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Biointensive management of leafhoppers and aphids in Bt cotton

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Abstract
The present investigation was conducted to evaluate the efficacy of various botanicals, biopesticides and plant extracts in controlling key sucking pests such as leafhoppers *Amrasca biguttula biguttula* I. and aphids *Aphis gossypii* G. on Bt cotton. The study employed in a randomized block design with five treatments replicated four times. Treatments included Azadirachtin 0.03% EC @ 5 ml/lit fb Azadirachtin 0.15% EC @ 5 ml/lit fb Azadirachtin 0.30% EC @ 4 ml/lit fb Azadirachtin 01.00% EC @ 2 ml/lit (M1), *Verticillium lecanii* 1.15% WP @ 5 g/lit fb *Metarhizium anisopliae* 1.15% WP @ 5 g/lit fb *Beauveria bassiana* 1.15% WP @ 5 g/lit fb *Verticillium lecanii* 1.15% WP @ 5 g/lit (M2), PDKV Dashparni Extract @ 12.5 ml/lit fb Neem seed extract 5% fb PDKV Brahmastra Extract @ 30 ml/lit fb PDKV Agniastra Extract @ 30 ml/lit (M3), Neem Seed Extract 5% fb Azadirachtin 0.15% EC @ 5 ml/lit fb *Verticillium lecanii* 1.15% WP @ 5 g/lit fb Azadirachtin 01.00% EC @ 2 ml/lit (M4) and untreated control (M5). The cumulative effect of different treatments inferred that Module 1 proved most effective in reducing the population of leafhoppers (0.98/leaf) and aphids (5.14/leaf) and it was found statistically at par with Module 4 (1.10; 5.62), Module 2 (1.29; 5.71)and Module 3 (1.31; 6.03) leafhoppers and aphids, respectively. The maximum pest population was recorded in (M5) untreated control (2.44; 11.96). All these treatment modules showed non-significant differences on population of natural enemies. The highest seed cotton yield of (13.39 q/ha) was observed in Module 1. These findings support the adoption of such eco-friendly, integrated pest management modules in cotton cultivation.

Keywords: Biopesticides, botanicals, plant extracts, leafhoppers, aphids

Introduction
Cotton (*Gossypium hirsutum* L.) is one of the most significant commercial cash crop in India, contributing approximately 23% to global cotton production. India ranks first globally in cotton acreage, with 130.61 lakh hectares under cultivation, accounting for nearly 40% of the world's total cotton-growing area (Ministry of Textiles, 2023) [3]. The crop supports the livelihoods of nearly 6 million farmers and provides employment to 40-50 million individuals engaged in processing, marketing, and trade. Cotton also contributes significantly to the Indian economy by supplying 65% of raw material to the textile industry and earning nearly one-third of the nation's agricultural foreign exchange (Mayee & Rao, 2002) [19].
The productivity of cotton in India, however, remains relatively low at 447 kg/ha, placing it 39th globally (Ministry of Textiles, 2023) [3]. One of the major constraints to enhanced cotton productivity is insect pest infestation, particularly the dominance of sucking pests in the post-Bt cotton cultivation era. The widespread adoption of Bt cotton and subsequent reduction in the use of broad-spectrum insecticides have led to an ecological shift favouring sucking pests such as aphids (*Aphis gossypii*), jassids (*Amrasca biguttula biguttula*), thrips (*Scirtothrips dorsalis*), and whiteflies (*Bemisia tabaci*) (Zanwar *et al.*, 2010) [27]. These pests cause significant damage throughout the crop growth period, leading to leaf yellowing, distortion, and honeydew secretion, which supports the growth of sooty mould and interferes with photosynthesis (Gore *et al.*, 2020) [13]. Yield reductions due to jassids have been reported to be 11.6% (Dhawan *et al.*, 1988) [8]. Chavan *et al.* (2010) [6] estimated that up to 28.3% of cotton yield loss is avoidable through better pest management.
Chemical control remains the most commonly used method for managing these pests due to its rapid and broad-spectrum action (Bashir *et al.*, 2020) [4].

