EFFECT OF SIX INSECTICIDES ON OIL PALM POLLINATING WEEVIL, *Elaeidobius kamerunicus* (COLEOPTERA: CURCULIONIDAE)

Norhayu Asib* & Nurnisa Nabilah Musli
Department of Plant Protection, Faculty of Agriculture,
Universiti Putra Malaysia, 43400 Serdang Selangor, Malaysia.
*Corresponding author: *norhayuasib@upm.edu.my*

ABSTRACT

The oil palm pollinator, *Elaeidobius kamerunicus* is a weevil that belongs to Curculionidae It has been found to have the highest capacity for efficient insect pollinator of oil palm. In order to control the damage from reaching or nearing the economic threshold level (ETL), planters are left with the option to use insecticides due to its fast action. Therefore, in this study the efficacy of chlorantraniliprole, cypermethrin, flubendiamide, *Bacillus thuringiensis*, cnidiadin and *Isaria fumosorosea* were tested on oil palm pollinator, *E. kamerunicus*. The pollens and pollinators were collected from FELDA Besout, Perak, Malaysia. Adult of *E. kamerunicus* were exposed to the insecticides residue and mortality was observed at 24, 48, 72 and 96 hours after exposure. The percentage of mortality *E. kamerunicus* was recorded to determine the insecticides efficacy. Mortality of *E. kamerunicus* was highest when exposed to cypermethrin and chlorantraniliprole with 100% mortality of the population, followed by flubendiamide (42%), *B. thuringiensis* (39%), cnidiadin (11%), *I. fumosorosea* (3%) and control (2%) at 96 hours post-exposure. Cypermethrin gave the shortest LT_{50} to killed *E. kamerunicus* at 17 hours, followed by chlorantraniliprole, flubendiamide and *B. thuringiensis* which were 31, 136 and 137 hours, respectively. Whilst, lethality index of cypermethrin showed the highest value, which was 91.50%, followed by chlorantraniliprole (76.50%), flubendiamide (27.25%), *B. thuringiensis* (25.25%), cnidiadin (5.25%) and *I. fumosorosea* (1.75%).

Keywords: Insecticide, *Elaidobius kamerunicus,* lethal time, mortality, lethality index.

ABSTRAK

Pendebunga kelapa sawit, *Elaeidobius kamerunicus* merupakan kumbang yang tergolong di bawah famili Curculionidae. Ia dikenalpasti sebagai serangga pendebunga kelapa sawit yang sangat cekap. Bagi memastikan kerosakan kelapa sawit tidak mencapai dan menghampiri aras ambang ekonomi (EIL), pengusaha kelapa sawit menggunakan racun serangga yang memberi kesan yang lebih cepat. Oleh itu kajian ini dijalankan bagi mengukur keberkesanan chlorantraniliprole, cypermethrin, flubendiamide, *Bacillus thuringiensis*, cnidiadin dan *Isaria fumosorosea* ke atas kumbang pendebunga, *E. kamerunicus.* Debunga dan kumbang pendebunga diambil dari FELDA Besout, Perak, Malaysia. *Elaeidobius kamerunicus* dewasa didedahkan pada residu racun serangga dan kematian kumbang diperhatikan pada tempoh 24, 48, 72 dan 96 jam selepas rawatan. Peratusan kematian *E. kamerunicus* direkod bagi menentukan keberkesanan racun serangga. Kematian *E. kamerunicus* yang tertinggi adalah apabila terdedah pada cypermethrin dan chlorantraniliprole dengan 100% kematian populasinya, diikuti oleh flubendiamide (42%), *B. thuringiensis* (39%), cnidiadin (11%), *I. fumosorosea* (3%) dan kawalan (2%) pada tempoh 96 jam selepas rawatan. Cypermethrin didapati mempunyai masa maut, LT_{50} yang paling singkat bagi membunuh *E. kamerunicus* iaitu selama 17 jam, diikuti oleh chlorantraniliprole, flubendiamide dan *B. thuringiensis* di mana masing-masing mengambil masa 31, 136 dan 137 jam. Cypermethrin mempunyai nilai indeks maut yang tertinggi iaitu 91.50%, diikuti oleh chlorantraniliprole (76.50%), flubendiamide (27.25%), *B. thuringiensis* (25.25%), cnidiadin (5.25%) dan *I. fumosorosea* (1.75%).

