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Evaluation of Biorationals for the management of sucking pests in fenugreek

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Abstract

A field experiment was conducted at the Seed Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Gujarat during the *Rabi* seasons of 2018–19, 2019–20 and 2020–21 to evaluate the efficacy of biorational insecticides against major sucking pests of fenugreek. All the biorational treatments significantly suppressed aphid and leaf hopper populations compared to the untreated control. The sequential application of *B. bassiana* 1.15 WP (40 g/10 L) followed by azadirachtin 10,000 ppm (30 ml/10 L) proved to be the most effective, recording the lowest aphid index (1.22) and leaf hopper population (1.24 per/leaves). The same treatment also produced the highest seed yield (1512 kg/ha) and the maximum protection cost-benefit ratio (7.95), the next best treatment was *B. bassiana* 1.15 WP followed by azadirachtin 1500 ppm. First foliar spray should be made at initiation of aphid or leaf hopper infestation and second spray at 10 days after first spray. The findings demonstrate that the sequential application of *B. bassiana* 1.15 WP followed by azadirachtin 10,000 ppm is an effective, eco-friendly and economically viable strategy for the management of aphid and leaf hopper infesting fenugreek.

Keywords: Azadirachtin, aphid, *B. bassiana*, *L. lecanii*, leaf hopper and fenugreek

Introduction

Fenugreek (*Trigonella foenumgraceum* L.) an important seed spice crop, is grown in India for domestic and export purposes. It is commonly known as Methi. Fenugreek seeds contain 13.7% water, 26.2% protein, 5.8% fat, 3.0% mineral matter, 7.2% fiber, 4.41% carbohydrate, 0.16% calcium, 0.37% phosphorus and 14.1 mg iron (Patel *et al.*, 2022). Fenugreek ranks as the third most important seed spice in India, followed by coriander and cumin (Kumar *et al.*, 2023). Aroma of fenugreek seeds is attributed to the presence of volatile oils (Ahmad *et al.*, 2016). In India, Rajasthan, Gujarat, Uttaranchal, Uttar Pradesh, Madhya Pradesh, Maharashtra, Haryana and Punjab are the major fenugreek producing states. Fenugreek is infested by a

variety of insect pests, including aphids (*Aphis craccivora* Koch) (Hemiptera: Aphididae); whitefly (*Bemisia tabaci* Genn.) (Hemiptera: Aleyrodidae); leafhopper (*Empoasca kerri* Pruthi) (Hemiptera: Cicadellidae); leaf miner (*Liriomyza congesta*) (Diptera: Agromyzidae); thrips (*Thrips tabaci* Lindeman) (Thysanoptera: Thripidae); leaf-eating caterpillar (*Spodoptera litura* Fabricius) (Lepidoptera: Noctuidae) and weevils (*Hypera postica* Gyllenhal) (Coleoptera: Curculionidae). Among these, *A. craccivora* is considered the most serious pest of fenugreek. It is a cosmopolitan and polyphagous species that not only causes significant yield losses but also reduces the quality of green leaves. Yield losses due to aphid infestation in fenugreek have been reported to range between 62.3 to 68.8 per cent (Mishra and Pande, 2023). Significantly less aphid index was recorded in the genotype LSVT-1 (0.60 A.I.) and LSVT-2 (0.70 A.I.) (Goswami *et al.*, 2025). Aphids are recognized as economically important insect pests of horticultural and seed spice crops caused significant losses and quality deterioration (Pathan *et al.*, 2024, Sonali and Pathan, 2024 and Dodiya *et al.*, 2025). Both nymphs and adults feed on the crop either individually or in colonies by inserting their sharp, needle-like stylets into plant cells to suck the cell sap. This feeding behavior results in leaf curling and the appearance of discoloured spots on the foliage. Heavy infestations cause stunted plant growth and significant reductions in seed yield. Aphids attack almost all aerial parts of the plant, including leaves, branches, stems, terminal shoots, flowers and pods. In addition, aphids excrete a sugary substance known as honeydew, which serves as a substrate for the growth of sooty mold. This fungal growth interferes with the photosynthetic activity of the plant, further affecting plant health and productivity (Thummar *et al.*, 2021).

