AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Publisher: Asian Economic and Social Society

Toxicity of Selected Insecticides (Spinosad, Indoxacarb and Abamectin) Against the Diamondback Moth (*Plutella xylostella* L.) On Cabbage

Fauziah Ismail (Entomologist (Associate Professor) Faculty of Plantation & Agrotechnology, Universiti Teknologi MARA Malaysia (UiTM)

Mohd Norazam, M. T. (Faculty of Plantation & Agrotechnology, Universiti Teknologi MARA Malaysia (UiTM)

Mohd Rasdi Z. (Faculty of Plantation & Agrotechnology, Universiti Teknologi MARA Pahang (UiTM)

Citation: Fauziah Ismail, Mohd Norazam, M. T. and Mohd Rasdi Z. (2012) "Toxicity of Selected Insecticides (Spinosad, Indoxacarb and Abamectin) Against the Diamondback Moth (*Plutella xylostella* L.) On Cabbage" Asian Journal of Agriculture and Rural Development Economic and Financial Review Vol. 2, No.1, pp.17-26

Toxicity of Selected Insecticides (Spinosad, Indoxacarb and Abamectin) Against the Diamondback Moth (*Plutella xylostella* L.) On Cabbage

Author(s)

Fauziah Ismail
Entomologist (Associate Professor)
Faculty of Plantation & Agrotechnology, Universiti Teknologi MARA Malaysia (UiTM)
E-mail: fauziah@salam.uitm.edu.my

Mohd Norazam, M. T.
Faculty of Plantation & Agrotechnology,
Universiti Teknologi MARA Malaysia (UiTM)
*E-mail:*azam_ucin@yahoo.com

Mohd Rasdi Z.
Senior Lecturer, Agriculture Entomologist
Faculty of Plantation & Agrotechnology,
Universiti Teknologi MARA Pahang (UiTM)
E-mail: dddpim@pahang.uitm.edu.my ; dddpim@yahoo.com

Abstract

Plutella xylostella L. is a most serious of insect pest for cruciferous or Brassica crops throughout the world. The common name of this insect pest is the Diamondback Moth (DBM). Plutella xylostella L. is an oligophagous insect which is feed on the group of botanically plants within the single plant family. This insect has become major serious problem to the crops because it easily and rapidly develops their resistance to insecticides. Insecticides were used to kill Plutella xylostella L. that contribute to minimize the level of infestation. Toxicity levels were measured by lethal concentration (LC_{50}) to estimate the effectiveness of selected insecticides. A total of three selected insecticides namely spinosad, indoxacab and abamectin had been tested against Plutella xylostella L. The data of LC_{50} was analyzed using PROBIT program. The result from this study had been used to estimate the effective dose or quantity of each insecticide need for controlling Plutella xylostella L. Besides that, the most effectiveness between the tested insecticides were selected for managing Plutella xylostella L. Results from this study shows that indoxacarb were most effective and toxic to control Plutella xylostella L. compared with spinosad and abamectin because it gave lower LC_{50} value (1010.080). In term of concentration, indoxacarb (1125 µl/5000 ml) and spinosad (2750 µl/5000 ml) was the effective concentrations for controlling Plutella xylostella L. by mortality rate more than 50%, 60% and 80% respectively.

Key words: Plutella xylostella, Diamondback Moth, Insecticide, Toxicity, and Cabbage

Introduction

The Diamondback moth (*Plutella xylostella* L.) is a most serious of insect pest for crucifers or brassica crops throughout the world. The control costs of *Plutella xylostella* L. approximately US $ 1 billion annually (Talekar, 1992). After several years, this insect pest has developed resistance to many types of insecticides and the population has been increasing from time to time (Sun, 1992). The infestation level of *Plutella xylostella* L. on the brassica crops especially cabbage varies according to the presence of natural enemies, locality and plant types. The management controlling of *Plutella xylostella* L. must be taken with effectively to avoid severe damage cause by this insect pest. The damage cause by this insect pest can reach up to 100% (Shelton *et al*., 1993). In India, *Plutella xylostella* L. causes serious crop damage cole crops and the area wherever crucifers are grown. Krishnamoorthy, (2004) documented that the infestation of *Plutella xylostella* L. causes 52% yield loss on cabbage plant. In Malaysia, *Plutella xylostella* L. is introduced through the development of the vegetable industry mainly the brassica crops and only one species of Plutella has been recorded. *Plutella xylostella* L. was first recorded in Malaysia in 1925. The infestation of this insect pest was reported at the Cameron highland in 1934 and until 1941, this insect pest does not seriously damage the crop growing at that particular area. However, *Plutella xylostella* L. has become a serious pest to the crucifers growing in the highlands and the lowlands areas in Malaysia after the mid 1940s (Corbett and Pagden, 1941). *Plutella xylostella* L. was first recorded in 1746 and probably from European origin. Nowadays, the distribution of this insect pest found throughout the Americas and in Europe, Southeast Asia, Australia and New Zealand. In 1854, *Plutella xylostella* L. was observed in North America and now recorded everywhere the cabbage grown in that area. This insect pest had spread to Florida and the Rocky Mountains by 1883. It is also can be found in Canada areas where it cannot successfully overwinter condition (Capinera, 2001). In 1939, the infestation of *Plutella xylostella* L. was recorded in 19 countries of South America, Europe and Africa. About 128 countries or regions reported infestation by this insect pest in 1972. The level of infestation is vary from place to place for example the infestation is serious in South and Southeast Asian countries and moderate in other Asian regions than the Mediterranean region (Harcourt, 1963). *Plutella xylostella* L. is a foreign pest with few natural enemies in Malaysia. Thus, this insect has become a major pest of the crucifers growing in Malaysia especially on the temperate crucifers in the Cameron Highlands. In 1950s, the use of synthetic insecticides was eliminated the natural insecticides application. Then, after several years, this insect pest became resistant to DDT and BHC (Henderson, 1957). Several new insecticides were recommended to control *Plutella xylostella* L. but the observation showed that 60% of the farmers cannot control this pest with effectively (Lim, 1974). In the 1980s, there have several new chemicals was introduced to control *Plutella xylostella* L. such as cartap, methomyl, permethrin, triazophos and fenvalerate. But, all of these insecticides have become less effective after two to five years use by farmers. Since these problems occur, the farmers have increases the recommended dosage, spraying frequency and mixed two or more chemicals to ensure the effective control. Although these practices are successful, it can create the other problems such as high residues in harvested product and high cost of production. To solve these problems, the need for implementation of Integrated Pest Management (IPM) programme where control measures are based on economic threshold, the right dosage or rate of insecticides application and use of botanical insecticides with effectively. The most important of study was to observe the initial indication of resistance level of *Plutella xylostella* L. population on cabbage plants. Specifically, to determine the lethal concentrations of LC_{50} and LC_{95} on each tested insecticides against *Plutella xylostella* L. and to identify the most effective dosage between test insecticides concentrations for controlling the *Plutella xylostella* L.

