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An evaluation of a basic IPM system for the control of coffee berry borer on Liberica coffee

(Penilaian sistem KPB asas untuk mengawal kumbang pengorek buah pada kopi Liberica)

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Key words: coffee berry borer, *Hypothenemus hampei*, IPM, Liberica coffee

Abstract

An integrated pest management (IPM) system for the control of the coffee berry borer, *Hypothenemus hampei* Ferr., was evaluated on Liberica coffee trees at MARDI Station, Kluang, Johor. Briefly, the IPM package included monthly coffee berry borer damage monitoring, insecticide spraying whenever damage threshold was exceeded, application of the white muscardine fungus *Beauveria* during the rainy season, and tri-yearly bored black berry collection as the cultural control method. Crop cultural practices tested as part of the IPM package included cover-cropping with the legume *Arachis pintoi*, and scheduled tree pruning.

The coffee plot managed under the IPM system gave better performance in terms of reducing coffee borer damage level and increasing coffee yield. Average coffee yield obtained in the IPM plot was 25.9 t/ha, which was 23.7% higher than the coffee plots under the simulated farmer-type system and 23.3% higher than the conventional pest management system. However, the production cost in the IPM system increased an average of 2.3 times and 0.5 times, respectively when compared to the simulated farmer's system and the conventionally-managed system. There was a slight increase in the net income of the IPM-managed system. Average net income increased by 7.3% and 23.9%, respectively when compared to the simulated farmer-type and conventional systems. It was concluded that the IPM system was a viable tool for the management of coffee berry borer on Liberica coffee in Malaysia, and further improvements would make control of the pest more effective and sustainable in the long run.

Introduction

The coffee berry borer (CBB), *Hypothenemus hampei* Ferr. is a major pest of coffee in Malaysia. Current recommendations for the control of the pest include a mix of cultural and chemical control methods which stress the elimination of pest sources (Mohd Anuar and Loh 1991). Another method to eliminate pest source include the drastic 'dead-season' technique in which coffee trees were kept berry-free for up to six months to deny regeneration of new individuals (Lim 1978).

Malaysia has made significant progress in implementing the Integrated Pest Management (IPM) concept on a number of

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crops in the country (Lee et al. 1984), but coffee has received scant attention in this area of crop protection. Further, there is now the emerging trend, for example in vegetable production, of looking at IPM within the wider scope of total crop care, or integrated crop management (ICM) (Md. Jusoh et al. 1997). ICM is a cropping strategy in which the producer seeks to conserve and enhance the environment, while economically producing safe and wholesome food (Anon. 2002a). Implicit within this concept is the need to reduce reliance on normal agricultural inputs, such as fertilizers and crop protection chemicals, by actively pursuing alternatives, and the need to maintain and manage the soil and its fertility.

Coffee is a small holder crop in Malaysia. It is generally grown as a low-input, and hence, a low-productivity crop by the farmers on small pieces of land around the house. The main reason for such state of affair is the narrow margin of return of the crop due to the historically low coffee prices. It is, however, an important crop in the rural economy as it is a hardy crop, able to tolerate neglect, and can quickly be returned to a productive state with the proper agronomic inputs. Thus, it can be turned into a ready source of cash for the farmer whenever the market price of coffee justifies increasing inputs for the crop. At the same time, there is also an increase in demand for coffee nationally, projected at 5.1% and 4.7% annually for coffee powder and instant coffee, respectively (Noor Auni 1991). Thus, there is the twin requirement of increasing coffee productivity to meet the national demand, and at the same time keeping cost of production low to maintain farmer's interest in the crop.

It was with this in mind that a study was conducted to evaluate an IPM system for local smallholders growing Liberica coffee. The IPM system was designed around the total crop care concept of ICM and employed many of the low-cost tactics used by farmers in growing their coffee crop, but had been implemented by them mostly in an ad-hoc manner. This study was designed to show that similar crop production practices employed strategically, or with slight modification, can help to alleviate the CBB problem. It will also be used to evaluate the workability of such a system in comparison to the ad-hoc farmer-type crop management system and to the conventional coffee production system.

