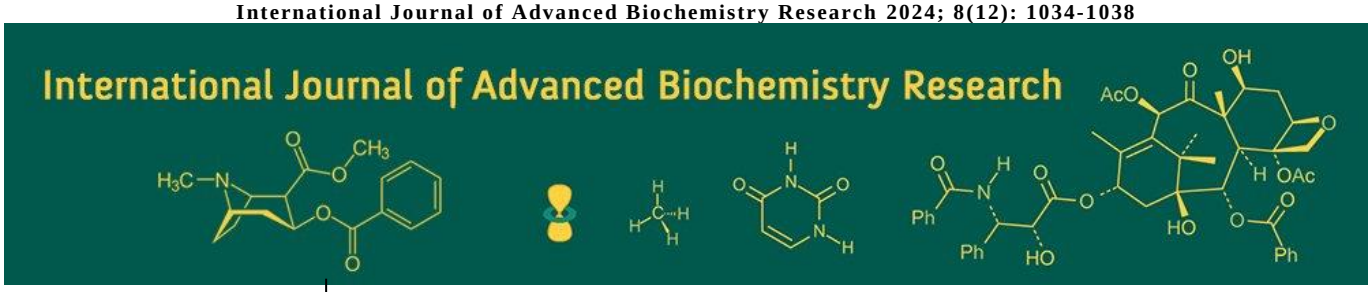

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Field-efficacy of biopesticides and insecticide combinations against diamondback moth at Bilaspur (Chhattisgarh)

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Abstract
The field experiment was conducted at Instructional farm of BTC CARS, Bilaspur, (C.G.) during *Rabi* 2023-24, to know the field efficacy of biopesticides and insecticide combinations against diamondback moth in cabbage crop. The mean on number of larvae/plant recorded after first and second spray showed that Spinetoram 11.7% SC recorded the lowest larvae (2.21 larvae/5plants) was shown to be substantially superior to all other treatments. *Bacillus thuringiensis* 10% (1x10^9 CFU/ml) + 50% dose of Spinetoram 11.7% SC (3.79 larvae/5plants) was the second-best treatment followed by Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (4.79 larvae/5plants), *Beauveria bassiana* 10% (1x10^9 CFU/ml) + 50% dose of Spinetoram 11.7% SC (6.00 larvae/5plants), Whereas, in untreated control (16.17 larvae/5plants) were observed.

Keywords: Efficacy, experiment, field, instructional, Spinetoram, diamondback moth

Introduction
Cabbage (*Brassica oleracea* var. *capitate* L.) is a widely cultivated highly remunerative cruciferous vegetable crop belongs to Brassicaceae family and mainly grown in winter season of India. India is the second leading country in producing cabbage with the area, production and productivity 430.27 thousand hectare, 9.95 million MT and 23.18 MT/ha (Anonymous, 2022-23). Insect pest menace is the major limiting factor for profitable cultivation of cabbage. Among those insect pest diamondback moth (*Plutella xylostella* L.) has become the most destructive pest with damaging potential ranging from 14 to 84 per cent (Abhijith *et al.*, 2019) [1]. Georghiou, (1981) [5] reported that diamondback moth developed resistance against almost all the available insecticides due to excessive use of chemical insecticides. About 29-33 different types of insecticides belonging to 13 groups are being sprayed between 10 to 20 times by majority of farmers in a single growing season in cabbage (Gangaraju *et al.*, 2020 and Biradar *et al.*, 2020) [4, 3].
By considering the insecticidal resistance developed mechanism a new method with economically fusible and eco-friendly approach that it meets profitable cultivation of cabbage is needed. A new insecticide with novel mode of action Spinetoram in combination with biopesticides *Beauveria bassiana, Metarhizium anisopliae, Bacillus thuringiensis* and Azadirachtin provides an alternative to reduce the negative effects of conventional insecticides. Such mixtures or combinations of insecticides increased toxicity against target pests more than that of a single product (Shabbir *et al*., 2021) [6].