Kata kunci: Racun serangga, *Elaeidobius kamerunicus*, masa maut, kematian, indeks maut.

INTRODUCTION

Elaeidobius kamerunicus Faust (Coleoptera: Curculionidae) also known as the African oil palm weevil was introduced into Malaysia in 1981 (Hussein et al. 1991). The purpose of this introduction was to increase the fresh fruit bunches by improving the method of pollination. Initially, oil palm plantations in Malaysia relied mainly on wind and insect pollination. But these insect pollinators such as *Thrips hawaiiensis* and *Pyroderces* sp were found to be less effective (Wahid and Kamarudin 1997). Hand pollination was then developed to improve yield. It was found that *E. kamerunicus* was the most suitable of all pollinator species as it was the most copious in both wet and dry seasons. It also has the highest capacity for efficient insect pollinator among all pollinators (Syed 1979). Hence, *E. kamerunicus* was introduced into Malaysia in 1980 and this took place in Johor and Sabah Pamol Plantations (Syed et al. 1982).

In a few short years, it was found that the weevils were able to multiply and spread rapidly in oil palm plantations nationwide. Thus, hand pollination was soon canceled in most parts of the country. Despite the rapid growth of the industry, the oil palm remains vulnerable to threats of various pests. Norman and Basri (2007) was reported that the most widely disseminated of bagworm species is *M. plana* followed by *P. pendula* in oil palm plantations in Peninsular Malaysia. The chemical control was widely used for controlling bagworm abundance in oil palm plantation due to fast action. The common insecticides used in oil palm plantations are chlorantraniliprole, cypermethrin, flubendiamide and *Bacillus thuringiensis*. However, the use of pesticides over the past five decades has led to a range of problems in agriculture, the environment and human health (Geiger et al. 2015). Additionally, not many people, especially smallholders, are aware if the insecticides they use have an effect on non-target or beneficial insects such as *E. kamerunicus*. Therefore, the aim of this study was to examine the efficacy of six insecticides on the oil palm pollinating weevil, *E. kamerunicus*. The outcome of this study will enable plantations to plan the best solution in controlling insect pest populations without harmful effects towards non-target organisms.

MATERIALS AND METHODS

The pollinating weevils, *E. kamerunicus* were obtained from male inflorescences of oil palms collected from FELDA Gunung Besout 4, Perak (3.7833° N, 101.2746° E). There were seven treatments used in this experiment; which included water as a control and six insecticides with different active ingredients. The active ingredients were chlorantraniliprole, cniadin, cypermethrin, flubendiamide, *Bacillus thuringiensis* and *Isaria fumosorosea*. The dosage applied is equivalent to the manufacturer's recommendation rate. Then, it was sprayed on the filter paper by using a hand sprayer. The filter papers were conceded to dry in the petri dish (150mm x 150mm) for two hours. Ten adults of *E. kamerunicus* were placed into a treated petri dish and represented as one replication. There were ten replications for each treatment. These experiments were observed for 24, 48, 72 and 96 hours after exposure. The number of mortality and alive *E. kamerunicus* were counted and recorded. It was considered alive when the weevil had the ability to move without any sign of uncoordinated or uncontrolled actions, while the criteria of the mortality when there was no movement and no response observed. This method was used to measure the effects of each insecticides against *E. kamerunicus* in the oil palm plantation.

