NATURAL ENEMIES, NATURAL ALLIES

- how scientists and coffee farmers forged new partnerships in the war against pests and low prices -

Project Completion Report of the Integrated Management of Coffee Berry Borer Project, CFC/ICO/02 (1998-2002)

A project funded by the Common Fund for Commodities, under the supervision of the International Coffee Organization, and executed on behalf of the above by CABI *Commodities*

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“A sine qua non *for successful development is the presence of active, farmer controlled institutions.”*

“If we expect pastoral idylls then we will have to pay.”

[Muir, 2000]

CONTENTS

ACKNOWLEDGMENTS

Too many people have been involved in the long gestation and execution of this Project to acknowledge them all separately. So we warmly thank all our counterparts in the eight (including the US) participating countries for their unfailing sociality and solidarity; coffee culture lives on.

But there is one person we especially salute: Caleb Dengu, Associate Project Manager at the Common Fund for Commodities. This is not a perfunctory nod to the major Project donor, but a sincere appreciation of a genial and committed colleague.

GLOSSARY

ACPC, Association of Coffee Producing Countries.

Anacafé, Asociación Nacional del Café, the Guatemalan coffee institute.

Anecafé, Asociación Nacional de Exportadores de Café, the coffee exporters association of Ecuador.

Biological control, using nature to control pests. All organisms have predators, but some manage to escape them by migrating. The coffee berry borer is one of them, its co-evolved natural enemies stayed in Africa. This Project helped them catch up with their prey.

CAB *International*, CAB *International* is a not-for-profit treaty level intergovernmental organisation with 41 member countries including several major coffee-producing countries. It consists of two divisions CABI *Bioscience* and CABI *Publishing*. Its main goals involve the generation and brokering of scientific knowledge for developing countries.

CABI *Commodities*, CABI *Commodities* is an initiative of CABI *Bioscience*, and its mission is to promote profitable, healthy and environmentally safe commodity production for resource-poor farmers through information, research and training.

CBB, coffee berry borer (*Hypothenemus hampei* (Ferrari 1867)) a 2 mm long black scolytid beetle (related to wood-boring beetles) that is the most significant pest of the world's most important tropical agricultural commodity.

CBI, The Coffee Board of India.

Cenicafé, Centro Nacional de Investigaciones del Café, the Colombian coffee research institute, a division of the Federation of Colombian Coffee Growers.

CFC, Common Fund for Commodities is an intergovernmental financial institution, funding commodity development projects globally. The Agreement establishing the Common Fund for Commodities was negotiated in the United Nations Conference on Trade and Development (UNCTAD) in the 1970s, concluded in 1980 and came into force in 1989. Currently the Common Fund has 104 Member Countries plus the European Community, the Organisation of African Unity/African Economic Community (OAU/AEC) and the Common Market for Eastern and Southern Africa (COMESA).

CIAL, Local Agricultural Research Committee, a farmer participatory research validation committee.

CIAT, Centre for Agricultural Research in the Tropics, Cali, Colombia.

CIB, Coffee Industry Board of Jamaica.

Cultural control, a broad term involving mostly manual control that includes hand picking of infested berries.

DFID, the Department For International Development (UK Governmental body, formerly known as the ODA).

ECOSUR, El Colegio de la Frontera Sur, Chiapas, Mexico.

FFS, farmer field school.

FPR, farmer participatory research.

Gleaning, the term for cultural control used in India, chiefly for cleaning up after the main harvest.

ICO, The International Coffee Organization (ICO) is an intergovernmental body whose members are coffee exporting and importing countries. Established in 1963 it administers the International Coffee Agreement from its Headquarters in London, and is committed to improving conditions in the world coffee economy through international co-operation, helping price equilibrium by developing demand for coffee in emerging markets and through projects to reduce damage from pests and improve marketing and quality, enhancing coffee growers' long-term competitiveness and contributing to the fight against poverty.

IHCAFE, Instituto Hondureño del Café.

IICA, Instituto Interamericano de Cooperación para la Agricultura.

IPM, Integrated Pest Management, a knowledge-intensive strategy for controlling pests where the farmer estimates current and future damage to his crop and picks from a range of techniques to optimise profit. The basic principal is that control measures should cost less than the losses incurred by inaction. It requires knowledge of pest biology, continual monitoring of the crop, the worth of control methods, simple maths and an understanding of commodity price dynamics.

Parasitoid, a specialised predator that lays its eggs on or (as in the case of *Phymastichus coffea*) in the insect. The egg hatches out and the larva kills its host by consuming it. Parasitoids differ from parasites in that the former always kill their host to complete their life-cycle.

PEA, Project Executing Agency (i.e. CABI *Commodities*).

PI, Participating Institution, these were Anecafé, Cenicafé, CBI and Promecafé (consisting of Anacafé, Ihcafé, CIB and Ecosur).

Promecafé, Programa Cooperativo Regional para el Desarrollo Technológico y Moderización de la Caficultura, a Central American coffee technology network formed under the auspices of IICA.

FOREWORD

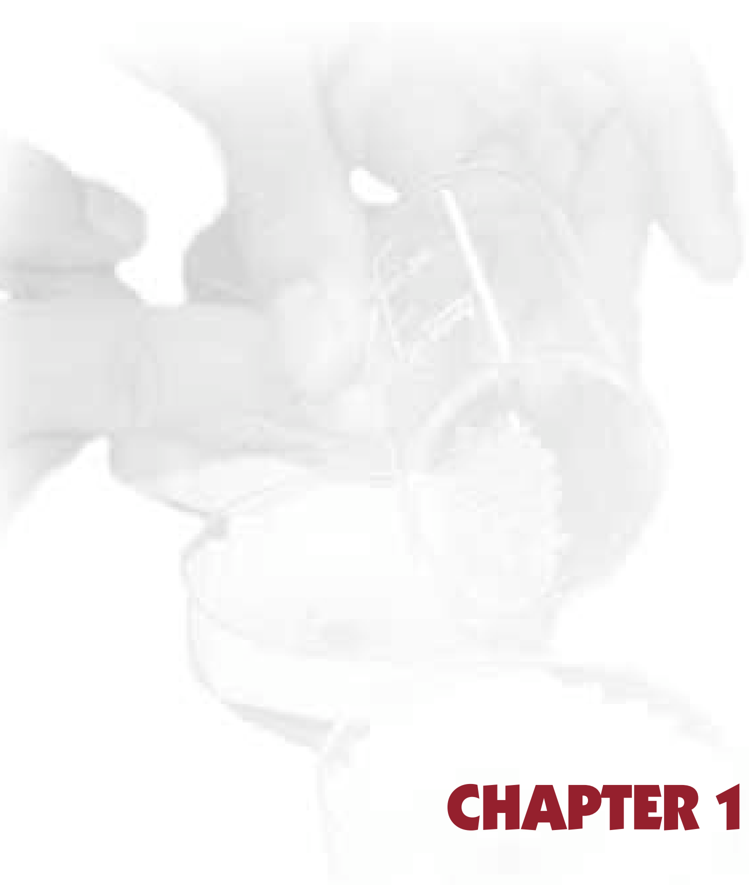
The Common Fund is financing and has financed 12 projects in the coffee sector to address problems faced by producers in developing countries. The total cost of these projects amount to USD 57,144,155 of which the Common Fund is financing USD 29,256,460. In this Project the main strategy employed by the Common Fund has been to empower the coffee producers by developing simple techniques, which are farmer friendly, to control the coffee berry borer. The control measures developed not only check the spread of the berry borer but, more importantly, farmers are shielded against contact with harmful chemicals.

Commodities are resources that can be used to generate income to assist farmers getting out of poverty. The Common Fund endeavours to promote measures that facilitate technology development and transfer, production efficiency and efficient marketing systems. The farmer participatory approach applied in this project has transformed coffee farmers from being recipients of technology to designers of appropriate technology.

The Common Fund is financing two related projects on "Integrated Stem Borer Management" and "Improvement of Coffee Production through the Control of the Coffee Wilt Disease". The experience gained from this completed project will be of benefit to the implementation of these two ongoing projects.

The Common Fund thanks the institutions from India, Colombia, Ecuador, Guatemala, Mexico, Honduras, and Jamaica for their co-operation. The assistance in developing the technology received from the United States Department of Agriculture is also highly appreciated. Last but not least, CABI *Bioscience*'s capacity and expertise have contributed to a successful implementation of this project.

Dr. Rolf W. Boehnke
Managing Director
Common Fund for Commodities



CHAPTER 1

INTRODUCTION

1.1 Overview

The Project described in this book began in one century and finished in the next and it seems to us that more than a numerical nicety separates us from the world in which this undertaking was conceived.

During the course of this Project, coffee suffered the greatest decline in absolute value of all time. This has occasioned widespread suffering of coffee communities, abandoned farms, marches, protests and riots. Oxfam (2001) and many others have documented cases of extreme personal hardship including malnutrition and families now unable to school their children. We do not doubt that these accounts are true because we have encountered similar stories. In our Project some farmers and extensionists even migrated to other countries during the course of the work. Additionally, the very institutes we worked with, already weakened by changing global policies, suffered steep decline. Now that the Project has finished, roughly half of the 18 or so professionals directly supported by the Project find themselves without a job.

Nonetheless, the Project was timely because it confronted head-on the following substantive problems:

- How to control a difficult pest without increasing inputs
- How to control a difficult pest cleanly so farmers could add value to their product
- How to improve the efficiency of technological innovation and delivery to farmers

Even though the economic climate grew steadily worse as the Project progressed, the principles upon which the work was based still stood. Because of the crisis, which we and so many of our colleagues have struggled to come to terms with, we feel compelled to place the Project's findings into the broader context of the crisis, and to draw attention to those aspects that we believe have a relevance beyond that of a pure pest control project. There will no doubt be many future books about the present crisis, but few perhaps by those who worked in the field while it happened and who tried to apply science to improve farmer livelihoods.

As such we have taken a few liberties with the usual format of a final report in order to make it readable for a wider audience. Some detail is shifted to boxes and a synopsis of the main Project activities are placed towards the end of the book, rather than at the outset, together with a compilation of data about the pest, drawn from CABI's Crop Protection Compendium (www.cabi.org/compendia/cpc/). More details relating to the Project's activities and achievements can also be found in other volumes prepared as final Project outputs (e.g. Manual for Collaborative Research with Smallholder Coffee Farmers (Bentley & Baker, 2002), Informe Final del Proyecto CFC/ICO/02 and Integrated Management of the Coffee Berry Borer, Final Report: India).

1.2 A preview

In the following chapters we will suggest that, in future, helping farmers to produce sustainable and sought-after coffee will require a detailed and sophisticated understanding of their problems as well as those of the institutes that support them.

We will highlight the benefits and shortcomings of the technology on offer, how we attempted to remedy it and the problems we encountered. We will further point out institutional weaknesses and, to those readers that are looking for an overarching theme, here it is: the institutional structures that have supported farmers for so long are in severe and terminal decline and in no way commensurate with the increasingly stringent requirements of a globalised consumer market for sustainable, high quality coffee, nor the sophisticated image that the coffee industry wishes to convey.

We argue that 21st century pest control must be embedded in concepts of economic, environmental and social sustainability, and that this requires a radical overhaul of coffee farmer support that one-off projects cannot by themselves solve. We believe that this can only come about by a new determination to provide ways of delivering the relevant knowledge that farmers need to satisfy demand and to thereby earn a just reward for their endeavours.

1.3 About the title
'Natural enemies, natural allies'

The title of this report is a play on the term 'natural enemy', which is the general description scientists use for the predators, parasites and diseases that control all animals and plants. In this Project we used them as allies to control the enemy of the farmer, the coffee berry borer. In the process, we also hoped to foster the relationship between scientists and farmers so that they too might become to be seen as the farmer's natural ally. So the title is something of paradox. Historically, paradoxes have been used to define conflicting modes of thought. We felt the title appropriate because during the course of the Project we encountered many paradoxes, dilemmas and disparities. In Box 1 we list a few of the most salient, manifesting themselves from the world of the individual farmer to the level of the global economic matrix:

1) Smallholders are locked into the free-market system but locked out of the transactions infrastructure to exploit it (Kidd, 2002).

2) Trade liberalisation has led to lower farm-gate prices but higher consumer prices.

3) Farmers often blame local stakeholders for global problems.

4) Farmer-support institutes are in steep decline just when new knowledge is increasingly needed to respond to heightened threats and opportunities.

5) The high level of staff laid-off after the end of the present Project suggests that the Project will not be fully sustainable.

6) Smallholder farmers can produce higher quality coffee than estates, but almost always end up with substantially lower prices.

7) Smallholder farmers often borrow funds from the same people to whom they sell their coffee.

8) Despite decades of CBB research, much control is still based on simple manual effort.

9) Gleaning CBB-infested berries and then selling them to pay for the operation controls the pest but may add to the triage coffee that the industry wants to destroy.

10) Large coffee estates tend to respond to low prices by intensifying production to remain profitable, locking them into a cycle which acts to further lower the price.

11) Smallholders respond to low prices by reducing production - which should cause a price rise. But intensification by large estates can block this, locking them out of the benefit of their own actions.

12) Profitable illegal drug crops sometimes now grow in the shade of coffee, the presently unprofitable legal drug.

13) Smallholder farmers are guardians of greater biodiversity than large farmers but are mostly locked out of potential rewards for this.

14) Despite good stewardship of their lands, many smallholders do not have legal title to them.

15) Many smallholder farmers are 'organic by default' (through being too poor to buy chemicals), but are not financially rewarded for it.

BOX 1 - Paradoxes & Incongruities.

CHAPTER 2

A BACKGROUND TO THE PROJECT

2.1 The coffee crisis

Globalisation, neo-liberal economics, currency devaluations, the crisis of confidence in development aid strategy, technological advances, environmental and health concerns are all part of the complex backdrop to the work of this Project.

There has never been a time like this for coffee and we believe, even when coffee prices climb again to more reasonable prices, that the industry will have changed for ever. But it would be wrong to assume that coffee, or even tropical commodities, are alone in this. A global agricultural transformation has occurred that few us can adequately comprehend.

We do not have the space for a detailed exposition of this phenomenon so we merely present the following graph, taken from official US statistics, to illustrate our point (Figure 1) and leave our readers to draw their own conclusions. Please note that we use US statistics here solely because they are freely available on the Internet.

What is very clear from this Project's interactions with farmers, many extensionists and even researchers, is that they are oblivious to these global changes and frequently ascribe their predicament solely to more local factors.

***FIGURE 1*[1]**

US farm and retail price changes over 50 years. The farm-to-retail price spread is the difference between the price consumers pay for a retail food product and the value of the farm ingredients used in that product.

1 Graph refers to a market basket of food bought in food stores in a base period, currently 1982-84. The retail price index is derived from data from the U.S. Department of Labor, Bureau of Labor Statistics. Farm value is based on prices farmers received for commodities. The spread between the retail price and farm value represents charges for processing and marketing. For further details please refer to: http://www.ers.usda.gov/briefing/foodpricespreads/trends/

The causes of the present coffee crisis are indeed complex. We cannot attempt here a comprehensive analysis - that will require a separate volume and an objectivity that only time can supply.

Simply put, there is a glut of coffee. But why is this? Commodity supply and demand have always fluctuated but there is a feeling that the present crisis is somehow different. However, we may be wrong, so here we will limit ourselves to an outline of some of the factors that we feel must have been at least partially responsible, without attributing to them direct causality nor level of importance.

Geo-political factors: the ICO's International Coffee Agreement (ICA) export quota system collapsed in 1989. It is credited with maintaining relatively stable and high prices for much of the two previous decades. Prices were set not purely by the market but by economic forces that were politically constrained (Akiyama & Varangis, 1990; Bates, 1997). It collapsed because changing market demands for coffee were not reflected in the voting strategies of members and the political will to enforce quotas was eroded as governments' views of the world changed in the late 1980s. The end of the ICA regime has profoundly affected the balance of power in the coffee chain (Ponte, 2001) and it eventually led to the dissolution of producer country government monopolies that fell out of favour in the neoliberal global economic culture. Subsequent efforts to limit exports, led by the ACPC, failed.

Monetary policy: in the late 1990s, devaluations in key economies, principally Brazil, stimulated production. At the same time, the collapse of the Russian Rouble weakened demand (Gérard & Ruf, 2001).

Weak demand: despite the gourmet coffee revolution, growth in consumption remains practically static. Except for Brazil, which has made a concerted effort to stimulate internal consumption, producer country consumption is low.

Poor marketing, and stiff competition from soft-drinks companies: in the US, the largest country market, these factors have led to a 50% reduction in per capita consumption from the 1960s onwards that has still not been reversed.

US-led health scares about coffee: these are now acknowledged to be largely baseless (Baker, 2001).

New producers: Vietnam has quite suddenly become the second largest coffee producer after Brazil. Some commentators blame them for the crisis and suggest that favourable donor fund aid fuelled this rise. The World Bank recently felt obliged to release a press notice denying that it had been involved in Vietnam's coffee expansion (World Bank, 2002). In fact, as much additional coffee has been planted in Brazil as in Vietnam in the last ten years (Knight, 2001). The Vietnamese themselves simply feel that it is their turn, and they tend to point out that they still produce much less than Brazil.

Changes in production technology: fast-developing dwarf hybrid varieties whose yields respond vigorously to fertiliser applications; rust-resistant varieties that lower input costs; shade removal that stimulates yield increases; and mechanisation that has allowed coffee production in Brazil to move away from southern frost-prone populated areas to more northerly frost-free low populated regions, are all recent changes. Intensive production methods were promoted by donors, especially in Central America, part of a world-wide trend towards more intensive farming.

Changes in processing technology: a patent (US4540591: robusta coffee steaming, roasting and blending method) filed by General Foods Corporation in 1985 has enabled roasters to reduce the harsh taste of robusta coffee through high-pressure steaming. This has led to greater content of robusta in many commercial ground coffees in some countries. 36% of beans now consumed in Germany are robusta (Knight, 2001) and this trend has reduced the demand for arabica, whose world production has remain relatively static over more than a decade.

Physiology: because of the increased use of robusta, which has higher levels of caffeine than arabica, Dr Ernesto Illy has claimed that this has led to lower consumption as drinkers adjust intake to maintain a constant caffeine fix (quoted in Breminer, 2001).

Power changes within the coffee chain: the coffee business is increasingly an example of what Gereffi (1994) calls *buyer-driven* commodity chains. This is where large retailers, merchandisers, and trading companies are the key actors in setting up de-centralised networks of trade in developing countries.

Changes in distribution and retailing in industrialised countries since the 1980s has demanded flexible agricultural production, involving a heterogeneous combination of firms, types of ownership, size, and relative access to markets (Ponte, 2001). This has led to increasing disparities between farm-gate prices and retail prices (Talbot, 1997; Morisset, 1998) as power ebbs away from producer-country institutions.

2.2 What this means to smallholder coffee producers

Prices are now very low, especially compared to retail prices (Figure 2). Ponte (2001) observes, "Grower organisations have not been able to substitute governments as organisers of coffee exports. 'Local' exporters have not been able to raise necessary funds to compete with international traders, and have now either disappeared or allied themselves with international traders. The general trend has been a strengthening of the position of roasters *vis à vis* other actors."

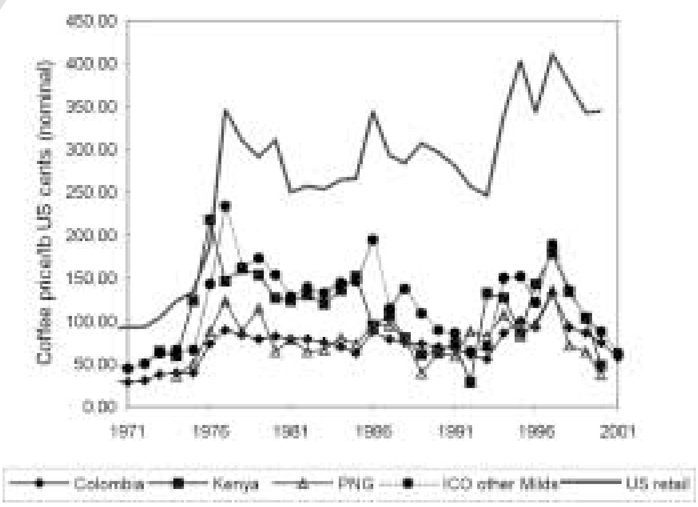
Ponte continues, "Roasters tend not to accept coffee for their blends from countries that cannot guarantee a reliable minimum amount of supply (in the case of arabica, around 60,000 tons a year) (Raikes and Gibbon, 2000). As a result, on the one hand, minor producers may become increasingly marginalized in the future - without necessarily increasing the bargaining power of major producers *vis à vis* roasters."

This has led to a break-down of producer quality control measures and because coffees bought by private traders are mixed together, it is more difficult to separate high quality coffee from the rest. Government-controlled marketing boards roles have been scaled back and credit arrangements have declined leading to lower use of agro-chemicals.

Even though a more efficient marketing system has meant that producers receive a higher share of the export price, because of low international

FIGURE 2.

Farm-gate coffee prices for Kenya, Papua New Guinea & Colombia, ICO "other milds" and US retail prices for coffee per lb. Many smallholders will not have achieved the full farm-gate prices.



prices and declining coffee quality, the overall result is that they receive decreasing farm-gate prices.

Tanzania is a good example of what has happened. Ponte (2001) reports that free-market domestic procurement of coffee has led to poorer primary-level quality control, poorer farm and processing practices due to lower farm-gate prices, and lower input application due to an increasing inputs/output price ratio. All these factors have contributed to quality deterioration. No price differentials are offered to farmers for good quality coffee, which further reduces their incentive to improve quality. Co-operatives, which in the past offered differentiated prices in relation to quality, have had to adapt to new market conditions and operate in a way similar to private traders.

Fitter & Kaplinsky (2001) confirm this, "The abolition of marketing boards proposed (or perhaps more accurately, imposed) by multilateral agencies on producer countries through structural adjustment programmes has meant that producers sell atomistically into commodity markets. It has also meant that one form of governance, agricultural extension, has been removed from the bottom end of the chain. These atomistic producers lack the capacity to combine (as do their governments, though the reasons for this are more problematic)".

This then is the climate in which the present Project operated, but before we can deal with the Project work itself, we need to outline some of the key aspects of pest control. An altogether more covert system, but one every bit as complex as the world drama we have outlined above.

2.3 The problem of pest control

Coffee production increased in many countries over the last decades of the 20th century through the use of high yielding varieties, fertilisers, high-density planting and pesticides. Indeed, because of increasing competition leading to overproduction and declining prices, farmers may feel forced to intensify production further in order to increase margins and stay in profit.

The principal problem is that the control of coffee berry borer (CBB), now present in all but a very few coffee-producing countries[2], becomes more

[2] Papua New Guinea, Hawaii and Panama are the only remaining CBB-free countries with any appreciable coffee production, though CBB is currently (April 2002) approaching the border between Irian Jaya and PNG.

difficult as production intensifies and trees are planted close together. In the case of chemical control, the problem becomes severe, as Figure 3 shows.

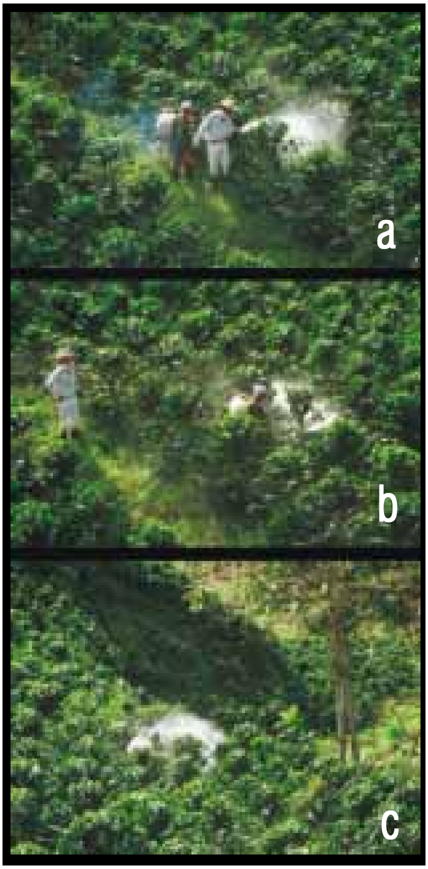


FIGURE 3.

a) The foreman checks the nozzle - note the lack of protection of operator's mouth and skin; b) the operator starts spraying; c) he is surrounded by a poisonous cloud.

Coffee farmers are thus in a dilemma. If they intensify to stay in profit, they risk the health of family members or hired hands, and lay themselves open to opposition and action from NGOs, unions, environmentalists and consumers. If they insist on full protective gear against poisoning, costs spiral because operatives are slower, uncomfortable and require frequent rest. In practice very few take more than the most rudimentary precautions; one Colombian farmer explained to us that although it was his son that now ran the farm, he still carried out the spraying to protect him and any future grandchildren from harm.

Until recently, it was common for governments, commodity boards and donors to subsidise pesticide inputs. Now subsidies are out of fashion and NGOs have done a good job of pointing out the perils of the cheap provision of poisons. Thus a principal tenet of the present Project is that the use of chemicals is increasingly unacceptable in modern coffee production, and that training programmes to inculcate good usage are impracticable and doomed to failure due to the high cost and high turnover of labourers.