However, the indiscriminate and repeated use of synthetic insecticides has led to several negative consequences, including pest resistance, resurgence, health risks to humans, disruption of natural enemy populations, and environmental pollution (Heneidy *et al.*, 2015; Kranthi *et al.*, 2002) [9, 18]. These issues have intensified the need for sustainable, eco-friendly pest management strategies.

Biopesticides and plant-based formulations offer a promising alternative to conventional chemical insecticides. And these substances are generally safer for the environment, less harmful to non-target organisms, and cost-effective, making them attractive options for smallholder and organic cotton growers (Silvie, 2023) [24]. Additionally, adopting biointensive Integrated Pest Management (IPM) strategies can reduce reliance on chemicals, minimize ecological harm, and promote long-term pest control effectiveness.

Given the urgency to develop and validate environmentally responsible pest control methods, this study aims to evaluate the efficacy of biopesticides, botanicals and plant extracts against key sucking pests such as leafhoppers *Amrasca biguttula biguttula* I. and aphids *Aphis gossypii* G. in Bt cotton. The outcomes are expected to contribute to the refinement of sustainable pest management practices while safeguarding natural-enemies population, enhancing yield and environmental integrity.

Material and Methods

The present investigation was carried out during *kharif* 2024 at the research field of Department of Entomology, Post Graduate Institute, Dr. PDKV, Akola in Randomized Block Design (RBD). The total experimental area of (82.8×18 m) was divided into four blocks having 1.80 m space between them and each block served as a separate replication. Further, each block was divided into five plots with individual plot sizes of 8.10x7.20 m. Ajeet 155 (BG II) cotton variety was grown in the field as per the package of practices. Five treatment modules including, Azadirachtin 0.03% EC @ 5 ml/lit fb Azadirachtin 0.15% EC @ 5 ml/lit fb Azadirachtin 0.30% EC @ 4 ml/lit fb Azadirachtin 01.00% EC @ 2 ml/lit (M1), *Verticillium lecanii* 1.15% WP @ 5 g/lit fb *Metarhizium anisopliae* 1.15% WP @ 5 g/lit fb *Beauveria bassiana* 1.15% WP @ 5 g/lit fb *Verticillium lecanii* 1.15% WP @ 5 g/lit (M2), PDKV Dashparni Extract @ 12.5 ml/lit fb Neem seed extract 5% fb PDKV Brahmastra Extract @ 30 ml/lit fb PDKV Agniastra Extract @ 30 ml/lit (M3), Neem Seed Extract 5% fb Azadirachtin 0.15% EC @ 5 ml/lit fb *Verticillium lecanii* 1.15% WP @ 5 g/lit fb Azadirachtin 01.00% EC @ 2 ml/lit (M4) and untreated control (M5) (Table 1). Application of all the treatments within each replication was done in random manner. All the treatments were replicated four times. First spray was done when the sucking pest incidence was observed and subsequent sprays were given at interval of 15 days. The observations recorded were subjected to statistical analysis. The observations were recorded from five randomly selected plants from each plot. Three leaves per section (upper, middle and bottom) of each selected plant were observed for a population of nymphs and adults. Pre-treatment observations were recorded one day before spraying of any treatment and post-treatment observations were recorded 7 and 14 days after each spray. The mean count of sucking pests per leaf was recorded in the data.

Table 1: Detail of treatments

Module No.	Treatments
M1	Azadirachtin 0.03% EC @ 5 ml/lit fb Azadirachtin 0.15% EC @ 5 ml/lit fb Azadirachtin 0.30% EC @ 4 ml/lit fb Azadirachtin 01.00% EC @ 2 ml/lit
M2	*Verticillium lecanii* 1.15% WP @ 5 g/lit fb *Metarhizium anisopliae* 1.15% WP @ 5 g/lit fb *Beauveria bassiana* 1.15% WP @ 5 g/lit fb *Verticillium lecanii* 1.15% WP @ 5 g/lit
M3	PDKV Dashparni Extract 12.5 ml/lit fb Neem seed Extract 5% fb PDKV Brahmastra Extract 30 ml/lit fb PDKV Agniastra Extract 30 ml/lit
M4	Neem seed Extract 5% fb Azadirachtin 0.15% EC @ 5 ml/lit fb *Verticillium lecanii* 1.15% WP @ 5 g/lit fb Azadirachtin 01.00% EC @ 2 ml/lit
M5	Untreated Control

