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Research Article

Bioefficacy of insecticides used against diamondbackmoth and their potential impact on natural enemies in cauliflower

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Abstract
Field experiments were conducted at two different geographical regions viz., tropical region (Naraseepuram village, Coimbatore) and temperate region (Kookal village, Kotagiri, The Nilgiris) in summer and winter season's to assess the bioefficacy of insecticides used against Diamondbackmoth (DBM), *Plutella xylostella* and their potential impact on natural enemies in cauliflower. The results revealed that the diamide insecticides like cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}, chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1} and flubendiamide 20 WG @ 18.24 g a.i ha^{-1} registered more than 95 percent population reduction over untreated control followed by emamectin benzoate 5 SG @ 10 g a.i ha^{-1} and thiodicarb 75 WP @ 750 g a.i ha^{-1}. Quinalphos 25 EC @ 500 g a.i ha^{-1}and chlorpyriphos 20 EC @ 400 g a.i ha^{-1} were observed as least effective among the treated insecticides. The diamide insecticides recorded considerably less toxic effect on the natural enemies, especially spiders and coccinellids. Population reduction of natural enemies was noticed immediately after insecticide spray but it gradually increased and was recorded on par with the control population. Hence, cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}, chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1} and flubendiamide 20 WG @ 18.24 g a.i ha^{-1} can be used as potential component in the integrated pest management against DBM in cole crops.

Keywords: Cauliflower, Chlorantraniliprole, Cyantraniliprole, DBM, Flubendiamide

INTRODUCTION

India is the second largest producer of cauliflower in the world contributing 33 per cent to global production. It occupies a total area of 4.52 lakh hectares with a production of 84,990 lakh tonnes. India's major cauliflower producing states are Bihar, Uttar Pradesh, Orissa, West Bengal, Assam, Haryana and Maharashtra (National Horticultural Board, 2017). Insect pests are a serious menace in the profitable cultivation of cauliflower. Diamond back moth (DBM), *Plutella xylostella* (Linn.), was the major destructive pest on cruciferous crops such as cauliflower, cabbage and mustard causing significant economic losses upto168 million US$ per year (Uthamasamy *et al.*, 2011). To reduce yield losses caused by this insect pest, many growers mainly use chemical control because of the lack of reliable alternatives and the availability of relatively cheap insecticides. Chemical insecticides are used as the frontline defense sources against these insect pests, in spite of their drawbacks and cauliflower growers in India depend heavily on synthetic pesticides to combat pests. Most of the insecticides used on agricultural / horticultural crops belong to a limited number of chemically different classes. Of them, the most important organic insecticides used against DBM belong to organophosphates, carbamates and synthetic pyrethroids (Preethi, 2019). In the recent past, synthetic pyrethroids have been extensively used for the control of DBM. The use of old broad spectrum insecticides resulted in resistance against insecticides, pest resurgence and accumulation of insecticide residues in the consumable produces at harvest. The use of synthetic pesticides in Indian agriculture cannot be dispensed with in view of the targets of food requirements projected for 2020 AD. So, the effort has been made for the development of less persistent insecticide molecules with novel mode of action to overcome the constraints in the older molecules *viz.,* resurgence, resistance and residues. At present, the Golden Age of insecticide research has met with selective, neuro active and easily degradable compounds. These newer molecules always have a higher stability and superiority over the conventional pesticides to control the pest population density in classical manner at field level. Hence, evaluation of new molecular insecticides is necessary to replace the highly effective broad spectrum compounds, which were restricted due to their high mammalian toxicity and other side effects on non-target organisms (Vinothkumar *et al.,* 2019). With this background, present study was under taken to evaluate the bioefficacy of new molecular insecticides against Diamondbackmoth (DBM), *Plutella xylostella* and their potential impact on natural enemies in cauliflower.

