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S Sambathkumar
Agricultural Officer, Pesticides Testing Laboratory, Department of Agriculture, Coimbatore, Tamil Nadu, India

Corresponding Author:
S Sambathkumar
Agricultural Officer, Pesticides Testing Laboratory, Department of Agriculture, Coimbatore, Tamil Nadu, India

In vitro efficacy of newer insecticide molecules against diamondback moth, *Plutella xylostella* (Linnaeus) and leaf webber, *Crocidolomia binotalis* Zeller in cabbage

S Sambathkumar

Abstract
Cabbage is an important cruciferous vegetable, infested by many insect pests and diamondback moth, *Plutella xylostella* and leaf webber, *Crocidolomia binotalis* Zeller are found to be predominant and highly devastating in nature and thereby offer huge economic losses. In viewing the drawbacks of conventional insecticides used to management, *in vitro* studies were attempted to find out the effect of some newer generation insecticide molecules against these pests. Among insecticides evaluated, Chlorantraniliprole 18.5% SC and Flubendiamide 39.5% SC up on exposure to short period, both larvae of *P. xylostella* and *C. binotalis* stopped feeding and found completely controlled. Later, Spinosad 2.5% SC @ 25 g a.i./ha, Emamectin Benzoate 5% SG @ 15 g a.i./ha and Fipronil 5% SC @ 750 g a.i./ ha were joined in the lineage through reducing the population of these pests. When compared to DBM larvae, these insecticides brought rapid and complete larval mortality of *C. binotalis* and this revealed their maximum susceptibility.

Keywords: Bioefficacy, chlorantraniliprole, flubendiamide, mortality, newer insecticides

Introduction

Vegetables have been one of the major foods for human from time immemorial. Their cultivation plays a significant role in economic prosperity of nation and they satisfied the nutritional requirement of people. Cabbage *(Brassica oleracea* var. *capitata* L.) is one such abundantly consumed commercial cruciferous vegetable crop, amenable to cultivate throughout the year. In India, its annual production was about 90,37,000 MT from an area of 3,99,000 ha [1]. Since it is a short duration crop, it is mainly cultivated in high altitude areas and also in plains. But in both cases, they are known to be infested by many insect pests. Among them, lepidopterans such as diamondback moth (DBM), *Plutella xylostella* (Linnaeus) (Family: Plutellidae) and leaf webber, *Crocidolomia binotalis* Zeller (Family: Crambidae) are found to be predominant and highly devastating in nature and thereby offer huge economic losses. Both these pests are attack the crop through skeletonization of leaves, voracious feeding on heads and remain on the undersurface of leaves in webs [2]. Apart from direct feeding, they indirectly affecting the quality of economic produce through these webbings entangled with excreta and thereby make the crop unfit for consumption. So, they become a major challenge for the cultivation of both cabbage and cauliflower [3].

On Cabbage, *P. xylostella* alone cause a yield loss of 50 to 80 per cent [4, 5, 6]. On the other hand, these two pests together may give up to 100 per cent crop losses when suitable control is not undertaken [7]. They often cause heavy damage on cabbage crops particularly in dry season. Many botanicals, biopesticides and chemical insecticides are in used practice to manage these pests. But, common strategy adopted by farmers in reducing their population in cabbage crops is use of many conventional synthetic insecticides at higher doses. Their indiscriminate application and repeated use resulted in remarkable reduction in population of their natural enemies with intrinsic development of resistance against them [8]. It was recorded the development of insecticide resistance in DBM against more than 69 molecules [9] and in addition it showed strong fight back to *Bt* under field conditions [10, 11]. Additionally, the excessive use of synthetic insecticides poses many undesirable effects to both the agricultural ecosystem and human health their long persistence as toxic residues in food chain. Insecticide residue in agricultural products majority of vegetable and fruit products particularly in cruciferous vegetables like cabbage and cauliflower and this is a growing concern for producers, traders and consumers [3]. Therefore, several efforts have been attempted to reduce to use of synthetic pesticides particularly the conventional insecticides. One of the alternative efforts is the introduction of promisive newer insecticide molecules with novel mode of action and less residual life. In view of keeping above points, an experiment was envisaged on effect of some newer generation low dose insecticide molecules with unique mode of action against *P. xylostella* and *C. binotalis* along with conventional chemicals.

Materials and Methods

Culturing of test insects

Larvae of *P. xylostella* and *C. binotalis* were collected from cabbage and cauliflower crop fields in and around College of Horticulture, Vellanikkara, Thrissur to mass culture their population. They were kept separately on plastic basins (30 cm dia. and 15 cm height) containing dry filter paper and fresh leaves of cabbage were provided for larvae and replaced periodically. Once the larval cycle was completed, the healthy and disease free pupae were carefully separately collected and 25 pupae were kept in accordance to insects in a white transparent plastic buckets (30 cm dia. x 25 cm height) for adult emergence, mating and oviposition. Fresh leaves were provided as source for egg laying and the mouth of the plastic bucket was covered with black coloured sterile muslin cloth, which also served as oviposition substrate. Ten per cent sugar solution with a drop of vitamin E swabbed absorbent cotton in suitable sterile glass vials kept inside the bucket as adult food and they were periodically replaced. The muslin cloths of each bucket covered on both adult moths of *P. xylostella* and *C. binotalis* and leaves kept for oviposition were incubated in plastic trays (30 cm dia. and 15 cm height) separately with fresh tender cabbage leaves. The highly active and disease free second instar larvae of both insects were separately collected and utilized for further toxicity studies. Larvae before used in the experiment, were starved for three hours without any food. Entire mass culturing was maintained at a temperature of 27.2 ± 1.6^{O} C and relative humidity (RH) of 80.3 ± 4.4 per cent until the expiry of experiment.

