



Effect of frequency and time intervention of insecticides on pink bollworm (*Pectinophora gossypiella*) management in *Bt* cotton

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ABSTRACT

The present study was carried out to investigate the frequency and time intervention of different insecticide against pink bollworm (PBW) in *Bt* cotton crops during 2020–21 and 2021–22 at University Agricultural Sciences, Raichur, Karnataka. The experiment was laid in randomised block design (RBD) in four replications having 10 treatments. The *Bt* cotton hybrid 'Jadoo (KCH-14K59)' was used for the study. Pooled data of both the seasons resulted in lowest PBW larval incidence, green boll damage, bad opened bolls, locule damage and highest good opened bolls was documented in the treatment, T₁ i.e. four sprays, viz. profenofos 50 EC, chlorantraniliprole 18.50 SC, emamectin benzoate 5 SG and bifenthrin 10 EC at 65, 80, 95 and 110 DAS), respectively which showed on par with the treatment, T₉ and treatment, T₅. Similarly, highest cotton yield and benefit-cost ratio was obtained from the treatment, T₁ which was on par with the treatment, T₉ and T₅. This highlights effective strategic use of insecticides with varied mode of action, particularly, by following ETL-based sprays or administering four sprays at 15 days interval starting from 65 DAS, can efficiently control PBW infestation. This strategic method of application of insecticides at a particular frequency with time interval boosts seed cotton production by reducing PBW incidence and its damage to *Bt* cotton with increased economic returns, emphasising its practical viability for cotton cultivation.

Keywords: Economic threshold level, Frequency, Green boll damage, Insecticides, Larval incidence

Cotton (*Gossypium* spp.), also known as "white gold" due to its pivotal role in industry, economy, and global trade. It stands as an ancient and paramount commercial crop in India, significantly impacting the nation's economic landscape. Cultivated across 111 nations worldwide (Rakesh and Kathane 1989), India leads in cultivation area at 119.10 lakh ha, boasting a production of 312.03 lakh bales and a productivity rate of 445 kg lint/ha (Anonymous 2022). Notably, *Gossypium hirsutum* contributes to 95% of global cotton yield among the four main cultivated species (Trapero *et al.* 2016).

Most dangerous and devastating pest of cotton bollworm complex is pink bollworm (Parmar and Patel 2016). It attacks both *Bt* and non-*Bt* cotton, due to resistance that has developed on 1st and 2nd generation *Bt* cotton hybrids in India (Dhurua and Gujar 2011, Naik *et al.* 2018), which has resulted in the greatest loss in both quality and quantity of seed cotton. Pink bollworm (PBW) neonate penetrates the young cotton bolls with few minutes to hours after emergence and pinholes of access are sealed off by larval excretions. Hence, difficult to get direct exposure of many

pesticides. Consequently, implementing a pest management strategy tailored to a particular target poses significant challenges. Also, the PBW larvae cause damage to flower, holes on septa between each locules, results in staining of lint and reduced quality cotton lint (Ateel and Karan 2020 and Divya *et al.* 2020). It reduces oil content by 2.10–47.10%, the seed cotton yield by 2.80–61.90% and the green boll damage by 10.00–55.00% (ICAR-CIRCOT 2018). The cotton plant's growth is hampered by partial boll opening, weaker and smaller staples, and an increased debris in the lint (Hassan and Sahfique 2014). In order to control this pest effectively and to prevent the indiscriminate use of insecticides, it is crucial to compare the effectiveness of insecticides against pests. The efficacy of insecticides plays a pivotal role in controlling this notorious pest, influencing both frequency and timing of intervention. Understanding the nuanced impact of these interventions on the pink bollworm's population dynamics and subsequent management is crucial for sustainable and effective pest control strategies in cotton cultivation. This study delves into the intricate relationship between frequency and timing of different insecticide sprays and its effect on managing the pink bollworm in *Bt* cotton fields, shedding light on optimal approaches for efficient pest management while minimising environmental impact and preserving crop health.

