IMPACT OF INSECTICIDE APPLICATION FREQUENCY AND TIME INTERVAL IN MANAGEMENT OF PINK BOLLWORM

Abstract: An experiment conducted at the Main Agricultural Research Station (MARS), University of Agricultural Sciences Raichur, focused on managing pink bollworm in Bt cotton using newer insecticides registered for cotton. Various spray frequencies and intervals were tested as part of an ETL (Economic Threshold Level) and prophylactic spray regimen. The results indicated that the treatment T1, which involved four sprays of profenofos 50 EC, chlorantraniliprole 18.50 SC, emamectin benzoate 5 SG, and bifenthrin 10 EC at 65, 80, 95, and 110 days after sowing (DAS), respectively, showed the lowest incidence of pink bollworm larvae, green boll damage, bad boll opening, locule damage, and the highest rate of good boll opening. This performance was comparable to treatment T5, which followed the same spraying schedule but with spinetoram 11.70 SC and fenpropathrin 10.00 EC instead of emamectin benzoate and bifenthrin, and treatment T9, which employed an ETL-based spray schedule using chlorantraniliprole 9.3 + lambda-cyhalothrin 4.6 ZC. Similarly, the highest yield of seed cotton was obtained from treatment T1 (18.10 q/ha), which was statistically equivalent to treatments T5 (18.12 q/ha) and T9 (18.10 q/ha). Additionally, the cost-benefit analysis revealed the highest benefit-cost ratio in treatment T1 (1.55), followed by treatments T9 (1.46) and T5 (1.44).

Keywords: Insecticide, Pink bollworm, incidence, Locule damage, Economic threshold level

INTRODUCTION

Cotton, scientifically known as *Gossypium* spp., earns the moniker "white gold" due to its significant role in various sectors such as industry, economy, and foreign exchange. It stands as one of India's oldest and most crucial commercial crops, contributing substantially to the nation's economic landscape. With cultivation spanning across more than 111 countries globally, India takes the lead in terms of land area dedicated to cotton cultivation, encompassing 119.10 lakh hectares, and producing 312.03 lakh bales with a productivity rate of 445 kg lint per hectare. Among the four cultivated species of cotton, *Gossypium hirsutum* dominates, contributing to 95 % of the global cotton yield. However, the pink bollworm (Parmar and Patel, 2016), a notorious pest within the cotton bollworm complex, poses a significant threat to both Bt and non-Bt cotton varieties in India. The emergence of resistance in the 1st and 2nd generations of Bt cotton hybrids (Dhurua and Gujar, 2011; Naik *et al*., 2018) has exacerbated the problem, leading to substantial losses in cotton quality and quantity. Pink bollworm larvae swiftly infiltrate young cotton bolls, sealing their entry points with excretions, making direct pesticide exposure challenging. Consequently, implementing targeted pest management strategies becomes arduous.

The damage inflicted by pink bollworm larvae extends beyond physical destruction to the cotton plant. They cause holes in the flower and septa between locules, resulting in lint staining and diminished lint quality (Ateel and Kara, 2020; Divya *et al*., 2020). Moreover, they decrease oil content by 2.10-47.10 %, seed cotton yield by 2.80-61.90 %, and inflict damage on green bolls ranging from 10-55 % (Anonymous, 2018). Partial boll opening, weakened and smaller staples, along with increased lint debris, hamper the growth of cotton plants (Hassan and Sahfique, 2014).

To effectively manage pests and curb the indiscriminate use of insecticides, it's essential to assess their effectiveness against specific pests. Therefore, this study aimed to evaluate various insecticides registered for cotton crops, each with distinct modes of action. These insecticides were applied at specific intervals to combat the pink bollworm. The methodology and results of this investigation are outlined below.

METERIALS AND METHODS

A field experiment was conducted at the Entomology block of MARS, Raichur during 2020-21 by employing a Randomized Block Design (RBD) with 10 treatments 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). To monitor pink bollworm moth activity, four pheromone traps with pectino-lure were strategically installed in the block, positioned 30 cm above the crop canopy, with pheromone lure replacement occurring every 15 days. Treatments were applied at varying intervals across different treatment blocks: 65, 80, 95, and 110 days after sowing (DAS) as a prophylactic measure, with one treatment based on Economic Threshold Level (ETL) for pesticide application (Table 1). ETL was defined as a mean trap catch ranging from 9 to 12 over three consecutive days (Qureshi *et al*., 1993). Observations on the number of larvae per 10 bolls were recorded at 15 days after the last spray (DALS) and at 130 days after sowing (DAS). Additionally, percent locule damage, the count of good and bad opened bolls per plant, and seed cotton yield were assessed at harvest time.