2. Materials and methods

The study had been carried out in the Crop Protection Laboratory, Faculty of Plantation and Agrotechnology, UiTM Shah Alam, Selangor under controlled condition with small ranged of controlled room temperature of 24.33 ± 0.14°C with dark and light ratio of 1:1 (12 hours: 12 hours).

Host plant

Cabbage plant had been used as a food supply during the rearing process as well as toxicity testing. Cabbage (Serbajadi Variety) seeds were sown in the seedling tray (size of 36 cm x 56 cm of 104 holes) at 1 cm depth for two weeks. The seedlings were watering daily, and after two weeks the seedlings were then transferred into a polystyrene cup (6.0 cm diam. x 9.5 cm). The planting mediums were mixed uniformly and filling up in the polybags with 3:2:1 ratio which consisted of top soil, organic soil and chicken dung, respectively had been used in this study to promote well growth.

Test insect (*Plutella xylostella*)

Plutella xylostella L. had been used for this experiment. Enough supply of 2^{nd} instar larvae of *Plutella xylostella* L. had been obtained from MARDI Serdang to supply enough insects for the experiments. Besides that, the larvae were also collected from MARDI Cameron Highlands reared in the laboratory under controlled temperature at 19ºC to 21ºC.

Stock culture of *Plutella xylostella* L.

The cabbage plants were prepared and placed into rearing cage. After that, the adults of *Plutella xylostella* L. were prepared and released inside the rearing cage. The cabbage plant was acted as an ovipositor site for adults of *Plutella xylostella* L. The cleaned rearing cages and the pest and diseases free of host plant had been used to maintain good stock culture.

Preparation of test insect

Prior experiments, 2-months-old of 30 cabbage plants were prepared and followed the procedure (Fauziah, 1990). A total of three cages were prepared which each cage contains one cabbage plants. About 100 adults of *Plutella xylostella* L. had been introduced individually to cabbage plants inside the oviposition cage (33 cm height x 31 cm wide) respectively. These plants had been left for 24 hours for oviposition. After 24 hours, the adults had been removed from oviposition cages. Then, the eggs underside the leaves were left to hatch on the growing plants for two weeks. When the larvae had reached at the second-instar, they had been counted and used for the toxicity experiments using leaf-dip bioassay method. The second and third generations of *Plutella xylostella* L. larvae had been used in the toxicity experiment, to avoid any parasitoids present inside the larvae.

Test insecticides

Three insecticides were tested in this study namely success, steward and agrimec. The active ingredient (*a.i*) of the insecticides tested is spinosad 2.5% w/w, indoxacarb 14.5% w/w and abamectin 1.9% w/w with different modes of action respectively. The selected insecticides used in this experiment were registered and the latest recommended insecticides in controlling *Plutella xylostella* L. by Pesticide Control Division, MARDI Cameron Highland (DOA, 2005 and Syed Abdul Rahman et al., 2000). The summary of insecticides tested is in Table 1.

Factors motivating beneficiaries' participation in development programs

As participation continues to remain a context-specific concept, so also the factors that motivate beneficiaries' participation varied from individuals, contexts and programs. The motivation to participate by and large depends on individual conceptions. Although, the reasons for beneficiaries' participation in development programs have not been consistent because the participatory literature is often vague as to what generally motivate people to participate (Cleaver, 1999), empirical evidences abound. For instance, whereas, Friedman (1992) places emphasis on economic rationality as the most influential factor

Table 1: Specification of selected Insecticides (Spinosad, Indoxacarb and Abamectin)

Common Name	Active Ingredient (*a.i*)	Class	Mode of Action
Success® 25 SC	Spinosad 2.5% w/w rate	IV	Contact and Stomach
Steward®	Indoxacarb 14.5% w/w rate	II	Contact and Stomach
Agrimec® 1.9 EC	Abamectin 1.9% w/w rate	II	Contact and Stomach

Treatments

A total of 13 treatments were tested in this experiment. For each concentration number 2 is recommended rate (µl / 5000 ml of water) from MARDI Cameron Highland. For each concentration 3 and 4 is the rate below recommended rate, and for each concentration 1 is the rate above recommended rate (Table 2).