Results and Discussion

Effect of different modules against cotton leafhoppers

The pre-treatment observations confirmed no significant differences in leafhopper populations among the treatments, indicating uniform infestation across the experimental plots. Mean data on leafhopper population at 7 days after spraying (DAS) ranged from 0.69 to 2.35 per leaf. The minimum leafhopper population of 0.69 per leaf was recorded in Module 1 (Azadirachtin 0.03% EC @ 5 ml/lit fb Azadirachtin 0.15% EC @ 5 ml/lit fb Azadirachtin 0.30% EC @ 4 ml/lit fb Azadirachtin 1.00% EC @ 2 ml/lit), which was significantly superior over all other treatments. Module 4 (Neem seed extract 5% fb Azadirachtin 0.15% EC @ 5 ml/lit fb *V. lecanii* 1.15% WP @ 5 g/lit fb Azadirachtin 1.00% EC @ 2 ml/lit) recorded 0.86 leafhoppers per leaf, Module 3 (PDKV Dashparni Extract 12.5 ml/lit fb Neem seed extract 5% fb PDKV Brahmastra Extract 30 ml/lit fb PDKV Agniastra Extract 30 ml/lit) and Module 2 (*V. lecanii* 1.15% WP @ 5 g/lit fb *M. anisopliae* 1.15% WP @ 5 g/lit fb *B. bassiana* 1.15% WP @ 5 g/lit fb *V. lecanii* 1.15% WP @ 5 g/lit) recorded mean populations of 0.98 and 1.01 per leaf, respectively, and were significantly on par with each other and Module 1. The maximum population of 2.35 per leaf was recorded in the untreated control.

At 14 DAS, a similar trend was observed (Table 2). Module 1 continued to exhibit the lowest leafhopper population (1.27 per leaf) and was significantly superior over all other modules. It was at par with Module 4 (1.34 per leaf), Module 2 (1.57/leaf) and Module 3 (1.63/leaf). The untreated control consistently recorded the highest population (2.53 per leaf) at 14 DAS.

The mean population further confirmed the superiority of Module 1 (0.98 per leaf) in reducing leafhopper incidence. This was followed by Module 4 (1.10 per leaf), Module 2

(1.29 per leaf), and Module 3 (1.31 per leaf),all of which were at par with Module 1. The untreated control recorded the highest cumulative mean population (2.44 per leaf). It was found that all the modules was found superior in controlling leafhoppers. Our results are in conformity with the findings of earlier workers such as Noonari *et al.* (2016) [20] recorded highest reduction of jassid (71.97%) in neem seed extract followed by Neem oil (70.06%), Hing (Asafoetida) (68.15%) and Tobacco (23.56%) after 96 h., of application of bio pesticides on cotton. Effective reduction in the population of leaf hoppers on brinjal crop due to spray treatments of various bio pesticides have been reported by Ali *et al.* (2017) [1] wherein the results revealed that Neem extract showed highest reduction percent (68.73%) followed by Tobacco extract (55.72%), Datura extract (50.76%) and untreated control (13.90%). Hole *et al.* (2015) found *V. lecanii* (2 x 10^{12} cfu/g) @ 2000 g/hectare + *M. anisopliae* (2 x 10^{12} cfu/g) @ 2000 g/ha effective against all major sucking pests of cotton. Gothi *et al.* (2024) [14] evaluated various botanicals during year 2022-23 against pigeon pea leafhopper and revealed that NSKE @ 5% + cow urine @ 10% was the most effective treatment, followed by NSKE @ 5% and dashparni ark @ 10%. Neemastra @ 10% and brahmastra @ 10% were also effective. Agniastra @ 10% and panchparni ark @ 10% were less effective. The control had the highest population. Thus, the present findings were in close agreement with the report of earlier researchers.

