RESEARCH ARTICLE

STUDIES ON BIO AND MODERN PESTICIDES FOR THE MANAGEMENT OF DIAMOND BACK MOTH, *PLUTELLA XYLOSTELLA* (LINN.) ON CAULIFLOWER

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Received-05.05.2016, Revised-25.05.2016

Abstract: The present study was undertaken the most effective as well as economical viable insecticide for the control of diamond-back moth *Plutella xylostella* L. on cauliflower. One bio-pesticide i.e. *Bacillus thuringiensis* (WP) and six modern insecticides i.e. Imidacloprid (17.8% SL), Acetamiprid (20% SP), Thiomethoxam (25% WG,) Fipronil (5% SC), Cartap hydrochlorid (50% SP) and PII-0111 (20% WDG) with an adjuvant "Chipco" were tested against the diamond back moth under natural field condition. In all two sprays were applied in morning hours when the pest attained a desired level of larval population. The result indicated that all the treatments were superior to the control in reducing the larval population of DBM after both applications of the sprays. After the first and second sprays fipronil proved to be the most effective and also gave significantly higher yield as compared with other treatments. The next effective treatment was cartap hydrochloride, which also gave significant reduction in the larval population after first and second sprayings. It also gave better yield and higher per cent increase in yield over control. Other treatments, i.e., PII-0111, thiomethoxam, acetamiprid, imidacloprid and *Bacillus thuringiensis,* were least effective.

Keywords: Cauliflower, Pesticides, Management, Population

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis*) is one of the most important cole crops of India. It occupies an important place in human diet. Cauliflower has high quality protein and is peculiar in stability of vitamin "C" after cooking. It is rich in minerals such as potassium, sodium, iron, phosphorus, calcium and magnesium. Cauliflower requires a cool and moist growing season and does not endure as much as cabbage does as it is more seriously affected by unfavorable conditions. Rich, heavy loam soils with good drainage and liberal supplies of moisture are ideal for cauliflower growing.

India is the world's second largest producer of vegetables, next to China. The total production of vegetable in India is 98.50 million tones and the total area is about 6.2 million/ha (Anonymous, 2002). In India, cauliflower is more widely grown as compared with cabbage. It is generally grown throughout India during winter season. In summer season it is grown in parts of Bihar, Madhya Pradesh, Himachal Pradesh, Maharashtra and Nilgiri Hills in Chennai.

The insect pest complex is a major menace in cauliflower production. Diamond back moth, *Plutella xylostella* (Linn.) is the major pest of cruciferous vegetables crop like cauliflower, cabbage and rapeseed and enjoys worldwide distribution (Chelliah and Srinivasan, 1986). The DBM is a serious pest of crucifer vegetables throughout Asia (NRI, 1991; Zhang, 1994) and it is a regular pest of cauliflower (Singh, 1980). In India, it was first recorded in 1914 on crucifer vegetable (Fletcher, 1914). Economic significance and remunerative nature of the cole crops in short span have compelled the growers to adopt intensive vegetable cultivation. It has been estimated that the insect pests are responsible for reducing more than 40 per cent yield in vegetables. Among these the diamond back moth is the most devastating and cosmopolitan pest of crucifer vegetables (CIE, 1967).

The pest is found to be active from July to April with two peak periods, one during September when up to 38 per cent cauliflower plants are infested and the other during December to February when 23 to36.9 per cent cauliflower, 27 to 49 per cent cabbage and 27 to 29 per cent radish plants are infested (Choudhary and Rawat, 1967).

Diamond back moth has developed resistance to nearly all classes of insecticides used in South- East Asian countries (Lim, 1996). In 1980s high level of resistance to synthetic pyrethroids, cypermethrin, fenvalerate and deltamethrin were reported from different parts of the country (Mehrotra, 1993). Management of the pest poses serious concern due to development of insecticide resistance to organophosphate (Noppun *et al.,* 1986), carbamates (Sun *et al.,* 1978) and synthetic pyrethroids (Liu *et al.,* 1981).

