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RESEARCH PAPER

Comparative bio-efficacy of different insecticides on major sucking pests of *Bt*-cotton

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Abstract: The field evaluation of various insecticides on major sucking pests of *Bt*-cotton during the 2022-23 season demonstrated significant reductions in pest occurrence across all treatments compared to the control. However, the efficacy varied depending on the insecticide used. Among all the treatments, Flonicamid 50 WG proved highly effective in managing all the sucking pests by recording lowest incidence of thrips (8.44/ 3 leaves), leaf hopper (5.43/ 3 leaves), aphid (3.64/ 3 leaves) and whitefly (3.29/ 3 leaves) with highest cotton yield (19.41 q/ha), net returns (53,540 ₹ /ha) and B: C ratio (1.85) as compared to all other treatments. In addition, other promising alternatives such as Dinotefuran 20 SG, Spinetoram 11.7 SC, and Diafenthiuron 50 WP for combating thrips, Dinotefuran 20 SG and Spinetoram 11.7 SC for addressing leaf hoppers, and Pyriproxyfen 10 EC, Diafenthiuron 50 WP, and Dinotefuran 20 SG can be utilized for managing aphids and whiteflies in *Bt*- cotton. Utilizing these findings to optimize the selection and application of insecticides can enable growers to more effectively control pest pressures, thereby enhancing both the productivity and quality of *Bt*-cotton crops. Overall, Flonicamid 50 WG emerged as the most cost-effective option, underscoring its potential as a key solution for managing sucking pests in *Bt*-cotton cultivation.

Key words: Bioefficacy, *Bt*-cotton, Insecticides, Sucking pests, Yield parameters

Introduction

Cotton, widely known as "White Gold" in India, plays a pivotal role in the country's agricultural landscape, thriving across diverse agro-climatic conditions and serving as the primary raw material source for the textile industry, meeting nearly two-thirds of its requirements. Despite India's global dominance in cotton area, its production ranks second behind China (CCI, 2021). The persistent challenge of low cotton productivity is largely attributed to insect pest infestations, presenting a significant obstacle to cultivation efforts (Manjunath, 2004). The advent of Bollgard technology in 2002 marked a turning point in cotton production, resulting in heightened yields, reduced losses from bollworms, and diminished reliance on insecticides (Rao and Dev, 2009). However, this break through inadvertently fueled the proliferation of other pest species, posing newfound economic threats to cotton cultivation. Notably, sucking pests like aphids, leafhoppers, whiteflies, and thrips emerged as formidable adversaries, causing substantial damage at various growth stages and ultimately diminishing crop yield. While transgenic cotton offers promise in combating bollworms (Kulkarni *et al.*, 2003), addressing the challenge of sucking pests necessitates the development of effective management strategies.

Cotton's global significance extends beyond India's borders, with cultivation spanning over seventy countries in tropical and sub-tropical regions. Key producers include China, the USA, India, Pakistan, and various others (Steven *et al.*, 2008). Despite its economic importance, cotton cultivation grapples with productivity issues, exacerbated by the pervasive threat of insect pests. The sheer diversity of pest species affecting cotton worldwide underscores the severity of the challenge, with sucking pests such as whiteflies, aphids, jassids, and thrips inflicting considerable economic losses, particularly in tropical regions. Even the adoption of *Bt*-cotton, with its inherent advantages, does not shield against yield losses inflicted by sap-feeding pests like leafhoppers, aphids, thrips, whiteflies, and mealybugs throughout the growing season (Biradar and Venilla, 2008). Given the high reproductive capacity of sucking pests, they pose a persistent menace to *Bt*- cotton crops. Consequently, farmers often resort to environmentally harmful chemical interventions to safeguard their yields, underscoring the urgent need for sustainable pest management alternatives. From this perspective, there exists an opportunity to leverage newer chemical compounds which demand minimal quantities to manage sucking insect pests while offering comparative environmental safety and economic efficiency in controlling sucking pests within the cotton ecosystem.

