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Bioefficacy of different insecticides on pink bollworm against *Bt* cotton

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Abstract: The field trial for evaluation of various against cotton pink bollworm was conducted at Main Agricultural Research Station (MARS), Raichur during 2020-21. Among all the treatments, Chlorantraniliprole 18.5 SC (150 ml/ha) sprayed plots showed significant reductions in pink bollworm larval incidence and green boll damage of 74.32 and 77.34 per cent over the untreated control, respectively. Similarly, highest seed cotton yield (16.86 q/ha) was recorded in the Chlorantraniliprole 18.5 SC sprayed plots with highest net returns (35327 ₹ /ha) and B: C ratio of 1.47 followed by Emamectin benzoate sprayed plots with net returns of 26208 ₹ /ha and B: C ratio of 1.42. Overall, Chlorantraniliprole 18.5 SC followed by Emamectin benzoate 5 SG demonstrated effective pest control and emerged as the most economically viable option, considering its higher net returns and better B:C ratio. Hence present findings are helpful for decision making while managing pink bollworm with insecticides.

Key words: Bioefficacy, *Bt*-cotton, Cost economics, Insecticides, Pink bollworm, Yield

Introduction

Cotton stands as a crucial fibre crop with a global reach, thriving in over 70 tropical and sub-tropical countries (Chakravarthy *et al*., 2014). India is an important cotton grower among all the cotton producing countries in the world and ranks first in area (129.57 lakh ha) with production of 371 lakh bales of 170 kg each with productivity of 487 kg lint/ha (Anonymous, 2021). The cultivation landscape in India spans three distinct agro-ecological zones - North, Central and South (Kranthi *et al*., 2001 and Gopalakrishnan *et al*., 2007). However, cotton production grapples with numerous biotic and abiotic stresses, including the notorious bollworm complex and sucking pests (Kranthi *et al*., 2002). Among these, the pink bollworm, *Pectinophora gossypiella*, has emerged as a significant threat to Indian cotton production (Dhurua and Gujar, 2011). Originating from the Indo-Pak region, it has spread widely across tropical regions worldwide, wherever cotton grows. This stenophagous insect feasts on malvaceous hosts like cotton, okra, deccan hemp, and roselle (CABI, 2017), wreaking havoc by devouring flowers, buds, bolls, and seeds, leading to malformation, premature opening, and heavy shedding of infested bolls. The resulting damage includes reduced fibre length and lint quality due to staining (Singh *et al*., 1988), causing yield losses ranging from 20% to a staggering 90% (Patil, 2003). The pink bollworm (PBW) remained consistently active on cotton year-round, with peak activity observed from the third week of October through the second week of December (Naik *et al*., 1996). Recent years have witnessed the pink bollworm's resilience, as it developed resistance to *Bt*-cotton in India, posing significant challenges to crop health (Kranthi, 2015). Initially effective in controlling the pest, *Bt* cotton expressing Cry1Ac toxin succumbed to the pink bollworm resistance (Dhurua and Gujar, 2011; Mohan *et al*., 2012; Ojha *et al*., 2014 and Naik *et al*., 2018), mirroring the plight faced in India (Naik *et al*., 2018). Traditional insecticide strategies, once relied upon heavily, have been thwarted by the emergence of resistance among insect species, exacerbating the complexities of pest management. This resistance not only renders insecticides ineffective but also necessitates repeated applications, contributing to environmental pollution (Kranthi, 2007). Moreover, the continued reliance on *Bt* formulations may further exacerbate resistance issues, akin to insecticide resistance in field conditions (Tabashnik *et al*., 2009).

With these perspectives in mind, it becomes crucial to assess the effectiveness of various insecticides in combating pests to ensure efficient pest management while minimizing the indiscriminate application of insecticides. Hence, this study was undertaken to evaluate the efficacy of different insecticides against the pink bollworm in *Bt* cotton.

