PUPATION AND ADULT EMERGENCE OF THE COCOA POD BORER, *Conopomorpha cramerella* (SNELLEN) AFTER TREATED WITH DELTAMETHRIN AND CYPERMETHRIN INSECTICIDES

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ABSTRACT - *Insecticide application is still preferable by the Malaysian cocoa growers in managing Conopomorpha cramerella. Two commonly used insecticides, Deltamethrin and Cypermethrin, were tested at three concentrations (1%, 2%, and 4%), and a comparison was made with water as a control. Insecticides were sprayed on the cocoa pod surface, and the numbers of pupa emerged, and adult emergence was recorded. Ten cocoa pods were selected for each treatment, and the study was replicated three times. Observations on pupa emergence were carried out from Day-1 through Day-14. The percentage of pupa emergence was the highest at Days-7 and 10, and the least was observed at Day-13 (0.00%) and Day-12 (1.82%). The pupation period was shortest at control (4 days), and the longest was nine days at Cypermethrin 1%, Deltamethrin 1, and 2%. The early emergence of adults resulted in a lighter weight of C. cramerella where the shortest pupation period (4 days) was only 0.0014 ± 0.0003 b and significantly different with a more extended pupation period. Days 5 and 6 recorded heavier adults with 0.0027 ± 0.0005 a. Contrary to pupa weight, no significant difference in adult weight was obtained from both Deltamethrin and Cypermethrin. These results suggested that insecticide spraying on the cocoa pods shows no negative impact due to their cryptic behavior, which the larvae spend their entire life inside the pods. The cocoa pod's insecticide residue fewer influences pupation due to the tendency to pupate on a less treated area than the pod surface.*

Key words: Cocoa pod borer, cypermethrin, *Conopomorpha cramerella,* deltamethrin, pupation, adult emergence

INTRODUCTION

Substantial pest infestations and disease occurrences are among the factors that contributed to the low productivity of cocoa. Pest and disease problems might inflict the healthy beans, low yields, dead trees, and severe repercussions on the income per hectare basis. The primary factor concerning the cocoa productivity in the Southeast Asia region is mainly contributed by the infestation of the cocoa pod borer, *Conopomorpha cramerella* Snellen (Lepidoptera: Gracillariidae) that caused substantial economic losses to the growers. The female *C. cramerella* can deposit random or aggregate eggs on the cocoa pod at the minimum size of 70 mm (Saripah, 2019). The egg will hatch within 2 to 7 days, and most preferably within 72 hours after the deposition. The early larva then tunnels into the pod, feeds on the mucilage and placenta, leaving brownish dark frass inside the pod. Cryptic behavior of *C. cramerella,* which spends their entire larva stage inside the pod, thus ensures they are fully protected from any control approach. Pre-pupa emerges after 14 to 20 days, quickly construct a cocoon as a physical barrier, and rest for approximately 6 to 7 days. Pupation occurs outside the pod within the oval-shaped silken cocoon on another part of the canopy, on the furrow of the pod, green or dried leaves, and other debris (Saripah *et al*., 2019b). There was a tendency that the pre-pupa might wander away and pupate on the different material if the cocoa pod is treated with insecticide or treatments (Saripah *et al.*, 2019a). The entire life stage of *C. cramerella* is complete with the emergence of an adult moth that generally lived for a week.

Pesticides become the preferable control by the cocoa growers to reduce the risk of insect infestation. Growers usually applied pesticides to limit their yield and monetary losses, supported by a broad range of pesticides offered in the market (Tijani, 2006). Concern on the safe use of pesticides was gained since the 1970s, where several chemicals were banned in developing countries; this issue also derived into attention started in the early 21st century (Bateman, 2015). Unfortunately, the Nigerian cocoa farmers widely applied some high-risk insecticides such as benzene hexachloride (BHC), aldrin, dieldren, carbamate, unden, and gamma BHC (Tijani, 2006). Meanwhile, 96.8% of the respondents used pesticides on their farms in Cameroon, and 22.5% continued to apply endosulfan even the insecticide was restricted since 2008 (Mahob *et al*., 2014). Some farmers were constantly using banned active ingredients (benomyl, propoxur, methyl-parathion, fenobucarb, profenofos, cartap, and diazinon) in their cocoa plantations.

