ISSN 2349-0837

Toxicity of Insecticides against the Diamondback moth, Plutella xylostella L. and Its Parasitoid, Cotesia plutellae, on Cauliflower Crop

G.H. Abro[1], T.S. Syed[1], M.S. Awan[2] I. Khanzada[1], L.B. Jarwar[1], M. Sattar[3], H. Azhar[2] and A. Sartaj[2]

[1]Department of Entomology, Sindh Agriculture University, Tandojam, Pakistan.
[2] Department of agriculture & Food Technology, Karakorum International University, Gilgit-Baltistan Pakistan.
[3]Division of Plant Protection, NIAB, Faisalabad.

Corresponding Author email: saeed.awan@kiu.edu.pk

Abstract

Field studies on efficacy of different insecticides against the diamondback moth, *Plutella xylostella* L. and their toxicity to parasitoid, *Cotesia plutellae* on cauliflower crop were carried out on farmers fields. The insecticides tested were abamectin, emamectin benzoate, lufenuran, spinosad, endosulfan, profenophos, and a mixture of endosulfan +lufenuran. The pretreatment observation was taken 24 hrs before and post treatment observations were recorded 48, 72 and 96 hrs, 7 and 15 days after application of insecticides. On overall basiss abamectin and emamectin benzoate were found to be the most effective insecticides against Plutella xylostella, followed by profenophos and lufenuron with *P. xylostella* population of 1.75, 2.12, 3.69, and 4.12 insects per plant, respectively. While, spinosad and lufenuron were found comparatively less toxic to parasitoid, *C. plutellae*, followed by endosulfan with parasitism of 36.74, 36.72 and 35.65%, respectively. Whereas, abamectin was highly toxic to *C. plutellae,* with parasitism of 19.83% only.

Key words: Insecticides; efficacy; toxicity; parasitoids; Pakistan.

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Journal: JOURNAL OF ADVANCES IN AGRICULTURE

Vol .4, No. 1

www.cirjaa.com, jaaeditor@gmail.com

ISSN 2349-0837

INTRODUCTION

The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is an important pest of crucifer plants and is widely distributed throughout the world (Talekar and Shelton 1993). In Southeast Asia, major outbreaks of *P. xylostella* can cause >90% crop losses (Verkerk and Wright, 1996). Use of insecticides remains the main control strategy for *P. xylostella* because insecticides are easy to apply and often are cost-effective (Talekar and Shelton 1993; Grzywacz et al., 2010). Despite the occurrence of insecticide resistant *P. xylostella* populations in some areas. The frequent use of insecticides has also caused the resurgence of *P. xylostella* in many areas (Hama 1986, 1990; Talekar and Shelton 1993). Integration of insecticides and biological control could play important role and be effective in reducing insect pest populations. Biological control agents could be an integral component of integrated pest management (IPM) programs because they help suppress insect pest populations in agricultural ecosystems (Tillman and Mulrooney 2000, Sarfraz et al. 2005). Identification and conservation of such natural enemies has been identified as a key strategy needed for control of *P. xylostella* (Grzywacz et al., 2010). It has been reported that before 1917 *P. xylostella* populations were suppressed to a level below economic thresholds solely by natural enemies in the United States and Europe (Marsh 1917; Mustata, 1992). In the Indo-Pakistan sub-continent, *P. xylostella* was first recorded in 1914 on cruciferous vegetables (Fletcher, 1914). It was a minor pest up to 1960s in Pakistan (Ghouri, 1960), subsequently, it became a serious pest, after frequent use of toxic insecticides on brassica vegetable crops (Abro et al., 1984). Control failures of *P. xylostella* caused by sole reliance on insecticides have revealed the need for IPM in combination with parasitoids such as *Cotesia plutellae* Kurdjumov) (Hymenoptera, Braconidae) (Biever et al., 1994; Potting et al., 1999), *Diadegma semiclausum* (Hellen) (Hymenoptera, Ichneumonidae) (Talekar and Yang, 1991), or *Oomyzus sokolowskii* Kurdjumov (Hymenoptera, Eulophidae) (Uematsu and Yamashita 1999).