Parameters

Insecticide Efficacy

The percentage of mortality weevils was used to measure insecticide efficacy of each insecticide against adult *E. kamerunicus* at 24, 48, 72 and 96 hours. Counts of moribund and mortality individuals were combined to calculate E_t (final efficacy) based on the fact that a moribund insect cannot play its role as a pollinator (Leskey et al. 2012).

Final vs Initial Efficacy (E_4 vs E_0)

The relationship between initial and final efficacy for each insecticide was examined by plotting the seven treatments for the initial efficacy at 24 hours (E_0) on the x -axis and the final efficacy at 96 hours (E_4) on the y-axis by using Microsoft Excel. From this, insecticides were grouped based on the magnitude of their initial efficacy (E_0), as well as the change after 96 hours ($E_4 – E_0$). The initial insecticide efficacy was classified as 'low', 'moderate', or 'high'. The low and high efficacy intervals were set as $E_0 \leq 10\%$ and $E_0 \geq 90\%$ respectively. The categories were established to show that the two ends, $E_0 \leq 10\%$ and $E_0 \geq 90\%$ represented very low and highly harmful insecticide towards initial impact on adult oil palm pollinating weevils, *E. kamerunicus.*

Furthermore, the changes of insecticide efficacy over the 96 hours period (E_4–E_0) were classified as 'stable', 'increasing' or 'decreasing'. The insecticide was classified as stable when the efficacy difference was within ±10% from the initial efficacy, E_0. If the efficacy value changed by >10% after 96 hours, it was classified as increasing ((E_4-E_0) >10%) or decreasing ((E_4-E_0) <-10%). In addition, the insecticide cannot be stated as decreasing when the initial efficacy value is low ($E_0 \leq 10\%$) because efficacy cannot decrease by >10% from the initial value. Similarly, the insecticide cannot be stated as increasing when the initial efficacy value is high ($E_0 \geq 90\%$) as efficacy cannot increase by >10% from the initial value.

Lethality Index

Lethality Index was used to compare the effect of insecticide on adult *E. kamerunicus,* over time after exposure. The lethality index was calculated using the following equation; (Leskey et al. 2012).

$$= (\text{No of adult alive} \times 0.0) + (\text{No of adult dead} \times 1.0)/\ (30 \times 3\ \text{days}) \times 100$$

This equation assigns a value of 1.0 or 0.0 to individuals classified as mortality or alive. Therefore, insecticides with a slow effect on the insects will have a lower lethality index value.

Statistical Analysis

The lethal time causing 50% mortality (LT_{50}) was estimated by EPA probit analysis. Data from the experiment were analysed using ANOVA Complete Randomized Design (CRD). The mean statistical significant difference was determined by Tukey test ($p<0.05$) by using Statistical Analysis System (SAS) program, software version 9.4.