Insecticides are integral inputs in fenugreek to combat these two sucking pests.

Chemical insecticides are commonly used by farmers for pest control; however, their indiscriminate use can lead to several adverse effects, such as pest resurgence, development of resistance and environmental pollution. Therefore, it is essential to promote eco-friendly alternatives, including pest monitoring, the use of biopesticides and the application

of botanicals. These integrated approaches not only reduce pesticide contamination in the soil but also help prevent broader environmental hazards. Therefore, the present investigation was undertaken to evaluate the efficacy of bio-rational insecticides for the management of sucking insect pests infesting fenugreek.

Material and Methods

The experiment was conducted at Seed Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan during the *Rabi*, 2018-19, 2019-20 and 2020-21. Fenugreek variety Gujarat Methi 2 was sown in plot size of 4.0 x 3.0 m by 30 cm line sowing in Randomized Block Design with three replications. The first spray of respective biopesticide was made at initiation of pest(s). The second spray was given after 10 days after first spray. The population of leaf hoppers and aphids were recorded before first spray and 3 and 7 days after both sprays. All the recommended agronomical practices were adopted for crop grown. The population of leafhopper was recorded from three leaves (top, middle and bottom). The aphid population was estimated using a 0-4 index scale, based on observations made on 10 cm terminal twigs of five randomly selected plants. The following index was suggested by Patel *et al.* (2011) for the estimation of aphid population.

Results and Discussion

Aphid

The pooled over years data indicated that *B. bassiana* 1.15 WP followed by azadirachtin 10000 ppm was the most effective treatment against aphid, recording the lowest aphid index of 1.22. It was followed by *B. bassiana* + azadirachtin 1500 ppm and *B. bassiana* + karanj oil + 0.1% soap solution, which recorded aphid indices of 1.82 and 2.58, respectively. Further, *L. lecanii* + azadirachtin 10000 ppm performed best among the *L. lecanii* based treatments with an aphid index of 3.09, followed by *L. lecanii* + azadirachtin 1500 ppm (3.43 aphid index) and *L. lecanii* + karanj oil + 0.1% soap solution (3.84 aphid index). The sequential applications of *B. bassiana* (4.07 aphid index) and *L. lecanii* followed by *B. bassiana* (4.23 aphid index) were comparatively less effective in suppressing the aphid population. Among all the treated plots, the sequential application of *L. lecanii* alone recorded the highest

aphid index (4.85 aphid index), indicating its comparatively lower efficacy. Nevertheless, all the biorational treatments were superior to the untreated control, which registered the highest aphid index of 7.47, demonstrating the effectiveness of the evaluated biorational treatments in reducing aphid infestation under field conditions.

Leaf hopper

The pooled over years data indicated that *B. bassiana* 1.15 WP followed by azadirachtin 10000 ppm was the most effective treatment against leaf hopper, recording the lowest leaf hopper population of 1.24 leaf hopper per 3 leaves. It was followed by *B. bassiana* + azadirachtin 1500 ppm and *B. bassiana* + karanj oil + 0.1% soap solution, which recorded 1.68 and 1.90 leaf hopper per 3 leaves, respectively. Further, *L. lecanii* + azadirachtin 10000 ppm performed best among the *L. Lecanii* based treatments with a leaf hopper population of 2.03 leaf hopper per 3 leaves, followed by *L. lecanii* + azadirachtin 1500 ppm (2.13) and *L. lecanii* + karanj oil + 0.1% soap solution (2.29). The sequential applications of *B. bassiana* (2.36 leaf hopper/3 leaves) and *L. lecanii* followed by *B. bassiana* (2.38 leaf hopper/3 leaves) were comparatively less effective in suppressing the leaf hopper population. Among all the treated plots, the sequential application of *L. lecanii* alone recorded the highest leaf hopper population (2.43 leaf hopper/3 leaves), indicating its comparatively lower efficacy. Nevertheless, all the biorational treatments were significantly superior to the untreated control, which registered the highest leaf hopper population (3.10 leaf hopper/3 leaves).