Cotesia plutellae is a solitary endoparasitoid of *P. xylostella* larva and has been used to suppress *P. xylostella* as a control agent in South and South-East Asia (Talekar and Shelton 1993; Kojima 1997; Okine et al., 1998; Potting et al., 1999; Haseeb et al., 2001). It has wider natural distribution and has been recorded to attack *P. xylostella* in many regions (Furlon et al., 2013). It is reported to be host-specific to *P. xylostella* (Verkerk and Wright, 1996). Field parasitism of P. xylostella larvae by C. plutellae ranges from 40% to 83.3% in Japan (Haseeb et al., 2001), 3.6–73.2% in Hawaii (Johnson et al., 1988), and 30–50% in South Africa (Waladde et al., 2001). Furthermore, field experiments in South Africa without insecticide application have shown that the parasitism of *P. xylostella* ranges from 90% to 95% (Waladde et al., 2001). The success and effectiveness of natural enemies as a control agent is often reduced by widespread use of broad spectrum insecticides, not only due to lethal effects but also due to sublethal effects on performance (Haseeb et al., 2001, 2004; Furlong et al., 2013). To preserve natural enemies by introducing selective reduced risk insecticides is one of the most important strategies to retard or avoid the development of resistance to insecticides (Saito *et al*. 1991). Kao and Tzeng (1992) evaluated toxicity of 17 commonly used insecticides to *C. plutellae*. Among them, seven insecticides were harmful (mortality >99%) to adults of *C. plutellae*, while the remaining 10 insecticides proved to be harmless (mortality <50%). Miyata (2001) evaluated the toxicity of insecticides on cocoons and adults of larval parasitoid, *C. plutellae* and effects of insecticides on parasitism. Insecticides applied at recommended concentrations showed high insecticidal activity against adults, but were less toxic to cocoons. However, parasitism by surviving adults was seriously affected. Some newer insecticides are promoted as being softer on natural enemies and may be incorporated into IPM programs more readily. For example, spinosad is in the naturalyte class of insecticides and classified as a reduced risk insecticide (Williams et al. 2003). It is primarily absorbed in the gut and kills by causing rapid excitation of the insect nervous system (Salgado 1998). It has been registered for use on over 180 crops in many countries for control of caterpillars, beetles, leafminers, and thrips (Zhao et al. 2002; Liu et al., 2012). The main purpose of this study was to investigate the efficacy of some of the commonly used insecticides to *P. xylostella* larvae, and their toxicity to parasitoid, *C. plutellae* on *P. xylostella* to better understand their potential in a combined strategy using *C. plutellae* and insecticides for IPM of *P. xylostella.* Spinosad was used as a standard softer insecticide for comparison.

MATERIALS AND METHODS

Experimental Design and Procedure

The experiment was laid out in a completely randomized block design (RCBD) with four replications and eight treatments including control (Table I). The plot size for each treatment was 22.6 m^2 with a row to row distance of 0.75 m and plant to plant distance of 0.5 m. The inter-replication and inter-treatment buffer boundaries were 1.8 and 1.0 m in width, respectively.

Cultural Practices

The nursery of cauliflower (cv. Shahzadi) was sown in a soft and loamy soil plot. The nursery plot was divided into four well-prepared seedbeds (3x5 ft). The seeds were covered by a crust of ash-silt sand mixture and watered by hand fountain twice a day in morning and evening. Twenty-five days old nursery was transplanted to the thoroughly prepared soil. The furrow and ridges were made at recommended distance. The plot shaped according to preplanned experimental design. All the recommended cultural practices were performed regularly.

Application of Insecticides

First spray was done on 19th of March 2010, 45 days after the transplanting of seedlings in field. The second spray was applied at 15 days interval on 5th April 2010. Calibration of sprayer was made before application of insecticides. The calibrated doses of pesticides were mixed with water to be sprayed with the help of knapsack sprayer operated manually and the sprayer was washed thoroughly before and after spraying. For safety purpose a mask, goggles, gloves, and protective clothing were used. The sprays were applied in the morning hours to reduce wind drift, evaporation and to avoid the breaking down of pesticides due to sunlight and heat and to save the predators, parasites and pollinators.

