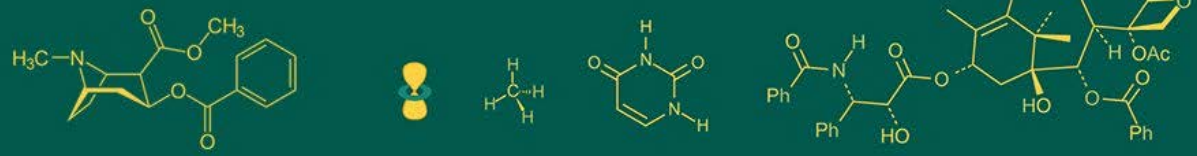
International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(12): 877-881
www.biochemjournal.com
Received: 15-09-2025
Accepted: 20-10-2025

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Crop loss assessment and ecofriendly management of Aphids, *Aphis gossypii* (Glover) on Isabgol, *Plantago ovata* (Forst)

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i12k.6675

Abstract
A field study entitled "Crop loss assessment and ecofriendly management of Aphids, *Aphis gossypii* (Glover) on Isabgol (*Plantago ovata*, Forsk)" was conducted during *Rabi* 2024–25 at the AICRP on MAP and Betelvine, MPKV, Rahuri. The bioefficacy trial comprising two foliar sprays of insecticidal and biopesticidal treatments revealed that Spinosad 45% SC was the most effective in rapidly suppressing *Aphis gossypii*, recording the highest seed yield (8.08 q/ha). This was followed by Abamectin 1.9% EC (7.22 q/ha) and Azadirachtin 10000 ppm (7.47 q/ha). Among the bioagents, *Lecanicillium lecanii* showed superior performance, achieving substantial aphid reduction and a yield of 7.13 q/ha. The yield loss assessment indicated that aphid infestation caused 29.02% reduction in seed yield of Isabgol. Economic analysis showed that *Lecanicillium lecanii* provided the highest incremental cost–benefit ratio (1:4.41), outperforming abamectin (1:3.56) and *Beauveria bassiana* (1:3.55). While chemical insecticides yielded higher outputs, their higher costs and residue concerns limit their suitability for a medicinal crop like Isabgol. In contrast, *Lecanicillium lecanii* emerged as an eco-friendly, residue-free and economically viable option. Botanical treatments such as azadirachtin also offered good efficacy and safety, though with moderate ICBR (1:1.40). Neem oil, neem seed extract and *Metarhizium anisopliae* showed comparatively lower efficacy.

Keywords: Aphid, bioefficacy, yield loss, spinosad 45% SC, *Lecanicillium lecanii*, biopesticides, incremental cost–benefit ratio

1. Introduction
Medicinal plants form a vital component of traditional healthcare systems and contribute significantly to global trade. Among these, Isabgol (*Plantago ovata* Forsk.), commonly known as psyllium, is an economically important medicinal crop valued for its mucilaginous seed husk, widely used in pharmaceutical, nutraceutical and food industries. India is the largest producer and exporter of Isabgol, with major cultivation concentrated in Gujarat, Rajasthan, Maharashtra and Madhya Pradesh.

Isabgol thrives in warm temperate climates and produces seeds rich in mucilage, which is utilized as a bulk-forming laxative and in the management of various gastrointestinal disorders. Psyllium husk also offers several health benefits, including hypoglycemic, hypo cholesterol emic, antioxidant and anti-ulcer properties.

Isabgol productivity is constrained by several insect pests. Among these, the aphid *Aphis gossypii* (Glover) is a major sap-sucking pest causing leaf curling, stunted growth, poor spike formation and significant yield loss, particularly during flowering and seed-setting stages. Infestations are common in Maharashtra, yet systematic studies on its management remain limited.

Evaluating eco-friendly biopesticides and sustainable management strategies is essential for safe and effective suppression of *A. gossypii* in Isabgol cultivation.

2. Methodology
The investigation entitled "crop loss assessment and eco-friendly management of aphids, *Aphis gossypii* Glover on Isabgol (*Plantago ovata*)" was conducted at AICRP on MAP and Betelvine, MPKV, Rahuri during *Rabi* 2024–25 with the Isabgol variety Gujarat Isabgol-1

was used. The experiment was laid out in a Randomized Block Design with 9 treatments and 3 replications. Plot size measured 4 m × 3 m. Sowing was done on 12 November 2024 and harvesting on 12–13 April 2025.