Material and methods

Field experiment was conducted at Entomology block, Main Agricultural Research Station (MARS), Raichur. The experiment was laid out in Randomized Block Design (RBD) with eight treatments (Table 1) and four replications. The *Bt*-cotton hybrid "Jadoo (KCH-14K59)" with a spacing 90 cm between rows and 60 cm between plants was sown and crop was raised as per recommended agronomical practices (Anon, 2020). Treatments were imposed as and when any one of the major sucking pests *viz*., thrips, leaf hopper, aphid and whitefly crossed economic threshold level (ETL). Totally, three sprays were given at 15 days interval for each treatment. The observation on the thrips,

Table 1. Treatment details to evaluate comparative efficacy of different insecticides against major sucking pests of *Bt*-cotton

Treatment number	Treatments	Trade name and Markert Cost	Dosage (g. *a.i.* / ha)	Formulation (mL or g / ha)	Cost of chemical (₹ / ha)
T1	Spinetoram 11.7 SC	Delegate(2350 ₹ /180 mL)	50	420	5483.33
T2	Pyriproxyfen 10 EC	Daita(640 ₹ / 500 mL)	100	1000	1280.00
T3	Dinotefuran 20 SG	Token(1237 ₹ / 250 gm)	30	150	742.20
T4	Spiromesifen 22.9 SC	Oberon(679 ₹ / 100 mL)	144	600	4074.00
T5	Diafenthiuron 50 WP	Pegasus(899 ₹ / 250 gm)	300	600	2157.60
T6	Flonicamid 50 WG	Ulala(328 ₹ / 30 gm)	75	150	1640.00
T7	Imidacloprid 17.8 SL	Confidor(389 ₹ / 100 mL)	25	125	486.25
T8	Control	-	-	-	-

leaf hopper, aphid and whitefly per three leaves were recorded from top three fully formed leaves per plant in 10 randomly selected plants of each treatment a day before spray and after spray *viz*., 3, 7 and 14 days after spray (DAS). The observations on per cent locule damage, good and bad opened bolls per plant, and seed cotton yield was recorded at the time of harvest. However, reduction of pest population and increase in the yield over control was calculated using the formula given below.

$$\text{Reduction of pest population over control (\%)} = \frac{\text{Number of insects in control} - \text{number of insects in treatment}}{\text{Number of insects in control}} \times 100$$

$$\text{Yield increase over control (\%)} = \frac{\text{Yield in treated plot} - \text{Yield in control plot}}{\text{Yield in treated plot}} \times 100$$

The data obtained in the experiments under current investigation for various parameters such as thrips, leaf hopper, aphid and whitefly per three leaves, number of good and opened bolls, locule damage (%) and seed cotton yield were subjected to ANOVA for a randomized complete block design with suitable statistical transformation (arc sine and square root) in R software (R Core Team, 2016).

Results and discussion

The comparative bioefficacy of different insecticides on major sucking pests of *Bt*-cotton was evaluated under field conditions in Entomology block, MARS, Raichur during 2022-23. In general, declined occurrence of major sucking pests following insecticide application across all treatments was noticed as compared to the untreated control. However, the effectiveness of each treatment against sucking pests was varied depending on the insecticides used.

Bioefficacy of different insecticides on thrips management in *Bt*-cotton

The outcomes of this investigation unveil varying degrees of effectiveness among the tested insecticides against thrips infestation in *Bt*-cotton fields. The plots treated with Spinetoram 11.7 SC, Dinotefuran 20 SG, Diafenthiuron 50 WP and Flonicamid 50 WG recorded on par results in managing thrips incidence after the sprays. However, the Flonicamid 50 WG recorded the lowest thrips incidence (8.44/ 3 leaves) after three sprays with highest reduction over control (73.71%) followed by the plot treated with Spinetoram 11.7 SC (9.15/ 3 leaves) with 71.53 per cent population reduction over control. However, control or untreated plots recorded the significantly higher thrips incidence (32.12/ 3 leaves) compared to other treatments (Table 2). Our research results are corroborated with the findings of Sasikumar *et al*. (2018), as they recorded lowest thrips (1.48/ 3 leaves and 0.81 /3 leaves during 2014-15 and 2015-16, respectively) in Flonicamid sprayed plots as compared to all other treatments. Similar results are also obtained by Nemade *et al*. (2017) and Gaurkhede *et al.* (2015), as they also recorded Flonicamid 50 WG and Dinotefuran 20 SG was effective in managing all the sucking pest of *Bt*-cotton as compared to other insecticides treatments.