The two most effective pesticides against CBB, endosulfan and chlorpyrifos, are also two of the most dangerous to apply. To put it simply, the argument for sustainable agriculture has been won, the chemical approach is no longer acceptable, as is now confirmed by the approaching EU-wide ban on many of these substances.

But if the farmer does not resort to pesticides, what should he do? The accepted answer is integrated pest management (IPM), where the farmer chooses from a range of options that may include cultural control (manual methods, trapping, *etc*.), biological control (using exotic parasitoids and microbials) and, if necessary, the occasional use of safer pesticides.

The fundamental idea behind IPM is that the farmer is sufficiently knowledgeable about his pest to estimate its economical potential to eat into his profit and employ the right control method at the right time to optimise his income and minimise his costs.

This is a tall order. The farmer is expected to make quite detailed field-measurements, take notes, calculate damage and employ a “just-in-time” approach to control.

The reality, as we hope to show, is that the farmer’s understanding and resources severely limit his ability to accomplish this. He therefore frequently adopts a “just-in-case” approach where he applies insecticide, perhaps several times a year, to suppress the problem. This may cost him more money, damage the environment, his health and the image of coffee.

We have indeed reached a witching hour: neo-liberal globalisation means the peasant’s way of life is over, but the means are not available to transform him into a savvy entrepreneur who can compete with agribusinessmen to provide the products that the modern consumer expects.

Hence, the main aim of this Project was to find practical solutions to coffee farmers’ pest problems, methods that would be cost-effective, simple to adopt, healthy and environmentally friendly.

Principally this involved focusing on biological control (also called biocontrol) and cultural control methods as the only presently feasible short to medium term responses. However, before we explain the Project, we need to give some brief details about the CBB[3] and possible ways to control it.

[3] A more detailed account of CBB is given in Appendix 1.

2.4 The problem of coffee berry borer (CBB)[4]

2.4.1 Life history

CBB live almost exclusively in coffee berries. There are a few records of them attacking other seeds, and alternative hosts are insignificant. A crucial point about the CBB is that it spends much of its life deep inside the berry and hence is difficult to control by chemicals. Each female (2 mm long) will lay 30 or more eggs that take four to six weeks to mature to new adults. Siblings incestuously mate inside the berry. Some females will then emerge but others will stay and start laying their own brood. Eventually the whole bean and its pair inside the fruit can be eaten out. But this takes many months and the majority of berries are harvested before this happens so that most berries harvested with a CBB entry-hole have one infested and one normal bean.

It was previously thought that CBB could only fly short distances. Now we know that at least half a kilometer is well within their range. Only the female flies and when she finds a new berry she immediately starts boring into it with her mandibles. When she gets to the bean (endosperm), she makes a decision that depends on its consistency. If it is more than about 20% dry weight she will carry on boring and start laying eggs within two or three days. If it is less than 20%, she will stop and most often she will wait in the short tunnel until the bean has developed further. Not surprisingly, the borer has the ability to find mature berries so that if these are present, they will be preferentially attacked. This gives rise to the following rules:

- When CBB levels are low, most of them will be found in maturing berries (>180 days after flowering)
- As CBB levels rise, available mature berries will be occupied and they will increasingly attack younger berries
- Younger berries are less good hosts for the CBB, fecundity is lower and mortality is higher
- Hence as populations rise there is a density dependent effect tending to reduce the rate of increase

[4] This section is based on Baker (1999) to which the reader is referred for more detail and references.

- This means that it may be very difficult to control CBB at low levels but easier at high levels

Hence the critical period for applying control of the CBB is before it does damage to the endosperm, i.e. before about 110 to 120 days after flowering. Hence farmers are exhorted to record moments of major flowering and carry out spraying at about 100 days after each of these events. This can work well in countries where there are one or two major flowerings and a few very minor ones. But in Colombia for instance, with many flowerings, this rarely applies. Thus the farmer has to take two sorts of measurements, pest levels (so that he monitors the population and takes action before CBB multiply) and flowerings. Unfortunately, smallholder farmers are not used to making measurements and recording them for future reference and action.

2.4.2 Principal ways of controlling CBB

Insecticides: a number of products are employed, though endosulfan is the overwhelming favourite of farmers and regrettably this is also the most toxic product to humans.

- **Advantages of insecticides:** efficient (80%+ mortality) to kill adult females in the entry tunnel
- **Disadvantages of insecticides:** health risk; environmental damage; costly to apply (up to 5 man-days/ha for a small farmer); CBB develops resistance; poor image for coffee exports

Biological control (wasps): there are four principal ones*, Cephalonomia stephanoderis, Prorops nasuta, Heterospilus coffeicola, Phymastichus coffea*. The first two have been studied extensively and released in many countries; although they establish readily in most regions, the control they exert is small and even when released in large numbers their control effect has been disappointing. *H. coffeicola* has been studied in the field and seems promising, but as yet rearing it has proved too difficult to allow it to be quarantined and shipped to other countries. *P. coffea* on the other hand can now be reared successfully and preliminary experiments suggest it is more effective than the previously tried wasps. For this reason, the Project focused most of its efforts on this wasp, to teach countries how to rear it to release in the field, and to work on ways to rear it more efficiently.

- **Advantages of wasps:** environmentally clean; no health risk; easy to use

- **Disadvantages of wasps:** too expensive for commercial augmentative release

Biological control (pathogens): *Beauveria bassiana* (*Bb*) is the most studied and field-tested. Lifetable studies in Colombia suggest that *Bb* is the major biotic mortality factor affecting the CBB in Colombia. Its effect is especially heavy when CBB are attacking young berries and in this case, and under rainy conditions, mortalities of > 80% were recorded. Considerable data is now available from small-scale spraying trials. Mortalities of 80% of adults in entry tunnels have been achieved, i.e. equivalent to the most efficient insecticides, but at doses far above the commercial dose and full mortality takes about a month to become apparent so even if sprayed, the female lives long enough to enter the berry and damage it.

- **Advantages of *Bb*:** environmentally clean; little health risk
- **Disadvantages:** slow acting; kills CBB in the entry tunnel but at a commercial dose only at about a half of the rate of insecticides; difficult to apply (up to 5 man-days/ha for a small farmer); quality control problems of commercially produced *Bb*; needs to be stored cool, for it has a shorter shelf-life than chemicals

***Cultural control*:** the simplest method, consists of hand removal of infested berries, most usually by paying extra labour to pick off all berries after harvest or by picking more regularly. It sometimes includes picking berries off the ground where, if conditions are not too wet, CBB can build up to very high numbers (in some cases more than 100 CBB per berry). However many farmers find this method unacceptably expensive.

- **Advantages of cultural control:** environmentally clean; no health risk; no equipment required
- **Disadvantages of cultural control:** costly and tedious; difficult to do on old trees; very dependent on quality of personnel

Thus there exists no simple way of controlling this pest, that is clean, efficient, and moderately priced.

One response made by farmers is to intensify production so that the extra income can pay for the control. Another is to do little, which causes loss of income and increases infestation of neighbours' plots as CBB migrate in. The Project sought to remedy this problem.

2.5 Project development and rationale

The Project was first conceived in 1994, when the president of Anecafé requested authority from the Ecuadorian Foreign Secretary to develop a project on the control of CBB and improvement of coffee farms. Ing. Pablo Delgado Alava had already made preliminary contact with Drs. Jorge Cárdenas and Néstor Osorio of the Colombian Coffee Federation to further this idea. In early 1995 permission was granted, and a draft Project Proposal was submitted to the ICO in August 1995. The latter appointed Drs Nicholas Wallis and Michael Bigger as consultants to develop the proposal further.

Submitted for approval to the ICO, the Project Proposal was subsequently approved by the ICO Council in May 1996. The Project Executing Agency (PEA) was identified as CABI *Bioscience*[5], based on its international reputation as an agricultural research body, and its expertise in biological control and coffee pests, drawing on a multi-disciplinary scientific capability providing research, training, consultancy and other specialized services worldwide.

Within CABI *Bioscience* this Project was managed by CABI *Commodities*[6], who aim to provide a comprehensive service to help farmers solve their problems in order to give added value to their coffee and cocoa. This is achieved through biocontrol methods, farmer participatory approaches, rational chemical use and advice on agronomic practices and processing, all aimed at reducing costs and enabling smallholder farmers to capitalize on a clean, quality product.

The Common Fund for Commodities Consultative Committee approved this Project Proposal in late 1996, and a Project Appraisal Report was finalised on 27th November of the same year. The final Project Agreement between the CFC, the ICO and CABI *Bioscience* was signed in March 1997. Please refer to Figure 4 below for a schematic representation of the Project lifecycle.

The financial contribution from the CFC to the Project totalled US$ 2,968,000, with US$ 1,649,000 in counterpart contributions from participating coun-

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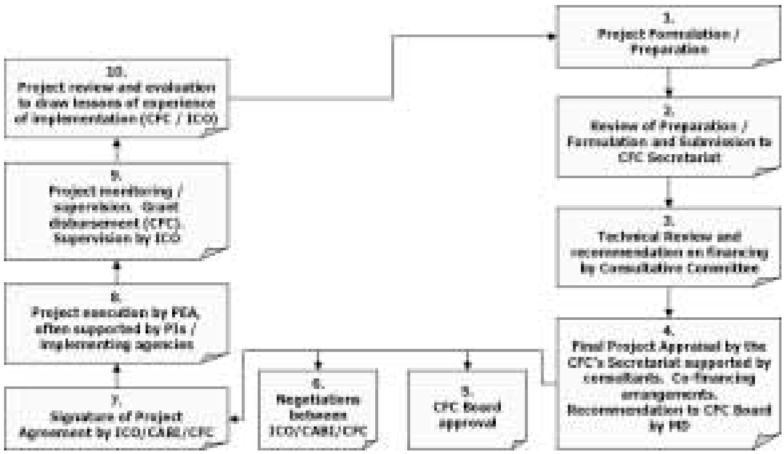
[5] At the time of project development the International Institute of Biological Control (IIBC) was identified as the PEA. In 1998 the four institutes of CAB International (including the IIBC) amalgamated to form CABI *Bioscience*. To avoid confusion CABI *Bioscience* is referred to throughout this report rather than the IIBC.

[6] For more information please refer to www.cabi-commodities.org.

FIGURE 4.

The CFC/ICO Project lifecycle.



tries (namely, Colombia, Ecuador, Guatemala, Honduras, India, Jamaica and Mexico).

Co-financing from the United States Department of Agriculture, Agricultural Research Service amounted to US$ 220,000, and related to activities undertaken by the Mass Rearing Research Unit at Mississippi State University in developing mass-rearing regimes for both CBB and parasitoid wasps.

The Project was designed to work on aspects of control of the CBB - to furnish, improve and test elements of a potential integrated pest management (IPM) system, and to develop ways of ensuring that they could be implemented effectively and sustainably. Activities started in early 1998, and comprised the following key components:

- The improvement and testing of mass rearing and delivery systems for natural enemies (pathogens and parasitoids) of the CBB
- The provision of natural enemies to participating countries
- The integration of biological control technologies and other methods for cultural and chemical control to develop IPM systems
- Dissemination of IPM technology/information and associated training to participating and other countries

To use a computing analogy, we worked on hardware (parasitoids, pathogens, cultural actions) and software (training, dissemination, farmer uptake pathways) with the aim of establishing new control systems that might be congruent with modern sustainable farming standards.

This proved to be a difficult task. As already indicated above, during the course of the Project a global coffee crisis developed. Producer country institutes, already weakened after nearly a decade of low prices, came under increased strain.

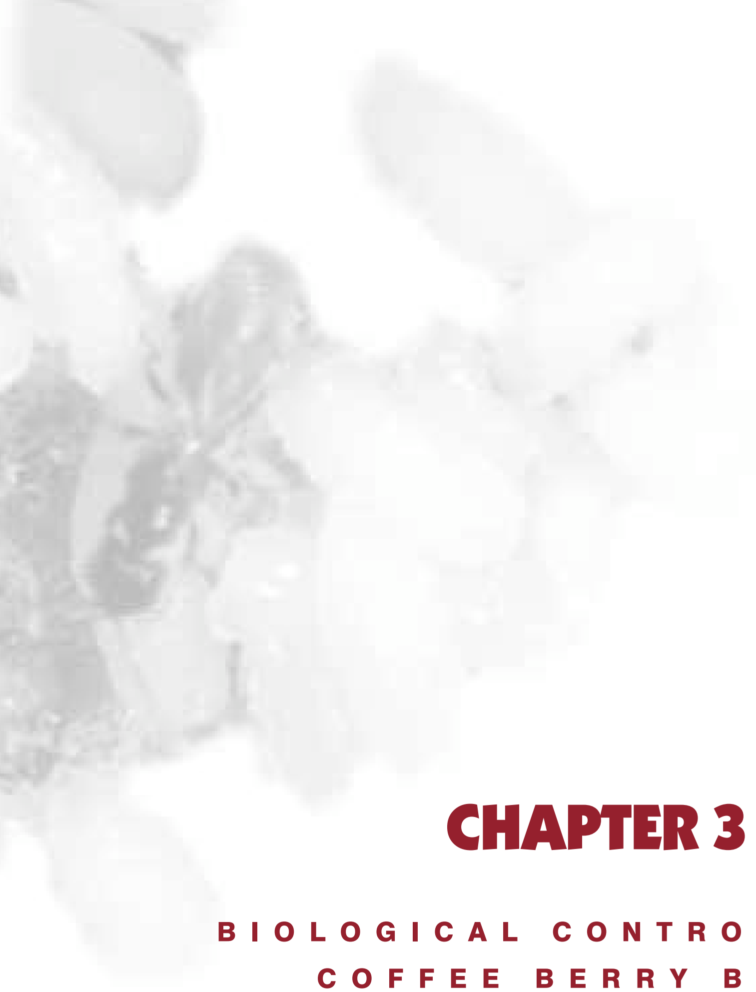
As the Project Executing Agency (PEA) we had already decided that innovative methods of developing IPM implementation were required. These new approaches focussed specifically on farmer participatory methods, especially since traditional extension systems in most participating countries were already weak and in one case (Mexico) non-existent.

We were now faced with a dilemma. Were institutes[7], faced with immediate problems of survival, ready to fully focus on the more long-term changes that were implied by our Project? The answer to this will become apparent in later chapters.

2.6 Synopsis

- CBB control measures available to farmers are expensive and not congruent with world demands for sustainable production
- This leads farmers to inappropriate measures that damage themselves, the environment and consumer image
- This Project focuses on how to solve this deep-seated problem

[7] The institutes involved in this Project were:
ANACAFÉ - Asociación Nacional del Café (the Guatemalan coffee institute)
ANECAFÉ - Asociación Nacional de Exportadores de Café (the coffee exporters association of Ecuador)
CBI - Coffee Board of India
CENICAFÉ - Centro Nacional de Investigaciones del Café, the Colombian coffee research institute, a division of the Federation of Colombian Coffee Growers
CIB - Coffee Industry Board of Jamaica
ECOSUR - El Colegio de la Frontera Sur, Chiapas (Mexico)
IHCAFE - Instituto Hondureño del Café
PROMECAFÉ - Programa Cooperativo Regional para el Desarrollo Technológico y Moderización de la Caficultura (a Central American coffee technology network formed under the auspices of IICA)
USDA-ARS - United States Department of Agriculture, Agricultural Research Service



CHAPTER 3

BIOLOGICAL CONTROL OF THE COFFEE BERRY BORER

Biological control was a major component of this Project, and included:

- Provision of a biocontrol agent, *Phymastichus coffea*, a parasitic wasp of African origin, to all participating countries

- Provision of two other agents, *Cephalonomia stephanoderis*, and *Prorops nasuta* to Jamaica and India respectively

- Training in rearing the insects on its host, CBB, so that each country could maintain and increase numbers to release throughout coffee zones

- Monitoring of released parasitoids to ascertain effectiveness and permanent establishment

- Mass rearing work to perfect cheaper methods of rearing with a view to regular augmentative wasp releases to suppress CBB populations

3.1 What is biological control[8]?

Remarkably few of the millions of insect species are pests, and the principal reason for this is that their numbers are severely restricted by various parasites, parasitoids (a parasite that invariably kills its host), predators and diseases. To date 1,424 pests of coffee have been recorded from 101 countries but very few of these are major pests, due mainly to the 705 species of natural enemy also reported (data from Bigger, 1999, and personal communication 2001).

Biological control uses these natural enemies in a variety of ways, but the central principle is always the same, to reduce population levels of a target pest by natural means. We want to use it whenever possible, because once chemical control becomes common, the chances increase of upsetting the delicate balance of so many potential pests and their natural controllers. Many of the birds and other wild animals found in coffee (and their existence can add value to the harvest) are directly or indirectly dependent on the diverse insect life supported by the crop, making this a further reason to understand and use biocontrol. As the biodiversity potential of coffee plantations becomes more widely known and marketed, this aspect will become more important. Biocontrol is safe to farmers and consumers (Box

8 The terms 'biological control' and 'biocontrol' are synonyms.

2).

In the case of CBB, the principal aim is to introduce the African natural enemies it escaped from when it was introduced to other countries. This is known as 'classical' biological control and once the organism is released and established, no further intervention is required. Sometimes, classical biocontrol can be a complete solution to a pest problem, because the agent concerned carries out the control so efficiently that the farmer may eventually become completely unaware of the pest and the natural enemy at work in his fields.

Unfortunately, in many cases the classical option does not produce complete control, which leads us either to try augmentation of the agent, by culturing and regular release, or to adopt other control measures that are compatible with biological control. But whatever methods are used, we always try to encourage biocontrol because it is the only method that is 'density-dependent,- this means that as pest numbers rise, control tends to become more effective, whilst as numbers fall, control declines so that a fluctuating equilibrium is reached. Hence biological control is concerned with ecological balance, which is a centrally important concept in sustainable coffee production.

In recent years biological control has come under increasing attack, mainly because of the fear that the introduced agent may attack other insects, some of which could be beneficial. However, if prior testing is carried out to measure specificity of the control agent, problems of this sort are very unlikely to emerge. And even in the few cases where non-specific agents have been released, to date there are no serious biological problems reported for insect control campaigns. Of the nearly 5,000 biocontrol introductions during the 20th century (Biocat biocontrol database, Greathead & Greathead, 1992 and personal communication, 2001) there is not one insect biocontrol mistake that has caused human suffering. Insect biocontrol has no Bhopal or 'Silent Spring', and unlike pesticides, it is not responsible for a regular toll of lives impaired or shortened by their routine use. Insect biocontrol is a farmer-friendly technology.

BOX 2 - Is biological control risky?

3.2. Introduction of *P. coffea*

The recently discovered *Phymastichus coffea* (Figure 5) is an unusual parasitoid because it attacks the adult insect. Very few parasitoids attack adult beetles, and possibly CBB is an exception because it is exposed and immobile in the entry tunnel to the coffee bean during the initial stages of its attack on the berry. According to Orozco (Cenicafé) the female mostly inserts her ovipositor into the abdomen and normally injects two eggs into

FIGURE 5.

***Phymastichus coffea** adult.*

the body of the adult female CBB where they develop, one in the abdomen, the other in the thorax; the egg-laying process takes about 2 minutes. The wasp can parasitise CBB in more than one infested berry (in the laboratory they can parasitise at least six), which makes it inherently more interesting as a biocontrol agent than the previously introduced parasitoids that normally stay in the only berry that they ever attack.

Phymastichus had already been introduced into Colombia in a previous project (Baker, 1999) and a strong and viable culture established. The Project supported the expansion of the culture in order to provide stock for other Project countries and training. For more detail on this refer to Box 3 and the individual country reports to be published from this Project.

3.3 Field establishment of *P. coffea*

A principal aim of this element of the Project was to ensure that the wasps had accepted their new environments and would survive indefinitely in the field.

In **Guatemala**, experiments by Anacafé (Figure 6) show that releases of the wasp quickly disperse over a period of 90 days to cover a 10 hectare area of coffee (10,000 wasps released in a plot with 40% shade cover and 16% infestation of CBB). Since the adult is short-lived, this is good evidence that the wasp is breeding freely and first and second generation descendants are present at detectable levels. In several arabica and robusta plantations in Guatemala, parasitism rates of 15, 21,23, 33 and 46% were recorded.

Encouraging data comes also from a **Colombian** student's study. Jaramillo (2002) took advantage of the large cultures of *P. coffea* to carry out some detailed studies where she released parasitoids over trees where branches

A Project course in **Colombia** in August 1998 showed Project scientists how to rear the wasp. Jaime Orozco of CENICAFE taught the course. Over the next three years, shipments were air-freighted from Colombia to Ecuador, Central America and India.

Ecuador established a strong culture in Santo Domingo though this was damaged by flooding caused by the El Niño event and it was subsequently moved to a new site in the same city. Releases began in 2001 and by the end of the project at least 188,000 *P. coffea* had been released into the field in eight provinces in Ecuador. Encouragingly, funds have been secured to maintain the wasp factory after the end of the project.

PROMECAFE: for logistical reasons, it was decided to send all shipments to Guatemala and thence to Honduras. Strong colonies of insects were established first in these two countries and then shipments made to ECOSUR (Mexico) and CIB (Jamaica). Subsequently shipments were also made to two non-project countries, El Salvador and Costa Rica where colonies have also been successfully established. In all, by the end of the project PROMECAFE countries had produced more than 2.5 million wasps and released over 1.6 million into coffee groves. Additionally PROMECAFE also sent shipments of *Cephalonomia stephanoderis* to Jamaica and provided training. Over 50,000 wasps were released in Rose Hill, Mountain Hill and Grenoch (Blue Mountains) with subsequent recoveries made from release sites and, significantly, from surrounding plots.

India: wasp cultures were established with more difficulty in India, most probably due to the long air route from provincial Colombia to Southern India, which may well have adversely affected the quality of the wasps. By the end of the project however, viable cultures had been established in India and releases reported.

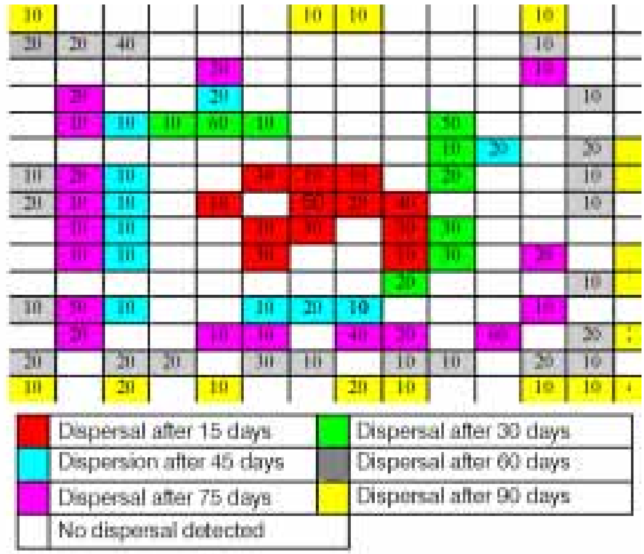
BOX 3 -Training in use of biocontrol agents and subsequent provision to project countries.

had previously been infested with CBB onto berries of known ages (90, 150 and 210 days after flowering). She released parasitoids at the rate of 1:1 (wasps:infested berries) either 1, 5, or 9 days after CBB infestation, depending on the treatment. She found very high mortalities for the 90 and 150 day old berries where the CBB had generally not progressed far enough into the berry to be beyond the reach of the probing wasps. In these two treatments, an overall mean of only 14% of CBB were found to be present and healthy at the termination of the experiment, whereas for the 210 day berries the survival was higher (46%). Such high rates of mortality (principally due to the wasp, but also natural infestations of the fungus *Beauveria bassiana*), suggest that regular releases of parasitoids could control the CBB.

Honduras, who produced 569,000 *Phymastichus coffea* and released 331,000 of them at altitudes between 650 and 1,100 m above sea level, registered levels of parasitism of between 5 and 25%. Also in Honduras, a

FIGURE 6.

*Detection of dispersal of **Phymastichus coffea** in 10 ha of coffee at various sample dates after release. A coloured square (each representing an area of 438 m²) signifies presence of the wasp, with the first date of detection indicated by the colour-code. Numerical value indicates % parasitism from 10 sampled berries /square.*



study of dispersal at three sites (altitudes: 700 m, 830 m and 920 m) with single releases of 11,500, 1,500 and 1,500 wasps respectively, recorded parasitism rates for the lowest site of 44% at a distance of 20 m from the release site at 23 days after the release. They detected wasps at a distance of 40 m of between 7% and 15% depending on the direction from the release point. For the medium and highest sites, even with the lower release rates, they still detected rates of 6% to 25% one month after release. These rates are encouraging and suggest healthy wasps adapting well to their first taste of freedom.

Interestingly in Honduras, up to four species of indigenous wasp were found associated with CBB populations, including one, *Horismenus* sp. (Eulophidae) that was reared out from adult CBB. The possibility of new associations between CBB and native wasps needs to be studied further since they have also been reported from Mexico (Perez-Lachaud & Hardy, 1999).

In **Mexico** the wasps were imported in 2000 after a lengthy consultation with national stakeholders about the pros and cons of introduction. The main worry was that the wasp had been shown to attack other related scolytid beetle species in the laboratory (López-Vaamonde *et al.*, 1997). However, as with other countries the risk of collateral damage (say to a rare species) was regarded as very small, so the introductions went ahead from March 2000 from the Guatemala laboratory to the ECOSUR laboratory in Tapachula. There they were multiplied (about half a million over the next year) and released in 13 sites over a range of altitudes (400 to 1100 m above sea level) at about 10,000 per site in one release per site. This was a sound release methodology. They covered a broad climatic range and released enough in each place to allow for predation and still leave sufficient to find CBB-infested berries and attack.