Materials and Methods
A field experiment was conducted at Horticultural Research Farm of BTC CARS, Bilaspur, (C.G.) during *Rabi* season of 2022-23 under field condition to know the field-efficacy of biopesticides and insecticides combinations. Pre-treatment observations will be recorded one day before the application of treatment, whereas post - treatment observations will be recorded at 3,7,10 and 15 days after spraying. *Plutella xylostella* L. larvae will be counted on 5 randomly selected plants in each plot. The cabbage variety, Namdhari seeds-22 with a spacing of 45 x 60 cm was transplanted on 15th January, 2024 with following recommended practices.

Experimental details

- **Location:** Horticultural Research Farm of BTC CARS, Bilaspur
- **Season:** *Rabi*, 2023-24
- **Design:** RBD (Randomized Block Design)
- **Replications:** 3
- **Treatments:** 7
- **Plot size:** 3.6 m x 3.15 m
- **Spacing:** 60 cm x 45 cm

Results and Discussion

First Spray

The data on number of *P. xylostella larvae*/5plants recorded after first spray presented in Table 1 and depicted in Fig. 1 and the data on three days after spraying revealed that the population of diamondback moth ranged from 2.67 to 15.00 larvae per five plants All the treatments recorded significantly lower diamondback moth population than untreated control. The treatment Spinetoram 11.7% SC was found to be the most effective treatment which recorded minimum diamondback moth population i.e. 2.67 larvae per five plants followed by *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (6.00) and it was at par with Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (6.33) followed by *Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (9.33) and it was at par with *Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (9.67) and Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) (10.33). The maximum (15.00 larvae per five plants) diamondback moth population was found in untreated control.

The data on seven days after spraying revealed that the population of diamondback moth ranged from 2.33 to 16.67 larvae per five plants. All the treatments recorded significantly lower population of diamondback moth than untreated control. The minimum diamondback moth population was observed in Spinetoram 11.7% SC (2.33 larvae per five plants) followed by *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (4.00), Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (5.67) and it at par with *Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (6.67), *Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (7.00) and Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) (8.00). The maximum (16.67 larvae per five plants) diamondback moth population was observed in untreated control.

The data on ten days after first spray revealed that the diamondback moth population gradually increased in all the treatments. The population of diamondback moth ranged from 3.00 to 17.00 larvae per five plants. The treatment Spinetoram 11.7% SC showed minimum diamondback moth population (3.00 larvae per five plants) followed by *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (3.67) and it was at par with Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (5.00), *Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (5.67), *Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (6.33) and Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) (7.67). The maximum (17.00 larvae per five plants) diamondback moth population was observed in untreated control.

The data on fifteenth days after first spray revealed that diamondback moth population gradually increased in some treatments. The population of diamondback moth ranged from 3.67 to 17.67 larvae per five plants. The minimum (3.67 larvae per five plants) diamondback moth population was recorded in Spinetoram 11.7% SC followed by *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (5.67), and it at par with Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (7.33), *Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (8.67), *Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (10.00) and Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) (10.00). The maximum (17.67 larvae per five plants) diamondback moth population was observed in untreated control.

Second spray

The data on number of *P. xylostella larvae*/5plants recorded after second spray presented in Table 2 and depicted in Fig. 2 and the data on three days after spraying revealed that the population of diamondback moth ranged from 1.33 to 18.88 larvae per five plants. The treatment Spinetoram 11.7% SC was found to be the most effective treatment which recorded minimum diamondback moth population i.e. 1.33 larvae per five plants followed by *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (3.33) it was at par with Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (4.00), *Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (4.67), *Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (6.00) and Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) (7.00). The maximum (18.88 larvae per five plants) diamondback moth population was found in untreated control.