Vegetable farming in different agro-climatic zones of Madhya Pradesh experiences heavy losses due to insect pests. Chemicals are resorted to by majority of farmers of the state to get rid of the pest problems. Keeping in view the present investigation on studies on bio and modern pesticides in the management of diamond back moth, *Plutella xylostella* (L.) on cauliflower" was undertaken.

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MATERIAL AND METHOD

The present investigation studies on bio and modern pesticides in the management of diamond back moth, *Plutella xylostella* (L.) on cauliflower was conducted during the rabi season. The recommended package of practices for growing the cauliflower crop was followed.

Experimental details

A field of 603.5 sq m was divided into 24 plots, the size of each sub-plot being 20 sq m. The experiment was conducted in a randomized block design. The experimental details are given in Table 1.The crop was cauliflower variety Madhuri Replicated three times eight treatments (including untreated control) and Plot size were 5m x 4m Distance between replication 1m Spacing, plant to plant 35 cm Spacing, row to row 45 cm No. of plants/plot 9 x 14 126 Total plant populations were 3024. Previous crop was cauliflower and Seed treatment was done with IPRODION-carbendazym and the number of insecticidal sprays were two times.

Details of insecticidal treatments

Eight treatments (six chemicals, one biopesticide and one untreated control) were tested in the field experiment against the diamond-back moth on cauliflower.

Table 1. Details of insecticides, their formulation, dose and source

Insecticides	Formulation	Dose/ha	Source
Imidacloprid	17.8% SL	100 ml	Bayer (India) Ltd., Mumbai
Acetamiprid	20% SP	50 g	DE-NOCIL Crop Protection Ltd., Mumbai
Thiomethoxam	25% WG	100 g	Syngenta (India) Ltd., Mumbai
Fipronil	5% SC	500 ml	Aventis Crop Science Ltd., Mumbai
Cartap hydrochloride	50% SP	1000 g	Dhanuka Pesticides Ltd., Haryana
PII-0111	20% WDG	100 g	PI-Industries Ltd., Rajasthan
Bacillus thuringiensis	WP	1000 g	Wockhardt Ltd., Mumbai
Untreated control	-	-	-

Method of application of insecticides

For spraying on individual plot the measured quantity of spray material of particular concentration was taken in a hand operated knapsack sprayer to which a fine single nozzle was attached. Due to waxy layer present on cauliflower leaf a sticking agent "Chipco" @ 5 ml lit^{-1} of the spray fluid was used with insecticide for better dispersion and adhesion of spray material. Before and after the preparation of material and spraying of individual insecticides, the sprayer and measuring cylinder were thoroughly washed with clean water. The first application of insecticides was given on 26/02/2003, just after population build up of the pest and the second spray was repeated after 15 day on 13/03/2003 in accordance with the treatments at the morning hours.

While spraying the bacterial insecticide *Bacillus thuringiensis,* it was important to maintain the pH of the spray fluid at neutrality. Hence, the performance of this bacterial insecticide had been enhanced by adding spray additives as molasses.

Methods of observations

Sampling Technique – Random sampling

Field trials were conducted to evaluate insecticides to find out the effective control measure for diamond back moth. Pretreatment population of DBM larvae were recorded before each spraying from 10 randomly selected plants from each plot. Post treatment larval population was recorded one, two, three, seven and ten days after spraying to assess the efficacy of the insecticidal treatments.

RESULT

To find the most effective as well as economical and viable insecticides for the control of diamond back moth, a field trial was conducted using biological and chemical insecticides.

Larval populations were recorded on 10 random plants per plot before insecticidal sprays and one, two, three, seven and ten days after spraying. The reductions in larval population were computed using the above data.

First foliar spray

Pretreatment population

The pretreatment mean larval population varied between 4.33 to 5.47 larvae/plant with non-significant difference among the treatments (table 2).

After one day

The data recorded after one day of spraying indicated that the mean population of insect varied between 2.26 to 4.16 larvae/plant. The two insecticides, namely fipronil and catap hydrochloride, were found superior treatments over the remaining treatments with 2.26 and 2.80 larvae/plant respectively. The untreated control recorded the maximum population (4.16 larvae/plant), which remained at par with PII-0111.