In an attempt to reduce the infestation of *C. cramerella*, the use of pesticides is a common practice and often dependent on the economic circumstances of the farmer. Cocoa growers are keen to implement insecticide spraying due to their quick action and availability in the market. Spraying is usually conducted using manual knapsack sprayers due to their suitability where cocoa trees are not too tall, small area, and limited resources (Saripah, 2014). A study has also compared two different spraying paraphernalia, knapsack, and thermal fogger, as Saripah and Alias (2020) reported. However, insecticide's effectiveness is associated with the active ingredients, spraying apparatus, and depending on the appropriate timing of spraying. The use of chemicals as a control measure against *C. cramerella* is considered the most reliable and effective method, with an estimated one year of operational cost (24-rounds /ha) of RM 1,367 (Ling, 2013). Growers always believe in the success of pesticides to suppress some insect species and sustain healthy crops; thus, they may be reluctant to avoid pesticides (Bateman, 2015). Fortnightly spraying is adopted, although two or three spraying programs were recommended per year during the two ascending peak cropping periods and another optional spraying during the trough period (Sidhu *et al*., 1987). The spraying calendar should be made according to the level of infestation rather than on a fixed schedule basis. Smallholders that apply prophylactic spraying based on a fixed bimonthly calendar regardless of the current status of the infestation; might suffer from high input and management costs and pest resistance. Heavy reliance on insecticides in managing *C. cramerella* was observed started in the 1990s (Beevor *et al*.,1993).

Pyrethroids group is among the most common uses of insecticides worldwide, accounting for more than 30% of global use (Shukla *et al.*, 2002). Insects of the order Lepidoptera, Coleoptera, Diptera, and Hemiptera were mainly controlled using these synthetic pyrethroids. Pyrethroids are also recorded as the most popular insecticide used against *C. cramerella* (Azhar *et al*., 2000). In Malaysia, the insecticide used in managing this notorious pest was deltamethrin, alphacypermethrin, cypermethrin, and chlorpyrifos (Lee *et al.,* 2013; Saripah, 2014). Among them, the most common insecticides are deltamethrin and cypermethrin (Lee *et al.,* 2013). Cypermethrin is from the pyrethroid group and was first synthesized in 1974. Cypermethrin works by quickly affecting the insect's nervous system and kill insects that eat or come into contact with their particles (NPIC, 1998). Cypermethrin is reported to have high toxicity to fish and bees and is very highly toxic to water insects. Deltamethrin also belongs to the pyrethroid family, and the manufactured versions of pyrethrin, a natural insecticide from chrysanthemum flowers, entered the marketplace in 1978 (NPIC, 2010). The mode of action of deltamethrin is by direct contact or through digestion. This active ingredient is not likely to evaporate into the air or dissolve easily in water, moderately to highly toxic to fish and honeybees under laboratory conditions. Still, the formulated products had a repellent effect that lasted two to three hours in the field studies.

Application of deltamethrin in managing *C. cramerella* was tested for 24-months, and the effectiveness was slightly below compared to the Cocoa black ants, *Dolichoderus thoracicus* throughout observation in both peak and drought pod seasons (Saripah, 2014). Meanwhile, in other observation, screening of seven different active ingredients of insecticides (thiamethoxam, fipronil, emmamectin benzoate, kaolin, the combination of kaolin and deltamethrin, deltamethrin and chlorantraniliprole) were undertaken for 12-months, denoted that deltamethrin was listed among the best active ingredients in term of good wet beans and Average Damage Severity Index (ADSI) values (Saripah and Alias, 2016).

Even several studies in controlling *C. cramerella* were carried out using insecticides in Malaysia, very little research was embarked on the pupation and adult emergence of *C. cramerella* after the pod surface was treated with treatments. The observation of insecticide effectiveness usually focuses on the ADSI values, the percentage of good pods, wet and dry bean weight, and the infestation parameters (egg sampling, entry holes, exit holes, and damage category). Therefore, the objective of this study is to evaluate the pupation rate and successful adult emergence after pods were treated with different rates of insecticide from deltamethrin and cypermethrin active ingredients. The study was attentive to the pupa emergence at the different days of observation, the pupation period, and the adult's weight after emerged from the pupa.