Bioefficacy of different insecticides on jassids management in *Bt*-cotton

Among the eight treatments, the plots treated with Flonicamid 50 WG, Dinotefuran 20 SG and Spinetoram 11.7 SC managed the jassids population effectively and statistically on par in managing the pest (Table 3). However, the Flonicamid 50 WG recorded the lowest (5.43/ 3 leaves) jassids incidence after three sprays with highest reduction over control (74.31%) followed by the plot treated with Dinotefuran 20 SG (6.72/ 3 leaves) and Spinetoram 11.7 SC (6.88/ 3 leaves) with 68.18 and 67.44 per cent population reduction over control, respectively. Conversely, control or untreated plots recorded the highest jassids incidence (21.13/ 3 leaves) after three sprays. Additionally, moderate reductions were observed with Diafenthiuron 50 WP with 65.89 per cent jassids population reduction over control. Our research results are corroborated with the findings of Sasikumar *et al*. (2018), as they recorded lowest leaf hopper (1.12 /3 leaves and 1.18 /3 leaves during 2014-15 and 2015-16, respectively) in Flonicamid sprayed plots as compared to all other treatments. Similarly, Kumar and Dhawan (2011) reported Dinotefuran 20 SG and Flonicamid 50 WG were effective against cotton leafhopper. Similar results also recorded by Sreekanth and Reddy (2011), Zala *et al.* (2014), Bajya *et al*. (2016), Chandi *et al*. (2016), Nemade *et al*. (2015), Sreenivas *et al*. (2015), Navi *et al*. (2021), Kumar and Sharma (2023).

Bioefficacy of different insecticides on aphids management in *Bt*-cotton

The results of current investigation reveal differing levels of efficacy among the insecticides tested for controlling aphids

Table 2. Comparative bioefficacy of different insecticides against thrips in *Bt*-cotton under field conditions during 2022-23.

Treatment number	Treatments	Pre-Count	Number of thrips / 3 leaves									Average	Reduction over control(%)
			First spray			Second spray			Third spray				
			3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
T1	Spinetoram 11.7 SC	26.26 (5.17)^{a}	11.12 (3.41)^{a}	4.80 (2.30)^{a}	13.04 (3.68)^{a}	6.83 (2.71)^{a}	3.21 (1.93)^{a}	12.55 (3.61)^{a}	6.93 (2.73)^{a}	2.29 (1.67)^{a}	4.42 (2.22)^{a}	9.15	71.53
T2	Pyriproxyfen 10 EC	24.54 (5.00)^{a}	18.45 (4.35)^{c}	12.13 (3.55)^{c}	20.37 (4.57)^{c}	14.16 (3.83)^{c}	10.54 (3.32)^{c}	19.88 (4.51)^{c}	14.26 (3.84)^{c}	9.62 (3.18)^{c}	11.75 (3.50)^{c}	15.57	51.53
T3	Dinotefuran 20 SG	25.62 (5.11)^{a}	11.85 (3.51)^{a}	5.53 (2.46)^{a}	13.77 (3.78)^{a}	7.56 (2.84)^{a}	3.94 (2.11)^{a}	13.28 (3.71)^{a}	7.66 (2.86)^{a}	3.02 (1.88)^{a}	5.15 (2.38)^{a}	9.74	69.68
T4	Spiromesifen 22.9 SC	25.95 (5.14)^{a}	18.76 (4.39)^{c}	12.44 (3.60)^{c}	20.68 (4.60)^{c}	14.47 (3.87)^{c}	10.85 (3.37)^{c}	20.19 (4.55)^{c}	14.57 (3.88)^{c}	9.93 (3.23)^{c}	12.06 (3.54)^{c}	15.99	50.22
T5	Diafenthiuron 50 WP	27.12 (5.26)^{a}	12.21 (3.57)^{a}	5.89 (2.53)^{a}	14.13 (3.82)^{a}	7.92 (2.90)^{a}	4.30 (2.19)^{a}	13.64 (3.76)^{a}	8.02 (2.92)^{a}	3.38 (1.97)^{a}	5.51 (2.45)^{a}	10.21	68.21
T6	Flonicamid 50 WG	22.63 (4.81)^{a}	10.39 (3.30)^{a}	4.07 (2.14)^{a}	12.31 (3.58)^{a}	6.10 (2.57)^{a}	2.48 (1.73)^{a}	11.82 (3.51)^{a}	6.20 (2.59)^{a}	1.89 (1.55)^{a}	6.55 (2.05)^{a}	8.44	73.71
T7	Imidacloprid 17.8 SL	23.52 (4.90)^{a}	15.24 (3.97)^{b}	8.92 (3.07)^{b}	17.16 (4.20)^{b}	10.95 (3.38)^{b}	7.33 (2.80)^{b}	16.67 (4.14)^{b}	11.05 (3.40)^{b}	6.41 (2.63)^{b}	8.54 (3.01)^{b}	12.58	60.84
T8	Control	22.36 (4.78)^{a}	25.64 (5.11)^{d}	27.35 (5.28)^{d}	28.35 (5.37)^{d}	26.45 (5.19)^{d}	35.42 (5.99)^{d}	38.62 (6.25)^{d}	42.15 (6.53)^{d}	43.65 (6.64)^{d}	31.25 (5.63)^{d}	32.12	0.00
	S. Em (±)	0.18	0.11	0.14	0.10	0.13	0.16	0.11	0.12	0.15	0.15		
	CD (%)	0.53	0.33	0.42	0.3	0.38	0.49	0.32	0.36	0.46	0.45		

Values in parenthesis are √x+0.5 transformed

Means followed by same alphabet in columns did not differ significantly (p=0.05) by DMRT

Table 3. Comparative bioefficacy of different insecticides against jassids in *Bt*-cotton under field conditions during 2022-23.