Table 2: Treatments Tested in the experiment

Treatment	Insecticides (*a.i*)	Concentration (µl/ml)
Treatment 0	Control (dip with distilled water only)	
Treatment 1	Spinosad with concentration 1	(6875 µl / 5000 ml)
Treatment 2	Spinosad with concentration 2	(5500 µl / 5000 ml) (MARDI)
Treatment 3	Spinosad with concentration 3	(4125 µl / 5000 ml)
Treatment 4	Spinosad with concentration 4	(2750 µl / 5000 ml)
Treatment 5	Indoxacarb with concentration 1	(1875 µl / 5000 ml)
Treatment 6	Indoxacarb with concentration 2	(1500 µl / 5000 ml) (MARDI)
Treatment 7	Indoxacarb with concentration 3	(1125 µl / 5000 ml)
Treatment 8	Indoxacarb with concentration 4	(750 µl / 5000 ml)
Treatment 9	Abamectin with concentration 1	(6250 µl / 5000 ml)
Treatment 10	Abamectin with concentration 2	(5000 µl / 5000 ml) (MARDI)
Treatment 11	Abamectin with concentration 3	(3750 µl / 5000 ml)
Treatment 12	Abamectin with concentration 4	(2500 µl / 5000 ml)

The treatments were assigned randomly (Completely Randomized Design-CRD) in each Petri dish before ten larvae of DBM had been placed in each of them. Thirteen treatments were randomly assigned in Petri dish with four replications. Leaf-disc of cabbage from stock culture was cut off with square shape (5 cm x 5 cm) and placed in Petri dish by exposing their upper surface in a quadrilateral arrangement (Hazmi et al., 2008). A moistened filter paper (diam. 9 cm) had been placed at the bottom of Petri dish (diam. 9 cm) to maintain the moisture. The leaves were also dipped into distilled water and dry it for a few minute. Then, the leaf-disc was immersed with the tested insecticides and dried it for a few seconds. Subsequently, ten larvae of *Plutella xylostella* L. from the stock culture were placed in each Petri dish and allowed them to feed the leaf-disc for one week. Each concentration for each insecticide had been tested using the tested insects. For the control, the leaf-disc was immersed with distilled water solely. Prior experiment, all larvae are not given any food for three hours to give them the same level of starvation.

Data collection

The numbers of larvae alive and dead were counted and recorded in a series of experiment of LC50 and LC_{95} values correspondingly. The data was collected at every 4 hours within two days.

3. Data analysis

The toxicity data were analyzed by using a special PROBIT program-single Line Analysis. The concentration was expected to produce mortality of 50% (LC_{50}) and 95% (LC_{95}). The data were also analyzed by using Analysis of Variance (ANOVA) from Minitab 16. Normality test has been carried out and found that the data was normally distributed.

4. Results and Discussion

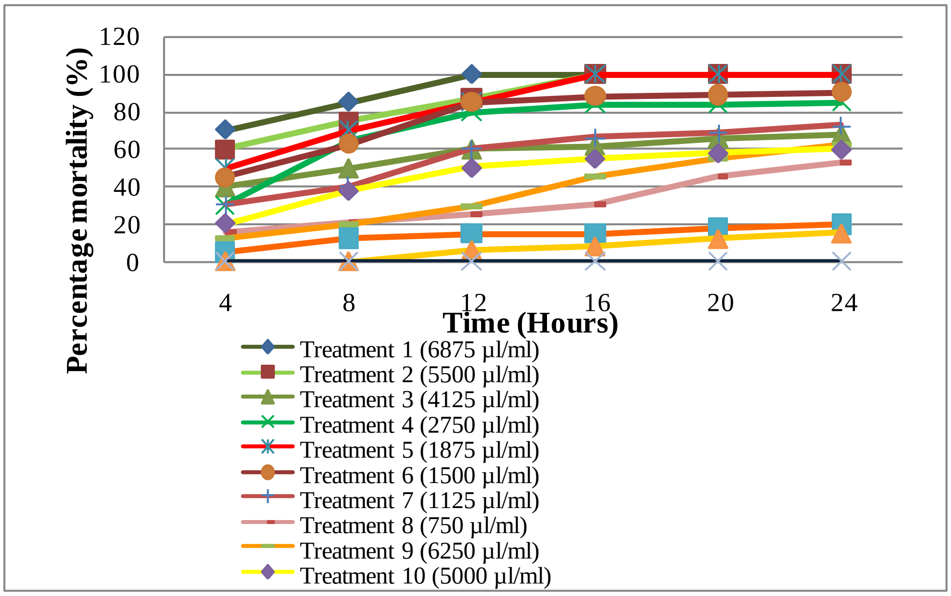

Figure 1 : Percentage mortality of *Plutella xylostella* L. on different treatment (concentrations) of insecticides over time (hours)