Effect of different modules against cotton aphids

The pre-treatment observations revealed no significant differences in aphid populations among the experimental plots, indicating a uniform level of infestation prior to the application of treatments. At 7 days after spraying, the mean aphid population ranged from 4.83 to 11.86 aphids per leaf. The lowest population (4.83 aphids/leaf) was observed in Module 1 (Azadirachtin 0.03% EC @ 5 ml/lit followed by Azadirachtin 0.15% EC @ 5 ml/lit, Azadirachtin 0.30% EC @ 4 ml/lit fb Azadirachtin 1.00% EC @ 2 ml/lit), which was significantly superior to all other treatments. This was at par with Module 4 (Neem seed extract 5% fb Azadirachtin 0.15% EC @ 5 ml/lit fb *V. lecanii* 1.15% WP @ 5 g/lit fb Azadirachtin 1.00% EC @ 2 ml/lit), recording 5.20 aphids/leaf, Module 2 (*V. lecanii* 1.15% WP @ 5 g/lit fb *M. anisopliae* 1.15% WP @ 5 g/lit fb *B. bassiana* 1.15% WP @ 5 g/lit fb *V. lecanii* 1.15% WP @ 5 g/lit) recording 5.71 aphids/leaf and Module 3 (PDKV Dashparni Extract 12.5 ml/lit fb Neem seed extract 5% fb PDKV Brahmastra Extract 30 ml/lit fb PDKV Agniastra Extract 30 ml/lit) recording 5.73 aphids/leaf. The untreated control plot recorded the highest aphid population (11.86 aphids/leaf), which was significantly higher than all treated plots.

A similar trend was recorded at 14 days after spraying (Table 2). Module 1 continued to show superior efficacy with a mean population of 5.44 aphids/leaf, and was at par with Module 2 with 5.72 aphids/leaf, Module 4 with 6.05 aphids /leaf and Module 3 recorded 6.34 aphids/leaf. The highest population of 12.07 aphids/leaf was again noted in the untreated control.

The cumulative mean over both observations reaffirmed the trend. Module 1 recorded the lowest overall mean aphid population (5.14 aphids/leaf), indicating consistent effectiveness across both time points. This was followed by Module 4 (5.62 aphids/leaf), Modules 2 (5.71 aphids/leaf) and Module 3 (6.03 aphids/leaf). The untreated control maintained the highest overall mean aphid population with averaging (11.96 aphids/leaf), demonstrating the absence of effective suppression.

Statistical analysis revealed that treatment effects were significant at all observation intervals ($p < 0.05$). Results are in conformity with the findings of earlier workers such as Gaikwad *et al.* (2020) [10] carried out an experiment including both the chemicals, botanicals and biorational-insecticides has been conducted to evaluate their efficacy against aphid on okra. The results revealed that most superior treatment for management of aphids on okra was thiamethoxam 25 WG followed by emamectin benzoate 5 SG, NSKE 5%, neem oil 0.2%, Dashparni ark 0.6%, *Verticillium lecanii* 0.4% and *Metarhizium* + *Beauveria bassiana* 0.4%. *Beauveria bassiana* 0.4%, Biomix 0.3%, Karanj oil 0.5%, and Eucalyptus oil 0.2% which was statistically at par with each other. Ghelani *et al.* (2006; 2014) [11] found that *V. lecanii* @ 5 g/ l was effective against *Aphis gossypii*; and *V. lecanii* @ 2.5 kg/ ha combined with azadirachtin @ 0.0009% were found moderately effective against major sucking pests of Bt cotton supports present study. Wawdhane *et al.* (2020) [26] observed that among biopesticides tested, neem oil, *V. lecanii*, *B. bassiana* and *Metarhizium anisopliae* were found effective for the control of major sucking pests.

Effect of different modules on population of natural enemies

The cumulative mean data on natural enemies' population presented in Table 3 revealed that there was no statistically significant differences observed in ladybird beetle populations among the various treatment modules across different observation intervals following each spray. Ladybird beetle population observed ranged from 1.10 to 1.41 beetles per plant. However, the untreated control plots recorded highest number of ladybird beetles with 1.46 beetles per plant. The data regarding chrysopids population, recorded at various observation intervals following each spray, did not differ significantly among the treatments. However, a higher numerical population was observed in the untreated control plot, with an average of 1.46 chrysopids per plant. In contrast, the different modules exhibited chrysopids populations ranging from 1.17 to 1.30 per plant. The results on mean spiders' population revealed non-significant differences among the treatment modules in respect of spider population recorded at different intervals of observations after each treatment sprays. The population of spider recorded in different modules ranged between 1.08 to 1.56 spiders per plant. Whereas, in untreated control plots numerically higher number of spiders were observed (1.63 spiders/plant).