ISSN 2349-0837

Observation and Collection of Data

The pretreatment observation was recorded one day before the application of insecticides and post treatment observations were recorded 48, 72, 96 hrs and 7 and 15 days after application of insecticides. The data was collected from five plants selected at random from each treatment. Each plant was thoroughly examined for counting the larvae and pupae of *P. xylostella.* As female wasp of *Cotesia plutellae* lays eggs on larvae of *P. xylostella* and young one of *C. plutellae* after emergence feed and pupate inside larvae of *P. xylostella* by killing it. Therefore, to record pre-treatment observation larvae of *Plutella xylostella* were collected one day before the application of pesticides from respective treatments. For this purpose, every plant in respective treatment was scanned carefully. Collected larvae of *P. xylostella* were taken into laboratory of Sindh Agriculture University, Tandojam where they were reared into Petri dishes, fed on cauliflower leaves and allowed to grow normally to observe parasitism and finally number of pupae of *Cotesia plutellae* emerged from larvae of *P. xylostella* was counted. Similarly for post-treatment observations larvae of *P. xylostella* were collected after 2, 3, 4, 7 and 15 days of spray from field and reared into laboratory and number of pupae of *C. plutellae* emerged from *P. xylostella* larvae were counted. Two applications of pesticides ware made and data were statistically analyzed.

RESULTS

First Spray/Application

The data in Table II indicated that average population of diamondback moth, *Plutella xylostella* at pre-treatment observation in different treatments ranged between 4.15 and 5.05 insects per plant which did not vary significantly from each other and indicated that pest population was almost uniformly distributed among experimental plots.

The post treatment observation after 48 hrs and 72 hrs of insecticides application indicated that the average population density of *P. xylostella* was not-significantly different from each other in different treatments. After 96 hours of insecticide application, there was a significant ($F_{7, 21}$=18.53; P≤0.01) difference between population means of different treatments. The average population density of diamondback in T1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 were 3.85, 3.05, 1.15, 3.40, 1.25, 3.25, 3.40 and 3.95 insects per plant, respectively. These figures show that after 96 hrs of insecticides application, abamectin was the most effective insecticide. The efficacy of these insecticides against *P. xylostella* in descending order was abamectin > emamectin benzoate > lufenuron > profenophos > endosulfan +lufenuron >spinosad endosulfan > control.