Figure 1 shows the changes in percentage mortality of *Plutella xylostella* L. larvae over time (hours). The graph was based on the means for four replications and each petri dish was placed with ten larvae of *Plutella xylostella* L. From the beginning of the experiment, the percentage mortality for all treatments is equal to zero. After 4 hours, all treatment increases gradually except for abamectin (T12) with concentration 2500 µl/5000 ml and control treatment. Spinosad (T1) with concentration 6875 µl/5000 ml showed a drastic increase in percentage of mortality at the 12th hour which reached up to 100%. Spinosad (T2) with concentration 5500 µl/5000 ml and indoxacarb (T5) with concentration 1875 µl/5000 ml also caused 100% of mortality after the 16th hour of treatment. Spinosad (T3) with concentration 4125 µl/5000 ml and spinosad (T4) with concentration 2750 µl/5000 ml increased gradually after 16 hours of being treated but only reached the 100% of mortality after the 28th hours. Indoxacarb (T6) with concentration 1500 µl/5000 ml and indoxacarb (T7) with concentration 1125 µl/5000 ml also increased slowly after 16 hours of being treated and reached total percentage of mortality at the 28th hour and 40th hour respectively. However, indoxacarb (T8) with concentration 750 µl/5000 ml showed only a slight increase in percentage mortality within the first 16 hours and did not reach more than 50% mortality even after 24 hours of treatment. But, the graph shows that all concentrations of abamectin increased slowly after treatment especially for abamectin (T11) with concentration 3750 µl/5000 ml and abamectin (T12) with concentration 2500 µl/5000 ml. These two concentrations showed the lowest percentage of mortality which is less than 20% within 24 hours after treatment.

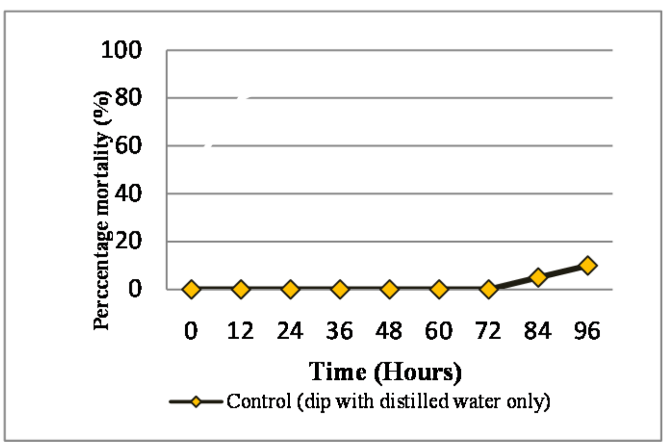

Figure 2 : Percentage mortality of *Plutella xylostella* L. influenced by control over time (hours)

Our result showed that all treatments with insecticides have shown a higher mortality of *Plutella xylostella* L. The control does not have any effect on the percentage of mortality of *Plutella xylostella* L. until the 72nd hour. However, 72 hours after the treatment, the percentage mortality of *Plutella xylostella* L. a minimum of 5% increase only reached the 10% mark after 96 hours. This means that the active ingredients (*a.i*) of insecticide itself is more toxic to the *Plutella xylostella* L. because it produce a large number of mortality after only a short period of time compared to the control treatment. The result showed that distilled water is not toxic to the larvae of *Plutella xylostella* L., since the result showed only 10% mortality even after three days after treatment. There is significant difference between the different concentrations and the effectiveness of spinosad, indoxacarb and abamectin on the mortality against *Plutella xylostella* L. (F = 8.40; df = 12,39; P = 0.000).

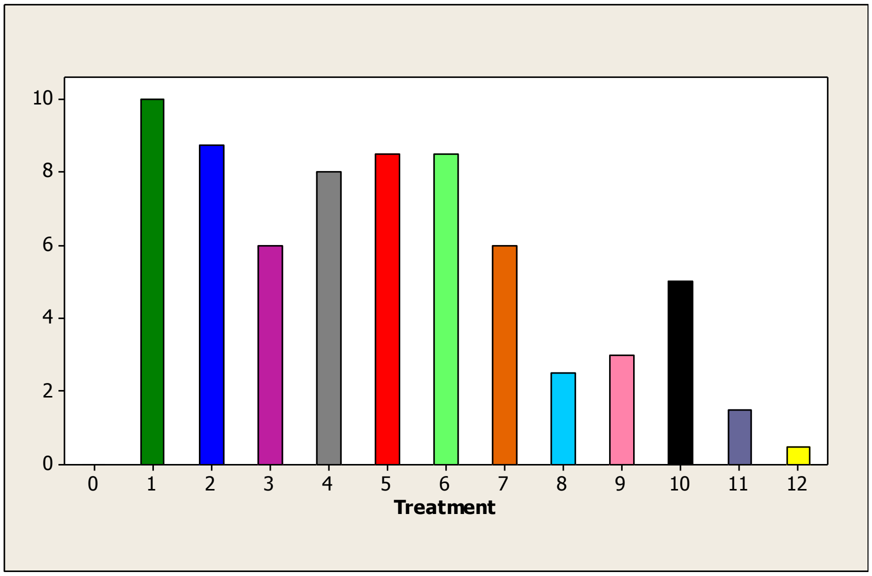

Figure 3 : Mean number of mortality for each treatment on *Plutella xylostella* L. (12 hours after treatment) [Values with a common letter are not significantly difference at p>0.05 by Duncan Multiple Range Test (DMRT)]