RESULTS AND DISCUSSION

Insecticide Efficacy, Et

The calculation of insecticide efficacy, E_t was based on the percentage ~~of~~ mortality of adult *E. kamerunicus* after exposure to insecticides for 24, 48, 72 and 96 hours. The insecticide efficacy, E_t was plotted over time (hours) in the x-axis and percentage of efficacy in the y-axis for each of the insecticide tested (Figure 1). The insecticide efficacy for cypermethrin and chlorantraniliprole were increased from 71%, 97%, 99% and 100% mortality for 24, 48, 72 and 96 hours exposure. Flubendamide and *B. thuringienensis* in the range value 10% to 42% of mortality for insecticide efficacy at 24, 48, 72 and 96 hours exposure. However, cniadin and *I. fumosorosea* gave the lowest insecticide efficacy value, 0% to 11% mortality of *E. kamerunicus* at 24, 48, 72 and 96 hours exposure. This result was proven by Yusdayati and Hamid (2015) which showed that cypermethrin caused the highest mortality rate of *E. kamerunicus* by achieving 100% mortality on the first day after application. According to previous research by Cox (1996), cypermethrin is a broad-spectrum insecticide and therefore can kill a wide range of insects. Bassi et al. (2007) stated that chlorantraniliprole is fundamentally effective on chewing pests through ingestion and by contact. However, the best method to enhance the survival of pollinators is by avoiding the use of toxic materials (Fishel 2017). The effects of flubendiamide and *B. thuringiensis* on *E. kamerunicus* were not comparable to those of cypermethrin and chlorantraniliprole. Flubendiamide is classified as a phthalic group acid diamide and is claimed to be effective against a broad range of lepidopteran insects (Tohnishi et al. 2005). However, there was mortality recorded on adult *Adalia bipunctata,* a (Coleopteran). It was concluded to be harmless because flubendiamide had a low mortality rate of only 14.29% mortality (Garzón et. al. 2015). *Isaria fumosorosea* and Cnidiadin showed a low percentage of mortality on *E. kamerunicus* within 96 hours of exposure. The strains of *I. fumosorosea* species complex have a wide host range with a good control on Lepidopteran species, but it is considered as narrow host range when compared to *Beauvaria bassiana* (Zimmermann 2007). According to Zimmermann (2008), *I. fumosorosea* was tested against *Tribolium confusum* a Coleopteran in the stored wheat. From the results, *I. fumosorosea* showed low mortality in adult *T. confusum*, while 100% mortality of larvae in the combination treatment of *I. fumosorosea* with SilicoSec after 3 weeks at the temperature of 20ºC. However, for cnidiadin, there was neither field nor laboratory result was published to support the results that has been done toward *E. kamerunicus* and other insects.

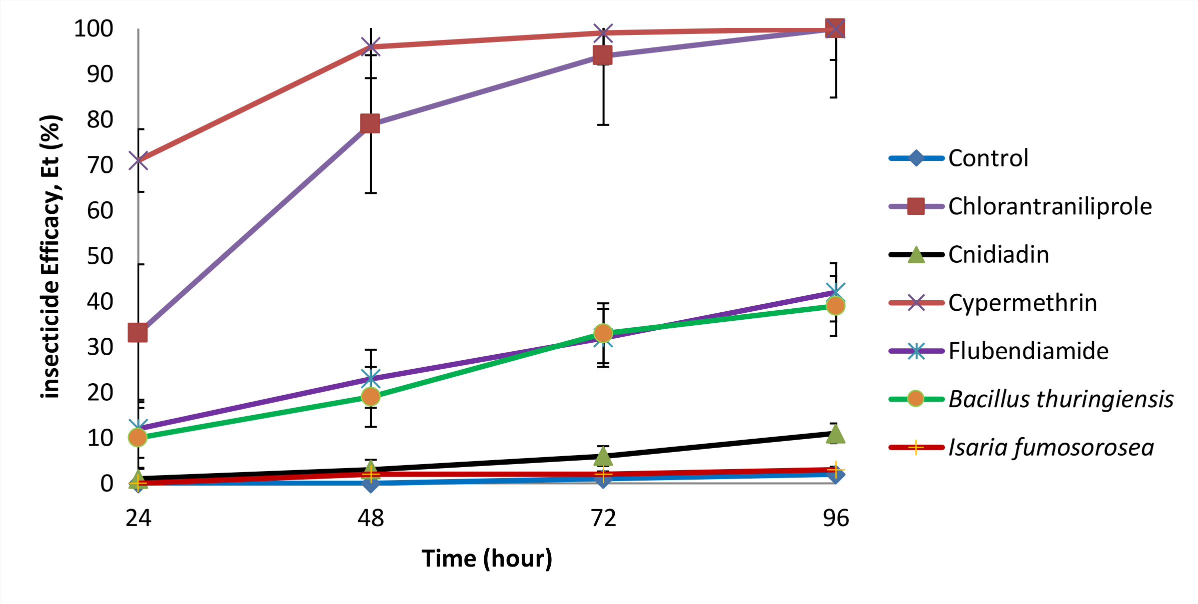

Figure 1. Percentage of insecticide efficacy towards *E. kamerunicus* after exposure to insecticides at 24, 48, 72 and 96 hours