After two days

Fipronil and catap hydrochloride (with 1.76 and 1.95 larvae/plant respectively) were significantly superior treatments to the untreated control (4.17 larvae/plant), as evident from table 1. The rest of the treatments could not perform well and remained statistically at par with each other, except the untreated control.

After three days

The larval population after three days of first spraying showed significant differences among the treatments. The mean population ranged from 1.50 to 4.23 larvae/plant. The minimum mean populations were recorded from the treatments fipronil and cartap hydrochloride (1.50 to 1.87 larvae/plant), both being were at par but superior to others. Cartap hydrochloride, PII-0111 and imidacloprid (1.87, 2.06 and 2.36 larvae/plant) remained statistically at par with acetamiprid (2.60 larvae/plant) and thiomethoxam (2.63 larvae/plant). Higher mean populations were recorded from the plots of *Bacillus thuringiensis* and untreated control, having 3.03 and 4.23 larvae/plant respectively.

After seven days

On the seventh day after first application of insecticide the minimum mean larval population as found in fipronil and cartap hydrochloride (1.23 and 1.40 larvae/plant) and the highest in the untreated control (4.30 larvae/plant). All the treatments proved significantly superior to the untreated control. Fipronil and cartap hydrochloride proved the best and significantly superior to all other treatments. Acetamiprid and PII-0111 (1.86 and1.90 larvae/plant) were at par and next better treatments which were significantly superior to the remaining treatments.

After ten days

Observation on larval population in different treatments after ten days of first spraying showed that all the treatments were significantly superior to the untreated control, reducing the larval population of *P. xylostella*. Fipronil and cartap hydrochloride (i.e. 1.90 and 2.10 larvae/plant) emerged to be superior to all other treatments. Acetamiprid, PII-0111, thiomethoxam and imidacloprid (2.53, 2.70, 2.93 and 3.20 larvae/plant respectively) were at par with each other and the next best treatments. The least effective treatment was *Bacillus thuingiensis* (3.66 larvae/plant).

Table 2. Evaluation of bio and modern pesticides against DBM (first spray)

Treatment	Dose/ha	Pre-treatment larval population/plant	Mean of three replication Mean larval population of DBM per plant at days after first spray					Overall mean
			1	2	3	7	10	
Imidacloprid (17.8%SL)	100 ml	4.47	3.06	2.77	2.36	2.46	3.20	2.77
Acetamiprid (20%SP)	50 g	5.03	3.36	2.50	2.60	1.86	2.53	2.57
Thiomethoxam (25%WG)	100 g	4.80	3.30	2.57	2.63	2.13	2.93	2.71
Fipronil (5% SC)	500 ml	4.33	2.26	1.76	1.50	1.23	1.90	1.73
Cartap hydrochlorid (50% SP)	1000 g	5.47	2.80	1.95	1.87	1.40	2.10	2.02
Bacillus thuringiensis (WP)	1000 g	4.37	3.26	3.07	3.03	2.90	3.66	3.18
PII-0111 (20% WDG)	100 g	4.70	3.76	2.47	2.06	1.90	2.70	2.58
Untreated control	-	4.93	4.16	4.17	4.23	4.30	4.57	4.28
S. Em. ± CD at 5% level		N.S.	0.36 0.77	0.36 0.77	0.25 0.53	0.28 0.60	0.35 0.75	0.20 0.42

Overall efficacy after first spray

The overall mean larval population after first spraying showed significant differences among the treatments. The population ranged from 1.73 larvae/plant in fipronil to 4.28 larvae/plant in the untreated control. The minimum larval population was recorded from fipronil (1.73 larvae/plant), which was significantly superior to rest of the treatments, except cartap hydrochloride (2.02 larvae/plant). The maximum larval population was recorded in the treatment of *Bacillus thuringiensis* and untreated control (3.18 and4.28 larvae/plant). Acetamiprid, PII-0111, Thiomethoxam and imidacloprid (with 2.57, 2.58, 2.71 and 2.77 larvae/plant) were the next best treatments and significantly superior to rest of the treatments.

The toxicity of different insecticides against DBM in descending order of efficacy were Fipronil > Cartap hydrochloride > Acetamiprid > PII-0111 > Thiomethoxam > Imidacloprid > and *Bacillus thuringiensis.*

Second foliar spray

Pretreatment population before second spraying

The pretreatment larval population of DBM before the second spraying showed non-significant differences among the treatments (table 3).