Treatment number	Treatments	Pre-Count	Number of jassids / 3 leaves									Average	Reduction over control(%)
			First spray			Second spray			Third spray				
			3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
T1	Spinetoram 11.7 SC	18.14 (4.32)^{a}	8.00 (2.92)^{ab}	2.68 (1.78)^{ab}	10.04 (3.25)^{ab}	3.71 (2.05)^{ab}	2.10 (1.61)^{ab}	8.69 (3.03)^{ab}	3.98 (2.12)^{ab}	4.33 (2.12)^{ab}	7.12 (1.99)^{ab}	6.88	67.44
T2	Pyriproxyfen 10 EC	17.54 (4.25)^{a}	13.10 (3.69)^{c}	7.32 (2.79)^{c}	14.56 (3.88)^{c}	8.21 (2.95)^{c}	6.53 (2.65)^{c}	13.24 (3.71)^{c}	8.73 (3.04)^{c}	6.13 (2.57)^{c}	8.57 (3.01)^{c}	10.39	50.81
T3	Dinotefuran 20 SG	17.34 (4.22)^{a}	8.73 (3.04)^{ab}	3.41 (1.98)^{ab}	10.77 (3.36)^{ab}	4.44 (2.22)^{ab}	2.83 (1.82)^{ab}	9.42 (3.15)^{ab}	4.71 (2.28)^{ab}	2.04 (1.59)^{ab}	3.52 (2.00)^{ab}	6.72	68.19
T4	Spiromesifen 22.9 SC	17.83 (4.28)^{a}	12.12 (3.55)^{c}	6.80 (2.70)^{c}	14.56 (3.88)^{c}	7.83 (2.89)^{c}	6.53 (2.65)^{c}	12.81 (3.65)^{c}	8.73 (3.04)^{c}	5.43 (2.44)^{c}	7.59 (2.84)^{c}	10.02	52.57
T5	Diafenthiuron 50 WP	19.21 (4.44)^{a}	9.09 (3.10)^{b}	3.77 (2.07)^{b}	11.13 (3.41)^{b}	4.80 (2.30)^{b}	3.19 (1.92)^{b}	9.78 (3.21)^{b}	5.07 (2.36)^{b}	2.40 (1.70)^{b}	3.63 (2.03)^{b}	7.21	65.89
T6	Flonicamid 50 WG	16.21 94.09)^{a}	7.27 (2.79)^{a}	1.95 (1.57)^{a}	9.31 (3.13)^{a}	2.98 (1.87)^{a}	1.37 (1.37)^{a}	7.96 (2.91)^{a}	3.25 (1.94)^{a}	0.91 (1.19)^{a}	3.07 (1.89)^{a}	5.43	74.31
T7	Imidacloprid 17.8 SL	15.84 (4.04)^{a}	12.12 (3.55)^{c}	6.80 (2.70)^{c}	14.16 (3.83)^{c}	7.83 (2.89)^{c}	6.22 (2.59)^{c}	12.81 (3.65)^{c}	8.10 (2.93)^{c}	5.43 (2.44)^{c}	7.59 (2.84)^{c}	9.69	54.14
T8	Control	15.46 (3.99)^{a}	17.23 (4.21)^{d}	18.64 (4.37)^{d}	19.67 (4.49)^{d}	22.6 (4.81)^{d}	220.15 (4.54)^{d}	23.46 (4.89)^{d}	23.84 (4.93)^{d}	24.85 (5.03)^{d}	25.34 (5.08)^{d}	21.13	0.00
	S.Em (±)	0.20	0.10	0.15	0.11	0.13	0.17	0.11	0.12	0.15	0.17		
	C.D (%)	0.59	0.30	0.45	0.33	0.38	0.51	0.32	0.36	0.45	0.5		

Values in parenthesis are √x+0.5 transformed

Means followed by same alphabet in columns did not differ significantly (p=0.05) by DMRT

infestation on *Bt*-cotton. The plots treated with Pyriproxyfen 10 EC, Diafenthiuron 50 WP, Dinotefuran 20 SG and Flonicamid 50 WG recorded on par results in managing aphids incidence after the sprays (Table 4). However, the Flonicamid 50 WG recorded the lowest (3.64/ 3 leaves) aphids incidence after three sprays with highest reduction over control (81.21%) followed by the plot treated with Pyriproxyfen 10 EC (4.33/ 3 leaves), Dinotefuran 20 SG (4.80/ 3 leaves) and Diafenthiuron 50 WP (5.26/ 3 leaves) with 77.67, 75.25 and 72.86 per cent population reduction over control, respectively. However, control or untreated plots recorded the highest aphid incidence (19.37/ 3 leaves) after three sprays. Our research findings are in line with the findings of Ghelani (2014), as they reported application of Flonicamid and dinotefuran effectively manage the aphids in *Bt* cotton.