Figure 3 shows the mean number of mortality for *Plutella xylostella* L. larva treated with the different levels of concentration of each test insecticide. The Figure 3 indicates that the highest mean number of mortality was by using spinosad (T1) with concentration 6875 µl/5000 ml (number of mortality = 10) and the lowest was in the control treatment (T0) by using only distilled water(number of mortality = 0). The figure indicates that spinosad (T1) with concentration 6875 µl/5000 ml, spinosad (T2) with concentration 5500 µl/5000 ml, spinosad (T3) with concentration 4125 µl/5000 ml, spinosad (T4) with concentration 2750 µl/5000 ml, indoxacarb (T5) with concentration 1875 µl/5000 ml, indoxacarb (T6) with concentration 1500 µl/5000 ml and indoxacarb (T7) with concentration 1125 µl/5000 ml showed significant difference compared to the control treatment (T0) with distilled water only, indoxacarb (T8) with concentration 750 µl/5000 ml, abamectin (T9) with concentration 6250 µl/5000 ml, abamectin, (T11) with concentration 3750 µl/5000 ml and abamectin (T12) with concentration 2500 µl/5000 ml. Besides that, abamectin (T10) with concentration 5000 µl/5000 ml also show significant difference than the control treatment (T0) with distilled water only.

Toxicity of three selected insecticides against *Plutella xylostella* L.

The study aimed to determine the toxicity of three insecticides tested namely success, steward and agrimec which are represented by spinosad, indoxacarb and abamectin respectively. Tables 3 until 4 are the summarized result of these three insecticides tested against larvae of *Plutella xylostella* L. and were analyzed by using Special Probit Programe - Single Line Analysis. The table 3, 4 and 5 show the number of *Plutella xylostella* L. larvae killed by different concentrations of insecticide together with percentage killed. This Probit programme calculated the lethal concentrations of LC_{50}, LC_{75}, and LC_{95} and the highest and lowest range of each concentration.

Table 3: Toxicity of spinosad against *Plutella xylostella* L. (12 hours)

Con.	Concentration µl/5000 ml of water	No of larvae	No of dead	Mortality rate (%)
1	6875	40	40	100.00%
2	*5500	40	35	87.50%
3	4125	40	24	60.00%
4	2750	40	32	80.00%
5	0	40	0	0.00%
	Lethal concentration	**Concentration**	**Min**	**Max**
	LC_{50}	1763.055	577.613	5381.393
	LC_{75}	3410.994	1298.387	8961.027
	LC_{95}	8816.074	3003.873	25874.320
	Slope : 2.353 +/- 0.798	**Chi square : 17.502**		

Note: * Recommended

There was no significant difference on the mortality of *Plutella xylostella* L. larvae among the four concentrations of spinosad used against these larvae. It was observed that concentration one (6875 µl/5000 ml of water) was significantly higher than the other three levels of concentration. The highest concentration of spinosad (6875 µl/5000 ml of water) gave 100.00% mortality and the lowest concentration (2750 µl/ 5000 ml of water) caused 80.00% mortality. However, the recommended rate of concentration is concentration number two, (5500 µl/5000 ml of water) since it could prevent the development of resistance population of *Plutella xylostella* L.

Table 4: Toxicity of indoxacarb against *Plutella xylostella* L. (12 hours)

Con.	Concentration µl/5000 ml of water	No of larvae	No of dead	Mortality rate (%)
1	1875	40	34	85.00%
2	*1500	40	34	85.00%
3	1125	40	24	60.00%
4	750	40	10	25.00%
5	0	40	0	0.00%
	Lethal concentration	**Concentration**	**Min**	**Max**
	LC_{50}	1010.080	897.479	1136.809
	LC_{75}	1407.129	1246.573	1588.364
	LC_{95}	2267.229	1787.814	2875.203
	Slope : 4.685 +/- 0.777	**Chi square : 1.916**		

Note: * Recommended

There were significant differences on the mortality of *Plutella xylostella* L. larvae among the four concentrations of indoxacarb that were used against these larvae. It was observed that concentration one (1875 µl/5000 ml of water) was significantly higher than the other three levels of concentration. The highest concentration of indoxacarb (1875 µl/5000 ml of water) killed 85% of the tested insects and the lowest concentration (750 µl/ 5000 ml of water) killed 25.00% of the overall tested insects. However, the recommended rate of concentration is concentration number two, (1500 µl/5000 ml of water) since it will prevent the development of resistance of *Plutella xylostella* L.