After 7 days of insecticide application abamectin and emamectin benzoate were the most effective insecticides against *P. xylostella* ($F_{7, 21}$=13.20; *P*≤0.01). The efficacy of different insecticides in a descending order was abamectin > emamectin benzoate > profenophos > lufenuron > endosulfan +lufenuron > spinosad > endosulfan > control. The results showed that there was a significant ($F_{7, 21}$=11.53; P≤0.01) difference in efficacy of insecticides against *P. xylostella* 15 days after application of insecticides. The efficacy of different insecticides in a descending order was abamectin > emamectin benzoate > profenophos > spinosad > endosulfan +lufenuron > control > lufenuron > endosulfan. It was clear from Table I that after 15 days of insecticide application abamectin and emamectin benzoate was found to be significantly the most effective insecticides against *P. xylostella.* The results of first application of insecticides indicated that the abamectin was the most effective insecticide, and then followed by emamectin benzoate, which were statistically most effective insecticides compared with other insecticides. The results of this study also indicated that except these two insecticides, other insecticides lost their effectiveness against *P. xylostella* at 15 days post-treatment interval. At pre-treatment observation the average percent parasitization of *C. plutellae* on *P. xylostella* in T_1, T_2, T_3 , T_4, T_5, T_6, T_7 and T_8 was 30.17, 17.67, 51.00, 46.83, 30.17, 24.00, 34.33, 26.00 percent, respectively. The post-treatment observation after 48 hours of insecticide application revealed that there was a significant ($F_{7, 21}$=2.56; P≤0.05) difference in toxicity insecticides to *C. plutellae.* The toxicity of these insecticides against *C. plutellae* in ascending order was endosulfan +lufenuron < lufenuron < spinosad and profenophos < endosulfan < emamectin benzoate < control and abamectin. After 48 hours of insecticide application the least toxic insecticide to *C. plutellae* was found to be the mixture of endosulfan +lufenuron. After 72 hours of insecticide application, the average parasitism of *C. plutellae* in T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 was 34.34, 30.17, 26.00, 59.34, 38.50, 42.67, 26.00 and 44.75 percent, respectively. The toxicity of different insecticides against parasitism in an ascending order was: spinosad < control < profenophos < emamectin benzoate < endosulfan lufenuron < abamectin and endosulfan +lufenuron. After 72 hrs of insecticide application, spinosad was found to be least toxic against *C. plutellae*. Average percent parasitism of *C. plutellae* after 96 hours of insecticide application in T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 was: 30.17, 30.17, 13.50, 38.50, 30.17, 38.50, 30.17 and 19.75%, respectively. This revealed that profenophos and spinosad were less toxic to parasitoids compared with other insecticides. Similarly the toxicity of different insecticides to *C. plutellae* after 7 days in ascending order was emamectin benzoate < lufenuron spinosad < endosulfan< endosulfan + lufenuron < abamectin <Control < profenophos. Emamectin benzoate was noticed to be significantly ($F_{7, 21}$=23.18; P≤0.01) the least toxic to parasitism. After 15 days interval, the parasitism in different treatments observed ranged between 20.00 and 43.5%. Endosulfan and lufenuron were the least toxic insecticides to parasitism. The mean toxicity of insecticides to *C. plutellae* after first application of insecticides in ascending order was: spinosad < lufenuron < emamectin benzoate < endosulfan +lufenuron < endosulfan < profenophos< lufenuron < abamectin. The results of first application showed that insecticides produced very little effect on parasitism after 48 hours and parasitism started to increase gradually from72 hours after application. Spinosad and lufenuron were the least toxic insecticides, which gave higher percentages of parasitism and abamectin was the most toxic to parasitoid.

Second Spray/Application

The data in Table IV indicated the efficacy of different insecticides at post-treatment intervals after second application of insecticides. After 48 hrs of insecticides application, the population density of pest in T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 were 5.80, 3.92, 1.85, 5.30, 2.30, 4.15, 5.60 and 6.40 insects per plant, respectively. The effectiveness of different insecticides in descending order was abamectin > emamectin benzoate > lufenuron> profenophos > spinosad> endosulfan +lufenuron >

endosulfan > control. The data reveal that after 48 hours of application, the minimum pest population was found in abamectin treated plots followed by emamectin benzoate and these insecticides were significantly more effective than other insecticides. After 72 hours of insecticide application, effectiveness of insecticides in descending order was abamectin > emamectin benzoate > profenophos > endosulfan +lufenuron > spinosad > lufenuron > control > endosulfan. These figures indicate that, after 72 hrs the most effective insecticide was abamectin followed by emamectin benzoate. The results indicated that at 96 hrs of insecticide application, the most effective insecticides were abamectin and emamectin benzoate.

The population density of *P. xylostella* after 7 days of insecticide application in T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 was recorded as 4.70, 4.60, 1.25, 5.30, 1.62, 3.0, 5.0, and 4.55 insects per plant, respectively. At 7 day interval abamectin and emamectin benzoate were significantly more effective against *P. xylostella* compared with other insecticides. *P. xylostella* population after 15 days of insecticide application in descending order was: abamectin > emamectin benzoate > lufenuron > profenopho > endosulfan +lufenuron > endosulfan > control> spinosad. It was noticed that after 15 days of insecticide application the most effective insecticides were abamectin and emamectin benzoate. The statistical analysis of the data show that abamectin was significantly most effective insecticide in reducing the pest population compared to other insecticides at the interval of 48 hrs, 72 hrs, 96 hrs, 7 days and 15 days, while the second most effective insecticide against *P. xylostella* was the emamectin benzoate.

