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The ecology of cocoa pod borer, *Conopomorpha cramerella* (Snellen) (Lepidoptera: Gracillariidae), in Malaysia: Dispersion pattern for eggs among trees

[Ekologi pengorek buah koko *Conopomorpha cramerella* (Snellen) (Lepidoptera: Gracillariidae) di Malaysia: Corak taburan telur di antara pokok]

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Key words: cocoa pod borer, dispersion pattern, sampling

Abstrak

Corak taburan telur ulat pengorek buah koko (UPBK) *Conopomorpha cramerella* (Snellen) pada buah koko di antara pokok-pokok telah dikaji. Di semua pokok di dua blok koko, bilangan telur pada buah-buah koko pada peringkat umur yang sesuai untuk UPBK bertelur (panjang >7 cm) telah dikira. Corak taburan telur didapati cenderung pada corak taburan yang berkelompok tetapi kepadatan purata telur pada tiap-tiap buah lebih merupakan rawak. Taburan bilangan telur pada buah di setiap pokok juga didapati berkelompok yang menunjukkan sebilangan pokok mempunyai telur yang lebih daripada pokok yang lain. Fenomena ini berlaku mungkin disebabkan oleh kekurangan buah yang peka di sebilangan pokok akibat variasi fenologi buah dan komposisi klon. Jumlah buah yang tidak diserang dalam sesuatu sampel ialah pengagak yang cekap untuk menentukan keseluruhan kepadatan telur UPBK.

Abstract

The egg dispersion pattern of cocoa pod borer (CPB), *Conopomorpha cramerella* (Snellen), on cocoa pods among trees was investigated. The number of eggs was counted on pods of susceptible egg-laying stage (>7 cm in length) on all trees from two cocoa blocks. The egg dispersion on pod tended to be highly contagious but the mean density of cocoa pod borer eggs per pod was more nearly random. It was also contagious (clumped) when the number of eggs per pod per tree was considered suggesting that some trees had more egg load than the others. The lack of susceptible pods on these trees, resulting from pod phenological and clonal variations, was suggested as one of the possible factors causing the observed phenomenon. The proportion of uninfested pods in a sample is an efficient estimator of overall egg density.

Introduction

The cocoa pod borer (CPB), *Conopomorpha cramerella* (Snellen) (Lepidoptera: Gracillariidae), is the most serious pest of cocoa in South East Asia. In the Malaysian state of Sabah, it was discovered in late 1980 in the Tawau district infesting about 5 000 ha of cocoa. Its presence in the

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Peninsular Malaysia was first discovered in September 1986 in Malacca (Anon. 1987). Since then, the pest is known to be present in all the cocoa growing areas in Malaysia except in a few smaller areas of the Peninsular's northeastern states of Terengganu and Kelantan.

Larvae which hatch from eggs deposited on the surface of cocoa pods, burrow directly into the pods to feed within the placenta. Since there is no feeding on the cocoa beans, infestation of fully ripened pods is not an economic problem to cocoa production. However, the penetration of the placenta in young pods causes retarded pod development and malformed beans which may not be extractable during harvest. The pest is insidious in that even a single burrowing larva may render a pod useless for harvest.

Since 1980, the biology of CPB and methods for its chemical and cultural control have been studied extensively in Malaysia (e.g. Lim et al. 1982; Day 1985; Azhar 1986a, b, c; Ooi et al. 1987; Azhar and Sabudin 1988; Tay et al. 1990). However, very little work has been carried out on procedures to estimate the density of CPB egg population. Azhar and Long (1991) reported the CPB egg distribution on pods and developed a sequential sampling protocol that saves time to estimate the egg population density. This paper is an extension of that work in comparing the distributions of eggs on pods and average CPB densities on trees in the development of a sampling protocol which allows for rapid and efficient survey of CPB egg densities. Specific questions asked were

- Are some cocoa trees more likely to be infested with CPB than others?
- Will CPB egg density be more efficiently estimated by sampling larger numbers of pods from fewer trees or fewer pods from more trees?

