INTEGRATED MANAGEMENT OF COFFEE BERRY BORER

FINAL REPORT - INDIA

CFC/ICO/02

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CONTENTS

Chapter 1

Introduction

Since 1990 the Coffee Board of India (CBI) has initiated various research and extension programmes to combat the pest problem of the coffee berry borer (CBB) (*Hypothenemus hampei*, Coleoptera, Scolytidae). As additional financial support was required to carry out the new programmes, the Ministry of Commerce, Government of India, was approached for specific projects under the CBI's Plan. Thus the first project cleared by the Ministry was a scheme to provide pesticide and plant protection equipment to the smallholder growers, which was launched during November 1991. Under this project, pesticide and sprayers were supplied to smallholder growers at subsidized rates.

In order to intensify the studies on developing an integrated management package for coffee berry borer with more focus on biological measures, another project, the Biological Control of Berry Borer, was initiated during May 1993. Studies were conducted on the possibilities of using biocontrol agents in the management of berry borer and studies were initiated on the indigenous fungal pathogen, *Beauveria bassiana*. Simultaneously, attempts were also initiated to import some exotic parasitoids of the borer as there was no parasitoid recorded from India. Two parasitoids, *Cephalonomia stephanoderis* and *Prorops nasuta* were introduced from Mexico during September 1995, and two entomologists were trained on the mass multiplication of the parasitoids at ECOSUR (El Colegio de la Frontera Sur), Tapachula, Mexico. From these activities, a culture of *C. stephanoderis* was established in India.

The Scientific Advisory Committee of the Ministry of Commerce under the Chairmanship of Dr. M.S. Swaminathan recommended, during August 1994, to consider the CBB as a national pest and implement a project that had a mission mode approach to intensify the ongoing programmes in a more effective way. Thus, the Ministry of Commerce sanctioned a project, the 'National Mission on Control and Prevention of Coffee Berry Borer', during December 1995 for a period of three years. All the existing programmes on CBB were integrated into this new project and new research and extension programmes were also started. This resulted in the emergence of a package of practices for the management of the pest, and the creation of awareness among growers on the importance of taking up timely measures for tackling the pest. The project was continued as an ongoing programme during the IX Plan Period (1997-98 to 2001-02).

As the CBB is a serious pest problem in most of the leading coffee growing countries in the world, and the fact that much progress had been achieved in research in biocontrol of CBB in Colombia and Mexico, the Coffee Board approached the International Coffee Organisation (ICO) to initiate an international project on the pest.

The ICO took an initiative in this direction, and during November 1995 a consultant, Dr. J. A. Nicholas Wallis was sent to India to prepare a draft proposal for an international project. CABI *Bioscience* was identified as the Project Executing Agency (PEA) for implementation of the project, and the Common Fund for Commodities (CFC) agreed to provide funds. The details of the project were worked out in a meeting of the participating countries (India, Colombia, Mexico, Ecuador, Guatemala, Honduras and Jamaica) with CABI *Bioscience* and the CFC at the ICO, London during July 1996. The Project was launched in January 1998 for a period of three years, which was later extended to December 2001. This project provided an opportunity for research and extension personnel to have first hand knowledge of the latest developments in CBB management worldwide. The technology of mass breeding CBB parasitoids developed at Cenicafé, Colombia was made available to India through training to researchers. Additionally, two parasitoids, *Phymastichus coffea* and *Prorops nasuta* were imported from Colombia under this project. A farmer participatory approach was highlighted in the process of technology development and implementation.

The detailed information on the various research and extension activities conducted under the Integrated Management of the Coffee Berry Borer Project (CFC/ICO/02) are the subject of this report. The information is reported in the context of the coffee industry in India, and previous work conducted on the CBB by the Coffee Board. A summary of the structure of the Board's research and extension infrastructure, and of the principal collaborating personnel, are provided in Appendix 1. A summary of the training and meetings visits made by some of these personnel under the project is given in Appendix 2. Finally, the visits of consultants to the project are summarized in Appendix 3.

Chapter 2

Coffee in India

THE INDIAN ECONOMY AND COFFEE

India's major agricultural exports are cereals, spices, cashew, oilcake/meal, tobacco, tea, coffee, and marine products. The value of agri-exports to total exports of the country normally ranges between 15% and 20%. Coffee exports have remained above US$ 400 million during the last 5 years, with the exception of 1999-2000 when it was US$ 315 million. Table 1 describes the composition of Indian agricultural exports between 1996-1997 and 1999-2000.

From Table 1, it is clear that some products have been increasing their share of exports, for instance spices, cashew, sesame, guar gum meal and seafoods. Other groups have remained more or less constant, including tea, coffee, tobacco, fruit & vegetables, meat & meat preparations. Overall coffee has remained constant at about 6% of agricultural exports, despite low international coffee prices during recent years. In the states where coffee is grown, coffee contributes between 3% and 4% of GNP (ICO, 1997).

In India there seems to be a consensus that the agricultural sector is suffering a serious crisis (Muralidharan, 2001). Several reasons have been suggested including issues related to the WTO and market liberalisation, climate problems and government agricultural policies. For example, in states such as Gujarat, Orissa and Rajasthan the monsoons have been deficient in the last two years. The main consequences of this have been a fall in the output of essential oilseeds (groundnut, mustard and soybean are most affected). On the other hand, food grain growth rates have declined from 3.5% in the 1980s to 1.8% in the last decade, while in the non-food grain economy the growth rates have fallen from 4% in the 1980s to 3.1% in the 1990s. Similarly, Menon (2001) points out that the fall in international prices of robusta coffee as well as pepper has also affected coffee farmers in Karnataka and Kerala states. Pepper is an important extra-income for many coffee farmers, but its productivity has been low (between 275 and 300 kg/ha), despite its potential. Additionally the price has seen reductions from Rs 22,600/quintal in 1999 to Rs 12,000/quintal in 2000. A similar situation has occurred with areca nuts. Prices fell from Rs 154/kg in September 1999 to Rs 78/kg a year later. This farming crisis deserves a more complete analysis, but the point here is to highlight how the Indian agricultural sector is facing a difficult period that is affecting many crops.

Table 1 - India's export of agricultural products expressed as a % of the total

Product	1996/1997	1997/1998	1998/1999	1999/2000
Tea	4.3	7.7	9.0	7.4
Coffee	5.9	6.9	6.8	5.7
Cereals	16.2	13.8	24.9	13.1
Tobacco	3.1	4.4	3.0	4.2
Spices	5.0	5.8	6.5	7.2
Cashew	5.3	5.7	6.4	10.3
Sesame and Niger Seeds	1.1	1.2	1.3	1.6
Guargum Meal	1.5	2.2	2.9	3.4
Oil Meals	14.4	14	7.7	6.8
Fruits & Vegetables	3.0	3.1	3.0	3.7
Processed Fruits & Juices	0.9	1.1	1.1	2.1
Meat & Preparations	2.9	3.3	3.1	3.3
Seafoods	16.5	18.3	17.3	21.6
Others	19.9	12.5	7.0	9.6

Coffee production

Coffee planted areas have increased markedly in India during the last half century. In 1950/51 there were 92,523 ha, but by 1999/00 the total area had grown to 340,306 ha. Figure 1 shows a very significant increase in total area during the 1970s and 1980s. Arabica increased by about 100,000 ha, whilst robusta rose by 146,000 ha. Areas planted to arabica and robusta are now roughly equal.

In 1950/51 production was estimated at about 18,893 metric tonnes while in 2000/01 the forecast is for 295,000 metric tonnes (Coffee Board, 2001). Figure 2 shows this clearly.

In 1950-51 coffee productivity was approximately 255 kg of parchment coffee per hectare, while in 2000-01 the expected productivity was about 1,084 kg of parchment coffee per hectare. The suggestion is that crop technology has been responsible for this increase in productivity. Figure 3 shows the trend in coffee productivity in India (x-scale not continuous).

Nevertheless, coffee yield remains close to 1 ton/ha, which is low in comparison to yields in other coffee countries. So, even without expansion in total area, there may still be considerable scope for an increase in total production.

Arabica and robusta are classified according to the post-harvesting processing method: "washed" and "non-washed" (naturals), and are further classified into 25 grades based on the size of the bean and on the total number of defects or imperfec-

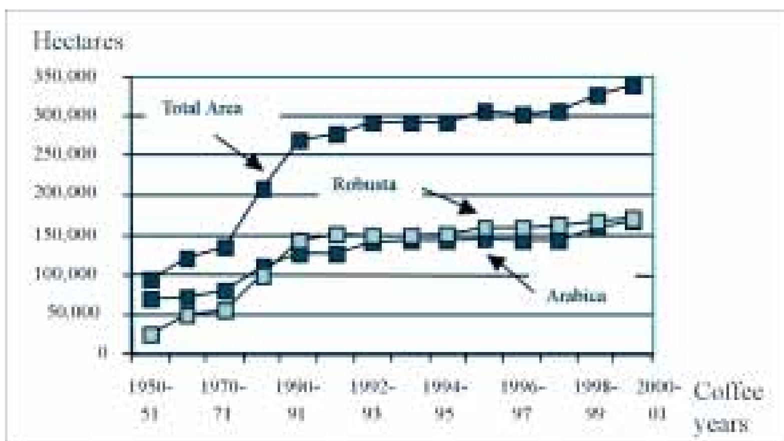


Figure 1. Area planted with coffee in India, 1950-51 / 2000-01

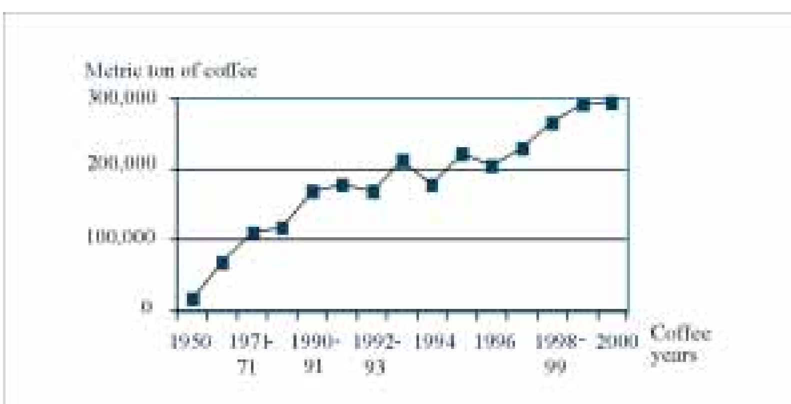


Figure 2. Coffee production in India, 1950-51/ 2000-01

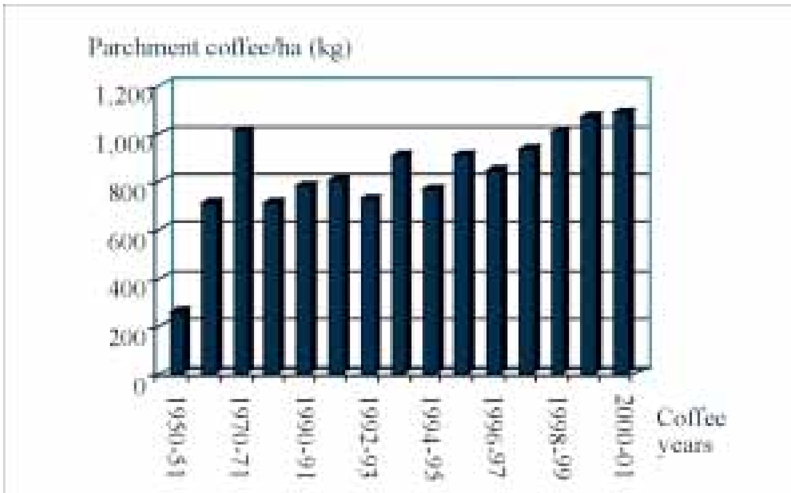


Figure 3. Yield per hectare in India, 1950-51/2000-01

tions (ICO, 1997). Separate from this system, specialty coffee is now the fastest growing segment, and India hopes to export more in the next few years. Organic coffee is also of increasing interest, especially for coffee grown on tribal land, which represents about 42% of the coffee area in India. Here coffee is managed in a less intensive traditional way, which is close to organic production guidelines (Central Coffee Research Institute, 2000). Some of the grades of specialty coffee and value added coffee are Mysore nuggets EB, Monsooned Malabar (AA, PB, C), Monsooned Arabica AA, Monsooned Robusta AA, Monsooned Arabica Tr., Monsooned Robusta Tr., Monsooned Basanally, Monsooned Arabica BBB, Monsooned Robusta C., Monsooned Robusta Bulk, Monsooned Robusta Blacks, Robusta Kapi Royale. Exports for these coffees have roughly doubled in the last decade (Table 2).

Coffee zones and growing

Ninety two percent of Indian coffee is grown in the states of Karnataka, Kerala and Tamil Nadu, the rest in small sectors of the states of Andhra Pradesh and Orissa, as well as in some of the North Eastern states. Table 3 describes production in the main coffee areas in India. Figure 4 shows a map of India, highlighting the main coffee states.

Forty nine percent of coffee in India is arabica and fifty one percent robusta. Coffee leaf rust (CLR, *Hemileia vastatrix*) is a major constraint to arabica production and efforts have been made to obtain resistant varieties. Hence the main goal in arabica varietal improvement is CLR resistance, together with high productivity, wide adaptability and improved quality. In the case of

Table 2 - Indian exports of specialty and value added coffees

Coffee year	Metric tonnes
1992-93	17,166
1993-94	21,464
1994-95	21,599
1995-96	25,393
1996-97	30,305
1997-98	40,728
1998-99	32,531
1999-00	37,888

Table 3 - Coffee regions in India			
State	Arabica	Robusta	Total
Karnataka	110,541	79,683	190,244
Kerala	3,893	79,790	83,683
Tamil Nadu	25,018	5,663	30,681
Non Traditional Areas	18,319	3,331	21,650
Non Conventional Areas	2,900	100	3,000

Figure 4. Main coffee producing states in India

robusta it is known that this species possesses high tolerance to leaf rust disease, white stem borer, nematode attacks and has good potential to give consistent yields. Research therefore is concentrated on its shortcomings: lack of drought-resistance, late stabilisation of yields and inferior cup quality.

But other factors such as soil characteristics and climate conditions have an important role in deciding what type of coffee should be grown. Table 4 describes the adequate conditions for each type of coffee.

The density of coffee trees per hectare varies according to several conditions. The density can range from 6,900 trees/ha in dwarf arabica varieties to 1,000 in robusta varieties such as SLN.1 R or SLN.3 R. The national average is around 1,000 to 1,400 coffee trees/ha.

The amount and the frequency of fertiliser use in India varies according to the coffee variety. For instance, there are four key periods to apply fertilisers: pre-blossom, post-blossom, monsoon and post-monsoon. For arabica, if a high yield is expected (above 1,000 kg parchment coffee/ha), coffee farmers should apply fertiliser in each of the above periods. But if the expected yield is below 1,000 kg, the monsoon period application can be avoided. On the other hand,

Table 4 - Soil and climate requirements for coffee types		
Factors	**Arabica**	**Robusta**
Elevation	1,000 – 1,500m	500 – 1,000m
Soils	Deep, friable, rich in organic matter, well drained and slightly acid (6.0 – 6.5 pH)	Same as for arabica
Slopes	Gentle to moderate slope is ideal	Gentle slopes to fairly level fields to be preferred
Temperature	15 – 25° C ideal = cool	20 – 30° C ideal = hot
Relative humidity	70 – 80%	80 – 90% (ideal)
Annual rainfall	1,600 – 2,500mm	1,000 – 2,000mm
Blossom showers	March – April (25 – 40mm)	February – March (25 – 40mm)
Backing showers	April – May (50 – 75mm)	March – April (50 – 75mm)
Shade	Medium to light shade, depending on elevation	Uniform thin shade

for robusta, if the yield is above 1,000 kg, farmers should apply fertilisers three times a year (pre-blossom, post-blossom and post-monsoon). When the expected yield is below 1,000 kg, it is recommended to apply pre-blossom and post-monsoon only.