Coccinellids

The results of individual years as well as in pooled data on population of predatory coccinellids per plant presented in the Table 3 revealed that the population of predatory coccinellids was 2.89 coccinellids per plant revealed significant higher population in untreated control and next higher population recorded in *B. bassiana* 1.15 WP followed by Azadirachtin 10000 ppm (2.51 coccinellids/plant). Lowest coccinellids population found in *L. lecanii* 1.15 WP followed by azadirachtin 1500 ppm with 2.19 coccinellids per plant.

Seed yield

The data on seed yield recorded from each biopesticidal treated as well as untreated plot for

pooled over year are presented in Table 4. The plots sprayed with *B. bassiana* 1.15 WP followed by Azadirachtin 10000 ppm had obtained the highest seed yield (1512 kg/ha) and remained at par with treatment *B. Bassiana* 1.15 WP followed by Azadirachtin 1500 ppm (1449 kg/ha) and the treatment *B. Bassiana* 1.15 WP 0.0046 per cent followed by karanj oil 0.2% + 0.1% soap solution (1398 kg/ha). A minimum seed yield (1062 kg/ha) was obtained in *L. lecanii* 1.15 WP followed by *L. lecanii* 1.15 WP followed by *L. lecanii* 1.15 WP followed by karanj oil + 0.1% soap solution (1223 kg/ha). The lowest seed yield was recorded in the untreated control (936 kg/ha).

Economics

Economics of various biopesticides (Table 5) evaluated against major sucking pests infecting fenugreek indicated that *B. Bassiana* 1.15 WP and azadirachtin 10000 ppm treated plots gave maximum benefit (PCBR: 7.95) followed by *B. Bassiana* 1.15 WP and azadirachtin 1500 ppm (PCBR: 7.65) gave higher additional income, net realization and Protection Cost Benefit Ratio (PCBR). While lowest PCBR was recorded in the plot treated with the treatment T₇ (PCBR: 0.66).

According to Selvaraj *et al.* (2010) from Hisar reported that *B. bassiana* (1.23×10^7 spores/ml) had significantly reduced of the aphid population (15.22%) in fenugreek crop. While Kant *et al.* (2013) reported that the treatment of *B. bassiana* (8.10 aphids/floret) was best for the control of fenugreek aphid. Patel (2014) found that plots treated with azadirachtin produced significantly higher seed yield (12.71 q/ha). Chaudhary *et al.* (2015) also reported that among different treatments applied azadirachtin spray 5 ml per liter was found the most effective measure for the control of aphid population. Sarvaiya (2017) revealed that azadirachtin showing its superiority over other treatments and found most effective in suppressing aphid population in fenugreek. The present finding was more or less in accordance with the earlier reports.

Conclusion

Overall, the plots treated with *B. bassiana* 1.15 WP followed by azadirachtin 10000 ppm recorded the least aphid infestation as well as the lowest leaf hopper population during all three years of study. These treatments also resulted in the highest seed yield of

fenugreek and maximum profit when compared to other treatments throughout the experimental period. Hence, the combined use of *B. bassiana* 1.15 WP and azadirachtin 10000 ppm proved to be effective and economical for the management of aphid and leaf hopper in fenugreek.

Conflict of Interest

The authors declare that they have no conflict of interest.

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

Where,

0, 1, 2, 3 and 4 are Aphid Index

N = Number of plants showing respective aphid Index

Treatment details:

