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Management of mustard aphid, *Lipaphis erysimi* through entomopathogenic fungi

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Abstract
Evaluation of different entomopathogenic fungi for managing mustard was carried out at Sardarkrushinagar in North Gujarat during *Rabi* season of 2016 under field condition. Among the different treatments evaluated against mustard aphid, *Lipaphis erysimi* the lowest aphid index (1.20) was observed in the plots treated with higher dose of *Lecanicillium lecanii* (1×10^9 cfu/gm) *i.e.* 60 g per 10 liter water and it was at par with higher dose of *Beauveria bassiana* (1×10^9 cfu/gm) *i.e.* 60 g per 10 liter water (1.27) at 9 days after 2nd spray. The highest grain yield (1356 kg/ha), maximum increase in grain yield (94.27%), minimum avoidable losses (4.13) as well as higher PCBR (1 : 4.19) was recorded from the plots treated with *L. lecanii* (1×10^9 cfu/gm) @ 60 g per 10 liter water and thus proved to be most effective against *L. erysimi*.

Keywords: *Lipaphis erysimi, Beauveria bassiana, Lecanicillium lecanii,* management

Introduction
The brown or Indian mustard locally known as rai (*Brassica juncea* L.) is important cruciferous oilseed crop grown during *rabi* season. Rapseed and Mustard play vital role in Indian economy. They are considered as “Cash Crop.” The oil content in mustard seed varies between 35 and 45 per cent and the protein content is between 20 and 24 per cent. Mustard meal or cake contains about 12 per cent oil and 38 to 42 per cent protein (Nagraj, 1995) [2]. Worldwide, India is the fourth largest mustard producer. European Union is the leading mustard seed producer in the world accounting for 35 per cent of the world production followed by China (22%), Canada (21%) and India (11%).
Insect pest is one of the most important yield limiting factors for the cruciferous oil seed crops. These crops are attacked by 21 to 38 insect pests at different location in India (Bakhetia and Sekhon, 1989) [1]. The important insect pests of mustard crops are aphid *Lipaphis erysimi*, sawfly, *Athalia lugens proxima*, leaf webber, *Crocidolomia binotalis* and painted bug, *Bagrada hilaris*. The mustard aphid, (*L. erysimi*) is a key pest of mustard. Although, the aphid remains present throughout the year in the field, but its population becomes very high during December to March. *L. erysimi* causes 35.4 to 73.3 per cent yield losses, 30.09 per cent seed weight loss and 2.75 per cent oil loss as reported by Bakhetia and Sekhon (1989) [1], Singh and Premchand (1995)[9] and Sharma and Kashyap (1998) [7], respectively. To manage mustard aphid, farmers generally utilizes chemical pesticides. These pesticides create several hazards to environment as well as important pollinators. On the other hand entomopathogenic fungi is safe for environment, beneficial insects and important pollinators. Therefore, the present study was conducted to evaluate different entomopathogenic fungi against mustard aphid in field conditions.

Materials and Methods
The field experiment was laid out in Randomized Block Design during *Rabi* 2016-17 at Agronomy Instructional Farm, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar for management of entomopathogenic fungi against mustard aphid, *L. erysimi*. mustard variety “GDM 4” was sown in plots size 4.0 m x 2.25 m at 45 x 10 cm spacing with 10 treatments (Table 1) replicated thrice. The first spray was applied at pest appearance and second spray which given after 10 days. Observations on mustard aphid index was recorded on ten randomly selected plants from each treatment before spray and 4, 6 and 9 days after spray. Aphid index was recorded using the following standard scale given by Patel *et al.*1995 [5] (Table 1).

Table 1: Aphid index and standard scale

Aphid index	Criteria
0	Plant free from aphid infestation
1	Only a few aphids with very little injury
2	Small aphid colonies on a few twigs, no curling or yellowing of leaves.
3	Aphid colonies on almost all the twigs, stunted growth, curling and yellowing of leaves
4	Very heavy population of aphid on leaves, inflorescences, stem and siliqua
5	Completely drying of plants due to heavy infestation of aphid

The average aphid index was worked out by using following formula:

$$\text{Average Aphid Index} = \frac{0N + 1N + 2N + 3N + 4N + 5N}{\text{Total number of plant observed}}$$

Where,
0, 1, 2, 3, 4 and 5 are the aphid indices.
N = Number of plants showing respective aphid index.

At harvest, based on grain yield, per cent increase in yield and avoidable losses calculated according to Khosla (1977) [3]. In order to know the economics of different treatments evaluated against *L. erysimi*, Protection Cost Benefit Ratio (PCBR) was worked out.