It is generally larger farmers who carry out coffee fertilisation. Large farms apply fertilisers near the recommended levels, while smallholders commonly choose lower rates or none at all. The use of organic matter is also frequent. The expected price for the coffee harvest obviously plays a key role in decisions about fertiliser application.

At the farm level, Indian coffee productivity is low in comparison with yields reached in other countries such as Brazil, Colombia or Vietnam. But productivity has been growing. Table 5 shows coffee productivity according to the species grown over the last five years.

Coffee farmers

In India there are estimated to be 140,293 coffee farmers while the total area planted in this crop is 340,306 ha; so the national average would be 2.42 ha of coffee per farmer, approximately 6.05 acres. This figure is similar to that found in other countries such as Colombia, Honduras or Mexico. Table 6 below describes the distribution pattern of holdings in different states of India (Coffee Board, 2000).

From Table 6, 98% of farmers have less than 10 ha, and 86% have 2 ha (5 acres) or less. This characteristic is important since the adoption of technologies is often affected by farm size. Duque *et al.* (2000), working in Colombia, found that the adoption of IPM in CBB management was higher with medium and large-scale farmers than with smallholder farmers (with less than 5 ha of coffee).

If this is true for other coffee countries, the strategy for transferring IPM should be designed to promote good adoption levels despite socio-economic barriers, but also the IPM strategy by itself should be made easy to adopt. Despite most coffee producers being smallholders, from Table 6 it can be concluded that for Indian coffee there is a land concentration and if we take the cumulative percentage of farmers and coffee areas we can quantify this as the Gini coefficient (Tascon, 1980). This indicator gives a measure of land concentration, which in this case has a value of 0.48 that indicates that there is some degree of land concentration, e.g. 80% of coffee farmers have just 40% of the coffee area farmed. The Indian

Table 5 - Coffee productivity in India (kg/ha)		
Year	Arabica Coffee	Robusta Coffee
1995-96	860	982
1996-97	724	907
1997-98	760	832
1998-99	678	1,055
1999-00	815	1,065

Table 6 - Distribution pattern of holdings in India, by state					
Size (ha)	Karnataka	Kerala	Tamil Nadu	Others	Total
I. Small Holdings					
0-2	27,109	71,245	11,396	10,502	120,252
2-4	6,580	2,995	1,246	6	10,827
4-10	4,160	1,676	728	-	6,564
Total	**37,849**	**75,916**	**13,370**	**10,508**	**137,643**
II. Large Holdings					
10-20	1,020	342	156	3	1,521
20-40	445	63	49	4	561
40-60	150	27	36	-	213
60-80	87	19	15	-	121
800-100	46	7	9	2	64
Above 100	107	19	29	15	170
Total	**1,855**	**477**	**294**	**24**	**2,650**
Total India	**39,704**	**76,393**	**13,664**	**10,532**	**140,293**

value of 0.48 compares to that of Colombia (0.57) and Mexico (0.43), i.e. that land concentration is lower than in Colombia, but higher than Mexico.

Land concentration can be seen from different points of view e.g. land reforms, but it is important for IPM management because the pest management proposal should take into account the farmers' resources (for instance, the method might create a high dependency on external inputs). It is logical to suppose that labour should be the most available resource for these types of farms. Another key point is that income generated by small farms is of course not high (Table 7), and if the market punishes coffee quality they could be severely affected by CBB.

The Figure 5 displays the graphical representation of the Gini coefficient. The 45˚ sloping line (Gini coefficient = 0) means no land concentration whereas a value of 1 would mean all land was concentrated in one farm. The coefficient equals the shaded area divided by the total area below the 45˚ line. This analysis is useful to help understand the importance of land distribution between owners, in order to design appropriate pest management strategies.

As mentioned above, 67% of the Indian workforce works in agriculture. According to a study carried out by the Project (data in preparation), Table 8 shows typical labour requirements for 3 Indian states and regions: Kogadu, Wayanad and Tamil Nadu (NB this excludes labour required for harvesting coffee). These are high requirements in comparison to other countries, but are less than other Indian estimates (e.g. Coffee Board, 2000). The ICO (1997) calculates that coffee production in India employs around 367,000 persons equaling 1.07 labourers per hectare. Labour costs show differences between producing states. Table 9 indicates the labour cost in four states of India.

Table 7 - Area and share of the production of coffee under different siz es of coffee holdings in India			
Size (ha)	Area under coffee		Share of production
	Area (ha)	% of total	
I. Small Holdings			
0-2	129,091	42.2	
2-4	29,978	9.8	
4-10	40,379	13.2	
Total	**199,448**	**65.2**	**60%**
II. Large Holdings			
10-20	26,613	8.7	
20-40	17,131	5.6	
40-60	11,624	3.8	
60-80	9,483	3.1	
800-100	7,036	2.3	
Above 100	34,567	11.3	
Total	**106,454**	**34.8**	**40%**
Total India	**305,902**	**100.0**	**100%**

Table 8 - Standard labour requirements/ha /yr		
Activity	Robusta	Arabica
Weeding	60	90
Manuring	45	45
Shade Regulation	10	20
Trenching	30	30
Shot hole borer	15	20
Dadap thug	10	0
Apply of Lime	10	15
Scuffling	50	50
Insecticide Spraying	5	5
Miscellaneous	40	40
Total	**275**	**315**

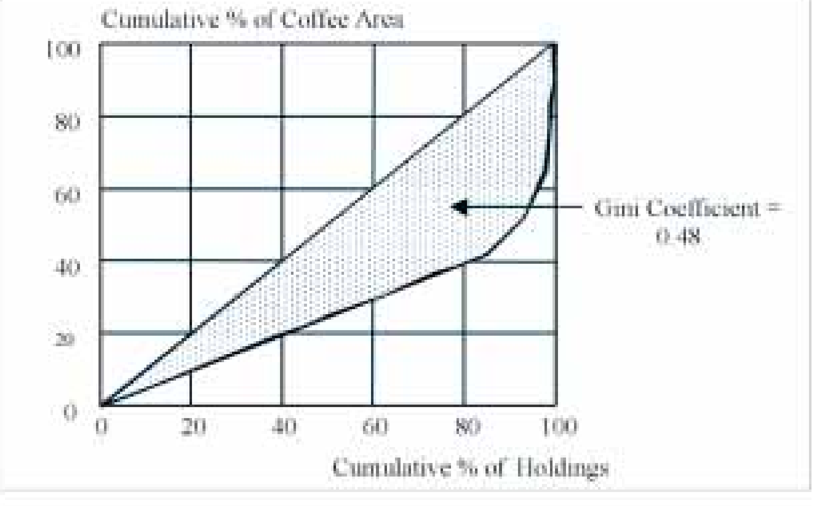


Figure 5. Land concentration in the coffee sector in India

Hence a contracted temporary worker could expect an annual income of around US$ 250 if he works all year. In comparison to many countries labour is therefore very cheap in India (e.g. compared with Colombia, where a labourer could earn the Indian yearly equivalent in about two months), and this is no doubt the reason why labour is a smaller proportion of the total production cost structure. IPM strategies often demand greater amounts of labour than another methods (e.g. chemicals), hence the low cost of the labour in this country could facilitate the adoption of an IPM strategy for managing CBB.

Coffee farmers' income is seasonal in India, which is a risky situation because there is just one peak of income per year. In order to minimise the effect of these seasonal variations, farmers can attempt to spread flows of labour and harvest production throughout the year. Upton (1996) points out that there are various strategies, such as diversification of agricultural production, to establish different on- and off-farm activities, storing food, seeds and animal fodder, etc. Seasonal income will have different effects depending on the period of the year when income is scarce because some activities have to be delayed to attend to a more important activity. The farmer has to manage different labour requirements and availability to optimise his gross income. In the case of CBB management, practices that can easily be accommodated by the farmer will be easier to transfer.

In order to diversify their income, Indian coffee farmers have developed production systems involving more than one crop in order to get income from different sources and in different periods of the year. In a survey carried out in the Project on coffee farmers in Karnataka it was found that 95.6% of them had pepper as an inter-crop. In many cases the inter-crop allows generation of an important part of the total farm income. For example, during Mr. Duque's visit to the Wayanad region, he met Mr. Vijayakumar who has a small farm of about 1 ha. He told him that his income depended on three sources - coffee, pepper and areca nut. The individual split of each appears in Figure 6 below.

Table 9 - Labour wages in different states of India (2000 prices)

State	Rs/day	US/day
Karnataka	56.25	1.25
Kerala	71.74	1.59
Tamil Nadu	46.50	1.03
Andhra Pradesh	61.70	1.37

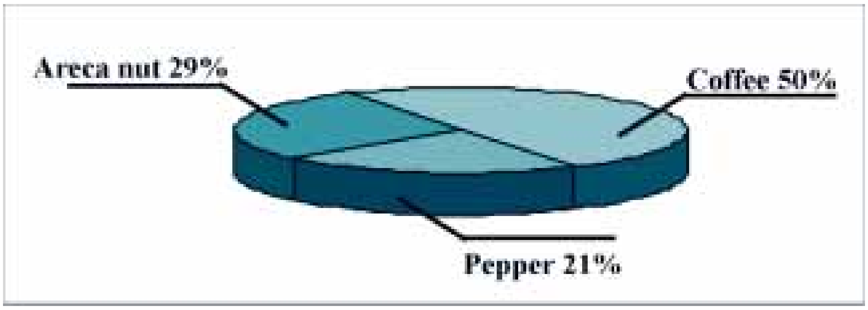


Figure 6. Income composition in a small farm, Wayanad district

It is therefore important to stress the contribution of other crops to the income composition of a normal coffee farm. It is quite possible that sometimes this alternative income becomes a relevant source to cover costs related to CBB management.

Coffee production costs

Coffee production costs in India for the year 2000-2001 was approximately Rs 15,952/acre, around US$ 340/acre. This figure is equivalent to US$ 850/ha/year. Table 10 shows the composition of the total production cost in terms of both fixed and variable costs.

From Table 10 it can be inferred that fixed costs are high, perhaps due to the irrigation equipment that was considered as a fixed cost. When the proportion of fixed costs is high it is more difficult to reach a break-even point. A break-even analysis can be useful to know how many kilograms of clean coffee are needed to cover all variable costs. Yield over the break-even point will cover fixed costs and the farm's profit. The formula proposed by Kay (1981) can be used for this purpose for robusta coffee, assuming a farm gate price of Rs 650/50 kg of cherry coffee (Coffee Board of India, 2001).

$$Break-even\ yield = \frac{Total\ Costs}{Output\ PRICE}$$

$$Break-even\ yield = \frac{Rs.15,952 / acre}{Rs.28.5 / Kg} = 559\ Kg / acre$$

If the average yield is 468 kg of clean coffee per acre (for 2000 – 2001), the average break-even point would not be reached by many Indian coffee farmers. This situation reflects the real world scenario of international coffee prices. The Figure 7 elaborates on this.

As can be seen in Figure 7 an 'average' coffee farm would not reach the break-even point, due mainly to high fixed costs and

Table 10. Composition of coffee production costs

Type of cost	Rupees	%
Fixed costs	5,539	34.7
Variable costs	10,413	65.3
Total costs	15,952	100

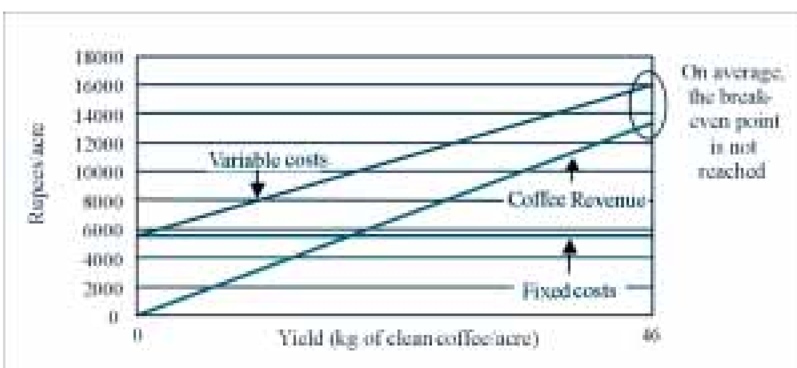


Figure 7. Break-even point for an average farm in the sample

low coffee prices. Assuming that all other variables analyzed remain constant, there would need to be an increase in coffee price of about Rs 35/kg to reach the break-even point. Thus CBB can play a key role in the economic performance of Indian coffee farms, because on the one hand high infestation levels will lead to higher CBB management costs, which would increase variable costs. But on the other hand, depending on the infestation level, CBB can reduce yield. If yield reduced so that the total revenue per acre was also reduced, the break-even point would be more difficult to reach.

Chapter 3

The CBB in India

Incidence and spread

The coffee berry borer was first reported from a large plantation in Gudalur, Nilgiri District, Tamil Nadu during February 1990. Damage to berries was first noticed in the curing works, where the coffee from this plantation was processed, and the cause was identified as insect damage. The matter was reported to the CBI's Research Department and the insect was identified as the coffee berry borer, *Hypothenemus hampei*. Immediate surveys in the surrounding areas revealed the presence of the borer in a few more plantations, and interim control measures were suggested based on the information available. Simultaneously, surveys and awareness campaign programmes were organized in the infested and surrounding areas. It is thought that Sri Lankan refugees who settled in the area might have brought berry borer infested coffee from Sri Lanka for domestic use, resulting in an accidental introduction of this pest.

On detection of the pest, the Coffee Board immediately initiated a series of steps to combat the new pest problem through its Research and Extension Departments. All the Extension and Research units were alerted and large-scale grower education programmes were launched in all the coffee zones. Intensive surveys were organised in the pest-affected areas and infested estates identified. The information on the possible techniques for combating the coffee berry borer was collected by literature survey and was passed onto coffee growers for immediate field application of suitable methods. Phytosanitary measures, such as a clean and timely harvest, proper gleaning collection, removal of left-over and off season berries and spot application of endosulfan were immediately advocated for the control of the pest. Simultaneously, experiments were initiated by the Research Department on the biology of the pest and the effectiveness of various methods for its management (see below for more details).

The Coffee Board, the Directorate of Plant Protection, Quarantine and Storage, Government of India, the Directorates of Horticulture, Govt. of Karnataka and Tamil Nadu, and the United Planters' Association of South India organized the first major survey of coffee berry borer during September 1990. A systematic sampling method was adopted to assess the infestation level in coffee estates as well as at coffee curing centers. In the field survey, 50 plants each from five locations in each estate were selected. Two branches from infested plants were selected for recording the number of infested berries and the percentage of plant and berry infestations were calculated.

At curing centres, composite samples were prepared by drawing one kilogram of sample from each bag, out of 10% of bags selected from 10% of the lots in storage. A working sample of one kilogram was further prepared out of four composite samples by dividing them into four equal parts. After screening the samples thoroughly for infested beans, the percentage of bean /cherry infestation was calculated.