After one day

The larval population after one day of second spraying depicted significant differences among the treatments. Only fipronil (with 1.83 larvae/plant) performed as a superior treatment over the remaining treatments. The next best treatments were cartap hydrochloride, PII-0111 and thiomethoxam (2.33, 2.36 and 2.70 larvae/plant respectively), which were at par with each other. Rests of the treatments were the least effective.

After two days

Significant differences were observed among the treatments for population after two days of second spraying. The minimum populations were recorded from fipronil, cartap hydrochloride and imidacloprid (1.60, 1.66 and 2.16 larvae/plant), which were at par with each other. Acetamiprid, thiomethoxam and PII-0111 (2.43, 2.46 and 2.53 larvae/plant) were intermediate. Rests of the treatments were the least effective against *P. xylostella.*

After three days

After three days of second spraying all the treatments were significantly superior to the untreated control. Fipronil maintained superiority, followed by cartap hydrochloride, PII-0111 and thiomethoxam, which were at par with each other. The next best treatments were imidacloprid, acetamiprid and *Bacillus thuringiensis* which were at par with each other.

After seven days

After seven days of second spraying all the treatments were found significantly superior to the untreated control in reducing the larval population of *P. xylostella.* Fipronil, cartap hydrochloride and thiomethoxam (1.00, 1.16 and 1.50 larvae/plant) were superior to all other treatments, followed by PII-0111 and acetamiprid (1.97 and 2.26 larvae/plant) which were statistically at par with the former. The least effective treatments were imidacloprid and *Bacillus thuringiensis* (2.53 and 3.03 larvae/plant).

After ten days

Significant differences among the treatments as far as larval population is concerned after ten days of second spraying were observed. Fipronil (1.70 larvae/plant) performed as a superior over the remaining treatments, followed by cartap hydrochloride and PII-0111, which were statistically at par with the former. Thiomethoxam and acetamiprid were the next best treatments and were at par with each other. The least effective treatments were imidacloprid and *Bacillus thuringiensis* (3.06 and 3.36 larvae/plant). The population of the untreated control (6.06larvae/plant) was significantly higher than rest of the treatments.

Overall mean population of second spray

The efficacy of the treatments indicated that the overall mean population reduction of *P. xylostella* larvae ranged between 1.47 to 5.34 larvae/plant. The minimum larval population was recorded from fipronil and cartap hydrochloride with 1.47 and 1.72 larvae/plant respectively, which were significantly superior to rest of the treatments. PII-0111 and thiomethoxam (2.17 and 2.19 larvae/plant) were intermediate. Imidacloprid and acetamiprid were the next best treatment and significantly superior to rest of the treatments. *Bacillus thuringiensis*, however the least effective in reducing the pest population.

Table 3. Evaluation of bio and modern pesticides against DBM (second spray)

Treatment	Dose/ha	Pre-treatment larval population/plant	Mean of three replication: Mean larval population of DBM per plant at days after second spray					Overall mean
			1	2	3	7	10	
Imidacloprid (17.8%SL)	100 ml	3.73	2.90	2.16	2.13	2.53	3.06	2.56
Acetamiprid (20%SP)	50 g	3.26	3.07	2.43	2.23	2.26	2.83	2.57
Thiomethoxam (25%WG)	100 g	3.16	2.70	2.46	1.96	1.50	2.33	2.19
Fipronil (5% SC)	500 ml	3.36	1.83	1.60	1.23	1.00	1.70	1.47
Cartap hydrochlorid (50% SP)	1000 g	3.23	2.33	1.66	1.40	1.16	2.03	1.72
Bacillus thuringiensis (WP)	1000 g	4.10	3.10	3.13	2.43	3.03	3.36	3.10
PII-0111 (20% WDG)	100 g	3.40	2.36	2.53	1.90	1.97	2.10	2.17
Untreated control	-	4.56	4.73	4.96	5.36	5.56	6.06	5.34
S. Em. ±		N.S.	0.23	0.33	0.38	0.40	0.38	0.18
CD at 5% level			0.49	0.70	0.81	0.85	0.81	0.38

The toxicity of different insecticides of *P. xylostella* in descending order of efficacy was as under.