Over the next four months they returned to the 13 release sites and took 200 infested berries from each place. They found mean parasitism levels of 42, 41, 30 and 28% for consecutive months. Since the parasitoid completes its life cycle in about 5 weeks, this means that at least three generations would have taken place from the moment of release. The rate of parasitism is encouragingly high and far exceeds that found for previously released parasitoids of CBB.

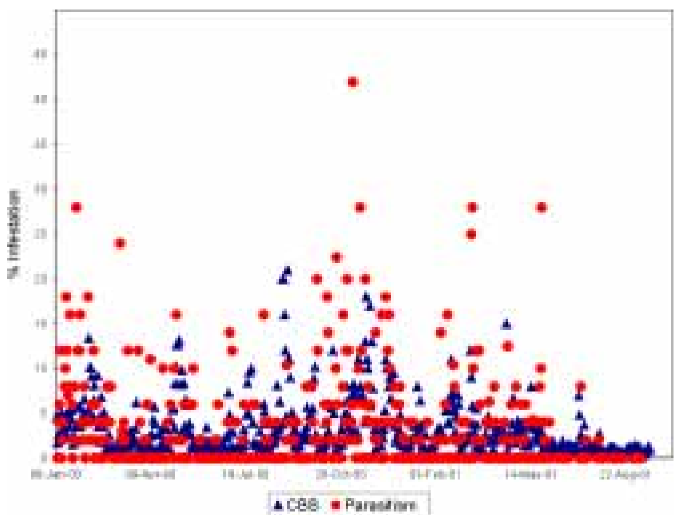
In **Ecuador**, recoveries have been made continuously from moment of the release and include wasps that comprise at least the fifth generation after release, strongly suggesting that the wasp is now establishing permanently in Ecuador. Parasitism rates of over 20% have been found which confirm that the wasp is flourishing and making an important contribution to CBB control. Production costs from the Santo Domingo production facility are around 500 wasps/US$1, though they believe they can substantially reduce this.

Good evidence for the effect of continual releases of wasps comes from **Colombia** where releases were made into 41 farms where participatory work had been initiated (Chapter 4). Over a course of 83 weeks Cenicafé researchers liberated some 2.2. million wasps in 123 separate releases on the 41 farms, i.e. a mean of three per farm. Space limits a full description, but the researchers made over 600 subsequent visits to these farms and carried out numerous evaluations of CBB and wasp infestation rates. Importantly, their measurements also included total tree counts to calculate the number of CBB per tree. Thus by also knowing total trees per plot, it was possible to estimate total CBB present and relate it to the number of wasps released. As can be seen from Figure 7, there were many cases of high parasitism recorded and although we cannot claim that the CBB in these plots were controlled by the wasps, the parasitism must be considered significant.

We calculate that over the 18 months of the experiment, a mean of 1.3 wasps per CBB-infested berry were released for each liberation. From the mass-rearing work in this project (see below), we believe it will be feasible

FIGURE 7.

*Mean % CBB infestation and mean parasitism of CBB by **P. coffea** in 41 Colombian coffee farms over 18 months.*



to release roughly this number of wasps, but three times more frequently. The levels of parasitism found in the field in this project thus gives support to the idea that the wasp could be used as an augmentative agent (see below).

3.4 Some laboratory studies

A problem that comes to light from laboratory studies in Mexico is that the female wasp is very short lived. She carries out most of her CBB attacks on the first and second day of her adult life, and by the fifth day she is dead (Figure 8a). This means that if augmentative releases are to be effective (see below), rearing facilities may have to be close to release sites. Alternatively the wasps might be deployed before they have emerged, i.e. whilst they are still inside the cadavers of their host CBB (Figure 8b), as the Mexicans did for their study.

Other work by Orozco (Colombia) shows that overcrowding in the colonies can lead to lower productivity (Figure 8c); clearly mass rearing will have to take account of this. His data from rearing experiments proved valuable for the economic cost model (below), we used his values from a Project experiment where 193 wasps were produced from 300 CBB hosts with 30 founder females.

We have not yet included a temperature component in the model, but Guatemala has already provided experimental data on *P. coffea* rates of development (Figure 8d).

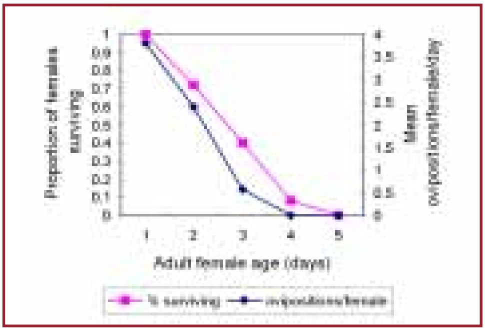


FIGURE 8A.

*A Mexican lab study on egg laying rate of female **P. coffea** and their longevity.*

FIGURE 8B.

*Ventral view of the abdomen of an adult CBB dissected to reveal a **P. coffea** pupa developing inside.*

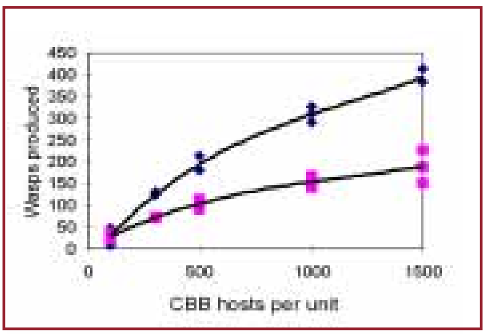


FIGURE 8C.

CBB hosts at high densities cause declines in wasp productivity (females – upper line; males – lower (a Colombian lab study).

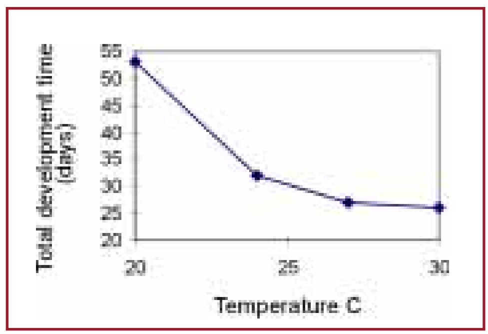


FIGURE 8D.

*Life-cycle development time for **P. coffea** (Guatemala lab study).*

3.5 Rearing wasps by the million

However well the wasps have established, we have to expect that 'classical' biological control, where we leave the wasp to work away in the field unaided, is unlikely to be a complete solution for the CBB problem. A principal reason is that the cradle of the developing wasp is the very same berry that the farmer picks, pulps and dries; in the process he destroys his tiny ally.

An alternative is augmentation, where laboratory-reared wasps are released periodically into the field to seek out and destroy CBB. This is a technology that has been developed and used with commercial success for other pest-crop systems, notably *Trichogramma* spp. for lepidopteran pests of mostly annual crops. But it has never, to our knowledge, been attempted for a coffee pest. Because of the intrinsic value of a hectare of high-quality arabica coffee, we felt that the costs of setting up such an operation could be recoverable, even given today's low coffee prices. The cost question will be dealt with further in Box 5.

Hence for this project we considered it important to foster the development of the augmentation approach. An additional reason for adopting this difficult task was that so few other viable, clean, labour-saving alternatives exist to control CBB, making us want to assiduously explore all avenues.

Results from Ecuador's parasitoid production studies suggest that sufficient wasps could be produced at a price that would make it feasible to release them using existing low-tech methods (i.e. labour intensive rearing involving parchment coffee as a substrate for the CBB host). Whereas this may be possible for Ecuador, with their currently low wage costs, we doubt that sufficient parasitoids could be produced in most countries by this method and we therefore need to look for other methods. This involves the use of high-tech machinery and semi-artificial diets.

Preliminary work had been done on diets by Colombian scientist Maribel Portilla as part of her Ph.D. studies in the UK under a previous project (Baker, 1999), so we determined to continue this work in the present project. We were very fortunate that the USDA ARS decided to support this line of research because, at their laboratories in Mississippi, they have the best facilities in the world for carrying out this work. Accordingly Dr Portilla was contracted by them to develop the CBB mass-rearing system and this turned out to be an ideal solution.

3.5.1 Mass-rearing CBB

A most important problem to solve for mass-rearing a biocontrol agent is to be able to rear the host efficiently. In this case, CBB has always been difficult and laboratory stocks have mostly been replenished regularly from field-collected berries because laboratory-reared stock tends to decline in quality. The Cenicafé stock cultures are still produced in this way and it is a costly procedure. Thus a vital objective is to make the colony self-sustaining: i.e. sufficient viable, fecund CBB must be raised to maintain the colony indefinitely and supply a large excess to feed the wasps. Secondly, the coffee beans that form the diet do not lend themselves to labour-saving devices and cleanliness, both of which are essential if millions of wasps per

1. Diet mixer and flash steriliser.

2. Dispensing the mixed diet into cells (manual for now, but to be automated later).

3. Adding CBB to the cells.

4. CBB in the diet cells.

5. CBB larvae and pupae developing in the diet.

6. ***Phymastichus coffea*** *parasitising CBB.*

BOX 4. Scenes from the USDA CBB mass rearing process.

week are to be produced. This means the development of an artificial or semi-artificial diet is required, that can be machine-made in large amounts, sterilized to stop fungal and bacterial growth and dispensed to rearing trays, all with the minimum of labour.

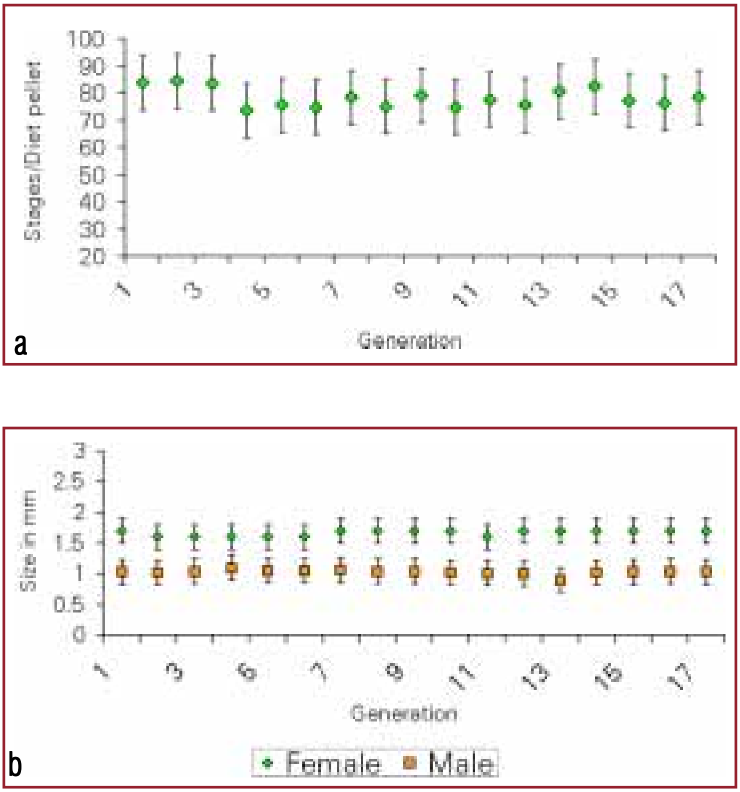
Previous work by Villacorta (1985) and Villacorta & Barrera (1996) in Brazil and Mexico laid the groundwork for the development of a semi-artificial diet, though there were still difficulties in maintaining CBB for more than a few generations on the diet.

Portilla (with crucial supervision from Don Nordlund and Allen Cohen of USDA) has now convincingly managed to solve both these problems. She has now produced more than 20 generations of CBB, reared continuously in the laboratory with no significant decline in fecundity on a semi-artificial medium (Figure 9). Some of the main rearing procedures are elaborated in a manual prepared separately as another output of the Project.

With these key rearing problems solved, the work becomes essentially a question of adjusting existing technology, successfully used to rear other insects, to suit the CBB's life cycle and habits. The major part of mass

FIGURE 9.

a) Mean total stages of CBB in 1 ml of diet through 17 generations; b) Size of adult female and male CBB through 17 generations on diet.



rearing is to provide a steady stream of cheap, uncontaminated food in manageable units so that the insects can multiply rapidly with low mortality. Hence diet mixing, sterilization, and packaging ready for insect application are key elements of the system. In the USDA case, these are all carried out in one process, which can produce thousands of portions of diet per hour with two to three semi-skilled operators.

Some of the main hurdles to overcome are how to efficiently locate CBB females into portions of diet and hold them secure whilst they lay their eggs and tend their brood. But this and other complications are matters of technical modification, not major scientific break-through. There is little doubt that with sufficient time and funds, a method of mass rearing millions of CBB per day is now within reach (Box 4).

3.5.2 A mass-rearing system for wasps

The remaining problem is how to easily mass-rear *P. coffea* from these CBB and get them to the field to release. Here we believe the most feasible method is:

- To mass-rear CBB in a large high-tech central facility in each country or region
- To ship the progeny, still in their diet packs, to local low-tech wasp rearing plants
- In these wasp factories, to simply parasitise CBB emerging from the packs with wasps and package the offspring for release into nearby farms.

Proximity to the field is important because of the short lifespan of the wasps. We envisage weekly shipments of CBB in diet from the central plant, which would then be placed into an emergence chamber for the adults to separate themselves from the diet (towards UV light). The CBB, which are easy to manipulate because they move slowly and fly reluctantly, could be manoeuvred onto a surface, perhaps containing an attractant that causes them to bore in, or otherwise be immobilised. The wasps from a stock culture could then be released onto the CBB to oviposit. They would then be held in a darkened room at a temperature between 20 and 25°C for about a month and then packaged to be sent to coffee fields in a radius of, say, 15 km; some wasps would be held back to infest the next shipment. This is a conceptually simple low-tech arrangement where a few semi-skilled workers could produce many millions of wasps. Such a set-up would provide local rural employment and potentially other farmer services could be built around it.

If the economics of this prove to be favourable, the next step would be to mount a pilot project to try to control, say, a few hundred hectares of coffee by mass releases alone. Accordingly, towards the end of the project, we felt that Portilla's work had advanced far enough to try to make first estimates of the cost for establishing a facility big enough to commercially control CBB as well as the local wasp-multiplication units as just described.

A modelling consultant, Dr Adrian Leach, was contracted to visit the USDA laboratory and develop a cost model for mass production to see whether costs were reasonable enough to develop this work further. The answer is promising; a brief account of his findings can be seen in Box 5.

3.6 Synopsis

Historically, there can be little argument that progress on biological control of this pest has been slow. There may be several reasons for this, but they are probably all related to two fundamental and unalterable facts,- a) the borer lives deep inside the berry making it hard to contact by most control methods and b) picking removes natural enemies which, we make no apologies for stressing, comprise the only self-sustaining, self-regulating and entirely natural method available.

Establishment: there is strong evidence that the wasp has established in the field in Central and South American participating countries and we have every hope that it will also become established in India. Levels of parasitism are variable but the evidence is that quite high levels of parasitism can be achieved from a single release and that two or more measurable generations may arise from a release. This is encouraging because the residual effect would give longer control for each release for no extra cost.

Mass rearing: we believe the major technical problems for mass rearing the wasp are now solved. Many minor problems remain, but our first estimation of mass rearing costs turn out to be similar to those for insecticide spraying or cultural control. We therefore believe that scaled-up trials with the wasp should now go ahead to determine the true effectiveness of the wasp when released on a larger scale.

Whatever the final outcome of this line of research, we are sure that a simple and viable way of continuously rearing CBB will emerge from this work, for which future generations of scientists, be they testing chemicals, biologicals or GM material, will have cause to be grateful for the advances made by the USDA team.

Consultant Adrian Leach visited USDA Starkville Miss, in October 2001 where mass rearing work had been carried out for the previous two years by Dr Maribel Portilla under the guidance of Don Nordlund and Allen Cohen.

From the data gathered during this visit, a spreadsheet cost model was developed. The model was costed both for a facility in Colombia and the US (with transshipment costs included for the latter).

The model supposes that CBB will be produced in very large numbers in a central "high-tech" facility, distributed in diet packs to "low-tech" local wasp production facilities for mass rearing of the wasp and subsequent dispatch and release to the field.

Using Colombia as an example, if we assume that:

- the CBB-infested area of coffee to be controlled in Colombia is 50,000 hectares
- there are approximately 100,000 founder female CBB within a single hectare (i.e. about 20 per tree)
- to achieve suppression we need to release somewhere between 0.33 and 1.0 female wasp per CBB founder females in the field, then the number to be released would be in the range of 33,000 to 100,000 wasps /ha every two months

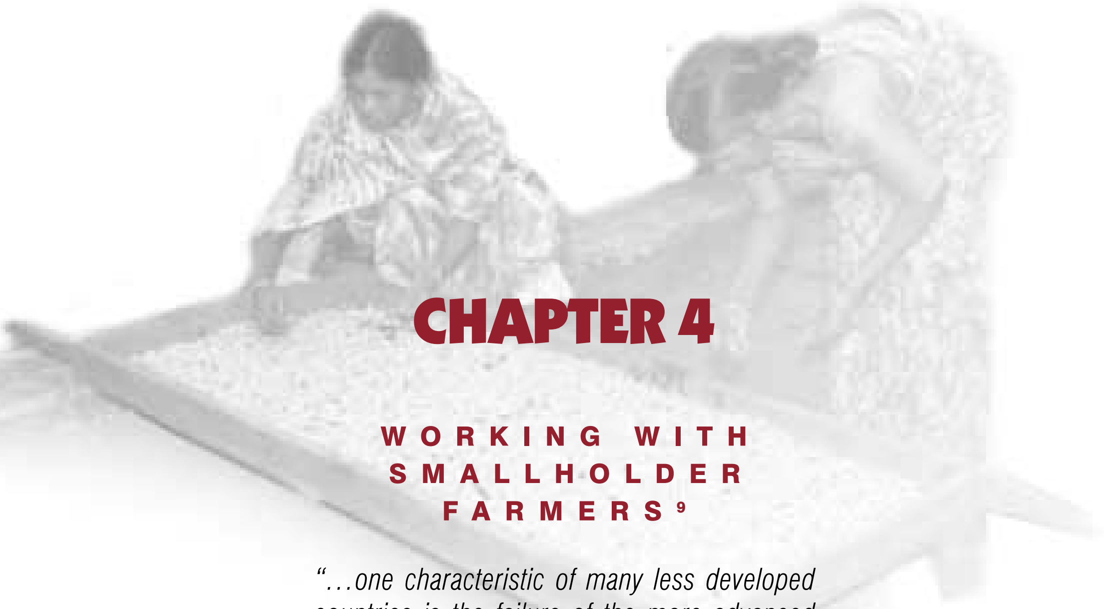
Then the model computes that the cost, over 10 years with a one-year start up time, would range between US$ 42 and US$ 116/ha/year. This compares favourably with present costs for control using cultural control or insecticides, currently estimated at over US$150/ha in Colombia using insecticides (the latter figure does not include any added externality costs for human and environmental damage).

The strategy depends on beginning with low populations or reducing them initially through other methods. It assumes neighbouring plots will also be adequately controlled. The results must be treated with caution because of the large numbers of assumptions made. But since the costs fall within an acceptable range for control of this pest, the case is here made that there is economic justification to proceed to a pilot project stage to validate the method in the field, perhaps on a scale of a thousand contiguous plots of high value coffee.

(Adapted from Leach A, 2001. A cost model for mass rearing of *Phymastichus coffea* for area-wide control of the coffee berry borer, *Hypothenemus hampei*, in Central and South America – processes and user's guide. A copy may be obtained from CABI *Commodities* on application).

BOX 5 - Feasibility of augmentative release of ***P. coffea*** to control CBB.

Overall: the work on *P. coffea* is a major success for the project and a good example of inter-institutional collaboration. The eventual spread of the wasp, even if augmentation options are not taken up, will mean that the costs of providing the wasp will be rapidly recouped in terms of lower CBB damage. The main beneficiaries will be smallholders who do little control at present. For them biocontrol is their only possible "free lunch".



CHAPTER 4

WORKING WITH SMALLHOLDER FARMERS[9]

"…one characteristic of many less developed countries is the failure of the more advanced sectors to penetrate deeply into society, resulting in what many have called "dual" economies in which more advanced production methods may co-exist with very primitive technologies."

[Stiglitz, 1998]

[9] This chapter is based on a manual prepared as an output of the project and available separately: Bentley & Baker (2002) *'Collaborative Research with Smallholder Coffee Farmers - what we learned from the CFC IPM coffee project (CFC/ICO/02)'*.

4.1 Introduction

An appreciable part of this Project dealt with participatory approaches to farmer research and training.

The reason for this is that the coffee industry now lags behind other crop systems in its approach to helping farmers. There remains a predominantly 'top-down' approach to transfer of technology which, although it can be successful in some circumstances (e.g. introduction of a pest resistant variety), is less successful when it requires a more knowledge-intensive approach to coffee management, such as is the case with IPM. Because of the worsening coffee crisis, we are convinced that in the future, institutes with scarce resources will have to cannily utilise the experience and inventiveness of farmers to design and implement sustainable enterprises. This will require retraining and re-orientation to overcome long-established practices; for this reason we also prepared a manual on participation as a dissemination output of this Project (Bentley & Baker, 2002).

Coffee is the world's most important perennial crop and, by its very nature, requires farmers to invest more in it than many other crops. In the case of coffee this has led to it becoming a culture in some countries, a way of life. Hence farmers know a lot about coffee and its immediate environment, but we as scientists have rarely consulted them in any formalised way about their knowledge. This project was one of the first to do this in a systematic fashion. It turns out, when we do ask them, that they have very interesting things to say, sometimes profound, sometimes completely erroneous, but frequently unexpected and thought-provoking.

The central problem we now all confront is that for a number of reasons, smallholder farmers are finding coffee-growing increasingly unprofitable and we, as so-called coffee experts, have not even told them about the great changes taking place. Neither have we given them sufficient new knowledge to cope with these changes, for, like many other businesses, coffee production is becoming more demanding.

It is ironic that whilst coffee farming has incurred mounting losses for most smallholders, there is increasing interest in sustainable coffee farming and a growing number of ways that farmers can add value to their produce. And remarkably, at the top of the market, the gourmet sector, there is a shortage of high quality coffee. Many small farmers could profit from these developments if they only knew how. They can, after all, produce good quality, and better than large estates because of their capacity to supply the labour to pick at peak quality, but they lack the means to fully benefit from this.

To help smallholder farmers is always a challenge, but a principal contention of this project is that if we set about the task logically and methodically we can do it, and that with limited resources we can best succeed by soliciting their active participation.

Farmers, after all, actually invented everything that was used on farms until formal research started about 1840 (Pretty, 1991). Farmer inventions can still be a source of ideas for scientists. Many scientists find this hard to accept.

A more pressing reason to adopt the participatory approach is that the 'Integrated Management' of the title of the project means:

- Farmers have to understand more about the pest-crop system and we need to develop ways of teaching them that are easily acceptable

- Integrated management is at least partially site specific, there is no simple "tech-pack" that they can universally adopt

The project therefore promoted the idea of a participatory approach, but what does this entail? Box 6 gives some examples developed in other crops.

4.2 Ways of involving the farmer

There are different levels of farmer involvement. Biggs (1989) proposed four levels of farmer participation in research. These ranged from the contractual (farmers participate the least, the experiment is under the complete control of the researcher), through to consultative, collaborative and finally, collegiate (farmers participate the most where they conduct their own research and the scientist offers support).

FPR (farmer participatory research) is difficult because it involves three main players, all with different backgrounds and agendas (Box 7). A principal problem is that there is no formal teaching for scientists in how to approach and work with farmers, how to elucidate their problems and unlock their potential. Hence either researchers completely avoid farmers or, unless naturally gifted, fail to strike up a meaningful dialogue with them. As we will elaborate in Chapter 6, we perceive a need to reassess scientist's professional training to equip them for this sort of work.

CIAL (Local Agricultural Research Committee): technology validation

CIALs were pioneered in the 1980s at CIAT. The CIAL is a method for validating technologies, especially new varieties of annual crops (Ashby, 1991). The CIAL is now becoming institutionalised, with booklets on how to organise communities to conduct formal experiments. Like the name suggests, the CIAL is based on a committee of farmers, chosen by other community members. The method involves a great deal of effort to organise people into a formal structure (president, vice-president, treasurer etc.). Researchers give the CIAL a small fund, which they use to finance their research. For example, the CIAL gets several new varieties of beans, and rears them out on their farms, and evaluates them. The CIALs work so well for judging varieties of annual crops that many of them have evolved into small seed companies (Ashby *et al.,* 2000).

Back-&-Forth: adaptive research

This is not a widely known method, which is the point: there are a lot of unsung, workable methods. Back-&-Forth (Ir-y-Venir) was developed in Bolivia in the 1990s to design ox-drawn implements. The context was PROMETA, a DFID-funded draught animal traction project at a public university. Back-&-Forth begins with a diagnostic survey in the communities, to learn what type of animal-drawn tools middle income campesinos need. Then a mechanical engineer designs a tool (typically a plough, but harrows, weeders and planters have also been developed). Researchers test the tool in laboratory and on-station. Then they return to communities for farmer comment, followed by redesign, lab and station testing and then, after several visits back and forth until the farmers are entirely satisfied. Finally it is manufactured. Unlike agronomic trials, which usually take a whole crop cycle, research with machinery is quicker, and Back-&-Forth is well suited to rapid R&D of farm tools.