This survey revealed that:

- Fourteen estates of 58 estates screened in 166 locations had CBB infestation - one in Sulthan Bathery, Wayanad, Kerala and 13 in Gudalur, Tamil Nadu. The range of plant infestation varied from 1% to 95% and berry infestation from 0.83% to 13.98%.

- The presence of CBB infested coffee was confirmed in two curing works, namely M/s. Kushalanagar Works, Kudige, and M/s. Karnataka Coffee Planters Coffee Curing Works (P) Ltd., Kushalnagar, on the basis of 1819 samples drawn from 76 lots from 50 go-downs in 6 curing centers. The range of infested beans varied between 0.22% and 1.26% of beans.

- The pest infestation had spread to more areas in Gudalur and shown its presence in Wayanad, Kerala. However, CBB had not entered into the plantations of Kodagu District, Karnataka.

Survey / campaign programmes were organized regularly in all the three districts (Nilgiris, Wayanad and Kodagu), and the infested areas identified for follow-up action. As the pest was spreading gradually to other areas, a second joint survey / awareness campaign was conducted in Nilgiris, Wayanad and Kodagu in association with the Directorate of Plant Protection, Quarantine and Storage during October 1991.

This survey revealed that as compared to 1990 the pest was widely spread in Gudalur and had entered into the adjacent Coonoor taluk of Nilgiris District. Fresh incidence of the pest was also recorded in 16 estates in Sulthan's Bathery and Vythiri taluks of Wayanad District. The presence of the pest was also confirmed in Kutta and Theralu villages of Virajpet taluk of Kodagu District. The berry borer incidence in Kodagu was earlier reported from Kutta during February 1991.

During 1992 pest build up was confined to areas identified in the previous years and fresh incidences were noticed to a limited extent. In another major survey conducted during September 1993, covering 1,328 estates in Kodagu region, the pest was observed in 16 villages of Siddapur and in one village each of Virajpet, Sunticoppa and Madikeri Liaison Zones. During the March 1994 survey, screening of 176 estates in Kodagu region confirmed the presence of the pest in two more villages of Siddapur and four more villages of Virajpet Zone. Further surveys were conducted during February 1995 in all the three Taluks of Kodagu district and the pest was recorded from four more villages of Gonicoppal, six in Virajpet, four in Siddapur, three in Madikeri and two in Sunticoppa Zones.

The coffee growing areas of Niligiri District of Tamil Nadu, Wayanad District of Kerala and Kodagu District of Karnataka together form a contiguous coffee growing tract. The CBB infestation in this region had spread from the Niligiris towards the North covering Wayanad and South Kodagu over a period of four to five years. The pest was first noticed outside this region in the Perumalmalai coffee zone of Pulney Hills ranges, Tamil Nadu, during September 1995. This region is quite far away from the Nilgiris-Wayanad region, and is separated by a large stretch of land not growing coffee.

Further spread of the CBB in Kodagu was noticed during June 1999, when it was recorded from three villages of Somwarpet zone in North Kodagu. The pest was also recorded in Hassan District for the first time in October 1999 from one village in Sakleshpur zone.

Though the pest was first recorded from Pulney Hills during 1995, the incidence was confined to one village of Pethuparai in Perumalmalai Zone till 1999. During the survey in October 1999, the pest was detected in 21 major coffee growing villages of the Pulney Hills. During December 1999, the pest was recorded from Adimali and Kattappana liaison zones in South Kerala, which are adjacent to the Pulney Hills.

During August 2000, the pest was recorded in Bodinayakanur, Tamil Nadu. By March 2001, the CBB had spread to an area of 118, 453 ha, accounting for 35% of the total coffee area of the country. The annual spread of the pest, and annual cumulative pest infested area, are graphically depicted in Figure 8.

The data show that the CBB spread during the first five to six years was rapid with an annual average increase of 35%. However, from 1996 onwards, the rate of spread declined to about 5.1%. The state-wise CBB infested area as of March 2001 is presented in Figure 9.

So far the coffee berry borer has not been noticed in Chikmagalur region, which is the major coffee growing district of Karnataka

State. The other major coffee growing areas still free from CBB incidence are Yercaud in Tamil Nadu, Biligiri Hills in Karnataka and Nelliampathy and Attappadi in Kerala.

An analysis of the nature and spread of the coffee berry borer incidence in the affected areas points to the fact that the build up and spread are faster in robusta areas when compared to arabica areas. The pest problem is acute in Wayanad and southern parts of Kodagu where robusta is predominantly cultivated. Inter-cropping dwarf varieties like Cauvery under robusta could aggravate the problem due to the availability of the right type of fruits for a longer time as Cauvery matures much earlier to robusta. Harvesting of arabica coffee is generally completed by December/January. The growers bestow more care on a timely harvest of arabica as most arabica coffee is prepared as washed coffee. On the other hand, robusta takes more time for ripening and so harvesting generally extends up to February/March. Since robusta coffee is processed by drying the fruits to prepare cherry coffee, there is a general tendency to prolong the harvesting due to various reasons, especially if there is a labour shortage. This offers the berry borer a better chance to multiply faster as the berries at this stage are best suited for their multiplication. If berries are left on the plants after ripening, the number of berries falling during harvest would be more. This leads to increased residual populations of the pest in the fallen

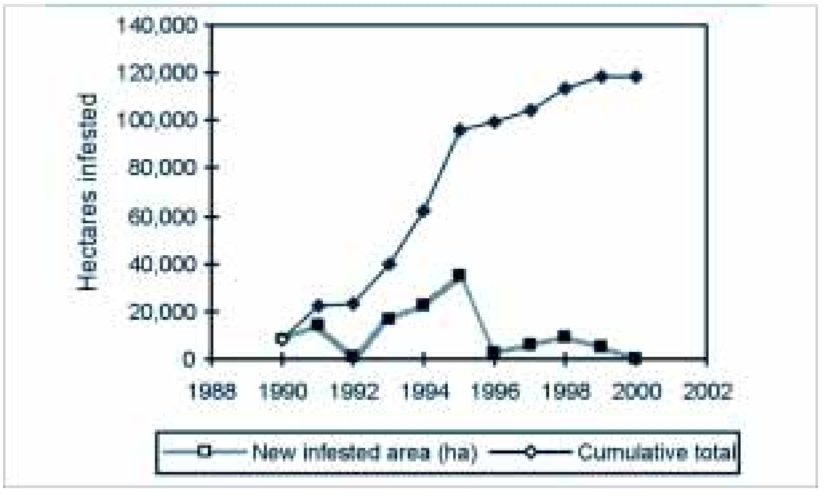


Figure 8. Spread of coffee berry borer in India

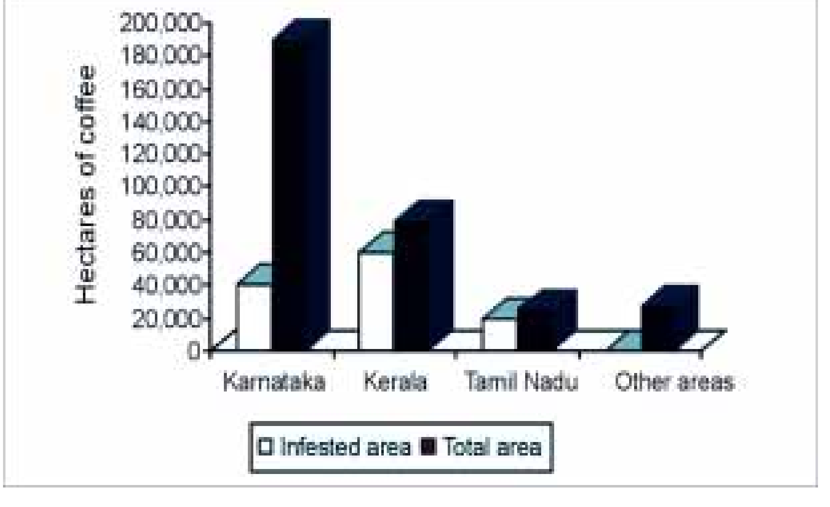


Figure 9. State-wise spread of CBB as of March 2001

berries (gleanings). Furthermore, berries left over on tall branches of big robusta bushes can also provide a refuge for the CBB.

The incidence level of CBB on Pulney Hills was found to be higher than in other areas. This is mainly due to the multiple blossom (i.e. running blossom) experienced in this region, which results in the availability of fruits almost throughout the year. This facilitates a continuous build up of the pest, and adoption of either cultural or phytosanitary control measures becomes impracticable.

Coffee phenology and CBB attack

It is important to consider how coffee phenology relates to CBB abundance in India. As in all coffee countries, rainfall pattern is a critical factor because of the way in which precipitation triggers flowering and hence the berries upon which CBB depends. In Figure 10 we can see that the rainfall pattern consists of four main phases: winter, pre-monsoon, monsoon and post-monsoon. Secondly, the main stages of

CBB entering coffee berry

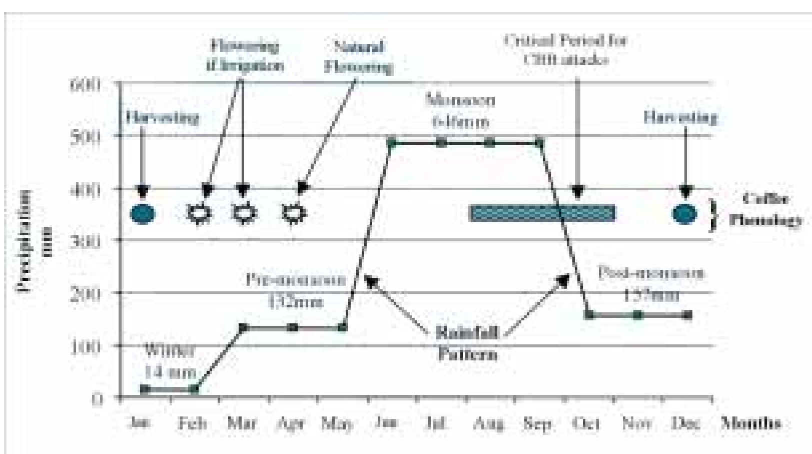


Figure 10. Rainfall pattern, coffee phenology and CBB attack

the coffee fruiting phenology is depicted, and finally the horizontal bar represents the most critical period for CBB management.

Flowering can occur in February or March if a farmer has irrigation facilities; if not, then they have to wait until April when natural flowering will follow the start of the rains. Because of this, the coffee harvest occurs in either December or January. A further variable is the variety - for robusta the flower-to-ripe-bean cycle is about 40 weeks, whilst for arabica it is less.

Finally in Figure 10 the most critical period for CBB attacks is depicted as the period between August and October, so labour and other inputs (e.g. spraying of insecticides) are particularly required at this time.

Chapter 4

Technology transfer and research

Overview of previous work in India

During monitoring surveys and visits to CBB affected estates, interactions with growers on management issues highlighted the following key factors:

- Robusta coffee, grown without proper pruning, poses problems in the adoption of phytosanitary measures and effective spraying operations

- Sprinkler irrigation, given to robusta relatively early, leads to faster growth of berries which results in the early establishment of berry borer when compared to fruits formed due to blossom naturally watered

- Arabica coffee, cv. Cauvery (catimor) interlined in robusta plantations facilitates early establishment of the borer in Cauvery, with subsequent migration to robusta

- No effective control measures are available once the borer is established within coffee berries

- There are limitations in the use of biopesticides and parasitoids

- Off-season crop provides a medium for the continuous breeding of the pest

- Constraints in timely harvest of crop due to shortage of labour

- Primitive and inadequate drying yard facilities, especially in the small grower sector, results in prolonged and improper drying of coffee and delayed harvest

- Transporting of infested coffee from place to place for processing and marketing, which facilitates spread of the pest to new areas

Thus, to address some of the management technology issues, the Coffee Board started a research programme in the early 1990s to evolve components for a management strategy based on integrated pest management (IPM) principles. The on-farm validation of these technologies is discussed later in this report.

Various projects were implemented to achieve this objective. In particular, studies were focussed on phytosanitary measures, need-based and judicious applications of pesticides, and biological control utilizing native fungal pathogens:

- Studies on phytosanitary and other cultural control methods showed the importance of these measures and also resulted in the development of some simple and effective techniques, e.g. the use of picking mats, - this work is summarized in Appendix 4

- A number of pesticides were screened by the Coffee Board but the only effective one proved to be endosulphan; this has been widely adopted by farmers although it is now being phased out by the Government of India due to environmental concerns

- Fungal pathogen work has largely focussed on *Beauvaria bassiana.* Laboratory and field studies indicated the potential of *B. bassiana* as a biopesticide against CBB when fresh cultures were applied at the appropriate period. High volume application was found to give better results than low volume sprays. Low percentage of infectivity was observed in some experiments and seemed to be due to unfavourable weather conditions or due to loss of infectivity of the culture. Whenever a 1 to 1½ month-old culture was used during favourable environmental conditions, the results were better. This revealed that purity of material and timing of the application are the two critical factors in obtaining better results. Unfortunately all the commercial formulations tested were of poor quality, without causing any appreciable infectivity. The major bottleneck in the large-scale use of *B. bassiana* is the constraint of making available large quantities of fresh material at the appropriate time (Coffee Board of India, 2001).

Research of the present Project

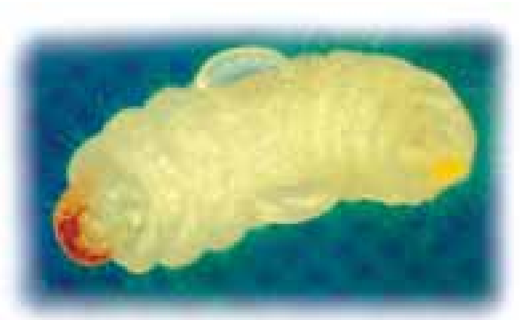
During the CFC/ICO/02 Project, research has focussed on the development of biological control with insect parasitoids (particularly on the rearing, release and evaluation of species received earlier), and on the mass-trapping of CBB adults.

Research on insect parasitoids

In India, no indigenous parasitoids were recorded during extensive surveys conducted in all CBB infested areas, indicating that the CBB was introduced without any complement of parasitoids. As parasitoids are being used for the biocontrol of CBB in various countries, introduction of promising parasitoids was attempted.

Importation and quarantining of parasitoids

Two bethylid parasitoids, *Cephalonomia stephanoderis* and *Prorops nasuta* were imported from Mexico in 1995. The first consignment from Ecosur, Tapachula, Chiapas, Mexico was received on 5th September 1995. This consignment consisted of 510 *C. stephanoderis* and 140 *P. nasuta*. Twenty-four (4.7%) of the former and 18 (12.86%) of the latter perished in transit. The live parasitoids were quarantined and multiplied at the Project Directorate of Biological Control (Indian Council of Agricultural Research), Bangalore. Two more consignments of parasitoids were later received from Mexico. The culture of *C. stephanoderis* established well in the laboratory, whereas *P. nasuta* failed to survive.



Cephalonomia stephanoderis eggs laid on CBB prepupa

Further, under the CFC/ICO/02 project, cultures of *Phymastichus coffea* and *P. nasuta* in CBB infested parchment were air freighted from Cenicafé, Colombia. The first consignment consisted of *P. nasuta* and *P. coffea* arrived Bangalore on 26th October 1999. As the first consignment of *P.coffea* did not establish, three more consignments were later sent.

Rearing, field release and evaluation of parasitoids

The rearing of *C. stephanoderis* and *P. nasuta* imported from Mexico was initiated at Coffee Research Sub Station, Chettalli, in January 1996.