MATERIALS AND METHODS

Field experiments were conducted to assess the efficacy of insecticides used against diamond backmoth, *P. xylostella* and their potential impact on natural enemies in cauliflower in two different geographical regions viz., tropical region (Naraseepuram village, Coimbatore) and temperate region (Kookal village, Kotagiri, The Nilgiris) in two different season's viz., July – August,2020 and January – May 2021. The experiments were laid out in Randomized Block Design witheight treatment and three replications in a plot size of 5 x 5 m. The treatment details were T_1. Cyantraniliprole 10.26 OD @ 60 g. ai. ha^{-1}, T_2. Emamectin benzoate 5 SG @ 10 g. ai. ha^{-1}, T_3. Flubendiamide 20 WG @ 18.24 g. ai. ha^{-1}, T_4. Thiodicarb 75 WP @ 750 g. ai. ha^{-1}, T_5. Chlorantraniliprole 18.50 SC @ 10 g. ai. ha^{-1}, T_6. Quinalphos 25 EC @ 500 g. ai. ha^{-1}, T_7. Chlorpyriphos 20 EC @ 400 g. ai. ha^{-1} and T_8. Untreated control. The treatments were imposed on 30 day old transplanted crop and applied twice at 14 days intervals. The treatments were sprayed with a pneumatic knapsack sprayer using 500 litres of spray fluid per hectare. The spraying was done during morning hours to give uniform coverage on foliage and to avoid drift. Indron® @ 1 ml l^{-1} was used as sticker / spreading agent. Larval population was recorded in five randomly marked plants from each plot. The observations on larval population were taken prior to spraying and at 3, 7, 10 and 14 days after spraying. From each plant, three leaves one each from top, middle and bottom canopies of plants were observed. The yield of marketable cauliflower curd was also recorded during the harvest. Population of general predators *viz.,* spiders and coccinellids were also recorded in five randomly marked plants from each plot prior to spraying followed by 3,7,10 and 15 days after each spray and expressed as number per five plants. The day observations were pooled, mean population and per cent reduction over control was calculated after each spray. Cauliflower yield per plot was recorded from each harvest and pooled to arrive at the total yield and expressed as tonnes ha^{-1}.The data on population number were transformed $\sqrt{x+0.5}$ before statistical analysis. The data were analysed in randomized block design (RBD) (Gomez and Gomez, 1984). The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951).

RESULTS AND DISCUSSION

Results revealed that the diamondbackmoth, *P. xylostella* population before the trial at Naraseepuram was recorded as 16.67 to 20.33 larvae per five plants during the first season (Table 1). After first spray, mean larval population was observed minimum in the plots treated with cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}, chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1}, flubendiamide 20 WG @ 18.24 g a.i ha^{-1} and emamectin benzoate 5 SG @ 10 g a.i ha^{-1} recorded 4.67, 5.78, 6.11 and 8.00 larvae per five plants, respectively. After second spray, more than 95 per cent population reduction over untreated control was noticed in the plots treated with cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1} (99.48 %), chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1} (98.45 %) and flubendiamide 20 WG @ 18.24 g a.i ha^{-1} (95.88 %). Emamectin benzoate 5 SG @ 10 g a.i ha^{-1}, thiodicarb 75 WP @ 750 g a.i ha^{-1} were recorded 92.27 and 90.21 percent reduction over untreated control, respectively. Quinalphos 25 EC @ 500 g a.i ha^{-1}and chlorpyriphos 20 EC @ 400 g a.i ha^{-1} were observed as least effective among the treated insecticides, which registered 80.41 and 79.90 per cent reduction of the larval population over untreated check, respectively. The same trend was observed in the trials conducted in temperate region of Kotagiri also. The pre-count populations of DBM larvae were 11.00 to 12.67 larvae per five plants during first season and 12.00 to 13.67 larvae per five plants during the second season (Table 2). Cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}, chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1} and flubendiamide 20 WG @ 18.24 g a.i ha^{-1}were registered more than 95 percent population reduction over untreated control in both seasons and they were on par with each other. The result of this study is in accordance with the finds of Patra *et al.* (2012), who reported that flubendiamide 480SC @ 20, 40 and 60 g a.i. /ha and Chlorantraniliprole 18.5 SC @ 15, 30 and 45 g a.i. /ha were very effective in reducing the larval population of diamondback moth in cabbage. Similarly, the present study is also in line with Seal and-Sabines(2013) who reported a significant reduction in mean number of diamondback moth larvae on 'Gourmet'cabbage seedlings following application of Coragen 20 SC (Chlorantraniliprole) @ 360 g/ha. Sharma *et al.*(2017) reported that chlorantraniliprole @ 37.5 and 50.0 ml/ha showed their supremacy in significantly