Materials and methods

The study was conducted at MARDI Research Station, Kluang, Johor (1998–2001) on a plot of 12-year-old Liberica coffee trees that had been kept with minimal maintenance. The plot was previously used for producing coffee seed for sale to farmers. For the purpose of the study, the plot was divided into three subplots, each of size 0.1 ha with 108 coffee trees. Two rows of coffee trees served as guard rows between the subplots, and two rows along the top and bottom subplot periphery served as buffers for possible incoming CBB population.

Three types of coffee berry borer management systems, with selected coffee production practices incorporated into each of the three, were used as treatment packages, viz. IPM, simulated farmer-type and conventional-type systems. The conventional and the farmer-type management systems are CBB control techniques practised by the local agriculture institutions and progressive coffee farmers, and the coffee smallholders, respectively. In brief, the IPM system involved a multiple control approach to CBB management based on regular pest monitoring and economic threshold, with emphasis on crop production practices beneficial to plant well-being.

In contrast, the conventional and simulated farmer-type management systems were more insecticide-based, dependant on the calendar, in the case of the former, and on convenience, in the case of the latter. Crop production-wise, the conventional management system relied heavily on normal agricultural inputs, while in the simulated farmer-type management system, the emphasis was on minimum production inputs, as is typical of small coffee farmers (Mohd Anuar 1998). Details of the components making up each of the CBB management package are provided in *Table 1*. In this study, the conventional-type system served as the standard, or check treatment. Treatment was assigned randomly to each subplot. Experiment design was the RCBD with three treatments and three replications, with harvesting seasons (twice/year) as the replicate. Liberica coffee in Johor has two main harvesting seasons; from April–June (38% of total production) and October–December (42% of total production) with minor harvesting cycles throughout the year (Muhamad Ghawas and Wan Rubiah 1991).

Pest control components

CBB damage monitoring Monthly monitoring for CBB damage level was carried out in the IPM system during the duration of the study. The purpose of the monitoring was to determine the current CBB infestation level in order to establish the need for pesticide spraying. This was done by randomly choosing 20 trees by drawing lots and inspecting three random fruit branches per tree for CBB damage on the coffee berries. Selected branches were approximately waist-high and chosen from any side of the leaf canopy. Damage counts were pooled for each tree and the average percentage of bored berries/tree in the plot was calculated for each sampling session. No monthly damage count was conducted in the other two treatments. Instead, five samples of 100 berries each were randomly collected from the harvested berries at certain harvesting season, and the average percentage of damage in all three treatments was determined for comparison between treatments in the data analysis.

Chemical control Pesticide spraying was carried out in the IPM system whenever average CBB damage exceeded the threshold damage level of 10% berry damage/tree (Mohd Anuar 1998). Spraying was not carried out close to harvest even if CBB damage was high, i.e. approximately one month before harvest. On the other hand, spraying was carried out in the conventional plot twice per season, once at the semi-mature berry stage and again one month later. In the simulated farmer-type system, spraying decision was based on the damage level in the mid-plot area which was inspected whenever high CBB damage became apparent in the periphery trees. Endosulfan at 0.1% a.i. was used in all plots for CBB spraying.

Table 1. Crop production practices implemented for coffee berry borer control under the various management systems

	IPM Package	Simulated farmer	Conventional practice (Check)
Cover-crop	*Arachis pintoi*	Natural cover	Natural cover
Fertilizer rate/Freq.	80 g N/tree/year; 4x/year	30 g N/tree/year; 1x/year	120 g N/tree/year; 4x/year
Weeding	As needed	As needed	As needed
Pruning frequency	4x/year	1x/year	2x/year
Black berry removal	3x/year	None	None
CBB monitoring	Monthly	None	None
Insecticide spraying	Exceed ET (>10 %)	As needed	2x/year; semi-mature berry stage onwards
Beauveria application	2x/year; semi-mature berry stage onwards	None	None