Material and methods

A field experiment was conducted at the Entomology block of MARS, Raichur during 2020-21 by employing a Randomized Block Design (RBD) comprising 10 treatments (Table 1) and four replications. The *Bt* cotton hybrid "Jadoo (KCH-14K59)" was sown with a spacing of 90 cm between rows and 60 cm between plants, following recommended agronomical practices (Anonymous, 2020). Treatments were implemented at 15-day intervals across different treatment blocks: 60, 75, 90 and 105 days after sowing (DAS), as a preventive measure. Observations on the number of larvae per 10 bolls were recorded at 7 and 14 days after spraying (DAS). Additionally, metrics such as percent locule damage, the count of good opened bolls (GOB's) and bad opened bolls (BOB's) per plant, and seed cotton yield were assessed at harvest time. Seed cotton picking was performed based on plot dimensions (7.4 × 5.0 m), with the yield recorded in kilograms per plot. The total yield from all pickings in each plot was aggregated to compute the hectare-based yield. The formula for estimating green boll damage, GOB, BOB and locule damage is given below.

$$\text{Per cent green ball damage} = \frac{\text{No. of damaged green bolls}}{\text{Total no of green bolls}} \times 100$$

$$\text{Per cent good opened boll damaged (\%)} = \frac{\text{Total no.of GOB's/plant}}{\text{Total opened bolls/plant}} \times 100$$

$$\text{Per cent bad opened boll damage (\%)} = \frac{\text{Total no of BOB's /plant}}{\text{Total opened bolls/plant}} \times 100$$

$$\text{Per cent locule damage (\%)} = \frac{\text{Damaged Locules}}{\text{Total no of Locules}} \times 100$$

The data obtained in the experiments under current investigation for various parameters such as number of larvae, per cent green boll damage, number of good opened bolls, number of bad opened bolls, per cent 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 study assessed the relative effectiveness of various insecticides against pink bollworm affecting *Bt*-cotton. The research revealed a notable reduction in the prevalence of pink bollworm across all treated plots compared to the untreated control. However, the efficacy in controlling PBW demonstrated variability contingent upon the specific insecticide utilized and the findings of the study are outlined below.

Bioefficacy of various insecticides on pink bollworm larval incidence in *Bt*-cotton

The outcomes of this investigation unveil varying degrees of effectiveness among the tested insecticides against pink bollworm infestation in *Bt*-cotton fields. The plots treated with Chlorantraniliprole 18.5 SC recorded lowest mean incidence of pink bollworm (3.26 larvae/ 10 bolls), with highest larval reduction over control (74.32%), which was on par with the treatments sprayed with Indoxacarb 14.5 SC (3.37 larvae/ 10 bolls), Spinosad 45 SC (3.45 larvae/ 10 bolls), Spinetoram 11.7 SC(3.49 larvae/ 10 bolls), Flubendiamide 39.35 SC (3.53 larvae/ 10 bolls), Pyridalyl 10 EC (3.74 larvae/ 10 bolls) and Emamectin benzoate 5 SG (3.85 larvae/ 10 bolls) with PBW incidence reduction over control was 73.47, 72.80, 72.50, 72.21, 70.57 and 69.69 percent, respectively. However, highest larval incidence was recorded in untreated control (12.70 larvae/ 10 bolls) and lowest reduction over control was recorded in the Profenofos 50 EC (58.63%) treated plots (Table 2).

The present findings on larval population of *P. gossypiella* per twenty bolls are in line with the results of Divya *et al.* (2020), who found that the chlorantraniliprole 18.5 SC recorded the lowest larval population with highest reduction over control (71.00%). Similarly, our findings are corroborated with the results of Bhute *et al.* (2023) and Pathan *et al.* (2021) as they recorded lowest larval incidence of 3.67 and 3.09/ 20 bolls, respectively in chlorantraniliprole 18.5 SC treated plots as compared to all other treatments.