Table 1. Effect of insecticides against diamondbackmoth in cauliflower (Location: Naraseepuram)

Sl. No.	Treatments	Season 1					Season 1I				
		Pre count	I Spray		II Spray		Pre count	I Spray		II Spray	
			Mean	PRC	Mean	PRC		Mean	PRC	Mean	PRC
1.	Cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}	18.33 (4.34)	4.67 (2.25)	77.17	0.11 (0.78)	99.48	8.33 (2.97)	1.22 (1.30)	86.42	0.11 (0.78)	98.96
2.	Emamectin benzoate 5 SG @ 10 g a.i ha^{-1}	19.00 (4.42)	8.00 (2.90)	60.87	1.67 (1.44)	92.27	9.00 (3.08)	2.44 (1.71)	72.84	1.78 (1.48)	83.33
3.	Flubendiamide 20 WG @ 18.24 g a.i ha^{-1}	16.67 (4.14)	6.11 (2.55)	70.11	0.89 (1.16)	95.88	8.67 (3.03)	1.67 (1.47)	81.48	0.56 (1.02)	94.79
4.	Thiodicarb 75 WP @ 750 g a.i ha^{-1}	16.67 (4.14)	8.33 (2.96)	59.24	2.11 (1.61)	90.21	8.67 (3.03)	3.33 (1.96)	62.96	2.33 (1.68)	78.13
5.	Chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1}	17.00 (4.18)	5.78 (2.48)	71.74	0.33 (0.90)	98.45	8.33 (2.97)	2.00 (1.58)	77.78	0.22 (0.84)	97.92
6.	Quinalphos 25 EC @ 500 g a.i ha^{-1}	18.67 (4.38)	9.78 (3.20)	52.17	4.22 (2.17)	80.41	8.00 (2.92)	4.44 (2.22)	50.62	3.11 (1.89)	70.83
7.	Chlorpyriphos 20 EC @ 400 g a.i ha^{-1}	20.33 (4.56)	9.89 (3.21)	51.63	4.33 (2.19)	79.90	8.67 (3.03)	4.22 (2.17)	53.09	2.89 (1.83)	72.92
8.	Untreated control	18.33 (4.34)	20.44 (4.58)	-	21.56 (4.70)	-	8.67 (3.03)	9.00 (3.08)	-	10.67 (3.34)	-
	SE(d)	0.24	0.08	-	0.21	-	0.14	0.09	-	0.17	-
	CD (0.05)	0.52	0.17	-	0.44	-	0.30	0.20	-	0.37	-

*Mean of four observations; Values in parantheses are square root transformed values; PRC – Percent reduction over control

Table 2. Effect of insecticides against diamondbackmoth in cauliflower (Location: Kotagiri)