The Table V indicated the percent parasitism of *P. xylostella* larvae by *C. plutellae* after second application of insecticides. The percent parasitization of *C. plutellae* at pre-treatment intervals was 41.68, 38.89, 30.00. 33.33, 28.33, 23.43, 31.94 and 37.50 percent per treatment, respectively. After 48 hours of insecticidal application, the parasitism of *C. plutellae* in T_I, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 was recorded as 38.37, 31.80, 18.33, 39.59, 31.25, 16.68, 41.08 and 26.31 percent per treatment, respectively. The data revealed that after 48 hours of application, the least toxic insecticide to parasitism was the mixture of endosulfan +lufenuron. After 72 hours of application the toxicity of insecticides in an ascending order was: endosulfan +lufenuron < endosulfan < spinosad < profenophos < control < lufenuron < emameclin benzoate < abamectin. The results showed that after 72 hours of insecticide application the toxicity of mixture of endosulfan +lufenuron insecticide was least to parasitism followed by endosulfan and spinosad. The analysis of data indicated that lufenuron was the least toxic to percent parasitism by *C. plutellae* on *P. xylostella* larvae. After 7 days of second application of insecticides, the toxicity of insecticides to parasitoid in ascending order was endosulfan +lufenuron < control < endosulfan < lufenuron < emamectin benzoate < profenophos < spinosad and < abamectin. It was observed that mixture of endosulfan +lufenuron was less toxic to parasitoids than any other insecticides listed. After 15 days of application the toxicity of insecticides in ascending order was endosulfan < lufenuron < control < endosulfan +lufenuron < spinosad < profenophos < emamectin benzoate and < abamectin.

The overall effectiveness of insecticide, after first and second applications showed that the efficacy of different insecticides in descending order was abamectin > emamectin benzoate > profenophos > lufenuron > endosulfan +lufenuron > spinosad > endosulfan > control. It could be concluded from this study that abamectin and emamectin benzoate were the most effective insecticides against *P. xylostella* followed by profenophos, lufenuron, endosulfan +lufenuron, spinosad and endosulfan. The overall toxicity of insecticides on parasitism could be interpreted in ascending order as spinosad < lufenuron < endosulfan< endosulfan +lufenuron < emamectin benzoate < control < profenophos < abamectin and it could be concluded from this study that spinosad and lufenuron were least toxic to *C. plutellae* followed by endosulfan and mixture of endosulfan +lufenuron compared with other insecticides.

DISCUSSION

The most common approach employed by farmers in many developing countries including Pakistan to control *P. xylostella* has been the use of different classes of insecticides. Our study indicated that the avermactins (abamectin and emamectin benzoate) were the most effective compounds followed by organophosphate insecticide, prophenophos and insect growth regulator, lufenuron against *P. xylostella*. Several studies have evaluated insecticides against *P. xylostella* in developing countries and have reported avermectins comparatively more effective than other insecticides as was found in this study. Abro et al., (1988) tested different insecticides against *P. xylostella* and found avermectin considerably more active than cypermethrin. Leibee and Savege, (1992) reported that chlorpyriphos, endosulfan mevinphos and B.t. kurstaki were effective in controlling *P. xylostella* than cypermethrin and permethrin. Liu *et al.,* (1992) found Agrimec (avermectin) at 9 to 18 ppm gave 82 to 91% control of P. *xylostella* within 10 days of spraying. Ooi (1992) observed abamectin more effective than leflubenzuron against *P. xylostella.* Diaz-Gomez et al. (1994) determined the susceptibility of three Mexican populations of *P. xylostella* by leaf residue feeding bioassay to Novo-Biobit, Dipel 2X, Javelin, Thuricide and Cutlass (all *Bacillus thuringiensis* subsp*. kurstaki* formulations) and by topical application to avermectin. *P. xylostella* was more susceptible to avermectin than to formulations of *B. thuringiensis*. Raju et al., (1994) conducted laboratory studies to evaluate the relative toxicity of different insecticides against *P. xylostella* and found cypermethrin and fenvalerate almost 10 to 15 times more toxic, respectively, than endosulfan. Wang et al., (1994) tested the toxicity of several chitin synthesis inhibitors to fourth instar *P. xylostella* in the laboratory and found them to be much more toxic than some conventional insecticides. Williams and Mansingh, (1996) reported that the compounds isolated from the neem plant manifested their effects on test organisms in many ways such as anti feedants, growth regulators, repellent toxicants and chemosterilants. Abro *et al*., (2013) tested toxicity of different insecticides against *P. xylostella* under laboratory conditions. The LC_{50} values of different insecticides varied significantly and feeding by *P. xylostella* on different host plants sometimes significantly affected their toxicity. The LC_{50} values of lufenuron, profenofos, λcyhalothrin, spinosad and avermectin alone were 1.14, 8.67, 0.0418, 0.37, and 0.013 mg $^{a.i}$ ml^{-1}, respectively.