ET = Economic threshold; CBB = Coffee berry borer

Biological control of CBB A local strain of *Beauveria* sp. isolated from diseased CBB found at MARDI Station, Kluang was used as the biological control agent for the borer. A pure strain of the fungus was obtained from laboratory cultures, multiplied on autoclaved rice and harvested after 7–10 days. The rice was mixed with sterile distilled water and blended into thin slurry before being filtered through a cheese cloth using a vacuum pump. The resultant supernatant was collected and adjusted to approximately 10^6 spores/ml using a haemacytometer before being delivered into the field using a knapsack sprayer. Fresh preparations were made for each field application. Applications were made at the onset of the rainy season to improve fungal efficacy.

Cultural control practices Black berries, especially those which showed signs of CBB damage, were collected at every four-month intervals from coffee trees and on the ground below the tree canopy in the IPM plot. All collected berries were destroyed by burying them in the soil.

Crop practice components

Ground cover and weed control Natural ground cover was maintained for the simulated farmer-type and conventional-type systems. On the other hand, the IPM-treated plot was maintained under *Arachis pintoi*, a shade-tolerant leguminous herb which had received a lot of interest lately for its suitability as a cover-crop for tropical trees, including coffee (Anon. 2002c). Weed control in all systems were done by spraying with paraquat or glyphosate, or done manually throughout the year for sparsely growing weeds within the IPM system. Weed control was carried out on a regular basis in the conventionally-managed system, while in the simulated farmer-type system weed control was carried out whenever weeds became overgrown.

Fertilizer application All plots were fertilized using a commercial compound fertilizer (12:12:17:2 + TE). Fertilizer rate and frequency of application depended on the management system. For trees managed under the conventional system, fertilization was based on the rate recommended by Yau and Abd. Rahman (1991), while under the IPM-system, fertilizer rate was based on the estimated N requirement of coffee trees grown under an *Arachis pintoi* regime (Tham, K.C., MARDI, pers. comm. 1996). For coffee trees managed under the simulated-farmer system, the rate and frequency of fertilizer application was arbitrarily decided, based on the result of a survey of coffee farmers in the Batu Pahat and Pontian area in Johor. The survey showed most of the farmers (51%) did not fertilize their coffee trees or only fertilized once a year (25.0%) at a much reduced rate (Mohd Anuar 1998). The rate and frequency of fertilizer application for each management system is given in *Table 1*.

Pruning Tree pruning was based on the normal agronomic practice of removing water-shoots, inward and vertical-growing branches and weak branches. All trees were maintained at 2 m height by de-topping whenever required.

Record collection and statistical analyses

Records of all crop production activities were collected as per treatment. Labour inputs were reduced to man-days equivalent and converted to cost per activity using a standardized rate of RM15/man-day. Material and labour cost were added together to become the cost of performing certain activity or operation. The cost variable was used for comparison between the treatments in the data analysis.

Fresh coffee berry yields were collected during the main harvesting season and the off-season. Income from yield was calculated at the flat rate of RM600/t. Data of the parameters collected were analysed using ANOVA test and means were separated for significance using the Duncan Multiple Range Test.

Results

Results showed that the IPM system performed better than the simulated farmer-type and the conventional pest management systems, both in terms of reducing CBB damage and increasing coffee yield.

Coffee berry samples collected at random harvest dates in 1999 and 2000 showed significant CBB damage levels between the systems *(Table 2)*. CBB damage on coffee berries harvested from the IPM system was significantly less ($p < 0.05$) compared to those from the other two systems at every harvesting date monitored, except for the June 1999 harvest where damage level was similar to those obtained from the conventionally-managed system. There was no significant difference ($p < 0.05$) in CBB damage between the conventionally-managed system and the simulated farmer-type system at most harvesting dates monitored. However, there was a trend for CBB damage to decrease, dramatically in the IPM plot, and more slowly in the conventional system plot, going into the third year of the study, while in the simulated-farmer plot, damage level tended to remain stable at a high level. In comparing overall damage mean, the IPM system showed a significantly lower ($p < 0.05$) damage level at harvest (mean 21.2% bored berries/ harvest) compared to the other two. For the conventional system, in spite of the general trend for CBB damage reduction, the overall mean damage level was not significantly different ($p < 0.05$) from that of the simulated-farmer system (mean 36.4% and 35.1% bored berries/harvest, respectively).