Toxicity bioassay

The biological efficiency of nine newer insecticide molecules belongs to different chemical groups *viz.,* Flubendiamide 39.5% SC, Emamectin Benzoate 5% SG, Fipronil 5% SC, Indoxacarb 14.8% SC, Chlorantarniliprole 18.5% SC, Diafenthiuron 50% WP, Spinosad 2.5% SC and Novaluron 10% EC was tested and compared with the conventional insecticide Thiodicarb 75 % WP against larvae of *P. xylostella* and *C. binotalis* on cabbage under laboratory conditions. The experiment was conducted by leaf dip bioassay method in completely randomized design with nine treatments and an untreated control (Table 1). Cabbage leaves were dipped in different insecticide treatments for 10 minutes and allowed to dry on a filter paper until leaves of free from wetness. They were kept in plastic containers (15 cm dia. x 15 cm height) with dry filter paper at bottom and in each treatment 20 numbers of pre starved second instar larvae of *P. xylostella* and *C. binotalis* were released separately and covered with muslin cloth and fastened with rubber band. Similarly, an untreated control was also maintained by dipping leaves in normal water. Likewise, twenty numbers of each *P. xylostella* and *C. binotalis* larvae of were used per replication in every treatment and thus five replications were maintained for each treatment. Larval mortality was recorded on 12, 24, 48, 72 and 96 HAT in each replication of all treatments and was converted to per cent mortality. In addition the per cent increase of larval mortality over control was calculated using following formula.

$$\text{Per cent increase of larval mortality over control} = \frac{\text{Larval mortality in treatment (\%) - Larval mortality in control (\%)}}{\text{Larval mortality in treatment (\%)}} \times 100$$

Statistical analyses

Per cent larval mortality of both insects obtained between 0.0 to 100.0 per cent was subjected to arcsine transformation. Analysis of variance was computed and means were separated by Tukey's HSD [12] at one per cent significance level [13]. Statistical analysis was done using SPSS (Statistical Package for Social Science) 16.0 version. The critical p- value of 0.01 was kept and analyzed for each test.

Results and Discussion

Efficacy of newer insecticides against *P. xylostella*

Results of Table 2 revealed that all insecticidal treatments under evaluation were observed to be significantly superior over conventional insecticide check and untreated control in reducing the larval population of *P. xylostella*. On 12 hours after treatment (HAT), early mortality of DBM larvae obtained from Spinosad 2.5% SC treated @ 25 g a.i./ ha (6.25 %) followed by 5.00 per cent in Chlorantarniliprole 18.5% SC @ 25 g a.i./ha and Fipronil 5% SC @ 750 g a.i./ ha and most significantly effective than others. Whereas in other treatments, larval mortality was recorded only less than 4.00 per cent. Suddenly on 24 HAT, DBM larvae treated with Chlorantarniliprole 18.5% SC @ 25 g a.i./ha, Flubendiamide 39.5% SC @ 25 g a.i./ha, Spinosad 2.5% SC @ 25 g a.i./ ha and Emamectin Benzoate 5% SG @ 15 g a.i./ha produced mortality of 58.75, 58.75, 52.50 and 42.50 per cent respectively and were observed to be highest and significant in causing mortality than other insecticides. Howbeit, it was recorded less than 23 per cent in other treatments. On 36 HAT, all DBM found dead (100 % mortality) in treatments, Chlorantarniliprole 18.5% SC @ 25 g a.i./ha and Flubendiamide 39.5% SC @ 25 g a.i./ha and were on par with each other indicating their equal bioefficacy in causing mortality against of *P. xylostella*. Further treatments like Spinosad 2.5% SC @ 25 g a.i./ ha (92.50%), Emamectin Benzoate 5% SG @ 15 g a.i./ha (81.25%), Fipronil 5% SC @ 750 g a.i./ ha (75.00%) were next in the order of effectiveness showing larval mortality of 92.50, 81.25 and 75.00 per cent respectively. In all other treatments the mortality was less than 50 per cent when compared to 3.75 per cent in untreated control.

Two days after insecticidal treatment (48 HAT), the other treatments *viz.*, Emamectin Benzoate 5% SG @ 15 g a.i./ha and Spinosad 2.5% SC @ 25 g a.i./ ha also caused complete mortality (100.00%) of *P. xylostella* and they were found to be on par with Chlorantarniliprole 18.5% SC @ 25 g a.i./ha and Flubendiamide 39.5% SC @ 25 g a.i./ha. Fipronil 5% SC @ 750 g a.i./ ha and Indoxacarb 14.5% SC @ 10 g a.i./ ha registered 96.25% and 86.25 per cent DBM mortality respectively and found be statistically on par with each other. Next to these, Novaluron 10% EC @ 300 g a.i./ ha (82.50%), Diafenthiuron 50% WP @ 500 g a.i./ ha (76.25%) and

Thiodicarb 75 % WP @ 750 g a.i./ ha (73.75%) found to significant in controlling *P. xylostella* larvae as compared to 12.50 per cent mortality in control. In addition, after three days of inception of bioassay (72 HAT), Fipronil 5% SC @ 750 g a.i./ ha registered larval mortality of 98.75 per cent and on par with other treatments which already caused complete mortality of *P. xylostella*. Next in order of effectiveness were observed in Novaluron 10% EC (96.25%) and Diafenthiuron 50% WP (95.00%) treated @ 300 g a.i./ ha and 500 g a.i./ ha and were equally effective against DBM larvae as against 31.25 per cent in control. On 96 HAT, complete larval death was observed except in treatments, Thiodicarb 75 % WP @ 750 g a.i./ ha (98.75%), Diafenthiuron 50% WP @ 500 g a.i./ ha (97.50%) and Novaluron 10% EC @ 300 g a.i./ ha (95.00%) and were statistically at par with each other as against 52.50 per cent in control.