Sl. No.	Treatments	Season 1					Season 1I				
		Pre count	I Spray		II Spray		Pre count	I Spray		II Spray	
			Mean	PRC	Mean	PRC		Mean	PRC	Mean	PRC
1.	Cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}	11.33 (3.44)	2.56 (1.72)	78.90	0.00 (0.71)	100.00	12.67 (3.63)	2.11 (1.61)	83.04	0.00 (0.71)	100.00
2.	Emamectin benzoate 5 SG @ 10 g a.i ha^{-1}	12.67 (3.63)	4.56 (2.24)	62.39	0.22 (0.83)	98.25	13.00 (3.67)	3.44 (1.98)	72.32	0.78 (1.12)	93.91
3.	Flubendiamide 20 WG @ 18.24 g a.i ha^{-1}	11.67 (3.49)	3.78 (2.06)	68.81	0.11 (0.78)	99.12	12.67 (3.63)	3.44 (1.98)	72.32	0.33 (0.90)	97.39
4.	Thiodicarb 75 WP @ 750 g a.i ha^{-1}	12.33 (3.58)	5.56 (2.45)	54.13	1.00 (1.20)	92.11	13.00 (3.67)	5.00 (2.33)	59.82	1.33 (1.35)	89.57
5.	Chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1}	11.00 (3.39)	3.33 (1.95)	72.48	0.11 (0.78)	99.12	12.00 (3.54)	2.89 (1.84)	76.79	0.11 (0.78)	99.13
6.	Quinalphos 25 EC @ 500 g a.i ha^{-1}	11.33 (3.44)	6.56 (2.65)	45.87	2.11 (1.60)	83.33	13.67 (3.76)	5.67 (2.48)	54.46	2.33 (1.67)	81.74
7.	Chlorpyriphos 20 EC @ 400 g a.i ha^{-1}	12.33 (3.58)	6.33 (2.61)	47.71	2.89 (1.83)	77.19	13.00 (3.67)	5.78 (2.50)	53.57	2.56 (1.73)	80.00
8.	Untreated control	11.33 (3.44)	12.11 (3.55)	-	12.67 (3.63)	-	12.00 (3.54)	12.44 (3.60)	-	12.78 (3.64)	-
	SE(d)	0.18	0.09	-	0.09	-	0.17	0.14	-	0.11	-
	CD (0.05)	0.39	0.19	-	0.20	-	0.37	0.29	-	0.25	-

*Mean of four observations; Values in parantheses are square root transformed values; PRC – Percent reduction over control

reducing the larval population of *P. xylostella* on cabbage and thus increasing the marketable yield of cabbage. The effectiveness of diamide insecticides against *P. xylostella* was also reported by Harika *et al.* (2019), Patel and Patel (2020) and Selvaraj and Kennedy (2017) on cauliflower, Patra *et al.* (2012) and Hiramoto (2007) on cabbage, Hu *et al.* (2010) and Kodandaram *et al.* (2017) on mustard and cabbage. These results suggest that diamide insecticides provided effective management of *P. xylostella* in cauliflower and can be used to delay the development of resistance in diamondback moth against broad spectrum insecticides.

The observation for the effect of insecticides on natural enemy populations *viz.,* spiders and coccinellids revealed that population of spiders in the precount were 4.67 to 6.33 and 2.67 to 3.67 spiders per five plants during first and second season, respectively (Table 3) at Naraseepuram and 3.00 to 4.00 and 2.00 to 2.33 spiders per five plants during first and second season, respectively (Table 4) at Kotagiri. The populations of

Table 3. Effect of insecticides against spiders in cauliflower ecosystem (Location: Naraseepuram)