The results revealed that all the treatments under the present investigation proved less detrimental to the predatory fauna like ladybird beetle, spiders and chrysopids in cotton ecosystem. Similar findings were reported by Chakraborti (2001) [5] that neem-based treatments like spraying of neem oil and NSKE were found safer to natural enemies and were on par with untreated check in brinjal ecosystem. The neem products registered far safer than chemical to the predatory coccinellids (Sakthivel and Qadri, 2010) [22] and the spiders

(Samiayyan and Chandrasekharan, 1998 and Joseph *et al.*, 2010) [23, 17]. However, Jayakumar (2002) [2] reported that the indigenous components like garlic (Allium sativum), custard apple (*Annona squamosa*), neem (*Azadirachta indica*), chilli (*Capsicum annum*), vishamdhari (*Clerodendron inermi*), turmeric (*Curcuma longa*), yekka (*Calotropis gigentia*), tobacco (*Nicotiana tabacum*), ginger (*Zingiber officinale*) and nirgudi (*Vitex negundo*) fermented with cow urine showed no significant differences in occurrence of natural enemies indicating safety to spiders, chrysoperla and coccinellids after seven day of application in okra ecosystem.

Effect of different modules on seed cotton yield

According to the data on seed cotton yield as in Table 2, Module 1 was found most promising in increasing seed cotton yield i.e., 13.39 q/ha. However, Module 1 (Azadirachtin 0.03% EC @ 5 ml/lit fb Azadirachtin 0.15% EC @ 5 ml/lit fb Azadirachtin 0.30% EC @ 4 ml/lit fb Azadirachtin 1.00% EC @ 2 ml/lit) is at par with Module 3 (PDKV Dashparni Extract 12.5 ml/lit fb Neem seed extract 5% fb PDKV Brahmastra Extract 30 ml/lit fb PDKV Agniastra Extract 30 ml/lit) (12.16 q/ha), Module 2 (*V. lecanii* 1.15% WP @ 5 g/lit fb *M. anisopliae* 1.15% WP @ 5 g/lit fb *B. bassiana* 1.15% WP @ 5 g/lit fb *V. lecanii* 1.15% WP @ 5 g/lit) (11.73 q/ha) and Module 4 (11.02 q/ha) (Neem seed extract 5% fb Azadirachtin 0.15% EC @ 5 ml/lit fb *V. lecanii* 1.15% WP @ 5 g/lit fb Azadirachtin 1.00% EC @ 2 ml/lit). Whereas, lowest yield was recorded in Module 5 (untreated control) (8.20 q/ha).

The present results regarding recovery of maximum seed cotton yield due to application of different biopesticides, botanicals and organic extracts are in confirmation with the result obtain by earlier workers like Deling *et al.* (2000) [7] obtained more yield from the cotton treated with azadirachtin due to its effects on the infestation of bollworm. Also, Anitha and Nandihalli (2008) [2] who reported that NSKE proved to be the most economical treatment as realized by highest yield of okra 40.21 q/ha and net returns of Rs. 6,418/ha. Also, Patel *et al.* (2017) [21] studied the comparative bio-efficacy of Brahmastra, Agniastra and Neemastra along with Neem Seed Kernel Suspension (NSKS) 5 percent against sucking pest of cotton and its safety to natural enemies during two consecutive years revealed that highest seed cotton yield was recorded in plots treated with Brahmastra (27.74 q/ha) followed by Agniastra (25.12 q/ha) and Neemastra (23.99 q/ha). Singh *et al.* (2011) [25] while studying the bio efficacy of neem products against mustard aphid recorded significantly high yield in treatment of neem oil (2%) (2380 kg/ha) followed by azadirachtin 1500 ppm (0.1%) (2340 kg/ha), NSK cold water extract (5%) (2290 kg/ha) over the control plot (1630 kg/ha).