Materials and methods

Numbers of CPB eggs per pod were recorded from 60 trees in each of the two blocks of hybrid cocoa at the Department of Agriculture Sabah's Cocoa Research Station, Quoin Hill, about 38 km northeast of Tawau, Sabah during August 1985 and again during January 1986. This was approximately mid-way between successive harvest (peak) periods. Then in April and May 1986, just prior to harvest during the peak period, both blocks were sampled again. Within each tree, all cocoa pods of susceptible stage (>7 cm in length) were inspected for CPB eggs (Azhar and Long 1991).

Frequency distributions for (i) number of eggs per pod for all trees combined, each block, each sampling date, and (ii) average eggs per pod per tree, in integral classes (0 to 0.99, 1.0 to 1.99, etc.), for each of the six sampling dates (three in each block) were characterized by calculating the mean, variance and negative binomial parameter k (Long and Theroux 1979). A common k was calculated (Bliss 1958; Bliss and Owen 1958) and tested for homogeneity (Southwood 1978). Analysis of variance and simple linear regression (Woolf 1968) were used to test relationships between statistics and observed mean densities.

Results and discussion

Over 24 643 pods were inspected among the six samples. Mean densities ranged from 0.44 to 3.67 eggs per pod (*Table 1*), with variances about three times the mean. This would indicate that the distribution of eggs per pod was not random for any sampling date. The numbers of eggs per pod ranged up to 32 although 97.6% of the pods had nine or fewer eggs. The negative binomial parameter k shows the distributions were similar between blocks during each sampling time, but differed markedly for the same block at different times. Fractional values for k indicate contagious dispersion patterns at the four lower densities. Thus, the best description for frequencies of eggs per pod was an exponential decay function (*Table 2*). The reciprocal of the common k was significantly linearly related to the

Table 1. Number of pods with the indicated number of CPB eggs and statistics used to describe the distribution of CPB eggs per cocoa pod for two plots, blocks 14 and 22, each sampled at three times from 1985 to 1986

No. of eggs per pod	No. of pods					
	14 Aug	22 Aug	14 Jan	22 Jan	14 Apr	22 May
0	481	509	1 071	1 619	7 128	2 913
1	430	477	696	628	652	339
2	366	418	283	261	554	249
3	362	381	290	207	218	130
4	261	280	260	178	116	31
5	249	238	127	66	33	13
6	289	266	114	64	54	9
7	172	173	94	42	35	2
8	85	79	64	16	10	0
9	105	77	58	10	7	0
>10	140	93	53	5	10	7
Total no. of pods	2 940	2 991	3 110	3 096	8 817	3 793
Mean	3.67	3.32	2.23	1.22	0.44	0.44
Variance	10.11	8.07	8.58	3.30	1.41	1.07
Neg. binomial k	2.09	2.32	0.78	0.72	0.20	0.27

Table 2. Exponential model best fit to the frequency distribution of eggs per cocoa pod for each sampling date in both blocks 14 and 22. *y* and *x* represent number of pods and eggs per pod classes

Sampling date	Exponential model	r^2
14 Aug	$y = 518.32*10^{-0.069x}$	0.83
22 Aug	$y = 617.32*10^{-0.089x}$	0.90
14 Jan	$y = 759.87*10^{-0.128x}$	0.95
22 Jan	$y = 1\,169.39*10^{-0.229x}$	0.98
14 Apr	$y = 1\,913.50*10^{-0.226x}$	0.91
22 May	$y = 788.55*10^{-0.286x}$	0.83

logarithm of mean number of eggs per pod ($r^2 = 0.86$; $p< 0.05$, $F[1,4] = 23.9$) and, therefore, is not useful for developing an overall sampling protocol (Southwood 1978).

The number of cocoa trees bearing pods and, therefore, examined varied from 868 to 1 195 in a sample, comprising a total of 6 259 sample trees. Estimated average eggs per pod were similar whether all pods in a sample were pooled, or means per tree were pooled. When pods from each tree in a sample were pooled, larger values for k indicated that distributions of average eggs per pod per tree were much less contagious, except at the lowest densities (*Table 3*).