- T₁ *Lecanicillium lecanii* 1.15WP (1x10⁹ cfu/g) 40 g/10 L followed by Azadirachtin 10000ppm 30ml/10 L
- T₂ *L. lecanii* 1.15WP (1x10⁹ cfu/g) 40 g/10 L followed by Azadirachtin 1500ppm 40ml/10 L
- T₃ *L. lecanii* 1.15 WP (1x10⁹ cfu/gm) 40g/10 L followed by Karanj oil 20ml/10 L+ 0.1% soap solution
- T₄ *Beauveria bassiana* 1.15 WP (1x10⁹ cfu/g) 40g/10 L followed by Azadirachtin 10000ppm 30ml/10 L
- T₅ *B. bassiana* 1.15 WP (1x10⁹ cfu/g) 40g/10 L followed by Azadirachtin 1500ppm 40ml/10 L
- T₆ *B. bassiana* 1.15 WP (1x10⁹ cfu/g) 40g/10 L followed by Karanj oil 20ml/10 L+ 0.1% soap solution
- T₇ *L. lecanii* 1.15 WP (1x10⁹ cfu/g) 40g/10 L followed by *L. lecanii* 1.15 WP (1x10⁹cfu/g) 40 g/10 L
- T₈ *L. lecanii* 1.15 WP (1x10⁹ cfu/g) 40g/10 L followed by *B. bassiana* 1.15 WP (1x10⁹ cfu/g) 40g/10 L
- T₉ *B. bassiana* 1.15 WP (1x10⁹ cfu/g) 40g/10 L followed by *B. bassiana* 1.15 WP (1x10⁹ cfu/g) 40 g/10 L
- T₁₀ Untreated control

Table 1: Evaluation of biorationals against aphid in fenugreek (Pooled over year)

Tr. No.	Treatments	Before spray	Aphid index			Pooled over year
			2018-19	2019-20	2020-21	
1.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 10000 ppm @ 30 ml/10 L	1.86 (2.96)	1.58 ^e (1.99)	1.60 ^{ef} (2.04)	1.58 ^{cd} (2.01)	1.59 ^d (3.09)
2.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 1500 ppm @ 40 ml/10 L	1.89 (3.07)	1.62 ^{de} (2.11)	1.64 ^{de} (2.17)	1.58 ^{cd} (2.02)	1.61 ^d (3.43)
3.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Karanj oil @ 20 ml/10 L + 0.1% soap solution	1.89 (3.07)	1.65 ^{cd} (2.21)	1.68 ^{cd} (2.32)	1.62 ^{bcd} (2.11)	1.65 ^c (3.84)
4.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 10000 ppm @ 30 ml/10 L	1.90 (3.11)	1.29 ^h (1.16)	1.37 ^h (1.38)	1.34 ^f (1.31)	1.33 ^g (1.22)
5.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 1500 ppm @ 40 ml/10 L	1.88 (3.03)	1.42 ^g (1.53)	1.44 ^g (1.58)	1.43 ^{ef} (1.56)	1.43 ^f (1.82)
6.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Karanj oil @ 20 ml/10 L + 0.1% soap solution	1.84 (2.89)	1.52 ^f (1.79)	1.55 ^f (1.90)	1.53 ^{de} (1.85)	1.53 ^e (2.58)
7.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	1.85 (2.92)	1.71 ^b (2.44)	1.77 ^b (2.65)	1.71 ^b (2.43)	1.73 ^b (4.85)
8.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	1.89 (3.07)	1.68 ^{bc} (2.31)	1.72 ^{bc} (2.46)	1.64 ^{bc} (2.19)	1.68 ^c (4.23)
9.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	1.90 (3.11)	1.67 ^{bc} (2.26)	1.70 ^c (2.39)	1.63 ^{bcd} (2.16)	1.67 ^c (4.07)
10.	Untreated control	1.91 (3.15)	1.92 ^a (3.18)	1.91 ^a (3.12)	1.92 ^a (3.34)	1.92 ^a (7.47)
S.Em.±	T	0.01	0.015	0.015	0.033	0.010
	P	-	0.023	0.007	0.010	0.010
	S	-	0.007	0.007	0.010	0.006
	Y	-	-	-	-	0.006
	TxP	-	0.021	0.021	0.033	0.015
	TxS	-	0.021	0.021	0.033	0.015
	PxS	-	0.009	0.009	0.015	0.007
	YxT	-	-	-	-	0.018
	YxP	-	-	-	-	0.008
	YxS	-	-	-	-	0.008
	TxPxS	-	0.029	0.029	0.046	0.021
	YxSxT	-	-	-	-	0.026
	YxSxP	-	-	-	--	0.011
	YxPxT	-	-	-	-	0.026
	YxSxPxT	-	-	-	-	0.036
C.D.at 5%	T	NS	0.041	0.041	0.107	0.029
	YxSxPxT	-	-	-	-	NS
C.V. (%)		2.25	3.18	3.08	4.98	3.88