As *C. stephanoderis* and *P. nasuta* have similar breeding habits, the rearing technique is common to both. Initially the parasitoids were multiplied by using naturally infested coffee fruits following the Mexican methodology. Infested berries collected from the field were spread on white paper, air dried for a few days and fruits with dark powder coming out from the hole, which is indication of all CBB life stages, were selected for parasitoid rearing. Mexican scientists had found greenish yellow, yellow and yellowish red fruits ideal, but red, green, and black unsuitable. However, over ripe, semi-dry robusta fruits also were found most suitable for parasitoid breeding under Indian conditions.

When naturally infested fruits with immature stages of CBB were not available, the Colombian method of using artificially infested parchment was employed. Fresh parchment was demucilaged by natural fermentation and treated with carbendazim at 3 g per litre of water. The parchment was spread in trays, air-dried in a room for a day, and the moisture level brought to 40-45%. Naked, broken, discoloured and diseased beans were removed and only healthy beans selected for CBB rearing. The selected good parchment was spread in metal or plastic trays of convenient size with ventilation. Beetles collected from the breeding stock of naturally infested fruits were then released in the trays at the rate of 2 per bean.

The trays were maintained at 25˚C and 80% relative humidity and examined on the 8th, 12th and 18th days after beetle release. Beans contaminated with fungi such as *Aspergillus* and *Beauveria* were discarded, and the frass removed by sieving. After 20-25 days, the infested beans had developed sufficient borer stages - eggs, larvae, prepupae and pupae - needed for parasitoid breeding. Only seeds with 2 or more holes were selected. The moisture level was around 30% at this stage. About 150 or 300 infested beans measured by volume were placed in plastic boxes of convenient size and the parasitoid released at the rate of 1 per 3 beans. If naturally infested fruits were used, parasitoids were released at the rate of 1 per 3 to 5 fruits, depending on the number of CBB stages. The containers were covered with lids having muslin cloth ventilation and maintained at 25˚C and 80% relative humidity.

Parasitoids started emerging 20 to 30 days after release. An emergence cage (a wooden box with blackened sides with transparent plastic jars fixed downwards) was used to collect the wasps. When the parasitoids were ready to emerge, the containers were placed in the emergence box. Tungsten filament lamps (60W) were provided near the jars to attract the wasps.

The wasps from the collection jars were removed using an aspirator and transferred into small plastic containers. The containers were covered with pieces of muslin cloth and closed with lids having circular holes in the centre. A few drops of half diluted honey were provided on the cloth. The containers were then taken to the field and wasps released on infested bushes by gently tapping the containers. When the wasps emerged in large numbers, they were quantified by volumetric measuring, each milliliter containing around 2000 individuals.

If released on the main crop, berries with the parasitoids were harvested in a short time and processed, before the wasps could establish themselves in the field. Hence, releases were made mostly on robusta plantations having left-over fruits during the post-harvest period.

For evaluation, infested berries from the release sites were examined at regular intervals and the percentage parasitism, as indicated by the presence of parasitoid stages, calculated.

Early releases and evaluation

The first test field releases of *C. stephanoderis* and *P. nasuta* were effected in January 1996 in Ballykilty estate, Cannoncadoo, North Kodagu. The parasitoids were confined using cloth sleeve cages on infested coffee branches. On day 35, the

Confined release of *Cephalonomia stephanoderis* coffee fruits were stripped off and maintained in the laboratory for adult emergence (Table 11).

A second test-caged release was done in February 1996 with *C. stephanoderis* on Achyutha estate, Maldare, South Kodagu and *P. nasuta* on M.K. Kalaiah's estate, Byrambada, South Kodagu (Table 12). The results indicated that the recovery of both *C. stephanoderis* and *P. nasuta* were poor in the first confined release made on Ballykilty estate during June. The recovery from second release during Febraury was more promising.

Furthermore, *P. nasuta* was released in small quantities in two sites on Pulney Hills, Tamil Nadu, but was only recovered from the site, with no further recovery made in subsequent observations.

Though *P. nasuta* could be recovered in small numbers from the confined release initially, it could not be found later. It did not survive in the laboratory culture, in spite of obtaining one consignment from Mexico and three from Colombia. Hence, more attention was given to the mass multiplication of *C. stephanoderis* and introduction of *P. coffea* from 1998 onwards.

Mass rearing and field release of *Cephalonomia stephanoderis*

Under Indian conditions, over-ripe fruits were found more suitable than artificially infested parchment for rearing the parasitoid. Progeny production of the wasp was 5.75 (1.60 to 10.50) in naturally infested fruits and 3.20 (1.30 to 7.50) in artificially infested parchment.

A total of 2,430,536 wasps were produced at CRSS, Chettalli and RCRS, Chundale during the period from January 1998 to September 2001. A total of 1,157,790 wasps were released into the field, during the post-harvest period, on 14 farms. The details of the field releases are presented in Table 13. The establishment of the parasitoid was studied by examination of left over black berries and in certain cases the ripe/green berries collected from release sites. About 100 fruits collected at random from each release site were examined in the laboratory for the presence of various stages of the parasitoid and the percentage parasitism calculated. A few non-release sites were also surveyed to study the spread of the parasitoid. The details of the evaluation tests are presented in Table 14.

Table 11 – Recovery of *C. stephanoderis* from confined release

Site of release	Date of release	No. of parasitoids	
		Released	Recovered
Ballykilty estate, Cannoncadoo, Kodagu.	11.1.96	77	22
Achyutha estate, Maldare, Kodagu	2.2.96	41	200

Table 12 – Recovery of *P. nasuta* from confined release

Site of release	Date of release	No. of parasitoids	
		Released	Recovered
Ballykilty estate, Cannoncadoo, Kodagu.	11.1.96	20	18
M.K.Kalaiah's estate, Byrambada, Kodagu	2.2.96	33	123

Table 13 - Details of field releases of *C. stephanoderis*		
Zone	**No. of farms where releases were made**	**No. of wasps released**
Suntikoppa	47	535,200
Siddapur	37	285,080
Virajpet	10	34,000
Balele	10	80,720
Srimangala	05	67,440
Napoklu	05	20,500
Madikeri	05	28,950
Somwarpet	04	23,000
Pannaikadu	01	2,000
Perumparai	05	18,600
Perumalmalai	03	12,500
Panamaram	01	2,000
S. Bathery	01	6,800
Kalpetta	04	32,500
Chundale	04	6,500
Coonoor	02	2,000
Total	**144**	**1,157,790**

Zone	**No. of farms released**	**No. of farms surveyed for parasitism**	**Release sites with *C. stephanoderis***			**No. of Non release sites surveyd**	**Non-release sites with *C. stephanoderis***		
			No. of farms	**% parasitism**			**No. of farms**	**% parasitism**	
				Range	**Mean**			**Range**	**Mean**
Suntikoppa	47	22	7	1 - 51	30	19	7	4 - 32	20
Siddapur	37	8	6	4 - 48	18	3	2	54-77	65.5
Virajpet	10	4	1	-	55	-	-	-	-
Balele	10	0	-	-	-	-	-	-	-
Srimangala	5	1	-	-	-	-	-	-	-
Napoklu	5	0	-	-	-	-	-	-	-
Madikeri	5	1	1	-	16	-	-	-	-
Somwa rpet	4	4	1	-	15	-	-	-	-
Pannaikadu #	1	1	1	-	-	-	-	-	-
Perumparai	5	1	1	-	5	-	-	-	-
Perumalmalai	3	1	0	-	0	-	-	-	-
Panamaram	1	0	-	-	-	-	-	-	-
Kalpetta **	4	4	1	-	-	-	-	-	-
Chundale **	4	4	1	-	-	-	-	-	-
Coonoor	2	-	-	-	-	-	-	-	-
Bathery **	1	1	1	-	0	-	-	-	-
Total	**144**	**52**	**21**	**20% mean**		**22**	**9**	**30% mean**	

From the observations so far made on the mass-rearing and establishment of the parasitoid, the following points emerged:

- Naturally infested fruits were ideal for rearing *C. stephanoderis* under Indian conditions
- There was no consistency in the establishment of the parasitoid on release sites
- Spread of the parasitoid to non-release sites with better establishment than in release sites was recorded

Survival of the parasitoid was observed in 21 out of 52 release sites surveyed. Parasitism was observed in red and black berries while that in green berries was rare. Nine out of 22 non-release sites also revealed parasitoid activity. In one case, the parasitism in leftovers in the release site was just 9%, whereas in two neighbouring farms (non-release sites) 54% and 77% of leftover fruits were parasitised. Carry-over of the parasitoid from one season to the other was observed in 5 cases.

Phymastichus coffea

The first consignment of *P. coffea* was received in October 1999, and the second in Febraury 2000. The parasitoid was reared using the method followed in Colombia. Unfortunately, both the cultures failed to survive beyond the 6th generation. A preliminary field trial with *P. coffea* on caged branches revealed parasitism between 4% and 7.3%, with a mean of 4.7%.

Three more consignments of the parasitoid were received from Cenicafé during June, July and September 2001. Progeny emerging from all the batches have established in the laboratory culture, and a total of 6,905 females have been released on four farms in Kodagu.

CBB beetle parasitised by *P. coffea*, showing characteristic hanging head

Mass-trapping studies

These studies were conducted in Wayanad, Kerala, and in Pulney Hills, Tamil Nadu. Here we report the work from Wayanad, as the other studies mostly confirmed the results of these.

Evaluation of traps and lures

As mass trapping is reported to be a new technique in the management of CBB, stud-

Multiple bottle top trap

ies were initiated to evaluate the effectiveness of various types of traps and lures. In Wayanad, a preliminary study was conducted in January and February 2000 in which the following four types of traps were tested. Each type of trap was baited with both ethanol-methanol and coffee fruit extract lures, and each treatment had 2 traps. All the treatments were placed both in non-harvested and harvested fields to find out differences, if any, in the pattern of attraction. The traps were hung randomly on the coffee bushes at a distance of 80 feet apart, at about 5-6 feet off the ground. The trap designs were as follows:

- *Multiple funnel traps made of plastic bottle tops*: The top portion of mineral water or soft drink bottles was removed and four such pieces in inverted position, resembling funnels, were arranged one over the other without touching using thin galvanised iron wire. The multiple funnel structure was provided with a hood made of plastic plate on top for protection against rain and dry leaves falling into the trap. A small plastic bottle with water (receptor) was fitted to the neck of the bottom funnel to collect the beetles. The receptor was provided with a few holes at about 3/4 of its height to allow rainwater to flow out. The lure dispensing bottle with a pinhole on its cap was kept hanging in the second funnel

- *Single funnel trap with receptor:* A single common funnel was fitted with the receptor and the hood as in the previous case. The bottle containing lure was hung from the hood

- *Single funnel without receptor:* In this case, a single funnel was provided

Table 15 - Field trapping of CBB during January - February 2000

Type of trap	Lure	Mean number of CBB beetles caught per trap			
		Harvested field		Non - harvested field	
		For 1 day	For 19 days	For 1 day	For 19 days
Multi-funnel trap (made from bottle tops)	Ethanol-Methanol	668	21063	72	12750
	Coffee fruit extract	173	12	2	257
Plastic can trap	Ethanol-Methanol	494	1609	1921	1338
	Coffee fruit extract	270	263	4	21
Single funnel trap with reservoir	Ethanol-Methanol	-	1417	11	478
	Coffee fruit extract	-	5111	-	10
Single funnel trap coated with "Trappit" insect glue	Ethanol-Methanol	-	133	-	135
	Coffee fruit extract	-	Nil	-	Nil

Table 16 - Field trapping of CBB during February - March 2000		
Type of trap	**Lure**	**Mean no. of CBB beetles caught per trap for 7 days in harvested field**
Multi-funnel trap (made from bottle tops)	Ethanol-Methanol	11663
Plastic can trap	Ethanol-Methanol	670
Single funnel trap with reservoir	Ethanol-Methanol	629
Single funnel trap (coated with "Trappit" glue)	Ethanol-Methanol	31

with a hood. The inside of the funnel was coated with "Trappit" insect glue (polybutene), replacing the receptor with water of the single funnel trap. The lure-dispenser bottle was hung from the hood

■ *Plastic can trap*: A plastic can (liquid container) of 2 litre capacity was provided with windows at the centre of its four sides and the bottom was filled with water, the trapping media. The lure-dispenser bottle was hung inside the container

Data obtained in the preliminary study are presented in Tables 15 and 16.

Data obtained in the preliminary trials showed that a 1:1 mixture of ethanol and methanol is effective in luring CBB beetles. The fruit extract in ethanol also lured the beetle, but to a smaller extent compared to the ethanol-methanol mixture. The multiple funnel trap made of plastic bottle top was the most effective trap among those evaluated. Furthermore, more beetles were trapped in harvested fields than in non-harvested fields.

Further evaluation of trap designs

The following models of traps baited with 1:1 mixture of ethanol and methanol were also tested along with the previously tested multiple funnel traps made of plastic bottle tops and single funnel traps with receptor. The treatments were replicated five times.

■ *Traps made of multiple funnel:* Four common funnels were arranged one over the other using thin galvanised iron wire, provided with a receptor fitting and hood as an alternative to

'Multiple funnel trap'

'Bottle trap'

Table 17 - Evaluation of trap design (June - July 2000)	
Type of trap	Mean no. of CBB trapped per trap
Single funnel trap	35
Multi-funnel trap	163
Multi-funnel trap made of bottle tops	435
Trap made of single plastic bottle ('Brocatrap')	350
F test	**
CD at 5%	211.3
CD at 1%	291.1

the multiple funnel traps made of plastic bottle tops. The lure-dispenser bottle was hung from the hood.

- *Bottle trap (the "Brocatrap"):* Plastic mineral water or soft drinks bottles were used in this case. Windows of about 1.5 to 2.0 inches width were cut on opposite sides, leaving only two small strips to keep the top and bottom together. A receptor with drain holes was fitted to the neck of the bottle and a third of it filled with water. The lure dispenser was placed inside the bottle. In another modification, the bottle cap replaced the receptor and the trapping media was held in the main body of the trap itself. The data obtained is presented in Table 17

As in the preliminary trial, the multiple funnel traps made of plastic bottle tops were found superior to all the other trap models. The new model Brocatrap was close in effectiveness to the multiple funnel traps made of plastic bottle tops. Being simple and easy to fabricate, the Brocatrap was very cheap costing around Rs 5 to 7 compared to Rs 14 to 20 for multiple funnel trap made of plastic bottle tops (depending on the quality the bottle).

The studies on the trap designs were continued with modifications incorporated in the Brocatrap to make it comparable in effectiveness with the multiple funnel traps made of plastic bottle tops. These studies indicated that a modified Brocatrap with 6 vertical windows of 3-inch size was superior to the standard Brocatrap and other designs, but not as effective as the multiple funnel traps made of tapering plastic bottle tops.

Evaluation of lures

A study was conducted on the lures using the Brocatrap. The chemical combinations evaluated in the Brocatrap were:

- Ethanol + Methanol
- Ethanol + Methanol + Methylene Blue
- Isopropanol + Methanol
- Diethyl Ether + Methanol
- Ethyl Acetate + Methanol
- Carbon Tetrachloride + Methanol
- Coffee Fruit Extract in Ethanol - Methanol mixture
- Coffee Fruit Extract in Ethanol
- Coffee Fruit Extract in Methanol
- Coffee Fruit Extract in Diethyl ether
- Coffee Fruit Extract in Isopropanol
- Coffee Fruit Extract in Ethyl Acetate
- Coffee Fruit Extract in Carbon Tetrachloride

The data is presented in Table 18. This study indicated that coffee fruit extract in 1:1 combination of ethanol and methanol, followed by coffee fruit extract in methanol, were superior to the standard 1:1 combination of ethanol and methanol.

