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Manoj Kumar Chandraker
Department of Entomology, Pt. Kishori Lal Shukla College of Horticulture and Research Station Rajnandgaon, Chhattisgarh, India

Dhanendra Kumar Rana
Department of Entomology, College of Agriculture, Raipur, Chhattisgarh, India

Bhagwat Saran Asati
Department of Vegetable Science, College of Agriculture and Research Station, Chhuikhadan, Chhattisgarh, India

Santosh Sahu
Department of Agronomy, Pt. Kishori Lal Shukla College of Horticulture and Research Station Rajnandgaon, Chhattisgarh, India

Corresponding Author:
Manoj Kumar Chandraker
Department of Entomology, Pt. Kishori Lal Shukla College of Horticulture and Research Station Rajnandgaon, Chhattisgarh, India

Efficacy of botanicals and microbial agents for the management of diamondback moth (*Plutella xylostella*) in cabbage

Manoj Kumar Chandraker, Dhanendra Kumar Rana, Bhagwat Saran Asati and Santosh Sahu

Abstract
The efficacy of certain botanicals and microbial agents was tested against DBM in the research field of Pt. KLS College of Horticulture and Research Station, Rajnandgaon during 2016-17 and 2017-18. Among the treatments, Spinosad 2.5% EC @ 1.4 ml l^{-1} found most effective treatment against DBM recorded minimum population of 1.80, 1.40, 0.90, 1.07 and 1.97 & 1.80, 1.27, 1.10, 1.33 and 2.43 larvae $plant^{-1}$ at 1, 3, 5, 7 and 10 days after first and second sprays, respectively with maximum yield (243.32 q ha^{-1}), high net returns (Rs 50,012.00 ha^{-1}) and maximum cost benefit ratio (1:2.61). Among the microbial agent, *Bacillus thuringiensis* @ 2 g l^{-1} was found second most effective treatment against DBM followed by NSK based (Azadirachtin 1% EC) @ 3 ml l^{-1}, NSK based (Azadirachtin 0.15% EC) @ 5 ml l^{-1}, *Beauveria bassiana* @ 2 g l^{-1}, *Metarhizium anisopliae* @ 2 g l^{-1}, dhenu astra @ 5 ml l^{-1}, neem oil (Pure extract) @ 5 ml l^{-1} and karanj oil (Pure extract) @ 5 ml l^{-1} were effectively decrease the larval population of DBM. On the basis of percent reduction of larval population over control, treatment spinosad 2.5% EC was found superior with 69.56 and 67.97 per cent population reduction after first and second spray, respectively.

Keywords: DBM, botanicals, microbial agents and cabbage

Introduction
Cabbage (*Brassica oleracea* var. *capitata*) is an important vegetable crop of cruciferous family (Brassicaceae), widely grown in the country. It is used as salad, boiled vegetable and dehydrated vegetable as well as in cooked curries and pickles. The cabbage crop is attacked by a number of insect pests. Diamondback moth (*Plutella xylostella* L.) is the most destructive insect pest and is the major limiting factor for successful cultivation of cruciferous crops resulting in loss of quality and production (Patil *et al.*, 1999) [3]. Diamondback moth has national importance on cabbage as it causes 50-80% annual loss in the marketable yield (Devjani and Singh, 1999) [1]. Hence, farmers are compelled to use chemical insecticides in order to cultivate lucratively, as traditional and cultural practices alone cannot not give satisfactory control over the pest menace. Frequent use of chemical insecticides at higher doses results in depredation of natural enemies and development of insecticide resistance in *P. xylostella* against a wide range of insecticides in different parts of India (Talekar *et al.*, 1990) [8]. This has necessitated the use of botanical and microbial agents to sustain the management of DBM. Botanical and microbial agents are effective and economic for the management of *P. xylotella* on cabbage. In this regards, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae*, *Azadirachtin*, Karanj oil and plant originated products are applicable for managing this pest. Botanical extracts can change the behaviour and development of harmful insect pests. These products are environmentally safe, the non-residual effect for consequence crops and also promotion to biodiversity in the ecosystem (Isman, 2008) [3]. Sewak *et al.* (2008) [7] tested that efficacy of plant originated product (Neem seed kernel extract 5 per cent) recorded significant results concerning pest incidence and yield of cabbage against DBM. The single approach is not effective for controlling DBM. Therefore, several strategies have been implied in reducing the DBM pest population. In these contexts, biological approaches are more powerful tools for managing pest incidence. Keeping this in view, an experiment was conducted on management of diamondback moth in cabbage by botanicals and microbial agents in Rajnandgaon district of Chhattisgarh.