FFS (Farmer Field School): participatory extension

FFS are now going through a period of rapid expansion and change. The original idea was to allow farmers to discover the concept of the ecosystem (including the idea of natural enemies), through field observations, and to decrease the use of insecticides to control brown planthopper in rice (Winarto, 1996). Farmers met for half a day every week, to observe insects and rice plants, while an extensionist facilitated a discussion of whether or not they needed to spray insecticides, that the damage from insects was not so much real as apparent. Later, FFS resource persons began to notice that some farmers conducted experiments and invented things on their own, following FFS. For example, some farmers in Indonesia learned through FFS that dragonflies prey on insect pests. The farmers responded by inventing perches: sticks in rice paddies where dragonflies could rest (Ooi, 1998).

The Zamorano method: encouraging farmer inventions

The Zamorano method is based on the simple, factual observation that farmers experiment on their own, and on a hypothesis that farmer experiments could be further stimulated by filling in the gaps in farmer knowledge, with short courses on insect bioecology. The Zamorano method is like FFS in some ways; both stress training in biology and ecology. A major

BOX 6 - *Farmer Participatory Research (FPR): A guide to some of the types (continued overleaf).*

difference is that FFS trainers return every week: the sessions follow the growth cycle of the crop. The Zamorano method is based on a short course (about three days) to teach general principles, and teach farmers to observe for themselves. This lowers costs and raises excitement. Zamorano researchers in Honduras taught farmers about insect reproduction, predators, parasitism, and entomopathogens. After training, farmers invented many techniques, most of which related to the conservation and manipulation of large, native predatory insects. Many farmers independently invented the idea of spraying sugar water on crops, to attract ants and wasps to control fall armyworm. The idea was based on farmers' existing knowledge that ants like sugar, combined with the new knowledge from the course about the ants and wasps that are insect predators (Bentley, 2000b). Farmers also learned that parasitic wasps drink the nectar of flowers. One farmer actually experimented with flowers of different colours, concluding that yellow attracted more parasitic hymenoptera to fields than did flowers of other colours (Meir, 2000). Meir found that of 100 farmers who had received Zamorano training, 25 had invented something significant (Meir, 1999).

BOX 6 - *Farmer Participatory Research (FPR): A guide to some of the types.*

Broadly we can split the countries up into two groups;

- Those that concentrated more on extension and training: Ecuador, Guatemala, and India
- Those that concentrated on IPM research and participatory research with farmers: Colombia, Honduras and Mexico

We did not plan this split - we wanted to see a diversity of approaches. All countries did some of each, but the preponderance was as stated. In what follows we will concentrate on the participatory work, because this is new. We have good evidence that the extension work went well in India and Ecuador and this is referred to in Appendix 1.

In a short time, the project produced a substantial list of R&D contributions:

Adaptive research:

- Forage groundnut as a cover crop (Guatemala)
- Coffee pulp as fertilizer (Guatemala)
- Use of *caturra* variety (Ecuador)
- Observations on problems with *beneficio ecológico* (Ecuador)
- Cultural control (Re-Re) economic validation (Colombia)

New technology, developed by scientist-farmer collaboration:

- Manure slurry to control coffee diseases (Ecuador)
- Picking mats (India)

Each player knows different things; the scientist dominates at the micro-scale (bugs and moulds), the farmer alone knows his farm and his economic reality; the extensionist understands local social mores and beliefs.

The smallholder farmer: during the project many of the farmers told us that they don't want their children to have the same life as they have had, they want something better for them, probably in the city. Farmers worry about going hungry, about not being able to feed and clothe their children. In some countries where land title is insecure, they fear having their land confiscated. They worry about thieves, and they worry about the rising prices of the inputs they buy, and the falling prices of the goods they sell. Contrary to naïve opinion, traditional, smallholder farmers are not in the least afraid of new technology. They are eager to adopt changes that will improve production, but they are worried that the extensionist or other outsider may not know what he is talking about, and may make exaggerated claims for the new idea, or that the new technique will increase risk (to which farmers are averse). They worry about insects and diseases; they believe that all insects are pests and that any insect or leaf spot can be dangerous to their harvest. Pesticide companies profit on such misperceptions.

The extensionist: extension work often requires one to be away from home for long days at a time. Most are motivated to go into extension by a desire to help people. If left alone in a community, they tend to spend their free time playing cards or football with farmers. Extensionists have been to university, or at least to technical secondary school. They all can write, but few enjoy it, and so extensionists are not entering the historical record as much as they could. They identify more or less with the middle class, but their material aspirations (car, house) are frustrated by their low salaries. They value education, but few can afford to send their children to elite schools.

Many extensionists are afraid of losing their job, but their biggest fear is losing credibility in front of farmers, of making a recommendation which later does not live up to its promise. Few extensionists have the logistical support they need. It is a rare extensionist who has a car or a motorbike. We have met extensionists who sleep in school houses, without plumbing or electricity, eating tinned sardines. Conditions are usually a little more comfortable in coffee-growing areas, because people and money (used to be) more plentiful around coffee, but most extensionists have had to rough it at least sometimes. They rarely have enough well-written, well-illustrated, pertinent technical literature to help them teach farmers. They are usually unable to buy any extra tools or supplies. Many have poor access to computers and e-mail. Even though there may be both in the local office, the extensionist either does not have the time or the information to make full use of them.

Researchers are mostly from higher social strata than farmers and extensionists. This can cause problems. And although they may be more privileged, they have their own special worries: careers in science are no longer the easy option they once were. Tenure is more difficult to come by and many institutes now base pay rises on publications, so anything that is not considered publishable in their target journals is not interesting to them. Something new such

BOX 7 – Participatory research, a guide to the players *(continued overleaf).*

as participatory studies might not be so easily publishable. And they may be worried about what their colleagues might think of farmer participatory work ("It's not science").

Researchers always lack time, because they have administrative duties as well as experiments to design, carry out, analyse and write up and these never go according to plan. They are used to working long hours, often to repeat things that failed for any one of a large number of reasons. Increasingly they are now also expected to find their own funds, which can involved elaborate project proposals. Sometimes quite junior scientists have to run a project more or less unaided, because their seniors have too many administrative tasks. Indeed, one of the main failings of participatory research so far is that there has been a real shortage of senior scientists in the field, working with farmers.

Researchers can often be constrained by a certain conceit that their ideas must be adopted by farmers ("How can we get these farmers to adopt our ideas?"). This is because they have not been trained specifically to do this job or sensitised to the farmer's situation. We contend that the curriculum and professional formation of these professionals is now seriously out of date, and does not prepare them for the real world, which is now set firmly against the gentlemanly pursuit of knowledge.

BOX 7 – Participatory research, a guide to the players.

- Strip applications near stumped groves (Honduras)
- Picking dry berries in March, then spraying (Honduras)
- Greased bin covers (Colombia)
- Greased harvesting barrel (Colombia)
- Trap trees in stumped groves (Colombia)

Validations by scientists of farmer technologies:
- Traditional planting styles in Ecuador
- Traditional harvesting in Honduras

Strategic, on-farm research with:
- Alcohol-bait traps (Ecuador, Colombia, India)
- Wasps (all countries)

A general rejection by farmers of unworkable technologies:
- *Beauveria bassiana*
- Sampling

The project scientists tried out a great range of experiments and styles. They seemed more comfortable working together on adaptive research (level 1 *sensu* Biggs, 1989), in more or less formal platforms (e.g. community research committees or with designated farmer-experimenters). Researchers were not as interested in trying to support farmers in collegiate, level 4, research where the farmers proposed and managed the topics. Simply, this was too big a leap of faith to make, in a time-limited project with lack of experience in the work, so they made the right choice. Thus in Ecuador, for example, researchers on this project tested CBB traps, working with different designs and baits. They needed some simple, numerical data (e.g. how many borer fell into which kind of alcohol). Rather than trying to involve farmers very much with this particular experiment, the researchers decided to carry it out themselves, on-farm, but with most of the decisions taken by researchers.

Researchers proposed ideas that were novel to the farmers, such as the use of coffee pulp as organic fertilizer, and forage groundnuts as cover crops (in Guatemala). These were not directly related to CBB control, for in some places CBB was not the major problem. As luck would have it, through climatic effects the general levels of CBB were depressed in some countries for much of the project.

In most project countries, researchers either introduced or reinforced cultural control to control the borer. The tendency for farmers was to adapt the recommendation, not necessarily collecting berries from the ground, but by performing an especially thorough harvest. They found this less tedious than ground gleaning, and it also gave them more marketable berries. In a nice piece of validation of this adaptation, Colombian researchers showed that the berries farmers collected during cleansing harvests paid for the labour needed in 98% of cases.

4.3 Some examples of what worked

We now give examples of interesting leads that have emerged from participatory work in coffee.

4.3.1 Indian picking mats

This first example started before the Project, but we include it here as an interesting case history. In 1990, the CBB came to Kerala. Coffee Board of India (CBI) entomologist C.B. Prakasan is from Kerala, but was working in Coorg, Karnataka from 1992 to 1996. In Kerala he had seen people tying a mat onto the tree at harvest, which is a traditional practice, to keep the berries from rolling down steep slopes. Prakasan thought that the same idea could be used for CBB control. Prakasan asked Thammaiah, an extension inspector, to make some bags. Thammaiah told some labourers to cut open some gunny bags and stitch them together. With the active involvement of Mr. H.K. Dhruvkumar, the then Junior Liaison Officer of Siddapur, they demonstrated the picking mats in a TV film on CBB in 1994. Then without any trials, but as a hypothesis, the researchers took the mats to the field. The extension service started teaching the mats to growers in the village of Ammathi, Kodagu, and the mats were adopted by the CBI for CBB management.

During his visit, project consultant anthropologist Bentley met Mr. Subaya of Akkee Estate, near the town of Murnad, Kodagu. He has used picking-mats and clean harvest since 1993 to help lower the incidence of CBB. He told us that the CBI should make the mats with a slit, and laces, like a shoe lace, and that the mat should be round, to make it easier to slip it around the tree and then lace it up, harvest and then unlace it. Mr Subaya showed us a mat he made, which was about 18 feet by 18 feet. It was square, with a slit up one side to the centre, for slipping it around tree trunks.

When Bentley saw the above example, some of the Board officers who were with him politely looked at the mat, but did not get overly excited about it. One of them told the grower that they could not make further changes in the specifications of the mats, because it was difficult enough to get the contractors to follow even the original specifications, let alone make modifications. Maybe the farmer was wrong, lacing up a mat sounds tedious but perhaps there could be a compromise. Would Velcro be too expensive? Maybe a round shape would be better.

It seems that many growers have made similar modifications to the mats. The Board asks farmers for their feedback at seminars, but this may be more oriented to judging growers' acceptance of technology than generating or modifying technology. This is not a criticism of the Board *per se*. Incorporating growers' (and even extensionists') suggestions into technology is not part of the standard operating procedure of most research institutes.

So what happened here? An observant scientist picks up an idea from farmers, tries it out with extensionists and they start to teach it. It works. But the process was not called participatory research and therefore did not trigger off a process that could have quickly improved it through a series of, say, Back-&-Forth exercises (Box 6).

The innovation was still a success, but too much was left to chance and the open-mindedness of a few key individuals. If the process had initially been sanctioned under a participatory label, with all players now aware of their role in an important process, the idea would not have depended on chance, and perhaps have been perfected and transferred at an earlier date.

4.3.2 Colombian sticky covers

A good example of the potential of participatory work comes from Colombia, where farmers readily took to the researchers' idea of covering harvested cherry containers (in the washing stations) with oil-smeared plastic covers to catch escaping CBB. In itself it only exerts a small control effect, but we think it indicative of the positive aspects of the process:

- The method is conceptually simple, cheap to install and service
- The farmer can quickly see the result
- It gives the farmer a quick idea of how many CBB may be in a particular plot and so might make him take remedial action there

So we believe it gives the farmer increased knowledge for very little outlay and in a sense empowers him. An indication of its success occurred after the 1999 Armenia (Colombia) earthquake when post-harvest processing facilities of many farmers were damaged. When they rebuilt them, they incorporated the covers into the new design.

Farmers then developed this idea further to catch CBB from the containers used to hold the harvested cherries in the field. And they also experimented with the covers placed over drying patios where they could also catch CBB. One farmer modified the Cenicafé design to help dry the coffee more efficiently; we cannot accurately assess the value of his improvements except to say that his modifications seem eminently reasonable. An additional bonus was that farmers proved several times that they could lower the cost of constructing an innovation such as a trap.

The above was a simple example but it would have taken a truly exceptional and intuitive scientist to think all this out through traditional research and then hand it over to the extension service in a fully implementable form. When we consider IPM in general and all the various elements, it becomes almost unthinkable that researchers could perfect a system on their own and then hand it over to extensionists. And yet this is what some have tried to do.

An interesting rider to the above success was the work with CBB field-traps, where all but 5% of 39 farmers gave up using the research-designed product over a few months. Problems included:

- The lure in the traps (alcohol) evaporated very quickly
- Farmers didn't like to count the CBB captured
- The levels of CBB were low during the study so few were caught

So the technology was not ready, but without trying this, we would not have guessed it. Negative results of this type are very useful when planning a new control strategy, and should become a routine technique to ensure that the farmers' attitude is not ignored even during the fairly early stages of testing.

4.3.3 Mexican 'hot-spots'

Another interesting example is the CBB 'hot-spot' work in Mexico. A 'hot-spot' is a patch of trees that are more infested than the rest of the plot, sometimes quite markedly so. It became apparent that farmers know where these foci of CBB infestation are located without having to sample formally as scientists would. When farmers were asked about this, they offered a number of ideas about where 'hot-spots' form. Mexican scientists then tested these ideas, with shade and borders seeming the most probable causes. Here the farmer is contributing to research even though passively. This realisation could lead to a way of helping cash-strapped farmers control these foci, or otherwise modify them to be less attractive. This would be a good participatory project.

Additionally, the knowledge displayed by farmers should make the researcher wonder how farmers detect hot-spots and estimate CBB levels. It might even stimulate him to do some studies to see how they do it and how accurate they are. From this could come a simpler and more user-friendly way for farmers to size-up their CBB problem, which is an essential component of IPM.

These three examples all get to the heart of practical IPM: how to make things easier for the farmer. All too often the scientist arrives with a complex package that the farmer cannot take up. The problem is that the small things that work are frequently not exciting research topics by which an ambitious young scientist is likely to make his name. He would much prefer to invent a big new way of controlling the pest using an exotic or esoteric technique. Here we see a problem that we will return to in Chapter 6 - career exigencies can get in the way of the more humble endeavours. But the *God of Small Things* must be heeded.

4.4 Problems and failures

There were many failures and we contend that failure is part of success. Most researchers were unwilling to write about them. Perhaps institutional culture and training was against this.

Farmer inventions. Researchers, and even extension agents, have a hard time relating to the idea that a farmer might invent something. Staff tend to treat such observations as amusing, or as irrelevant or unimportant, and not as something to pick up and work on. Even the formal, participatory research movement is much more comfortable with involving farmers in last-link, adaptive trials (Ashby. *et al.* 2000).

Looking for a method. From the beginning of the project, national staff wanted the protocol for participatory research spelled out in great detail. They were more comfortable with experiments that resembled experimental station trials, in part because the method was easy to extrapolate from their university training. Experts brought in to teach participatory research were more interested in philosophical issues, which the national staff found frustrating. It took us a while to begin working on nuts-and-bolts recommendations for how-to-do participatory research. To their credit, the national projects all did something worthwhile, and unique.

If farmers really participate in trial design, then there are no replicates. In the case study of Honduras (Bentley & Baker. 2002), the experiment was designed to have one treatment (IPM), and a control (farmers' practices). Yet, in each case, farmers introduced changes (one applied insecticides, one gathered first fruits, one stumped part of the plot). In other words, farmers are individuals, and when they have the freedom to change a variable, they will do so in individual ways. Each plot will be different. In the Honduran case instead of having a treatment plus a control on four replicates, they ended up with eight treatments and no replicates. One wonders about the statistical validity of the large amount of data taken on these plots. In such cases, we need to spend more time thinking about why the farmers made the changes they did, their opinion of them, and collect some basic data on costs, plant health, and harvest. In these cases the experiments can profitably be written up qualitatively and the lessons learned used to design new ones, some of them perhaps on experimental stations. Researchers however, were unhappy about simple descriptive analysis.

Sampling. An inordinately tedious sampling method cropped up in Ecuador, Honduras and India, although in a different form in each one. In Ecuador, extensionists were using it in 2000, but by 2001 seemed to have abandoned it. In Honduras the project was paying farmers to do the sampling on the IPM plots under study (because the data was useful to researchers, but farmers would not have done it without payment). And in India, extensionists made numerical sampling a major part of their work in pilot FPR villages, although few farmers seem to have adopted sampling on their own.

In hindsight. We as project executors should have been more participatory ourselves. We held a workshop in Colombia in 1999, but it should have been followed up immediately by field visits. The anthropologist (Bentley) had more of an impact on project researchers by working with them in the field than through workshops. The project started in mid-1998, but the anthropologist did not start working with the researchers until well after the workshop. By then the country programmes had planned their research, and the workshop had not given them the firm guidelines in method that they expected, so interventions by the anthropologist and other FPR experts at that workshop were of little value. However, Bentley's visits to each project began to have an effect. Bentley, Jarquín, Barrera and others noticed that farmers perceive hot-spots in Mexico and in Honduras, and this made its way into the research, at least in Chiapas. In Guatemala, they planned the groundnut and pulp experiments during Bentley's visit (June 2000), and researchers presented the results in October 2001. In Ecuador, most of the research was planned during Bentley's trips there (May 2000 and June 2001).

4.5 Participation as a process

The Colombian Project developed a functional, pragmatic structure for collaborating with farmers. It was based on the existing community groups, which were supported by municipal extension agents of the Colombian Coffee Grower's Federation, with ideas for research provided during weekly visits by scientists from the Federation's Cenicafé (research centre). In other words, like much that happens in Colombia, the work was based on a *sui generis* model rather than on trendy concepts from the development literature. The Colombians adapted half a dozen researcher ideas to farmer conditions and encouraged the further development of one of the farmers' own ideas. Farmer-researcher meetings were also successful in providing feedback to Colombian scientists at the station, who did not visit communities, an important but often neglected part of FPR. The Colombians advanced further in participatory research than did most other countries. This was largely because they concentrated intensively on this aspect, had the facilities and personnel to do it and had been previously exposed to some of the concepts. We are confident that with the right training and sufficient time, all countries could do as well. The following is an outline of the process that Colombian scientists evolved during the project.

First encounters: for the first four months they visited the areas with local extension agents, getting to know the areas, and gaining farmers' trust.

Individual visits with farmers, to learn what they know and the gaps in their knowledge. They conducted individual diagnoses of 113 farmers, to learn the farmers' concerns and knowledge.

The method: the researchers had a written format to fill in, but did not administer it like a questionnaire. They visited the farm household, walked with them over their land, chatted informally, and filled in the form later.

They led Participatory Rural Appraisal (PRA) diagnostic sessions in each of 9 communities, to identify problems, solutions and to brainstorm CBB control ideas to research. These formal, quantitative methods allowed them to assess farmer knowledge.

Training farmers, involving extension agents to fill in the gaps in farmers' knowledge thus creating a level playing field for collaboration. Evaluation of training is also carried out.

Establishing and carrying out tests on things that are likely to work. From the above steps things are agreed upon for further action. Some are farmer inventions, but most are scientist inventions. Farmers modify some of the techniques during the tests.

Farmers present results of the research in a farmer-scientist workshop. Three well-attended and comprehensive events were held.

Evaluate the cost-effectiveness of the process. A full economic analysis with an agricultural economist, e.g for CBB cultural control.

A future step is to train extension agents, using practical demonstrations (hammer and nails, not talk and chalk) of the most promising technologies. This might include the entry-level "most-likely-to-enthuse-farmers" technique (perhaps the sticky covers because they are cheap, easy to install and give quick visual results) and a series of subsequent steps leading up to more difficult concepts. There would also be some "don't-even-think-about-it" advice and ways to monitor achievement and encourage farmers (the regional events, prizes, etc.).

Even this would be a pilot extension project, preferably with researchers monitoring it, followed by a full-scale roll-out at a regional level of the validated techniques.This last step is the most crucial because it is the link to a following project. Too many projects finish and no-one takes them up because they do not have ownership of the original. This may well happen in the present case because the funding is finished and project staff will be laid off or reassigned.

4.6 A code for working with farmers

A code of conduct for working with farmers could evolve from this work and the manual produced. In FPR we need a code of conduct that emphasises the positive things we need to do to facilitate productive research with farmers, more than a list of "thou-shalt-nots".

What works with farmers? One thing that works is going to an organised community with a nearly finished technology for them to validate. The community often finds something useful in the idea. We had several examples of this during this Project:

- Control of berry borer with sticky covers in Colombia
- The *caturra* coffee variety in Ecuador
- IPM techniques in Honduras
- Organic fertiliser in Guatemala

In India, Ecuador and Colombia researchers are working on berry borer traps with farmers. While a final trap has not been developed, scientists in all three countries have worked side by side with farmers, hanging the traps in trees, pouring in the alcohol bait, evaluating the results. Because of this, the scientists realise that their traps are not ready. Had they tried the traps on-station, they might be under the impression that the technology was complete.

One-off trials with machinery are really worthwhile. The water-saving mechanical pulpers (*beneficio ecológico*) developed by Cenicafé, Colombia seemed like such a good idea for dry areas of Ecuador. Yet watching farmers and extension agents try to make the Colombian machines work in Ecuador immediately showed how we would have to work with Ecuadorian harvesters to pick only ripe berries.

What doesn't work? Researchers rarely notice farmers' own innovations or even farmers' adaptations of new technologies. The picking mat was an exception but with proper training, young researchers could come to regard this as normal.

Where to now? The work in most countries did not progress far enough for new methods to emerge for transference by extensionists. But some ideas are starting to emerge. For instance, if you are starting with a new group of farmers, and you want to transfer best practice CBB control, what do you start with, the most important thing? Or the easiest thing? Or maybe the most interesting thing? When the most important thing is also the hardest (i.e. cultural control, gleaning) maybe you shouldn't start there. Maybe you need to start with something that is easily adopted, that particularly suits the farmer's mind-set. Once you have a small success, e.g. the sticky covers on his cherry hoppers, you can lead the farmer to the fields to look at the source of the problem and start to build up, in logical small steps, a way that works for him. Working with farmers in this way is as much a confidence building exercise as it is a progression of logical steps in the participatory validation of best practice methodologies.

4.7 Participating with farmers, a summing up

The participatory part of the project tried the difficult task of researching a famously difficult, cryptic insect pest in a tree crop, in only three years, yet we still came up with some worthwhile results. Like all research, FPR takes time. This project could have used another two years. We hope this work can be carried on, but reports from countries by the end of the project suggest that funding will not be available in most countries.

The approach elicited a great range of approaches, encounters, experiments, results, misconceptions, successes and failures. We wanted to dip into the great diversity of coffee growing experience that only a project of this sort can access and this is exactly what we got.

At the same time we have to conclude that FPR is difficult, it requires a certain confidence and detachment, and an ability to synthesize different modalities of information and knowledge that come streaming in after even a few brief encounters with farmers. In effect the researcher has to ask "What is really going on here?", and be able to provide plausible hypotheses to test.

A relatively short project such as this one was not long enough to develop this field sufficiently. It takes time for project personnel to get used to working and thinking in different ways. We also believe, as we will expand in Chapter 6, that the institutional structures and training are not sufficiently robust and flexible to easily accommodate such a new approach.

Nevertheless, we were encouraged by the results. We believe this sort of approach, adapted and extended as local culture and perceptions dictate, is a powerful tool to help bridge the knowledge gap that exists between the farmer and his support institutes.

We may have been too ambitious. Most participatory projects only work in one country. We worked in six (not counting Jamaica). One thing that saved us is that in each country researchers were involved on some level - they never turned everything over completely to the extension agents. The researchers had met before, at coffee berry borer conferences, so they knew each other, and shared information with colleagues in other countries.

Pests can be maddening to research, because one year a species may almost disappear, only to return in force a few years later. Towards the middle of this project, the target pest, the coffee berry borer, suffered a dramatic decline in many countries. We are still not sure whether this was due to the fact that farmers had adopted technical recommendations, or because of the stochastic fluctuation of the insect's population. But by the end of the project, farmers no longer felt that the berry borer was nearly as serious a problem as the serious erosion of the price of coffee. Farmers' priorities can change quickly and this may cause problems for the scientist.

The overwhelming feeling we have is that there is enormous untapped human potential available, which would be both beneficial to coffee farmers and salutary to the rest of the coffee industry.

We believe that we have shown enough advances in this small time to show that this pursuit has merit and should be developed further. If a few highly trained teams in several countries could work unhindered with farmers on a range of topics, we think that many of their difficulties could be eased and that such improvements could have vital empowering effects.

A final word from Joseph Stiglitz (2001 Nobel Prizewinner and scourge of the World Bank).......