Initial versus Final Efficacy (E_0 vs E_4)

Figure 2 shows that the initial efficacy of cypermethrin (71%), chlorantraniliprole (33%), flubendiamide (12%), *B. thuringiensis* (10%), cnidiadin (1%) and *I. fumosorosea* (0%). It also showed the final efficacy of cypermethrin (100%), chlorantraniliprole (100%), flubendiamide (42%), *B. thuringiensis* (39%), cnidiadin (11%) and *I. fumosorosea* (3%). The initial efficacy, E_0, three insecticides were classified as moderate which are chlorantraniliprole, cypermethrin and flubendiamide because the initial efficacy value was more than 10% and less than 90%, ($10\% < E_0 < 90\%$). Other insecticides were classified as an increased efficacy change from the moderate initial efficacy because the values were increased by more than 10% after 96 hours exposure. cnidiadin, *B. thuringiensis* and *I. fumosorosea* insecticides were classified as low initial efficacy because the initial efficacy value was less than 10%, ($E_0 \leq 10\%$). For efficacy change of these insecticides, only *B. thuringiensis* showed an increasing efficacy value after 96 hours exposure because the value increased more than 10%. However, cnidiadin and *I. fumosorosea* showed a stable efficacy value after 96 hours of exposure because the efficacy does not show any increment at 10% and classified as stable efficacy changed with low initial efficacy. The choice of selecting chemical is an important factor to be considered before applying the insecticide and this includes the effects toward non-target organisms, environmental residue and toxicity to the pest and natural enemies (Godfrey et al. 1994). According to Das (2013), it is important to understand how pesticides work by knowing their Mode of Action. For instance, cypermethrin is a broad spectrum insecticide with a fast-acting neurotoxin with good contact and stomach action (Manna et al. 2005). Meanwhile, chlorantraniliprole is one of the most widely used broad-spectrum pesticides (Du et al 2018). Therefore, these two insecticides are not suitable to be used in oil palm plantations as they are lethal to an important pollinator, *E. kamerunicus*. According to Cloyd (1999), *B. thuringiensis* products have a slower effect when compared to the other conventional insecticides. Products with *B. thuringiensis* as their active ingredient are not a broad spectrum insecticides. Generally, bacteria must be ingested by the insects to be effective. The final efficacy for *I. fumosorosea* only showed 3% mortality of *E. kamerunicus*. Hunter et al. (2011) was reported on *Diaprepes abbreviatus* L. (citrus root weevil) that there was no mortality within 4 days of exposure after treated with *I. fumosorosea*, 7% mortality within 8 days exposure and reached 100% mortality after 35 days of exposure.