Materials and Methods

Effectively management of diamondback moth on cabbage by botanicals and microbial agents study was carried out during year 2016-17 and 2017-18 at Rajnandgaon district of Chhattisgarh. Different concentrations of botanicals (Neem, Karnaj and Dhenu Astra), microbial agents (*Beuveria bessiana, Bacillus thuringiensis and Metarrhizium anisoplae* and Spinosad 2.5% EC) were applied. The experiment was laid out in a randomized block design (RBD) with ten treatments including untreated control and replicated three times. The crop was raised with recommended agronomic practices. Five randomly selected plants were observed from each plot; number of larvae per plant was counted one day before application and subsequently 1st, 3rd, 5th, 7th and 10th days after the application of treatments. Applications of these above treatments were repeated at 15 days interval on the basis of larval population. Besides this observation, economic profitability of different treatments, cost of cultivation, gross returns, net returns and benefit cost ratio of each treatment were calculated.

Results and Discussion

Efficacy of certain botanicals and microbial agents was tested against DBM in the research field of Pt. KLS College of Horticulture and Research Station, Rajnandgaon during 2016-17 and 2017-18. Among the treatments, Spinosad 2.5% EC @ 1.4 ml l^{-1} found most effective treatment against DBM recorded minimum population of 1.80, 1.40, 0.90, 1.07 and 1.97 and 1.80, 1.27, 1.10,1.33 and 2.43 larvae $plant^{-1}$ at 1, 3, 5, 7 and 10 days after first and second sprays, respectively. The microbial agent, *Bacillus thuringiensis* @ 2 g l^{-1} was recorded as second best effective treatment in terms of minimum DBM population $plant^{-1}$ recorded 3.00, 2.87, 1.63, 1.83, and 2.83 & 3.37, 3.33, 2.20,1.90 and 2.97 larvae $plant^{-1}$ at 1, 3, 5, 7 and 10 Days after first and second sprays, respectively followed by NSK based (Azadirachtin 1% EC) @ 3 ml l^{-1}, NSK based (Azadirachtin 0.15% EC) @ 5 ml l^{-1}, *Beuveria bassiana* @ 2 g l^{-1}, *Metarrhizium anisoplae* @ 2 g l^{-1}, dhenu astra @ 5 ml l^{-1}, neem oil (Pure extract) @ 5 ml l^{-1} and karanj oil (Pure extract) @ 5 ml l^{-1} were effectively decrease the larval population of DBM (Table 1&2). Similar findings was observed by Venkateswarlu *et al.* (2011) who reported 83.65 and 82.08 per cent reduction of *P. xylostella* during 2009-10 and 2010-11, respectively when cabbage crop was applied with chlorantraniliprole @ 10 g a.i.ha-1 . Nikam (2013) also recorded mean larval population of 0.69 larvae plant-1 with 92.12 per cent efficacy against *P. xylostella* when cabbage crop was applied with chlorantraniliprole 18.5 SC.