Results and Discussion

Efficacy of various entomopathogenic fungi against mustard aphid

The results on aphid index per plant before spraying indicated that there was no significant difference between treatments (Table 2).

However, all the treatments remained significantly superior over untreated control in terms of aphid index at 4, 6 and 9 days after first and second spray. The lowest aphid index was recorded in *L. lecanii* (1 × 10^9 cfu/gm) @ 60 g per 10 liter water (1.20/plant). It remained at par with *B. bassiana* (1 × 10^9 cfu/gm) @ 60 g per 10 liter water (1.27/plant) at 9 days after second spray. The treatments *viz.*, *M. anisopliae* (1 × 10^9 cfu/gm) @ 40 g per 10 liter water (2.80/plant), *B. bassiana* @ 20 g per 10 liter water (2.83/plant) and *M. anisopliae* (1 × 10^9cfu/gm) @ 20 g per 10 liter water (3.13/plant) found less effective and remained at par in terms of efficacy against *L. erysimi*. The maximum aphid index was noticed in untreated control (4.27/ plant).

Based on results of first and second spray, it clearly indicated that *L. lecanii* (1 × 10^9 cfu/gm) @ 60 g per 10 liter water was most effective treatment against mustard aphid under field conditions followed by *B. bassiana* (1 × 10^9 cfu/gm) @ 60 g per 10 liter water. Rana (2005) [6] reported that the initial mustard aphid population (1.2 aphid index) declined (0.1 index) significantly a week after application of *Verticillium lecanii* fungus. Singh *et al.* (2009) [8] also observed that *V. lecanii* @ 108 spores/ml reduced aphid population up to 84.90 per cent after the 10 days of spray.

Grain yield (kg/ ha)

All entomopathogenic fungi at higher dose produced significantly higher yield than rest (Table 3). The treatment with *L. lecanii* (1 × 10^9 cfu/gm) @ 60 g per 10 liter water produced the highest (1356 kg/ha) yield of mustard seed, however it remained at par with *B. bassiana* (1 × 10^9 cfu/gm) @ 60 g per 10 liter water (1300 kg/ha) and *L. lecanii* (1 × 10^9 cfu/gm) @ 40 g per 10 liter water (1240 kg/ha). The lowest yield was harvested from untreated control (698 kg/ ha) and it was at par with *M. anisopliae* (1 × 10^9 cfu/gm) @ 20 g per 10 liter water (780 kg/ha), *B. bassiana* (1 × 10^9 cfu/gm)@ 20 g per 10 liter water (802 kg/ha), *M. anisopliae* (1 × 10^9 cfu/gm) @ 40 g per 10 liter water (837 kg/ha) and *L. lecanii* (1 × 10^9 cfu/gm) @ 20 g per 10 liter water (873 kg/ha).

Table 2: Efficacy of entomopathogenic fungi against mustard aphid

Treat. No.	Treatment	Dose (g/10 lit. water	Aphid index (0-5) day after spray						
			Before spray	1st spray			2nd spray		
				4	6	9	4	6	9
T_1	*Beauveria bassiana*	20	1.67	1.66	1.67	2.60	2.30	2.17	2.83
T_2	*Metarhizium anisopliae*	20	1.80	1.78	1.73	2.80	2.37	2.27	3.13
T_3	*Lecanicillium lecanii*	20	1.63	1.62	1.37	2.10	1.90	1.77	2.33
T_4	*Beauveria bassiana*	40	1.67	1.59	1.30	2.03	1.83	1.70	2.27
T_5	*Metarhizium anisopliae*	40	1.63	1.63	1.63	2.53	2.27	2.13	2.80
T_6	*Lecanicillium lecanii*	40	1.73	1.30	0.90	1.53	1.37	1.27	1.73
T_7	*Beauveria bassiana*	60	1.53	1.20	0.60	1.10	0.97	0.90	1.27
T_8	*Metarhizium anisopliae*	60	1.63	1.33	1.00	1.60	1.43	1.33	1.80
T_9	*Lecanicillium lecanii*	60	1.70	1.10	0.53	1.07	0.93	0.80	1.20
T_{10}	Control (untreated)	-	1.63	1.90	2.00	3.20	3.37	3.60	4.27
S.Em.±			0.10	0.10	0.08	0.11	0.11	0.12	0.14
C.D. at 5 %			NS	0.31	0.23	0.34	0.33	0.34	0.43
C.V. %			10.18	11.80	10.51	9.55	10.33	11.19	10.56

Increase in yield over control (%)