Figures in parenthesis are retransformed values, those outside are $\sqrt{x + 0.5}$ transformed values, DAS: Days after spray; Treatments means with the letter (s) in common are not significant by DNMRT at 5% level of significance

Table 2: Evaluation of biorationals against leaf hopper in fenugreek (Pooled over year)

Tr. No.	Treatments	Before spray	Leaf hopper/3 leaves			
			2018- 19	2019- 20	2020- 21	Pooled over year
1.	<i>Lecanicilliumlecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 10000 ppm @ 30 ml/10 L	1.83 (2.85)	1.60 ^{*d} (2.07)	1.58 ^{de} (1.99)	1.58 ^b (2.03)	1.59 ^d (2.03)
2.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g)@ 40 g/10 L followed by Azadirachtin 1500 ppm @ 40 ml/10 L	1.84 (2.89)	1.65 ^{cd} (2.21)	1.62 ^{cde} (2.12)	1.59 ^b (2.06)	1.62 ^d (2.13)
3.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Karanj oil @ 20 ml/10 L+ 0.1% soap solution	1.83 (2.85)	1.70 ^{bc} (2.37)	1.67 ^{bcd} (2.28)	1.64 ^b (2.21)	1.67 ^c (2.29)
4.	<i>Beauveria</i> bassiana1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 10000 ppm @ 30 ml/10 L	1.86 (2.96)	1.33 ^f (1.28)	1.28 ^g (1.20)	1.30 ^d (1.25)	1.31 ^g (1.24)
5.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 1500 ppm @ 40 ml/10 L	1.87 (3.00)	1.50 ^e (1.76)	1.46 ^f (1.63)	1.46 ^c (1.64)	1.47 ^f (1.68)
6.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Karanj oil @ 20 ml/10 L + 0.1% soap solution	1.81 (2.78)	1.57 ^{de} (1.96)	1.53 ^{ef} (1.84)	1.55 ^{bc} (1.91)	1.55 ^e (1.90)
7.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	1.87 (3.00)	1.76 ^b (2.59)	1.72 ^b (2.41)	1.67 ^b (2.30)	1.72 ^b (2.43)
8.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	1.84 (2.89)	1.73 ^{bc} (2.49)	1.71 ^{bc} (2.41)	1.65 ^b (2.23)	1.70 ^{bc} (2.38)
9.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	1.83 (2.85)	1.72 ^{bc} (2.44)	1.69 ^{bc} (2.35)	1.66 ^b (2.28)	1.69 ^{bc} (2.36)
10.	Untreated control	1.87 (3.00)	1.90 ^a (3.09)	1.89 ^a (3.06)	1.91 ^a (3.14)	1.90 ^a (3.10)
S.Em.±	T	0.02	0.026	0.029	0.038	0.010
	P	-	0.014	0.006	0.021	0.012
	S	-	0.006	0.06	0.010	0.104
	Y	-	-	-	-	0.006
	T x P	-	0.020	0.020	0.033	0.014
	T x S	-	0.020	0.020	0.033	0.014
	P x S	-	0.009	0.009	0.015	0.006
	Y x T	-	-	-	-	0.017
	Y x P	-	-	-	-	0.008
	Y x S	-	-	-	-	0.008
	T x P x S	-	0.028	0.028	0.046	0.020
	Y x S x T	-	-	-	-	0.025
	Y x S x P	-	-	-	-	0.011
	Y x P x T	-	-	-	-	0.025
	Y x S x P x T	-	-	-	-	0.035
C.D.at 5%	T	NS	0.083	0.092	0.120	0.028
C.V. (%)	Y x S x P x T	-	-	-	-	NS
		2.79	2.97	3.01	5.00	3.73