Efficacy of newer insecticides against *C. binotalis*

In the second experiment, on 12 HAT, almost all treatments with newer molecules brought early larval mortality of *C. binotalis* and it was highest in larvae treated with Flubendiamide 39.5% SC @ 25 g a.i./ha (13.75%) followed by 12.50, 8.75 and 6.25 per cent in treatments Chlorantarniliprole 18.5% SC @ 25 g a.i./ha, Spinosad 2.5% SC @ 25 g a.i./ ha and Emamectin Benzoate 5% SG @ 15 g a.i./ha respectively as against complete larval survival registered in Indoxacarb 14.5% SC @ 10 g a.i./ ha, Diafenthiuron 50% WP @ 500 g a.i./ ha, Novaluron 10% EC @ 300 g a.i./ ha and untreated control (Table 3). However, appreciable hike in the larval mortality observed on 24 HAT and during that time, Chlorantarniliprole 18.5% SC @ 25 g a.i./ha caused a significant maximum cumulative larval mortality of *C. binotalis* (82.50%) and this is partially on par with Flubendiamide 39.5% SC @ 25 g a.i./ha (80.00%). Next to these, Spinosad 2.5% SC @ 25 g a.i./ ha and Emamectin Benzoate 5% SG @ 15 g a.i./ha showed 7750 and 53.75 per cent cumulative larval mortality respectively. In other treatments, it ranged from 8.75 (Indoxacarb 14.5% SC @ 10 g a.i./ ha) to 28.75 (Fipronil 5% SC @ 750 g a.i./ ha) and in control all larvae were found to be alive.

On 36 HAT, complete and highest cumulative larval mortality was registered in Chlorantarniliprole 18.5% SC @ 25 g a.i./ha and Flubendiamide 39.5% SC @ 25 g a.i./ha followed by Spinosad 2.5% SC @ 25 g a.i./ ha (98.75%) and were statistically on par with each other. This showed their equal potency Chlorantarniliprole 18.5% SC and Flubendiamide 39.5% SC against larvae of *C. binotalis*. In addition, other insecticides also gave significant increase of larval mortality as 76.25 (Emamectin Benzoate 5% SG @ 15 g a.i./ha), 71.25 (Fipronil 5% SC @ 750 g a.i./ ha), 56.25 (Diafenthiuron 50% WP @ 500 g a.i./ ha) per cent larval morality. Whereas, in other treatments the cumulative mortality ranged from37.50 to 42.50 per cent in Indoxacarb 14.5% SC @ 10 g a.i./ ha and Novaluron 10% EC @ 300 g a.i./ ha compared to only 2.50 per cent in un treated control. Two days after insecticidal treatments (48 HAT), mortality of 100.00, 98.75 and 98.75 per cent were reported in larvae exposed to Spinosad 2.5% SC @ 25 g a.i./ ha, Emamectin Benzoate 5% SG @ 15 g a.i./ha and Fipronil 5% SC @ 750 g a.i./ ha. By this way, they accompanied with Chlorantarniliprole 18.5% SC and Flubendiamide 39.5% SC and were statistically on par to each other *via* their consistent superiority in reducing the populations of *C. binotalis*. In addition to this, Diafenthiuron 50% WP @ 500 g a.i./ ha and Novaluron 10% EC @ 300 g a.i./ ha caused 93.75 and 92.50 per cent larval mortality respectively Whilst, Thiodicarb 75 % WP @ 750 g a.i./ ha gave 83.75 per cent mortality. In contrast to these, only a cumulative of 20.00 per cent larvae was found dead in untreated control.

After three days of insecticide exposure (72 HAT), complete larval mortality reached in all treatments and have found equally superior against *C. binotalis* except Diafenthiuron 50% WP @ 500 g a.i./ ha (98.75 %) and Novaluron 10% EC @ 300 g a.i./ ha (97.50%) treatments. But within next 12 hours (96 HAT), these two insecticides also caused 100 per cent cumulative larval mortality of *C. binotalis* and registered at par with all other insecticidal treatments. At the same time, 60.00 per cent cumulative larval mortality was recorded in untreated control.

Comparison of effect of newer molecules on *P. xylostella* and *C. binotalis*

Among different molecules evaluated on larvae of *P. xylostella*, mortality data after 36 HAT revealed a clear outlook that Chlorantarniliprole 18.5% SC @ 25 g a.i./ha and Flubendiamide 39.5% SC @ 25 g a.i./ha had superior impact against *P. xylostella* larvae through causing higher and significant mortality in account of effect posed by untreated control. Later Spinosad 2.5% SC @ 25 g a.i./ ha, Emamectin Benzoate 5% SG @ 15 g a.i./ha and Fipronil 5% SC @ 750 g a.i./ ha were joined in this lineage against DBM larvae. Unlike previous experiment, Chlorantarniliprole 18.5% SC @ 25 g a.i./ha and Flubendiamide 39.5% SC @ 25 g a.i./ha had brought earlier larval mortality of *C. binotalis* on 24 HAT than other insecticides. This clearly revealed that *C. binotalis* is highly susceptible than DBM larvae in terms of complete and rapid larval killing by all tested newer molecules. Also, mortality data clearly explicit, after 24 HAT Chlorantarniliprole 18.5% SC @ 25 g a.i./ha, Flubendiamide 39.5% SC @ 25 g a.i./ha, Spinosad 2.5% SC @ 25 g a.i./ ha and Emamectin Benzoate 5% SG @ 15 g a.i./ha had ascendancy by controlling more than 50 per cent of *C. binotalis* larval population by considering the effect of untreated control.