Present study shows that spinosad and lufenuron were comparatively less toxic to parasitoid, *C. plutellae* followed by endosulfan and mixture of endosulfan and lufenuron with parasitism of 36.74, 36.72, 35.65% and 35.58%, respectively. Whereas, abamectin was highly toxic to *C. plutellae* with parasitism of *P. xylostella* as 19.83% only. Protocols have been developed for testing toxicity of insecticides against natural enemies (Hassan et al., 1985; 1987). Insecticides harmless to a particular natural enemy in the laboratory test were assumed to be harmless to the same organism in the field and no further

testing was recommended (Hassan, 1989). There are many studies reported which show the toxicity of insecticides to *C. plutellae* under laboratory and field conditions. Biever e*t al*. (1994) described the evaluation and implementation of a biological control-integrated pest management system for lepidopterous pests of crucifers, developed over a period of 24 years. Mani (1995) reported that fungicides Matalaxyl, Mencozeb, Chlorothalonil, Copperoxychloride and insecticides Fluvalinate, Carbaryl, Acephate, Methyl-demeton, neem seed kernel extract and Neemark (containing neem) were harmless to adult parasitoid, *C. plutellae*. Dimethoate, Dichlorvos and Endosulfan were the least persistent insecticides, whereas Chloropyrifos was highly persistent against *C. plutellae*. Chilcutt and Tabashnik (1999) used computer simulations to understand how to combine microbial insecticide *Bacillus thuringiensis* Berliner and *C. plutellae* to control diamondback moth, *P. xylostella* . Xu e*t al*. (2004) evaluated effects of eight insecticides on *Diadegma insulare* (Cresson) in laboratory. The insecticides were three azadirachtin-based products, two Bt. products, indoxacarb, spinosad and λ- cyhalothrin. When *D. insulare* pupae were treated, none of the insecticide treatments except λ-cyhalothrin significantly reduced adult emergence, with 76-90% adults emerged from the treated pupae. In the λ-cyhalothrin treatment, only 10% *D. insulare* pupae produced adult wasps. Liu at el (2012) evaluated the toxicity of two insecticides λ-cyhalothrin and spinosad on the parasitoid, *Diadegma insulare* (Cresson), and the predator, *Coleomegilla maculate* (DeGeer), both natural enemies of the diamondback moth,*P. xylostella* in the laboratory and in cages in the greenhouse. λ-cyhalothrin was very toxic to both natural enemies. Spinosad was less toxic to *C. maculata* adults and larvae, and slightly toxic to *D. insulare*. Liu at el., (2012) further show that λ-cyhalothrin had direct toxicity to these two natural enemies, could affect their host foraging and acceptance of *P. xylostella* and consequently would not be compatible in conserving these natural enemies in a program for suppression of *P. xylostella*. Their studies suggested that treatment with spinosad had much less effect on these natural enemies and would allow them to help suppress populations of *P. xylostella*. Studies on the toxic effects of pesticides on parasitoids of *P. xylostella* have been carried out in many countries (Fang and Wang, 1984; Mani and Krishnamoorthy, 1984; Kao and Tzeng, 1992; Mani, 1995; Furlong and wright, 1993; Furlong et al., 1994; Idris and Grafius, 1993 a,b,c; Chilcutt and Tabashnik, 1997, 1999).