Bioefficacy of different insecticides on whiteflies management in *Bt*-cotton

The latest findings from our investigation demonstrate varying degrees of effectiveness among the insecticides

Table 4. Comparative bioefficacy of different insecticides against aphids in *Bt*-cotton under field conditions during 2022-23.

Treatment number	Treatments	Pre-Count	Number of aphids / 3 leaves									Average	Reduction over control(%)
			First spray			Second spray			Third spray				
			3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
T1	Spinetoram	15.59	11.15	5.37	12.61	6.26	4.58	11.29	6.78	4.18	6.62	8.44	56.41
	11.7 SC	(4.01)[a]	(3.41)[c]	(2.42)[c]	(3.62)[b]	(2.60)[c]	(2.25)[c]	(3.43)[b]	(2.70)[c]	(2.16)[b]	(2.67)[b]		
T2	Pyriproxyfen	16.19	6.05	0.73	8.09	1.76	0.15	6.74	2.03	0.00	1.52	4.33	77.67
	10 EC	(4.09)[a]	(2.56)[ab]	(1.11)[ab]	(2.93)[a]	(1.50)[ab]	(0.81)[ab]	(2.69)[a]	(1.59)[ab]	(0.71)[a]	(1.42)[a]		
T3	Dinotefuran	15.39	6.78	1.46	8.82	2.49	0.88	7.47	2.76	0.33	1.57	4.80	75.25
	20 SG	(3.99)[a]	(2.70)[ab]	(1.40)[b]	(3.05)[a]	(1.73)[b]	(1.17)[ab]	(2.82)[a]	(1.81)[b]	(0.91)[a]	(1.44)[a]		
T4	Spiromesifen	15.88	11.15	8.37	15.73	9.40	7.79	14.38	9.67	7.00	10.18	10.96	43.44
	22.9 SC	(4.05)[a]	(3.41)[c]	(2.98)[d]	(4.03)[c]	(3.15)[d]	(2.88)[d]	(3.86)[c]	(3.19)[d]	(2.74)[c]	(3.27)[c]		
T5	Diafenthiuron	17.26	7.14	1.82	9.18	2.85	1.24	7.83	3.12	0.45	1.68	5.26	72.86
	50 WP	(4.21)[a]	(2.76)[b]	(1.52)[b]	(3.11)[a]	(1.83)[b]	(1.32)[b]	(2.89)[a]	(1.90)[b]	(0.97)[a]	(1.48)[a]		
T6	Flonicamid	14.26	5.32	0.00	7.36	1.03	0.00	6.01	1.30	0.00	1.12	3.64	81.21
	50 WG	(3.84)[a]	(2.41)[a]	(0.71)[a]	(2.80)[a]	(1.24)[a]	(0.71)[a]	(2.55)[a]	(1.34)[a]	(0.71)[a]	(1.27)[a]		
T7	Imidacloprid	13.89	10.17	4.85	12.21	5.88	4.27	10.86	6.15	3.48	5.64	7.74	60.04
	17.8 SL	(3.79)[a]	(3.27)[c]	(2.31)[c]	(3.57)[b]	(2.53)[c]	(2.18)[c]	(3.37)[b]	(2.58)[c]	(1.99)[b]	(2.48)[b]		
T8	Control	13.51	15.28	16.69	19.67	20.67	18.20	21.51	21.89	22.90	23.39	19.37	0.00
		(3.74)[a]	(3.97)[d]	(4.15)[e]	(4.49)[d]	(4.60)[e]	(4.32)[e]	(4.69)[d]	(4.73)[e]	(4.84)[d]	(4.89)[d]		
	S.Em (±)	0.21	0.11	0.15	0.11	0.14	0.19	0.12	0.14	0.17	0.15		
	C.D. (%)	0.64	0.32	0.46	0.33	0.43	0.58	0.35	0.42	0.52	0.45		