At global level before 1990s, many broad spectrum conventional insecticides had been developed and utilized in the management of majority of insect pests. Due to their continuous and sub lethal doses of application led to tremendous increase and development of resistance in many insect pests across globe. Ultimately, these gave new way to synthesize newer insecticide molecules with novel action by act on specific target site and interfering with either biochemical or physiological processes present in specific insect groups at relatively lower doses. Their minimal residue life in the natural agro-ecosystems, relative safety to non target organisms and less risk in development of toxic food chain made them to adopt by majority of farmers in the context of insect pest control across diverse agro ecosystems.

A significant *P. xylostella* larval reductions of 97.20, 87.55 and 86.61 per cent was recorded in cabbage plots treated with Chlorantraniliprole 18.5% SC, Spinosad 45% SC and Flubendiamide 39.5% SC [14]. Similarly, Purushotam *et al.*, (2017) [15] recorded more than 65 per cent of reduction in larval population of *P. xylostella* after through application of Chlorantarniliprole 18.5 SC in cabbage whereas, in cauliflower, Selvaraj and Kennedy, (2017) [16] reported up to 90 per cent of larval suppression DBM. Further, the greater effectiveness of Chlorantraniliprole 18.5% SC against DBM larvae was opined on cabbage [17, 18, 19, 20, 21] and raddish [22].

The bio-efficacy of spinosad 2.5% SC (up to 25 g a.i./ ha) proven to be effective against larvae of *P. xylostella* [15, 23, 24, 25, 26, 27] and *C. binotalis* in cabbage [23, 24]. The superiority of spinosad and emamectin benzoate in controlling the cabbage leaf webber in the present study is also in conformity with the reports of Peter *et al*. (2000) [28]. Among the different newer insecticides tested by Shaila (2007) [29], spinosad 2.5% SC @ 15 g a.i./ha, Emamectin benzoate 5% SG @ 7.5 g a.i/ha, indoxacarb 14.5% SC @ 35 g a.i/ha, and Novaluron 10% EC @ 50 g a.i/ha in that order proved significantly superior in reducing the larval population of *P. xylostella*, *S. litura* and *C. binotalis* throughout the crop period. Among different pesticides evaluated by Mohite and Patil (2005) [30] and Suganyakanna *et al*. (2005) [31] against *P. xylostella* and *C. binotalis* in cabbage, Emamectin benzoate 5% SG caused maximum significant larval mortality. Similarly in cauliflower, significant efficacy of Emamectin benzoate 5% SG against larvae of *P. xylostella*, *S. litura* was reported [32]. Apart from appreciable level of larval control in DBM, the maximum marketable yield was recorded in plots treated with spinosad 2.5% SC (25 g a.i./ha) followed by Indoxacarb 14.5% SC (350 g a.i./ha) in cauliflower [33] and cabbage [34, 35]. Superiority of Flubendiamide 39.5% SC [15, 27, 36] along with Spinosad 2.5% SC [36, 37] had already proven against *P. xylostella* on cabbage and cauliflower respectively.

Other newer molecules evaluated against these pests also effective but produced delayed mortality as compared to insecticides discussed earlier. Their efficacy is also to be considered during management of above pests. The use of bio-rational and low dose insecticidal compounds also may effectively brought desirable population reduction of *P. xylostella* and *C. binotalis* as compared to other insecticides. In addition to this, their relative safety on natural enemy populations, less residual life in environment, cost of chemical and potential to boost up the net profit may be taken in to consideration to include them as more appropriate component in IPM. Similarly effectiveness of Indoxacarb 14.5% EC against larval population of diamondback moth was reported on cabbage [38, 39, 40, 41]. According to Sannaveerappanavar *et al*. (2003) [42] rotational spray of Novaluron 5.4 % EC with NSKE (5%) was effective to check the larval populations of DBM. Similarly, effectiveness of Novaluron 5.4 % EC against DBM larvae was observed in cabbage [43, 44, 45, 46] and apart from this, it showed less toxicity to larval parasitoid of DBM, *Diadegma* sp. than many broad spectrum conventional insecticides [45]. Whereas, in cabbage, Lufenuron 5.4% EC (30 to 40 g a.i./ ha) was found to be effective to reduce DBM larval infestation [47, 48]. Cartap hydrochloride 50% SP [49] and Lufenuron 5.4% EC [50] were found to be effective against DBM larvae. Similar observations were made by Vastrad *et al*. (2003) [51] that Thiodicarb 75 % WP, Lufenuron 5.4% EC and Spinosad 2.5% SC were more promisive in the management of larvae of *P. xylostella* and *C. binotalis* with higher cabbage yield. Apart from these, efficacy above newer molecules has also been successfully proved on larvae of *Maruca vitrata* Geyer [52, 53] *Helicoverpa armigera* Hubner [52, 53, 54, 55] and other important lepidopteran insect pests.

In conclusion, data on per cent increase of larval mortality over control in both experiments, revealed that up to 24 HAT, it was 100 per cent in all treatments and this indicated that larvae in untreated control was affected only after 24 HAT. This had significant influence on actual larval Mortality up to the end of observations made (Tables 2 and 3). In particular, effect of treatments such as Diafenthiuron 50% WP, Indoxacarb 14.8% SC, Novaluron 10% EC and Thiodicarb 75 % WP were greatly affected by larval mortality in control, as their cumulative efficacy against both larvae of *P. xylostella* and *C. binotalis* was increased in later stages of observations and this coincided to the mortality in control. This phenomenon gave inevitable impact on actual mortality caused by these insecticides.