Bioefficacy of various insecticides on green boll damage caused by pink bollworm in *Bt*-cotton

Similar to the pink bollworm larval incidence, the green boll damage caused by pink bollworm was reduced in all the treatments sprayed with insecticides as compared to untreated control. The plots treated with Chlorantraniliprole 18.5 SC recorded lowest mean green boll damage caused by pink bollworm (16.5%), with highest reduction over control (77.34%), which was on par with the treatments sprayed with Spinosad 45 SC (16.62%), Spinetoram 11.7 SC (16.75%), Indoxacarb 14.5 SC (17.14 %), Flubendiamide 39.35 SC (17.54 %), Emamectin benzoate 5 SG (17.74%) and Pyridalyl 10 EC (18.25%) with PBW green boll damage reduction over control was 77.20, 77.02, 76.48, 75.94, 75.66 and 74.95 percent, respectively. However, highest green boll damage was recorded in untreated control (72.88%) and lowest reduction over control was recorded in the Profenofos 50 EC (65.15%) treated plots (Table 3). The present findings are in line with the findings of Bhute *et al.* (2023), Pathan *et al.* (2021) and Sarode *et al.* (2019) as they recorded lowest green boll damage of 11.33, 8.78 and 3.50 per cent in chlorantraniliprole 18.5 SC treated *Bt* cotton plots as compared to all other treatments.

Good opened bolls (GOB's), Bad opened bolls (BOB's) and Locule damage (LD)

Good opened bolls were increased in all the treatments sprayed with insecticides as compared to untreated control.

Table 1. Treatment details of various insecticides in pink bollworm management

Sl. No.	Treatment details	Trade name	Dosage (ml or gm per ha)	Cost of Insecticide
T1	Bifenthrin 10 EC	Talstar	800	1200 ₹ / 1000 ml
T2	Cypermethrin 25 EC	Cype	200	605 ₹ / 1000 ml
T3	Fenpropathrin 10 EC	Danitol	800	950 ₹ / 1000 ml
T4	Profenofos 50 EC	Curacron	2000	870 ₹ / 1000 ml
T5	Spinetoram 11.7 SC	Delegate	420	2350 ₹ /180 ml
T6	Flubendiamide 39.35 SC	Fame	100	1097 ₹ / 50 ml
T7	Indoxacarb 14.5 SC	Avaunt	500	1054 ₹ / 250 ml
T8	Chlorantraniliprole 18.5 SC	Coragen	150	1097 ₹ / 60 mL
T9	Spinosad 45 SC	Tracer	165	1829 ₹ / 75 ml
T10	Emamectin benzoate 5 SG	Kita Kata	220	440 ₹ /100 g
T11	Pyridalyl 10 EC	Sumipleo	750	779 ₹ / 250 ml
T12	Control	-	-	-

Table 2. Effect of different insecticide treatments on larval incidence of pink bollworm in *Bt* cotton