Maximum cabbage yield i.e. 243.32 q ha^{-1} was obtained when crop treated with spinosad 2.5% EC @ 1.4 ml l^{-1} followed by *Bacillus thuringiensis* @ 2 g l^{-1}, NSK based (Azadirachtin 1% EC) @ 3 ml l^{-1}, NSK based (Azadirachtin 0.15% EC) @ 5 ml l^{-1}, *Beuveria bassiana* @ 2 g l^{-1}, *Metarrhizium anisoplae* @ 2 g l^{-1}, dhenu astra @ 5 ml l^{-1}, neem oil (Pure extract) @ 5 ml l^{-1} and karanj oil (Pure extract) @ 5 ml l^{-1} with 233.29, 226.93, 221.56, 212.35, 208.76, 203.34, 193.97 and 189.81 q ha^{-1}, respectively (Table 3). Net profit over control was calculated and the highest price obtained with treatment spinosad 2.5% EC @ 1.4 ml l^{-1} (50,012.00 Rs ha^{-1}) followed by *Bacillus thuringiensis* @ 2 g. l^{-1}, NSK based (Azadirachtin 1% EC) @ 3 ml l^{-1}, NSK based (Azadirachtin 0.15% EC) @ 5 ml l^{-1}, *Beuveria bassiana* @ 2 g l^{-1}, *Metarrhizium anisoplae* @ 2 g l^{-1}, dhenu astra @ 5 ml l^{-1}, neem oil (Pure extract) @ 5 ml l^{-1}, karanj oil (Pure extract) @ 5 ml l^{-1} with 40,088.00, 34,950.00, 31,404.00, 24,136.00, 21,964.00, 18,178.00, 10,682.00 and 7,354.00 Rs ha^{-1}, respectively (Table 3). Present findings are in agreement with the finding of Gupta (2000) [2] who observed that the application of spinosad 2.5 SC @ 10-25 g a.i. ha^{-1} provided significantly higher yield and minimum population count of diamondback moth, semi looper and tobacco caterpillar on cabbage. Wraight *et al.* (2001) [10] tested foliar application of *Beauveria bassiana* (Daman) 10g $litre^{-1}$ and 5g $litre^{-1}$ against DBM with significantly minimum population of *Plutella xylostella* with 0.37 and 0.75 larvae $plant^{-1}$, respectively along with maximum yield of 134.63 and 130.63 kg per 20 m^{-2}, respectively. These findings are supported to present one. Investigation of Pramanik and Chatterjee (2003) [6] are in accordance with present study where they evaluated the efficacy of newer insecticides against diamondback moth, *P. xylostella* on cabbage and they reported that the spinosad (0.005%) was found to be most effective and reduced pest population.

Table 1: Larval population of DBM in pre-treatment and post treatment observations after first spray of botanicals and microbial agents (Pooled 2016-17 and 2017-18)

Treatments	Dose (g or ml l^{-1})	Mean larval population (Larvae $plant^{-1}$)							
		Pre-treatment	Post-treatment (first spray)					Cumulative population	% reduction over control
			1 DAS	3 DAS	5 DAS	7 DAS	10 DAS		
Karanj oil (Pure extract)	5 ml l^{-1}	4.70 (2.38)	4.33 (2.30)	3.70 (2.17)	3.20 (2.05)	3.43 (2.10)	4.87 (2.41)	3.91 (2.13)	16.64
Neem oil (Pure extract)	5 ml l^{-1}	4.43 (2.33)	4.20 (2.28)	3.63 (2.15)	3.07 (2.00)	3.23 (2.06)	4.57 (2.36)	3.74 (2.11)	20.20
Dhenu astra	5 ml l^{-1}	4.77 (2.40)	3.97 (2.23)	3.57 (2.13)	2.97 (1.97)	3.03 (2.00)	4.30 (2.30)	3.57 (2.11)	23.90
Beauveria bassiana	2 g l^{-1}	4.97 (2.44)	3.83 (2.19)	3.50 (2.11)	2.00 (1.70)	2.43 (1.84)	3.63 (2.17)	3.08 (2.03)	34.28
Bacillus thuringiensis	2 g l^{-1}	5.17 (2.48)	3.00 (2.00)	2.87 (1.95)	1.63 (1.57)	1.83 (1.66)	2.83 (2.02)	2.43 (1.91)	48.08
Metarhizium anisopliae	2 g l^{-1}	4.77 (2.40)	3.90 (2.20)	3.53 (2.13)	2.37 (1.83)	2.47 (1.84)	3.87 (2.22)	3.23 (2.04)	31.15
NSK based (Azadirachtin 0.15% EC)	5 ml l^{-1}	5.37 (2.52)	3.73 (2.18)	3.43 (2.10)	1.97 (1.69)	2.37 (1.76)	3.57 (2.16)	3.01 (2.02)	35.70
NSK based (Azadirachtin 1% EC)	3 ml l^{-1}	4.77 (2.40)	3.50 (2.12)	3.27 (2.06)	1.90 (1.65)	1.93 (1.69)	3.17 (2.13)	2.75 (1.93)	41.25
Spinosad 2.5% EC	1.4 ml	5.03	1.80	1.40	0.90	1.07	1.97	1.43	69.56