Sl. No.	Treatments	Season 1					Season 1I				
		Pre count	I Spray		II Spray		Pre count	I Spray		II Spray	
			Mean	PRC	Mean	PRC		Mean	PRC	Mean	PRC
1.	Cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}	4.67 (2.27)	2.22 (1.64)	54.55	2.56 (1.74)	46.51	3.67 (2.04)	1.89 (1.54)	51.43	2.11 (1.61)	50.00
2.	Emamectin benzoate 5 SG @ 10 g a.i ha^{-1}	5.33 (2.42)	2.22 (1.65)	54.55	2.44 (1.70)	48.84	2.67 (1.78)	1.67 (1.47)	57.14	2.44 (1.71)	42.11
3.	Flub endiamide 20 WG @ 18.24 g a.i ha^{-1}	4.67 (2.27)	2.33 (1.68)	52.27	2.22 (1.64)	53.49	3.00 (1.87)	1.56 (1.43)	60.00	2.33 (1.68)	44.74
4.	Thiodicarb 75 WP @ 750 g a.i ha^{-1}	6.33 (2.61)	1.89 (1.54)	61.36	1.67 (1.45)	65.12	2.67 (1.78)	1.89 (1.54)	51.43	1.89 (1.53)	55.26
5.	Chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1}	6.33 (2.61)	2.33 (1.68)	52.27	2.44 (1.70)	48.84	3.00 (1.87)	1.89 (1.54)	51.43	2.22 (1.64)	47.37
6.	Quinalphos 25 EC @ 500 g a.i ha^{-1}	6.00 (2.55)	1.11 (1.26)	77.27	1.56 (1.42)	67.44	3.00 (1.87)	1.33 (1.35)	65.71	1.56 (1.41)	63.16
7.	Chlorpyriphos 20 EC @ 400 g a.i ha^{-1}	4.67 (2.27)	1.22 (1.31)	75.00	1.44 (1.39)	69.77	2.67 (1.78)	1.67 (1.47)	57.14	1.78 (1.50)	57.89
8.	Untreated control	5.67 (2.48)	4.89 (2.32)	-	4.78 (2.30)	-	3.33 (1.96)	3.89 (2.09)	-	4.22 (2.17)	-
	SE(d)	0.24	0.11	-	0.14	-	0.22	0.09	-	0.10	-
	CD (0.05)	0.51	0.25	-	0.29	-	0.48	0.20	-	0.22	-

*Mean of four observations; Values in parantheses are square root transformed values; PRC – Percent reduction over control

Table 4. Effect of insecticides against spiders in cauliflower ecosystem (Location: Kotagiri)

Sl. No.	Treatments	Season 1					Season 1I				
		Pre count	I Spray		II Spray		Pre count	I Spray		II Spray	
			Mean	PRC	Mean	PRC		Mean	PRC	Mean	PRC
1.	Cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}	3.00 (1.87)	2.11 (1.59)	45.71	2.11 (1.60)	48.65	2.33 (1.68)	1.22 (1.30)	59.26	1.67 (1.45)	40.00
2.	Emamectin benzoate 5 SG @ 10 g a.i ha^{-1}	4.00 (2.12)	2.00 (1.57)	48.57	2.44 (1.72)	40.54	2.67 (1.78)	1.44 (1.37)	51.85	1.44 (1.38)	48.00
3.	Flubendiamide 20 WG @ 18.24 g a.i ha^{-1}	3.33 (1.96)	2.00 (1.57)	48.57	2.22 (1.64)	45.95	2.00 (1.58)	1.33 (1.34)	55.56	1.67 (1.47)	40.00
4.	Thiodicarb 75 WP @ 750 g a.i ha^{-1}	3.33 (1.96)	1.78 (1.51)	54.29	1.78 (1.51)	56.76	2.00 (1.58)	1.33 (1.35)	55.56	1.44 (1.39)	48.00
5.	Chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1}	3.67 (2.04)	2.00 (1.58)	48.57	2.11 (1.59)	48.65	2.33 (1.68)	1.67 (1.44)	44.44	1.56 (1.39)	44.00
6.	Quinalphos 25 EC @ 500 g a.i ha^{-1}	3.33 (1.96)	1.44 (1.36)	62.86	1.67 (1.47)	59.46	2.00 (1.58)	0.89 (1.17)	70.37	1.11 (1.25)	60.00
7.	Chlorpyriphos 20 EC @ 400 g a.i ha^{-1}	4.00 (2.12)	1.11 (1.25)	71.43	1.78 (1.51)	56.76	2.33 (1.68)	1.11 (1.26)	62.96	0.89 (1.17)	68.00
8.	Untreated control	3.67 (2.04)	3.89 (2.09)	-	4.11 (2.15)	-	2.33 (1.68)	3.00 (1.87)	-	2.78 (1.81)	-
	SE(d)	0.25	0.11	-	0.17	-	0.20	0.12	-	0.10	-
	CD (0.05)	0.53	0.24	-	0.36	-	0.44	0.26	-	0.22	-