> *"Some, in their enthusiasm for ownership and participation, have implied that these participatory processes by themselves would suffice.*

But while individuals within a community may actively participate in discourse about what to do and how to do it, there must be more to this process than simple discourse. First, for participation to be fully meaningful, it should be based on knowledge; hence the crucial role of education and of capacity building. Second, merely calling for participation does not resolve the issue of incentives: individuals (and groups of individuals or organizations) need to be motivated to be involved. In particular, it will be difficult to sustain participation if participants sense that they are not being listened to, that their views are not taken into account in decision-making."

[Stiglitz, 1998]

…and a Colombian coffee farmer from the project:

"We must work and go to the field to study together, we can't be content with the theories that they give us, there should be research directly with the farmer to improve his coffee."

CHAPTER 5

THE ECONOMICS OF CBB INTEGRATED PEST MANAGEMENT (IPM)[10]

10 This chapter is based on Duque & Baker (2002) '*The Economics of coffee berry borer IPM*', published as a separate output of the Project. For a definition of IPM see Chapter 2.3

5.1 The problem with IPM

Coffee farmers were not ready for IPM. It presupposes a certain level of education that is frequently lacking and a way of looking at things that is foreign. Intrinsically it is a very modern concept, a "knowledge intensive" solution and we believe it is emblematic of smallholders' problems. At the heart of the neo-liberal trade model is the assumption that "all players have complete information about all aspects of business, including market opportunities, available technology, costs of production and alternative production arrangements, quality of goods produced and the intentions of their fellow actors" (Dorward *et al.,* 1998, p9).

IPM was not developed in the tropics for smallholder farmers but in northern countries. The aim was to reduce the worrying dependence of farmers on pesticides. As such it has only been partially successful, e.g. Norton & Mumford (1993) cite the case of a UK apple IPM project that was not implemented because, amongst other reasons, the required monitoring was too costly and skilled people to do it were not available.

IPM principally depends on measurement of pest levels followed by calculations to estimate crop damage and then a decision by the farmer on whether to control or not, and if so which method to use. In its original form, it is predicated upon the farmer having at least secondary education and a fairly sophisticated knowledge of pest biology so that he can apply the correct control at the moment when the pest is at its most vulnerable or before it is at its most damaging. It is rooted in a certain ethic, where the farmer invests in knowledge, equipment and extra labour in the expectation of it saving him more in the long run than he expends.

The problem is that this reasoning is not readily transportable to smallholder farmers with at most primary education, less than perfect confidence in experts and limited resources. What is worse, many scientists and extensionists who serve these farmers, have been taught about IPM as though it is an established fact and not something that is necessarily work-in-progress, questionable, negotiable or subject to revision.

Because of inadequate training (see next chapter), we maintain that many researchers and extensionists do not fully understand the economic and cultural limitations of farmers nor the shortcomings and costs of the techniques they are implementing. This severely limits their capacity to advance a farmer-friendly IPM strategy. We have seen cases where extensionists have drawn up more than a dozen actions that the farmers should take to control CBB. Not surprisingly in such a case, farmers end up not adopting IPM because they find it too difficult and costly and are unsure about its worth.

IPM, almost by definition, consists of a range of techniques (Chapter 2). The problem is that some are more effective than others and some are more easy to understand. Each element needs to have coherence and be viably cost-effective, or if not, it has to be bundled with another element so that the two can work synergistically. Rarely in the Project countries did we see the elements proffered to farmers backed by fully validated and costed experiments.

This chapter therefore takes a practical look at the economics of IPM as carried out by coffee farmers in Project countries, it examines farmers perceptions and costs and tries to synthesize the information into some general rules and pointers to the future. In keeping with the participatory theme of the Project, we are looking at specific cases from countries, and arguing from the specific to the general to inform our pragmatic approach to CBB IPM and where it might lead in the future. The data is based mostly on that provided by countries to Project consultant Hernando Duque, plus what he was able to learn from short visits to the countries in question. Additional inputs were provided by the senior author and Gerard Stapleton (LMC International) in the case of Colombia. For the sake of conciseness, in this account we will concentrate mostly on two cases, India, where labour costs are the lowest of the Project countries, and Colombia, where they are the highest. A fuller account can be found in Duque & Baker 2002.

5.2 The cost of CBB

This is hard to accurately assess, simply because coffee is grown in so many ways. With increasing technological development and niche coffees, the crop is becoming ever more varied. Indeed, Gilbert (2002) classes robusta as a separate system from arabica, the former having more the bulk commodity characteristics of cocoa rather than arabica coffee.

5.2.1 How CBB causes loss

There are three possible ways in which CBB causes losses to the farmer:

***Loss in weight*:** CBB infestation causes the conversion factor (out-turn) to change. The conversion factor is the ratio between the weight of freshly picked coffee cherries and the weight of the resultant parchment coffee, processed and dried to about 12% humidity. Customarily this ratio is about 5 to 1 for washed arabica. CBB infestation eats out the berry making it lose weight and if sufficiently destroyed, causes the cherries to float off during the initial separation process (together with other defects such as unfilled beans) and be treated as low-grade or triage coffee. This can raise the conversion factor to six to one, or more, and therefore a tonne of cherries will yield less than 200 kg of parchment.[11] If the infested bean is less heavily eaten out, it will pass through this crude separation and become part of the principal harvest which will still weigh less than a CBB-free batch.

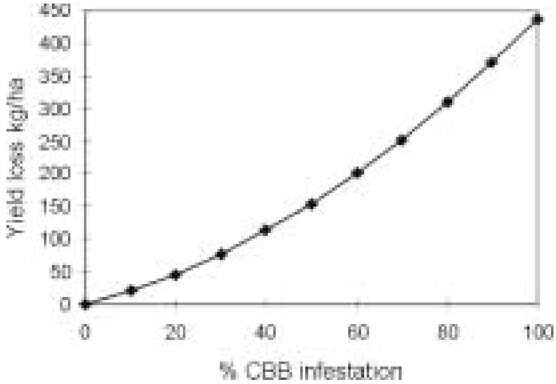
In this Project, Prakasan studied the effect of weight loss on Indian unwashed arabica for different levels of CBB attack (Figure 10).

***Loss in quality*:** the resultant parchment coffee with the characteristic shot-holes may also cause loss in value through inspection and price penalties at the point of purchase from the farmer. Colombia however is currently the only country to have a nationwide quality system of this sort. In other countries we found little evidence of quality inspection by buyers at the farm-gate; seemingly they automatically assume CBB (and other deficiencies) will be present and offer a uniformly low price.

We believe this may be a severe hurdle to IPM adoption because farmers have less incentive to control CBB if they know that they will not be rewarded for quality. They may either assume that carrying out CBB control

FIGURE 10.

Yield loss due to varying levels of CBB attack in India for unwashed arabica.



[11] Saldarriaga (1994) reports conversion rates of 17:1 for heavy infestations in Colombia.

to improve the conversion factor is not worth the effort, or not fully appreciate the weight losses caused by the insect. The latter case seems to have pertained in the case of Ecuador, who made an significant effort during the course of the project to educate farmers about this factor.

At the international level, coffees produced by a country are subject to marking up from the standard New York ”C” quote (e.g. Colombia) or down (e.g. Honduras) on the basis of overall perception about the coffee quality, including CBB and other defects. Countries which are marked down are in a bind: they want to improve quality, which would result in better prices to farmers, but have not managed to instigate incentives for the farmers to achieve it. Thus what may collectively be a good course (exhorting farmers to “improve quality at all costs”) is not attractive to the individual farmer.

Premature drop: CBB can cause young berries to drop. Surprisingly perhaps, there is little more than anecdotal evidence about this. We suspect it occurs under certain circumstances, when there is heavy attack and CBB are forced to infest young berries that are not ready to sustain a brood of eggs. In these cases, infections may enter the watery endosperm causing destruction of the berry. A study of this in Colombia is still in execution.

5.2.2 The costs to the farmer

There is no standard cost, because of the range of climates over which coffee is grown and the almost infinite variety in planting density, yield, tree age etc. We take the cases of India and Colombia to illustrate this.

5.2.2.1 CBB management costs in India

Duque & Baker (2001) tried to establish a standard CBB management cost with extensionists in Kalpetta. The average cost of their estimates was about US$ 60 /ha/yr but with a wide spread (Figure 11). This shows the problem of determining true costs, even for one region of one state in one country.

Later, Setti and Gowda of the Coffee Board of India consulted farmers and found that the farmers themselves estimated their costs lower than the extensionists had done (Figure 12).

If we pick a value of US$ 23 as the standard CBB cost for this region, and then estimate the losses caused by CBB (on a weight-loss basis only) for a range of infestation levels, we can begin to give extensionists and farmers

FIGURE 11.

Cost per hectare of CBB management, the Kalpetta extensionists' view.

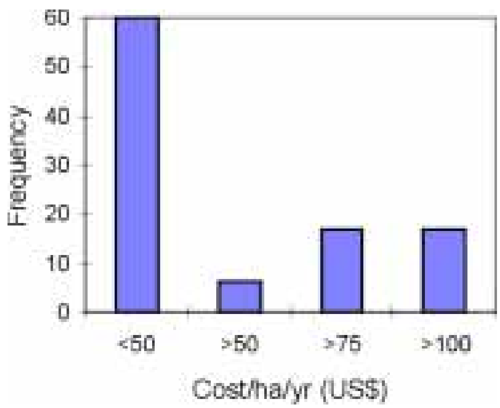
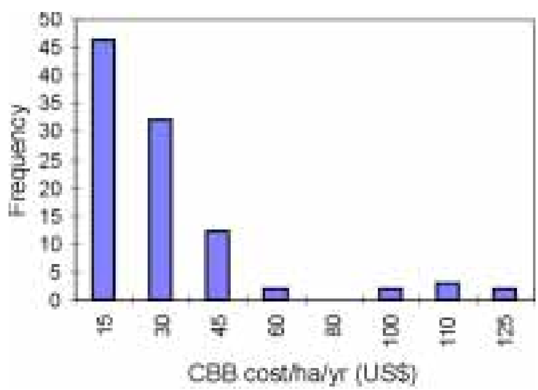


FIGURE 12.

Cost per hectare of CBB management, the farmers' view.



an idea of thresholds above which CBB control is definitely worth carrying out (Figure 13).

From this diagram, a rational decision could be made on whether to control or not, assuming that the farmer can estimate future losses and accurately calculates the cost of control. In this case he/she should aim to control if harvest-time attack levels are expected to exceed about 15%. In practice, because farmers do not sample, and extrapolation some months ahead to gauge harvest losses is difficult, they may either tend to expend too much on control or too little. Over several years however, they may well begin to get an idea of how much damage at various stages of the crop cycle related to final harvest yields. This could be an area for future participatory research, presumably a few farmers at least become experts at knowing when and when not to apply control, based simply on trial and error and a good memory.

In Figure 13 we included two levels of productivity, because higher productivity leads to higher losses and hence greater reward for CBB control. Smallholders with generally low productivity may come to realise that accepting a higher level of CBB damage is to their advantage. Here we face a problem: if there are many smallholders and a few larger farms, the smallholders will do less control and higher levels of CBB will emerge from their plots and infest the large farmers, who may well find themselves having to do more control because of it. It is in cases like this that an area-wide control scheme, as mooted in Chapter 3 for mass parasitoid releases, would benefit everyone.

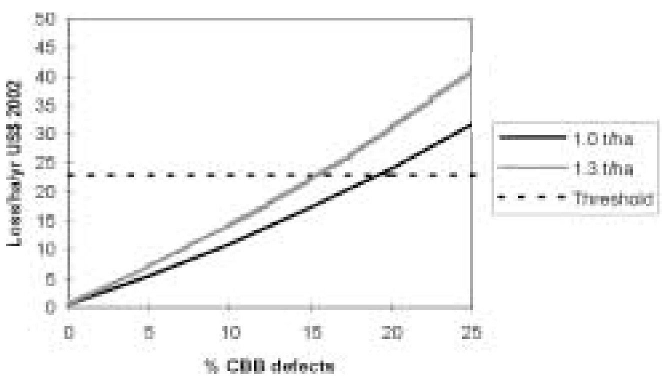
5.2.2.2 CBB management costs in Colombia

The most detailed costs of CBB come from Colombia where they have a well defined quality control system in place that makes economic losses due to quality deterioration easy to calculate. The buyers always sample the parchment beans, they take a 100 g sample and manually divide the beans into two, normal and defective. The defectives are then further separated into traditional defectives (over fermented, 'vinegar', etc.) and CBB-attacked. Each group of defectives is weighed and for the CBB defectives, if the weight is above a threshold of 3.5% of the total sample, a price reduction of 1% is made for every 1% over the 3.5% limit. A price premium is also given if all defectives come to less than 3.5% by weight.

Interestingly this is not the way that the proposed ICO quality standards are calculated, which are done by numbers of defects, not weight (Anon, 2002). The weight system is particularly demanding for CBB control be-

FIGURE 13.

Losses for two yields/ha of Indian coffee (1.0 & 1.3 tonnes/ha) due to increasing CBB levels according to weight loss only caused by CBB consumption of the bean. Threshold line = control costs of US$23/ha/yr.

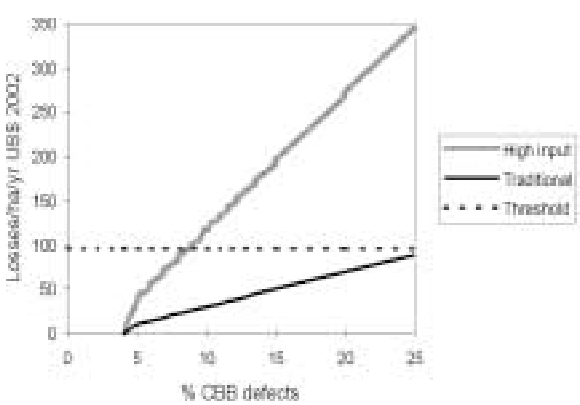


cause it means that very slight CBB damage (say, from a boring that was unsuccessful or where the CBB was killed before it could penetrate deep into the endosperm) weighs more and exerts a higher penalty than a bean that is riddled with galleries. The implications of this for CBB control have perhaps not been fully worked through.

With this system it is therefore easy to calculate the loss for different yields (Figure 14). The costs of the full IPM package have also been worked out. Duque (2001) averages them over the recommended five-year cycle for the crop and estimates a mean of US$95/ha/yr for cultural control plus a further US$50 for other control methods. If we use cultural control costs alone as the threshold, we see from Figure 14 that traditional growers cannot expect to recoup the costs of CBB control and even intensive producers should theoretically not control if they expect to produce less than, say, 10% defects, which in the field translates to roughly 20% CBB infestation. In fact the traditional grower may supply his own labour which he may value at less, and because of low tree densities his costs are lower, but even so, it seems unlikely that he will be stimulated to carry out efficient control for so little gain. Thus from both modes of growing coffee CBB must currently affect quality. From the international perspective, this is a disaster for Colombian coffee because it would raise the defect levels and potentially reduce the premium that the coffee fetches on the New York market. At such extremely low prices the concept of control and quality begin to break down and it becomes understandable why governments are tempted to subsidise prices. As things stand, the extra quality premium that Colombian farmers receive for very low CBB levels, is just enough to keep them in profit (Duque, personal communication, April 2002).

FIGURE 14.

Losses (in 2002 US$) for high input Colombian coffee (yield = 1.63 tonnes parchment/ha) and traditional, low-input coffee (yield= 0.44 tonnes/ha) due to increasing levels of CBB defects, according to Colombian quality criteria for parchment coffee purchase. Threshold line = full cultural control costs only.



In the field it gets more complicated than this. Some years are good or bad for CBB (resulting from different combinations of rainfall pattern and intensity) so even if a farmer carries out frequent control, he may not be able to avoid penalties because he cannot predict future rains. Or if conditions prove unfavourable to CBB, he might control too much and see neighbours who have done little still bring in a reasonably clean harvest. Large farmers, who have much invested, tend to apply more control than is economic, but in so doing uphold the quality image of Colombian coffee.

From the two cases above we see an unhappy irony: India has the lowest costs of controlling CBB but lacks the quality incentive to spend a bit more to reduce CBB levels. Colombia has exactly the reverse: an exacting quality control system but the labour costs are too high to take full advantage of it.

5.3 What farmers say

The senior author remembers asking a group of Colombian farmers about how they were coping with CBB. They replied that they were keeping on top of the problem but added "we've never been so busy in our lives". This is a troubling answer because the duty of development scientists is to make farmers' lives easier.

During the course of the Project there were many encounters with farmers structured along Participatory Rural Appraisal guidelines. We asked them many things about coffee and their problems. Low prices were of course the primary concern but we have omitted this from the following account to avoid repetition.

In India in 2001, two groups of farmers (in Kodagu and Kalpetta) cited 'marketing problems' as principal problems and as a solution, they wanted the government to play a more active part in strategies at the national level. The marketing complaints are perhaps surprising since a recent report by the World Bank (Akiyama 2001) cited India as a good example of a successful transition to a free market. Perhaps our small groups were not representative. In both groups, CBB was only cited fifth in importance. This is congruent with the very low CBB control costs compared to other countries we encountered.

Ecuador on the other hand cited lack of community organisation and low productivity as their key problems followed by commercialisation. If we look at the pricing situation in Ecuador in Table 1, based on data that we col-

TABLE 1. Price analysis for Ecuadorian arabica (2000).

Commercialisation stages	US cents/green lb
1. International price – arabica washed	**103**
less quality penalty	- 16
2. Sub-total	**87**
less exporters fixed costs	- 12
3. Sub-total	**75**
less exporters profit	- 3
4. Sub-total	**72**
less first intermediary	- 8
less second intermediary	- 8
less third intermediary	- 8
5. Coffee farmers' price	**48**

lected, we can begin to appreciate their problems. Since this estimate was made in 2000, prices have fallen by about 50% but since some of the costs are fixed, we expect farmers may currently (April 2002) be getting significantly less than 24 US cents/lb.

A group of Honduran farmers on the other hand more directly blamed intermediaries (*coyotes*) as their chief problem, and another group cited lack of credit. The Guatemalan farmers we met cited lack of commitment and organisation as their main problems, similar to Ecuador. Mexican farmers cited lack of rural credit, climate problems (droughts and floods) and high transportation costs as principal problems. In Colombia, apart from low prices, CBB was their most important problem, reflecting the peculiar severity of the problem in this country.

When farmers complained of commercialisation and marketing, we take this as an indication of poor price for the quality that they know they are producing. Significantly, Colombian farmers never complained of this, though from other sources we know that some are now questioning the lack of freedom for farmers' groups to export directly to specialty buyers.

What were farmers trying to tell us? Looking at the problems of the non-Colombian countries together, there is little doubt that most farmers find commercial problems in their broadest sense, centering around credit and marketing, as their principal difficulties. They tend to focus blame on intermediaries and government for the problems - they never mentioned the wider world and the globalisation debate.

Because of the lack of premiums for quality, we conclude that developing a sophisticated IPM package for CBB is doomed to fail in most countries. Too many farmers simply do not see their coffee as a high value product that will repay careful tending. Probably the single most important step towards controlling CBB would be the introduction of a country-wide quality scheme such as in Colombia. It is lamentable indeed that in Colombia where one exists, the costs of production are currently too high for farmers to fully profit from complying with it.

5.4 A summing up

We have to ask some difficult questions: are country coffee policies congruent with farmers' problems? How does an IPM approach fit in with country's strategy? Does the Project meet and solve these problems? Is it all sustainable?

Farmers problems. They have many, mostly revolving around low prices. They can either intensify production to improve profits, if they can source the funds, or in the case of nearly all smallholders, scale down their efforts until prices improve and concentrate on other crops in the meantime. With CBB, the smallholders may find, if they do nothing, that the crop is hardly worth picking.

Countries' coffee strategies. It was clear from our visits that all countries are keen to promote quality, but we did not see enough evidence in most that quality premiums for the smallholder farmer are near to being universally instigated. Indeed, because institutes are now severely short of funds it is difficult to see how they can easily bring this about. To us, it looks like liberalisation, together with an untimely glut of coffee on the market, caught countries unprepared. In retrospect, funds should have been supplied to establish quality norms and generally buffer countries that have large numbers of smallholders through the transition period.

Hence until transparent quality schemes are introduced, and private buyers monitored (e.g. to check accuracy of scales, a lingering doubt in the minds of Mexican and Honduran farmers at least), we feel any campaign against CBB is doomed to failure under present price strictures. The best that could be done is to promote CBB control on the back of a price rise, by vigorously promoting the concept that the farmer is losing income through loss of weight of his crop. In the present project Ecuador seemed to have some success by proselytising this message. To be convincing, such a campaign would require practical demonstrations at washing stations with before-and-after weighings, as well as memorable ways to show the economic impact of the pest.

So does an IPM strategy fit into country strategies and capabilities? Not really. *Sensu strictu*, IPM implies measurement, calculation, just-in-time control and, frankly, we think many farmers find this too difficult. With the current staff levels of extension services in some countries (not more than one extensionist per thousand farmers is normal) promoting this is doubly difficult. IPM is undeniably desirable for producer countries, to show the world that they are conscious of the need to protect farmers and the environment, but with scarce resources, institutes should be putting all their efforts into a quality reward system first. IPM activities should be confined to working with small groups of farmers to perfect acceptable ways of area-wide transfer when the time is right, as we have tried to show in Chapter 4 and another output of this Project (Bentley & Baker, 2002).

As for specific elements of CBB control, manual collection is still the overwhelming favourite. It is conceptually easy and requires no equipment. But we confess to being concerned that countries are too dependent on this method, which, we feel will become increasingly difficult to sustain as farmers look to save on costs in an increasingly competitive market. We are worried that some have encouraged farmers to pick up fallen berries, which from experience we know is burdensome and not particularly efficient (Baker 1999). Only Colombia is looking concertedly at labour-saving devices, because of their high wage environment, but other countries would do well to follow their example. The picking-mat example of India (Chapter 4) is a good example of what can be done for relatively little investment.

All countries have struggled to some extent with IPM and, in most cases have not convincingly been able to show adoption. Indeed, with the exception of Colombia, surveys of farmers at the start of the Project revealed widespread ignorance about IPM.

Does the present Project meet the requirements of countries' IPM strategies? Yes, for two reasons:

Firstly, the parasitoid establishment programme can only help to combat CBB, although by how much we still cannot say. There is no identifiable down-side to wasp introduction and costs of introduction will be quickly recouped through less damage to beans. Once successfully established, wasps are forever. Secondly, the farmer participatory approach, we hope, should lead to a more pragmatic and flexible approach to IPM rather than the somewhat dogmatic stance we have come across in some countries.

Is it all sustainable? The history of CBB IPM, we submit, has not been a success. It has led to over-complex control regimes that have understandably not been widely adopted. We even wonder if IPM is the best terminology to use. Control has mostly been a combination of manual methods and insecticides, but applied by farmers on *ad hoc* and poorly researched criteria. We desperately need new methods to offer that comply with consumer and farmer demands. This was the difficult task that we undertook.

5.5 Conclusions

What is good for the coffee quality of a country is not necessarily good for the individual and CBB accentuates this conflict. Quality is clearly the goal of all countries in this Project, but has to be built on a system of individual reward, rather than central control of quality at washing stations and mills together with subsidised services as was formerly provided.

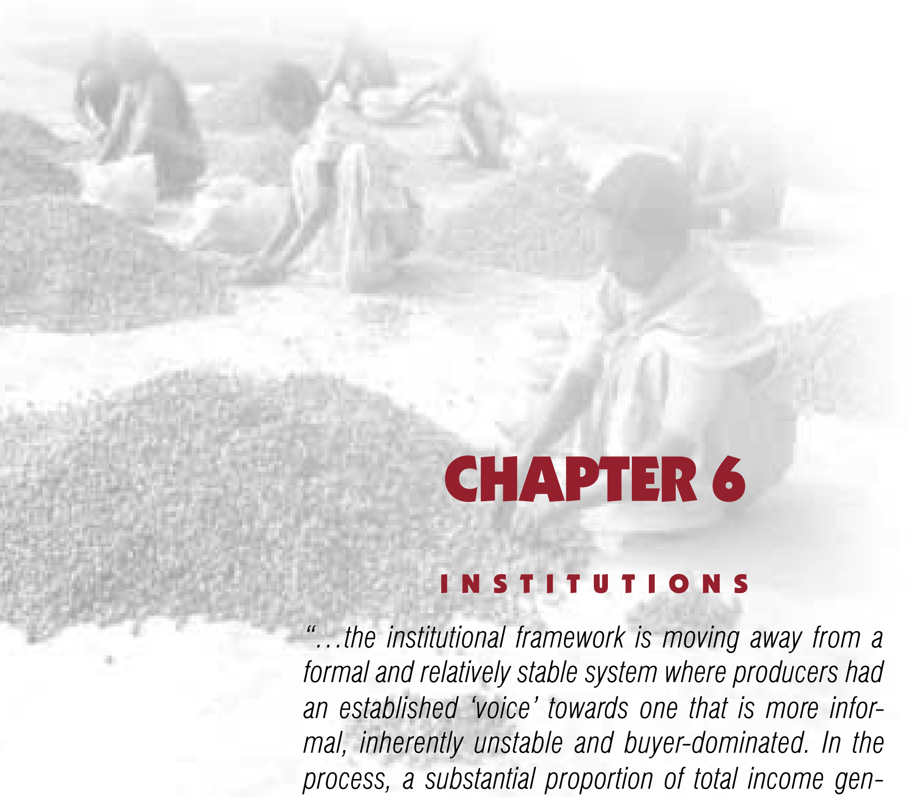
Unfortunately, in the future there may be very few extensionists around to teach farmers the nuances of CBB control, and they may tell them things that are not in their own individual interests (*'keep CBB as low as possible'*). This will lead to increasing farmer disaffection.