Evaluation of trap heights

To find out the optimum height for trap placement, multiple funnel traps were tested at 3, 5 and 7 feet above the ground. Each treatment was replicated five times with a single trap per replication.

The results indicated no significant difference in catch at different heights. There was a slightly higher catch, though not statistically significant, at 5 feet height, so further placement of traps were made at this height.

Evaluation of trap colour

To study the preference of colour in combination with the lure, Brocatraps were painted orange, red, green, yellow, white, as well as a transparent version. All versions were evaluated with five replications per treatment and 5 traps per replication. The results showed that a significantly higher catch was obtained in the transparent Brocatrap.

Trap spacing

To study the spacing or trap density per unit area, multiple funnel traps at distances of 20 feet (109 traps/acre), 40 feet (27 traps/acre), 80 feet (7 traps/acre) and 120 feet (4

Table 18 - Evaluation of lure

Treatments	Average catch/trap
Ethanol + Methanol	603
Ethanol + Methanol + Methylene Blue	492
Isopropanol + Methanol	83
Ether + Methanol	377
Ethyl Acetate + Methanol	348
Carbon Tetrachloride + Methanol	599
Fruit Extract in 1:1 Ethanol - Methanol mixture	1084
Fruit Extract in Ethanol	41
Fruit Extract in Methanol	759
Fruit Extract in Diethyl Ether	4
Fruit Extract in Isopropanol	16
Fruit Extract in Ethyl Acetate	41
Fruit Extract in Carbon Tetrachloride	2
CD at 5%	401
CD at 1%	536

Table 19 - Evaluation of trap spacing

Trap distance	Residual population (estimated no. of beetles in an acre)	Catch/acre June-July, 2000	% catch Catch/acre	July-Sept. 2000
20 feet (109 traps/acre)	1,425,618	9906	0.70	1038
40 feet (27 traps/acre)	1,260,688	2284	0.20	259
80 feet (7 traps/acre)	1,395,636	651	0.05	116
120 feet (4 traps/acre)	1,496,387	637	0.04	45
F test		**		**
CD at 5%		4676.6		295.4

trap/acre) were evaluated in a randomised block design. Each treatment was replicated five times. The study commenced in June, the time when the residual population of CBB in the gleaning / leftover fruits migrate to the new crop.

Before imposing the treatments, the total residual fruits and total population of the borer were estimated by sampling the fruits left on the plant and on the ground. Number of infested fruits left on the plant was estimated by sampling all the fruits in 10 randomly selected plants and the number of fruits on the ground was estimated by sampling 10 sites at random in an acre using quadrats of 1 square foot size. The number of CBB beetles trapped was recorded after a month, in July, and then again in September. The weather parameters during the study were recorded. The data is presented in Table 19.

The data indicated that more beetles are trapped when the traps were set up at closer spacing. However, the percentage of beetles trapped was very low compared to the estimated CBB population in the field and hence the real impact of trapping on beetle population needs further investigation. Some progress was made in the following study.

Evaluation of trap density and effect on CBB incidence

The trial was conducted by installing the traps in coffee field after harvest at 10, 20, 40, 80 and 120 feet spacing corresponding to trap densities of 435, 109, 27, 7 & 4 respectively per acre. The post-harvest catch of CBB per acre and the fresh incidence of CBB in the new crop were recorded, as shown in Table 20.

The data revealed that catch per acre was significantly higher with close spacing or higher trap density, which is in conformity with the result of the previous experiment. The higher trap density reduced the infestation considerably by around 67% to 73% in the new crop as compared to the control. But, considering economic factors, a trap density of 27 per acre seems to be optimal. From the studies on mass trapping conducted so far the following inferences could be drawn for further investigation:

- The coffee fruit extract in 1:1 combination of ethanol and methanol, followed by coffee fruit extract in methanol, were superior to the standard 1:1 combination of ethanol and methanol

Table 20 - Evaluation of trap distance (density per acre)

Trap Spacing (Density/acre)	Catch/Acre (Mar-June)	% CBB infestation in new crop	% Reduction in infestation over control
10 Feet (450)	17,688	1.6	73.5
20 Feet (109)	12,996	1.9	69.3
40 Feet (27)	3,834	2.0	67.3
80 Feet (7)	609	4.8	21.0
120 Feet (4)	560	5.0	18.2
Control	-	6.1	
CD at 5%	8222.4	3.3	
CD at 1%	11,214.2	4.4	

- The multiple funnel trap made of plastic bottle tops is the most effective trap, followed by the modified Brocatrap with 6 vertical windows each of 3-inch size. Considering its simplicity, economy and its effectiveness, the modified Brocatrap with 6 vertical windows is preferable for field applications

- Higher trap density reduced the infestation considerably by around 67% to 73% in the developing new crop compared to the control. However, a trap density of 27 per acre seems to be optimal

Additional studies indicated that commonly available alcoholic beverages could be used in place of ethyl alcohol in the lure.

Chapter 5

Testing, validation and integration of components

Despite some differences in CBB management between arabica and robusta the following calendar of operations represents, ideally, the most important practices in CBB management in robusta coffee. Table 21 describes these monthly operations. As may be concluded from Table 21, there are some key months in CBB management, such as those from the beginning of the year, and those from August to December.

By the start of the CFC/ICO/02 CBB project a number of cultural control and other management interventions were being promoted by the CBI in line with the above calendar; these were based on the earlier research conducted on the CBB (e.g. see Appendix 4). In order to test more fully the impact of the suggested interventions, particularly their integration, on-farm studies of IPM were set up during the Project across the whole coffee-growing region affected by the CBB.

A total of 52 such plots of approximately one hectare each were established in different agro-climatic zones. Small, medium and large-scale growers were all included in the study. The farmers or farm managers were fully engaged in the study in an attempt to make the study as participatory as possible.

A systematic sampling technique was adopted to assess the incidence levels in the on-farm plots by taking periodical counts and recording the data regularly. A sample size of 10 plants in the case of robusta and 20 plants for arabica plants was fixed for assessing the incidence level. The total number of berries and the number of infested berries on five randomly selected branches on the selected plants were recorded before suggesting the measures or interventions required to keep the pest under control. The following were the major activities suggested for the IPM plots depending on the conditions prevailing in each plot:

- Timely harvest
- Thorough and clean harvest
- Collection of gleaning
- Removal of infested berries
- Removal of off-season and left over berries
- Use of picking mats
- Drying coffee to the standard test weight
- Early disposal of the coffee produced
- Maintenance of trap plants around drying yard
- Spot spraying of endosulfan wherever absolutely necessary, as a last resort

The data on the borer incidence was collected at regular intervals and necessary measures were suggested accordingly. Until March 2000 the data collection was done bi-monthly and since April 2000 on monthly basis. The monthly percentage incidence levels for each plot was worked out and average levels of incidence of all IPM plots for three different regions are presented in Table 22.

The average incidence-level from August to December 2000 varied from 0.6% to 1.1% in IPM plots of Kodagu region, 1.0% to 1.8% in Wayanad region and 5.9% to 7.4% in Pulneys region. The level of incidence came down to less than 0.5% from December onwards in both Kodagu and Wayanad regions, but

Picking mat used whilst harvesting

it continued to be as high as 5% in Pulneys. The level of inoculum in leftover berries was significantly low and stood at 0.1% to 0.35% during June and July 2000 in Kodagu region, at around 0.5% in Wayanad and at 5.5% in Pulneys. The weighted average of the incidence level (worked out from June to February), indicated the monthly rate of incidence at 0.6% in Kodagu, 1.0% in Wayanad and 7.7% (excluding June/July incidence) in Pulneys.

The data revealed that the CBB incidence could be kept at low levels in Wayanad and Kodagu by adopting IPM measures, particularly cultural and phyto-sanitary measures.

The incidence level on Pulney Hills was comparatively higher, mainly due to the prevalence of more favourable conditions, especially multiple blossoms which allows the borer to have uninterrupted generations.

Table 21 - Calendar of operations in CBB management – robusta coffee

Month	Main CBB Operations
January	Start harvest from infested blocks / Leave few plants unharvested Dry the coffee to the standard weight
February	Complete crop harvest / Treat the floats in boiling water / Dry the coffee as indicated
March	Similar operations as February / Harvest remaining crop near the drying yard / Collect gleanings and leftover berries and subject these to boiling water before drying
April	Continue collection of leftover fruits and gleanings, boil and bury them
May	Monitor the pest / Spray insecticide if needed / Remove all of the off -season fruits or monsoon coffee / Give them the boiling water treatment
June	Monitor the pest closely / Remove off season coffee / Spray insecticide if needed
July & August	Monitor the pest closely / Spray insecticide only if absolutely needed
September	Programme insecticide spraying depending on the level of infestation
October	Monitor the pest closely as also the development of the berries / Spray insecticide if required and not done before
November	Monitor the pest closely, identifying hot spots in the estate / Deploy biological control if needed
December	Monitor the pest closely identifying hot spots in the estate / Deploy biological control if needed

Table 22 - Monthly averages of CBB incidence levels recorded in on-farm IPM plots of Kodagu, Wayanad and Pulneys during 2000/2001

Month	Average incidence level (% CBB infested fruits)		
	Kodagu	Wayanad	Pulneys
June 2000	0.2	0.6	12.2
July 2000	0.3	0.7	14.2
August 2000	0.6	1.0	5.9
September 2000	0.6	1.4	6.7
October 2000	0.9	0.6	6.3
November 2000	1.0	1.3	6.1
December 2000	1.1	1.8	7.4
January 2001	0.6	0.4	5.5
February 2001	0.3	Not recorded	5.0
Weighted average from June to Feb	0.6	1.0	7.7

Chapter 6

The economics of CBB

Losses due to CBB

In a study conducted by the Central Coffee Research Station (2001), an estimation of crop loss due to CBB was carried out. Crop loss was estimated at different levels of infestation from 0% to 100%. The study included loss in weight, but not in quality, although it is known that CBB affects quality as well. Unfortunately, up to now, the internal coffee market in India does not have a clear standard of rules for both so as to punish or to reward coffee depending on quality. However, the study is required from the point of view of yield loss. The data collected are: the loss in forlits and in percentage of clean coffee is shown in Table 23.

From this information a loss function has been estimated, where the independent variable is the percentage of infestation caused by CBB, and the dependent variable the loss in percentage of clean coffee.

The model of loss obtained was of a quadratic type, (Probability > F = 0.0001) and has a very high coefficient of determination (R-square = 0.9944; Adjusted R-square = 0.9916). So the model can forecast up to 99% of the variations in percentage of weight lost due to different infestation levels of CBB. The main features of the model appear in Table 24.

The model can be expressed mathematically as follows:

$$Y = 0.076 + 0.149\, INF + 0.002\, INF^2$$

Where:

INF = Percentage of infestation

The following graph (Figure 11) shows the model. This function represents an increasing return function, which means in this case that every successive increase in the infestation level results in higher additional loss.

From the farmers point of view this kind of function is quite dangerous because the losses will increase more than proportionally for a certain level of pest attack. So they should adopt the techniques and components needed to ensure infestation levels

Table 23 - Loss due to CBB according to different levels of infestation (1 forlit = 16.5kg)

% of infestation	Loss in forlits per 1000 kg of clean coffee	Loss in percentage of clean coffee
0	0.0	0.0
10	2.8	2.7
30	5.2	5.1
50	12.8	12.6
70	23.8	23.4
90	31.6	31.3
100	37.9	37.2

Table 24 - Characteristics of the model

Variable	Parameter	P value
Intercept	0.0756	0.9480
Infestation	0.1490	0.0545
Infestation	0.0025	0.0137

that can be managed easily and to avoid sudden high pest levels.

With reference to the model, a simulation of crop loss was carried out assuming an average yield of 468 kg of clean coffee per acre (see the section on coffee production above) and a coffee price of Rs 28.5 per kg of clean coffee. The simulation involved infestation levels between 0% and 100%, and the percentage of loss was calculated (Table 25).

From Table 25 it is clear that when infestation levels are low, expected losses are also low. So farmers should carry out those control measures needed to keep the pest at this level or below. However, at this point, it is quite possible that the willingness to invest in pest control is more related to the pest level.

In Figure 12 are shown the potential losses due to different infestation levels, expressed in Rupees/acre.

Figure 12 shows that potential losses can be severe and thus even a moderate infestation of CBB can make it more difficult for farmers to reach the break-even point, let alone generate a profit.

Cost of CBB management

In the last year of the Project, an assess ment was made of 97 farms/estates involving both IPM plots (described ear-

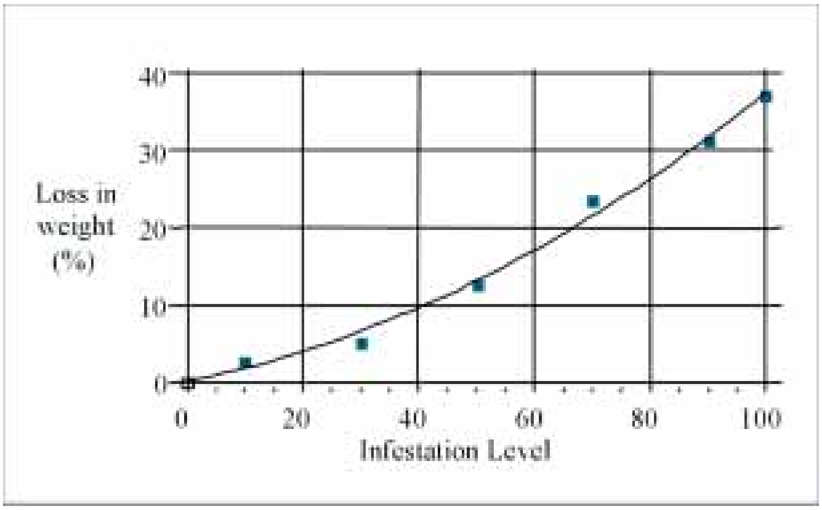


Figure 11. Loss function due to CBB attacks in India

Table 25 - Simulation of crop losses

Infestation Level	% of Loss	Yield lost (kg/acre)
0	0.08	0.35
10	1.79	8.38
20	3.95	18.50
30	6.57	30.73
40	9.63	45.05
50	13.14	61.49
60	17.101	80.02
70	21.51	100.65
80	26.37	123.39
90	31.67	148.23
100	37.43	175.17

lier) and non-IPM plots. From a general point of view the average cost for CBB management was 426 Rs/acre/year (approximately US$9.06), which equates to around US$22.60 per hectare/year. The maximum cost observed was about 2,344 Rs/acre, which equals US$124.00 a hectare. On average the share of CBB management over the total production cost was 3.8% - this is lower than observed in other countries, like Colombia, where the share is about 7%.

However the CBB cost is quite variable according to variations in farm size. Table 26 shows the CBB cost estimated for four farm sizes. As can be seen, the observed tendency is for CBB management to be more costly with increasing coffee farm size with the exception of the largest ones where the cost was lower than in categories 2 and 3. This might indicate that some economies of scale are present. What is very clear is that smallholder farmers tend to invest less in CBB management. If we assume that cost of a man-day is about 60 Rs/day, this would imply that these small farmers are investing the equivalent of 5.3 man-days per acre per year in pest control. Farmers belonging to category 3 are spending 10.3 man-days - almost twice the smaller farm sizes. Figure 13 describes the frequency distribution of CBB cost per acre/year.