MATERIALS AND METHODS

Observation on the pupation and adult emergence of *C. cramerella* after being treated with insecticides were commenced at the Cocoa Research and Development Center (CRDC), Malaysian Cocoa Board, Jengka, Pahang, Malaysia (Longitude 100° 30' 31.64" E, Latitude 3° 36' 59.73° N). Two different active insecticide ingredients were tested, one of each deltamethrin (Trade name: BM Deltamethrin, 3.8% w/w, Behn Meyer Agricare (M) Sdn. Bhd) and cypermethrin (Trade name: ENVO-CYPER, 5.5 % w/w, Imaspro Biotech Sdn. Bhd). Another name, chemical formulation, class or family, and source of reference for both active ingredients were described in Table 1. Deltamethrin and cypermethrin were tested at three concentrations (1%, 2%, and 4%), and a comparison was made with water as a control. Ten mature cocoa pods with the symptoms of infestation, approximately 5.0 to 5.5 months old, were selected for each treatment. The pods were clean using wet tissue and placed inside the insect cage. Insecticides were diluted to exceed 1000 ml of concentrated and placed in the plastic bottle sprayer. Insecticides were sprayed on the cocoa pod surface at a range of 15 cm, the number of pupae that emerged and adult emergence was recorded at 24-hour intervals. The study was replicated three times. Observations on pupa emergence were carried out from Day-1 through Day-14. The data collected were the percentage of pupation, days of emergence, pupation period, and weight of *C. cramerella* adult. Data were arranged separately in Microsoft® Excel 2007, subjected to statistical analysis using Analysis of Variance (ANOVA) and PROC GLM, SAS software from SAS® Version.

Table 1. Another name, chemical formula, and class/family of cypermethrin and deltamethrin active ingredients

Active ingredients	**Another name**	**Chemical formula**	**Class/Family**	**Source of reference**
Cypermethrin	[Cyano-(3-phenoxyphenyl)methyl]3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropane-1-carboxylate	$C_{22}H_{19}Cl_2NO_3$	Pyrethroid	National Pesticide Information System Center (NPIC, 1988) http://npic.orst.edu/factsheets/cypermethrin.pdf
Deltamethrin	[(*S*)-Cyano-(3-phenoxyphenyl)-methyl] (1*R*,3*R*)-3-(2,2-dibromoethenyl)-2,2-dimethyl-cyclopropane-1-carboxylate	$C_{22}H_{19}Br_2NO_3$	Pyrethroid	National Pesticide Information System Center (NPIC, 2010). http://npic.orst.edu/factsheets/DeltaGen.pdf

RESULTS AND DISCUSSIONS

The results on the day of emergence and the number of pupae that emerged at different treatments were evaluated and denoted that the *C. cramerella* could pupate from Day-1 through 11 at Deltamethrin 1%. Meanwhile Day-4 through 14 at Deltamethrin 2%, Day-3 through 10 (Deltamethrin 4%), Cypermethrin 1% (Day-2 through 14), Day-8 through 11 (Cypermethrin 2%) and Day-1 through 14 from Cypermethrin 4%. Meanwhile, the percentage of pupa emergence regardless of the treatment was fluctuated (Figure 1), and the highest was recorded at Days-7 and 10 (18.18%). The least pupation was observed at Day-13 (0.00%) and Day-12 (1.82%). These results might suggest that even insecticide spraying was targeted on the cocoa pod surface, *C. cramerella* was still able to bear out from treated pods and successfully pupate either on the pod surface or dry cocoa leaves. *C. cramerella* was also able to pupate even from the rotten cocoa pods for the next 14 days.