Figures in parenthesis are retransformed values, those outside are $\sqrt{x + 0.5}$ transformed values, DAS: Days after spray; Treatments means with the letter (s) in common are not significant by DNMRT at 5% level of significance

Table 3: Effects of biorationals on predatory coccinellids in fenugreek (Pooled over year)

Tr. No.	Treatments	Before spray	Predatory Coccinellids/ plant			
			2018-19	2019-20	2020-21	Pooled over year
1.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 10000 ppm @ 30 ml/10 L	1.69 (2.36)	1.67 ^{cd} (2.29)	1.65 ^{bc} (2.22)	1.69 ^{bc} (2.36)	1.67 ^{cd} (2.29)
2.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g)@ 40 g/10 L followed by Azadirachtin 1500 ppm @ 40 ml/10 L	1.69 (2.36)	1.67 ^{cd} (2.29)	1.63 ^c (2.16)	1.69 ^{bc} (2.13)	1.64 ^d (2.19)
3.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Karanj oil @ 20 ml/10 L+ 0.1% soap solution	1.67 (2.29)	1.67 ^{cd} (2.29)	1.63 ^c (2.16)	1.64 ^c (2.20)	1.65 ^d (2.22)
4.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 10000 ppm @ 30 ml/10 L	1.68 (2.32)	1.75 ^b (2.56)	1.69 ^b (2.36)	1.76 ^{ab} (2.60)	1.73 ^b (2.51)
5.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 1500 ppm @ 40 ml/10 L	1.67 (2.29)	1.73 ^b (2.49)	1.65 ^{bc} (2.22)	1.65 ^{bc} (2.23)	1.68 ^{cd} (2.31)
6.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Karanj oil @ 20 ml/10 L + 0.1% soap solution	1.69 (2.36)	1.73 ^b (2.49)	1.69 ^b (2.36)	1.70 ^{bc} (2.39)	1.71 ^{bc} (2.41)
7.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	1.67 (2.29)	1.63 ^d (2.16)	1.64 ^{bc} (2.34)	1.66 ^{bc} (2.26)	1.65 ^d (2.25)
8.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	1.71 (2.42)	1.71 ^{bc} (2.42)	1.65 ^{bc} (2.22)	1.63 ^c (2.16)	1.67 ^{cd} (2.27)
9.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	1.71 (2.42)	1.71 ^{bc} (2.42)	1.67 ^{bc} (2.29)	1.61 ^c (2.09)	1.67 ^{cd} (2.27)
10.	Untreated control	1.71 (2.42)	1.87 ^a (2.98)	1.81 ^a (2.78)	1.84 ^a (2.90)	1.84 ^a (2.89)
S. Em.±	T	0.01	0.016	0.017	0.03	0.015
	P	-	0.007	0.008	0.010	0.012
	S	-	-	-	-	-
	Y	-	-	-	-	0.006
	T x P	-	0.021	0.025	0.030	0.015
	T x S	-	-	-	-	-
	P x S	-	-	-	-	-
	Y x T	-	-	-	-	0.018
	Y x P	-	-	-	-	0.008
	Y x S	-	-	-	-	-
	T x P x S	-	-	-	-	-
	Y x S x T	-	-	-	-	-
	Y x S x P	-	-	-	-	-
	Y x P x T	-	-	-	-	0.025
C.D.at 5%	Y x S x P x T	-	-	-	-	-
	T	NS	0.04	0.05	0.11	0.043
C.V. (%)		1.72	2.11	2.58	3.12	2.59

Figures in parenthesis are retransformed values, those outside are $\sqrt{X + 0.5}$ transformed values, DAS: Days after spray; Treatments means with the letter (s) in common are not significant by DNMRT at 5% level of significance