Sl. No.	Treatment details	Pink bollworm larval count (Number/ 10 bolls)									Mean	% Reduction over control
		Precount	First spray		Second spray		Third spray		Fourth spray			
			7 DAS	14 DAS	7 DAS	14 DAS	7 DAS	14 DAS	7 DAS	14 DAS		
T1	Bifenthrin 10 EC	10.00 (3.24)[a]	8.00 (2.92)[b]	6.68 (2.68)[b]	6.00 (2.55)[b]	5.33 (2.41)[b]	4.33 (2.20)[b]	2.00 (1.58)[b]	1.77 (1.51)[b]	1.52 (1.42)[b]	5.07	60.08
T2	Cypermethrin 25 EC	10.00 (3.24)[a]	8.33 (2.97)[b]	6.68 (2.68)[b]	6.33 (2.61)[b]	5.00 (2.35)[b]	4.33 (2.20)[b]	2.33 (1.68)[b]	2.10 (1.61)[b]	1.85 (1.53)[b]	5.22	58.92
T3	Fenpropathrin 10 EC	10.34 (3.29)[a]	7.67 (2.86)[b]	6.33 (2.61)[b]	5.67 (2.48)[b]	4.67 (2.27)[b]	4.00 (2.12)[b]	1.67 (1.47)[b]	1.44 (1.39)[b]	1.19 (1.30)[b]	4.78	62.40
T4	Profenofos 50 EC	9.34 (3.14)[a]	8.33 (2.97)[b]	7.00 (2.74)[b]	6.34 (2.62)[b]	5.33 (2.41)[b]	4.67 (2.27)[b]	2.33 (1.68)[b]	2.10 (1.61)[b]	1.85 (1.53)[b]	5.25	58.63
T5	Spinetoram 11.7 SC	9.00 (3.08)[a]	6.33 (2.61)[a]	5.00 (2.35)[a]	4.67 (2.27)[a]	3.33 (1.96)[a]	2.67 (1.78)[a]	0.33 (0.91)[a]	0.10 (0.77)[a]	0.00 (0.71)[a]	3.49	72.50
T6	Flubendiamide 39.35 SC	9.00 (3.08)[a]	6.33 (2.61)[a]	5.33 (2.41)[a]	4.33 (2.20)[a]	3.67 (2.04)[a]	2.67 (1.78)[a]	0.33 (0.91)[a]	0.10 (0.77)[a]	0.00 (0.71)[a]	3.53	72.21
T7	Indoxacarb 14.5 SC	9.34 (3.14)[a]	6.00 (2.55)[a]	5.00 (2.35)[a]	4.33 (2.20)[a]	3.33 (1.96)[a]	2.33 (1.68)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	3.37	73.47
T8	Chlorantraniliprole 18.5 SC	9.34 (3.14)[a]	6.00 (2.55)[a]	4.68 (2.28)[a]	4.00 (2.12)[a]	3.00 (1.87)[a]	2.33 (1.68)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	3.26	74.32
T9	Spinosad 45 SC	9.00 (3.08)[a]	6.33 (2.61)[a]	5.00 (2.35)[a]	4.33 (2.20)[a]	3.33 (1.96)[a]	2.67 (1.78)[a]	0.33 (0.91)[a]	0.10 (0.77)[a]	0.00 (0.71)[a]	3.45	72.80
T10	Emamectin benzoate 5 SG	10.00 (3.24)[a]	6.67 (2.68)[a]	5.33 (2.41)[a]	4.67 (2.27)[a]	3.67 (2.04)[a]	3.00 (1.87)[a]	0.67 (1.08)[a]	0.44 (0.97)[a]	0.19 (0.83)[a]	3.85	69.69
T11	Pyridalyl 10 EC	9.00 (3.08)[a]	6.67 (2.68)[a]	5.33 (2.41)[a]	4.67 (2.27)[a]	3.67 (2.04)[a]	3.00 (1.87)[a]	0.67 (1.08)[a]	0.44 (0.97)[a]	0.19 (0.83)[a]	3.74	70.57
T12	Control	10.34 (3.29)[a]	11.00 (3.39)[c]	13.33 (3.72)[c]	12.67 (3.63)[c]	11.33 (3.44)[c]	12.67 (3.63)[c]	14.33 (3.85)[c]	14.10 (3.82)[c]	14.55 (3.88)[c]	12.70	0.00
S.Em (±)		0.12	0.05	0.06	0.06	0.11	0.12	0.15	0.12	0.15		
C D @ p=0.05		0.36	0.15	0.18	0.18	0.33	0.36	0.45	0.36	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

The plots treated with Chlorantraniliprole 18.5 SC recorded highest average good opened bolls (39.25/ plant), with lowest bad opened bolls (14.98/ plant) and locule damage of 26.27 percent. However, lowest good opened bolls (6.42/ plant), with highest bad opened bolls (47.81/ plant) and locule damage of 86.81 per cent was recorded in untreated control (Table 4). These results are in line with the research outcome of Divya *et al.* (2020) as they recorded lowest bad opened bolls (10.80/ plant) and locule damage (18.89%) with highest good opened bolls of 10.80 per plant in chlorantraniliprole 18.5 SC treated plots as compared to all other treatments. Similar results were also noticed by Bhute *et al*. (2023), Pathan *et al*. (2021), Sarode *et al*. (2019), Manikrao (2017), Naik *et al*. (2015) and Bajya *et al*. (2015).