*Mean of four observations; Values in parantheses are square root transformed values; PRC – Percent reduction over control

coccinellids before imposing the treatment were 2.33 to 3.33 and 1.67 to 2.33 coccinellids per five plants during the first and second season respectively at Naraseepuram (Table 5) and 1.67 to 2.33 & 2.00 to 2.67 coccinellids per five plants during first and second season respectively at Kotagiri (Table 6). After two rounds of spray invariably in all insecticide treated plots, population reduction of spiders and coccinellids was noticed. Plots treated with diamide insecticides cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}, chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1} and flubendiamide 20 WG @ 18.24 g a.i ha^{-1}recorded less than 50 percent reduction of natural enemy population. Whereas organo phosphorous insecticides quinalphos 25 EC @ 500 g a.i ha^{-1}and chlorpyriphos 20 EC @ 400 g a.i ha^{-1} were recorded more than 60 percent reduction of spiders and coccinellid population. The cauliflower ecosystem normally contains beneficial predators and parasitoids in numbers that frequently provide partial to satisfactory pest control. To conserve natural enemies, care should be

Table 5. Effect of insecticides against coccinellids in cauliflower ecosystem (Location: Naraseepuram)

Sl. No.	Treatments	Season 1					Season 1I				
		Pre count	I Spray		II Spray		Pre count	I Spray		II Spray	
			Mean	PRC	Mean	PRC		Mean	PRC	Mean	PRC
1.	Cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}	3.00 (1.87)	1.89 (1.54)	41.38	1.89 (1.51)	50.00	2.00 (1.58)	1.89 (1.54)	19.05	1.44 (1.39)	50.00
2.	Emamectin benzoate 5 SG @ 10 g a.i ha^{-1}	3.33 (1.96)	1.78 (1.51)	44.83	2.11 (1.59)	44.12	1.67 (1.47)	1.67 (1.47)	28.57	1.89 (1.54)	34.62
3.	Flubendiamide 20 WG @ 18.24 g a.i ha^{-1}	3.33 (1.96)	1.67 (1.45)	48.28	2.00 (1.57)	47.06	1.33 (1.35)	1.56 (1.43)	33.33	1.56 (1.43)	46.15
4.	Thiodicarb 75 WP @ 750 g a.i ha^{-1}	2.67 (1.78)	1.78 (1.50)	44.83	1.67 (1.45)	55.88	2.33 (1.68)	1.89 (1.54)	19.05	1.22 (1.31)	57.69
5.	Chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1}	3.33 (1.96)	1.78 (1.48)	44.83	2.00 (1.57)	47.06	2.33 (1.68)	1.89 (1.54)	19.05	1.56 (1.43)	46.15
6.	Quinalphos 25 EC @ 500 g a.i ha^{-1}	2.33 (1.68)	1.00 (1.20)	68.97	1.56 (1.41)	58.82	1.67 (1.47)	1.33 (1.35)	42.86	1.22 (1.30)	57.69
7.	Chlorpyriphos 20 EC @ 400 g a.i ha^{-1}	3.33 (1.96)	1.11 (1.26)	65.52	1.33 (1.34)	64.71	2.00 (1.58)	1.67 (1.47)	28.57	1.44 (1.39)	50.00
8.	Untreated control	2.33 (1.68)	3.22 (1.93)	-	3.78 (2.07)	-	2.33 (1.68)	2.33 (1.68)	-	2.89 (1.84)	-
	SE(d)	0.24	0.11		0.14		0.22	0.10	-	0.12	
	CD (0.05)	0.51	0.24		0.30		0.48	0.21	-	0.26	