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MATERIALS AND METHODS

The present field experiment was conducted during 2020–21 and 2021–22 at Main Agricultural Research Station, University of Agricultural Sciences, Raichur, Karnataka. The experiment was laid in randomised block design (RBD) with four replications and 10 treatments. Treatments were imposed at different frequency and time intervals in different treatment blocks, viz. 65, 80, 95 and 110 days after sowing (DAS) as prophylactic measure and one treatment consisting of Economic threshold level (ETL) based pesticide application (Table 1). The *Bt* cotton hybrid 'Jadoo (KCH-14K59)' in a spacing 90 cm × 60 cm was sown. Four pheromone traps with pectino-lure were installed in block at 30 cm above crop canopy and pheromone lure was changed at every 15 days intervals to monitor the moth activity of PBW. Mean trap catches of about 9–12 for subsequent three days was taken as ETL (Qureshi *et al.* 1993). The observations on number of larvae/10 bolls were recorded at 15 days after last spray (DALS) and 130

DAS. Per cent locule damage, bad opened bolls, good opened bolls per plant and seed cotton yield was recorded at the time of harvest.

Pink bollworm incidence and green boll damage: Observations on the incidence and green boll damage was recorded at 15 DALS and 130 DAS by random collection and cut opening of 10 green bolls. The PBW larval incidence expressed as number of larvae/10 bolls. However, the percentage of green boll damage was calculated as:

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

Good opened boll, bad opened boll and locule damage: Before commencement of each picking, total number of good opened boll (GOB), bad opened boll (BOB) and locule damage was counted on 20 randomly selected plants. Based on this, per cent good or bad opened bolls and locule damage/plant was calculated using the given formula:

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

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

Seed cotton yield and cost economics: Seed cotton picking occurred regularly on a plot-sized basis measuring 7.2 m × 4.8 m. The recorded cotton yield was measured in kg/plot and the cumulative yield from all pickings within each plot was aggregated to determine the yield/ha. The evaluation of insecticide efficacy was based on the cost-effectiveness computed from net returns. Net returns for each treatment were calculated by subtracting the total treatment cost, inclusive of cultivation and plant protection expenses, from the gross returns. The percentage reduction compared to the untreated control was determined utilising a modified Abbot's formula (Fleming and Ratnakaran 1985).

RESULTS AND DISCUSSION

Pink bollworm larval incidence: The efficacy of different insecticides was tested against pink bollworm (PBW) at different intervals with combination of insecticides sprayed at 65, 80, 95 and 110 DAS. During 2020–21, the effect of PBW larvae in cotton bolls on the basis of different frequency and time interval of spray showed that the lowest mean larval incidence of 15 DLAS and 130 DAS was recorded in the treatment, T₁ (1.76 larvae/10 bolls) sprayed with profenofos 50 EC, chlorantraniliprole 18.50 SC, emamectin benzoate 5 SG and bifenthrin 10 EC at 65, 80, 95 and 110 DAS, respectively and treatment, T₉ sprayed with chlorantraniliprole 9.30 + lambda-cyhalothrin 4.60 ZC based on the ETL of the pest, which was on par with the treatment, T₅ (2.01 larvae/10 bolls) sprayed with profenofos 50 EC, chlorantraniliprole 18.50 SC, spinetoram 11.70 SC and fenpropathrin 10.00 EC at 65, 80, 95 and 110 DAS, respectively. Whereas, the treatment T₁₀ without any spray recorded highest larval incidence (13.38 larvae/10 bolls) as compared to all other treatments. Similar trend was followed during 2021–22 with the treatments, T₁ and

Table 1 Treatment details of different insecticides used for management of PBW

Treatments	Dose (g a.i./ha)	Formulation (mL or g/ha)
T ₁ , Profenofos 50 EC (65 DAS)	750	1500
Chlorantraniliprole 18.5 SC (80 DAS)	30	150
Emamectin benzoate 5 SG (95 DAS)	11	229
Bifenthrin 10 EC (110 DAS)	80	800
T ₂ , T ₁ without Chlorantraniliprole 18.5 SC @80 DAS	-	-
T ₃ , T ₁ without Emamectin benzoate 5 SG @95 DAS	-	-
T ₄ , T ₁ without Bifenthrin 10 v @110 DAS	-	-
T ₅ , Profenofos 50 EC (65 DAS)	750	1500
Chlorantraniliprole 18.5 SC (80 DAS)	30	150
Spinetoram 11.7 SC (95 DAS)	56	470
Fenpropathrin 10 EC (110 DAS)	75	750
T ₆ , T ₅ without Chlorantraniliprole 18.5 SC @80 DAS	-	-
T ₇ , T ₅ without Spinetoram 11.7 SC @95 DAS	-	-
T ₈ , T ₅ without Fenpropathrin 10 EC @110 DAS	-	-
T ₉ , Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC	37.50	250
T ₁₀ , Untreated control	-	-

DAS, Days after sowing.