Table 1: List of insecticides used in the experiment and their chemical groups and source of procurement

S. No.	Treatments	Chemical group	Brand Name and Company	Dose
1.	Flubendiamide 39.5% SC	Pthalic acid diamide	Fame- M/s. Bayer Crop Science	25 g a.i./ha (0.1 mL/ lit)
2.	Emamectin Benzoate 5% SG	Avermectin	Proclaim- M/s. Syngenta India Ltd.	15 g a.i./ha (0.6 g/ lit)
3.	Fipronil 5% SC	Phenyl pyrazole	Regent- M/s. Bayer Crop Science	750 g a.i./ ha (3mL/ lit)
4.	Indoxacarb 14.8% SC	Oxadiazone	Avaunt- M/s. DuPont	10 g a.i./ ha (1mL/ lit)
5.	Chlorantarniliprole 18.5% SC	Anthranilic diamide	Coragen- M/s. DuPont	25 g a.i./ha (0.3 mL/ lit)
6.	Diafenthiuron 50% WP	Thio urea compound	Pegasus- M/s. Syngenta India Ltd.	500 g a.i./ ha (2g/ lit)
7.	Spinosad 2.5% SC	Spinosyn	Success- M/s. Dow Agro Sciences	25 g a.i./ ha (2mL/ lit)
8.	Novaluron 10% EC	Benzoyl phenyl urea	Remostar- M/s. Swal Corporation Ltd	300 g a.i./ ha (4mL/ lit)
9.	Thiodicarb 75 % WP	Thiocarbamate	Larvin- M/s. Bayer Crop Science	750 g a.i./ ha (2 g/ lit)

Table 2: Efficacy of newer insecticides against *P. xylostella*

Treatments	Mean of Cumulative per cent mortality											
	12 HAT	**PIC**	**24 HAT**	**PIC**	**36 HAT**	**PIC**	**48 HAT**	**PIC**	**72 HAT**	**PIC**	**96 HAT**	**PIC**
Flubendiamide 39.5% SC	3.75ab (11.17)	100.00	58.75a (50.04)	100.00	100.00a (90.00)	96.25	100.00a (90.00)	87.50	100.00a (90.00)	68.75	100.00a (90.00)	47.50
Emamectin Benzoate 5% SG	2.50ab (9.10)	100.00	42.50c (40.69)	100.00	81.25c (64.34)	95.38	100.00a (90.00)	87.50	100.00a (90.00)	68.75	100.00a (90.00)	47.50
Fipronil 5% SC	5.00a (12.92)	100.00	25.00d (30.00)	100.00	75.00d (60.00)	95.00	96.25b (78.83)	87.01	98.75a (83.58)	68.35	100.00a (90.00)	47.50
Indoxacarb 14.8% SC	0.00b (0.00)	0.00	16.25ef (23.77)	100.00	47.50ef (43.57)	92.11	86.25b (68.23)	85.51	95.00b (77.08)	67.11	100.00a (90.00)	47.50
Chlorantarniliprole 18.5% SC	5.00a (12.92)	100.00	58.75a (50.04)	100.00	100.00a (90.00)	96.25	100.00a (90.00)	87.50	100.00a (90.00)	68.75	100.00a (90.00)	47.50
Diafenthiuron 50% WP	0.00b (0.00)	0.00	15.00f (22.79)	100.00	48.75e (44.28)	92.31	76.25d (60.83)	83.61	95.00b (77.08)	67.11	97.50b (80.90)	46.15

Spinosad 2.5% SC	6.25^{a} (14.48)	100.00	52.50^{b} (46.43)	100.00	92.50^{b} (74.11)	95.95	100.00^{a} (90.00)	87.50	100.00^{a} (90.00)	68.75	100.00^{a} (90.00)	47.50
Novaluron 10% EC	0.00^{b} (0.00)	0.00	17.50^{ef} (24.73)	100.00	42.50^{g} (40.69)	91.18	82.50^{c} (65.27)	84.85	90.00^{c} (71.57)	65.28	95.00^{c} (77.08)	44.74
Thiodicarb 75 % WP	2.50^{ab} (9.10)	100.00	21.25^{de} (27.45)	100.00	43.75^{fg} (41.41)	91.43	73.75^{e} (59.18)	83.05	96.25^{b} (78.83)	67.53	98.75^{b} (83.58)	46.84
Untreated control	0.00^{b} (0.00)		0.00^{g} (0.00)		3.75^{h} (11.17)		12.50^{f} (20.70)		31.25^{d} (33.99)		52.50^{c} (46.43)	
SED	1.5275		2.0913		1.4376		0.8602		0.6879		0.3916	
CD (P= 0.05)	3.1196		4.2709		2.9359		1.7568		1.4050		0.7997	
CD (P= 0.01)	4.2007		5.7509		3.9534		2.3656		1.8919		1.0768	

*Mean of 5 replications and each replication comprised of 20 larvae; HAT – Hours after Treatment; PIC- Per cent increase over control
Figures in the parentheses are values of arcsine transformation;
In a column, means followed by the common letter(s) are not significantly different from each other (*P* <0.01) for various treatments (as indicated by Tukey's HSD)