Yield and cost economics

The plots treated with Chlorantraniliprole 18.5 SC recorded highest cotton yield (16.86 q/ha), with highest yield increase over control (72.95%) followed by the treatment sprayed with Spinosad 45 SC (15.02 q/ha) which was on par with the treatments, Spinetoram 11.7 SC (14.92 q/ha), Emamectin benzoate 5 SG (14.68 q/ha), Indoxacarb 14.5 SC (14.65 q/ha), Flubendiamide 39.35 SC (14.45 q/ha) and Pyridalyl 10 EC (14.25 q/ha) with yield increase over control was 69.64, 69.44, 68.94, 68.87, 68.44 and 68.00 per cent, respectively. However, lowest cotton yield (4.56 q/ha) was recorded in untreated control (Table 5). Among the different insecticide treatments, the treatment sprayed with Chlorantraniliprole 18.5 SC recorded highest net returns (32,190 ₹ / ha) and B:C ratio (1.47). This followed by the treatment sprayed with Emamectin benzoate 5 SG, Indoxacarb 14.5 SC, Spinetoram 11.7 SC and Flubendiamide 39.35 SC recorded the net returns of 26208, 21468, 20550 and 19924 ₹ /ha, respectively with the B: C ratio of 1.42, 1.32, 1.30 and 1.30, respectively. The present findings on seed cotton yield corroborate with the results of Divya *et al.* (2020) who reported highest seed cotton yield of 20.02 q/ha in chlorantraniliprole 18.5 SC. Similar results were also noticed by Bhute *et al.* (2023), Pathan *et al.* (2021) and Sarode *et al.* (2019) as they recorded highest cotton yield of 20.05, 20.45 and 12.46 q/ha in chlorantraniliprole 18.5 SC treated plots as compared to other treatments.

Chlorantraniliprole, an insecticide categorized under the anthranilic diamide class, operates by targeting the ryanodine receptors (RyRs) found in the muscles of insects. These receptors play a pivotal role in regulating calcium release within muscle cells, essential for facilitating muscle contraction. When chlorantraniliprole binds to the RyRs in PBW muscle cells, it induces prolonged activation of these receptors, resulting in the uncontrolled release of calcium ions from intracellular stores. This disruption severely impairs muscle function, eventually leading to paralysis. The paralysis caused by chlorantraniliprole has far-reaching effects on the pink bollworm's ability to feed and move effectively. With their

Table 3. Effect of different insecticide treatments on green boll damage caused by pink bollworm in *Bt* cotton