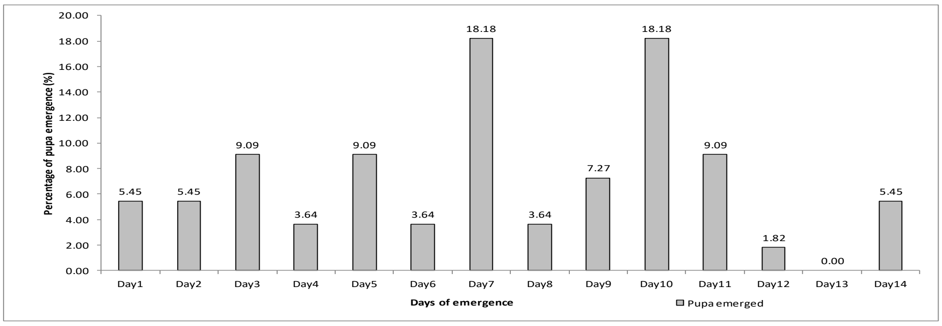

Figure 1. Percentage of pupa emerges at different days of observation

Percentage of pupa emergence shows the highest at Deltamethrin 4% (23.64%), followed by Deltamethrin 1% (21.82%), Deltamethrin 2% (14.55%) and Cypermethrin 4% (14.55%). The lowest percentage of pupa emergences was recorded in control, 7.27 % (Figure 2).

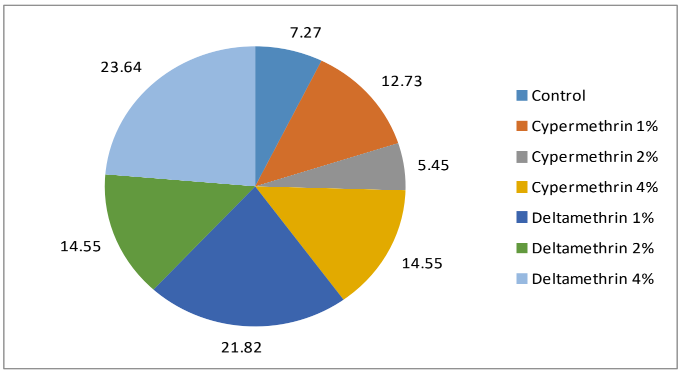

Figure 2. Percentage of pupa emergence of different treatment

The pupation period and the weight of *C. cramerella* adult are shown in Table 2. *C. cramerella* underwent 4 to 8 days of pupation period in control, 5 to 9 days in Cypermethrin treatments, and 5 to 9 days in Deltamethrin treatments (Table 2). The shortest period was recorded in the control (4 days), and the most prolonged pupation period was nine days at Cypermethrin 1%, Deltamethrin 1, and 2%.

Table 2. Pupation period and the weight of *C. cramerella* adult

Treatment	Pupation period	Weight of *C. cramerella* adult
Control	4	0.0014
	6	0.0022
	8	0.0022
Cypermethrin 1%	5	0.003
	6	0.0025
	7	0.0028
	9	0.0018
Cypermethrin 2%	6	0.0021
	7	0.0022
Cypermethrin 4%	5	0.0025
	6	0.0026
	7	0.0024
Deltamethrin 1%	5	0.0027
	6	0.003
	7	0.002

	8	0.0022
	9	0.0026
Deltamethrin 2%	6	0.0027
	7	0.002
	8	0.0031
	9	0.0019
Deltamethrin 4%	5	0.0029
	6	0.0028

The results obtained from this study denoted that the early emergence of adults will result in a lighter weight of *C. cramerella* (Table 3). The weight of an adult *C. cramerella* with the shortest pupation period (4 days) was only 0.0014 ± 0.0003 b and significantly with a more extended pupation period. Days 5 and 6 recorded heavier adults with 0.0027 ± 0.0005 a. However, regardless of the different treatments applied in this study, the results denoted no significant difference in adult weight obtained from both deltamethrin and cypermethrin active ingredients (Table 4).