T₉ recorded lowest larval incidence (2.25 larvae/10 bolls) which was statistically on par with the treatment, T₅ with 2.50 larvae/10 bolls (Table 2).

The pooled mean of both the seasons data on PBW larval incidence on *Bt* cotton green bolls indicate that, treatment T₁ and T₉ recorded lowest larval incidence (2.00 larvae/10 bolls) with highest reduction over control (84.64%) followed by the treatment, T₅ (2.25 larvae/10 bolls) with 82.73% reduction over control (Table 2). The control recorded highest incidence (13.04 larvae/10 bolls) of PBW larvae as compared to all other treatments. However, the treatments T₁ and T₅ received four sprays after 65, 80, 95 and 110 DAS, likewise T₉ also received four sprays based on ETL at the interval of 15 days. The ETL based spray and treatments received 4 sprays at 15 days interval after 65 DAS were significantly superior in managing the PBW over rest of the treatments (Table 3, Table 4).

Per cent green boll damage: During 2020–21, the lowest mean green boll damage of 15 DLAS and 130 DAS was recorded in the treatment, T₁ (10.88 %) sprayed with profenofos 50 EC, chlorantraniliprole 18.50 sc, emamectin

benzoate 5 SG and bifenthrin 10 EC at 65, 80, 95 and 110 DAS, respectively which was statistically on par with the treatment, T₉ (11.03 %) sprayed with chlorantraniliprole 9.30 + lambda-cyhalothrin 4.60 ZC based on the ETL of the pest and T₅ (11.23%) sprayed with profenofos 50 EC, chlorantraniliprole 18.50 sc, spinetoram 11.70 sc and fenpropathrin 10.00 EC at 65, 80, 95 and 110 DAS, respectively. Whereas, the treatment control recorded highest green boll damage (63.00%) as compared to all other treatments. Similar trend was followed during 2021–22. The treatments, T₁, T₉ and T₅ recorded lowest green boll damage of 12.68, 12.83 and 13.03% which were statistically superior managing pest (Table 3).

The pooled mean of both the seasons recorded, treatment T₁ having lowest green boll damage (11.78%) with highest reduction over control (82.10%) followed by the treatment, T₉ (11.93% green boll damage) with 81.88% reduction over control and T₅ (12.13% green boll damage) with 81.57% green boll damage reduction over control. The control recorded highest green boll damage (65.80%) as compared to all other treatments (Table 3). However, the

Table 2 Effect of frequency and time intervention of insecticides on incidence of pink bollworm in *Bt* cotton