Fipronil > Cartap hydrochloride > PII-0111 > Thiomethoxam > Imidacloprid > Acetamiprid > *Bacillus thuringiensis.*

Impact of insecticidal treatments on cauliflower yield

The yield of cauliflower (curds with half cutting of leaves) was recorded in various insecticidal sprays (Table 4). The cumulative yield was expressed as weight of harvested cauliflower curds per plot as well as total weight of all two pickings from each plot.

The yield of crop ranged between 92.75 kg/plot and 122.16 kg/plot (i.e. 46.37 to 61.08 t/ha). The maximum yield was recorded from the plots treated with fipronil as 122.16 kg/plot (61.08 t/ha), which was significantly superior over rest of the treatments. The next in order of effectiveness were the cartap hydrochloride and PII-0111 with the yield of 115.33 kg/plot (57.66 t/ha) and 112.50 kg/plot (56.25 t/ha) respectively. The next in order of comparative effectiveness were the thiomethoxam and acetamiprid with the yield of 109.33 kg/plot (54.66

t/ha) and 105.41 kg/plot (52.70 t/ha) which were at par with each other.
The lowest yield was recorded from the untreated control plot with the yield of 92.75 kg/plot (46.37 t/ha), which was at par with Bt and imidacloprid with the yield of 97.66 and 98.58 kg/plot (48.83 and 49.29 t/ha), respectively.

Table 4. Impact of insecticidal treatments on cauliflower yield (t/ha)

Treatment	Dose/ha	Overall mean of total yield (kg/plot)	Overall mean of total yield (t/ha)	Percentage increase in yield over control	Percentage avoidable loss
Imidacloprid (17.8%SL)	100 ml	98.58	49.29	6.29	19.30
Acetamiprid (20%SP)	50 g	105.41	52.70	13.65	13.71
Thiomethoxam (25%WG)	100 g	109.33	54.66	17.87	10.51
Fipronil (5% SC)	500 ml	122.16	64.08	31.72	-
Cartap hydrochlorid (50% SP)	1000 g	115.33	57.66	24.34	5.59
Bacillus thuringiensis (WP)	1000 g	97.66	48.83	5.30	20.05
PII-0111 (20% WDG)	100 g	112.50	56.25	21.30	7.90
Untreated control	-	92.75	46.37	-	24.08
S. Em. ± CD at 5% level		3.69 7.91	1.84 3.94		

The per cent increase in overall yield due to insecticidal treatments was computed from the overall yield of various treatments (Table 4). Fipronil gave 31.72 per cent increase in yield over the untreated control, which was maximum as compared with other treatments. The second in order of effectiveness were cartap hydrochloride and PII-0111, where the per cent increase in yield was recorded as 24.34 and 21.30 respectively. The next in order of effectiveness were thiomethoxam and acetamiprid where the per cent increased yield was estimated as17.87 and 13.65 respectively. The minimum yield increase was recorded from imidacloprid and *Bacillus thurigiensis* as 6.29 and 5.30 per cent respectively.
The per cent avoidable loss was computed and it revealed that in the untreated control 24.08 per cent avoidable loss was recorded as compared with the best treatment, i.e., fipronil. In case of *Bacillu thuringiensis* and imidacloprid the avoidable losses were 20.05 and 19.30 per cent respectively. The comparatively lower avoidable losses were recorded fro cartap hydrochloride, PII-0111, thiomethoxam and acetamiprid, i.e. 5.59, 7.90, 10.50 and 13.71 per cent, respectively.
The overall perusal of data on the total cauliflower yield as affected by different insecticidal treatments against DBM in clearly indicated that fipronil was the most effective treatment amongst all the treatments. The per cent increase in yield over the untreated control was also maximum in fipronil. Cartap hydrochloride and PII-0111 were found the next best treatments in efficacy against DBM. The rest of the treatments, i.e. *Bacillus thuringiensis,* imidacloprid, acetamiprid and thiomethoxam were intermittent, through they proved better than the untreated control.