The proportion of pods without eggs was inversely related to overall egg population density in a block (*Table 4*) although the relationship may be non-linear at densities outside the range encountered in the study. The proportion of trees with an average of less than 1 egg/pod was also inversely related to overall density, but the relationship may not be as reliable as the one above. It is not known what the economic threshold for CPB egg per pod should be. A plantation with an overall density of about 1 egg/pod may have a large proportion of pods that have not been infested. However, this situation may only be true during the early part of cropping season as many pods are still in their early phenological development. It may not be necessarily so during later part of the cropping season because all pods essentially may have received more than one eggs as the cropping season progressed, or during the trough period when pods are small in numbers and gravid females are forced to oviposit on any available pods.

Table 3. Number of trees with the indicated number of CPB eggs per pod and statistics used to describe the distribution of CPB eggs per cocoa pod per tree for two plots, blocks 14 and 22, each sampled at three times from 1985 to 1986

No. of eggs per pod	No. of trees					
	14 Aug	22 Aug	14 Jan	22 Jan	14 Apr	22 May
0	97	74	242	486	1 009	822
1	172	196	308	350	160	99
2	171	156	246	162	17	10
3	159	150	157	42	1	4
4	140	113	98	24	1	4
5	106	69	43	8	2	2
6	76	48	27	1	1	1
7	50	24	11	2	1	0
8	19	17	6	3	0	0
9	16	11	2	1	0	0
>10	22	10	7	2	1	0
Total no. of trees	1 028	868	1 147	1 078	1 195	943
Mean	3.65	3.30	2.28	1.20	0.42	0.34
Variance	5.94	4.69	4.54	1.29	0.60	0.53
Neg. binomal k	5.82	7.83	2.30	16.00	0.98	0.61

Table 4. Predictors of overall density of CPB eggs per pod for all samples combined

Predictor	Intercept	Coeff. of regression	F(1,4)	r^2
Proportion of pods without eggs	4.10	–4.76	99.4	0.96
Proportion of trees with <1 egg/pod	3.50	–3.84	46.2	0.92
Negative binomial k egg/pod	0.311	1.47	36.1	0.90

Although contagion decreased when tree means were considered, large contributions to the value of Chi-square would come from the rare trees which have high egg densities when the best poisson fit to any of the samples is examined *(Figure 1)*. Furthermore, the results show that at the lowest overall densities individual trees cannot be considered poisson quadrats. That is, at very low levels of CPB egg density, trees are not attacked randomly but certain trees are more likely to be infested than the others (*Table 3*). Because the number of trees examined is large and, therefore, degrees of freedom are high, the occurrence of a few trees with high CPB egg density is sufficient to reject the hypothesis of randomness. These rare trees may have resulted from any of several causes including varying susceptibility of tree of different clones to attack (Azhar et al. 1995). The preference for egg-laying on pods of more than 3 months old (Azhar and Long 1996) may also explain for the aggregated spatial distribution of the CPB oviposition. The presence of non-bearing trees within the blocks and the variability in fruiting phenology, resulting in the differential presence of more susceptible pods on certain trees than the others, are other possible factors explaining for the aggregated distribution of CPB eggs on pods.

Currently, MARDI recommends a minimum of five cocoa clones in cocoa plantations for adequate pollination (Sapiyah, S., MARDI, Hilir Perak, pers. comm. 1995). Sampling every tree or even