Treatments	PBW larval incidence (No. of larvae/10 bolls)								Mean larval incidence of both years	Reduction over control (%)
	2020–21				2021–22					
	PC	15 DALS	130 DAS	Average	PC	15 DALS	130 DAS	Average		
T ₁	6.16 (2.58)	2.25 (1.66) ^a	1.26 (1.33) ^a	1.76 (1.50) ^a	6.52 (2.65)	2.58 (1.75) ^a	1.92 (1.56) ^a	2.25 (1.66) ^a	2.00 (1.58) ^a	84.64
T ₂	6.12 (2.57)	4.25 (2.18) ^b	3.26 (1.94) ^b	3.76 (2.06) ^b	6.48 (2.64)	4.58 (2.25) ^b	3.92 (2.10) ^b	4.25 (2.18) ^b	4.00 (2.12) ^b	69.31
T ₃	6.54 (2.65)	4.50 (2.24) ^b	3.51 (2.00) ^b	4.01 (2.12) ^b	6.90 (2.72)	4.83 (2.31) ^b	4.17 (2.16) ^b	4.50 (2.24) ^b	4.25 (2.18) ^b	67.39
T ₄	6.75 (2.69)	5.75 (2.50) ^c	4.76 (2.29) ^c	5.26 (2.40) ^c	7.11 (2.76)	6.08 (2.57) ^c	5.42 (2.43) ^c	5.75 (2.50) ^c	5.50 (2.45) ^c	57.80
T ₅	6.33 (2.61)	2.50 (1.73) ^a	1.51 (1.42) ^a	2.01 (1.58) ^a	6.69 (2.68)	2.83 (1.82) ^a	2.17 (1.63) ^a	2.50 (1.73) ^a	2.25 (1.66) ^a	82.73
T ₆	6.04 (2.56)	4.33 (2.20) ^b	3.34 (1.96) ^b	3.84 (2.08) ^b	6.40 (2.63)	4.66 (2.27) ^b	4.00 (2.12) ^b	4.33 (2.20) ^b	4.08 (2.14) ^b	68.69
T ₇	6.12 (2.57)	4.66 (2.27) ^b	3.66 (2.04) ^b	4.16 (2.16) ^b	6.48 (2.64)	4.99 (2.34) ^b	4.33 (2.20) ^b	4.66 (2.27) ^b	4.41 (2.22) ^b	66.18
T ₈	6.33 (2.61)	5.66 (2.48) ^c	4.67 (2.27) ^c	5.17 (2.38) ^c	6.69 (2.68)	5.99 (2.55) ^c	5.33 (2.41) ^c	5.66 (2.48) ^c	5.41 (2.43) ^c	58.49
T ₉	6.66 (2.68)	2.25 (1.66) ^a	1.26 (1.33) ^a	1.76 (1.50) ^a	7.02 (2.74)	2.58 (1.75) ^a	1.92 (1.56) ^a	2.25 (1.66) ^a	2.00 (1.58) ^a	84.64
T ₁₀	6.12 (2.57)	10.25 (3.28) ^d	16.50 (4.12) ^d	13.38 (3.72) ^d	6.48 (2.64)	9.75 (3.20) ^d	15.66 (4.02) ^d	12.71 (3.63) ^d	13.04 (3.68) ^d	0.00
SEM ±	0.11	0.06	0.07	0.06	0.09	0.05	0.07	0.06	0.06	
CD (<i>p</i> =0.05)	0.33	0.18	0.21	0.18	0.27	0.15	0.19	0.17	0.19	

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. DALS, Days after last spray; DAS, Days after sowing; PC, Precount. Refer to Table 1 for Treatment details.

Table 3 Effect of frequency and time intervention of insecticides on green boll damage in *Bt* cotton