Table 3: Efficacy of newer insecticides against *C. binotalis*

Treatments	**Mean of Cumulative per cent mortality**											
	12 HAT	**PIC**	**24 HAT**	**PIC**	**36 HAT**	**PIC**	**48 HAT**	**PIC**	**72 HAT**	**PIC**	**96 HAT**	**PIC**
Flubendiamide 39.5% SC	13.75^{a} (21.87)	100.00	80.00^{ab} (63.43)	100.00	100.00^{a} (90.00)	97.50	100.00^{a} (90.00)	80.00	100.00^{a} (90.00)	61.25	100.00^{a} (90.00)	40.00
Emamectin Benzoate 5% SG	6.25^{cd} (14.57)	100.00	53.75^{c} (47.25)	100.00	76.25^{b} (60.83)	96.72	98.75^{a} (83.58)	79.75	100.00^{a} (90.00)	61.25	100.00^{a} (90.00)	40.00
Fipronil 5% SC	2.50^{de} (9.10)	100.00	28.75^{d} (32.42)	100.00	71.25^{c} (57.58)	96.49	98.75^{a} (83.58)	79.75	100.00^{a} (90.00)	61.25	100.00^{a} (90.00)	40.00
Indoxacarb 14.8% SC	0.00^{e} (0.00)	0.00	8.75^{f} (17.21)	100.00	37.50^{f} (37.76)	93.33	95.00^{b} (77.08)	78.95	100.00^{a} (90.00)	61.25	100.00^{a} (90.00)	40.00
Chlorantarniliprole 18.5% SC	12.50^{ab} (20.70)	100.00	82.50^{a} (65.37)	100.00	100.00^{a} (90.00)	97.50	100.00^{a} (90.00)	80.00	100.00^{a} (90.00)	61.25	100.00^{a} (90.00)	40.00
Diafenthiuron 50% WP	0.00^{e} (0.00)	0.00	21.25^{e} (27.55)	100.00	56.25^{d} (48.59)	95.56	93.75^{bc} (75.52)	78.67	98.75^{b} (83.58)	60.76	100.00^{a} (90.00)	40.00
Spinosad 2.5% SC	8.75^{bc} (17.20)	100.00	77.50^{b} (61.78)	100.00	98.75^{a} (83.58)	97.47	100.00^{a} (90.00)	80.00	100.00^{a} (90.00)	61.25	100.00^{a} (90.00)	40.00
Novaluron 10% EC	0.00^{e} (0.00)	0.00	25.00^{de} (30.00)	100.00	42.50^{e} (40.69)	94.12	92.50^{c} (74.11)	78.38	97.50^{b} (80.90)	60.26	98.75^{a} (83.58)	39.24
Thiodicarb 75 % WP	1.25^{e} (6.42)	100.00	22.50^{e} (28.32)	100.00	41.25^{e} (39.96)	93.94	83.75^{d} (66.23)	76.12	100.00^{a} (90.00)	61.25	100.00^{a} (90.00)	40.00
Untreated control	0.00^{f} (0.00)		0.00^{g} (0.00)		2.50^{g} (9.10)		20.00^{e} (26.57)		38.75^{c} (38.50)		60.00^{b} (50.77)	
	1.4907		1.6619		1.2110		0.6928		0.4243		0.6000	
	3.0444		3.3941		2.4733		1.4149		0.8665		1.2254	
	4.0995		4.5702		3.3304		1.9053		1.1667		1.6500	

*Mean of 5 replications and each replication comprised of 20 larvae; HAT – Hours after Treatment; PIC- Per cent increase over control
Figures in the parentheses are values of arcsine transformation;
In a column, means followed by the common letter(s) are not significantly different from each other (*P* <0.01) for various treatments (as indicated by Tukey's HSD)

Conclusion

The present study clearly revealed that among the evaluated insecticides Chlorantraniliprole 18.5% SC and Flubendiamide 39.5% SC up on exposure to short period of one day, both larvae of *P. xylostella* and *C. binotalis* stopped feeding and found died. So, further studies on field efficacy and environmental safety of evaluated under different ecosystems with these molecules are required for sustainable management of both *P. xylostella* and *C. binotalis* along with other feasible IPM tools.

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References

1. Horticultural Statistics at a Glance. Over view of Horticulture Sector. In: Horticulture Statistics, Division Department of Agriculture, Cooperation & Farmers' Welfare, Ministry of Agriculture & Farmers' Welfare, Government of India, 2018, 458p.
2. Kunjwal N, Srivastava RM. Insect Pests of Vegetables. In: Pests and Their Management, (Omkar, ed.), Springer, Singapore, 2018, 221p. DOI: https://doi.org/10.1007/978-981-10-8687-8_7
3. Dadang, Eva-Dwi-Fitriasari, Djoko-Prijono. Effectiveness of two botanical insecticide formulations to two major cabbage insect pests on field application. J ISSAAS. 2009; 15(1):42-51.
4. Devjani P, Singh TK. Ecological succession of aphids and their natural enemies on cauliflower in Manipur. J Aphidiol. 1998; 12(1-2):45-51.
5. Ayalew G. Comparison of yield loss on cabbage from diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae) using two insecticides. Crop Prot. 2006;