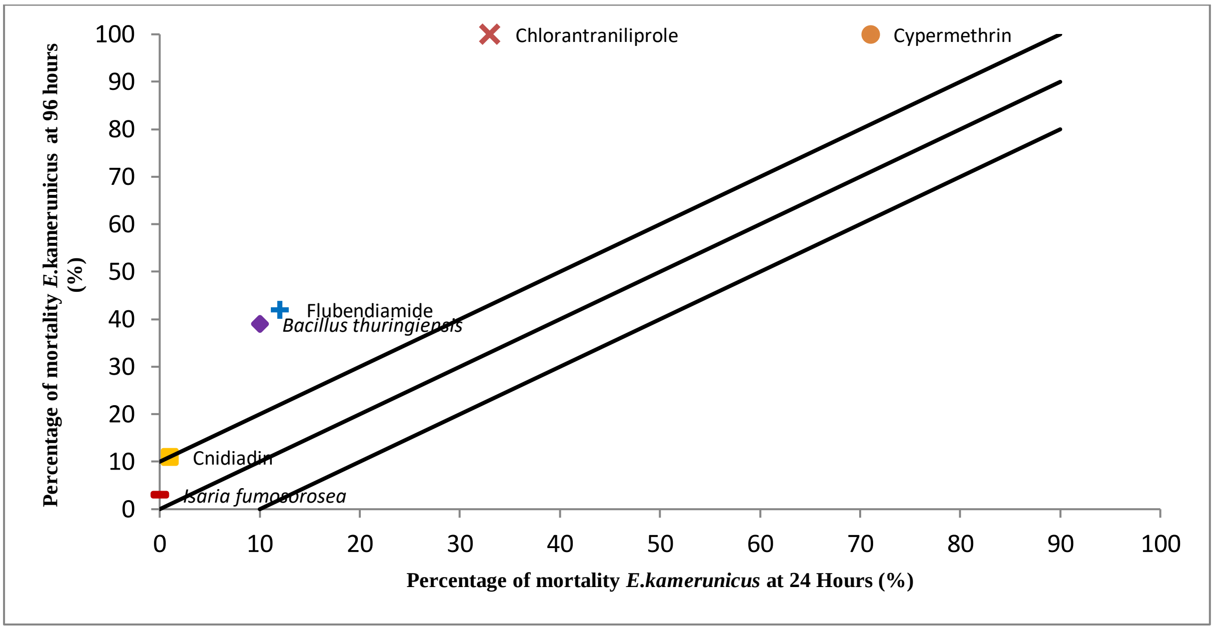

Figure 2. Insecticide efficacy values 24 hours (E_0) and 96 hours (E_4) after treatment.

Lethal Time (LT_{50})

Based on Table 1, results showed that cypermethrin gave the shortest LT_{50}value, 17 hours to killed 50% of *E. kamerunicus* populations, followed by chlorantraniliprole, flubendiamide and *B. thuringiensis* which are 31, 136 and 137 hours respectively. But, cniadiadin and *I. fumosorosea* showed that no mortality was observed within exposure time. According to Adams et al. (2016), chlorantraniliprole resulted in 89% to 96% mortality of corn earworms, while flubendiamide caused only 11% to 16% mortality of corn earworms within 31 days after treatment. In addition, an experiment conducted by Kok et al. (2012) showed that chlorantraniliprole and cypermethrin were among the fastest acting insecticides tested on *Metisa plana* with the LT_{50} values of 17.04 and 28.63 minutes respectively. Meanwhile, *B. thuringiensis* was slowest acting insecticide and required more than 2000 minutes to kill half the population of *M. plana* larvae.

Table 1. The Lethal time mortality of *E. kamerunicus* after 24, 48, 72 and 96 hours treatment

Conventional insecticide	**LT_{50}**	**Slope ± SE**	**X^2**	**95% Confidence Limit**	
				Lower	**Upper**
Chlorantraniliprole	31.430	4.570	1.830	28.025	34.570
Cniadiadin	NA	NA	NA	NA	NA
Cypermethrin	17.726	3.996	0.268	13.188	21.127
Flubendiamide	136.803	1.784	0.104	102.439	257.428
Bacillus thuringiensis	137.831	1.978	0.416	104.955	249.613
Isaria fumosorosea	NA	NA	NA	NA	NA