*Mean of four observations; Values in parantheses are square root transformed values; PRC – Percent reduction over control

Table 6. Effect of insecticides against coccinellids in cauliflower ecosystem (Location: Kotagiri)

Sl. No.	Treatments	Season 1					Season 1I				
		Pre count	I Spray		II Spray		Pre count	I Spray		II Spray	
			Mean	PRC	Mean	PRC		Mean	PRC	Mean	PRC
1.	Cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}	2.33 (1.68)	1.11 (1.26)	60.00	1.44 (1.36)	45.83	2.67 (1.78)	1.22 (1.30)	50.00	1.56 (1.41)	44.00
2.	Emamectin benzoate 5 SG @ 10 g a.i ha^{-1}	1.67 (1.47)	1.56 (1.43)	44.00	1.44 (1.37)	45.83	2.33 (1.68)	1.44 (1.37)	40.91	1.44 (1.38)	48.00
3.	Flubendiamide 20 WG @ 18.24 g a.i ha^{-1}	1.67 (1.47)	1.67 (1.46)	40.00	1.33 (1.32)	50.00	2.00 (1.58)	1.11 (1.26)	54.55	1.56 (1.42)	44.00
4.	Thiodicarb 75 WP @ 750 g a.i ha^{-1}	2.00 (1.58)	1.22 (1.30)	56.00	1.11 (1.26)	58.33	2.33 (1.68)	1.11 (1.27)	54.55	1.33 (1.33)	52.00
5.	Chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1}	2.00 (1.58)	1.78 (1.51)	36.00	1.56 (1.41)	41.67	2.67 (1.78)	1.67 (1.44)	31.82	1.44 (1.38)	48.00
6.	Quinalphos 25 EC @ 500 g a.i ha^{-1}	1.67 (1.47)	1.33 (1.34)	52.00	1.11 (1.26)	58.33	2.33 (1.68)	0.89 (1.17)	63.64	1.11 (1.26)	60.00
7.	Chlorpyriphos 20 EC @ 400 g a.i ha^{-1}	2.00 (1.58)	0.78 (1.12)	72.00	1.22 (1.30)	54.17	2.00 (1.58)	1.11 (1.26)	54.55	1.11 (1.26)	60.00
8.	Untreated control	2.33 (1.68)	2.78 (1.81)	-	2.67 (1.78)	-	2.00 (1.58)	2.44 (1.72)	-	2.78 (1.81)	-
	SE(d)	0.21	0.17	-	0.12	-	0.19	0.14	-	0.16	-
	CD (0.05)	0.45	0.36	-	0.25	-	0.41	0.29	-	0.35	-

*Mean of four observations; Values in parantheses are square root transformed values; PRC – Percent reduction over control

taken in selecting appropriate insecticides for pest management to reduce the harmful effects caused by them. The diamide insecticides recorded considerably less toxic effect on the natural enemies, especially spiders and coccinellids. Population reduction of natural enemies was noticed immediately after insecticide spray, but it gradually increased and was recorded on par with the control population. The present result confirms the findings of Hiramoto (2007) and Patel and Patel (2020), who reported that diamide insecticides were relatively safe for spiders and coccinellids.

Conclusion

The bioefficacy of insecticides used against diamondbackmoth and their potential impact on natural enemies in cauliflower revealed that cyantraniliprole 10.26 OD @ 60 g a.i ha^{-1}, chlorantraniliprole 18.50 SC @ 10 g a.i ha^{-1} and flubendiamide 20 WG @ 18.24 g a.i ha^{-1} were very effective for the management of DBM, *P. xylostel-*

la. The novel mode of action of the diamide insecticides made this group a valuable option for integrated management programs of vegetables in addition to the safety of key beneficial insects. Even though it has many advantages over other insecticides, its indiscriminate use should be avoided for unprovoked development of resistance in the most tarnished pest of cole crops.

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Conflict of interest

The authors declare that they have no conflict of interest.

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