Treatments	Green boll damage (%)								Mean green boll damage of both years	Reduction over control (%)
	2020–21				2021–22					
	PC	15 DALS	130 DAS	Average	PC	15 DALS	130 DAS	Average		
T ₁	26.25 (30.82)	15.6 (23.26) ^a	6.15 (14.36) ^a	10.88 (19.25) ^a	29.40 (32.83)	18.05 (25.14) ^a	7.30 (15.68) ^a	12.68 (20.86) ^a	11.78 (20.07) ^a	82.10
T ₂	28.75 (32.42)	18.83 (25.72) ^b	9.38 (17.83) ^b	14.11 (22.06) ^b	31.90 (34.39)	21.28 (27.47) ^b	10.53 (18.94) ^b	15.91 (23.50) ^b	15.01 (22.79) ^b	77.20
T ₃	27.50 (31.63)	19.15 (25.95) ^b	9.70 (18.15) ^b	14.43 (22.32) ^b	30.65 (33.62)	21.60 (27.69) ^b	10.85 (19.23) ^b	16.23 (23.75) ^b	15.33 (23.05) ^b	76.71
T ₄	26.75 (31.14)	22.94 (28.62) ^c	13.49 (21.55) ^c	18.22 (25.26) ^c	29.90 (33.15)	25.39 (30.26) ^c	14.64 (22.50) ^c	20.02 (26.58) ^c	19.12 (25.93) ^c	70.95
T ₅	26.25 (30.82)	15.95 (23.54) ^a	6.50 (14.77) ^a	11.23 (19.57) ^a	29.40 (32.83)	18.40 (25.40) ^a	7.65 (16.06) ^a	13.03 (21.16) ^a	12.13 (20.38) ^a	81.57
T ₆	26.15 (30.76)	18.95 (25.81) ^b	9.50 (17.95) ^b	14.23 (22.16) ^b	29.30 (32.77)	21.40 (27.56) ^b	10.65 (19.05) ^b	16.03 (23.60) ^b	15.13 (22.89) ^b	77.01
T ₇	27.25 (31.47)	19.25 (26.02) ^b	9.80 (18.24) ^b	14.53 (22.40) ^b	30.40 (33.46)	21.70 (27.76) ^b	10.95 (19.32) ^b	16.33 (23.83) ^b	15.43 (23.13) ^b	76.56
T ₈	28.54 (32.29)	22.86 (28.56) ^c	13.41 (21.48) ^c	18.14 (25.20) ^c	31.69 (34.26)	25.31 (30.20) ^c	14.56 (22.43) ^c	19.94 (26.52) ^c	19.04 (25.87) ^c	71.07
T ₉	27.15 (31.40)	15.75 (23.38) ^a	6.30 (14.54) ^a	11.03 (19.39) ^a	30.30 (33.40)	18.20 (25.25) ^a	7.45 (15.84) ^a	12.83 (20.98) ^a	11.93 (20.20) ^a	81.88
T ₁₀	25.45 (30.30)	50.75 (45.43) ^d	75.25 (60.17) ^d	63.00 (52.54) ^d	28.60 (32.33)	54.45 (47.55) ^d	82.75 (65.46) ^d	68.60 (55.92) ^d	65.80 (54.21) ^d	0.00
SEM ±	1.15	0.68	0.98	0.73	1.09	0.65	0.85	0.75	0.78	
CD (<i>p</i> =0.05)	3.45	2.05	2.95	2.18	3.26	1.95	2.54	2.24	2.35	

Values in parenthesis are arcsine transformed, Means followed by same alphabet in columns did not differ significantly (*p*=0.05) by DMRT. DALS, Days after last spray; DAS, Days after spray; PC, Precount. Refer to Table 1 for Treatment details.

treatments sprayed based on ETL and treatments received 4 sprays at 15 days interval after 65 DAS significantly controlled the damage caused by PBW over remaining treatments (Table 4).

Good opened bolls, bad opened bolls and locule damage: The open bolls observation made at the time of harvest recorded that the highest average good opened bolls (GOB) of both the seasons (Table 4) in the treatment, T₁ (85.90%) which was on par with the treatments, T₉ (85.10%) and T₅ (84.73%) with lowest GOB in control (27.80%). Conversely, lowest bad opened bolls (BOB) and locule damage (LD) was recorded in the treatment, T₁ (14.10 and 11.75%, respectively) which was on par with the treatments, T₉ (14.90 and 12.55%, respectively) and T₅ (15.27 and 12.92%, respectively) with highest BOB and LD was recorded in control with 72.20 and 69.85%, respectively (Table 4).

Seed cotton yield (q/ha): During 2020–21, the highest seed cotton was obtained from the treatment T₁ (18.32 q/ha) which was on par with the treatment, T₉ (18.26 q/ha) and T₅ (18.12 q/ha) (Table 5). The lowest seed cotton yield

recorded in control with 7.45 q/ha which was statistically less as compared to all other treatments. Similar trend has been witnessed during 2021–22 with highest cotton yield of 17.46 q/ha in the treatment T₁ which was on par with the treatments, T₉ (17.40 q/ha) and T₅ (17.31 q/ha). The pooled data of cotton yield during the cotton season 2020–21 and 2021–22 indicated that T₁ recorded highest yield (17.89 q/ha) followed by T₉ (17.83 q/ha) and T₅ (17.72 q/ha) which received four sprays either based on ETL or prophylactic at fixed intervals (Table 5). However, lowest cotton yield recorded in control (7.02 q/ha) without any insecticide spray (Table 4).