Figure 1 showed the mean monthly coffee berry borer damage/tree in the IPM-treated plot during August 1998 to June 2001. As before, the general reduction in coffee berry borer infestation in the IPM plot was also shown here. CBB infestation was generally higher than the economic threshold level for the first 15 months of the

Table 2. Average coffee berry borer damage of coffee berries collected at random harvesting dates from three pest management systems during 1999–2000

Harvest date	Mean (n = 5) bored berries/sample (%)		
	IPM	Conventional	Simulated farmer
June 1999	32.3a	37.0a	48.6b
January 2000	23.5a	43.0b	29.0a
February 2000	16.0a	37.0b	30.0b
August 2000	13.1a	28.6b	33.0b
Mean/harvest	21.2a	36.4b	35.1b

Means followed by the same letter within rows are not significantly different ($p = 0.05$) according to DMRT

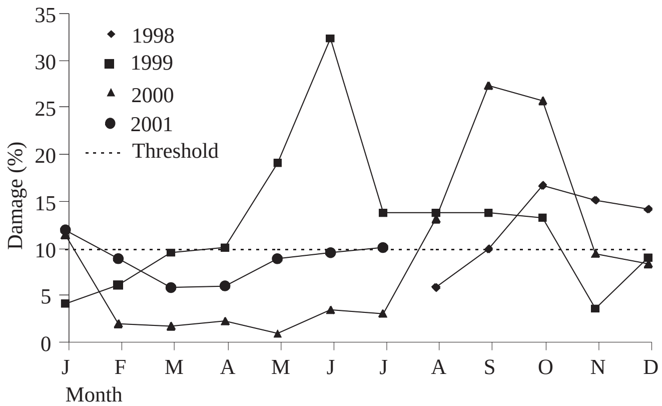

Figure 1. Mean monthly coffee berry damage/tree in the IPM-treated plot during the period August 1998 to June 2001

study, but it gradually dipped below the threshold for the rest of the study period, except for two months in the year 2000. Mean monthly CBB damage was 10.6% bored coffee berries/tree, while damage level ranged from 0.9–32.3% bored berries/tree over the study period. Borer damage tended to be heavier towards the main harvesting seasons, some time in June and September, as coffee berries mature and ripened, but tended to lessen as damaged berries were collected with harvesting *(Figure 1)*.

The average yearly costs of operating the three management systems are shown in *Table 3*. Management of the IPM plot incurred significantly (p <0.05) higher cost, by an average of 2.3 times, when compared to the simulated-farmer management system. However, when compared to the conventional system, the cost of running the IPM plot, an increase of only 0.5 times over the conventional, was not significant *(Table 3)*. Weed control was the highest cost component in both the IPM and the simulated-farmer-type systems, while fertilizer cost was highest in the conventional management system. Average management cost of the IPM system was RM417.87/year, compared to RM274.85/ year for the conventional system and RM126.16/year and for the simulated-farmer system, respectively.