Table 5: Toxicity of abamectin against *Plutella xylostella* L. (12 hours)

Con.	Concentration µl/5000 ml of water	No of larvae	No of dead	Mortality rate (%)
1	6250	40	12	30.00%
2	*5000	40	20	50.00%
3	3750	40	6	15.00%
4	2500	40	6	15.00%
5	0	40	0	0.00%
	Lethal concentration	**Concentration**	**Min**	**Max**
	LC_{50}	8461.838	3529.538	20286.707
	LC_{75}	18289.184	5081.711	65823.156
	LC_{95}	55439.317	7454.982	412277.04
	Slope : 2.015 +/- 0.756	**Chi square : 9.014**		

Note: * Recommended

There were significant differences on the mortality of *Plutella xylostella* L. larvae among the four concentrations of abamectin that were used against these larvae. It was observed that concentration one (6250 µl/5000 ml of water) was significantly higher than the other three levels of concentration. The highest concentration of abamectin (6250 µl/5000 ml of water) gave 30.00% mortality and the lowest concentration (2500 µl/ 5000 ml of water) gave 15.00% mortality. However, the recommended rate of concentration is concentration number two (5000 µl/5000 ml of water) since it will prevent the development of resistance of *Plutella xylostella* L.

Lethal Concentration 50% (LC_{50})

LC_{50} is a lethal concentration where dosage of a chemical which is lethal to 50% of the tested insects, usually expressed in ml per litter of water. The level of toxicity is related to the LC_{50} value where the lower LC_{50} value, the more toxic the insecticides is. Thus, the greater LC_{50} value can result in lower toxicity.

Table 6: The LC_{50} value of three insecticides against *Plutella xylostella* L.

Insecticides Active ingredient (*a.i*)	LC_{50} (µl/ 5000 ml of water)	Relatives Potency (RP) = Highest LC_{50} / Individual LC_{50}
Spinosad	1763.055 (577.613 - 5381.393)	4.80
Indoxacarb	1010.080 (897.479 - 1136.809)	8.38
Abamectin	8461.838 (3529.538 - 20286.707)	1.00

Table 6 summarizes results of the LC_{50} values and relative potencies of three selected insecticides that were tested against *Plutella xylostella* L. All of these insecticides were effective against *Plutella xylostella* L. larvae. When LC_{50} value of mortality was compared among three insecticides, it was found that abamectin gave the highest LC_{50} value (8461.838) compared to other insecticides. However, indoxacarb was found to have the lowest LC_{50} value (1010.080). Indoxacarb attacked through contact and stomach is more toxic to *Plutella xylostella* L. compared to other insecticides. Then, abamectin is a less toxic insecticides compared to the others. From the studies, result of LC_{50} showed indoxacarb gave a smaller value (1010.080) followed by spinosad (1763.055) and lastly the highest value is abamectin (8461.838). The lower LC_{50} value, the more toxic the chemical is because only a small amount of active ingredient can give higher percentage of the insect mortality. Thus, indoxacarb is highly toxic to larvae with significantly lower LC_{50} value than spinosad and abamectin. The relative potency of the three tested insecticides are in the following sequence; indoxacarb (8.38) > spinosad (4.80) > abamectin (1.00). Thus, indoxacarb with 8.38 and 1.75 was more potent than abamectin and spinosad respectively.

Lethal concentration 95% (LC_{95})

Table 7: The LC_{95} value of three insecticides against *Plutella xylostella* L.

Insecticides Active ingredient (*a.i*)	LC_{95} (µl/ 5000 ml of water)	Relatives Potency (RP) = Highest LC_{95} / Individual LC_{95}
Spinosad	8816.074 (3003.873 - 25874.320)	6.29
Indoxacarb	2267.229 (1787.814 - 2875.203)	24.45
Abamectin	55439.317 (7454.982 – 412277.04)	1.00

Table 7 shows the LC_{95} value and relatives potency of three selected insecticides that were tested against *Plutella xylostella* L. All of these insecticides were effective against *Plutella xylostella* L. larvae. When LC_{95} value of mortality was compared among three insecticides, it was found that abamectin gave the highest LC_{95} value (55439.317) compared with other insecticides. However, indoxacarb was found to have the lowest LC_{95} value (2267.229). This can show that indoxacarb have more toxic to *Plutella xylostella* L. compared to other insecticides. Then, abamectin is a less toxic insecticide compared to the other insecticides. From these studies, result on LC_{95} showed indoxacarb gave smaller value (2267.229) followed by spinosad (8816.074) and the highest value is abamectin (55439.317). The lower LC_{95} value, the more toxic the chemical because only a small amount of active ingredient can give higher percentage of killings of the insects which is 95% from the 100% of total tested insect. Thus, indoxacarb also were highly toxic to larvae of *Plutella xylostella* L. with significantly lower LC_{95} value than spinosad and abamectin. The relative potency of the three tested insecticides is in the following sequence indoxacarb (24.45) > spinosad (6.29) > abamectin (1.00). Thus, indoxacarb are 24.45 and 3.89 was more potent than abamectin and spinosad respectively.

Table 8: Slope and standard error of three insecticides (Spinosad, Indoxacarb and Abamectin)

Insecticides (*a.i*)	Slope ± S.E	Insecticides group
Spinosad	2.353 +/- 0.798	IV
Indoxacarb	4.685 +/- 0.777	II
Abamectin	2.015 +/- 0.756	II

The slope value in the Table 8 shows the different toxicity levels among insecticides. The more gradient of linear graph, means the more toxic the insecticides. The less gradient of linear graphs the less toxic of insecticides due to the big change in dose (X-axis) but small number of kill insect changed in Y-axis. Table 8 shows the slope of six insecticides tested and can be divided into three groups namely (I) highly toxic, (II) moderately toxic and (III) slightly toxic and (IV) relatively non toxic. Form the result, indoxacarb which is active ingredient (*a.i*) for steward® show the more gradient in their slopes and more toxic to *Plutella xylostella* L. Besides that, these insecticides belong to the group II which is very toxic or moderately toxic to the *Plutella xylostella*. Thus, the result from the Probit analysis shows the steward insecticide (indoxacarb) was the most effective on the mortality of larvae for *Plutella xylostella* L. followed by success insecticide (spinosad) and lastly agrimec insecticide (abamectin). The sequence is steward > success > agrimec.