Table 2: Effect of treatment modules on leafhoppers, aphids and seed cotton yield.

Module No.	Treatments	Cumulative mean population of leafhopper/leaf			Cumulative mean population of aphids/leaf			Seed cotton yield (q/ha)
		7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	Mean
1	Azadirachtin 0.03% EC @ 5 ml/lit fb Azadirachtin 0.15% EC @ 5 ml/lit fb Azadirachtin 0.30% EC @ 4 ml/lit fb Azadirachtin 01.00% EC @ 2 ml/lit	0.69 (1.08)	1.27 (1.32)	0.98 (1.20)	4.83 (2.23)	5.44 (2.31)	5.14 (2.27)	13.39
2	*Verticillium lecanii* 1.15% WP @ 5 g/lit fb *Metarhizium anisopliae* 1.15% WP @ 5 g/lit fb *Beauveria bassiana* 1.15% WP @ 5 g/lit fb *Verticillium lecanii* 1.15% WP @ 5 g/lit	1.01 (1.21)	1.57 (1.42)	1.29 (1.31)	5.71 (2.39)	5.72 (2.40)	5.71 (2.40)	11.73
3	PDKV Dashparni Extract 12.5 ml/lit fb Neem seed Extract 5% fb PDKV Brahmastra Extract 30 ml/lit fb PDKV Agniastra Extract 30 ml/lit	0.98 (1.20)	1.63 (1.44)	1.31 (1.32)	5.73 (2.39)	6.34 (2.46)	6.03 (2.43)	12.16
4	Neem seed Extract 5% fb Azadirachtin 0.15% EC @ 5 ml/lit fb *Verticillium lecanii* 1.15% WP @ 5 g/lit fb Azadirachtin 01.00% EC @ 2 ml/lit	0.86 (1.15)	1.34 (1.34)	1.10 (1.24)	5.20 (2.30)	6.05 (2.44)	5.62 (2.37)	11.02
5	Untreated control	2.35 (1.66)	2.53 (1.72)	2.44 (1.69)	11.86 (3.37)	12.07 (3.37)	11.96 (3.37)	8.20
	'F' Test	Sig	Sig	Sig	Sig	Sig	Sig	Sig
	SE (m)±	0.07	0.08	0.08	0.18	0.15	0.17	0.80
	CD at 5%	0.23	0.27	0.25	0.55	0.48	0.52	2.48
	CV%	11.99	12.18	12.08	14.36	12.54	13.45	14.25

Note: Figures in parentheses are corresponding square root ($\sqrt{x + 0.5}$) transformation values. DAS-Days after spraying, fb-Followed by.