Values in parenthesis are $\sqrt{x+0.5}$ transformed

Means followed by same alphabet in columns did not differ significantly (p=0.05) by DMRT

evaluated for managing whitefly infestations on *Bt*-cotton. Plots treated with Spinetoram 11.7 SC, Diafenthiuron 50 WP, Dinotefuran 20 SG and Flonicamid 50 WG exhibited comparable results in controlling whitefly incidence following the application of sprays (Table 5). However, the Flonicamid 50 WG recorded the lowest whiteflies incidence (3.29/ 3 leaves) after three sprays with highest reduction over control (82.43%) followed by the plot treated with Dinotefuran 20 SG (4.34/ 3 leaves), Spinetoram 11.7 SC (4.79/ 3 leaves) and Diafenthiuron 50 WP (4.80/ 3 leaves) with 76.82, 74.41 and 74.36 per cent population reduction over control, respectively. Further, control or untreated plots recorded the highest whiteflies incidence (18.72/ 3 leaves) after three sprays. Our research results are corroborated with the findings of Sasikumar *et al.* (2018), as they recorded lowest whiteflies (0.9 /3 leaves and 0.97 /3 leaves during 2014-15 and 2015-16, respectively) in Flonicamid sprayed

Table 5. Comparative bioefficacy of different insecticides against whiteflies in *Bt*-cotton under field conditions during 2022-23.

Treatment number	Treatments	Pre-Count	Number of whiteflies / 3 leaves									Average	Reduction over control(%)
			First spray			Second spray			Third spray				
			3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
T1	Spinetoram	14.85	5.69	0.37	7.73	1.40	0.00	6.38	1.67	3.56	6.26	4.79	74.41
	11.7 SC	(3.92)[a]	(2.49)[a]	(0.93)[ab]	(2.87)[a]	(1.38)[ab]	(0.71)[a]	(2.62)[a]	(1.47)[a]	(1.98)[b]	(2.60)[b]		
T2	Pyriproxyfen	14.25	10.79	5.01	12.25	5.90	4.22	10.93	6.42	3.82	1.16	7.48	60.07
	10 EC	(3.84)[a]	(3.36)[b]	(2.35)[c]	(3.57)[b]	(2.53)[c]	(2.17)[b]	(3.38)[b]	(2.63)[b]	(2.08)[b]	(1.29)[a]		
T3	Dinotefuran	14.05	6.42	1.10	8.46	2.13	0.52	7.11	2.40	0.00	1.21	4.34	76.82
	20 SG	(3.81)[a]	(2.63)[a]	(1.26)[ab]	(2.99)[a]	(1.62)[ab]	(1.01)[a]	(2.76)[a]	(1.70)[a]	(0.71)[a]	(1.31)[a]		
T4	Spiromesifen	12.55	9.81	4.49	11.85	5.52	3.91	10.50	5.79	3.12	5.28	7.28	61.10
	22.9 SC	(3.61)[a]	(3.21)[b]	(2.23)[c]	(3.51)[b]	(2.45)[c]	(2.10)[b]	(3.32)[b]	(2.51)[b]	(1.90)[b]	(2.40)[b]		
T5	Diafenthiuron	15.92	6.78	1.46	8.82	2.49	0.88	7.47	2.76	0.09	1.32	4.80	74.36
	50 WP	(4.05)[a]	(2.70)[a]	(1.40)[b]	(3.05)[a]	(1.73)[b]	(1.17)[a]	(2.82)[a]	(1.81)[a]	(0.77)[a]	(1.35)[a]		
T6	Flonicamid	12.92	4.96	0.00	7.00	0.67	0.00	5.65	0.94	0.00	0.76	3.29	82.43
	50 WG	(3.66)[a]	(2.34)[a]	(0.71)[a]	(2.74)[a]	(1.08)[a]	(0.71)[a]	(2.48)[a]	(1.20)[a]	(0.71)[a]	(1.12)[a]		
T7	Imidacloprid	14.54	11.04	5.26	12.50	6.15	4.47	11.18	6.67	4.07	6.51	8.24	55.99
	17.8 SL	(3.88)[a]	(3.40)[b]	(2.40)[c]	(3.61)[b]	(2.58)[c]	(2.23)[b]	(3.42)[b]	(2.68)[b]	(2.14)[b]	(2.65)[b]		
T8	Control	12.17	14.92	16.33	17.36	20.31	17.84	21.15	21.53	22.54	23.03	18.72	0.00
		(3.56)[a]	(3.93)[d]	(4.10)[d]	(4.23)[c]	(4.56)[d]	(4.28)[c]	(4.65)[c]	(4.69)[c]	(4.80)[c]	(4.85)[c]		
	S. Em (±)	0.25	0.15	0.21	0.12	0.19	0.22	0.14	0.21	0.25	0.27		
	CD (%)	0.75	0.45	0.62	0.36	0.56	0.66	0.42	0.63	0.74	0.82		