Increase in yield over control ranged from 11.74 to 94.27 per cent in various treatments (Table 2). Maximum increase in grain yield (94.27%) was recorded in the plots treated with *L. lecanii* (1 × 109 cfu/gm) @ 60 g per 10 liter water followed by *B. bassiana* (1 × 109 cfu/gm) @ 60 g per 10 liter water (86.25%), *L. lecanii* (1 × 109 cfu/gm) @ 40 g per 10 liter water (77.65%), *M. anisopliae* (1 × 109 cfu/gm) @ 60 g per 10 liter water (60.88%), *B. bassiana* (1 × 109 cfu/gm) @ 40 g per 10 liter water (53.72%) showed mediocre increase in yield over control. However, *L. lecanii* (1 × 109 cfu/gm) @ 20 g per 10 liter water (25.07%), *M. anisopliae* (1 × 109 cfu/gm) @ 40 g per 10 liter water (19.91%) and *B. bassiana* (1 × 109 cfu/gm) @ 20 g per 10 liter water (14.89%). *M. anisopliae* (1 × 109 cfu/gm) @ 20 g per 10 liter water (11.74%) showed lower increase in yield over control.

Table 3: Mustard yield, increase in yield and avoidable losses due to *L. erysimi*

Treat. No.	Treatments	Dose (gm/ 10 liter)	Yield(kg/ha)	Increase in yield over control (%)	Avoidable losses (%)	PCBR
T_1	*Beauveria bassiana*	20	802	14.89	40.85	1 : 0.87
T_2	*Metarhizium anisopliae*	20	780	11.74	42.47	1 : 0.47
T_3	*Lecanicillium lecani*	20	873	25.07	35.62	1 : 2.15
T_4	*Beauveria bassiana*	40	1073	53.72	20.87	1 : 3.11
T_5	*Metarhizium anisopliae*	40	837	19.91	38.27	1 : 0.52
T_6	*Lecanicillium lecani*	40	1240	77.65	8.55	1 : 4.94
T_7	*Beauveria bassiana*	60	1300	86.25	4.13	1 : 3.75
T_8	*Metarhizium anisopliae*	60	1123	60.88	17.18	1 : 2.35
T_9	*Lecanicillium lecani*	60	1356	94.27	-	1 : 4.19
T_{10}	Control (Untreated)	-	698	-	48.52	-
S.Em.±			61.32	-	-	
C.D. at 5 %			182.20	-	-	
C.V. %			10.54	-	-	

Avoidable losses (%)

The avoidable losses in grain yield due to various entomopathogenic fungi ranged from 4.13 to 48.52 per cent in different treatments (Table 2). There was no avoidable loss in the plots treated with *L. lecanii* (1×10^9 cfu/gm) @ 60 g per 10 liter water. Minimum avoidable losses in yield was recorded in the treatment with *B. bassiana* (1×10^9 cfu/gm) @ 60 g per 10 liter water (4.13%) followed by *L. lecanii* (1×10^9 cfu/gm) @ 40 g per 10 liter water (8.55%). The maximum avoidable losses in yield was recorded in untreated control (48.52%) followed by *M. anisopliae* (1×10^9 cfu/gm) @ 20 g per 10 liter water (42.47%), *B. bassiana* (1×10^9 cfu/gm) @ 20 g per 10 liter water (40.85%).

The highest Protection Cost Benefit Ratio (PCBR) (1:4.94) was recorded in the treatment *L. lecanii* @ 40g per 10 liter water (Table 2) and it was followed by *L. lecanii* (1×10^9 cfu/gm) @ 60 g per 10 liter water (1 : 4.19) and *B.bassiana* (1×10^9 cfu/gm)@ 60 g per 10 liter water (1:3.75). The PCBR (1:0.47) was calculated in the treatment with *M. anisopliae* (1×10^9 cfu/gm) @ 20 g per 10 liter water followed by *M. anisopliae* (1×10^9 cfu/gm) @ 40 g per 10 liter water (1:0.52) and *B. bassiana* (1×10^9 cfu/gm) @ 20 g per 10 liter water (1:0.87).

The results are in close accordance with findings of Meena *et al.* (2013) [4], where he reported that the highest protection cost benefit ratio was obtained under the treatment *Verticillium lecanii* @ 5 g per liter of water (1:10), *Beauveria bassiana* @ 5 g per liter of water (1:10), *Metarhizium anisopliae* @ 5 g per liter of water (1:8), tobacco extract @ 5 per cent (1:6) and water spray (1:2).

Conclusion

The treatment with entomopathogenic fungi *L. lecanii* (1×10^9 cfu/gm) at higher dose *i.e.* 60 g per 10 liter water was most effective treatment in terms of efficacy against *L. erysimi*, grain yield, increase in yield over control, avoidable losses and economics and it was followed by higher doses of *B. bassiana* (1×10^9 cfu/gm) *i.e.* 60 g per 10 liter water.

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