Table 4: Seed yield of fenugreek

Tr. No.	Treatments	2018-19	2019-20	2020-21	Pooled
1.	<i>Lecanicilliumlecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 10000 ppm @ 30 ml/10 L	1115 ^{abc}	1564 ^a	1359 ^{bcd}	1346 ^{bc}
2.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g)@ 40 g/10 L followed by Azadirachtin 1500 ppm @ 40 ml/10 L	1043 ^{bcd}	1429 ^{ab}	1335 ^{bcd}	1269 ^c
3.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Karanj oil @ 20 ml/10 L+ 0.1% soap solution	1022 ^{bcd}	1389 ^{ab}	1258 ^{de}	1223 ^c
4.	<i>Beauveria</i> bassiana1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 10000 ppm @ 30 ml/10 L	1315 ^a	1653 ^a	1568 ^a	1512 ^a
5.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Azadirachtin 1500 ppm @ 40 ml/10 L	1211 ^{ab}	1618 ^a	1516 ^{ab}	1449 ^{ab}
6.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by Karanj oil @ 20 ml/10 L + 0.1% soap solution	1126 ^{abc}	1602 ^a	1465 ^{abc}	1398 ^{ab}
7.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	894 ^d	1240 ^{bc}	1052 ^{ef}	1062 ^d
8.	<i>L. lecanii</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	990 ^{cd}	1516 ^{ab}	1318 ^{cd}	1275 ^c
9.	<i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L followed by <i>B. bassiana</i> 1.15WP(1x10 ⁹ cfu/g) @ 40 g/10 L	988 ^{cd}	1512 ^{ab}	1304 ^{cd}	1268 ^e
10.	Untreated control	874 ^d	1057 ^c	877 ^f	936
	S.Em.±	63	87	60	41
	C.D.at 5%	186	258	178	116
	C.V.%	10.25	10.30	7.95	9.63
	Y X T				NS

Figures in parenthesis are retransformed values, those outside are $\sqrt{X + 0.5}$ transformed values, DAS: Days after spray; Treatments means with the letter (s) in common are not significant by DNMRT at 5% level of significance

Table 5: Economic of different treatments

Tr. No.	Quantity of materials (Kg or L/ha)	Cost of materials (Rs/ha)	Labour charges (Rs/ha)	Total cost of treatment (Rs/ha)	Yield (Kg/ha)	Gross realization (Rs/ha)	Net realization (Rs/ha)	Net gain (Rs/ha)	PCBR
1	L.L-2.0, Aza-1.5	2500.00	1360	3860.00	1346	80760.00	24600.00	20740.00	1: 5.37
2	L.L-2.0, Aza-2.0	2200.00	1360	3560.00	1269	76140.00	19980.00	16420.00	1: 4.61
3	L.L-2.0, Karanj oil-1.0	2000.00	1360	3360.00	1223	73380.00	17220.00	13860.00	1: 4.13
4	B.B-2.0, Aza-1.5	2500.00	1360	3860.00	1512	90720.00	34560.00	30700.00	1: 7.95
5	B.B-2.0, Aza-2.0	2200.00	1360	3560.00	1449	86940.00	30780.00	27220.00	1: 7.65
6	B.B-2.0, Karanj oil-1.0	2000.00	1360	3360.00	1398	83880.00	27720.00	24360.00	1: 7.25
7	L.L-4.0	3200.00	1360	4560.00	1062	63720.00	7560.00	3000.00	1: 0.66
8	L.L-2.0, B.B-2.0	3200.00	1360	4560.00	1275	76500.00	20340.00	15780.00	1: 3.46
9	B.B-4.0	3200.00	1360	4560.00	1268	76080.00	19920.00	15360.00	1: 3.37
10	-	-	-	-	936	56160.00	-	-	-

Price of fenugreek: Rs. 60/kg; *L.lecanii* 1.15WP: Rs.800/kg.;
 Azadirachtin 300 ppm: Rs.300/lit. ;Azadirachtin 1500 ppm: Rs.300/lit.;
B. bassiana 1.15 WP: Rs.800/kg;Azadirachtin 10000 ppm: Rs. 600/lit.;
 Karanj oil: Rs. 400/lit.; Labour cost: Rs. 340/day (2 labours/spray/ha)

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