Values in parenthesis are $\sqrt{x+0.5}$ transformed

Means followed by same alphabet in columns did not differ significantly (p=0.05) by DMRT plots as compared to all other treatments. Similarly, Nemade *et al*. (2017) and Gaurkhede *et al.* (2015) also recorded that the Flonicamid 50 WG and Dinotefuran 20 SG was effective in managing all the sucking pest of *Bt*-cotton as compared to other insecticides treatments. Similar results also recorded by Sreekanth and Reddy (2011), Zala *et al.* (2014), Bajya *et al.* (2016), Chandi *et al*. (2016), Nemade *et al*. (2015), Sreenivas *et al*. (2015), Navi *et al*. (2021), Kumar and Sharma (2023).

Comparative bioefficacy of insecticides on yield parameters and yield of *Bt*-cotton

The good open bolls (GOB's) observation made at the time of harvest recorded that the highest good opened bolls in the treatment sprayed with Flonicamid 50 WG (40.16/ plant) which was on par with the treatment sprayed with Spinetoram 11.7 SC (39.80/ plants), Dinotefuran 20 SG (39.52/plant) and Diafenthiuron 50 WP (39.35/ plant). The control recorded with lowest good opened bolls (8.12/ plant) and showed significantly inferior as compared to all the other treatments. However, lowest bad opened bolls were recorded in the treatment sprayed with Flonicamid 50 WG (12.83/ plant) which was on par with the treatment sprayed with Spinetoram 11.7 SC (13.19/ plants), Dinotefuran 20 SG (13.47/ plant) and Diafenthiuron 50 WP (13.98/ plant). The control recorded with highest bad opened bolls (44.01/ plant) and showed significantly inferior as compared to all the other treatments. The locule damage (%) observation made at the time of harvest recorded that the lowest locule damage in the treatment sprayed with Flonicamid 50 WG (24.21 %) which was on par with the treatment sprayed with Spinetoram 11.7 SC (24.89%), Dinotefuran 20 SG (25.42%) and Diafenthiuron 50 WP (26.21%). The control recorded with highest locule damage (84.42%) and showed significantly inferior as compared to all the other treatments (Table 6).

The seed cotton yield among the different insecticides sprayed three times at 15 days interval against major sucking pests of *Bt*-cotton found that the highest seed cotton was obtained from the treatment sprayed with Flonicamid 50 WG (19.41 q/ha) which was on par with the treatment sprayed with Spinetoram 11.7 SC (18.68 q/ha), Dinotefuran 20 SG (18.40 q/ha) and Diafenthiuron 50 WP (198.02 q/ha). Whereas, significantly, lowest seed cotton yield was recorded in control (6.13 q/ha) compared to other treatments (Table 6). Our research findings are in line with findings of Nemade *et al*. (2017), as they recorded Flonicamid 50 WG and Diafenthiuron 50 WP insecticides in managing the major sucking pests of *Bt* cotton effectively with highest seed cotton yield (1681.02 Kg/ha) was obtained from Flonicamid 50 WG followed by Diafenthiuron 50 WP (1222.84 Kg/ha). Gaurkhede *et al.* (2015) also recorded Flonicamid 50 WG and Dinotefuran 20 SG in managing all the sucking pest of *Bt* cotton and recorded highest cotton yield.

Cost economics

Among the different insecticide treatments, the treatment sprayed with Flonicamid 50 WG recorded highest net returns (₹ 53,540.00 / ha) and B:C ratio (1.85). This followed by the treatment sprayed with Dinotefuran 20 SG, Diafenthiuron 50 WP and Spinetoram 11.7 SC recorded the net returns of 50173, 43647 and 37630 ₹ /ha, respectively with the B: C ratio of 1.83, 1.68 and 1.51, respectively (Table 7).

Overall, Flonicamid 50 WG emerged as the most cost-effective option, underscoring its potential as a key solution for managing sucking pests in *Bt*-cotton cultivation. Flonicamid is a systemic insecticide that works by inhibiting the feeding of pests like thrips, leaf hopper, aphids and whiteflies. It belongs to the pyridinecarboxamide class of chemistry and is a member of a new group of insecticides called chordotonal organ modulators (IRAC class 29). The primary insecticidal mechanism of Flonicamid is starvation, achieved through the inhibition of stylet penetration into plant tissues. This interference disrupts insect chordotonal organs responsible for functions such as hearing, balance, and movement, ultimately leading to the cessation of feeding. For instance, when aphids treated with Flonicamid attach their heads to a leaf surface, both salivation and sap feeding are significantly hindered. Flonicamid effectively controls target pests through both contact and ingestion, inducing rapid and irreversible cessation of feeding. It is commonly available as wettable granules to be mixed with water prior to application via spraying. Importantly, Flonicamid