According to Figure 13, the distribution is biased to the right. It is evident that to find coffee growers investing more than 1500 Rs/acre when controlling CBB is rare. The majority of farmers tend to spend up to 600 Rs/acre, since 78.3% of the sample is in that range. Taking into account that the survey was carried out in 2000-2001, when international coffee prices were better than 2001-2002, it is likely that this investment capacity has been reduced. If this hypothesis is true then the willingness to spend large amounts of money when managing CBB will be lower. Farmers will thus choose the most adequate practices that they believe will reduce production costs.

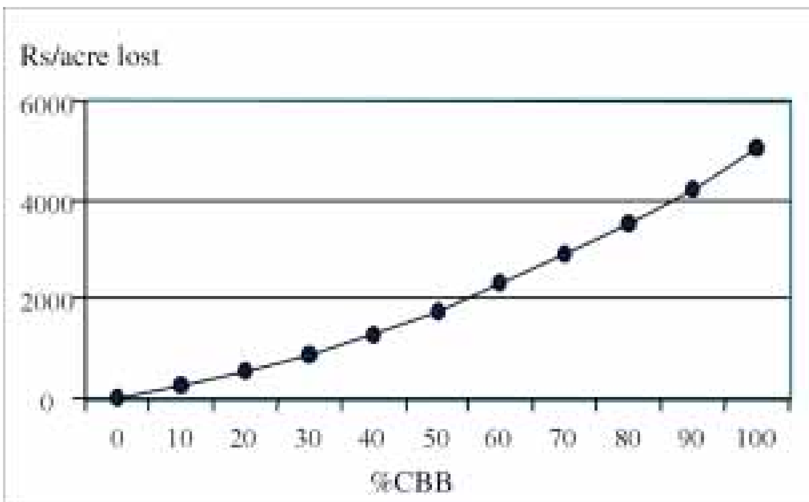


Figure 12. Simulation of crop losses due to CBB infestation levels (Rupees/acre)

Table 26 - Cost of CBB management according to farm size

Farm Size	Group	CBB cost (Rs/acre)	CBB cost (Rs/ha)	CBB cost (US$/ha)
Up to 4 acres	1	321	803	17
> 4 up to 7 acres	2	502	1254	27
> 7 up to 14 acres	3	622	1554	33
> 14 acres	4	466	1166	25

Another element of CBB management cost is that when productivity is higher, the pest problem tends to be more difficult to deal with. Thus the investment required might also be higher. Table 27 describes coffee productivity according to holding size, indicating that when a holding is larger, productivity is higher.

In this way the investment required to control CBB should be higher. Figure 14 depicts this tendency, despite the large scatter of points.

From the data above it can be observed that when productivity is above 700 kg of coffee/ha CBB cost tends to be higher, above

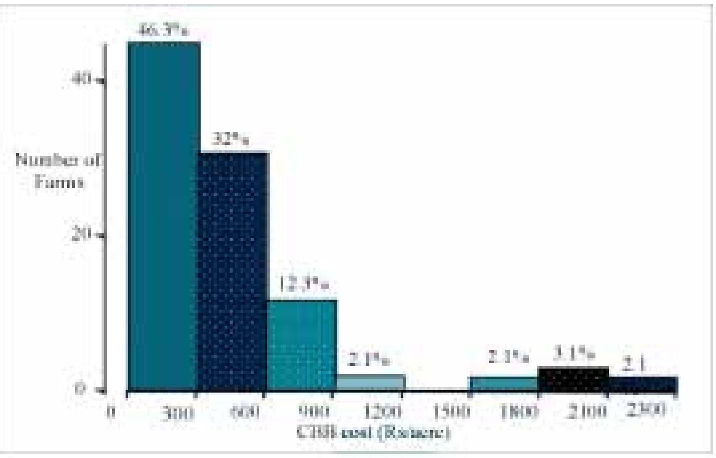


Figure 13. Cost of CBB management - histogram of frequencies

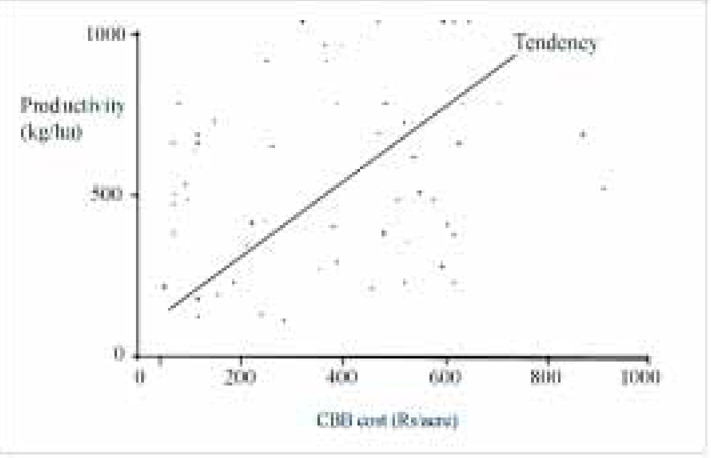


Figure 14. Relationship between cost of CBB management and holding size

Table 27 - Coffee productivity and holding size		
Farm Size	Group	Productivity (kg clean coffee)
Up to 4 acres	1	312
> 4 up to 7 acres	2	499
> 7 up to 14 acres	3	526
> 14 acres	4	552

Rs 600/acre. However, for the sample farms in the study, there were both IPM and non-IPM plots. Table 28 shows the CBB cost breakdown for both types.

Although the costs are apparently different, a statistical analysis for mean differences the results show that the CBB cost is equal (P value = 0.3062), whether or not the plot was in the Project.

In summary, in general terms, the cost of CBB management/acre is relatively low (Rs 426/acre). Given the steep increase in loss in revenue with increasing CBB infestations, farmers should consider investing in management strategies at low CBB infestation rates.

Table 28 - CBB cost a ccording to strategy of managing

Type of plot	Cost in Rupees/acre
IPM - plot	558
Non IPM - plot	442

Chapter 7

IPM information dissemination

The farmer participatory method (FPM)

The Coffee Board's extension network has been unique in many ways from the viewpoint of working in close proximity with the growers as field units are located in plantation areas. This enables a friendly rapport to be maintained with all growers in a Liaison Zone through personal contact with extension staff. Conventional extension methods have been successfully followed for the past half a century, transferring coffee cultivation technologies and dealing with the welfare of coffee growing communities.

With a view to strengthening the extension delivery system, Farmer Participatory Methods (FPM) were adopted under the CFC/ICO/02 CBB Project in order to widen the scope of dealing with CBB in relation to all aspects of coffee husbandry. Under the auspices of the Project, Dr. Falguni Guharay of CATIE, Nicaragua, an expert in FPM techniques, visited India during January 2000 and conducted master training sessions with 126 research and extension personnel of the Coffee Board. These master trainees later on conducted FPM programmes in their respective zones.

The FPM technique was adopted with the following objectives:

- To bring the farmer, researcher and extensionist together on 'one platform'

Dr Falguni Guharay conducting FPM workshop

- To find out the adoption levels of recommended packages of practices
- To improve the growers' decision-making abilities
- To identify constraints in adopting technologies
- To identify innovative, locally adopted, technologies
- To improve the productivity and quality of coffee grown
- To improve the overall socio-economic status of the farmer

FPM is a three way interactive process wherein researchers, extensionists and farmers meet on a bi-monthly basis to discuss not only CBB issues, but also all other aspects of coffee cultivation. It involves a combination of conventional extension methods such as group gatherings and meetings, as well as field visits to conduct demonstrations, in addition to FPM techniques. In the FPM mode, the active participation of the farmer needs to be ensured for the successful adoption of technologies, unlike other conventional extension methods.

Farmer-researcher-extensionist meetings

Farmer-researcher-extensionist meetings at periodic intervals, at pre-se lected estates, were conducted. Participating farmers were divided into groups to visit the estate and to identify problems. These groups collected specimens and made observations from the field. The leaders of each sub-group presented the group's views on the standard of maintenance by using flip charts. Deliberations on the observations and various technologies adopted were held to analyse the gap between locally adopted and recommended practices. The facilitators and researchers then helped the groups todiscuss the problems identified, and to find solutions using the basket of technologies available.

The problems identified were ranked, based on merit. The most urgent and need-based problems were then selected for discussion. Finally, feedback from all growers of a group were collected and analyzed for further improvement.

In addition, bi-monthly workshops involving researchers and extensionist were conducted at research centres to deliberate on the feedback of FPM meetings and to empower extensionists. Under FPM activities, 24 regional technical workshops were held at different research stations during this Project.

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. Details are presented in Table 29.

Impact of the FPM programme

The various activities conducted under this new extension method made the following impressions on the extension programme, extensionists and coffee growers:

1. On the extension programme in general:
   - Location specific technologies/practices coming to the fore
   - Opportunity for verification of field validity of different technologies/practices
   - Continuous feedback from the field for researchers/extensionists
   - FPM as a new technique - a refreshing process

2. On extentionists:
   - Providing an opportunity to exhibit their talent and abilities
   - Improving upon their communication and other extension skills
   - Sharpening their technical knowledge and skills
   - Interacting at regional research workshops and updating knowledge frequently
   - Feeling better, to have first hand feedback from many farmers
   - Developing more of a team-work attitude
   - Using a wider variety of tools (like flip charts) to put across their ideas
   - Opportunity to develop new ideas to convince the farmers

3. On growers:
   - Opportunity to express their views freely
   - Chance to learn what other growers are doing
   - Verifying field validity of different technologies/practices
   - Learning latest techniques
   - Focusing more sharply on current problems
   - Participating and learning continuously
   - Knowing about cost reduction opportunities

Table 29 - Details of FPM groups and meetings conducted

States	No. of FPM groups			Total no. of growers			No. of meetings held		
	2000-2001	2001-2002	Total	2000-2001	2001-2002	Total	2000-2001	2001-2002	Total
Karnataka	22	48	70	469	980	1449	132	122	254
Kerala	11	23	34	215	461	676	66	58	124
T Nadu	07	15	22	145	309	454	42	38	80
Total	40	86	126	829	1750	2579	240	218	458

Thus, the FPM programme launched as a part of the CBB management activity under this Project resulted in extension activities being made more visible, in motivating growers to actively participate in such activities and it inspired extensionists to adopt new extension tools made available to them.

Women empowerment programme (WEP)

The Indian women empowerment programme (WEP) came about as a result of a visit by Dr. ST Murphy of CABI *Bioscience* in April 2001, when it was decided to initiate special activities on the empowerment of women in CBB management and other coffee cultivation aspects. This was as a direct result of the fact that most women could not attend FPM activities due to 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 coffee plots. Encouraged by the positive response from these meetings, similar programmes were organized in all CBI liaison zones. A total of 26 meetings were held in different areas between April and October 2001 (Table 30).

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

WEP participants

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 were also interested to train on coffee cultivation, preferably at local level and in the local language.

Summary of extension activities carried out during 1999 to 2001

The details of various extension activities conducted by the Coffee Board of India to combat Coffee Berry Borer between 1998 and 2001 are summarized in Table 31.

FPM-style group gatherings at IPM plots

The FPM style was adopted to disseminate the inferences of IPM observations in the IPM plots. FPM-style group meetings at IPM plots were held in-

Table 30 - Details of WEP meetings held

STATES	No. of meetings conducted	No. of women participated
KARNATAKA	13	45
KERALA	8	218
TAMIL NADU	5	198
TOTAL	26	870

Table 31 - Summary of Extension activities					
ACTIVITIES	1998-1999	1999-2000	2000-2001	2001-2002	Total (to 31-08-01)
Contact visits	9811	3442	11671	3546	28470
Technical workshops (research & extension)	3	6	18	8	35
Farmers' group workshops (extension)	0	0	240	153	393
Regional review workshops (district level)	0	1	8	2	11
Apex level workshops (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 campaigns					
a) Newspaper	15	5	13	5	38
b) Radio announcements	19	1	4	4	28
c) Radio talks	4	3	5	1	13

volving neighbouring farmers to disseminate the knowledge generated at on-farm IPM plots. A total of 17 such meetings were held in different regions, eight in Kerala, five in Karnataka and four in Tamil Nadu.

Conclusions

The various extension programmes carried out over the last twelve years have been successful in creating an awareness about the coffee berry borer problem and motivating the growers to take up control measures, which is evident from the low levels of CBB incidence reported from many of the estates and the reduced rate of spread of the pest in the recent years. The incentive provided to the growers, especially pesticides at subsidised rates during the early years, played an important role in convincing the growers about the possibility of controlling the pest if control measures are adopted on-time. Though pesticide use was higher in the initial years, its use has now reduced considerably as growers realize that strict adoption of phyto-sanitary measures can bring down CBB pest incidence to very low levels. The establishment of IPM plots in growers' fields under the CFC/ICO/02 CBB Project has played a significant role in bringing about this change. The extent of adoption, and the current constraints to this, is considered in the next chapter.

Chapter 8

Socioeconomic studies on the adoption of IPM

Methodology

A study was made of socioeconomic constraints to the adoption of CBB management interventions in 97 estates including both IPM plots and non-IPM plots during the 2000 and 2001. This study was conducted by the Coffee Board and a consultant to the Project, Dr Hernando Duque of Cenicafé.

The ratio of IPM to non-IPM plots was 1:2, so as to include more plots that were not directly linked to project activities. In the selected plots several interventions had been made under the guidance of researchers and extensionists working on the Project. In non-IPM plots the extent of any adoption of interventions was purely the result of farmer decision-making. The main interventions used in the IPM plots and being recommended in general have already been referred to, and were listed above in the chapter on 'Testing, Validation and Integration of Components'. They are listed again here for convenience:

- Timely harvesting
- Thorough and clean harvest
- Gleaning collections
- Removal of infested berries
- Removal of off-season and leftover berries
- Use of picking mats
- Drying coffee up to the accepted standards
- Early disposal of the coffee produced (early selling)
- Spot spraying of endosulfan wherever necessary as last option
- Biological control methods
- Use of plans traps surrounding the drying yard
- Use of CBB traps

All 97 estates were located in three states involved in the Project, and distributed as shown in Table 32.

The following analysis is aimed at highlighting some of the results obtained during this study.

Extent of adoption of management interventions

The adoption of the interventions proposed for CBB management showed important differences. For instance, the components such as gleaning collections and the use of picking mats were the most adopted. However the fungus *B. bassiana* was the least adopted intervention by farmers, as was the use of sticky traps. Table 33 summarizes the adoption of all the components comprising the IPM strategy for controlling CBB in India.

From Table 33, it is clear that the most adopted components are those related to cultural control, such as the use of picking mats and gleaning collections. The adoption of these components showed different tendencies according to the state analyzed.

A statistical analysis was done in order to test for differences between proportions

Table 32 - Distribution of coffee plots for socioeconomic purposes

Regions	Practicing IPM		Non practicing IPM		Total
	Arabica	Robusta	Arabica	Robusta	
Kogadu	0	11	0	25	36
Wayanad	0	11	0	19	30
Pulneys/Nilgiris	5	3	4	19	31
Total	**5**	**25**	**4**	**63**	**97**

according to the procedure suggested by Walpole *et al.* (1998) and Levin *et al.* (1994).