Lethality Index

Table 2 showed the values of lethality index among the six insecticide treatments, ranging from 1.75 for *I. fumosorosea* to 91.50 for cypermethrin. From the results obtained, cypermethrin showed the highest value of lethality index, which was 91.50%, followed by chlorantraniliprole (76.50%), flubendiamide (27.25%), *B. thuringiensis* (25.25%), cnidiadin (5.25%) and *I. fumosorosea* (1.75%).From the lethal values of the six selected insecticides, cypermethrin and chlorantraniliprole had high values that can cause detrimental effects to *E. kamerunicus*. Cypermethrin and chlorantraniliprole both exceeded 50% lethality. These insecticide formulations can have detrimental effects on the beneficial pollinating weevil, *E. kamerunicus*. Meanwhile, *I. fumosorosea* showed the lowest lethality index, which is 1.75%, followed by cnidiadin (5.25%). From these values, *I. fumosorosea* have the lowest lethality index among the other insecticides, but they are also suitable to be used in oil palm plantations since they have little effect on *E. kamerunicus* populations. The lethality index for *B. thuringiensis* in this experiment was 25.25%, which is less than 50%. According to Yusdayati and Hamid (2015), when *B. thuringiensis* was applied, the result showed that there was 97.5% mortality of *E. kamerunicus* on the fifth day after application. However, this is probably because they sprayed the insecticide on the spikelets, which is the source of food for *E. kamerunicus.* According to Glare and O'Callaghan (2000), *B. thuringiensis* will cause mortality when ingested. *Isaria fumosorosea* had the lowest lethality index compared to the other insecticides. Hunter et al. (2011) reported, coleopterans or weevils have a much bigger body size with a thicker cuticle layer that might cause difficulties for *I. fumosorosea* to penetrate.

Table 2. Lethality index of insecticide as well as the initial efficacy rating and the change in efficacy over 96 hours after treatment

Rank	**Conventional Insecticides**	**Lethality Index (%)**	**Initial Efficacy[a] (E_0)**	**Efficacy Change[b] (E_4 - E_0)**
1	Cypermethrin	91.50	Moderate	Increasing
2	Chlorantraniliprole	76.50	Moderate	Increasing
3	Flubendiamide	27.25	Moderate	Increasing
4	*Bacillus thuringiensis*	25.25	Low	Increasing
5	Cniadiadin	5.25	Low	Stable
6	*Isaria fumosorosea*	1.75	Low	Stable

[a]E_0 = the percentage of dead insects at 24 hours. Low for E0 $\leq$ 10%; Moderate for 10% < E_0<90%; High for $E_0 \geq$ 90%.
[b]Increasing for (E_4 -E_0) > 10%; Decreasing for (E_4 -E_0) < -10%; Stable for -10% $\leq$ (E_4 –E_0) $\leq$ 10%.

CONCLUSIONS

Since *E. kamerunicus* plays a major role in the oil palm plantation, thus, the insecticides that could control the pests without being harmful to the beneficial insects are encouraged to be used. Based on this experiment, *E. kamerunicus* is highly susceptible to two types of insecticide which are cypermethrin and chlorantraniliprole, both showed more than 50% of lethality index. Therefore, these insecticides are not suitable to be used in the oil palm plantation in order to conserve the population of beneficial insects which can assist in producing more yield of oil palm.

REFERENCES

Adams, A., Gore, J., Catchot, A., Musser, F., Cook, D., Krishnan, N. & Irby, T. 2016. Residual and systemic efficacy of chlorantraniliprole and flubendiamide against Corn Earworm (Lepidoptera: Noctuidae) in Soybean. *Journal of Economic Entomology* 109: 2411-2417.

Bassi, A., Alber, R., Wiles, J. A., Rison, J. L., Frost, N. M., Marmor, F. W. & Marcon, P. C. 2007. Chlorantraniliprole: A novel anthranilic diamide insecticide. *Proceedings of XVI International Plant Protection Congress* 1: 52-59.

Cloyd, R. A. 1999. Using *Bacillus thuringiensis* effectively. http://hyg.ipm.illinois.edu/pastpest/199903e.html [12 June 2018].

Cox, C. 1996. Insecticide factsheet- Cypermethrin. *Journal of Pesticide Reform/Summer* 16: 2.

Das, S. K. 2013. Mode of action of pesticides and the novel trends – A critical review. *International Research Journal of Agricultural Science and Soil Science* 3(11): 393-401.

Du, D., Liu, P. J., Shi, Z. P., Ren, G. B., Qi, M. H., Li, Z. & Xu, X. Y. 2018. Three solid forms of chlorantraniliprole: Structure, characterization, and phase transformation. *Journal of Molecular Structure* 1171: 323-332.