	l^{-1}	(2.45)	(1.67)	(1.55)	(1.37)	(1.44)	(1.84)	(1.79)	
Control	-	4.40 (2.32)	4.70 (2.37)	4.57 (2.36)	4.60 (2.36)	4.63 (2.37)	4.93 (2.42)	4.69 (2.35)	
S.Em ±	-	0.05	0.07	0.10	0.14	0.13	0.10	0.07	
CD at 5%	-	NS	0.20	0.29	0.41	0.40	0.28	0.22	

Note: Figure in parenthesis are root square transformed value, NSK =Neem Seed Kernel, DAS= Days after spray

Table 2: Larval population of DBM in pre treatment and post treatment observations after second spray of botanicals and microbial agents (Pooled 2016-17 and 2017-18)

Treatments	Dose (g or ml l^{-1})	Mean larval population (Larvae $plant^{-1}$)							
		Pre-treatment	Post-treatment (Second spray)					Cumulative population	% reduction over control
			1 DAS	3 DAS	5 DAS	7 DAS	10 DAS		
Karanj oil (Pure extract)	5 ml l^{-1}	5.30 (2.50)	4.80 (2.40)	4.13 (2.26)	3.53 (2.05)	3.37 (2.04)	4.97 (2.44)	4.16 (2.18)	16.02
Neem oil (Pure extract)	5 ml l^{-1}	5.17 (2.48)	4.33 (2.30)	3.97 (2.22)	3.47 (2.01)	3.20 (2.04)	4.87 (2.42)	3.97 (2.16)	19.92
Dhenu astra	5 ml l^{-1}	5.30 (2.51)	4.30 (2.30)	3.90 (2.21)	3.17 (1.98)	3.13 (2.02)	4.80 (2.40)	3.86 (2.20)	22.07
Beauveria bassiana	2 g l^{-1}	5.30 (2.51)	4.13 (2.26)	3.77 (2.16)	2.80 (1.94)	2.90 (1.97)	3.83 (2.19)	3.49 (2.13)	29.61
Bacillus thuringiensis	2 g l^{-1}	5.80 (2.61)	3.37 (2.08)	3.33 (2.06)	2.20 (1.75)	1.90 (1.69)	2.97 (2.01)	2.75 (1.98)	44.41
Metarhizium anisopliae	2 g l^{-1}	5.30 (2.51)	4.20 (2.28)	3.83 (2.17)	2.87 (1.95)	2.97 (1.99)	3.97 (2.23)	3.57 (2.12)	27.99
NSK based (Azadirachtin 0.15% EC)	5 ml l^{-1}	6.10 (2.66)	4.03 (2.24)	3.67 (2.16)	2.73 (1.91)	2.83 (1.93)	3.70 (2.16)	3.39 (2.12)	31.49
NSK based (Azadirachtin 1% EC)	3 ml l^{-1}	5.23 (2.49)	3.80 (2.19)	3.60 (2.15)	2.60 (1.88)	2.77 (1.92)	3.60 (2.15)	3.27 (2.11)	33.92
Spinosad 2.5% EC	1.4 ml l^{-1}	5.13 (2.48)	1.80 (1.67)	1.27 (1.51)	1.10 (1.50)	1.33 (1.58)	2.43 (1.89)	1.59 (1.78)	67.97
Control	-	4.33 (2.31)	5.03 (2.45)	4.87 (2.42)	4.63 (2.37)	5.00 (2.45)	5.23 (2.49)	4.95 (2.40)	
S.Em ±	-	0.06	0.09	0.10	0.12	0.09	0.11	0.08	
CD at 5%	-	NS	0.26	0.29	0.36	0.27	0.32	0.25	