Discussion

The result of this study indicates that the various insecticides concentration have difference effects on the mortality of *Plutella xylostella*. It was obviously observed that the active ingredient of success insecticide (spinosad) for all the four levels of concentrations showed that mortality is more than 50%. Similarly, the previous study reported by Travis and Rick, (2000) showed that in leaf-dip bioassay, larval mortality of *Plutella xylostella* on leaves treated with spinosad and permethrin were considerably higher than other insecticides. Besides that, in the leaf-dip and residual bioassays, spinosad caused 100% mortalities to *Plutella xylostella* larvae and adults 72 hours after treatment. Thus, because of the high selection pressure induced by permethrin and spinosad, it is important that the frequency of exposure of these two materials to *Plutella xylostella* L. populations to be minimized to uphold the integrity of a resistance management program (Travis and Rick, 2000). Therefore, it is important to realize the effect of these insecticides on *Plutella xylostella* L. population dynamics rather than just larval mortality (Hoy and Hall 1993, Lin *et al*., 1993). Idris and Grafius, 1993 reported that synthetic insecticides are toxic to both the larval and adult stages of *Plutella xylostella* L. which should dramatically reduce the populations. However, these materials are also highly toxic to its parasitoid *Diadegma insulare.* Besides that, spinosad has a unique mode of action and controls insect pest that are resistant to conventional insecticides. The active constituent was derived from fermentation of a naturally occurring micro-organism. It has low toxicity to mammals, birds and fish. Spinosad is a broad-spectrum and organic insecticide. It means this insecticide is toxic to wide variety of insects especially for controlling lepidopterous insects (Simon, 2009). Success Naturalyte Insect Control can be used in Integrated Pest Management (IPM) programme and conventional insect control programme. Exposed insects stop feeding almost immediately but may take up to two days to die (Simon, 2009). The results from study also showed that the concentrations of indoxacarb were a very effective toxic to *Plutella xylostella* which caused more than 50% mortality after 12 hours. Besides that, exposed pests to this insecticide can stop feeding in zero to four hours, resulting in excellent crop protection (Simon, 2009). At label rates, steward can provide 14 days residual protection of treated crops depending on the type of insect, population pressure and environmental conditions. Basically, steward has a 12 hour re-entry interval and provides excellent rain fastness after two hours drying time (Simon, 2009). The result was reported by Srinivas *et al*. (2003), which both indoxacarb and fipronil could provide alternatives to unaffected by resistance because both represent unique modes of action. From our result, it was also observed that the active ingredient of agrimec insecticide which is abamectin for all the four levels of concentrations showed that mortality were below 50%. As we know, *Plutella xylostella* L. had been developing their resistance towards many types of insecticides (Miyata *et al*., 1986). The study reported by Sun, (1990) showed that *Plutella xylostella* L. become resistance to abamectin, benzophenyl ureas and *Bacillus thuringiensis*. Therefore, in this study, there are enough evidence to say that the resistance had been developed to abamectin and since the higher concentration (6250 µl/5000 ml) showed that mortality less than 50% even though that concentration is above the recommended rate by Malaysian Agricultural Research Development Institute (MARDI). Besides that, *Plutella xylostella* L. has develop resistance to almost all groups of insecticides including organochlorines, organophosphates, carbamates, abamectins and *Bacillus thuringiensis* (Moham and Gujar, 2003; Qian *et al*., 2008). In recent years, no proper experiments was carried out to identify the most effective concentration rate of abamectin and also to determine whether this active ingredients were still being applied for controlling *Plutella xylostella* L.

5. Conclusion

There were significant difference between the different concentrations and the effectiveness of spinosad, indoxacarb and abamectin on the mortality of *Plutella xylostella* L. The concentration of spinosad (2750 µl/5000 ml) and indoxacarb (1125 µl/5000 ml) were the best concentrations for controlling *Plutella xylostella* L. with mortality of more than 50% which (80%) and (60%) respectively. Of the three tested insecticides to control *Plutella xylostella* L. in cabbage (*Brassica oleraceae*), indoxacarb was found to be the most effective insecticide followed by spinosad while the least effective insecticide was abamectin. Results from the study suggested rotating the insecticides used with different modes of action. Besides that, other methods of bioassay such as vial-dry method, leaf-spray and syringe should be explored. Lastly, further research should be conducted by using different types of biopesticide such as garlic and chilli ethanol extract to test the mortality of *Plutella xylostella*.

References

Capinera J. L. (2001) "Handbook of Vegetable Pests" Academic Press, San Diego. Pp.729

Corbett, G. H., and **Pagden, H.T. (1941)** "A review of some recent entomological investigations and observations", *The Malaysian Agriculture Journal*, Vol. 29, pp. 347-75.