The data on seven days after first spray indicated the significant difference among the treatments. All the treatments recorded significantly lower population of diamondback moth than untreated control. The observations recorded on seven days after spraying revealed that the population of diamondback moth ranged from 1.00 to 17.00 larvae per five plants. The minimum diamondback moth population was observed in T_6- Spinetoram 11.7% SC (1.00 larvae per five plants) followed by *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (2.33) and it was at par with Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (3.33), *Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (3.67), *Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (4.33) and Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) (5.67). The maximum (17.00 larvae per five plants) diamondback moth population was observed in untreated control.

The data recorded on ten days after first spray the population of diamondback moth ranged from 1.67 to 15.00 larvae per five plants. The treatment Spinetoram 11.7% SC showed minimum diamondback moth population (1.67 larvae per five plants) and it at par with *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (2.00), Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (2.33), *Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (3.33), *Metarhizium anisopliae* 10% ($1x10^9$

CFU/ml) + 50% dose of Spinetoram 11.7% SC (4.00) and Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) (5.33). The maximum (15.00 larvae per five plants) diamondback moth population was observed in untreated control.

The data on fifteenth days after first spray revealed that diamondback moth population gradually increased in some treatments. The population of diamondback moth ranged from 2.00 to 12.67 larvae per five plants. The minimum (2.00 larvae per five plants) diamondback moth population was recorded in Spinetoram 11.7% SC and at par with *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (3.33), Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (4.33), *Beauveria bassiana* 10% ($1x10^9$CFU/ml) + 50% dose of Spinetoram 11.7% SC (5.33), *Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (5.67) and Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) (7.33). The maximum (12.67 larvae per five plants) diamondback moth population was observed in untreated control.

Overall mean of number of diamondback moth larvae/5plants (average of two spray)

The data on overall mean of two sprays revealed that the significant difference was found among the treatments. All the treatments recorded a significantly lower population of diamondback moth than untreated control. The diamondback moth population ranged from 2.21 to 16.17 larvae per plant. The treatment Spinetoram 11.7% SC showed minimum diamondback moth population (2.21 larvae per five plants) The next effective treatment was *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (3.79) and it was at par with Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (4.79), *Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (6.00), *Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (6.67) and Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) (7.71) The maximum (16.17 larvae per five plants) diamondback moth population was noticed in untreated control.

Table 1: Effect of different Biopesticide and Insecticides combinations on diamondback moth (*Plutella xylostella* L.) after first spray

Tr. No.	Treatment	PTO	Number of diamondback moth larvae/5 plants				Mean
			3 DAS	7 DAS	10DAS	15DAS	
T_1	*Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC	18.67	9.33^{b} (3.05)	6.67^{bc} (2.57)	5.67^{bc} (2.38)	8.67^{bc} (2.93)	7.58^{c} (2.75)
T_2	*Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC	18.67	9.67^{b} (3.11)	7.00^{bc} (2.64)	6.33^{b} (2.51)	10.00^{b} (3.15)	8.25^{bc} (2.87)
T_3	*Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC	18.00	6.00^{c} (2.44)	4.00^{d} (2.00)	3.67^{d} (1.90)	5.67^{c} (2.37)	4.83^{e} (2.20)
T_4	Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC	16.67	6.33^{c} (2.51)	5.67^{c} (2.38)	5.00^{cd} (2.23)	7.33^{cd} (2.70)	6.08^{d} (2.46)
T_5	Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml)	15.67	10.33^{b} (3.21)	8.00^{b} (2.83)	7.67^{b} (2.76)	10.33^{b} (3.20)	9.08^{b} (3.01)
T_6	Spinetoram 11.7% SC	15.00	2.67^{d} (1.58)	2.33^{e} (1.52)	3.00^{e} (1.72)	3.67^{d} (1.88)	2.92^{f} (1.71)
T_7	Untreated Control	14.67	15.00^{a} (3.87)	16.67^{a} (4.08)	17.00^{a} (4.12)	17.67^{a} (4.20)	16.58^{a} (4.07)
	C.D. (5%)	NS	0.50	0.36	0.46	0.45	0.20
	SEm(±)	NS	0.16	0.12	0.15	0.15	0.07
	C.V.	NS	9.97	7.81	10.18	8.66	4.173

*Figures in parentheses are the square root transformed values, PTO: Pre-treatment observations, DAS: Day after the spray.