It is concluded from this study that some insecticides are highly toxic to natural enemies of *P. xylostella,* therefore, not suitable to be applied frequently against *P. xylostella*. Natural enemies such as *C. plutellae* and *Oomyzus sokolowskii* are active in brassica vegetable crops (Abro unpublished data) and play important role in population suppression of *P. xylostella*. Insecticides such as spinosad are reported to be less toxic to natural enemies are advised to be selected for application under field conditions for the population management of *P. xylostella*. Such insecticides are compatible with biological control and less toxic to natural enemies to perpetuate and carryout their activities against pest insects. This approach will provide biological based IPM of *P. xylostella* in brassica vegetable crops. It will also reduce the harmful impact of insecticides in the environment.

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Table I. Insecticides, their trade and common names, chemical group and dose/ acre used in the study.

	Common name	**Chemical group**	**Dose/acre (ml)**
T1=Thiodan 35EC	Endosulfan	Organochlorine	1000
T2=Match 50EC	Lufenuran	Insect Growth Regulator	200
T3=Sure 1.8 EC	Abamectin	Avermectin	200
T4=Tracer240 SC	Spinosad	Naturalyte	40
T5= Proclaim19EC	Emamectin benzoate	Avermectin	200
T6=Curacron500EC	Profenophos	Organophoshorus	1000
T7=Thiodan 35EC+ Match 50 EC	Endosulfan +lufenuran	Organochlorine + Insect Growth Regulator	1000 +200 ml
T8=Control	--	--	--

ISSN 2349-0837

Table II. Efficacy of different insecticides against diamondback moth on cauliflower under field conditions after 1st spray (Mean± S.E.).

Treatments	*P. xylostella* (larvae and pupae)						Mean
	Pre-treatment 24hrs. before spray	After spray at intervals					
		48hrs	72 hrs	96 hrs	7 days	15 days	
Endosulfan	4.35±0.85a	4.60±1.51 a	4.65± 1.36a	3.85±0.30c	3.65±0.55 b	6.35±1.75d	4.62
Lufenuran	4.40±0.83a	4.70±1.42 a	3.85±0.77 a	3.05±0.55 b	3.10±0.25b	6.15±1.76cd	4.17
Abamectin	4.45±1.17a	4.45± 1.17a	1.60±0.36 a	1.15±0.19a	1.05±0.19a	1.95 ±0.73 a	2.04
Spinosad	5.05±1.61a	5.05±1.61 a	4,.15±0.80 a	3.40±0.56 be	3.40±1.24b	5.25±0.59bc	4.25
Emamectin benzoate	4.15±0.61a	4.0±0.78a	1.70±0.38 a	].25±0.19a	1.35±0.10a	2.80±0.74 a	2.22
Profenophos	4.75±0.70a	4.75±0.70 a	3.60±1.37 a	3.25±0.71 be	2.80±0.28 b	4.50±0.73 b	3.78
Endosulfan +lufenuran	4.25±0.71a	4.25±0.71 a	3.35±0.52 a	3.40±0.36bc	3.40±0.76 b	5.52±0.25 bed	3.98
Control	4.35±1.70a	4.35±1.70 a	4.45±0.91 a	3.95±0.71 c	4.70± 1.08 c	5.80±1.2bcd	4.65
LSD 0.05	-	-	-	0.73	0.96	1.37	-

Figures followed by same letters are not significantly different from each other (P<0.05) by LSD test

Table III. Toxicity of insecticides on the mean percent parasitization of *P. xylostella* larvae by *C. plutellae* under field conditions after first spray.

Treatments	Pre-treatment	Percent parasitization					Mean
		48 hr.	72 hr.	96hrs.	7 days	15days	
Endosulfan	30.17a	21.83b	34.34a	30.17a	42.67bcd	43.5a	34.50
Lufenuran	17.65a	34.33b	30.17a	30.17a	46.83cd	41.0a	36.50
Abamectin	51.00a	2.0 a	26.00a	13.50a	30.17abc	32.67a	20.87
Spinosad	46.83a	26.0 b	59.34a	38.50a	46.83cd	33.50a	40.84
Emamectin benzoate	30.17a	17.67cd	38.5a	30.1 7a	59.33 d	30.17a	35.17
Profenophos	24.00a	26.0 h	42.67a	38.50a	17.67 a	26.0a	30.17
Endosulfan +lufenuran	34.33a	38.49 c	26.0a	30.17a	42.67bc	36.0a	34.62
Control	26.0a	13.5 ab	44.75a	19.75a	22.88 ab	41.0a	28.38
CD 0.05	0.00	21.28	0.00	0.00	23.18	0.00	0.00

1) Figures followed by same letters are not significantly different from each other (P<0.05) by LSD test.