2.1 Yield Loss Assessment due to *Aphis gossypii* on Isabgol

A field experiment was conducted to quantify the impact of *Aphis gossypii* infestation on the seed yield of Isabgol (*Plantago ovata* Forsk.) under treated and untreated conditions. The study included replicated plots treated with Spinosad and untreated control plots. Yield increase over control and avoidable yield loss were calculated following Poul (1976), whereas the Net Incremental Cost–Benefit Ratio (NICBR) was estimated using treatment cost and yield data.

Aphid populations were recorded weekly throughout the crop season. In each plot, ten plants were randomly selected and all visible aphids were counted manually during morning hours to minimize diurnal variation. Mean aphid population per plant was used to assess infestation dynamics and treatment efficacy.

At maturity, each plot was harvested separately. The produce was dried, cleaned and weighed, and yields were expressed in kg/ha. The data from treated and untreated plots were statistically compared using a t-test to determine the significance of yield differences.

For determine of increase in yield over control and avoidable loss, following formula given by Poul (1976) were used:

$$\text{Per cent increase in Yield over control} = \frac{\text{Yield of treatment} - \text{Yield of control}}{\text{Yield of control}} \times 100$$

$$\text{Avoidable loss (\%)} = \frac{\text{Highest yield in treated plot} - \text{Yield in treated plot}}{\text{Highest yield in treated plot}} \times 100$$

Insecticidal Treatments and Aphid Incidence

Bioefficacy of insecticidal and biopesticidal sprays was evaluated through systematic observations taken before and after application. Treatments were applied as foliar sprays using a calibrated knapsack sprayer at 500 L/ha. Two sprays were given at 15-day intervals, with the first applied on 7 February 2025 when aphid populations reached the economic threshold.

Pre-spray counts were taken one day before the first spray, followed by post-spray observations on the 3rd, 7th and 14th day after each application. The 14th day count after the first spray served as the pre-spray count for the second application.

In each plot, five plants were randomly selected at each interval. All visible aphids on leaves, stems and inflorescences were counted manually. The mean population was used for statistical analysis. Data were analyzed using RBD.

Seed Yield of Isabgol

The crop was harvested when spikes and peduncles turned reddish-brown. The seed yield was recorded in kg/ha for further analysis.

3. Result and discussion

3.1 Avoidable Yield Loss Due to *Aphis gossypii*

A field experiment with treated and untreated plots across ten replications assessed the impact of *A. gossypii* infestation on Isabgol yield. Spinosad 45% SC effectively suppressed aphids, with treated plots recording a mean of 6.17 aphids/plant compared to 57.63 aphids/plant in untreated plots. Reduced aphid incidence in treated plots resulted in higher yields (mean 804.70 kg/ha), whereas untreated plots recorded substantially lower yields (mean 571.10 kg/ha). Yield loss in untreated plots ranged from 27.33% to 30.08%, with an average avoidable loss of 29.02%. The highest yield loss (30.08%) corresponded to replications with greater aphid pressure.

Table 1: Avoidable yield loss due to aphids, *Aphis gossypii* on Isabgol, *Plantago ovata* (Forsk)

Replications	Number of aphids per plants in treated plot	Yield in treated plot (kg/ha)	Number of aphids per plants in untreated plot	Yield in untreated plot (kg/ha)	Avoidable yield loss (%)
1.	6.09	808.43	58.90	573.23	29.09
2.	5.78	817.3	57.76	589.11	27.91
3.	5.96	810.14	56.99	577.73	28.67
4.	6.89	792.47	55.73	561.12	29.19
5.	5.45	797.68	56.89	579.67	27.33
6.	7.32	805.71	58.45	563.47	30.06
7.	6.29	803.87	57.23	574.55	28.52
8.	5.91	791.23	56.45	553.17	30.08
9.	6.67	811.31	59.09	570.14	29.72
10.	5.40	808.94	58.87	568.89	29.67
Mean	6.17	804.70	57.63	571.10	29.02

Previous studies also highlight the substantial impact of aphid damage on crop productivity. Patel *et al.* (2004) [9] reported yield losses of up to 100% in unprotected mustard, emphasizing the need for timely pest management. The present findings are comparable with those of Kumar *et al.* (2022) [5], who observed 25.92–26.25% loss in mustard, and slightly higher than the 4.56–12.51% loss reported by Fakhouri *et al.* (2021) [3] in lentil. However, they remain lower than the severe losses noted by Faheem *et al.* (2022) [2] in *Brassica juncea* (70.77%) and Thorat *et al.* (2024) [12] in safflower (79.10%). The yield advantage recorded in treated plots is consistent with Singh (2024), who also reported significant yield improvement following aphid management practices.