Table 3: Effect of different modules on population of natural enemies

Module No.	Treatments	Average population of ladybird beetle/plant			Average population of chrysopids/ plant			Average population of spiders/plant		
		7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean
1	Azadirachtin 0.03% EC @ 5 ml/lit fb Azadirachtin 0.15% EC @ 5 ml/lit fb Azadirachtin 0.30% EC @ 4 ml/lit fb Azadirachtin 01.00% EC @ 2 ml/lit	0.98 (1.21)	1.23 (1.31)	1.10 (1.26)	0.96 (1.20)	1.38 (1.36)	1.17 (1.28)	0.94 (1.19)	1.23 (1.31)	1.08 (1.25)
2	*Verticillium lecanii* 1.15% WP @ 5 g/lit fb *Metarhizium anisopliae* 1.15% WP @ 5 g/lit fb *Beauveria bassiana* 1.15% WP @ 5 g/lit fb *Verticillium lecanii* 1.15% WP @ 5 g/lit	1.40 (1.37)	1.42 (1.38)	1.41 (1.37)	1.28 (1.32)	1.32 (1.34)	1.30 (1.33)	1.54 (1.42)	1.58 (1.43)	1.56 (1.43)
3	PDKV Dashparni Extract 12.5 ml/lit fb Neem seed Extract 5% fb PDKV Brahmastra Extract 30 ml/lit fb PDKV Agniastra Extract 30 ml/lit	1.36 (1.35)	1.41 (1.37)	1.38 (1.36)	1.23 (1.30)	1.34 (1.35)	1.28 (1.33)	1.32 (1.34)	1.28 (1.33)	1.30 (1.33)
4	Neem seed Extract 5% fb Azadirachtin 0.15% EC @ 5 ml/lit fb *Verticillium lecanii* 1.15% WP @ 5 g/lit fb Azadirachtin 01.00% EC @ 2 ml/lit	1.18 (1.29)	1.24 (1.31)	1.21 (1.30)	1.16 (1.28)	1.29 (1.33)	1.22 (1.30)	1.33 (1.34)	1.21 (1.30)	1.27 (1.32)
5	Untreated control	1.44 (1.38)	1.48 (1.40)	1.46 (1.39)	1.34 (1.35)	1.58 (1.43)	1.46 (1.39)	1.62 (1.45)	1.64 (1.45)	1.63 (1.45)
	'F' Test	NS	NS	NS	NS	NS	NS	NS	NS	NS
	SE (m)±	0.05	0.05	0.05	0.06	0.07	0.07	0.07	0.07	0.07
	CD at 5%	0.17	0.16	0.17	0.19	0.24	0.21	0.23	0.22	0.22
	CV%	8.50	7.92	8.21	9.81	11.41	10.61	11.19	10.44	10.82

Note: Figures in parentheses are corresponding square root ($\sqrt{x + 0.5}$) transformation values. DAS-Days after spraying, fb-Followed by.

Conclusion

The present investigation revealed that all the tested treatment modules were significantly more effective than the untreated control in managing leafhoppers *Amrasca biguttula biguttula* I. and aphids *Aphis gossypii* G. on Bt cotton. In terms of natural enemies such as ladybird beetles, chrysopids, and spiders, all the bio-rational treatments comprising botanicals, biopesticides, and plant extracts were found to be safe and non-disruptive. Regarding yield performance, all modules significantly outperformed the untreated control, with Module 1 producing the highest seed cotton yield. However, it was statistically at par with Modules 2, 3, and 4, further reinforcing the effectiveness of these treatments in not only pest suppression but also yield enhancement. Hence, all the four treatment modules proved effective in suppressing sucking pest populations, proved less detrimental to natural enemies' population, enhancing yield, and maintaining ecological balance. These findings support the adoption of such eco-friendly, integrated pest management modules in cotton cultivation for sustainable and profitable crop production.

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References

1. Ali SS, Ahmed SS, Rizwana H, Bhatti FU, Khoso AG, Mengal MI, *et al.* Efficacy of different bio-pesticides against major sucking pests on brinjal under field conditions. Journal of Basic & Applied Sciences. 2017 Jan 5;13:133-138.
2. Anitha KR, Nandihalli BS. Utilization of botanicals and mycopathogens in the management of sucking pests of okra.
3. Anonymous. Ministry of Textiles report. 2023 [cited 2025 Jul 28]. Available from: https://ministryoftextiles.gov.in/vc-link
4. Bashir MA, Atta S, Nisar MS, Khan AK, Batool M, Khan KA, *et al.* Management of sucking insects' pest complex of cotton through foliar spray of insecticides. Fresenius Environmental Bulletin. 2020 Jan 1;29(7A):5777-5785.
5. Chakraborti S. Neem-based integrated schedule for the control of vectors causing apical leaf curling in chilli. 2000;79-84.
6. Chavan SJ, Bhosle BB, Bhute NK. Estimation of losses due to major insect-pests in desi cotton (*Gossypium arboreum* L.) in Maharashtra. 2010;95-96.
7. Deling MA, Gordh G, Zalucki MP. Toxicity of biorational insecticides to *Helicoverpa* spp. (Lepidoptera: Noctuidae) and predators in cotton field. International Journal of Pest Management. 2000 Jan 1;46(3):237-240.
8. Dhawan AK, Sidhu AS, Simwat GS. Assessment of avoidable loss in cotton (*Gossypium hirsutum* and *G. arboreum*) due to sucking pests and bollworms. 1988.
9. El-Heneidy AH, Khidr AA, Taman AA. Side-effects of insecticides on non-target organisms: 1-In Egyptian cotton fields. Egyptian Journal of Biological Pest Control. 2015;25(3):685-688.
10. Gaikwad BB, Bhosle BB, Bhede BV. Evaluation of different bio-pesticides against aphid on okra. Journal of Entomology and Zoology Studies. 2020;8(3):339-345.
11. Ghelani YH, Jhala RC, Vyas HN. Bioefficacy of botanicals and microbial insecticides against cotton aphid, *Aphis gossypii* (Glover); 2006.
12. Ghelani MK, Kabaria BB, Chhodavadia SK. Field efficacy of various insecticides against major sucking pests of Bt cotton. Journal of Biopesticides. 2014 Jan 2;7:106-110.
13. Gore AK, Sant SS, Kadam AK, Dhurgude SS, Patange SB. Effect of botanicals and biopesticides on sucking pest in cotton. Journal of Entomology and Zoology Studies. 2021;9(1):1262-1265.