DISCUSSION

The results of seven pesticides tested against DBM under field condition has shown (Table 2 & 3) that all the treatments were significantly superior to the untreated control. The modern insecticide fipronil proved the most effective treatment as it gave maximum reduction in larval population, followed by cartap hydrochloride, while other treatment s were intermediate, after one, two and three days of first and second sprayings. After seven days of the first and second sprayings, all the treatments were superior to control in reducing the larval population of *P. xylostella*. Fipronil was again superior overall the treatments, followed by cartap hydrochloride. After ten days of the first and second sprayings, fipronil maintained its superiority. The next best treatment was cartap hydrochloride, which was significantly superior to rest of the treatments. The least effective treatment was *Bacillus thuringiensis.*
In view of overall efficacy after first and second sprayings it was concluded that fipronil was significantly superior to rest of the treatment and the next best treatment was cartap hydrochloride. The other treatments viz., PII-0111, thiomethoxam, acetamiprid and imidacloprid were intermittent and at par with each other. The least effective treatment was *Bacillus thuringiensis.* The inherent toxicity of these insecticides against DBM could be arranged in the decreasing order as follows.
Fipronil > Cartap hydrochloride > PII-0111 > Thiomethoxam > Acetamiprid > Imidacloprid > *Bacillus thuringiensis.*
The findings of the present investigation was in accordance with that of Panda *et al.* (1999) who recorded the foliar application of fipronil 5 % SC @50g ai/ha reduced the incidence of DBM (*P. xylostella* L.) on cabbage and was more effective

than cartap hydrochloride and endosulfan during 1996-97 in Orissa. In the present investigation fipronil 5% SC @ 500 ml/ha was also found to be more effective than cartap hydrochloride against DBM on cauliflower and Ridland and Endersby (2011) who also recorded the reduced susceptibility to fipronil against diamond back moth on *Brassica* vegetables in Australia. Nagesh and Verma (1997) who found that cartap hydrochloride was the most effective treatment in controlling the diamond back moth among various insecticides tested, while cartap hydrochloride @ 100 g ai/ha was not found effective when sprayed twice on cabbage to control DBM as reported by Rajavel and Babu (1989). However, in the present investigation cartap hydrochloride 50 % SP @1000 g/ha, when sprayed twice was found effective, next to the best treatment, i.e. fipronil 5% SC @500 mi/ha, as for as the control of *P. xylostella* on cauliflower is concerned. Takahashi *et al.* (1999) they reported the acetamiprid (2 %) granules suitable for the control of diamond back moth on cabbage, whereas in the present experiment it was intermediate in efficacy and significantly superior to imidacloprid and *Bacillus thuringiensis*. Joia *et al.* (1994) reported the DBM resistance to quinalphos at 170 fold. They also found that a new insecticide cartap hydrochloride was successful in controlling the multi resistant population of *P. xylostella,* as found in the present studies. Joshi and Jhala (1999) also found the cartap hydrochloride, spark, deltamethrin and *Bacillus thuringiensis* were the most effective treatment and recorded significantly lower larval population and per cent infested capsules with higher seed yield of cress (*Lipidium sativam* L.) crop against DBM. Sharma *et al.* (2000) tested three formulations of *Bacillus thuringiensis* subsp *kurstaki* (bioasp and biolep each at 10, 1.5 and 2.0 kg/ha and halt at 1.0 kg/ha) against DBM on cauliflower and found that biosp and biolep at 2 kg/ha gave the highest larval mortality. In the present findings *Bacillus thuringiensis* (halt, 1.0 kg/ha) was not effective in both the sprays, which contradicted earlier results. The inefficacy of *B. thuringiensis* in the present studies did not support Ravendra *et al.* (1995) who found that, fenvalerate, monocrotophos, chlorpyriphos and *Bacillus thuringiensis* were equally effective against the DBM larvae in Tamil Nadu. Nowrocka (1986) found that dipel (*B. thuringiensis*) and thuricide HP (*B. thuringiensis*) i.e. bactospeine and entobacterin against DBM in Poland. In the current findings halt (*B. thuringiensis*) was not effective in reducing the DBM population.

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