To us the inescapable conclusion is that the full cost of producing high quality, environmentally friendly coffee that includes the maintenance of a high level of ability by technical support agencies, is not reflected in the farm-gate price. To an extent, human capital built up in institutes under the previous quota system is still in the process of depreciation.

Broadly for CBB management, the rich man sprays and the poor man gathers. IPM as currently conceived in some countries, is not user-friendly for smallholders. It assumes levels of education, knowledge availability and economic potential that mostly do not exist.

For a snapshot of smallholder sentiment, Duque & Baker (2001) noted the following:

> *"… there was little evidence of an entrepreneurial attitude among coffee farmers. On the contrary most of them appear to accept the present situation; they just want to get better prices rather than start new production strategies. The present coffee situation requires a major change in thinking by all players about how to reorganise this business. We see little sign that farmers are thinking creatively about their predicament."*



CHAPTER 6

INSTITUTIONS

"…the institutional framework is moving away from a formal and relatively stable system where producers had an established 'voice' towards one that is more informal, inherently unstable and buyer-dominated. In the process, a substantial proportion of total income generated in the coffee chain has been transferred from farmers to consuming country operators."

[Ponte, 2001]

"…it would be a huge mistake to cut public sector agricultural research on behalf of smallholders. It is funded because of real market failures, which globalisation will not sweep away. Rather, the issue is to find a way of making agricultural research in poor countries more successful."

[Kydd, 2002]

"As governments retreat from the regulation of domestic coffee markets, farmer organizations lose a political forum of negotiation. The weakness and inherent instability of the institutional framework falls straight on the shoulders of farmers."

[Ponte, 2001]

This chapter is mainly anecdotal. It was not the purpose of this Project to study the institutions involved and it is only now, in retrospect, and from the perspective of the project executing agency, that we feel the need to make some comments. From our privileged position of having worked and communicated with these bodies on a regular basis, we believe we should make some points to inform the on-going debate about institutional support and development.

6.1. General situation

As we noted in the Introduction, market liberalisation has led to the decline of farmer-support institutions (i.e. research, extension, technical services) that have not been replaced by private bodies. In some countries NGOs and donors have shored up the existing infrastructure, but frequently the former lack the funds and complex technical know-how, and the latter the long-term commitment, to make a lasting difference. As pointed out by Akiyama (2001), a number of countries need to strengthen their research and extension services, which were significantly weakened with the abolition of parastatals.

Existing coffee research and extension institutions are thus in severe crisis, simply through lack of funds. Few of the professionals and technicians that have worked on this Project will continue in similar work now that it is over. We are aware that at least half of the 18 staff that worked on the Project are currently unemployed (as of mid-April, 2002).

6.2 Project staff

Through our interactions with the many country Project staff and those associated with them, we have come to have a great regard for their resolution, good sense and, above all, resilience under frequently trying and sometimes dangerous conditions. They have established good relations with farmers and communities, travelled great distances and worked long hours; they have patiently endured. Many were very moderately remunerated for what they did. We salute these unsung heroes for their effort; they are a great credit to the coffee industry as are many of their fellow countrymen in the upper reaches of the coffee chain. What we have reported in these pages, and elsewhere, gives sufficient proof of their commitment and endeavour.

However, due to the seismic changes occurring in the industry, they may well be the last of a breed. In a way we hope they are, because future demands will require an altogether better trained and better paid cadre of professionals to cope with new demands. Under the prevailing anti-institutional climate that has filtered down from international forums and policy makers, field-research for a bright young scholar is, in our judgment, no longer a viable career option.

6.3 Institutional weaknesses

We believe that the forms of training, career development and institutional development currently practiced in most of the Project countries are old-fashioned and uninformed by both current and future commercial needs.

The problem is much wider than just the coffee industry - it encompasses the whole agricultural sector (and we suspect beyond) in many developing countries.

It is our simple belief, based on many hours of listening to our colleagues, that a major effort is required to re-establish some parity in the intensity of scientific and technical enterprise for producer country coffee institutes. A simple illustration of this can be seen at encounters such as the ASIC biennial coffee conference, where a gulf is readily observable between the presentations of producer and consumer countries. This gulf is due to impoverished support, and not intellectual ability.

Simply put, coffee research institutes are failing. Through the work of this Project we discovered a widespread loss of morale. This is not caused solely by the present crisis, but is both broader and deeper, extending back through many years of cutbacks, conflicting development policies and financial constraints.

This Project involved the partnership of many institutes and some are in a much better state than others. But it was clear from interactions with institutes that even the most basic tasks, e.g. to carry out cost-benefit analyses of the various recommended actions, were frequently lacking. Whereas one or two institutes made a concerted effort to adequately assess and monitor research output, this was by no means universal. Frequently no systematic attempt was made to assess the relevance of research, the successes and failures of adoption, nor its economic, social or environmental relevance. It was most unusual to see any data that supported, in economic terms, the usefulness of projects and programmes being undertaken. Some institutes had only a very imperfect idea of their constituents, the farmers; their number, family size, type of dwelling, coffee holding, crop diversification *etc*. This sort of data is desperately needed by institutes so that they can plan convincingly for the future.

6.4 Lack of guidance

Much of the fieldwork was done by young professionals, often with little previous experience, and insufficient guidance from more senior scientists. There were few opportunities to update skills and learn new ones. Access to information was difficult for many scientists and, in the case of Latin American countries, their knowledge of English is sufficiently poor to limit their ability to process a large amount of published research output.

The staffing structures we found were predominantly hierarchical and inflexible, with too much decision-making left to those with inadequate time to become fully acquainted with Project goals.

We found a strong tendency in some institutions for scientists to relentlessly pursue certain lines of research, sometimes for many years, even after clear scientific evidence had been gathered that these avenues would be unprofitable for farmers, and would never be taken up as standard agronomic practice. This, we feel, is due to a narrow academic background which has inadequately prepared scientists for a role in applying science towards practical farmer-oriented goals.

6.5 What to do

Some of the institutes we have worked with are failing, but this is not a reason to remove them, or replace them. As R.H. Bates put it at the World Coffee Conference (2001),

> *"…economists have had to moderate their critical appraisal of the role of marketing boards and to view them as institutional innovations that enabled the industry to enhance its performance in areas of economic life in which markets are prone to fail."*

We hold similar views about the relationship between science and technical institutions.

We have found little evidence that sustained efforts have been made to modernise, retrain and, above all, independently monitor the goals and outputs of these entities. We believe this to be due to a lack of political will. Few experienced researchers and trainers ever make it to the top levels of decision-making. Those in control apparently do not recognise the worth or complexity of research and development, that new techniques and trends are available, or that effective monitoring, training and management can work wonders.

6.6 Recommendations

From our interactions with coffee institutes, and from our present perspective, we recommend some, or all, of the following courses of action:

A skills requirements review for coffee producing countries in the 21st century. To maintain competence, let alone cutting edge research, in agronomy, breeding, molecular biology, physiology, pathology, entomology, mechanics, modelling, statistics, economics, farmer participatory studies, environmental and other disciplines related to the complex business of growing and processing coffee, will be a major drain on resources. Even Cenicafé in Colombia, which has by far the best facilities and support of any coffee institute in the world, has closed a whole department and reduced several lines of research. If even this illustrious institute is struggling to maintain these lines of work, how can other, smaller countries manage?

Regional collaboration. In the future most national coffee institutes will be unlikely to be able to afford to maintain the full gamut of skills that the international market expects. Some of these skills should therefore be provided by larger regional institutions. This solution is fraught with political and funding difficulties but it should, nevertheless, be seriously considered.

A review and redesign of school, college and university curricula to provide the right mix of skills for young people rentering agribusiness professions such as coffee. The knowledge and skills base of young professionals entering these institutes needs critical examination, and changes made to college curricula to furnish the increasingly complex requirements of the coffee/commodity industries. This in turn implies upgrading of training-of-trainer activities. Particularly apparent in the present Project was the poor appreciation that many researchers have of the severe economic constraints that farmers face. This leads them to exaggerated expectations regarding adoption of technology that could be costly to implement and cause no, or only marginal, yield improvements. One ex-Project member has currently embarked upon a part-time economics diploma course because, from his involvement with the Project, he realises the need to improve his knowledge.

Another Project scientist was asked for his views on the relevance of his university curriculum to the sort of work he has had to carry out since leaving university. He readily confirmed that it "left much to be desired" and was "excessively theoretical". "What we need", he said, "is a more practical, hands-on approach to the subject". He added that learning long lists of names of obscure insects in no way prepared him for the difficulties he faced in developing a career in agriculture. We can only suggest that there needs to be a major re-think of how agriculture students are taught and that the coffee industry, if it expects high quality, sustainably produced coffee, should take active steps to ensure that in-country professionals are equipped to deliver it.

A review of the knowledge and information services, to keep scientists abreast of latest developments in their field. Surprisingly perhaps, in this era of information overload, many researchers do not have adequate and up-to-date information in a form that they can readily assimilate. They are busy, and their English is frequently poor; the amount of new information they can process in a limited time is generally inadequate. Their situation is entirely out of kilter with the high-tech facilities and procedures of consumer country coffee research and technology. They need easy access to more than just primary research documents, which are frequently hard to understand for non-English speakers.

Courses, scholarships, prizes, summer schools: we know the above recommendations are unlikely to be implemented unless championed by a major donor. Therefore, we suggest that the coffee industry itself needs to make its own commitment to change by funding the upgrading of skills. This should be directed to young professionals (between 25 and 35 years of age) who have shown demonstrable ability (theses and papers written) on coffee-related subjects. One-off courses, attachments to overseas institutes, scholarships and modest research grants are all possibilities to augment skills and maintain the morale of young professionals.

Institutional audits: regular audits of research and extension outputs, analogous to financial audits, should be carried out. These should be judged on the basis of economic, environmental and social goals that should be matched to the missions and strategy of the parent institute, the capabilities of their staff, and the requirements of the global coffee market.

6.7 Overview of institutions

In summary, the funding, skills-base, organisation and overall strategy of coffee institutes is, with a few exceptions, now largely inadequate for the extremely complex tasks that are either expected of them, or which they need to possess to ensure their future. This leads to loss of morale of staff that may be aware of the problems, but powerless to change them. In turn this can lead to career abandonment or, to those that stay, an evasive turn of mind where new knowledge and ideas are spurned and cast aside.

There is simply no way that farmers will be willing to pay directly for the bulk of services that they have come to expect for free. This will lead either to forms of contract farming where all inputs are supplied by large companies in return for a fixed price, or reversion to low input subsistence-style farming.

We suggest that adequate provisioning of national research undertakings will become increasingly onerous for all but the largest producing countries, and that due consideration should be put towards the establishment of regional entities that can take advantages of economies of scale.

The industry needs to decide the future profile of farmer support institutes. New institutions will not readily spring up, nor will existing ones readily sustain, or re-invent themselves, as neo-liberal theorists have supposed.

6.8 Project management

Finally, in this section, we turn briefly to the management of this Project. As Project implementers under the auspices of both the ICO and CFC, CABI *Bioscience* was charged with the technical and financial administration of the Project across institutions in eight countries.

6.8.1 Technical administration

Close monitoring of a Project spread across India, Central and South America proved very difficult. Once annual work-plans had been agreed, the PEA had to leave Project institutions to implement them, backed up by short visits from ourselves and consultants. This was only partially effective. It worked best with the 'hardware' aspects of training and the provision of parasitoids as evidenced by the successful introduction and establishment of the wasps in all countries.

Where it worked least well was in the farmer participatory approaches - success here was more patchy. In retrospect we were too ambitious to expect all the institutes involved to radically change their approach to farmer support. Nonetheless, we felt compelled to make this effort because the coffee industry now lags behind other crop systems in its approach to helping farmers, and we see no other viable alternative. Large extension services have had their day.

To try to ensure that the approach we fostered is sustainable, we invested Project funds in the development of a farmer participatory manual. We felt this was necessary because the discipline is new, and the concepts strange to some and subject to misinterpretation. We hope this volume (*"Manual for Collaborative Research with Smallholder Coffee Farmers"*, Bentley & Baker (2002), available in both English and Spanish) will help to fill a gap in the literature.

Recommendations

Involving seven countries (plus operations in one co-financing country, the USA) in three sub-continents is too many for a Project of this nature. We suspect that when the Project was initially conceived, it was thought that a cost-effective IPM package already existed and the task was simply one of adaptation to local conditions and training. The reality, as we hope we have shown, is more complex. This is especially true when dealing with smallholder farmers. In any case, the downward spiral in coffee prices has severely tested some of the assumptions of the IPM approach as practiced by some countries, which were unhappily convoluted, difficult to implement and, in some aspects, lacking in close economic scrutiny.

A three-year project is too short for a perennial crop. Due to a slow start this Project lasted almost four years, which was long enough for the establishment of parasitoids, but not long enough to bring about a sea-change in farmer-collaborative approaches.

Some project implementing institutions are now so weak that future projects of this sort will experience problems in implementation and sustainability. We recommend that institutes should be skills-audited before a project agreement is finalised to determine the most appropriate actions to carry out there. We do not suggest that institutes should be denied funds, only that they are assessed objectively to determine the best way to support them.

Future projects should ensure that in each country a principal investigator/leader is assigned exclusively to the project and that he/she should have no other tasks. Carrying out an international project, to deliver goals on time and within budget and to complete comprehensive reports, is a demanding business and requires the full attention of a professional with a proven record of delivery in the area of expertise required.

6.8.2 Financial administration

The issues associated with the technical management, as noted above, of a multi-million dollar project involving numerous stakeholders in numerous countries also manifested themselves in the financial administration of the Project.

Initially, there was a lack of understanding of the financial requirements of the key donor (the CFC), and the processes to be followed regarding reimbursement of project funds or direct payments for capital expenditure, as well as the responsibilities that signing the project agreement with the PEA entailed. The PEA must accept some responsibility for this situation, as it was unable to appoint a dedicated Project administrator until the second half of 1999. However, all participating institutions were, by the end of the project, submitting properly prepared project documentation.

The PEA also notes that there were some problems with on-going, and accurate, budgetary control, especially for Promecafé, where a regional 'umbrella' organization was running activities in four separate countries. This was to do with the inadequacies of internal control systems of the institutions involved (though there were some notable exceptions under this Project), and the difficulties of communications.

Without prejudice to the final Project audit, the PEA is satisfied that Project funds have been used in an acceptable and responsible manner for Project activities, with the cost of activities coming in under the global Project budget agreed in 1997.

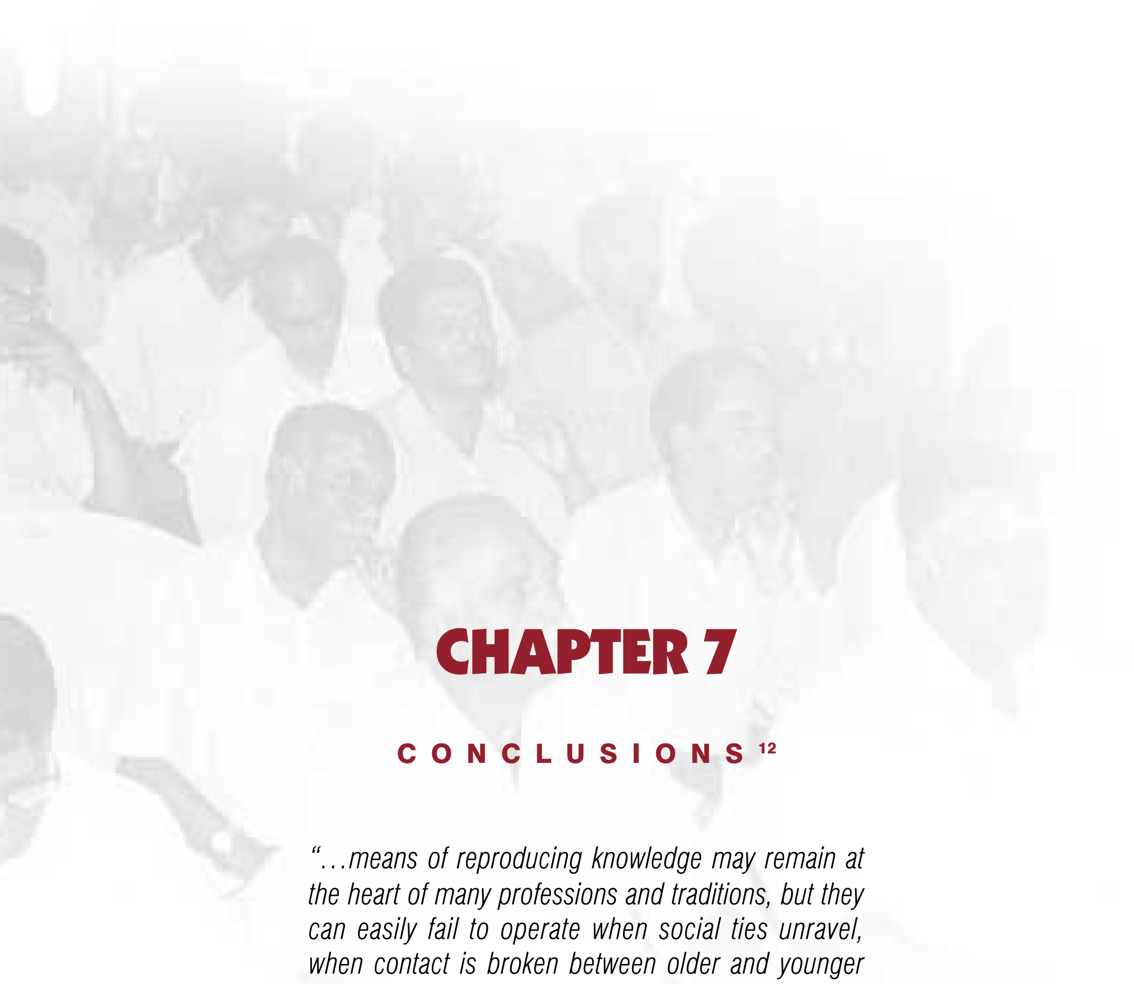
Recommendations

Involving seven countries (plus operations in one co-financing country, the USA) in three sub-continents is too many for a Project of this nature. Administratively, this multi-lateral, multi-country project was both complex and time consuming. The importance of a dedicated Project administrator/co-ordinator based at the PEA headquarters cannot be underestimated in the context of the Project's success.

An initial training course run by the PEA in Project processes (reimbursement claims etc). This should take place at the very start of the project, preferably at each country's institution (so the local context can be evaluated by the PEA), and be attended by both the implementing country's project administrator and project leader.

Some project implementing institutions are now so weak that future projects of this sort will experience problems in implementation and sustainability. In order to ensure timely project administration and transparent financial management, a skills and processes audit of an institute's internal administrative and financial processes would be useful before a project agreement is finalized - e.g. measurement against International Accounting Standards. This would help ensure that an institute is capable of dealing with the administrative requirements such a project presents.

Future projects should ensure that in each country a project administrator is assigned exclusively to the project and that he/she should have no other tasks. In the present Project where this requirement was met, it certainly facilitated administrative and financial interactions between the PEA and the institute. A project administrator should have the skills and, importantly, the authority, to deal with annual budgets (and exercise day-to-day budgetary control), collation of progress and technical reports, preparation of reimbursement claims, assistance with audits, travel arrangements *etc*.



CHAPTER 7

CONCLUSIONS [12]

"…means of reproducing knowledge may remain at the heart of many professions and traditions, but they can easily fail to operate when social ties unravel, when contact is broken between older and younger generations and when professional communities lose their capacity to act in stabilizing, preserving and transmitting knowledge. In such cases, reproduction grinds to a halt and the knowledge in question is in imminent danger of being lost and forgotten."

[David & Foray, 2001]

[12] A review of main project achievements are contained in Appendix 1.

In this concluding section we try to draw the work together and make some suggestions and predictions. Chiefly we will ask:

- Where do we go from here?
- Will these results be taken forward by countries and acted upon?
- Is what we have done congruent with producers' needs and capabilities?

However, before we answer these questions, we shall briefly review where we think coffee production is headed, for, without tying what we have done to some clearly stated concepts, there can be no logical answers to the above questions.

7.1 Where is coffee going?

In the Introduction, we put the case that in the economic, technical, ideological and market-driven world that the smallholder coffee farmer now finds himself, he is going to have immense difficulties extracting a viable living from coffee.

As technical advances continue, and here we are thinking especially of mechanisation, Internet auctions and perhaps (if consumer sentiment allows) GM coffee, smallholders will find competitivity or natural advantage increasingly eroded. Ways for large farms to produce good quality at a low price will be found. Smallholders will then neither be able to supply the quality nor the quantity to compete for the bulk of the market. Neither will they be sufficiently organised to offer an attractive proposition to traders. A small percentage will be able to compete by farming high altitude coffee (say, above 1500 m) and by forming themselves into effective groups that specialty buyers will want to take the trouble to find and work with. Others will also manage it by producing other niche coffees (e.g. 'bird friendly', organic, etc.) or through Fair Trade, which is a form of charity that coffee drinkers of good conscience are willing to underwrite. These niches are likely to remain small however, perhaps never comprising more than 20% of the total retail market.

The problem will therefore essentially become a political one. Will governments want smallholders to survive? If they don't, then they will have to decide what will become of them. We suggest that they *will* want them to survive, for the purposes of maintaining rural stability and keeping under management those upland areas that may one day be needed to supply food as climate change continues and lowland areas dry up. If the true externalities are taken into account, including a comprehensive estimate of social, economic, human and natural capital, then governments will come to realise the true worth of smallholders and decide to return to some of the checks and balances that have been stripped out by the neo-liberal paradigm shift. From this it follows that various modalities will need to be put in place to achieve it.

However, if this does not happen, then coffee smallholder farmers will tend to disappear, at least in some countries. They will probably be replaced (to some extent) by those in other low-wage countries (perhaps Burma, Angola and parts of Indonesia) where, combined with a favourable rate of exchange, farmers will be able to extract a living from coffee. If this does happen, then the coffee industry should surely want to foster good agricultural practice in these new areas, and this in turn implies new institutional arrangements being put in place.

In short, whatever happens, we argue that the present *laissez-fair* market-driven system is not truly sustainable and the institutes with which we have worked are not capable of furnishing all the services that are now becoming both possible and increasingly desirable. They cannot do this because insufficient profits generated by the coffee chain come to them. There has to be a way of providing these services.

But what has all this got to do with a Project to control coffee berry borer? Quite simply that the ways of controlling CBB will depend to a great extent on the sort of farms that exist in the future, the prevailing market forces, economic ideology, the type of institutional structures that support them and who pays the bills.

7.2 CBB and the future of institutes

Because we cannot foretell the future, we will discuss how the pest problem might be addressed in each of the following scenarios.

- *Continuing weak institutes* - where most services to farmers will wither away

- *Transformed institutes* - what we want to see most. Well trained units, aided by regional centres of excellence, providing sophisticated community-based support and high-tech services

- *New entrants* - new countries developing a coffee industry, that should be encouraged to do it in a knowledge-intensive and environmentally friendly way

7.2.1 Continuing weak institutes

A few poorly equipped and trained scientists and technicians, inadequately paid and without tenure, will simply be unable to provide the sophisticated services implied by modern pest management. In Chapter 5 we argued that as IPM is currently promoted, it is not user-friendly for smallholders. It assumes levels of education, knowledge availability and economic potential that mostly do not exist. In this climate our efforts to promote use of parasitoids and re-orientate research towards participation will not be taken up.

Extension services that remain will not deliver convincing improvements. Farmers will abandon coffee or resort to intensive production and chemicals. This will result in poisonings and bad publicity for coffee generally. The larger farmers may find specialty buyers and re-instate IPM at their own cost to comply with required norms.

With regard to CBB biocontrol, this will lead to:

- *Traditional-style niche coffee* - the wasp will work by itself whatever happens and help organic farmers especially who may have the extra labour, say, to see that some wasps are saved from the harvest and returned to the fields

- *Rustic / abandoned coffee* - the wasp will work by itself and reduce CBB levels that would otherwise migrate to other, more managed, coffee farms

- *Some collateral help to large estates* - the wasp will act to reduce CBB inward migration from surrounding smallholders

- *The largest coffee estates with top quality or organic coffee* - these might actively encourage the wasp or even culture it for regular releases, if they are convinced of its efficacy

7.2.2 Transformed institutes

A cadre of well-trained and economically literate scientists and technicians will devise a number of ways of working with farmers to solve immediate problems thus empowering them to take on more responsibilities themselves. Empowerment will include the timely provision of a wide range of knowledge and opportunities for distance learning which will lead to them increasingly adopting a variety of jobs, some unrelated to coffee or agriculture. Some of the most motivated will develop their own marques of coffee and present attractive opportunities to specialty buyers; others will offer ancillary services including tourism (coffee can be beautiful, just visit Southern India).

In regard to CBB:

- *Rustic coffee with all natural enemies in place* - CBB maintained to, say, 15% damaged beans by natural control alone. Coffee with CBB purchased at a moderate discount, removed by electronic sorting in large plants and destroyed. The farmer produces 15% more coffee to compensate rather than expending resources on controlling CBB (Box 8).