Department of Agriculture Malaysia (2005) "List of Chemicals for Major Insect Pest of Major Crops. Pesticides Board", Crop Protection Branch, Department of Agriculture, Kuala Lumpur, Unpublished report. pp. 6.

Fauziah, I. (1990) "Studies on Resistance to Acylurea Compounds in *Plutella xylostella* L. (Lepidoptera: Yponomeutidae)" PhD. Thesis, University of London, pp. 259.

Harcourt, D. G. (1963) "Major Mortality Factors in the Population Dynamics of the Diamondback Moth, Plutella maculipennis (Curt.) (Lepidoptera: Plutellidae. *Memoirs of the Entomological Society of Canada*, Vol. 95(32), pp. 55-56.

Hazmi A. D., Fauziah I., Low S. M., Siti Noor Hajjar M. L., Mohd Rasdi Z., Fairuz K., and **Kamaruzaman J. (2008)** "Toxicity of Selected Insecticides against Nymph of Whitefly (*Bemisia tabaci* Gennadius)" *Journal Agriculture Science & Technology*, David Publishing Co., Chicago, USA . 10p.

Henderson, M. (1957) "Insecticidal control of diamondback moth on cabbage at Cameron Highlands", *The Malaysian Agriculture Journal*, Vol. 40, pp. 275-79.

Hoy, C. W., and **F. W. Hall. (1993)** "Feeding behaviour of *Plutella xylostella* and *Leptinotarsa decemlineata* on leaves treated with *Bacillus thuringiensis* and esfenvalerate", *Pesticide Science*, Vol. 38: pp. 335-40.

Idris, A. B., and **E. Grafius., (1993)** "Differential toxicity of pesticides to *Diadegma insulare* (Hymenoptera: Ichneumonidae) and its host, the diamondback moth (Lepidoptera: Plutellidae)" *Journal of Economic Entomology*, Vol. 86, pp. 529-36.

Krishnamoorthy, A. (2004) "Biological control of diamondback moth, Indian Scenario with reference to past and future strategies" In : Kirk, A.A., Bordat D. (Eds.), *Proceedings of the International Symposium*, 21–24 october 2002,Montpellier, France, CIRAD, 204-211.

Lim, G. S. (1974) "Integrated pest control in developing countries of Asia" In: Divorlein, D.H. (ed.*). Environment and Development Scope Mis*. Publ., 47-76.

Lin, H., C. W. Hoy, and **G. Head (1993)** "Olfactory response of larval diamondback moth (Lepidoptera: Plutellidae) to permethrin formulation", *Environ. Entomol.*, Vol. 22, pp. 1096–1102.

Miyata, T., T. Saito, and **V. Noppun (1986)** "Studies on the mechanism of diamondback moth resistance of insecticides" *In* (N.S. Talekar ed.) Diamondback Moth Management: *Proceedings of the First International Workshop,* AVRD 347-357.

Moham, M., and **Gujar, G. T. (2003)** "Local variation in susceptibility of the diamondback moth to insecticides and role of detoxification enzymes", *Crop Protection*, Vol. 22, pp. 495-504.

Qian, L., Cao, G., Song, J., Yin, Q., and **Han, Z. (2008)** "Biochemical mechanism conferring cross resistance between tebufenozide and abamectin in *Plutella xylostell" Pesticide Biochemistry and Physiology*, Vol. 91, pp. 175-79.

Shelton, A. M., Wyman, J. A., Cushing, N. L., Apfelbeck, K., Dennehy, T. J., Mahr, S. E. R., and **Eigenbrode, S. D., (1993)** "Insecticide resistance of diamondback moth (Lepidoptera: Plutellidae) in North America", *Journal of Economic Entomology*, Vol. 86, pp. 11–19.

Simon, J. Y. (2009) "The Toxicology and Biochemistry of Insecticides" CRC Press,25 pp.

Srinivas, P., Lance, J. M., and **Timothy, M. N., (2003)** "Toxicity of insecticide-bait mixtures to insecticide resistant and susceptible western corn rootworms" *Crop Protection*, Vol. 22, pp. 781-86.

Sun, C. (1990) "Insecticide resistance in diamondback moth. *In* (N. S. Talekar ed.) Diamondback Moth Management" Proceedings *of the Second International Workshop*, AVRDC. 419-426.

Sun, C. N. (1992) "Insecticide resistance in diamondback moth" In: Talekar, N.S. (Ed.), Management of diamondback moth and other crucifer pests. *Proceedings of the Second International Workshop*, AVRDC, Taiwan, 419-426.

Syed Abdul Rahman, S. A. R., Sivapragasam, A., Loke, W. H., and **Mohd. Roff, M. N. (2000)** "Whiteflies Infesting Vegetables in Malaysia. MARDI Research Station, Cameron Highlands" Strategic, Environment and Natural Resources Center, MARDI Serdang, CABI-SEARC, UPM Serdang, and MARDI Research Station, Jalan Kebun. pp. 38-43.

Talekar, N. S. (1992) "Management of diamondback moth and other crucifer pest" *Preceedings of the Second International Workshop*, AVRDC, Taiwan, 603pp.

Travis, A. H., and **Rick E. F. (2000)** "Effect of insecticides on the Diamondback moth and its Parasitoid *Diadegma insulare*" Department of Entomology. Pp. 763-68.