Sl. No.	Treatment details	Precount	Green boll damage (%)								Mean	% Reduction Over control
			First spray		Second spray		Third spray		Fourth spray			
			7 DAS	14 DAS	7 DAS	14 DAS	7 DAS	14 DAS	7 DAS	14 DAS		
T1	Bifenthrin 10 EC	58.35	38.65	31.22	25.54	20.90	15.28	10.92	9.47	8.61	24.33	66.62
		(49.81)^{a}	(38.44)^{b}	(33.97)^{b}	(30.36)^{b}	(27.20)^{b}	(23.01)^{b}	(19.30)^{b}	(17.92)^{b}	(17.06)^{b}		
T2	Cypermethrin 25 EC	58.64	39.14	31.71	26.03	21.39	15.77	11.41	9.96	9.10	24.79	65.98
		(49.98)^{a}	(38.73)^{b}	(34.27)^{b}	(30.68)^{b}	(27.55)^{b}	(23.40)^{b}	(19.74)^{b}	(18.40)^{b}	(17.56)^{b}		
T3	Fenpropathrin 10 EC	60.52	38.13	30.70	25.02	20.38	14.76	10.40	8.95	8.09	24.11	66.92
		(51.07)^{a}	(38.13)^{b}	(33.65)^{b}	(30.01)^{b}	(26.84)^{b}	(22.59)^{b}	(18.81)^{b}	(17.41)^{b}	(16.52)^{b}		
T4	Profenofos 50 EC	55.05	40.25	32.82	27.14	22.50	16.88	12.52	11.07	10.21	25.38	65.17
		(47.90)^{a}	(39.38)^{b}	(34.95)^{b}	(31.40)^{b}	(28.32)^{b}	(24.26)^{b}	(20.72)^{b}	(19.43)^{b}	(18.63)^{b}		
T5	Spinetoram 11.7 SC	53.35	30.85	23.42	17.74	13.10	7.48	3.12	1.67	0.00	16.75	77.02
		(46.92)^{a}	(33.74)^{a}	(28.94)^{a}	(24.91)^{a}	(21.22)^{a}	(15.87)^{a}	(10.17)^{a}	(7.43)^{a}	(0.00)^{a}		
T6	Flubendiamide 39.35 SC	54.85	31.65	24.22	18.54	13.90	8.28	3.92	2.47	0.00	17.54	75.94
		(47.78)^{a}	(34.23)^{a}	(29.48)^{a}	(25.50)^{a}	(21.89)^{a}	(16.72)^{a}	(11.42)^{a}	(9.04)^{a}	(0.00)^{a}		
T7	Indoxacarb 14.5 SC	56.74	31.15	23.72	18.04	13.40	7.78	3.42	0.00	0.00	17.14	76.48
		(48.87)^{a}	(33.93)^{a}	(29.15)^{a}	(25.13)^{a}	(21.47)^{a}	(16.20)^{a}	(10.66)^{a}	(0.00)^{a}	(0.00)^{a}		
T8	Chlorantraniliprole 18.5 SC	56.49	30.25	22.82	17.14	12.50	6.88	2.52	0.00	0.00	16.51	77.34
		(48.73)^{a}	(33.37)^{a}	(28.54)^{a}	(24.46)^{a}	(20.70)^{a}	(15.21)^{a}	(9.13)^{a}	(0.00)^{a}	(0.00)^{a}		
T9	Spinosad 45 SC	54.85	30.68	23.25	17.57	12.93	7.31	2.95	0.00	0.00	16.62	77.20
		(47.78)^{a}	(33.63)^{a}	(28.83)^{a}	(24.78)^{a}	(21.07)^{a}	(15.69)^{a}	(9.89)^{a}	(0.00)^{a}	(0.00)^{a}		
T10	Emamectin benzoate 5 SG	58.37	31.24	23.81	18.13	13.49	7.87	3.51	2.06	1.20	17.74	75.66
		(49.82)^{a}	(33.98)^{a}	(29.21)^{a}	(25.20)^{a}	(21.55)^{a}	(16.29)^{a}	(10.80)^{a}	(8.25)^{a}	(6.29)^{a}		
T11	Pyridalyl 10 EC	53.46	32.43	25.00	19.32	14.68	9.06	4.70	3.25	2.39	18.25	74.95
		(46.98)^{a}	(34.71)^{a}	(30.00)^{a}	(26.07)^{a}	(22.53)^{a}	(17.52)^{a}	(12.52)^{a}	(10.39)^{a}	(8.89)^{a}		
T12	Control	60.05	63.35	66.65	63.35	69.87	75.34	86.15	84.70	86.46	72.88	
	0.00											
		(50.80)^{a}	(52.74)^{c}	(54.73)^{c}	(52.74)^{c}	(56.71)^{c}	(60.23)^{c}	(68.15)^{c}	(66.97)^{c}	(68.41)^{c}		
S.Em (±)		1.45	0.82	0.98	0.95	1.28	1.54	1.61	1.54	1.61		
C.D @ p=0.05		4.36	2.46	2.94	2.86	3.85	4.62	4.83	4.62	4.83		

Values in parenthesis are arcsine transformed.Means followed by same alphabet in columns did not differ significantly (p=0.05) by DMRT

Table 4. Effect of different insecticide treatments on cotton yield parameters and seed cotton yield