Cost economics: Among the treatments, the highest net profit (42,907 ₹/ha) was recorded in the treatment, T₁ sprayed with profenofos 50 EC, chlorantraniliprole 18.50 SC, emamectin benzoate 5 SG and bifenthrin 10 EC at 65, 80, 95 and 110 DAS, respectively followed by the treatment, T₉ (38,985 ₹/ha) sprayed with chlorantraniliprole 9.3 + lambda-cyhalothrin 4.60 ZC (based on ETL) and T₅ (37,256 ₹/ha) sprayed with profenofos 50 EC, chlorantraniliprole 18.50 SC, spinetoram 11.70 SC and fenpropathrin 10.00 EC

Table 4 Effect of frequency and time intervention of insecticides on PBW infestation and yield in *Bt* cotton during 2020–21 and 2021–22 (Pooled data)

Treatments	Larval incidence (larvae/10 bolls)*	Green boll damage (%) **	Good opened bolls (%)**	Bad opened bolls (%)**	Locule damage (%)**	Yield (q/ha)*
T ₁	2.00 (1.58) ^a	11.78 (20.07) ^a	85.10 (67.29) ^a	14.90 (22.71) ^a	12.55 (20.74) ^a	17.89 (4.29) ^a
T ₂	4.00 (2.12) ^b	15.01 (22.79) ^b	77.69 (61.81) ^b	22.31 (28.19) ^b	19.96 (26.53) ^b	14.85 (3.92) ^b
T ₃	4.25 (2.18) ^b	15.33 (23.05) ^b	77.50 (61.68) ^b	22.50 (28.32) ^b	20.15 (26.67) ^b	14.76 (3.91) ^b
T ₄	5.50 (2.45) ^c	19.12 (25.93) ^c	72.79 (58.56) ^c	27.21 (31.44) ^c	24.86 (29.90) ^c	13.11 (3.69) ^c
T ₅	2.25 (1.66) ^a	12.13 (20.38) ^a	84.73 (67.00) ^a	15.27 (23.00) ^a	12.92 (21.06) ^a	17.72 (4.27) ^a
T ₆	4.08 (2.14) ^b	15.13 (22.89) ^b	77.60 (61.75) ^b	22.40 (28.25) ^b	20.05 (26.60) ^b	14.81 (3.91) ^b
T ₇	4.41 (2.22) ^b	15.43 (23.13) ^b	77.39 (61.61) ^b	22.61 (28.39) ^b	20.26 (26.75) ^b	14.65 (3.89) ^b
T ₈	5.41 (2.43) ^c	19.04 (25.87) ^c	72.84 (58.59) ^c	27.16 (31.41) ^c	24.81 (29.87) ^c	13.48 (3.74) ^c
T ₉	2.00 (1.58) ^a	11.93 (20.20) ^a	85.90 (67.94) ^a	14.10 (22.06) ^a	11.75 (20.04) ^a	17.83 (4.28) ^a
T ₁₀	13.04 (3.68) ^d	65.80 (54.21) ^d	27.80 (31.82) ^d	72.20 (58.18) ^d	69.85 (56.69) ^d	7.02 (2.74) ^d
SEM(±)	0.06	0.78	0.88	0.93	1.02	0.04
CD (<i>p</i> =0.05)	0.19	2.35	2.64	2.78	3.07	0.13

*Values in parenthesis are $\sqrt{x+0.5}$ transformed; **Values in parenthesis are arcsine transformed; Means followed by same alphabet in columns did not differ significantly (*p*=0.05) by DMRT. DALs, Days after last spray; DAS, Days after sowing, PC, Precount. Refer to Table 1 for Treatment details.

at 65, 80, 95 and 110 DAS, respectively. However, lowest net profit (-15,880 ₹/ha) was recorded in control (Table 6).

The present investigation indicated that the highest B:C ratio was obtained in treatment, T₁ (1.67) which received four sprays at 15-days interval from 65 DAS followed by treatment, T₉ (1.57) received sprays based on ETL and treatment, T₅ (1.54) which also received four sprays at 15-days interval from 65 DAS. However, lowest B:C ratio was recorded in untreated control, T₁₀ (0.73). Even though on par yield obtained in the treatments T₁, T₅ and T₉, because of low cost of insecticides which were used in the treatment T₁ (1.67) recorded with highest B: C ratio followed by the treatments, T₉ (1.57) and T₅ (1.54).