Pink bollworm incidence and green boll damage

We recorded observations on the occurrence of PBW in green bolls and green boll damage 15 days after the final spray and 130 days after sowing. This was done through random collection and cutting open of ten green bolls. Subsequently, we calculated the percentage of green boll damage using a formula

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

Good opened boll (GOB), Bad opened boll (BOB) and Locule damage

Before starting each picking session, we counted the total number of Good bolls (GOB's) (Figure 1), bad bolls (BOB's) (Figure 2), and locule damage on 20 randomly chosen plants. Using this data, we calculated the percentage of good or bad opened bolls and locule damage per plant using the given formula.

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

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

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

Seed cotton yield and cost economics

Cotton picking was carried out on a plot basis, with each plot measuring 7.2 × 4.8 m. The yield of cotton was measured in kilograms per plot, and the combined yield from all pickings in each plot was used to calculate the yield on a hectare basis. The cost effectiveness of each insecticide was evaluated by determining the net returns. The net return of each treatment was calculated by subtracting the total cost of the treatment from the gross returns. The total cost of production encompassed both cultivation expenses and plant protection measures. The percentage reduction over the untreated control was determined using the modified Abbot's formula provided by Fleming and Ratnakaran (1985).

RESULTS AND DISCUSSION

Various insecticides were assessed for their effectiveness against pink bollworm at various intervals, employing combinations sprayed at 65, 80, 95, and 110 days after sowing (DAS). The combinations were applied at different time points, and the findings of this study are outlined below.

Pink bollworm larval incidence and green boll damage after treatment imposition

Outcome of the data pertaining to the impact of pink bollworm larvae in cotton bolls on the basis of different frequency and time interval of spray showed that the lowest larval incidence of 3.25 larvae per 10 bolls in the treatment, T_1 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, T_9 sprayed with chlorantraniliprole 9.30+lambda-cyhalothrin 4.60 ZC based on the ETL of the pest which was on par with the treatment, T_5 (3.5 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. The treatment, T_8 (6.75 larvae/10 bolls) sprayed with profenofos 50 EC, chlorantraniliprole 18.50 SC and spinetoram 11.70 SC at 65, 80 and 95 DAS, respectively was at par with T_3, T_2 and T_1. But the untreated control recorded highest larval incidence (14.5 larvae/10 bolls) and showed statistically inferior to all the treatments, at 15 days after last spray (Table 2). Similar trend was followed even after 130 days after sowing in all the treatments. However, the treatments T_1 and T_5 received four sprays after 65, 80, 95 and 110 DAS, like wise T_9 also received four sprays based on ETL at the interval of 15 days and they were significantly superior over rest of the treatments.

With respect to the per cent green boll damage after 15 DALS, treatments, T_1 and T_9 recorded 22.5 per cent green boll damage and which were on par with the treatment, T_5 (25.00 %), followed by the treatments, T_3 and T_7 recorded with 32.50 per cent green boll damage which were on par with T_2 and T_6 recorded with 35.00 per cent green boll damage (Table 2). The next best treatments were T_4 (37.50 %) followed by T_8 (37.80 %). However, significantly highest green boll damage (70.00 %) was recorded in untreated control. Similar trend was followed in 130 days after spray. The latest research findings align with previous studies by Divya (2019) and Anonymous (2018a), which reported the lowest larval infestation and green boll damage in the treatment involving four sprays (azadirachtin, thiodicarb, chlorpyriphos, and lambda cyhalothrin at 45, 60, 90, and 120 DAS respectively), followed by the treatment with three sprays (thiodicarb, chlorpyriphos, and lambda cyhalothrin at 60, 90, and 120 DAS respectively). Similarly, Krishna and Reddy (2020) found that deploying pheromone traps at 45 DAS and applying Neem oil at 1500 ppm @ 5 mL/L, Chlorantraniliprole 18.5 SC @ 0.3 mL/L, followed by Bifenthrin 10 EC @ 1 mL/L weekly after the pink bollworm crosses ETL, resulted in the lowest green boll damage (33.36%) and pink bollworm larval incidence (6.67/20 green bolls).