Sl. No.	Treatment details	Good opened boll (No./plant)	Bad opened boll (No./plant)	Locule damage (%)	Yield (q/ha)	% yield increase over control
T1	Bifenthrin 10 EC	31.43 (5.65)^{b}	22.80 (4.83)^{b}	40.69 (39.63)^{b}	12.65 (3.63)^{b}	63.95
T2	Cypermethrin 25 EC	30.84 (5.60)^{b}	23.39 (4.89)^{b}	41.77 (40.27)^{b}	12.14 (3.56)^{b}	62.44
T3	Fenpropathrin 10 EC	31.94 (5.70)^{b}	22.29 (4.77)^{b}	39.75 (39.08)^{b}	12.86 (3.66)^{b}	64.54
T4	Profenofos 50 EC	30.12 (5.53)^{b}	24.11 (4.96)^{b}	43.10 (41.04)^{b}	11.95 (3.53)^{b}	61.84
T5	Spinetoram 11.7 SC	38.46 (6.24)^{a}	15.77 (4.03)^{a}	27.72 (31.77)^{a}	14.92 (3.93)^{a}	69.44
T6	Flubendiamide 39.35 SC	37.85 (6.19)^{a}	16.38 (4.11)^{a}	28.85 (32.49)^{a}	14.45 (3.87)^{a}	68.44
T7	Indoxacarb 14.5 SC	37.15 (6.14)^{a}	17.08 (4.19)^{a}	30.14 (33.30)^{a}	14.65 (3.89)^{a}	68.87
T8	Chlorantraniliprole 18.5 SC	39.25 (6.30)^{a}	14.98 (3.93)^{a}	26.27 (30.83)^{a}	16.86 (4.17)^{a}	72.95
T9	Spinosad 45 SC	38.69 (6.26)^{a}	15.54 (4.00)^{a}	27.30 (31.50)^{a}	15.02 (3.94)^{a}	69.64
T10	Emamectin benzoate 5 SG	37.04 (6.13)^{a}	17.19 (4.21)^{a}	30.34 (33.42)^{a}	14.68 (3.90)^{a}	68.94
T11	Pyridalyl 10 EC	36.16 (6.05)^{a}	18.07 (4.31)^{a}	31.96 (34.43)^{a}	14.25 (3.84)^{a}	68.00
T12	Control	6.42 (2.63)^{c}	47.81 (6.95)^{c}	86.81 (68.70)^{c}	4.56 (2.25)^{c}	0.00
S.E m (±)		0.09	0.14	1.42	0.05	
C D @ p=0.05		0.28	0.42	4.25	0.16	

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

muscles incapacitated, these insects struggle to inflict damage on crops, notably cotton plants in the case of pink bollworms. Moreover, chlorantraniliprole exhibits larvicidal and ovicidal properties, making it effective against both pink bollworm larvae and eggs. Upon contact or ingestion, it can swiftly eliminate larvae and prevent the hatching of eggs or kill newly hatched larvae. Additionally, chlorantraniliprole demonstrates systemic activity within plants, enabling absorption and translocation to various tissues. This systemic action provides protection to different plant parts, including those not directly treated with the insecticide. Overall, by disrupting the normal physiological processes in pink bollworms, chlorantraniliprole effectively induces paralysis, inhibits feeding, and ultimately leads to the demise of these pests. Its multifaceted mode of action positions it as a potent tool for managing pink bollworm populations in agricultural settings.

Table 5. Cost economics of different insecticide treatments imposed against pink bollworm management in *Bt* cotton

	Treatments	Seed cotton yield (q/ ha)	Cost of protection (₹)	Cost of production (₹)	Total cost of cultivation	Market value (₹/q)	Gross returns (₹/ha)	Net returns (₹/ha)	B: C Ratio
T1	Bifenthrin 10 EC	12.65	3840	58000	61840	6000	75900	14060	1.23
T2	Cypermethrin 25 EC	12.14	484	58000	58484	6000	72840	14356	1.25
T3	Fenpropathrin 10 EC	12.86	3040	58000	61040	6000	77160	16120	1.26
T4	Profenofos 50 EC	11.95	6960	58000	64960	6000	71700	6740	1.10
T5	Spinetoram 11.7 SC	14.92	21933	58000	79933	6000	89520	9587	1.12
T6	Flubendiamide 39.35 SC	14.45	8776	58000	66776	6000	86700	19924	1.30
T7	Indoxacarb 14.5 SC	14.65	8432	58000	66432	6000	87900	21468	1.32
T8	Chlorantraniliprole 18.5 SC	16.86	10970	58000	68970	6000	101160	32190	1.47
T9	Spinosad 45 SC	15.02	16095	58000	74095	6000	90120	16025	1.22
T10	Emamectin benzoate 5 SG	14.68	3872	58000	61872	6000	88080	26208	1.42
T11	Pyridalyl 10 EC	14.25	9348	58000	67348	6000	85500	18152	1.27
T12	Control	4.56	0	58000	58000	6000	27360	-30640	0.47

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