Table 2: Effect of different Biopesticide and Insecticides combinations on diamondback moth (*Plutella xylostella* L.) after second spray

Tr. No.	Treatment	PTO	Number of diamondback moth larvae/5 plants				Mean
			3 DAS	7 DAS	10DAS	15DAS	
T_1	*Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC	10.67	4.67^{cd} (2.15)	4.33^{bc} (2.20)	3.33^{cd} (1.82)	5.33^{bc} (2.41)	4.42^{c} (2.10)
T_2	*Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC	11.00	6.00^{bc} (2.43)	4.67^{bc} (2.24)	4.00^{bc} (1.99)	5.67^{bc} (2.47)	5.08^{bc} (2.24)
T_3	*Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC	9.67	3.33^{d} (1.82)	2.33^{d} (1.68)	2.00^{e} (1.38)	3.33^{de} (1.92)	2.75^{d} (1.65)
T_4	Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC	9.67	4.00^{d} (1.99)	3.33^{cd} (1.95)	2.33^{de} (1.52)	4.33^{cd} (2.18)	3.50^{cd} (1.86)
T_5	Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml)	11.33	7.00^{b} (2.64)	5.67^{b} (2.48)	5.33^{b} (2.31)	7.33^{b} (2.80)	6.33^{b} (2.52)
T_6	Spinetoram 11.7% SC	7.00	1.33^{e} (1.14)	1.00^{e} (1.17)	1.67^{e} (1.28)	2.00^{e} (1.56)	1.50^{e} (1.20)
T_7	Untreated Control	18.00	18.88^{a} (4.28)	17.00^{a} (4.18)	15.00^{a} (3.87)	12.67^{a} (3.63)	15.75^{a} (43.97)
	C.D. (5%)	NS	0.44	0.48	0.38	0.44	0.39
	SEm(±)	NS	0.14	0.15	0.12	0.14	0.13
	C.V.	NS	10.40	11.76	10.62	10.18	9.94

*Figures in parentheses are the square root transformed values, PTO: Pre-treatment observations, DAS: Day after the spray.