The current research results are similar with the findings of Divya (2019) and Anonymous (2018a), who recorded the lowest green boll damage, larval incidence and locule damage (7.61%) with the highest yield in the treatment with four sprays (azadirachtin, thiodicarb, chlorpyrifos and lambda cyhalothrin at 45, 60, 90 and 120 DAS, respectively) followed by the treatment with three sprays (treatment sprayed with thiodicarb, chlorpyrifos and lambda cyhalothrin at 60, 90 and 120 DAS, respectively).

Similarly, Krishna and Reddy (2020) revealed that erection of pheromone traps at 45 DAS and spray of neem oil 1,500 ppm @5 mL/L, Chlorantraniliprole 18.5 sc @0.3 mL/L followed by spray of Bifenthrin 10 EC @1 mL/L at weekly intervals after PBW crossing ETL had recorded lowest green boll damage (33.36%), open boll damage (10.66%) and lowest PBW larvae (6.67/20 green bolls) with highest yield. However, in our study yield of seed cotton was lower due to heavy rains received during the season. Hence, lower yield in all the treatments was attributed to the lower B: C ratio.

After 45–50 DAS cotton starts flowing and boll formation at that time PBW starts laying its eggs on flower and bolls. Hence, an organophosphate chemical, profenofos which acts as ovicide and larvicide, was sprayed at 65 DAS and an anthranilic diamide chlorantraniliprole acting on ryanodine receptor modulator sprayed at 80 DAS. The emamectin benzoate (contraction of muscle and continuous flow of chloride ions in GABA and H-Glutamate receptor sites) and spinetoram (nicotinic acetyl choline receptor allosteric activator) sprayed at 95 DAS. However, synthetic pyrethroid bifenthrin and fenpropathrin having adulticidal

Table 5 Effect of frequency and time intervention of insecticides on yield parameters of *Bt* cotton

Treatments	Good opened bolls (%)		Bad opened bolls (%)		Locule damage (%)		Yield (q/ha)	
	2020–21	2021–22	2020–21	2021–22	2020–21	2021–22	2020–21	2021–22
T ₁	87.65 (69.43) ^a	84.15 (66.54) ^a	12.35 (20.57) ^a	15.85 (23.46) ^a	10.48 (18.89) ^a	13.01 (21.14) ^a	18.32 (4.34) ^a	17.46 (4.24) ^a
T ₂	79.44 (63.04) ^b	75.94 (60.63) ^b	20.56 (26.96) ^b	24.06 (29.37) ^b	18.69 (25.61) ^b	21.22 (27.43) ^b	15.28 (3.97) ^b	14.42 (3.86) ^b
T ₃	79.25 (62.90) ^b	75.75 (60.50) ^b	20.75 (27.10) ^b	24.25 (29.50) ^b	18.88 (25.75) ^b	21.41 (27.56) ^b	15.19 (3.96) ^b	14.33 (3.85) ^b
T ₄	74.54 (59.70) ^c	71.04 (57.44) ^c	25.46 (30.30) ^c	28.96 (32.56) ^c	23.59 (29.06) ^c	26.12 (30.74) ^c	13.54 (3.75) ^c	12.68 (3.63) ^c
T ₅	86.48 (68.43) ^a	82.98 (65.63) ^a	13.52 (21.57) ^a	17.02 (24.37) ^a	11.65 (19.96) ^a	14.18 (22.12) ^a	18.12 (4.32) ^a	17.31 (4.22) ^a
T ₆	79.35 (62.97) ^b	75.85 (60.57) ^b	20.65 (27.03) ^b	24.15 (29.43) ^b	18.78 (25.68) ^b	21.31 (27.49) ^b	15.24 (3.97) ^b	14.38 (3.86) ^b
T ₇	79.14 (62.82) ^b	75.64 (60.43) ^b	20.86 (27.18) ^b	24.36 (29.57) ^b	18.99 (25.83) ^b	21.52 (27.64) ^b	15.08 (3.95) ^b	14.22 (3.84) ^b
T ₈	74.59 (59.73) ^c	71.09 (57.47) ^c	25.41 (30.27) ^c	28.91 (32.53) ^c	23.54 (29.02) ^c	26.07 (30.70) ^c	13.91 (3.80) ^c	13.05 (3.68) ^c
T ₉	86.85 (68.74) ^a	83.35 (65.92) ^a	13.15 (21.26) ^a	16.65 (24.08) ^a	11.28 (19.62) ^a	13.81 (21.82) ^a	18.26 (4.33) ^a	17.40 (4.23) ^a
T ₁₀	29.55 (32.93) ^d	26.05 (30.69) ^d	70.45 (57.07) ^d	73.95 (59.31) ^d	68.58 (55.91) ^d	71.11 (57.49) ^d	7.45 (2.82) ^d	6.59 (2.66) ^d
SEM ±	0.95	0.78	0.89	0.85	1.03	0.92	0.04	0.03
CD (<i>p</i> =0.05)	2.85	2.34	2.67	2.55	3.09	2.76	0.12	0.09