14. Gothi HR, Panickar BK, Rabari PH, Patel BC, Barad CS. Field efficacy of botanicals against sucking pests in pigeonpea (*Cajanus cajan* (L.) Millsp.) under organic cultivation. Journal of Advances in Biology & Biotechnology. 2024 Sep 30;27(10):624-635.
15. Hole UB, Gangurde SM, Sarode ND, Bharud RW. Bioefficacy of mycopathogens *Verticillium lecanii* Zimmermen and *Metarhizium anisopliae* Metchnikoff against sucking pests of Bt cotton. 2015;138-142.
16. Jayakumar R. Survey of indigenous practices for the management of pests in Raichur district and evaluation of few practices against okra pests [M.Sc. (Agri.) thesis]. Raichur: University of Agricultural Sciences; 2002 Nov.
17. Joseph RA, Premila KS, Nisha VG, Rajendran S, Mohan SS. Safety of neem products to tetragnathid spiders in rice ecosystem. Journal of Biopesticides. 2010;3(Special Issue):88-91.
18. Kranthi KR, Jadhav DR, Kranthi S, Wanjari RR, Ali SS, Russell DA. Insecticide resistance in five major insect pests of cotton in India. Crop Protection. 2002 Jul 1;21(6):449-460.
19. Mayee CD, Rao MR. Study of cotton pest. Journal of Plant Protection Environment. 2002;1(1/2):40-45.
20. Noonari AM, Abro GH, Khuhro RD, Buriro AS. Efficacy of bio-pesticides for management of sucking insect pests of cotton, *Gossypium hirsutum* (L.). Journal of Basic & Applied Sciences. 2016 Jan 5;12:306-313.
21. Patel RD, Bharpoda TM, Borad PK, Bhatt NA, Mahida RD. Efficacy of different bio-pesticides against sucking pests of Bt cotton. AGRES-An International e-Journal. 2017;6(1):171-180.
22. Sakthivel N, Qadri SM. Impact of insecticides and botanicals on population build-up of predatory coccinellids in mulberry. Journal of Biopesticides. 2010;3(1):85-87.
23. Samiayyan K, Chandrasekharan B. Influence of botanicals on the spider populations of rice. Madras Agricultural Journal. 1998;85(7/9):479-480.
24. Silvie P. Plant-based extracts for cotton pest management in Sub-Saharan Africa: a review. Botany Letters. 2023 Jan 2;170(1):28-41.
25. Singh SP, Singh YP, Kumar A. Bio-effectiveness of neem products against mustard aphid, *Lipaphis erysimi* (Kalt.) in mustard crop. Annals of Plant Protection Sciences. 2011;19(2):278-281.
26. Wawdhane PA, Nandanwar VN, Mahankuda B, Ingle AS, Chaple KI. Bio-efficacy of insecticides and bio pesticides against major sucking pests of Bt-cotton. Journal of Entomology and Zoology Studies. 2020;8(3):829-833.
27. Zanwar PR, Deosarkar DB, Yadav GA, Shelke LT. Field performance of Bt cotton genotypes against sucking pests. Annals of Plant Protection Sciences. 2010;18(2):490-491.