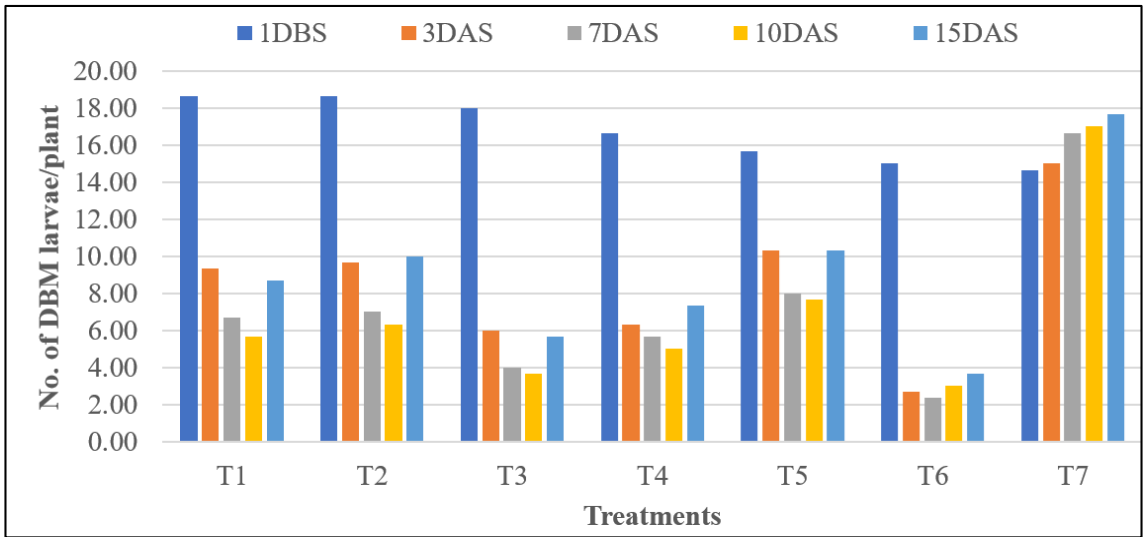

Fig 1: Number of DBM larvae/plant during first spray

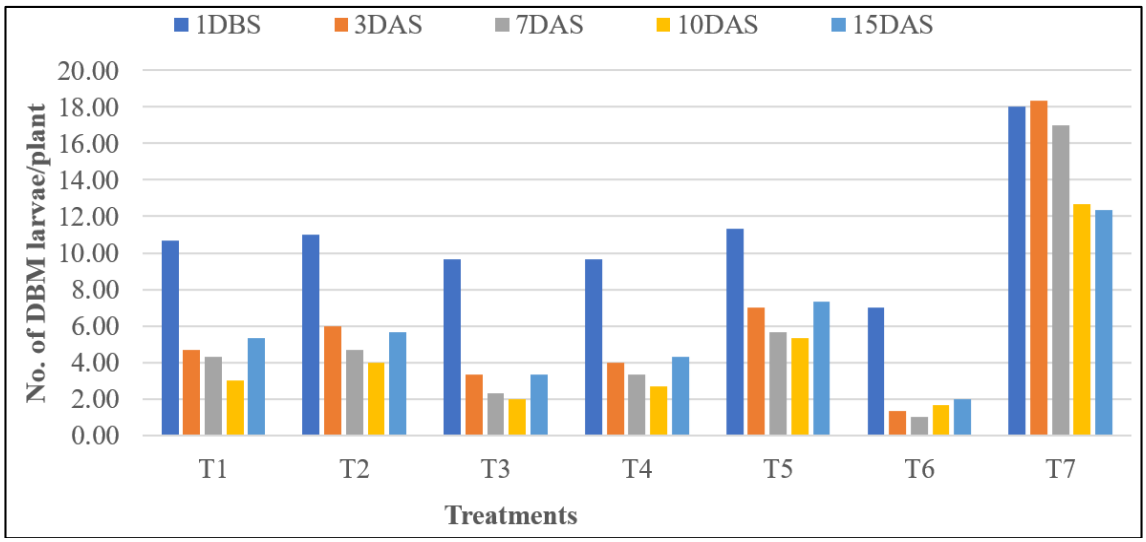

Fig 2: Number of DBM larvae/plant during second spray

Table 3: Effect of different Biopesticide and Insecticides combinations on diamondback moth (*Plutella xylostella* L.) (Avg. of two spray)

Tr. No.	Treatment	Number of diamondback moth larvae/5 plants
T_1	*Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC	6.00
T_2	*Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC	6.67
T_3	*Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC	3.79
T_4	Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC	4.79
T_5	Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml)	7.71
T_6	Spinetoram 11.7% SC	2.21
T_7	Untreated Control	16.17

Conclusion

The least population of diamondback moth was observed in the treatment Spinetoram 11.7% SC (2.21 larvae per five plants) with highest (86.34%) percent reduction over untreated control while, the highest population were observed in untreated control (16.17 larvae per five plants). The next effective treatment was *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (3.79) and it was at par with Azadirachtin 0.03% EC + 50% dose of Spinetoram 11.7% SC (4.79), *Beauveria bassiana* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (6.00), *Metarhizium anisopliae* 10% ($1x10^9$ CFU/ml) + 50% dose of Spinetoram 11.7% SC (6.67) and Azadirachtin 0.03% EC + *Bacillus thuringiensis* 10% ($1x10^9$ CFU/ml) (7.71) with 76.55, 70.36, 62.89, 58.76 and 52.32 percent reduction over untreated control, respectively.

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