3.2 Bioefficiency of plant products and biopesticides against aphids, *Aphis gossypii* on Isabgol, *Plantago ovata*

A field experiment evaluated nine treatments, including entomopathogenic fungi, botanicals, neem-based formulations, microbial metabolites and a chemical

insecticide, against *Aphis gossypii* on Isabgol. Pre-treatment aphid populations were statistically uniform across treatments. Three days after spraying, spinosad 45% SC recorded the sharpest decline, indicating strong immediate action. By 7 DAS, spinosad and azadirachtin maintained low aphid numbers, while *Metarhizium anisopliae* and NSE showed weak performance. At 14 DAS, *Lecanicillium lecanii* produced the lowest aphid population, reflecting superior residual efficacy. Percent reduction at 14 DAS was highest in *L. lecanii* (73.33%), followed by azadirachtin (71.32%) and *Beauveria bassiana* (63.24%). Spinosad and neem oil showed moderate suppression, while abamectin, NSE and *M. anisopliae* were less effective. The study highlights *L. lecanii*, azadirachtin and *B. bassiana* as the most reliable treatments for sustainable aphid management in Isabgol.

Table 2: Bioefficacy of different insecticides against aphids, *Aphis gossypii* on Isabgol after first spray during *Rabi* 2024

Sr. No.	Treatments	Dose (g or ml/L)	Pre-count	3 DAS**	7 DAS	14 DAS	Percent reduction of aphid population
T1	Lecanicillium lecanii 1.15 % WP	5	51.27 (7.19)	43.27 (6.57)*	35.00 (5.91)	13.67 (3.69)	73.33
T2	Beauveria bassiana 1.15 % WP	5	46.80 (6.87)	45.47 (6.78)	37.87 (6.19)	17.20 (4.21)	63.24
T3	Metarhizium anisopliae 1.15 % WP	5	47.53 (6.92)	46.60 (6.86)	41.33 (6.49)	38.80 (6.22)	18.36
T4	Azadirachtin 10000 ppm	2	54.40 (7.40)	31.60 (5.66)	14.27 (3.84)	15.60 (4.01)	71.32
T5	Neem oil 1 %	10	48.53 (6.99)	36.40 (6.07)	23.33 (4.88)	24.33 (4.98)	49.86
T6	NSE 5 %	50	53.20 (7.33)	39.87 (6.35)	36.20 (6.06)	37.53 (6.17)	29.45
T7	Spinosad 45 % SC	0.3	50.87 (7.16)	7.73 (2.87)	13.73 (3.77)	24.93 (5.04)	50.99
T8	Abamectin 1.9 % EC	0.3	52.07 (7.25)	15.67 (4.02)	25.87 (5.08)	35.73 (5.97)	31.38
T9	Untreated control	–	49.67 (7.04)	54.60 (7.38)	56.27 (7.50)	57.80 (7.53)	–
	S. Em. (±)		0.15	0.13	0.11	0.09	
	C.D. at 5 (%)		NS	0.39	0.35	0.29	

*Figures in parentheses are $\sqrt{X + 0.05}$ transformed value, **DAS- Days After Spray

The second spray evaluation showed significant differences in aphid suppression across treatments. At 3 DAS, spinosad (T7) recorded the lowest aphid count, followed by azadirachtin (T4) and *Lecanicillium lecanii* (T1), indicating rapid initial action. By 7 DAS, azadirachtin showed the minimum population, whereas spinosad exhibited reduced residual activity. At 14 DAS, *L. lecanii* maintained the lowest aphid population, followed by azadirachtin and *Beauveria bassiana*. Percent reduction at 14 DAS was highest in *L. lecanii* (73.37%), azadirachtin (71.34%) and *B. bassiana* (63.19%). Spinosad and neem oil provided moderate control, while *M. anisopliae* and NSE remained less effective.

Table 3: Bioefficacy of different insecticides against aphids, *Aphis gossypii* on Isabgol after second spray during *Rabi* 2024

Sr. No.	Treatments	Dose (g or ml/L)	3 DAS**	7 DAS	14 DAS	Percent reduction of aphid population
T_1	Lecanicillium lecanii 1.15 % WP	5	11.53 (3.39)*	9.33 (3.05)	3.64 (1.90)	73.37
T_2	Beauveria bassiana 1.15 % WP	5	16.67 (4.14)	13.93 (3.80)	6.33 (2.61)	63.19
T_3	Metarhizium anisopliae 1.15 % WP	5	38.00 (6.16)	33.76 (5.81)	31.81 (5.64)	18.01
T_4	Azadirachtin 10000 ppm	2	9.07 (3.09)	4.07 (2.14)	4.47 (2.23)	71.34
T_5	Neem oil 1 %	10	18.27 (4.33)	11.67 (3.48)	12.20 (3.56)	49.85
T_6	NSE 5 %	50	28.13 (5.35)	25.53 (5.10)	26.40 (5.19)	29.65
T_7	Spinosad 45 % SC	0.3	3.73 (2.06)	6.73 (2.69)	12.27 (3.57)	50.78
T_8	Abamectin 1.9 % EC	0.3	10.72 (3.27)	17.86 (4.22)	24.65 (4.96)	31.01
T_9	Untreated control	–	58.40 (7.64)	58.33 (7.63)	54.93 (7.41)	–
	S. Em. (±)		0.10	0.09	0.11	
	C.D. at 5 (%)		0.31	0.28	0.32	

