Operational Centers and farmer groups, through revitalized sub district centers to implement short, medium and long term cocoa yield and quality improvement programs at farm level.

Opportunities

Indonesia is emerging as the worlds number two producer of cocoa and has good opportunities to benefit from re engagement with the world cocoa industry after a difficult period following the 1997 financial crisis. In particular, membership of the International Cocoa Council Organization (ICCO) and the Cocoa Producer's Alliance would facilitate access to a greater range of international grant funds for research and development and would help to put Indonesian producers at the leading edge of cocoa production.

Indonesian Cocoa: Toward Sustainable Development.

Djoko Said Damardjati
Director General Processing and Marketing of Agriculture Product, Ministry of Agriculture of Indonesia.

Indonesia is the third largest producer of cocoa in the world after Ivory Coast and Ghana. Current average yield of cocoa plantation in Indonesia is 630 kg/ha, with the potential yield from 1.0 and 1.5 tons/hectare. Around 87 percent of 917,000 ha total cocoa plantation in Indonesia is cultivated by smallholders. The rest are cultivated by private company (5 %) and state own company (8%).

In 2004 Indonesia export 368, 757 tons and value at US $ 547 million in the form of cocoa bean, butter, cake, liquor and powder. On the other hand , Indonesia also import fermented cocoa bean around 48,000 tons , to fulfill the need of 13 factories which require around 293,000 tons of fermented cocoa.

The major problems facing by Indonesian cocoa industry are: low productivity and infestation of Cocoa Pod borer (CPB) and Vascular Streak Dieback (VSD) and low bean quality. With regard to overcome the problems of low productivity, CPB and VSD, and low bean quality, Indonesian Cocoa and Coffee Research Institute in collaboration with international institution has conducted significant research to develop superior clones, biological control systems, crop management and post harvest technology.

The policy and strategy toward sustainable cocoa development in Indonesia are : 1) Increased Productivity through: replanting and rehabilitation program; accessibility to credit for smallholder farmers to purchase agricultural inputs; and promoting investment in processing industries development; 2) Foster and expedite research programs to overcome problem of CPB and VCD i.e. provision of improved and CPB resistant planting material; 3) Improved Quality through : implementation of GAP and HACCP; provision of formal enforcement mechanisms to ensure compliance with prevailing quality standards required by domestic and international market.

The Indonesian government has been working in some program such as: cocoa industry coordination, farmer's extension/ technology transfer and farmer empowerment in collaboration with IFC-PENSA and FEATI Project with the World Bank. Nationally, Indonesian Cocoa Commission consists of cocoa industry stakeholders in supporting the development of cocoa industry in Indonesia has established at 5th January 2006.