Values in parenthesis are arcsine transformed, Means followed by same alphabet in columns did not differ significantly (*p*=0.05) by DMRT. DALs, Days after last spray; DAS, Days after spray; PC, Precount. Refer to Table 1 for Treatment details.

Table 6 Effect of frequency and time intervention of insecticides on cost economics in *Bt* cotton during 2020–21 and 2021–22

Treatments	Yield (q/ha)	Cost of production (₹)	Cost of protection (₹)	Total cost of cultivation (₹)	Gross returns (₹/ha)	Net returns (₹/ha)	B: C ratio
T ₁	17.89	58,000	6,433	64,433	1,07,340	42,907	1.67
T ₂	14.85	58,000	3,691	61,691	89,100	27,409	1.44
T ₃	14.76	58,000	5,465	63,465	88,560	25,095	1.40
T ₄	13.11	58,000	5,016	63,016	78,660	15,644	1.25
T ₅	17.72	58,000	11,034	69,034	1,06,290	37,256	1.54
T ₆	14.81	58,000	8,291	66,291	88,860	22,569	1.34
T ₇	14.65	58,000	4,898	62,898	87,900	25,002	1.40
T ₈	13.48	58,000	10,184	68,184	80,880	12,696	1.19
T ₉	17.83	58,000	9,995	67,995	1,06,980	38,985	1.57
T ₁₀	7.02	58,000	0	58,000	42,120	-15,880	0.73

Refer to Table 1 for Treatment details.

property causing voltage gated sodium channel modulator were sprayed at 105 DAS. As per the recommendation of package of practices we placed a single spray of pyrethroids after 100 DAS to avoid resurgence of whiteflies and

increased PBW adult activity coincides with the spray of pyrethroids (110 DAS) having adulticidal property helps in reducing the pest load. Treatment T₄ and T₈ skipped with the application of pyrethroid at 110 DAS that leads

to the increased incidence, green boll damage, BOB, LD and decreased yield. Hence, four sprays (frequency) at an interval of 15 days from 65 DAS (time intervention) and spraying based on ETL (moth trap catches) were found superior in reducing the pink bollworm incidence as well as damage. This ETL and prophylactic based spraying of different combination of insecticides with different mode of action combined at different frequency and interval was successful in managing the pink bollworm in *Bt*-cotton.

The study investigating the frequency and time intervention of various insecticide treatments against PBW in *Bt* cotton crops over two seasons during 2020–21 and 2021–22 highlighted, treatments involving sprays at specific intervals exhibited superior management of PBW infestation and consequent damage. Across both seasons, treatments T₁, T₉ and T₅ consistently showcased the lowest PBW larval incidence and green boll damage, recording remarkable reductions compared to untreated controls. These treatments, receiving four sprays based on ETL or 4 sprays at 15-day intervals from 65 DAS, exhibited statistically superior control over other approaches. Moreover, observations at harvest indicated that T₁, T₉ and T₅ sustained significantly higher proportions of good opened bolls while minimising bad opened bolls and locule damage, which significantly contrasted with the control group. The positive impact extended to yield outcomes, with treatments T₁, T₉, and T₅ consistently yielding higher cotton output compared to other treatments. Importantly, T₁, receiving four specific sprays, displayed the highest seed cotton yield and net profit per hectare, closely followed by T₉ and T₅. Overall, the findings strongly support the efficacy of strategic insecticide applications, especially those aligned with ETL-based sprays or four sprays at predetermined intervals from 65 DAS, in effectively managing PBW infestation. This strategic approach not only minimises pest damage but also maximises cotton yield and economic returns, emphasising its practical viability for cotton cultivation.

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