■Firstly, for spot spraying, the observed adoption in the states of Kerala and Tamil Nadu was statistically higher than in Karnataka, but nonetheless appeared equal between them. Secondly, the adoption of blanket spraying was highest in Tamil Nadu, indicating that this region is characterized by a way of using of insecticides that is some distance from the IPM concept. Then there were the farmers from Karnataka State and finally the lowest adoption of blanket spraying was in Kerala. It is interesting to note that farmers from Kerala have adopted well the idea of spot spraying.

■The adoption of hot water treatment was statistically equal between Karnataka and Kerala, and between Karnataka and Tamil Nadu. However Tamil Nadu showed a higher adoption in this component than coffee growers in Kerala State.

■Sticky traps had a very low rate of adoption, but this rate was similar among all three states.

■In general, the use of picking mats has been well adopted in all states. The highest adoption was in Karnataka. followed by Kerala with the lowest rate in Tamil Nadu.

■The adoption of *B. bassiana* was very low across the board, as shown in Table 33.

■Finally, the component with a high rate of adoption was gleaning collection, which was statistically similar in all the states.

Constraints in CBB management technology adoption

The coffee farmers involved in the survey comprised 30% IPM plots, and the other 70% were farmers close to these plots but not taking an active part in the Project. Additionally 83% were owners while 17% were paid managers.

Some constraints to the adoption of interventions were identified during the study. For instance, in the case of spot spraying the coffee growers mentioned a number of constraints, which are shown graphically in the next figure.

From Figure 15, it is clear that problems related to labour is a major restriction. Furthermore, spot spraying operations are seen as costly. A low percentage of growers did not know about the use of this practice.

The main constraints in the adoption of blanket spraying are depicted in Figure 16.

Table 33 - Adoption of components in IPM

Component	Non-adoption (%)	Adoption (%)
Beauveria bassiana	95	5
Spot sprayings	65	35
Blanket sprayings	59	41
Hot water treatment	80	20
Sticky traps	97	3
Picking mats	26	74
Gleaning collections	5	95

In this case the main difficulty is the high cost. Of course blanket spraying requires the whole coffee plot to be covered and the amount of labour needed and the input cost (insecticide) is expensive to carry out this operation. Additionally, the lack of knowledge is another important factor acting as a barrier.

For hot water treatment the main problems when adopting this component were the cost of the activity and the lack of knowledge to do it, as shown in Figure 17. As explained above, gleanings collection is the most adopted component of the IPM strategy against CBB in India. The main constraints to its adoption appear in Figure 18, where it can be concluded that the majority of the coffee growers see this component as a beneficial and effective intervention. However, gleaning collection is costly for more than 20% of coffee growers. But undoubtedly this component is playing a key role in the control of CBB.

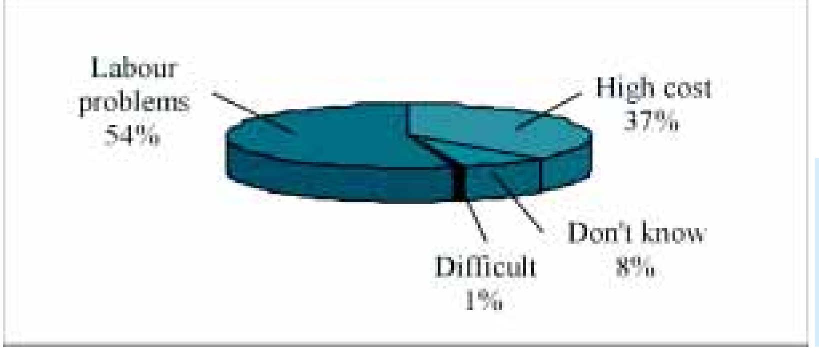


Figure 15. Adoption of CBB components by State

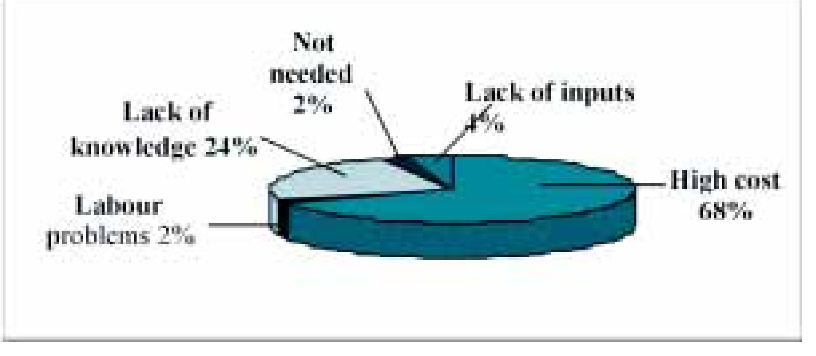


Figure 16. Main constraints in adoption of blanket spraying

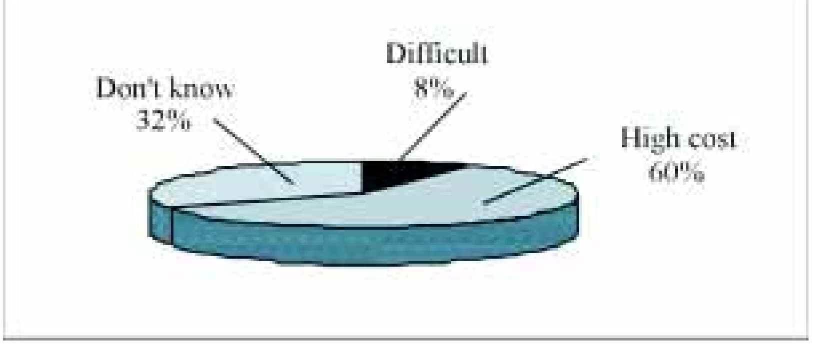


Figure 17. Main constraints in hot water treatment adoption

In the same way the adoption of picking mats, which are spread under the coffee trees to reduce gleanings, was also very good. Currently many coffee growers think that this is very useful intervention because in farms where it is used, new crops seem to become less infested. Figure 19 describes the main barriers in the adoption of this component.

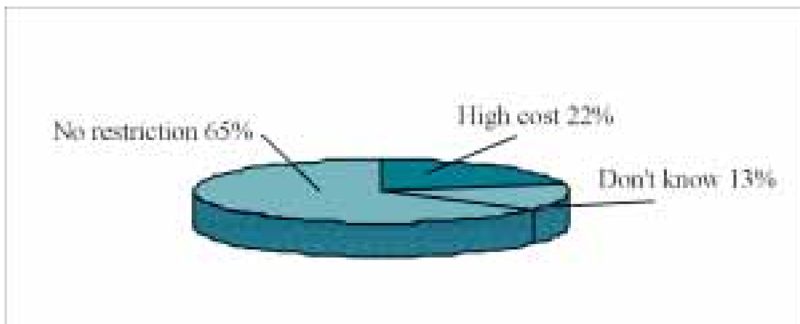
The answers were similar to the gleanings case since 58% of the farmers did not see any restriction in adopting this component. Nonetheless, some of them have the opinion that picking mats are costly.

In the case of *B. bassiana*, the main obstacles (Figure 20) are the lack of inputs, perhaps the supply of the fungus itself, but also maybe another inputs such as mineral oil and spray equipment. As in the other components there is a lack of knowledge about the technology, and in some cases it is seen as difficult to use and not practical at all as a control measure.

Awareness about CBB concepts

The socioeconomic study aimed to establish the level of awareness of some basic concepts related to IPM. Table 34 describes the results obtained. Despite

Figure 18. Main constraints in gleaning collection adoption



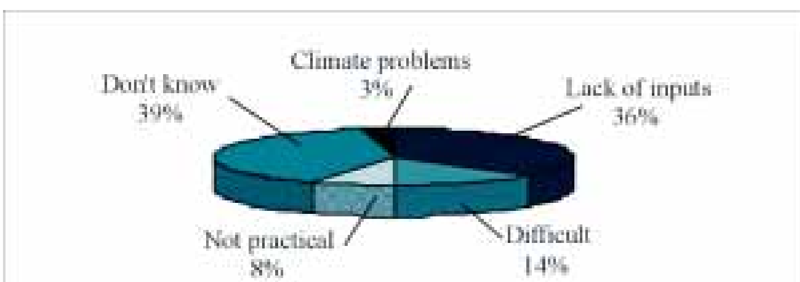
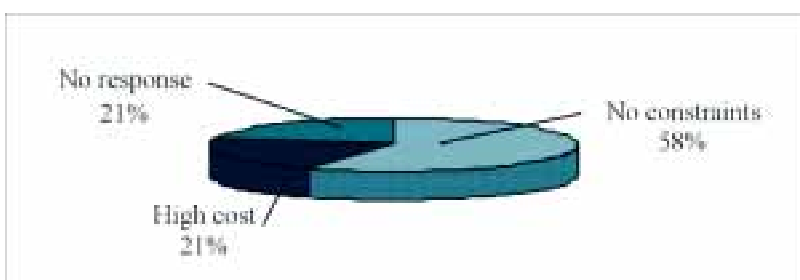


Figure 20. Main constraints in *Beauveria bassiana* adoption

Figure 19. Main constraints in picking mat adoption



the effects of irrigation on the homogeneity of the blossom, most of the farmers do not believe (73%) this operation has any result in CBB management. In this instance steps could be taken to teach farmers how important it is to have a single blossom instead of several flowerings when managing CBB.

A key factor that motivates the adoption of any technology is the importance of the problem it helps to solve. In this way more than 96% of the farmers are aware of the effects that CBB can have on coffee quality, which is very important since they should be interested in producing good quality coffee, as prices are normally better. Additionally, the majority sees that this pest can cause damage on young berries. However, despite the fact that the majority think that CBB can damage young coffee berries, there is scope to emphasize this kind of loss in those that are not aware of it.

Chapter 9

Conclusions

At present, coffee berry borer is present in approximately 35% of the total coffee growing area in India. Taking into account the experience of CBB in other countries, further spread of this pest to other coffee growing areas is likely. Hence, there is every need to continue with the programme of CBB control in India and to use the experiences gained so far to improve strategies in the future. Some key points arising out of the CFC/ICO/02 Project are outlined below.

In general there is a good level of awareness among farmers about CBB and its implications. Farmer participatory methods adopted during the Project have helped with the dissemination of information to farmers, and have also been educational for extension workers and researchers as well. For instance, coffee farmers are clear about the type of damage CBB can cause and some of the methods that exist to manage the pest. However, they are not very clear about how factors such as irrigation can affect CBB incidence.

With respect to the adoption of the available IPM components outlined in the chapter above, it is clear that those related to cultural control (such as gleaning collection and the use of picking mats) have been successfully adopted in many areas. Spot spraying and blanket spraying have been less adopted largely because of high costs; labour costs are a particularly important constraint. However, in the IPM context, spot spraying is clearly preferable, and should be promoted as such.

The most common constraint identified by the farmers was the high cost when implementing the IPM components for CBB management. This problem is clearly linked to current low coffee prices - and these low prices are the principal problem faced by Indian coffee farmers at present. Nonetheless, it should be highlighted that in the case of gleaning collection and use of picking mats, the majority of coffee growers did not identify any real constraints in adopting them.

For the sample of farms analyzed during the Project, the average total production cost per acre/year was about Rs 15,952 (approximately US$339.40). Fixed costs make-up 34.7% of total production costs while variable costs contribute 65.3%. From a general point of view, the fixed cost percentage is high. While the average yield was 468 kg of clean coffee per acre, the break-even point has been estimated at 559 kg at current (2002) prices.

Many Indian coffee growers are simply not reaching this point, and are thus facing a very difficult economic situation. From the sample analyzed, some 60% of farmers were not reaching this break-even point. Two possible ways for the farmers to reach the break-even point have been identified. The first is to get a price of Rs 35 per kilogramme of clean coffee. The second is to improve coffee productivity. However, both of these are hard to attain. A key aspect here is to avoid any yield reduction as a result of CBB.

The average cost for CBB management was about Rs 426 per acre, which is a relatively low cost. However some farmers are investing more than Rs 1,000 per acre, and in some cases CBB management costs reached US$ 124 per hectare. CBB management costs tend to increase as coffee productivity increases – a tendency that can be seen in other countries, e.g. Colombia.

As high costs are the main barrier for technology adoption, and most of the components are necessarily linked to use of labour, the future strategy for CBB management should be based on management components that are less labour dependent. In this context, more emphasis should be placed on biological control.

Work on the development of an artificial diet for rearing CBB and its parasitoids is underway in different laboratories. *Cephalonomia stephanoderis* has shown some promise in the evaluation tests and this parasitoid is now being distributed in many CBB affected areas. Also a culture of *Phymastichus coffea* has now been established in India and release and assessment studies are underway. Any further development of *Beauvaria bassiana* as a biocontrol agent will have to address critical issues such as mass production techniques and quality control management. The timing of applications and the right local climate conditions are important factors for success and thus these factors combined could limit the usefulness of this agent.

More generally, farmers have a marked difficulty in assessing crop losses due to CBB attacks. A participatory approach is needed to devise farmer-friendly ways of sampling and calculating losses as this will help ensure the long-term stable adoption of an IPM strategy

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Video documentaries

Short video film on CBB in English and vernacular languages (Kannada, Malayalam and Tamil).

Appendices

APPENDIX 1:

Coffee Board of India infrastructure and main personnel engaged in the Project

In the early 1940s the Indian Board for the Expansion of the Coffee Market was created and later renamed the Coffee Board of India, renamed again in 1955 as the Coffee Board (ICO, 1997). The Coffee Board has several functions:

- To promote sales and coffee consumption in India and around the world
- To commercialise coffee through a common fund (this function has recently changed)
- To research coffee with the aim of developing new production technologies
- To offer technical advice in order to improve coffee farming with emphasis on smallholders
- To improve coffee quality
- To manage and lead the coffee sector at both national and international levels

After the market liberalisation the Coffee Board reduced its role in coffee commercialisation. Thus coffee farmers are now free to sell their coffee in whatever way they want. However, the Coffee Board has a set of responsibilities that it carries out to benefit the coffee sector.

The president is the executive director of the board and he reviews all structural changes resulting from the opening of the coffee market. This liberalisation requires the Board to focus on research and development, quality control, market information, promotion, extension and development of a free market.

Extension offices are dispersed throughout all coffee regions giving technical advice according to the farmers' requirements. In total there are 45 extension units covering an average of 5,800 ha each. Most extension activities are related to technical support, farm visits, transfer of technical knowledge through rural meetings and other media. The extension service has a set of model coffee plots to carry out demonstrations about correct practices and new technologies. Other services provide seeds of new varieties, link farmers with research, forecast harvests, as well as estimating the incidence and importance of pests and diseases.