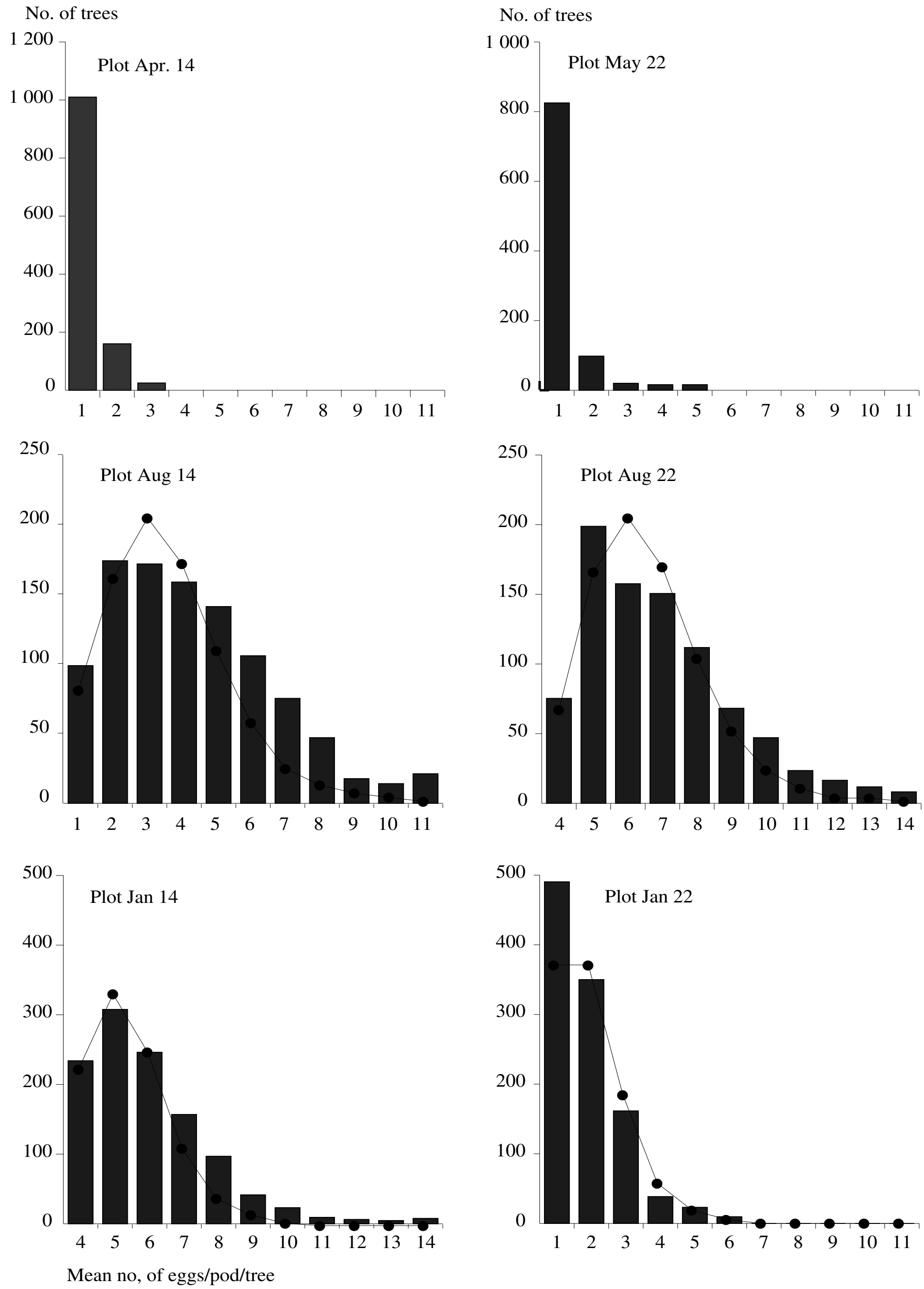

Figure. 1. Histograms showing numbers of trees with the indicated average eggs per pod per tree in integral classes (0 to 0.99, 1.0 to 1.99, etc), for each of the 6 samples. The curve represents the best poisson fit to each histogram. A few trees with high CPB densities cause rejection of the null hypothesis that averages are randomly distributed among trees.

every clone in a commercial block each time the block is surveyed for CPB eggs is not likely to occur. From a practical standpoint, it appears reasonable to estimate the frequency of pods without eggs by examining a few pods on several trees as quickly as possible, and then to estimate overall mean density from the regression in *Table 4.*

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