Table 3. Adult *C. cramerella* weight at different pupation period

Pupation period	Adult *C. cramerella* weight (gram)
4 days	0.0014 ± 0.0003 b
5 days	0.0027 ± 0.0005 a
6 days	0.0027 ± 0.0005 a
7 days	0.0023 ± 0.0005 a
8 days	0.0026 ± 0.0004 a
9 days	0.0022 ± 0.0004 a

Table 4. Adult *C. cramerella* weight at different treatments

Treatment	Adult CPB weight (gram)
Cypermethrin 1%	0.0020 ± 0.0003 a
Cypermethrin 2%	0.0025 ± 0.0004 a
Cypermethrin 4%	0.0024 ± 0.0004 a
Deltamethrin 1%	0.0025 ± 0.0006 a
Deltamethrin 2%	0.0026 ± 0.0078 a
Deltamethrin 4%	0.0027 ± 0.0005 a

The pre-pupa emerged from the treated pods from Day-1 through Day-14 regardless of the different concentrations of cypermethrin and deltamethrin. This result might suggest that even though the pod surface was treated at a high concentration, pupae could successfully bore from inside the pod to the surface. The emergence of *C. cramerella* pupae were the highest after Day 6, and this was in agreement with the observation from Saripah (2019) when the number of pupae was the highest at Day-8 after being treated with Zingiberaceae treatments. Therefore, it is not advisable to pluck the infested pods and leave it on the ground, even after it is treated with insecticide. Bagging the infested pod or leftover pod husk inside the plastic bag or gunny sack is recommended to break the cycle of this Lepidopteran.

Insecticides were applied mainly to control the *C. cramerella* eggs and adult moths; however, it was unsuccessful in targeting the larva due to their insidious characteristic, which feeds inside the pod. In agreement with this, the chemical control against the larvae of the cotton pink bollworm, *Pectinophora gossypiella*, is usually ineffective because they feed within the fruiting bodies protected (Hill, 1983). The insecticide particle may stay on the surface and did not able to penetrate to the inner layer of the cocoa pod husk. Therefore, as expected, the cryptic behavior of the larva can ensure that they are safe and might be fully protected from any treatment throughout their feeding process. The spraying may not be targeted directly at the larvae, and there might be a time lag between the application and effect (Wood *et al*., 1992). The larva is the only fully protected stage compared to the eggs, pupa, and adult stages.

The presence of a suitable substrate is critical to complete the pupal-adult metamorphosis of insects (Wang *et al*., 2018). Saripah *et al*., (2019b), in their observation, reported that the preference of an adult *C. cramerella* to deposit egg might be lesser when higher insecticide residue is found on the pod surface. This deterrence action might be due to the greater chance of egg survival when low treatment residue is located on the cocoa pod. As escapism from the residue of treatments on the pod surface, *C. cramerella* shows the tendency to pupate on materials other than the pod surface. Most of the newly-emerged pupa will crawl to find a convenient place for pupation. This pre-pupa tends to wander away from areas with the presence of organic or non-organic particles. Pupa tends to be more exposed to treatments or management approaches than the larva stage, especially during their early pupa emergence (Saripah *et al*., 2019a). The number of *C. cramerella* pupation on cocoa pods was lower than cocoa leaves regardless of different treatments through their 10-days of observation. The cocoa leaves that adjacent to the cocoa pods might be preferable by the pre-pupae construct their silken cocoon. This escaping action may reduce pupation on pods, compared to the dry cocoa leaves where treatment did not directly spray onto the surface.

Despite repeated insecticide treatments following the recommended calendars by the manufacturer, the infestation caused by *C. cramerella* continues to cause an unacceptable level of damage. The damage may be influenced by the oviposition preference to laying the egg on the pod free from treatments or pod in the area that can hide or escape during spraying. In the natural field, it is challenging to ensure all the pod surface is covered by the spraying particles due to the pod location itself, compared to the experiment conducted in the laboratory. The pod hanging on the branch is easier to be sprayed and susceptible to more spraying coverage than the pod on the trunk or located in the dense cocoa canopy.

CONCLUSIONS

The results suggested that insecticide spraying on the cocoa pods shows a negative impact due to the cryptic behavior of *C. cramerella*, which the larvae spend their entire life inside the pods. With minimum time outside the pod as a prepupa, the pupation is less influenced by the insecticide residue on the pod surface due to the tendency to pupate on a less treated area, the cocoa leaf. Different active ingredients of insecticide and different concentrations provide almost similar results for the adult weight of *C. cramerella*, where no significant difference was observed in this study.

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