Fishel, F. M. 2017. *Pesticide Effects on Nontarget Organisms.* IFAS Extension University of Florida.

Garzón, A., Medina, P., Amor, F., Viñuela, E. & Budia, F. 2015. Toxicity and sublethal effects of six insecticides to last instar larvae and adults of the biocontrol agents *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) and *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae). *Chemosphere* 132: 87–93.

Geiger, F., Jan, B. & Frank, B. 2015. Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. *Basic and Applied Ecology* 11: 97–105.

Godfrey, L. D., Goodell, P. B., Natwick, E. T., Haviland D. R. & Barlow, V. M. 1994. Cotton, selectivity of insecticides and miticides. Interactions between fungal pathogens and insect hosts. *Annual Review of Entomology* 39: 293-322.

Hunter, W. B., Avery, P. B., Pick, D. & Powell, C. A. 2011. Broad spectrum potential of *Isaria fumosorosea* against insect pests of citrus. *Florida Entomologist* 94(4): 1051-1054.

Hussein, M. Y., Lajis, N. H. & Ali, J. H. 1991. Biological and chemical factors associated with the successful introduction of *Elaeidobius kamerunicus* Faust, the oil palm pollinator in Malaysia. *Acta Horticulture* 288: 81-87.

Kok, C. C., Eng, O. K., Razak, A. R., Arshad, A. M. & Marcon, P. G. 2012. Susceptibility of bagworm *Metisa plana* (Lepidoptera: Psychidae) to clorantraniliprole. *Pertanika Journal of Tropical Agricultural Science* 35(1): 149-163.

Leskey, T. C., Lee, D., Short, B. D. & Wright, S. E. 2012. Impact of insecticides on the invasive *Halyomorpha halys* (Hemiptera: Pentatomidae): Analysis of insecticide lethality. *Journal of Economic Entomology* 105(5): 1726-1735.

Manna, S., Bhattacharya, D., Mandal T. K. & Das, S. 2005. Neuropharmacological effects of Alfa-cypermethrin in Rats. *Indian Journal Pharmacology* 37: 18-20.

Norman, K. & Basri M. W .2007. Status of common insect pest in relation to technology adoption. *The Planter* 83: 371-385.

Syed, R. A. 1979. Studies on oil palm pollination by insects. *Bulletin of Entomology Research*. 69: 213-224.

Syed, R. A., Law, I. H. & Corley, R. H. V. 1982. Insect pollination of oil palm: Introduction, establishment and pollinating efficiency of *Elaeidobius kamerunicus* in Malaysia. *The Planter* 547-561.

Tohnishi, M., Steffens, R. & Buckelew, L. 2005 Flubendiamide: The next generation of chemistry for Lepidoptera pest management. In Lauderdale, F. (ed.). *The Larry L Larson Symposium: New Frontiers in Pest Management. The 2005 ESA Annual Meeting*. 15-18 *December.* Florida: Entomology Society of America.

Wahid, M. B. & Kamarudin, N. H. 1997. Role and effectiveness of *Elaeidobius kamerunicus, Thrips hawaiiensis* and *Pyroderces* sp. in Pollination of mature oil palm in Peninsular Malaysia. *Elaeis* 9 (1): 1-16.

Yusdayati, R. & Hamid, N. H. 2015. Effect of several insecticide against oil palm pollinator's weevil, *Elaeidobius kamerunicus* (Coleoptera: Curculionidae). *Serangga* 20 (2): 27-35.

Zimmermann, G. 2007. Review on safety of the entomopathogenic fungi *Beauveria bassiana* and *Beauveria brongniartii. Biocontrol Science and Technology* 17: 553-596.

Zimmermann, G. 2008. The entomopathogenic fungi *Isaria farinosa* (formerly *Paecilomyces farinosa)* and the *Isaria fumosorosea* species complex (formerly *Paecilomyces fumosoroseus*): Biology, ecology, and use in biological control. *Biocontrol Science and Technology* 18 (9): 865-901.