ISSN 2349-0837

Table IV. Efficacy of different insecticides against diamondback moth on cauliflower under field conditions after 2nd spray. (Mean ± S.E)

Treatments	*P. xylostella* (Larvae and Pupae)						Mean
	Pre-treatment 24 hrs. before spray	After spray at intervals					
		48 hrs	72 hrs.	96 hrs	7 days	15 days	
Endosulfan	5.90±1.03	5.80±l.lld	6.40±1.33b	5.25±1.57bcd	4.70±1.94c	3.40±0.87de	5.11
Lufenuran	5.30±1.31	3.92±0.99b	4.95±1.34b	4.75±1.80bc	4.60±1.54c	2.75±0.52bc	4.19
Abamectin	2.0±0.36	1.85±0.66b	1.15±0.61 a	0.75±0.34 a	1.25±0.59a	1.60±0.28a	1.32
Spinosad	5.15±0.34	5.30±1.94cd	4.85±1.94cd	5.55±0.99cd	5.30±1.90c	3.85±0.99e	4.97
Emamectin benzoate	2.60±0.99	2.30±0.95 a	1.95±0.99a	1.50±0.50a	1.62±0.67a	2.15±0.66ab	1.9p
Profenophos	4.60±0.80	4.15±1.02bc	4.65± 1.73 b	4.05±1.48b	3.0±1.24b	2.95±0.37 cd	3.76
Endosulfan +lufenuran	5.25±1.42	5.60±1.45d	4.80±0.58 b	5.90±0.52 cd	5.0±2.03 c	2.95±0.44 cd	4.85
Control	6.15±0.86	6.40±1.33d	5.95±0.85 b	6.15±1.64d	4.55± 1.07 c	3.75±0.52 e	5.36
LSD 0.05	-	1.34	1.78	1.20	1.23	0.64	-

Figures followed by same letters are not significantly different from each other (P<0.05) by LSD test.

Table V. Toxicity of insecticides on the percent parasitization of *P. xylostella* larvae by *C. plutellae* under field conditions after second spray.

Treatments	Pretreatment	Percent parasitization					Mean
		48 hrs.	72 hrs	96 hrs.	7 days	15 days	
endosulfan	41.68a	38.33a	39.93 **a**	29.J7a	41.18a	35.42a	36.80a
lufenuran	38.89a	31.80a	27.58a	5 1.56a	38.75a	35.00a	36.94a
abamectin	30.00a	18.33a	13.33a	15.38a	28.57a	18.33a	18.79a
Spinosad	33.33a	39.59a	34.72a	29.4a	32.81a	26.69a	32.64a
emamectin benzoate	28.33a	3 1.25a	15.28a	23.08a	36.73 a	20.00a	25.27a
profenophos	23.43a	16.68a	29.42a	25.00a	34.72a	25.00a	26.17a
endosulfan +lufenuran	31.94a	41.00a	41.67a	2 1.43a	46.62a	31.67a	36.49a
Control	37.5a	26.3 1 a	28.12a	26.57a	43.75a	32.15a	31.38a

Figures followed by same letters are not significantly different from each other (P<0.05) by LSD lest.

ISSN 2349-0837

Table VI. Overall toxicity of insecticides on parasitization of *P.xylostella* larvae by *C. plutellae* under field conditions.

Treatments	1st spray	2nd spray	Overall mean
endosulfan	34.50	36.80	35.60
lufenuran	36.5	36.94	36.72
abamectin	20.87	18.79	19.83
Spinosad	40.84	32.64	36.74
emamectin benzoate	35.17	25.27	30.22
profenophos	30.17	26.17	28.17
endosulfan +lufenuran	34.67	36.49	35.58
Control	28.38	31.38	29.88