*Figures in parentheses are $\sqrt{X + 0.05}$ transformed value, **DAS- Days After Spray

The cumulative evaluation of two sprays revealed significant differences among treatments across all observation periods. At 3 DAS, spinosad recorded the lowest aphid population, followed by abamectin and azadirachtin, whereas the untreated control remained highest. By 7 DAS, azadirachtin, *Lecanicillium lecanii* and *Beauveria bassiana* showed the most pronounced reductions, while *M. anisopliae* and the control maintained high infestation. At 14 DAS, *L. lecanii* achieved the lowest aphid count, with azadirachtin and *B. bassiana* also maintaining strong suppression. Percent reduction was highest in *L. lecanii* (73.35%), azadirachtin (71.33%) and *B. bassiana* (63.22%). Spinosad and neem oil offered moderate control, whereas abamectin and NSE were less effective. *M. anisopliae* showed minimal reduction and remained close to the untreated control.

Table 4: Cumulative effect of different insecticides against aphids, *Aphis gossypii* on Isabgol during *Rabi* 2024

Sr. No.	Treatments	Dose (g or ml/L)	Mean number of aphids per plant			
			3 DAS	7 DAS	14 DAS	Percent reduction of aphid population
T1	Lecanicillium lecanii 1.15 % WP	5	27.40 (4.98)*	22.17 (4.48)	8.66 (2.94)	73.35
T2	Beauveria bassiana 1.15 % WP	5	31.07 (5.46)	25.90 (5.08)	11.77 (3.41)	63.22
T3	Metarhizium anisopliae 1.15 % WP	5	42.30 (6.51)	37.55 (6.15)	35.31 (5.93)	18.19
T4	Azadirachtin 10000 ppm	2	20.34 (4.38)	9.17 (2.99)	10.04 (3.12)	71.33

T5	Neem oil 1 %	10	27.34 (5.20)	17.50 (4.18)	18.27 (4.27)	49.86
T6	NSE 5 %	50	34.00 (5.85)	30.87 (5.58)	31.97 (5.68)	29.55
T7	Spinosad 45 % SC	0.3	5.73 (2.47)	10.23 (3.23)	18.60 (4.31)	50.89
T8	Abamectin 1.9 % EC	0.3	13.20 (3.65)	21.87 (4.65)	30.19 (5.47)	31.20
T9	Untreated control	–	56.50 (7.51)	57.30 (7.57)	56.37 (7.47)	–
	S. Em. (±)		0.11	0.10	0.10	
	C.D. at 5 (%)		0.35	0.315	0.30	

*Figures in parentheses are $\sqrt{X + 0.05}$ transformed value, **DAS- Days After Spray

Field results were strongly supported by earlier research demonstrating the effectiveness of plant products and entomopathogenic fungi against *A. gossypii*. Several studies, including Patel (2002) [8], Anitha & Nandihalli (2008) [1] and Gupta and Pathak (2009) [4], highlighted the economic and biological efficacy of NSKE and neem oil across crops. Similar findings by Suganthy and Sakthivel (2012) [10] and Vinodhini and Malaikozhundan (2011) [13] further confirmed neem-based products as reliable aphid suppressants. Recent findings (Landge 2023 [6]; Tathode 2024) [11] reaffirmed *L. lecanii* and azadirachtin as eco-friendly and effective options.

Yield

Spinosad yielding the highest seed output (8.08 q/ha), followed by azadirachtin (7.47 q/ha) and *L. lecanii* (7.13 q/ha). *M. anisopliae* recorded the lowest yield among treated plots, marginally above the untreated control.