- *Rustic or high-tech coffee without self-sustaining natural enemies -* wasps produced and released by an institute or private enterprise over a wide area and paid for by a tax on the higher quality coffee it manages to sustain.

- *Large estate coffee with direct marketing to specialty or organic buyer-* have funds to pay institute to supply wasps, or for small private company to carry out sophisticated IPM monitoring.

7.2.3 New entrants

New coffee farmers in countries with little coffee tradition - Either these will unsustainably exploit "forest rents" and repeat the mistakes of other countries or, through donor, industry and NGO guidance, set up sustainable systems that provide at least some niche coffee. Wasps and other natural enemies will be introduced, with low maintenance weeding, useful shade trees and inter-cropping to provide a diversified system.

Modern coffee processing techniques that incur zero water pollution (e.g. the Colombian ecological processor) and composting of coffee pulp for worm compost to feed chickens, *etc*. The choices are there, which of the above come to pass will depend on political will. It is clear that the future we would like to see will not be brought into play by an invisible hand.

Biological control remains the only possible "free-lunch" for farmers; the wasp works away seven days a week, unseen and unpaid, so we should try our utmost to make it work. This Project introduced a promising agent and fostered work on its successful rearing and establishment. There is one more agent to test fully, *Heterospilus coffeicola*. This is the final parasitoid wasp to study in order to complete the introduction of the most notable control agents of CBB. The CBB biocontrol options, as they exist, are as follows:

- *Classical biocontrol* with these wasps (i.e. without human intervention) is unlikely to reduce damage levels to the very low levels required by industry. But if the wasps were to stabilise damage at, say 15%, then could post harvest methods economically remove the rest? Electronic sorting devices are becoming increasingly sophisticated. They now examine 7 images of each bean and reject those that do not conform to a pre-set standard, all in a few milliseconds. It would seem likely that in the future these machines could detect enough of the damaged beans to produce exportable coffee. Then the farmer would be able to stop all control measures, let the wasp work unhindered and relocate resources to increasing production to allow for the deficit. Essentially, the CBB then becomes a triage problem, so thought should be given to see whether both problems could be solved together.

- *Augmentative control.* Thanks to recent work, the possibility now exists to try this technology out, on a pilot scale to see if it can be validated in the field. If it worked then significant investment in a CBB production plant and wasp rearing facilities would be required.

Ironically perhaps, both solutions outlined above, both fashionably clean and uncontroversial, nevertheless imply substantial investment by donors or in-country institutions that is currently very unlikely. We highlight them here to show that sometimes technology might be both environmentally sustainable and smallholder-friendly but incompatible with economic theory.

If full economic evaluation of mass release is unfavourable, and if all the parasitoids have been evaluated fully and prove to be inadequate to control CBB, there are then two very different avenues to take:

- The first is to *develop IPM*, stripping it down to its essentials, probably a mix of cultural and biological control and trapping (the French advances in CBB trapping technology are promising, Delabarre, 2001). But, as we have pointed out, this would require major investment in properly validating the system, in a range of habitats, followed by a rigorous economic analysis, with a subsequent transfer of the most appropriate technology. To stand a chance of success, the methods would have to be developed with farmers, to make them comprehensible and hence adoptable. But with world prices depressed, it is questionable whether costs could be kept under control. Unless dissuaded (e.g. pesticides taxes, government intervention *etc.*) farmers would most likely resort to the easiest option.

BOX 8 – CBB control technology, where is it going? (continued overleaf).

- The second approach is *plant resistance*. This in itself is a long-term strategy and will not be easy. The most likely line of research, genetic engineering, has added difficulties since most likely a gene coding for a toxin would have to be expressed in the bean itself, which might face consumer resistance.

BOX 8 – CBB control technology, where is it going?

7.3 A summing up

In this Project we placed emphasis on two main things.

- *Biological control*, because this is in keeping with modern sustainable agriculture objectives. Natural enemies maintain a dynamic balance, they are self regulating, unlike other forms of pest control

- *Farmer participation*, because we felt sure that existing ways of transferring technology to farmers were flawed and no longer adequate to deal with the increasing demands of the industry

At the end of the Project we feel vindicated in our approach, though we regret, because of institutional problems in some countries, the work may not be continued as we would have hoped. Our main findings for decision-makers are as follows:

1. Farmers need a quality incentive price scheme in order to encourage them to adopt new ways of controlling CBB.

2. Solutions to deep-seated problems cannot adequately be resolved by producer institutions under their current financing structures.

3. Many producer country institutes are now so weak that they are unable to fully benefit from projects of this nature, as evidenced by the unacceptably high number Project staff laid off as it closed.

4. There remains a predominantly 'top-down' approach to transfer of technology which, although it can be successful in some circumstances (e.g. introduction of a pest resistant variety), is less successful when it requires a more knowledge-intensive approach to coffee management, such as is the case with IPM. In future, institutes with scarce resources will have to cannily utilise the experience and inventiveness of farmers. We tried to inculcate these skills but much more is needed to bring about lasting change.

5. There is a skills shortage. Most importantly we rarely detected adequate appreciation of the economic realities of farmers in the current world context. We conclude that college curricula are out-of-date, causing a narrow specialisation in classical agronomy. Added to this is poor motivation caused by low salaries and uncertain career prospects.

6. Researchers often lacked access to timely and relevant knowledge; despite the prevalence of information and communications technology, we felt that researchers, and especially extensionists and farmers, did not have ready access to the knowledge that they need to bring about change.

7. To a varying extent, Project countries made up for these deficiencies by committed and intensive effort by key staff. We stress that any failings are not the fault of individuals but of the system. Simply, the burdens of brokering knowledge for one of the world's major commodities fell too heavily on too few and unprepared shoulders.

8. All producer country stakeholders, farmers, extensionists, scientists, other supporting agencies support officials *etc*., lack the knowledge to adapt to rapidly changing circumstances. A major effort is required to empower this part of the coffee chain.

7.4 Chief recommendations

1. *New ways of supplying information and knowledge are required.* At the heart of all the problems we encountered is a knowledge gap. Digital media must play an important part in this because of its cost-effectiveness. Technological development and lower entry costs must surely make this a predominant way for disseminating knowledge in the future, even to rural communities.

2. *Professional training for coffee professionals is out-dated.* We recommend curriculum revision in schools and colleges to prepare professionals with broader knowledge of commodity chains, farmers, economics and project administration as well as science, statistics. In the shorter term we suggest that intensive courses should be offered to prepare project staff for the exacting requirements of an international project.

3. Institutional audits are needed, to assess requirements for retraining and strengthening in line with overall country coffee strategy. At present most producer country operations are not commensurate with the sophistication of the rest of the industry.

4. Firm decisions by the industry and donors about the strategic future of support services so that all stakeholders, from the farmer to the international organisation, are clear about what is going to happen and can plan accordingly.

5. Political leaders have to decide if smallholder farmers should be saved. From a narrow economic perspective they should most likely disappear. But from a wider social and environmental one, we believe they must stay and if the full externalities are examined, this opinion is justified.

6. Instigate a quality incentive scheme for farmers.

7.5 Postscript

This report has necessarily adopted a pessimistic and critical tone; as faithful executors of the Project we felt we could do no other than report what we have seen. But we want to end on a note of optimism.

In Colombia, Project scientists approached the communities with which they had worked over the last four years, with the idea of creating a web-page about them, their livelihoods and the Project. We had collectively thought of a web-page for the Project, but in the end a farmer page seemed more appropriate; several visits and discussions later, the scientists, charged with ideas and verbatim statements from farmers, duly obliged. It is now viewable at "www.CABI-Commodities.org" but as yet in Spanish only (Figure 15).

We are not surprised that the farmers readily agreed to this, as we know that they are not afraid of new technology. It seems that many of them understand something about the Internet, even though few of them have direct experience of it.

But, you may ask, is there any point to this farmer page apart from as a curiosity shop? We firmly believe there is. The future of smallholders must be to band together and enter the global market. Inevitably this means digital communication, email and the Internet. And, as we know from our own experience, expressing what you want the world to know about you, is

a salutary experience. It concentrates the mind, but we hope it may also be empowering.
One of the website communities has indeed been sufficiently empowered by the experience to want to attempt to commercialise their own coffee. One of the researchers will be trying to help them in his spare time.

We wish them all good fortune and success.

FIGURE 15. *The Colombian coffee community web site, see www.CABI-commodities.org.*

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APPENDIX 1

MAIN PROJECT ACHIEVEMENTS

In this Project we have made some significant advances towards a more rational, economic and environmentally friendly way of controlling the major pest of coffee, the coffee berry borer, which we believe are conformable with the wishes of consumers and much of the industry. We have also attempted to change the prevailing mind-set of institutions in the way they interact with farmers towards a more participatory approach.

Essentially the project was about two categories of work:

- *Biocontrol:* we have introduced a new natural enemy of the coffee berry borer, studied its establishment and effect, and looked at ways in which it might be used.

- *IPM and how to get farmers to adopt*: we have tried to change the way that IPM and other technology is researched, developed and transferred to farmers.

Biocontrol

Parasitoid training: a successful training course in Colombia in August 1998 where countries sent one to two representatives. Further training was provided in three separate courses run by Cenicafé in Colombia for scientists from India, Central America, Mexico and Ecuador in 1999. Two Jamaicans were trained in 2000. A special course was also arranged for Pascal Wegbe of Togo in April 2002, whom we believe to be one of the very few African scientists currently studying CBB. As Togo provided some of the first wasp shipments to Colombia in the 1980s this was a fitting end to the present project activities.

Follow-up visits were made by Orozco (of Cenicafé) to Ecuador, Central America and India to give first hand advice on the developing wasp cultures in these countries.

Parasitoid shipments: numerous shipments were sent from Cenicafé's facility to Ecuador, Guatemala (and thence to Honduras) and India. Honduras supplied Jamaica with wasps and Guatemala supplied stocks to non-Project countries El Salvador and Costa Rica. Wasp and CBB material were also sent to USDA-ARS at Mississippi.

***Parasitoid culturing*:** at its peak, the Colombian facility was regularly producing nearly three million wasps per month; a decade earlier some of us had thought that rearing it successfully in the laboratory might be too difficult. That the difficulties have been so comprehensively overcome, and the techniques so readily transferable to other countries, is a tribute to Mr.

Orozco and his staff. Other laboratories in Ecuador, India, Central America and Jamaica had much smaller facilities but, over the course of the project, those of Ecuador, Honduras and Guatemala had each managed to produce approximately a million wasps.

Ecuador has subsequently received a US$98,000 grant from CORPEI (Corporación de Promoción de Exportaciones e Invesión) to continue producing wasps after the CFC project ends.Rearing of *P. coffea* continues at CARDI (Jamaica) and one rural rearing facility has now managed to produce 30,000 wasps.

***Parasitoid releases*:** in recipient countries a total of more than two million were released into the field during the course of the project.

***Parasitoid field studies*:** establishment seems certain for Colombia, Ecuador, Guatemala, Honduras and Mexico. India has started releasing (6,900 in 4 farms) but it is too early to confirm establishment there.

Levels of parasitism varied widely, from 3 to 50 %. This is to be expected given the wide range of habitats, climatic conditions and coffee growing systems, and especially since over the course of much of the project conditions were not ideal for CBB (such as prolonged rains due to *La Niña*). More prolonged studies will be needed to ascertain long-term levels.

***Mass rearing on artificial diet*:** the original plan was to do much of this at Cenicafé and experiments were carried out there for the first two years, but yielded no measurable improvement so they were suspended. All subsequent work was done by Dr. Portilla at the USDA-ARS laboratories in Mississippi. By the end of the project a sustainable and healthy rearing system for CBB was established. Dr. Portilla continues in this work until 2004 thanks to USDA support. She has prepared a manual of mass rearing techniques as a separate output of the project.

***Parasitoid economic feasibility*:** a cost model was constructed by consultant Dr. Adrian Leach. Costs for regular releases of up to 100,000 wasps / ha were calculated to be comparable to those of other control methods. An unpublished report of this assignment is available from CABI *Commodities*.

IPM and participation

***Economic studies of IPM*:** audits of each project country's IPM activities were carried out by Hernando Duque for Ecuador, Guatemala, Honduras, Mexico and India. The one for Colombia was undertaken by Gerard Stapleton of LMC. These separate studies have been compiled into book form as a separate output of the project (Duque & Baker, 2002).

Training in participatory research: training and in-country assessments of participatory research were carried out by Dr. Jeffery Bentley, a consultant anthropologist. The result of these various assignments have been compiled into a farmer participatory manual as a separate output of the project.

In a relatively short time the project produced a substantial list of R&D contributions as a result of farmer participatory research (see Bentley & Baker, 2002, for more detail):

Adaptive research:

- Forage groundnut as a cover crop (Guatemala)
- Coffee pulp as fertilizer (Guatemala)
- Use of *caturra* variety (Ecuador)
- Observations on problems with *beneficio ecológico* (Ecuador)
- *Re-Re* (economic validation, Colombia)

New technology, developed by scientist-farmer collaboration:

- Manure slurry to control coffee diseases (Ecuador)
- Picking mats (India)
- Strip applications near stumped groves (Honduras)
- Picking dry berries in March, then spraying (Honduras)
- Greased bin covers (Colombia)
- Greased harvesting barrel (Colombia)
- Trap trees in stumped groves (Colombia)
- Identification of ‘hot-spots’ (foci of CBB infestation) by farmers

Validations by scientists of farmer technologies:

- Traditional planting styles (Ecuador)
- Traditional harvesting (Honduras)

Strategic, on-farm research:

- With alcohol-bait traps (Ecuador, Colombia, India)
- With wasps (all countries)

Rejection by farmers of unworkable technologies:

- *Beauveria bassiana*
- Standard numerical sampling

In summary, some countries took better to participatory work than others. Most of the topics above are unlikely to be followed up after the project ends and as such the project was too short to show more concrete advances and institutes too cash-strapped to allow them to continue after it ended. One group in **Colombia** however has been sufficiently empowered by the activities to try to commercialise their own coffee.

Guatemala also undertook some on-farm IPM experiments on a large farm which Anacafé scientists undertook themselves, with little or no farmer input.

Both Drs Baker (PEA) and Duque (Cenicafé) examined the results and found the experimental design flawed. The Guatemalan scientists, under the guidance of Bentley (independent consultant), developed and undertook some participatory work with farmers of the Chocolá community, mostly on organic compost and cover crops, which showed some promising advances.

In **Mexico** the results of a detailed study between two extension methods ('traditional' *vs.* 'participatory') showed significantly lower levels of CBB infestation in the seven plots studied with the participatory focus (analysis of variance, P=0.027) than the 'institutional' focus.

Questionnaires revealed a higher level of knowledge amongst the participatory farmers, and they manifested fewer problems with CBB or coffee diseases. Attendance at meetings was also higher when using the participatory system.

Operational costs of this method were considerably higher, especially in the first year when the regular presence of a facilitator was essential. But costs fell over time as farmers became more empowered and proactive, whereas the institutional groups' service costs would level off.

Some final points were made by the leader of the project in Mexico, Ramón Jarquín:

> *"Both methods can be effective if well executed, especially if the technology used can show a positive impact on the problem in question."*

"The participatory model enthused the participants much quicker than the institutional model, but makes greater demands on facilitators."

Dissemination

Mass extension, and training of trainers, was performed mainly by Ecuador and India. The other countries concentrated more on developing participatory studies with smaller groups of farmers as reported above, and in the manual prepared for this project (Bentley & Baker, 2002).

Guatemala concentrated on one small community of farmers (Chocolá). The Promecafé 2000 project progress report stated that between 18 and 28 farmers would attend the meetings. High levels of adoption of technology of this group were reported, but no attempt seems to have been made to disseminate to farmers outside this group.

In **Ecuador**, Anecafé calculates that more than 9,000 farmers were exposed to training and dissemination as a result of this project, which means that the CFC funds were spent at an average of US$ 61 per farmer. Since coffee prices halved during the project it is difficult to see whether this expenditure was recouped, but judging by reductions in CBB levels recorded, this is quite possible.

Some 500 farmers also received a total of 400,000 coffee plants, and training on renovation. Anecafé felt that replanting is an important element of CBB control to ensure the plots are yielding sufficiently to make it worth the extra trouble of the farmer to control the pest. Additionally, 330 school children in village schools in the Cotopaxi province, together with 70 farming families, have produced a further 320,000 plants of which 280,000 have now established in the field. The PEA visited two schools in January 2001 and was impressed by the collaborative spirit of teachers, children and parents that attended meetings.

Anecafé points to evidence (gathered during the project) of very low capabilities of both extensionists and farmers who are resistant to change. Effectively, the challenge has been to upgrade skills of extensionists sufficiently to be able to convince farmers to change. Although there have been encouraging signs, the coffee crisis has been a major brake on this process. Evaluations carried out during the project on extensionists (based on CATIE protocols provided by Dr. Guharay) give the following global picture and the improvement during the project (Table A1).

TABLE A1. *Knowledge uptake in Ecuador.*

% Possessing relevant knowledge on…	Jul 1998	Aug 1999	Mar 2001
Relation between farmer and extensionist	40%	60%	72%
Training methods	28%	46%	68%
Experimentation methods	21%	42%	50%
Recording of data	32%	56%	75%
Knowledge of bio-ecology	26%	41%	65%
Planning and participatory evaluation	28%	45%	60%
Options for managing the plantation	29%	47%	73%
Economic analysis	26%	40%	50%
Gender knowledge	25%	45%	55%

In **India** the Coffee Board (CBI) considers that the most significant training programme was that of the Training in Farmers' Participatory Methods (FPM) conducted by the Board during January 2000. Dr. Falguni Guharay (Consultant, CATIE, Nicaragua), visited India and conducted master training of 126 research and extension personnel of the Coffee Board. These master trainees later on conducted FPM programmes in their respective zones in the techniques of:

- Field assessment of pest incidence through participatory methods for effective participatory assessment
- Dissemination of IPM techniques (tested at on-farm IPM plots) to the smallholder farmers

The FPM technique was adopted with the following objectives:

- To bring the farmer, researcher and extensionist together on 'one platform'
- To find out the adoption level of the recommended package of practices
- To improve the growers' decision making ability
- To identify the constraints in adopting technologies
- To identify innovative, locally adopted technologies
- To improve the productivity and quality of coffee
- To improve the overall socio-economic status of the farmer

Dr. Guharay conducted two workshops of four days each at two different locations, and also exposed a couple of groups of farmers and enlightened planters to the participatory techniques. These workshops were held from 17th January 2000 to 22nd January 2000 in Kodagu zone, and 24th January 2000 to 27th January 2000 in Kerala zone.

From April 2000 the Training of Trainers (ToT) workshops conducted by Dr. Guharay led to the implementation of a pilot project for FPM as part of the

TABLE A2. Details of Indian FPM groups and meetings conducted.

States	No. of FPM groups			Total no. of growers			No. of meetings held		
	2000-01	2001-02	Total	2000-01	2001-02	Total	2000-01	2001-02	Total
Karnataka	22	48	70	469	980	1449	132	122	254
Kerala	11	23	34	215	461	676	66	58	124
T. Nadu	7	15	22	145	309	454	42	38	80
Total	40	86	126	829	1750	2579	240	218	458

CBI's regular transfer of technology programme. Accordingly, 40 farmers' groups (consisting of 20-30 farmers each), were selected in all the Senior Liaison Officer/Junior Liaison Officer zones. The FPM process is a three-way interactive mode between Research-Extension-Farmers and consists of regional technical workshops between research and extensionists and farmers' participatory workshops involving farmers' groups and extensionists. Both types of workshops are held on a bi-monthly basis in the regional research stations and in the villages of the farmers' group.

In summary, FPM Groups consisting of 20-30 growers each were formed in all the liaison zones in the three states of Karnataka, Kerala and Tamil Nadu during the years 2000 and 2001. The details of the number of FPM groups formed and meetings held are presented in Table A2.

The training programme enthused the master trainers to an extent that the majority of them expressed the desire to adopt the participatory methods in their function as extensionists. Apart from the training workshop for master trainers, a planters' meet was organized in Kodagu zone wherein the team of entomologists from the Board and an elite group of planters with great experience in CBB Management came together in a face-to-face interactive discussion.

Dr. Falguni and the project staff also visited 3 small holders estates in Kodagu zone and had detailed interactive discussions with farmers regarding CBB Management and other integrated crop technology practices.

The **Indian Women Empowerment Programme (WEP)** came about as a result of a visit by Dr. S.T. Murphy in April 2001. It was decided to initiate special activities on the empowerment of women in CBB management and other coffee cultivation aspects. This was because most women could not attend the FPM activities because of other chores. Two workshops were held at Kalpetta and Somawarpet to gauge the response of the women and the degree of their involvement in managing the coffee estates. Encouarged by the extensive response from these meetings, similar programmes were organized in all Liaison zones. A total of 26 meetings were held in different zones, during April to October 2001, as given in Table A3.

The assessment reports received from field units revealed that the awareness of women/spouses of estate owners, on coffee cultivation varied from 60 to 80%, but with regard to technical aspects it varied from 20 to 30%. Their involvement in decision making on the management of estates varied from 10 to 20% and they said that men generally take decisions.

The WEP meetings gave women an opportunity to get motivated and understand that they have a greater role to play in the management of estates. They are interested to undergo training on coffee cultivation preferably at local level and in vernacular language.

Mass Media Programme: the Board's extension department has also been organising on a continuous basis a number of mass media campaigns e.g. inserting clippings / publicity material / periodical guidelines and warnings on CBB management in all regional and national newspapers, offering talks on CBB management on All India Radio, production of video film on CBB management and telecasting on national TV (Doordarshan).

Training and dissemination: many training events were held. For example, the first bi-monthly farmer participatory management workshops (a total of 40) were held during April/May 2000 in different zones as indicated below:

- **Kodagu zone:** Madikeri, Napoklu, Shanivarasanthe, Suntikoppa, Siddapur, Virajpet, Srimangala & Ammathi.
- **Chikmaglur / Hassan zone:** Giris, Balehonnur, Kalasa, Aldur, Koppa, Mudigere, Sagar, Mallandur, Gonibeedu, Yeslur, Hanbal, Rayarkopal, Belur & Sakleshpur
- **Wayanad zone:** Kalpetta, Chundale, Meenangadi, Manantoddy, Panamaram, Pulpally, Sultan Battery, Vandiperiyar, Kattapana, Adimali, Palakkad
- **Tamilnadu zone:** Bodinayakanur, Batlagundu, Yercaud, Coonoor, Adalur, Pannaikadu, Perumalmalai

TABLE A3. *Details on regionwise women empowerment meetings held in India.*

States	No. of meetings conducted	No. of women participated
Karnataka	13	454
Kerala	8	218
T. Nadu	5	198
Total	26	870

Through the 40 workshops during April/May 2000 and another 40 during June/July 2000, all the relevant technologies as per the time plan were thoroughly discussed through participatory methods to achieve maximum effectiveness. More were held in the following year. Table A4 summarises this Project's extension and training activities in India between 1998 and 2002.

Other dissemination material: Ecuador carried out a series of radio spots, posters and bulletins with information about the pest.

Summary

Finally, we present a synopsis of Project activities in the following Table A5 overleaf.

TABLE A4. *Summary of Extension activities in India.*

Activities	1998-99	1999-00	2000-01	2001-02	Total to 08/01
Contact visits	9811	3442	11671	3546	28479
Technical workshop (Research & extension)	3	6	18	8	35
Farmer's group workshops (extension)	0	0	240	153	393
Regional review workshop (district level)	0	1	8	2	11
Apex level workshop (State level)	0	0	1	1	2
Seminars on CBB	3	1	12	4	20
IPM plots	50	52	52	52	52
Group gatherings at IPM plots	0	1	17	1	19
Study tours	0	0	43	0	43
Issue of advisory letters on CBB	1925	331	1729	466	4451
Contact/assessment camps	13	3	11	1	28
Media campaign					
a) newspapers	15	5	13	5	38
b) radio announcemt	19	1	4	4	28
c) radio talk	4	3	5	1	13

TABLE A5. *Synoptic table of Project Implementation activities by Activity as itemised in the original CFC appraisal report.*

Planned activities	Targets set	Final status	Remarks
Activity 1.1			
Develop diet and rearing systems.	Develop mass rearing for CBB and *C. stephanoderis.*	Mass rearing of *Cephalonomia* abandoned in favour of *Phymastichus.* Artificial diet and CBB breeding work stopped at Cenicafé due to lack of progress. All diet work USDA Starkville with new co-financing.	Clear evidence that *Cephalonomia* is not economic. All resources should be channeled to *Phymastichus*. Significant progress by USDA on continuous CBB rearing on diet (20+ generations) with good quality. Initial "ball-park" feasibility of the method undertaken with positive results.
Activity 1.3			
Training course on *Phymastichus.*	1st year training course.	Took place in Aug 1998 in Colombia.	Successful course All country participants subsequently reared *P. coffea.*
Activity 1.4			
Training course on farmer participatory research.	2nd year training course.	Took place in May 1999 in Colombia.	Moderately successful course, from later interactions it became clear that many participants did not fully understand the concepts.
Activity 1.5			
Training course on IPM of CBB. Central American training course on participatory research. Training for 3-member Indian team.	3rd year training.	Took place in May 2000 in Mississippi. Took place in Aug 2000. Took place in Oct 2001.	Successful course Participants exposed to the concepts of true mass rearing. C. American course by Bentley more successful. Indian training undertaken in Nicaragua.