25:915-919. DOI: 10.1016/j.cropro.2005.12.001

6. Grzywacz D, Rossbach A, Rauf A, Russell DA, Srinivasan R, Shelton AM. Current control methods for diamondback moth and other *brassica* insect pests and the prospects for improved management with lepidopteran-resistant *Bt* vegetable brassicas in Asia and Africa. Crop Prot. 2010; 29(1):68-79. DOI: 10.1016/j.cropro.2009.08.009
7. Sudarwohadi S. Correlation between planting time of cabbage and population dynamics of *Plutella maculipennis* Curt. and *Crocidolomia binotalis* Zell. Bull Penel Hort. 1975; 3:3-14.
8. Talekar NS, Yang JC, Lee S. Annotated Bibliography of Diamondback Moth, Shanhua, Taiwan, Asian Vegetable Research and Development Centre. 1990; II:199p.
9. Talekar NS, Shelton AM. Biology, ecology and management of the Diamondback moth. Annu Rev Entomol. 1993; 38:275-301.
10. Pernag FS, Yao MC, Hung GF, Sun CN. Teflubenzuron resistance in diamondback moth (Lepidoptera: Plutellidae). J Econ Entomol. 1988; 81:1277-1282.
11. Tabashnik BE, Cushing NL, Finson N, Johnson MW. Field development of resistance to *Bacillus thuringiensis* in Diamondback moth (Lepidoptera: Plutellidae). Econ Entomol. 1990; 83:1671-1676. DOI: 10.1093/jee/83.5.1671
12. Tukeys JW. The Problem of Multiple Comparisons. (Unpublished manuscript), Princeton University, 1953, 300p.
13. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research, 2nd ed., John Wiley & Sons, New York, 1984, 680p.
14. Sawant CG, Patil CS. Bio-efficacy of newer insecticides against diamondback moth (*Plutella xylostella* linn.) in cabbage at farmer's field. Int J Curr Microbiol Appl Sci. 2018; 7(7):2986-2998. DOI: https://doi. org/10.20546/ijcmas.2018.707.349
15. Purushotam KC, Sharma SK, Kumawat, Khinchi, Virendra Kumar, Baddhri *et al*. Bioefficacy of different insecticides against diamondback moth. Int J Chem Studies. 2017; 5(3):891-893.
16. Selvaraj C, Kennedy JS. Bio-efficacy of some new generation insecticides on *Plutella xylostella* L and toxicity on two natural enemies. Int J Agric Sci. 2017; 9(3):3680-3682.
17. Venkateswarlu V, Sharma RK, Kirti Sharma. Evaluation of eco-friendly insecticides against major insect pests of cabbage. Pestic Res J. 2011; 23(2):172-180.
18. Vaseem MS, Kumar H, Kaushlendra Mohd A. Efficacy of newer insecticides against diamondback moth (*Plutella xylostella* Linn.) on cabbage under polyhouse condition. J Expt Zool. 2014; 17(2):487-489.
19. Chowdary LR, Kumar LR, Ghante VK. Rynaxypyr 20 SC (Coragen) green labeled insecticide for the management of head borer (*Hellula undalis* Fab.) in cabbage. J Expt Zool. 2015; 18(2):803-805.
20. Narendra PK. Bio-efficacy of newly evolved novel insecticides against cabbage insect pests. M. Sc. (Ag) thesis, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madya Pradesh, India, 2017.
21. Meghana CJ, Jayappa N, Aswathanarayana Reddy V, Devappa V, Sridhar, Jyothi Kattegoudar *et al*. Assessing susceptibility of diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae) population of different geographic region to selected newer insecticides. J Entomol Zool Studies. 2018; 6(1):320-327.
22. Han W, Zhang S, Shen F, Liu M, Ren C, Gao X *et al*. Residual toxicity and sublethal effects of chlorantraniliprole on *Plutella xylostella*. Pest Mgmt Sci. 2012; 68(8):1184-1190. DOI: 10.1002/ps.3282
23. John PA, Srinivasan K, Chelliah. Bio-efficacy of spinosad a new class of insecticide against cabbage pests. Pest Mgmt Hort Ecosyst. 2000; 6(1):40-46.
24. Gupta HCL. Bio-efficacy of spinosad 2.5 SC against pests of cabbage. In: Final Technical Report of the project sponsored by De-Nocil Crop Production Limited. Agriculture University, Udaipur, 2000, 1-17.
25. Pramanik P, Chatterjee ML. Efficacy of some new insecticides in the management of diamondback moth, *Plutella xylostella* (L.) in cabbage. Indian J Plant Prot. 2003; 31(2):42-44.
26. Tambe AB, Mote U. Effectiveness of new molecule, spinosad 2.5 SC against diamondback moth, *Plutella xylostella* (L.) on cabbage. J Appl Zool Res. 2003; 14(1):44-45.
27. Kikuchi Y, Yara K, Krikrathok C, Shimoda T. Effect of insecticides on the survival of the diamondback moth, *Plutella xylostella* (L.) and the native parasitoid *Cotesia vestalis* (Halliday). Annu Rep Soc Plant Prot N Jpn. 2013; 64:182-185.
28. Peter JA, Srinivasan K, Chelliah S. Bioefficacy of spinosad: A new class of insecticides against cabbage pests. Pest Mgmt Hort Ecosyst. 2000; 6(1):40-46.
29. Shaila HM. Life table studies and management of diamondback moth, *Plutella xylostella* through organic approach in cabbage. Ph.D. thesis, Department of Agricultural Entomology College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, 2007, 144p.
30. Mohite PB, Patil SRA. Evaluation of new molecule spinosad 2.5 SC for the management of diamondback moth, *Plutella xylostella* on cauliflower. J Plant Prot Environ. 2005; 2: 17-19.
31. Suganyakanna S, Chandrasekaran S, Regupathy A, Lavanya D. Emamectin 5 SG (Proclaim) - a new insecticide for Diamondback moth, *Plutella xylostella* management in cabbage. Pestology. 2005; 24:24-27.
32. Muhammad Ramzan, Ghulam Murtaza, Muhammad Javaid, Nadeem Iqbal, Taqi Raza, Abdullah Arshad *et al*. Comparative efficacy of newer insecticides against *Plutella xylostella* and *Spodoptera litura* on cauliflower under laboratory conditions. Indian J Pure Appl Biosci. 2019; 7(5):1-7. DOI: http://dx.doi.org/10.18782/2320-7051.7796
33. Gill CK, Kaur S, Joia BS. Efficacy of new insecticides for the management of diamondback moth, *Plutella xylostella* (L.) on cauliflower and cabbage. J Insect Sci. 2008; 21(2):171-177.
34. Meena SC, Singh V. Bio-efficacy of insecticides against diamondback moth, *Plutella xylostella* (L.) on cabbage, *Brassica oleracea* var. *capitata* L. In: National Conference on Plant Protection in Agriculture, ARS, Durgapura, Jaipur, 2010, 227-228.
35. Chauhan SK, Raju SVS, Meena BM, Nagar R, Kirar VS, Meena SC *et al*. Bio-efficacy of newer molecular insecticides against diamondback moth (*Plutella xylostella* L.) on cauliflower. Agric Sustainable Dev. 2014; 2(1):22-26.