Fresh coffee berry yield was significantly (p <0.05) higher in the IPM system giving a mean of 2,594 kg/plot, or 25.94 t/ha *(Table 4)*. This was 23.7% higher than the simulated farmer-type system, which showed an average yield of 1,979 kg/plot, or 19.79 t/ha. IPM plot yield was also significantly higher, by 23.3%, when compared to coffee berry yield in the conventionally-managed plot. Mean fresh

Table 3. Average yearly cost and cost components for coffee berry borer control of coffee plots (0.1 ha) under different pest management systems*

Pest control actions	Costs of pest management system (RM)		
	IPM	Conventional	Simulated farmer
Cover crop/Weed control	137.25	57.73	65.83
Pruning	117.73	42.81	32.50
Pest damage monitoring	30.00	0.00	0.00
Black berry collection	17.81	0.00	0.00
Beauveria field-application	18.40	0.00	0.00
Insecticide spraying	12.02	9.36	5.89
Fertilizer application	84.66	164.95	21.94
Total	417.87b	274.85b	126.16a

Means followed by the same letter are not significantly different (p = 0.05) according to DMRT
*2001 prices

Table 4. Average yearly yield, pest control costs and net income of coffee plots (0.1 ha) under different pest management systems*

	IPM System	Conventional	Simulated farmer
Coffee berry yield[1] (kg/plot)	2,594b	1,989a	1,979a
Gross income[2] (RM/plot)	1,556.40	1,193.40	1,187.40
Pest control costs (RM/plot)	417.87	274.85	126.16
Net income[3] (RM/plot)	1,138.53	918.55	1,061.24

[1]Means followed by the same letter within row are not significantly different (p = 0.05) according to DMRT
[2]Calculated at the flat-rate price of RM600/t
[3]Means not significantly different at p = 0.05
*2001 prices

coffee berry yield in this plot was recorded at 1,989kg/plot, or 19.89 t/ha.

The IPM system also registered a slightly higher average net income (by 23.9% and 7.3%, respectively) when compared to the farmer and conventional-type system. Mean net income per year was RM1,138.53 for the IPM system, RM1,061.24 for the simulated-farmer system and RM918.55 for the conventional system. However, analysis using ANOVA showed the yearly net income difference was not significant ($p < 0.05$) *(Table 4).*

Discussion

IPM is a viable option for the control of coffee berry borer on Liberica coffee. While the control tactics were basic and simple, the IPM nevertheless had the desired effect of reducing CBB damage. However, the effect of the IPM practices on the suppression on CBB population was relatively slow to take effect as it took almost two years before CBB damage level fell below that of the economic threshold *(Figure 1)*. Many of the tactics tested in the IPM package are also known and used by the farmers in growing their coffee crop, but they are usually employed irregularly and in an ad-hoc manner, i.e. as time, labour and funds permit. This study showed that normal agronomic practices, carried out to fulfill crop-growing requirements, also had the effect of alleviating CBB damage on the crop, if planned and carried out well. Coffee tree pruning, for example, is necessary from the agronomic viewpoint to develop a balanced tree form, promote new productive branches, and cut down on irregular bearing (Yau and Abd. Rahman 1991). From the pest control perspective, pruning promotes airiness within the tree canopy making the condition less favourable for pest and disease development (Anon. 2002b).

The study also tried to include some elements of the ICM concept within the IPM treatment design. Cover-cropping with *Arachis pintoi*, for example, was included in the IPM design with the intention of promoting vigorous crop growth, maintaining soil fertility and cutting down on inorganic fertilizer requirements, in line with the ICM principles of reduced reliance on inorganic inputs (Anon. 2002a). As a result, fertilizer application to the IPM plot could be reduced to about 33% of what was applied to the standard plot without sacrificing yield. In fact, the yield of the IPM plot was found to be significantly higher ($p < 0.05$) compared to the conventional plot, which had the full fertilizer rate; thus indicating the positive effect of using the cover-crop.

Studies have shown that the use of *Arachis pintoi* in coffee holdings did not increase CBB damage, nor contribute to increased coffee leaf rust disease incidence (Mohd Anuar 1998).

Yield improvement in the IPM system, undoubtedly, was also not due solely to the control of CBB damage but also to the effect of the pruning regime implemented. Yau and Abdul Rahman (1990) showed that tree pruning helped increase coffee yield by as much as 60% within the first five years of planting. However, in this study the contribution of each of these factors to yield improvement was not determined.