The research studies on the CBB were initiated during 1990 at the Regional Coffee Research Station, Chundale, which is situated in the berry borer affected region in Kerala State. Later on, studies were conducted at the Coffee Research Sub-Station, Chettalli, Kodagu District, Karnataka and the Regional Coffee Research Station, Thandigudi, Tamil Nadu as the CBB spread to these regions. The personnel involved in various studies are as follows:

Name	Major areas of work
Sri. C.B. Prakasan	Survey, crop loss studies, evaluation of pesticides, mass trapping and biocontrol
Sri. P.K. Vinod Kumar (till 1993)	Survey, evaluation of pesticides, crop loss studies
Sri. Stephen D. Samuel	Survey, mass trapping
Sri. M.M. Balakrishnan	Survey, evaluation of pesticides and biocontrol
Sri. P. Abdul Rahiman	Survey, evaluation of pesticides
Dr. C.K. Vijayalakshmi	Survey, bioecology and evaluation of pesticides
Sri. K. Sreedharan, Head, Division of Entomology/Nematology, CCRI	Coordinated the various research projects on CBB

APPENDIX 2:

Overseas visits to attend meetings, training and conferences on CBB

Personnel	Place Visited	Period	Mission	Sponsor
Sri. P.K. Krishnamorthy Bhat, Head, Division of Entomology/Nematology, CCRI, CR Station	ECOSUR, Tapachula, Mexico	December 1991	First Inter-Continental Conference on Coffee Berry Borer	Invitation by Organizers
Sri. K. Sreedharan, Head, Division of Entomology/Nematology, CCRI, CR Station & Sri. S. Ramani, Scientist (Entomology), Project Directorate of Biological Control, Bangalore	ECOSUR, Tapachula, Mexico	13th August-2nd September 1995	Training on biocontrol of coffee berry borer using parasitoids and import of parasitoids, *Cephalonomia stephanoderis* and *Prorops nasuta*	Government of India
Sri. Philippose Matthai, Chairman, Coffee Board & Sri. K. Sreedharan, Head, Division of Entomology/Nematology	International Coffee Organization (ICO), London, UK	July 1996	Final discussions on the CFC/ICO Project on Coffee Berry Borer and preparation of project proposal	Government of India
Dr. R. Naidu, Director of Research & Sri. K. Sreedharan, Head, Division of Entomology/Nematology	ECOSUR, Tapachula, Mexico	29th March – 2nd April 1998	Second Inter-Continental Conference on Coffee Berry Borer	CFC/ICO/02 Project
Sri. C.B. Prakasan, Field Entomologist, RCRS, Chundale & Sri. M.M. Balakrishnan, Assistant Entomologist, CRSS, Chettalli	Cenicafé, Chinchina, Manizales, Colombia	10th August – 4th September 1998	Training on biocontrol of coffee berry borer and mass multiplication of parasitoids	CFC/ICO/02 Project
Sri. P.K. Vinod Kumar, Entomologist, CCRI Sri. P. Abdul Rehiman, Assistant Entomologist, & Mrs. C.K. Vijayalakshmi, Assistant Entomologist, RCRS, Chundale	Cenicafé, Chinchina, Colombia	28th September – 23rd October 1999	Training on biocontrol of coffee berry borer and mass breeding of parasitoids	CFC/ICO/02 Project
Dr. R. Naidu, Director of Research Sri. K. Sreedharan, Head, Division of Entomology/Nematology & Sri. M.M. Balakrishnan, Scientific Officer, CRSS, Chettalli	Mississippi State University, Mississippi, USA	1st – 6th May, 2000	International Workshop on mass rearing of berry borer on artificial diet	CFC/ICO/02 & USDA
Sri. Nitin R.Gokarn, Secretary, Coffee Board Sri. K. Annapurnaiah, Deputy Director (E), Mysore & Sri. Stephen D. Samuel, Biological Control Officer, RCRS, Thandigudi	CATIE, Nicaragua	October – November 2000	Training on Farmer Participatory Methods in the IPM of Coffee Berry Borer	CFC/ICO/02 Project

APPENDIX 3:
Visits of consultants to India under the CFC-ICO project

Expert/Consultant	Period of visit	Mission
Mr. J.A. Nicholas Wallis, ICO Consultant	Nov. 1995	Preparation of a draft project proposal on coffee berry borer
Dr. Sean T. Murphy, CABI Bioscience, UK	Nov. 1997 Mar. 1998 Nov. 1998 Mar. 1999 Nov. 1999 Mar. 2000 Nov. 2000 Mar. 2001	Planning programmes, review of Project progress and suggesting required remedial measures
Dr. Stephanie Williamson, Consultant	Mar. 1998	Consultancy on farmer participatory IPM programme
Dr. Peter Baker, CABI Bioscience	Nov. 1998	Project review and guidance
Dr. Adrian Leach, Imperial College, UK	Nov. 1998	Collection of economic and management data for modelling coffee berry borer in India
Dr. Falguni Guharay, CATIE, Nicaragua	Jan. 2000	Conducting training on Farmer Participatory Method in CBB IPM programme
Mr. Jaime Orozco Hoyos, Entomologist, Cenicafé	Feb. 2000	Technical guidance on mass breeding of CBB parasitoids
Dr. Jeff Bentley, Consultant	Nov. 2000	Study on the sociological aspects of berry borer management
Mr. Hernando Duque, Agricultural Economist, Cenicafé	Jan. 2001	Study on the economic aspects of berry borer management

APPENDIX 4:
Earlier Indian studies on CBB ecology and cultural control

Cultural and phytosanitary measures are known to be effective in the management of CBB in various countries. Hence, experiments were conducted to evaluate the effect of various components of cultural and phytosanitary measures such as timely harvest, gleaning collection, *etc.*, on CBB ecology. Some of this work is reported here.

■ Effect of delayed harvest on the population build up of CBB

CBB infestation in the field was enumerated at fortnightly interval from December to February (i.e. until harvest) on an estate in Kodagu and the pest build up recorded until the coffee was harvested. The data recorded are presented in Table A4-1.

The data showed that a 26-day delay in harvesting (beyond the period when 60% of the fruits were ripe) caused about a 35% increase in CBB incidence.

In another study in Kodagu, the effect of delayed harvest on the coffee berry borer build up ('flare-up') on the standing crop was studied by comparing the infestation in crops harvested on time, and in standing crops allowed to over ripen and dry on the plant (in the same estate). A 17-day delay in harvesting resulted in about 6-fold increase of fruit infestation. In a study in Wayanad, the level of infestation on new crop, and berry drop due to CBB, were recorded from timely and delayed harvested estates. The data are presented in Table A4-2.

Table A4-1 - Effect of delayed harvest on CBB build up

Name of estate	% incidence of CBB				
	December 14th 1995	January 2nd 1996	January 18th 1996	February 1st 1996	February 14th 1996
Ballykilty estate, Cannancadoo, Kodagu	18.76	26.03	44.78*	46.64	79.57

(* About 60% ripe fruits)

Table A4-2 - Effect of late harvest on CBB build up

Name of estate	Per cent CBB infestation	Per cent fruit drop due to CBB
Late harvest		
Rippon Estate, Arappatta	21.78	5.10
Nellimunda Estate, Meppadi	11.95	2.59
Calicut Estate, Attamala	18.65	5.23
Mean	17.46	4.31
Timely harvest		
Spices Garden, Meppadi	1.30	0.18
Shilpakala Estate, Meenangadi	1.05	0.17
Kalyanamandiram Estate, Puliyarmala	1.94	0.40
Rockside Estate, Kainatty	0.37	0.13
Mean	1.20	0.22

The data indicated that the percentage berry infestation and fruit drop due to coffee berry borer was higher in late harvested estates than in timely harvested estates.

Study on CBB build-up on a non-harvested estate

A study was carried out on Rippon estate, Arappatta, where harvesting was not done until May 1996, due to unavoidable reasons, to assess the build up of incidence. Different types of berries, i.e. berries from the plant, fallen berries and off-season berries, were collected from the infested field at different locations and examined in the laboratory.

The counts of the infested and non-infested berries were recorded. Among the three types of berries examined, the highest percentage of coffee berry borer infestation was recorded on fallen berries (97.60%) followed by the berries on the plant (70%) and off-season berries (13%). Furthermore, the counts of different stages of coffee berry borer were also recorded by cutting open 25 berries of each type. The observations showed that the maximum number of adults were evident in fallen berries, followed by berries on the plant. Further, the off-season berries showed more number of eggs compared to other types of berries. These observations revealed that CBB infestation could build up to very high levels if harvesting is not completed on time.

Field study on the impact of gleaning on the build up of CBB

A replicated field trial was conducted to study the impact of infested fallen berries on the build up of CBB in the new crop, by placing different numbers of infested berries under caged plants. The resultant infestation in the new crop was recorded after one month. The experiment was conducted for three seasons and the results are presented in Table A4-3.

It is evident from the data that the incidence of CBB in the new crop significantly increases with increase in the number of infested fallen berries present on the ground (gleaning).

In another study, data on percentage fruit infestation by CBB in the new crop was re-

Table A4-3 - Impact of gleaning on CBB build up

Treatment (Number of infested fruits on the ground below plant with immature fruits)	Mean % Infestation		
	1996-97	1997-98	1998-99
One	2.72	6.12	2.86
Five	7.03	7.33	4.62
Ten	6.77	7.59	4.74
Fifteen	9.46	11.03	5.05
Twenty	9.47	12.35	7.56
Thirty	16.96	15.41	8.39
Fifty	18.42	16.74	9.85
Seventy five	21.24	17.13	11.45
One hundred	25.93	20.24	16.21
Control (no infested fruit below plant)	0.00	0.00	0.00
'F' Test	**	**	**
C D at 5%	4.92	4.53	3.96
C D at 1%	6.74	6.21	5.34

corded from ungleaned and gleaned estates. In this study, three ungleaned plots were compared with a gleaned plot. In each test plot 10 plants and four branches per plant were taken to arrive at the infestation level. There was a marked difference in infestation level in gleaned and ungleaned estates. The average infestation on the three ungleaned estates was 13.56% compared to that of 1.49% on gleaned estates.

- **Use of picking/harvesting mats**

Removal of fruits that fall on the ground (gleaning) and those remaining on the plant (left over) after harvest is the most important practice for the management of CBB.

Manual gleaning is often laborious and expensive. In this context, harvesting coffee with mats spread under the plants was thought to be an effective method to reduce gleaning in coffee fields. This method was demonstrated in Kodagu in 1993. The Coffee Board supplied picking mats to all the small growers in Byrambada village, Kodagu, on an experimental basis, and it resulted in reduction of pest incidence in the new crop in the village. As a result of this, use of picking mats gained wider acceptance among the growers and the Coffee Board continued to supply the picking mats at subsidised rate.

In order to quantify the effect of using picking mats on CBB incidence, a replicated trial was carried out at four locations in Wayanad. At each location, two sets of treatments, i.e. harvesting with picking mats spread under the plant and without picking mats, were imposed. The number of fallen berries on the ground after the harvest in the treatment plots was assessed by taking counts of fallen berries in a quadrate of one-foot size. Counts of 5 quadrates each was taken from 20 sites in each location and the mean number of fallen fruits in a square foot area was calculated. The results are presented in Table A4-4. Further, the infestation of CBB in the new crop in the experimental plots was assessed, and the data is given in Table A4-5.

Table A4-4 - Effect of using picking mat on gleaning

Treatment	No. of fallen fruits per sq. ft.				
	Kusumam Estate	Bhakthi Nivas Estate	CDF Kalpetta	RCRS Chundale	Mean of 4 locations
Harvesting with picking mats	1.23	2.61	3.29	1.5	2.16
Harvesting without picking mats	12.84	6.65	6.48	5.02	7.75
CD at 5%	1.76	1.49	0.97	1.25	
CD at 1%	2.35	1.99	1.55	1.67	

Table A4-5 - Effect of using picking mats on CBB infestation

Treatment	% CBB infestation in the new crop				
	Kusumam Estate	Bhakthi Nivas Estate	CDF Kalpetta	RCRS Chundale	Mean of 4 locations
Harvesting with picking mats	0.86	0.81	1.25	1.04	0.99
Harvesting without picking mats	6.83	2.36	2.93	1.75	3.47

The data showed that the use of picking mats helped in collection of fruits falling on the ground thereby reducing the gleaning by 72.13%. This has resulted in the reduction of CBB infestation in the new crop by 71.47% compared to that in the plot harvested with out picking mats.

Finally, the data on the picking efficiency, quantity of gleaning collected and the labour requirement for gleaning with and without the use of picking mats were collected from the above mentioned trial locations and the same are given in Table A4-6.

The use of picking mats increased the picking efficiency of workers by 48.56%. The amount of gleaning was reduced by about 58% when the harvest was done using the picking mat. As a result the manpower required for gleaning was also reduced by 43.33%.

- **Beetle population in left over berries**

Berries left on coffee plants after the harvest are found to harbour large numbers of beetles, which can then infest the new crop. In order to quantify the beetle population in the left over berries, a study was conducted on three estates on Pulney Hills, Tamil Nadu for two years. From each plot, 100 left over berries each were collected from five sites in May and the berries classified, based on the number of beetles present in each berry. The percentage of berries containing different ranges of beetle populations (e.g. zero, 1-5, 6-10) was worked out. Results are presented in Table A4-7.

The data show that beetles were present in all the berries except in one case in a plot during the year 2000 in which beetles were absent in 1% of the berries examined. The population level of more than 10 beetles per berry was recorded from 72.00% and 89.67% of berries examined during 2000 and 2001 respectively. The percentage of berries containing more than 50 beetles per berry was 13% and 28.33% during the years 2000 and 2001 respectively. It is evident from this study that the left over berries harbour large numbers of beetles, which could form the main source for carrying over the inoculum to the new crop. Hence, removal of these berries is essential to reduce pest build up.

Table A4-6 - Effect of using picking mats on harvesting

Treatments	Fruits harvested/ worker/day (Kg)	Gleaning per acre (Kg)	Labour requirement per acre for gleaning
Harvesting with picking mats	118.56	39.88	4.25
Harvesting without picking mats	79.82	94.88	7.50

Table A4-7 - Population of CBB beetles in left over berries

No. of beetles/berry	Percentage of left over berries					
	Estate -I		Estate -II		Estate -III	
	2000	2001	2000	2001	2000	2001
Nil	-	-	-	-	1	-
1-5	14	1	19	3	12	1
6-10	9	9	16	7	13	10
11-20	22	23	30	21	29	17
21-30	12	13	9	15	21	21
31-40	15	10	15	16	5	14
41-50	10	14	3	9	6	11
> 50	18	30	8	29	13	26

Effect of hot and cold water treatment of infested berries on CBB

Hot water treatment

The studies were conducted at RCRS, Chundale during 1994. Infested fruits were dipped in boiling water for 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 minutes. There were six treatments and each treatment was replicated three times with 25 kg of fruit per replication. Mortality was calculated after cutting open 500 treated fruits from each replication. The data are presented in Table A4-8. The data revealed that dipping infested fruits in boiling water for a period of 2.0 minutes was sufficient to kill all the stages inside the berry.

Cold water treatment

An experiment was conducted to study the effect of immersing infested berries in water for 12, 24, 36 and 48 hours. Each treatment was replicated four times with 5 kg of fruit per replication. The percentage mortality was assessed after cutting open 250 treated fruits per replication. The data are presented in Table A4-9. The results indicated that 100% of adult and larvae were killed in 48 hours of immersion in cold water.

Table A4-8 - Effect of dipping CBB infested berries in boiling water on CBB stages

Dipping in boiling water	Percentage mortality	
	Beetles	Larvae
0.5 Minute	55.33	55.50
1.0 Minute	75.33	80.83
1.5 Minutes	95.00	98.00
2.0 Minutes	100.00	100.00
2.5 Minutes	100.00	100.00
3.0 Minutes	100.00	100.00
'F' test	*	*
C D at 5%	1.20	1.44

Table A4-9 - Effect of cold water soaking on CBB mortality

Dipping in boiling water	Percentage mortality	
	Beetles	Larvae
12 Minutes	20.83	30.50
24 Minutes	48.00	50.33
36 Minutes	75.00	92.67
48 Minutes	100.00	100.00
'F' test	*	*
C D at 5%	1.45	1.60