Activity 2			
Transfer of parasitoids to recipient countries.	Shipments of parasitoids by end of Year 1.	All designated countries have received shipments of *Phymastichus.* Jamaica has received *Cephalonomia* , *Prorops* and *Phymastichus.* Jamaica has also received training in *Phymastichus* rearing.	*Phymastichus* released into the field in Honduras, Guatemala, Mexico, Ecuador. India now has a strong culture. Some released into the field.
Activity 3			
On farm plots.	Initiation of IPM plots and participatory work with farmers by month 9 of Year 1.	Preliminary surveys carried out in all countries and areas for plots identified. On farm activities in all countries, a wide range of activities.	Valuable baseline data on farmers collected. Evidence of a significant impact of the project in India and Ecuador as extension exercises. Some true progress on participatory work in Colombia and Mexico. Less in other countries.
Activity 3.3			
Audit by PEA of IPM activities.	Audit of countries IPM activities in relation to farmers needs.	Field-work carried out in all countries.	Reports available: Ecuador, Mexico, Honduras, India, Guatemala, Colombia
Activity 4			
Training information and dissemination. |	Informal training only in Year 1. Training courses for extensionists Project meeting.	Training undertaken in all countries. Courses in Ecuador, India carried out. April 1998, Mexico May 1999, ColombiaMay 2000, Mississippi, October 2001 in Costa Rica. Farmer participatory manual produced.	Indian training in Jan 2000, Central America (Honduras) Aug 2000. Ecuador & India have produced many posters, flyers and folders on IPM, aimed at farmers.

APPENDIX 2 [13]

COFFEE BERRY BORER COMPENDIUM

[13] Condensed from www.CABI.org/compendia/cpc/

Preferred Scientific Name: *Hypothenemus hampei* (Ferrari, 1867).

Common Names: English, coffee berry borer; Spanish, la broca del café; French, scolyte du grain de café; Portuguese, broca do café.

Notes on Taxonomy and Nomenclature

The genus *Hypothenemus* was first described by Westwood in 1836. The coffee berry borer was first described by Ferrari in 1867 from specimens received in traded coffee but he placed it in the genus *Cryphalus*. It was then transferred to the genus *Stephanoderes* by Eichhoff (1871). Subsequently, and after much dispute, *Stephanoderes* and *Hypothenemus* were united under *Hypothenemus* by Browne (1963) and this is the currently accepted position.

Diagnostic features of the female include: the frontal margin of the pronotum has four teeth (rarely six), setae (bristles) erect, at least eight times as long as they are wide, on smooth and shiny elytra. The median frontal suture of the head is long and well defined. Adult females measure 1.4-1.6 mm long; and the males are always much smaller.

Biology and Ecology

The female attacks developing coffee berries from about 8 weeks after flowering up to harvest time (32+ weeks). It shows a marked preference for older berries if they are available. The endosperm is the site of oviposition but is only suitable for development of the brood if it is solid, i.e. if it has more than about 20% dry weight (J.F. Barrera and P.S. Baker, ECOSUR, personal communication, 1995). This stage of development of the berry may only be arrived at about 16 weeks after flowering (depending on ambient temperature). Thus if the female attacks a berry with a young watery endosperm, it penetrates only to the mesoderm and waits in a short tunnel, sometimes for several weeks, whilst the berry matures. Studies suggest that mortality of the borer is high when it attacks young berries, presumably because it is only in a superficial position and thus more exposed to natural enemies and pesticides applied by the farmer (R. Ruiz, in Baker, 1999). Attacks by the fungus *Beauveria bassiana* may be particularly heavy at this time especially in very humid climates. This is easily diagnosed by the presence of a white powdery patch at the apex of the berry with a dead female underneath.

When the endosperm has hardened, the borer enters and begins to excavate irregular tunnels and galleries in which she lays clusters of eggs. These 30-50 eggs develop to adult over a period that may range from as little as 25 days to more than 60, depending on temperature and the consistency of the endosperm. The female stays with her brood and does not leave to start another one in another berry (Baker *et al*., 1992a). When the progeny reach adulthood, the females (which out-number males by about 10:1) mate with their dwarf flightless brothers. Recent research suggests that the mating system is functionally haplo-diploid, so that males contain functioning genes only from their mothers and do not pass genetic material from their fathers to their daughters (Brun *et al*., 1995).

Although reproduction is overwhelmingly incestuous, it is possible that out-breeding occasionally occurs when two females attack the same berry and the male offspring of one female finds a female offspring of the other founder female.

Some of the mated females from the first brood stay in the berry and egg-laying resumes (Baker *et al*., 1992a).

Others leave the berry though the number departing and the stimuli causing them to leave, rather than start a new brood, are not yet well understood. A perfect understanding of the fecundity and mortality inside the berry is difficult because the females carry out brood hygiene and may eject dead or dying immature and adult stages from the berry (Baker *et al*., 1994). This makes accurate assessment of mortality factors in the field almost impossible; the best estimate of reproduction so far gives r = 0.065; R_o = 25.0; T = 45.2 (Baker *et al*., 1992a). Intrinsic rates of increase have now been established in relation to the age of the berry on which the CBB feeds (Ruiz, in Baker 1999). Up to three generations are possible inside the berry though it is likely that the first two generations are the most important. In old dry berries left after harvest it is not uncommon to find more than 100 individuals. It is frequently stated that the borer goes through eight or more generations per year, but with the often slow start to attack and the possible long wait in an old berry before emerging, it is unlikely that many borers give rise to more than five generations per year.

Fallen berries in dry conditions can build up large numbers of adults which are triggered to emerge by high humidity (>90% RH) that occurs after rain (Baker, 1984). Before emergence the borers are in a quiescent state, more research is needed to determine if this is true diapause or not.

Laboratory studies (Baker *et al*., 1994) show that the borer is surprisingly sensitive to low humidities thus she possibly waits to emerge until after rain so that she has a better chance of avoiding desiccation before she finds a new berry.

The emerged females typically fly from late morning to late afternoon; they are not thought to fly at night. They are slow fliers but are capable of sustained flight of at least 30 minutes and probably much longer (Baker, 1984). They may fly for many minutes around a tree before finally finding a berry to attack, they land on a branch and walk around for many minutes before finally selecting a berry (F. Posada, Cenicafé, personal communication, 1996). When different maturities are present on the same branch, there is a strong selection for mature berries with over 25% dry matter content (Castaño and P.S. Baker, Cenicafé, personal communication, 1996).

In coffee plantations attack is frequently aggregated towards a part of a field, often where there is shade or higher humidity or a border (Barrera, 1994). If the infestation is not controlled, attack becomes general over the entire plot.

Genetics

Preliminary DNA studies in Norway indicate that all of the coffee berry borers from Latin America are genetically very similar but the coffee berry borer from Jamaica is slightly different, suggesting that this introduction (in the late 1970s) was maybe directly from Africa or Asia. Considering Jamaica's close affinity with Ethiopia, it is interesting to speculate whether the coffee berry borer came from this part of Africa, the country of origin of *Coffea arabica* (Baker, 1997).

Morphology

Eggs are elliptical or ovoid in shape, milky-white and shiny when first laid, 0.5-0.8 mm long, 0.25-0.35 mm wide (Bergamin, 1943; Hernandez-Paz and Sanchez de Leon, 1978; Johanneson, 1984).

Larvae: there are two larval instars for the female and one for the male. White, legless, vermiform body with fine but sparse hairs, brown hypognathous head, 3-segmented thorax and 9-segmented abdomen. Well-developed mouth parts. First instar is about 0.6-0.8 mm long, and a fully developed second instar female larva is about 2.2 mm long (Mbondji, 1973; Johanneson, 1984).

Pupae: white, becoming yellow after 10 days of development. Mandibles, eyes, antennae, elytra and membraneous wings are differentiated and easily visible. Female body length 1.7 mm; male 1.2 mm (Mbondji, 1973; Johanneson, 1984).

Adults: males are often apterous, stunted and deformed. Females with body 1.4-1.6 mm long and 2.3 times as long as wide, entirely black. Antennal funicle usually 5-segmented, antennal club with suture 1 almost straight and partly septate; suture 2 slightly procurved and marked by setae. Frons broadly convex, with a deep, long median groove, surface finely wrinkled with net-like markings. Eyes with slight indentation. Pronotum with fine, raised basal and posterolateral marginal bead, anterior margin bearing 4-8 coarse teeth of about equal size, disc convex, summit rather high, rather shiny, not reticulate, small rasp-like teeth on anterior slope abundant, 25 or more, rather small, posterior area subreticulate, with small, isolated, rather numerous granules, intermixed with some shallow punctures laterally. Elytra with declivity convex, gradual, extending almost to middle of elytra, striae scarcely impressed, strial punctures rather coarse, moderately deep, usually reticulate at centre, each with a minute, non-erect seta, interstices smooth, shining, as wide as striae, with single rows of non-granulate punctures bearing unflattened, slender scales, each at least 8 times longer than wide, spaced between rows by scale length, slightly closer within rows, discal and declival scales equal in width, without additional vestiture (Booth *et al*., 1990).

Host Range

The borer is sometimes reported attacking and breeding in plants other than coffee. There are no convincing published studies of this with supporting expert taxonomic identification. However, a Colombian study (L Ruiz, Cenicafé, personal communication, 1994) reports rearing the borer through to adulthood on seeds of *Melicocca bijuga*, and a Guatemalan study (O Campos, Anacafé, personal communication, 1984) reports the same for *Cajanus cajan*. As there is much current interest in mass production of the borer, further studies of alternative food sources would be of interest. Nevertheless, all field studies of the borer suggest that coffee is the only primary host and that population fluctuations are hence due almost entirely to its interaction with coffee and not to the presence of alternative hosts.

Cultural Control

Harvesting berries is itself an important control measure. Rigorous collection of remnant berries after harvest, both from tree and ground, can substantially reduce infestations as it breaks the cycle and leaves little substrate for immigrating coffee berry borers. These collected berries should be boiled or buried if infestation levels are high. If processed, they should be placed in a drier, or if sun-dried, placed under netting smeared with grease or oil to capture escaping borers.

These methods are most successful when done carefully by resource-poor farmers (Le Pelley, 1968). However, such manual collection methods are laborious, especially the collection of fallen berries or those on the lower branches. Studies in Colombia have shown that farmers tend to leave many berries after harvest, especially low down on the trees and that the older the tree, the harder the farmers find it to remove the berries (Peralta, cited in Baker, 1997). Many experiments have been carried out in Colombia to accelerate decomposition of the fallen berries and on the feasibility of collecting them by manual or machine methods. So far no practical progress has been achieved (Baker, 1999).

Biological Control

The two bethylid parasitoids, *Cephalonomia stephanoderis* and *Prorops nasuta* have been introduced from Africa to many Latin-American countries in the 1980s and 1990s thanks to programmes funded by GTZ, DFID, EU, IDRC and various national programmes. The few studies undertaken on their effectiveness suggest that in general they have only a moderate controlling effect and that it is rare to find more than 5% of perforated berries parasitised one or more years after releases were made (Barrera, 1994). This may be because the berries are harvested before the wasps have a chance to emerge, though more studies are needed to explain their scarcity in the field. Both species parasitise only one berry: the female enters and stays with her brood, rather similar to the borer's maternal behaviour. From the point of view of biocontrol this is unfortunate as a parasitoid that lays eggs in many berries might be more effective. Quintero *et al.* (1997) carried out similar studies in S. Colombia two years after *C. stephanoderis* and *P. nasuta* were last released. They found *C. stephanoderis* in only 27% of the release sites whereas *P. nasuta* was found in 73% of sites. Mean parasitism rates were less than 5% for both species. A new and indigenous bethylid, *Cephalonomia hyalinipennis* has recently been found parasitising CBB in Mexico (Perez-Lachaud

1998) but it is likely that parasitism rates for this species will also turn out to be very low.

Phymastichus coffea may be a promising biocontrol agent because it attacks adults and thus might help to prevent establishment of the borer in the endosperm, where economic damage is caused. It can also parasitise CBB from more than one berry and the few studies on this in the field suggest it is a more effective control agent than the bethylids (Baker, 1999).

Beauveria bassiana (*Bb*) is found naturally wherever the borer is present. In humid climates infection may reach more than 50%, and is probably the most significant natural control agent of *H. hampei*. Pascalet (1939) found it prevalent in the forest zone of Cameroon and concluded that conditions favourable to an outbreak were a dense borer population, 20-30°C temperature, sufficient rain to produce the humidity necessary for vigorous sporulation, followed by one or two sunny days to induce an even distribution of spores, followed by light rains to favour development of spores on the bodies of the borers. Little epidemiological work has been done since this study and this has hampered our understanding of the natural epizootics of this insect.

Intensive efforts in Colombia, Nicaragua, Mexico and other places have been made to develop an effective mycopesticide based on *B. bassiana*. Results are typically variable with sprays (with varying concentrations of fungal spores/tree) causing anything from 10-86% mortality (Lacayo, 1993; Sponagel, 1994; Bravo, 1995; O Londoño, Cenicafé, personal communication, 1995; Florez, quoted in Bustillo and Posada, 1996; Baker, 1999). High mortality of the coffee berry borer in the entry canal of the berry (80%+) has been achieved but only at uneconomically high doses. At lower doses the mortality is usually between 20 and 50% of coffee berry borer adult females entering the berry. Research is currently underway at Cenicafé, to improve formulation and application techniques.

Control with *Bb* is difficult because:

- The fungus deactivates fast, especially where shade is light and temperatures elevated.
- Good coverage is difficult with inexpensive traditional spray machinery.
- The fungus does not penetrate well into the bored berry so will be most effective when applied on berries of a major flowering where large numbers of CBB are in the early peripheral attack phase.
- Commercialising the product and ensuring viability whilst it reaches remote mountainous areas means it is unlikely to be a cheap alternative for many farmers.
- Several chemical insecticides are often reasonably effective against CBB so there might be no incentive for farmers to change.

- Since many farmers can not afford to spray anyway, (it can take up to 5 days to spray one ha of mountain coffee) it does not match the criterion of a sustainable control method.

Relatively little effort has been dedicated to the use of nematodes to control *H. hampei*. They would be difficult to apply to coffee trees, but might be easier to apply to the ground under the trees where the microclimate might be very suitable for them. The fallen berries under the tree are known to be a very important reservoir of re-infestation and yet difficult to control either by chemicals, fungi or manual collection and experimental releases of parasitoids suggest that few of them attack fallen berries. Hence what is needed is something that could actively search for an infested berry and tunnel its way into the berry to attack the coffee berry borer inside. Lopez-Nuñez of Cenicafé, Colombia, working with *Steinernema carpocapsae* (All strain), *S. glaseri* and *Heterorhabditis bacteriophora* has achieved infection and mortality of CBB in laboratory and small scale field trials (López 2002, Molina & López 2001). Efforts continue to evaluate its performance in larger field trials.

Chemical Control

Insecticides can be effective if they are applied when the female is in the entry tunnel before she penetrates the endosperm. They are not effective at controlling mature infestations, especially on fallen berries. Endosulfan is generally regarded as causing the highest mortality, though borers in New Caledonia are showing resistance to it (Brun *et al.*, 1989). As coffee trees are frequently densely planted and taller than the persons spraying them, serious contamination is likely; pesticide poisonings and deaths are reported from Colombia. For this reason, less toxic alternative pesticides (e.g. fenitrothion, fenthion and pirimiphos methyl) are often used (Villalba *et al.*, 1995). However, full-scale independent field trials followed through to harvest damage assessment appear to be lacking.

Integrated Pest Management

A crude version of IPM is employed by many farmers, involving some cultural control and insectice spraying. Different schemes, based on sampling and economic thresholds have been developed (Decazy and Castro, 1990), but it is difficult to establish simple thresholds on a perennial crop with a prolonged flowering period and a long berry development period. Further, chemical control needs to be carried out many weeks (16 or more) before harvest when the borers are in their most susceptible stage (Decazy *et al.*, 1989; Barrera, 1994). Establishment of an economic threshold is equally difficult when the coffee farmer is unsure of the impact of the post-harvest borer population on the next harvest many months hence.

Extensive studies of Colombian farmers attest to the difficulty of adoption of complex IPM regimes (Duque and Chaves, 2000). The prospects for IPM of CBB are dealt with in detail in Baker (1999).

Host-Plant Resistance

Chevalier (cited in Le Pelley, 1968) found *Coffea liberica* almost immune followed by *C. excelsa, C. dewerei, C. canephora* and *C. arabica* in increasing order of attractiveness to the borer. Villagran (1991) found that the borer had difficulty in penetrating the hard exterior of *C. liberica* berries. However, Roepke (in Le Pelley, 1968) states that *C. liberica* is preferentially attacked. Extensive studies by Kock (1973) reported *C. canephora* variety Kouilou (or Quoillou) is attacked less than the robusta variety. The general consensus is that little true resistance is present in these species.

Villagran (1991) found *C. kapakata* supporting very significantly fewer immature stages of the borer than other varieties and some tendency for *C. arabica* variety Mundo Novo also to support fewer progeny. Olfactometry tests by Duarte (1992) showed *C. kapakata* to be significantly less attractive. *C. kapakata* appears to be one of the most resistant coffee species currently known but this is not a commercial variety and does not resemble a coffee plant to the casual observer.

In general it is likely that some slight resistance or antibiosis to the borer exists even within *C. arabica* or *C. canephora*, but that apparent resistance to attack in the field may often be confused with the berries being too young to be fully attractive to the borer, which preferentially selects ripening berries when available. Resistance to attack and even moderate antibiosis is worthy of further study because even a relatively small increase in development time or decrease in fecundity might have a pronounced effect on infestation levels under certain field conditions.

A joint collaboration between CIRAD and Nestlé has succeeded in producing a *Bt* transgenic coffee plant with resistance to leafminers but there is no information about its effect on CBB (Leroy *et al.*, 2000). Cenicafé and Cornell University (USA) have collaborated on a project to engineer resistance into the coffee berry, but not based on a *Bt* gene. This work is at an early stage and is expected to take many years before a transgenic plant is available (Baker, 2001).

Phytosanitary Measures

Transportation of seeds containing the borer has been the reason for its spread worldwide. Very few coffee-producing countries are still free of this insect and in these cases stringent quarantine precautions are strongly recommended.

Monitoring

A model has been developed for the coffee tree, the coffee berry borer and its parasitoids (Gutierrez *et al.*, 1998). A coffee berry borer only model has been developed by Leach, Bustillo and Prieto at Cenicafé. These developments are welcome because of the complexity of studying a pest on a perennial with several flowerings per year. An accurate model could enable numerous simulations to be carried out, with varying combinations and timings of cultural control, parasitoids, insecticides etc, and thus help guide researchers in the field on optimal combinations for validatory experiments.

Detection and Inspection Methods

Tree: inspect the berries and look for a small cylindrical perforation. Look at the lower branches and fallen berries as these may be more likely to be infested. There are numerous sampling methods, many based on counting all berries on 30 or more branches over a hectare and evaluating percentage attack. As yet there is no easy or universal way to relate level of crop attack to future loss at harvest. A figure of 5% infested berries is often used as an economic threshold for field control activities, but more study on this is needed.

Coffee beans (parchment): as the perforation on berries may be difficult to see, rub suspect beans between the hands to remove the parchment and look for the perforation. Often a small indentation will be present where the borer started to attack but failed to establish itself.

A trap based on ethanol and methanol has been developed but it also catches many other scolytids. It is useful to monitor emergence flight activity, most notably when rains follow a dry period. Recent French research which has added terpines to the alcohol mix has renewed interest in trapping as a form of control, initial results are encouraging though more research needs to be done to confirm the economic viability of this method (Dufour *et al.*, 1999).

Economic Impact

The coffee berry borer is the most serious pest of coffee in many of the major coffee-producing countries. Crop losses caused by this pest can be severe, ranging from 50-100% of berries attacked if no control measures are applied (Le Pelley, 1968). By harvest time the borer has usually not had time to infest both cotyledons of the berry, so that even 100% attack of berries is unlikely to cause more than 50% perforated coffee beans. This amount of damage, however, will produce poor quality coffee and be difficult to market.

The economic threshold for *H. hampei* is around 5% of infested berries on the tree for intensively produced coffee when chemical pest control is used (Klein-Koch and Miranda, 1990). No economic threshold has been established for cultural control after harvest, and in general thresholds are difficult to establish for this pest because the desirable period for control may be several months before harvest. It is difficult to predict weather, flowering patterns, borer immigration, borer emergence from the ground, etc., which greatly affect the abundance and oviposition of this pest.

Notes on Natural Enemies

The two bethylid parasitoids, *Cephalonomia stephanoderis* and *Prorops nasuta* have been introduced from Africa to many Latin American countries in the 1980s and 1990s. Both seem to have established easily, though the latter, despite persistent attempts has never established in Mexico. *P. nasuta* can still be found in Brazil (Minas Gerais), some 60 years after first introduction (Yokoyama *et al.*, 1978). Because of the relatively few parasitoids available to control the borer, intensive efforts have been made in Colombia and Mexico cheaply to mass-rear the two bethylids as a potential augmentative control measure. Recent research suggests that *C. stephanoderis* breeds too slowly to be a useful candidate in practice (Portilla, in Baker 1999). Another bethylid, *Sclerodermus cadavericus*, occurs in Africa but causes dermatitis and is not recommended for rearing (Murphy and Moore, 1990).

Phymastichus coffea is an eulophid parasitoid that attacks the adult female, producing only one or two offspring per host but ovipositing in several hosts. This is one of very few parasitoids that are known to attack adult beetles. Initial rearing problems associated with this parasitoid have been solved and it was successfully imported to Colombia in 1995 where it is now in culture in Cenicafé, Caldas (Baker, 1999).

Heterospilus coffeicola: the fourth and possibly the last parasitoid of CBB, the braconid *Heterospilus coffeicola*, has yet to be reared successfully and hence we know less about its potential than the others. The female can visit more than one infested berry where she lays only one egg per berry, which hatches out and consumes the younger stages of the CBB. Recent work in Uganda by Murphy *et al.* (2001) suggests that the parasitoid lays eggs predominantly in berries with young CBB broods, peaking at around one week after CBB perforation of the berry. Other preliminary data gathered so far suggest this species prefers shade and is most active early in the morning. It was attracted to trays of infested berries placed in the field and tended to preferentially attack higher concentrations of CBB infested berries. Dissections of females reared from field-collected berries and fed on different combinations of honey, sugar, water, pollen etc., revealed very few eggs however, suggesting that an important element of its diet is still missing to ensure adequate fecundity.

Apart from these wasps there are numerous occasional predators, including ants, from such genera as *Crematogaster, Wasmania, Solenopsis*, etc. None of these are thought to be important control agents but little work has been carried out on them. Recently Vega *et al.* (1999) have reported the predatory beetle *Leptophloeus* sp. nr. *punctatus* preying on CBB larvae in Togo and Côte d'Ivoire and Padi (1999) has also reported this beetle in association with coffee berries in Ghana.

The entomopathogenic fungus *Beauveria bassiana* is found everywhere that the borer occurs. In very wet regions such as Colombia, it is a major natural control agent.

Field lifetable studies of the coffee berry borer in Caldas, Colombia, which has a continuously humid climate, shows that natural levels of *B. bassiana* are responsible for up to 80% mortality of adults when they are attacking young berries (>90 days old) and this means that the fungus is the largest biotic mortality factor for the borer under these conditions (Baker, 1999). Other fungi are occasionally found attacking the borer, including *Hirsutella eleutheratorum, Fusarium* sp., *Paecilomyces* sp. and *Metarhizium anisopliae*, all reported from Colombia (F. Posada, Cenicafé, personal communication, 1996).

Symptoms

The borer attack begins at the apex of the coffee berry from about 8 weeks after flowering. A small perforation about 1 mm diameter is often clearly visible though this may become partly obscured by subsequent growth of the berry or by fungi that attack the borer. During active boring by the adult female, she pushes out the debris, which forms a deposit over the hole. This deposit may be brown, grey or green in colour.

Infestation is confirmed by cutting open the berry. If the endosperm is still watery, the female will be found in the mesoderm between the two seeds, waiting for the internal tissues to become more solid. If the endosperm is more developed, the borer will normally be found there amongst the excavations and irregular galleries that it has made.

The borer sometimes causes the unripe endosperm to rot, most commonly by *Erwinia* sp. bacteria, causing it to turn black (Sponagel, 1994) and the borer to abandon the berry.

Similarities to other species/conditions

It is sometimes possible to confuse an attack of *H. hampei* with that of the 'false borer' (*H. obscurus* or *H. seriatus*), but the false borer does not enter the endosperm, laying its eggs in the mesoderm tissue between the two cotyledons. Thus if a small scolytid beetle is found in the endosperm with immature stages, it is most likely to be the coffee berry borer, *H. hampei*.

Taxonomically they can be separated most easily by the shape of the elytral setae, which in *H. hampei* are longer and cylindrical whereas in the false borer they are shorter and more conical with dentate tips (visible under high magnification).

To anyone but a taxonomist, *H. hampei* resembles many other species of *Hypothenemus* and other scolytid genera such as *Xyleborus* and *Xylosandrus*, some of which are pests. There are no simple ways to distinguish these tiny beetles with the unaided eye, and if in doubt it is best to consult an expert taxonomist (see Booth *et al.*, 1990).

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