Table 5: Effect of insecticides treatment on yield of Isabgol

Tr. No.	Treatments	Dose (g or ml/L)	Yield (q/ha)	Additional yield over control (q/ha)	Percent increase in yield over control
T_1	*Lecanicillium lecanii* 1.15 % WP	5	7.13	1.25	21.25
T_2	*Beauveria bassiana* 1.15 % WP	5	6.93	1.05	17.85
T_3	*Metarhizium anisopliae* 1.15 % WP	5	6.25	0.37	6.29
T_4	Azadirachtin 10000 ppm	2	7.47	1.59	27.04
T_5	Neem oil 1 %	10	6.94	1.06	18.02
T_6	NSE 5 %	50	6.48	0.60	10.20
T_7	Spinosad 45 %SC	0.3	8.08	2.20	37.41
T_8	Abamectin 1.9 % EC	0.3	7.22	1.34	22.78
T_9	Untreated control		5.88	-	-
	S. Em. (±)		0.49	-	-
	C.D. at 5(%)		1.46	-	-
	C. V. (%)		13.28	-	-

The additional yield over the control indicated clear economic benefits of effective aphid management in Isabgol. Spinosad recorded the highest net gain (2.20 q/ha), followed by azadirachtin (1.59 q/ha) and abamectin (1.34 q/ha), while *Metarhizium anisopliae* showed minimal advantage (0.37 q/ha). The highest percent increase in yield over control was again observed with spinosad (37.41%), supported by azadirachtin (27.04%) and abamectin (22.78%). Treatments such as *Lecanicillium lecanii* and neem oil also enhanced yield by 21.25% and 18.02%, respectively, indicating suitability for eco-friendly production systems. In contrast, *M. anisopliae* showed the lowest improvement (6.29%).

Economic

Spinosad the highest seed yield (8.08 q/ha), followed by azadirachtin, abamectin and *L. lecanii*. Overall, bio-rational treatments provided substantial yield and economic gains over the untreated control.

Table 6: Economics of different treatments evaluated against aphid, *Aphis gossypii* on Isabgol

Tr. No.	Treatments	Dose of insecticide (g or ml/L)	Yield (q/ha)	Additional yield over control (q/ha)	Additional income (Rs/ha))	Additional cost of plant protection (Rs/ha)	Net profit (Rs/ha)	ICBR
T_1	*Lecanicillium lecanii* 1.15 % WP	5	7.13	1.25	16250	3000	13250	1:4.41
T_2	*Beauveria bassiana* 1.15 % WP	5	6.93	1.05	13650	3000	10650	1:3.55
T_3	*Metarhizium anisopliae* 1.15 % WP	5	6.25	0.37	4810	3000	1810	1:0.60
T_4	Azadirachtin 10000 ppm	2	7.47	1.59	20670	8600	12070	1:1.40
T_5	Neem oil 1 %	10	6.94	1.06	13780	9300	4480	1:0.48
T_6	NSE 5 %	50	6.48	0.60	7787	2750	5037	1:1.83
T_7	Spinosad 45 % SC	0.3	8.08	2.20	28600	8270	20330	1:2.46
T_8	Abamectin 1.9 % EC	0.3	7.22	1.34	17420	3815	13605	1:3.56
T_9	Untreated control		5.88		-	-	-	-

1. *Lecanicillium lecanii*- Rs.200/kg, *2. Beauveria bassiana*- Rs. 200/kg,
3. Metarhizium anisopliae -200/kg, 4. Azadirachtin 10000 ppm – Rs 2300/L, 5. Neem oil- Rs.729/L, 6. NSE- Rs 15/ Kg, 7. Spinosad- Rs.26800/L,
8. Abamectin – Rs. 6050/L, Isabgol – Rs. 13000/q, Labour charges: Rs. 1000/spray/ha.
Spinosad 45% SC yielded the highest net profit (₹20,330/ha), followed by abamectin, *Lecanicillium lecanii* and azadirachtin. Based on ICBR, *L. lecanii* (1:4.41) was the most economical, outperforming abamectin and *B. bassiana*, while neem oil and *M. anisopliae* were uneconomical. Spinosad's profitability was linked to its rapid action and strong aphid suppression, whereas the higher cost of botanicals reduced overall returns. Entomopathogenic fungi, particularly *L. lecanii*, provided both effective aphid control and high cost-efficiency.

Summary
Avoidable yield loss due to aphid attack averaged 29.02%, confirming substantial production losses in untreated fields. Spinosad 45% SC was the most effective treatment, recording the lowest aphid population and the highest yield (8.08 q/ha). Considering Isabgol as a medicinal crop, *Lecanicillium lecanii* and Azadirachtin 10000 ppm were identified as safer and effective bio-based options. *Lecanicillium lecanii* recorded the highest economic return with an ICBR of 1:4.41, outperforming chemical treatments in cost-effectiveness.

Acknowledgement
Authors express sincere thanks to the Head, Department of Entomology, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, for providing necessary facilities and encouragement during investigation.

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