Note: Figure in parenthesis are root square transformed value, NSK =Neem Seed Kernel, DAS= Days after spray

Table 3: Economics of different botanicals and microbial agents due to DBM Incidence on cabbage

Treatment	Yield (q ha^{-1})	Increase yield over control (q ha^{-1})	Price of increased yield over control (Rs ha^{-1})	Management cost (labour + botanical and microbial bioagents) (Rs ha^{-1})	Net profit over control (Rs ha^{-1})	C:B ratio
Karanj oil (Pure extract)	189.81	14.89	11912	4558	7354	1:2.04
Neem oil (Pure extract)	193.97	19.05	15240	4558	10682	1:2.08
Dhenu astra	203.34	28.42	22736	4558	18178	1:2.18
Beauveria bassiana	212.35	37.43	29944	5808	24136	1:2.24
Bacillus thuringiensis	233.29	58.37	46696	6608	40088	1:2.44
Metarhizium anisopliae	208.76	33.84	27072	5108	21964	1:2.22
NSK based (Azadirachtin 0.15% EC)	221.56	46.64	37312	5908	31404	1:2.34
NSK based (Azadirachtin 1% EC)	226.93	52.01	41608	6658	34950	1:2.37
Spinosad 2.5% EC	243.32	68.40	54720	4708	50012	1:2.61
Control	174.92					

Price of botanicals and microbial agents = T_1- Karanj oil@ 450 Rs kg^{-1}, T_2- Neem oil @ 450 Rs kg^{-1}, T_3- Dhenu astra @ 450 Rs kg^{-1}, T_4- *B*eauveria *bassiana* @ 775 Rs kg^{-1}, T_5- *Bacillus thuringiensis* @ 775 Rs kg^{-1}, T_6- *Metarhizium anisopliae* @ 775 Rs kg^{-1}, T_7- Azadirachtin 0.15% EC @ 1237.50 Rs kg^{-1}, T_8- Azadirachtin 1% EC @ 4100 Rs kg^{-1} & T_9- Spinosad 2.5% EC @ 492.50 Rs kg^{-1}.

* Labour charge=Rs 283 $manday^{-1}$

*Price of cabbage = Rs 800 q^{-1}

Conclusion

Under the study, Spinosad 2.5% EC @ 1.4 ml l^{-1} found most effective treatment among all the treatments against DBM recorded minimum population of 1.80, 1.40, 0.90, 1.07 and 1.97 & 1.80, 1.27, 1.10,1.33 and 2.43 larvae $plant^{-1}$ at 1, 3, 5, 7 and 10 days after first and second sprays, respectively with maximum yield (243.32 q ha^{-1}), high net returns (Rs 50,012.00 ha^{-1}) and maximum cost benefit ratio (1:2.61). On other hand, *Bacillus thuringiensis* @ 2 g l^{-1} was found second most effective treatment among the various microbial agents used against DBM followed by NSK based (Azadirachtin 1% EC) @ 3 ml l^{-1}, NSK based (Azadirachtin 0.15% EC) @ 5 ml l^{-1}, *Beuveria bassiana* @ 2 g l^{-1}, *Metarrhizium anisoplae* @ 2 g l^{-1}, dhenu astra @ 5 ml l^{-1}, neem oil (Pure extract) @ 5 ml l^{-1} and karanj oil (Pure extract) @ 5 ml l^{-1} were effectively decrease the larval population of DBM. On the basis of percent reduction of larval population over control, treatment spinosad 2.5% EC was found superior with 69.56 and 67.97 per cent population reduction after first and second spray, respectively.

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