An anomalous result from the study was shown by the simulated farmer-type plot, which had an unusually high yield of 1,979 kg/plot (19.79 t/ha.), in spite of the low inputs applied. A possible explanation for this phenomenon might be attributed to the status of the plot as an ex-seed production area. It had received normal agricultural inputs, including the full fertilizer rate for many years prior to the experiment. It was possible that the high yield shown was the carry-over effect from fertilizers applied previously. It is expected that the effect of the low fertilizer regime treatment may eventually be expressed over time.

Net income was not significantly different ($p < 0.05$) among the treatments. This was because pest control cost was not high in comparison to the other cost components in treatment packages. Fertilizer cost was a large component of the production cost, being 20.2% of the average cost of implementing IPM and 60.0% in the conventional-type crop management. In comparison, fertilizer cost was only 17.4% in the case of the farmer-type management *(Table 3)*. This fact, plus the unusually high yield obtained from the farmer-type plot, helped narrow the net income difference with the IPM plot, and pushed it higher than the net income from the conventional-managed coffee plot.

The role of the biological control agent, *Beauveria* sp. in keeping down the population of CBB was negligible, as monitoring showed it could not become established during the duration of the study. Further work is needed to understand the disease epidemiology and the prerequisites required for disease spread under local conditions.

Conclusion

The study had shown that the deliberate, systematic and proper application of various currently available control methods could be made into a successful IPM package for the control of coffee berry borer. Ideally, IPM should be designed to closely harmonize with the agronomic requirements of the crop and be implemented within the scope of integrated crop management. Equally important, IPM protocols should be guided by the needs, capabilities and constraints of the clients, i.e. the coffee farmers, for it to work. It is suggested that to improve farmers' receptivity to IPM, recommendations should fit closely to farmers' routine practice, not too technically difficult, and not too time consuming or too costly to implement. In the short term, IPM has shown itself to be viable as the basis for CBB control practice in Malaysia.

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Abstrak

Sistem pengurusan perosak bersepadu (PPB) bagi mengawal kumbang perosak buah kopi, *Hypothenemus hampei* Ferr. pada kopi Liberica telah dinilai di Stesen MARDI Kluang, Johor. Secara ringkas, pakej PPB tersebut merangkumi aktiviti pemantauan kadar kerosakan kumbang pengorek secara bulanan, semburan racun serangga apabila kadar kerosakan buah melepasi tahap ambang ekonomi, penggunaan kulat muskardin putih *Beauveria* pada musim hujan, dan kutipan buah hitam berlubang tiga kali setahun sebagai kaedah kawalan kultur. Amalan kultur tanaman yang diuji sebagai sebahagian daripada pakej PPB termasuk penggunaan kekacang penutup bumi, *Arachis pintoi*, dan pemangkasan pokok berjadual.

Terdapat peningkatan prestasi bagi petak kopi yang diurus mengikut sistem KPB, iaitu dari segi pengurangan kadar serangan kumbang dan peningkatan hasil kopi. Purata hasil kopi yang dikeluarkan dari petak KPB adalah sebanyak 25.9 t/ha., iaitu 23.7% lebih tinggi daripada petak kopi yang diurus di bawah sistem ala petani dan 23.3% lebih tinggi daripada petak di bawah sistem pengurusan biasa. Akan tetapi, kos pengeluaran sistem KPB juga turut meningkat, secara purata, 2.3 kali ganda berbanding dengan sistem ala petani dan 0.5 kali ganda berbanding dengan sistem konvensional. Terdapat sedikit peningkatan pulangan bersih bagi sistem KPB. Purata pulangan bersih meningkat sebanyak 7.3% berbanding dengan sistem ala petani dan 23.9% berbanding dengan sistem konvensional. Disimpulkan bahawa sistem KPB ialah satu kaedah yang berdaya maju untuk pengurusan kumbang pengorek buah untuk kopi Liberica di Malaysia, dan peningkatan berterusan pada sistem akan menjadikan sistem kawalan perosak ini lebih berkesan dan mapan dalam jangka masa panjang.

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