36. Deivendran A, Yadav GS, Rohilla HR. Efficacy of some insecticides against, *Plutella xylostella* (L.) on cauliflower. J Insect Sci. 2007; 20(1):102-105.
37. Ameta OP, Bunker GK. Efficacy of UNI 001 (flubendiamide) 480 SC against diamondback moth, *Plutella xylostella* (L.) in cabbage and its effect on natural enemies under field conditions. Pestology. 2007; 30(6):21-24.
38. Patel JJ, Patel BH, Bhatt PD, Kathiria KB. Indoxacarb 15 EC- a newer insecticidal formulation for diamondback moth, *Plutella xylostella* (L.) management in cabbage. In: National Conference on Applied Entomology, 26-28, September, RCA, Udaipur, 2005, 120-121.
39. Kumar A, Satpathy S, Shivalingaswamy TM, Rai M. Field efficacy of Indoxacarb against diamondback moth, *Plutella xylostella* (L.) on cabbage. Pestology. 2007; 31(4):41-46.
40. Liu TX, Sparks Jr AN, Chen W. Toxicity, persistence and efficacy of indoxacarb and two other insecticides on *Plutella xylostella* (Lepidoptera: Plutellidae) immatures in cabbage. Int J Pest Mgmt. 2003; 49:235-241.
41. Gupta GP, Birah A, Shukla UK. Response of novel insecticides on diamondback moth, *Plutella xylostella* L. Indian J Entomol. 2008; 70:47-50.
42. Sannaveerappanavar VT, Kamla NV, Shankaramurthy M, Chandrashekhara K. Field evaluation of insecticides against diamondback moth on cabbage. In: National Symposium on frontier areas of Entomological Research. 5th to 7th November, New Delhi, 2003.
43. Seal RD. Effectiveness of novaluron in controlling diamondback moth in cabbage (online), 2003. http://amt.oxfordjournals.org/. 10th May 2020 12:40 P.M.
44. Maxwell EM, Fadamiro HY. Evaluation of several reduced-risk insecticides in combination with an action threshold for managing lepidopteran pests of cole crops in Alabama. Fl Entomol. 2006. 89:117-126. DOI: 10.1653/0015-4040(2006)89 [117:eosrii] 2.0.co;2
45. Ayalew G. Effect of the insect growth regulator novaluron on diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae), and its indigenous parasitoids. Crop Prot. 2011; 30:1087e1090. DOI:10.1016/j.cropro.2011.03.027
46. Choudhary RK, Swathi P, Upadhyay S, Singh SB, Sharma M. Efficacy of insect growth regulators against diamondback moth and tobacco caterpillar infesting cabbage crop. Ann Plant Soil Res. 2014; 16:308-311.
47. Sakthi E, Seenivasan N, Devrajan J, Selvraj N. Bioefficacy of new insecticides against cabbage diamondback moth, *Plutella xylostella* (L.). Pestology. 2003; 27(4):35-37.
48. Sharma SK. Eco-safe management of major insect pests of cabbage, *Brassica oleracea* var. *capitata* Linn. Ph.D. thesis, Rajasthan Agricultural University, Bikaner, 2004.
49. Nagesh M, Verma S. Bioefficacy of certain insecticides against diamondback moth, *Plutella xylostella* (L.) on cabbage. Indian J Entomol. 1997; 59(4):411-414.
50. Goud CR, Rao SRK, Chiranjeevi CH. Influence of weather parameters on the population build up of diamondback moth, *Plutella xylostella* (L.) infesting cabbage. Pest Mgmt Hort Ecosyst. 2006; 12(1):103-106.
51. Vastrad AS, Linmgappa S, Basavanagoud K. Management of insecticides resistant populations of diamondback moth, *Plutella xylostella* (L.) (Yponomentidae: Lepidoptera). Pest Mgmt Hort Ecosyst. 2003; 9(1):33-40.
52. Sambathkumar S, Durairaj C, Ganapathy N, Mohankumar S. Field evaluation of newer insecticide molecules and botanicals against pod borers of redgram. Legume Res Int J. 2013; 39(1):1-8.
53. Sambathkumar S, Durairaj C, Ganapathy N, Mohankumar S. Field efficacy of newer insecticides against legume pod borer, *Maruca vitrata* in green gram. Indian J Plant Prot. 2014; 42(1):1-5.
54. Hannig GT, Ziegler M, Macron PG. Feeding cessation effects of chlorantraniliprole, a new anthranilic diamide insecticide, in comparison with several insecticides in distinct chemical classes and mode of action groups. Pest Mgmt Sci. 2009; 65: 12-16.
55. Suhas Y, Sidde-Gowda DK, Patil BV. Efficacy of Indoxacarb (Avaunt 15% SC) against pigeonpea pod borer *Helicoverpa armigera* (Hubner). Pestology. 1999; 11:60-64.