Table 6. Comparative bioefficacy of different insecticides on yield parameters and seed cotton yield

Treatment number	Treatments	Good opened bolls (No. /plant)	Bad opened bolls (No. /plant)	Locule damage (%)	Yield q/ha)	Yield increase over control (%)
T1	Spinetoram 11.7 SC	39.80 (6.35)[a]	13.19 (3.70)[a]	24.89 (29.93)[a]	18.68 (4.38)[a]	67.18
T2	Pyriproxyfen 10 EC	33.95 (5.87)[b]	18.18 (4.32)[b]	34.87 (36.20)[b]	14.68 (3.90)[b]	58.24
T3	Dinotefuran 20 SG	39.52 (6.33)[a]	13.47 (3.74)[a]	25.42 (30.28)[a]	18.40 (4.35)[a]	66.68
T4	Spiromesifen 22.9 SC	28.84 (5.42)[c]	23.29 (4.88)[c]	44.68 (41.94)[c]	11.85 (3.51)[c]	48.27
T5	Diafenthiuron 50 WP	39.35 (6.31)[a]	13.98 (3.81)[a]	26.21 (30.80)[a]	18.02 (4.30)[a]	65.98
T6	Flonicamid 50 WG	40.16 (6.38)[a]	12.83 (3.65)[a]	24.21 (29.48)[a]	19.41 (4.46)[a]	68.42
T7	Imidacloprid 17.8 SL	34.25 (5.89)[b]	17.88 (4.29)[b]	34.30 (35.85)[b]	14.82 (3.91)[b]	58.64
T8	Control	8.12 (2.94)[d]	44.01 (6.67)[d]	84.42 (66.75)[d]	6.13 (2.57)[d]	0.00
	S.Em (±)	0.11	0.14	1.15	0.11	
	C.D (%)	0.33	0.42	3.45	0.34	

Values in parenthesis are √x+0.5 transformed (Except locule damage, which is arcsine transformed)
Means followed by same alphabet in columns did not differ significantly (p=0.05) by DMRT

Table 7. Cost economics of different treatments imposed against major sucking pest of *Bt*-cotton

Treatment number	Treatments	Seed cotton yield (q/ ha)	Cost of protection (₹)	Cost of production (₹)	Total cost of cultivation (₹)	Market value (₹)	Gross returns (₹ / ha)	Net Returns (₹ / ha)	B: C Ratio
T1	Spinetoram 11.7 SC	18.68	16450	58000	74450	6000	112080	37630	1.51
T2	Pyriproxyfen 10 EC	14.68	3840	58000	61840	6000	88080	26240	1.42
T3	Dinotefuran 20 SG	18.40	2227	58000	60227	6000	110400	50173	1.83
T4	Spiromesifen 22.9 SC	11.85	12222	58000	70222	6000	71100	878	1.01
T5	Diafenthiuron 50 WP	18.02	6473	58000	64473	6000	108120	43647	1.68
T6	Flonicamid 50 WG	19.41	4920	58000	62920	6000	116460	53540	1.85
T7	Imidacloprid 17.8 SL	14.82	1459	58000	59459	6000	88920	29461	1.50
T8	Control	6.13	0	58000	58000	6000	36780	-21220	0.63

mode of action differs from that of other insecticides, such as neonicotinoids, pymetrozine, and pyrifluquinazon. Additionally, there have been no reports of cross-resistance between Flonicamid and other conventional insecticides.

Conclusion

The findings of this comprehensive study shed light on the diverse efficacy levels exhibited by various insecticides against thrips, jassids, aphids, and whiteflies infesting *Bt*-cotton fields during the 2022-23 season. Notably, Flonicamid 50 WG emerged as a standout performer across all pest types, showcasing remarkable efficacy. Alongside other promising options like Dinotefuran 20 SG, Spinetoram 11.7 SC and Diafenthiuron 50 WP against thrips; Dinotefuran 20 SG and Spinetoram 11.7 SC against leaf hopper; Pyriproxyfen 10 EC, Diafenthiuron 50 WP and Dinotefuran 20 SG against aphids and whiteflies management in *Bt* cotton which suggests the potential for improved pest management strategies in *Bt*-cotton cultivation. By leveraging these findings to optimize insecticide selection and application practices, growers can mitigate pest pressures more effectively, leading to enhanced crop productivity and quality in *Bt*-cotton. Additional investigation and on-site validation are necessary to delve into the enduring efficacy and ecological ramifications of these insecticides, thereby guaranteeing the adoption of sustainable pest management strategies within agricultural environments.

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