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

The open bolls observation made at the time of harvest recorded that the highest per cent GOB's, BOB's and LD in the treatment, T_1 (79.75, 20.25 and 20.21 %, respectively) which was on par with the treatment, T_5 (79.25, 20.75 and 20.76 %, respectively) and T_9 (79.15, 20.85 and 20.92 %, respectively), followed by the treatment, T_3 (74.25, 25.75 and 32.26 %, respectively) which was on par with the treatments, T_7 (74.04, 25.96 and 32.56 %, respectively), T_2 (73.60, 26.40 and 33.92 %, respectively) and T_6 (73.42, 26.58 and 34.08 %, respectively) (Table 3). However, the untreated control recorded with lowest GOB's (29.99 %), BOB's (77.01 %) and LD (80.44 %) and showed significantly inferior as compared to all the other treatments. The latest research findings align with previous studies by Divya (2019) and Anonymous (2018a), which reported the lowest locule damage (7.61 %) in the treatment involving four sprays (azadirachtin, thiodicarb, chlorpyriphos, and lambda cyhalothrin at 45, 60, 90, and 120 DAS respectively), followed by the treatment with three sprays (thiodicarb, chlorpyriphos, and lambda cyhalothrin at 60, 90, and 120 DAS respectively). Similarly, Krishna and Reddy (2020) found that deploying pheromone traps at 45 DAS and applying Neem oil at 1500 ppm @ 5 mL/L, Chlorantraniliprole 18.5 SC @ 0.3 mL/L, followed by Bifenthrin 10 EC @ 1 mL/L weekly after the pink bollworm crosses ETL, resulted in the open boll damage (10.66%).

Seed cotton yield (q/ ha) and Cost economics

The seed cotton yield among the different insecticides sprayed at different frequency and interval against pink bollworm found that the highest seed cotton was obtained from the treatment T_1 (18.10 q/ ha) which was on par with the treatment, T_5 (18.12 q/ ha) and T_9 (18.10 q/ ha) followed by the treatment T_3 (13.03 q/ ha) which was on par with the treatments T_7 (12.93 q/ ha), T_2 (12.89 q/ ha), T_6 (12.77 q/ ha), T_4 (12.54 q/ ha) and T_8 (12.51 q/ ha). The lowest seed cotton yield recorded in control with 7.40 q/ ha which was statistically less as compared to all other treatments (Table 3). Among the treatments, the highest net profit (35,639.4 Rs. / ha) was recorded in the treatment, T_1 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, T_9 (31,527.5 Rs. / ha) sprayed with chlorantraniliprole 9.3+lambda-cyhalothrin 4.60 ZC (based on ETL) and T_5 (30,626.4 Rs. / ha) 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. However, lowest net profit (-17,300 Rs. / ha) was recorded in untreated control (Table 4). The present investigation indicated that the highest benefit cost ratio was obtained in treatment, T_1 (1.55) 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 treatment, T_9 (1.46) sprayed with chlorantraniliprole 9.30 + lambda-cyhalothrin 4.60 ZC (Based on ETL) and treatment, T_5 (1.44) 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. However, lowest benefit cost ratio was recorded in untreated control, T_{10} (0.70). Even though on par yield obtained in the treatments T_1, T_5 and T_9, because of high cost of the insecticides, treatment T_1 (1.55) recorded with highest B: C ratio followed by the treatments, T_9 (1.46) and T_5 (1.44).

The latest research findings align with previous studies by Divya (2019) and Anonymous (2018a), which reported the highest yield in the treatment involving four sprays (azadirachtin, thiodicarb, chlorpyriphos, and lambda cyhalothrin at 45, 60, 90, and 120 DAS respectively), followed by the treatment with three sprays (thiodicarb, chlorpyriphos, and lambda cyhalothrin at 60, 90, and 120 DAS respectively). Similarly, Krishna and Reddy (2020) found that deploying pheromone traps at 45 DAS and applying Neem oil at 1500 ppm @ 5 mL/L, Chlorantraniliprole 18.5 SC @ 0.3 mL/L, followed by Bifenthrin 10 EC @ 1 mL/L weekly after the pink bollworm crosses ETL, resulted in the highest yield. However, our study observed lower seed cotton yield across all treatments due to delayed sowing in August and heavy rainfall during the season. Consequently, the diminished yield in all treatments was attributed to a lower B:C ratio.

Profenofos, an organophosphate compound functioning as both ovicide and larvicide, was applied at 65 days after sowing (DAS), followed by chlorantraniliprole, an anthranilic diamide targeting the ryanodine receptor modulator, sprayed at 80 DAS. Emamectin benzoate, which induces muscle contraction and facilitates chloride ion flow at GABA and H-Glutamate receptor sites, along with spinetoram, an allosteric activator of the nicotinic acetylcholine receptor, were administered at 95 DAS. Synthetic pyrethroids such as bifenthrin and fenpropathrin, acting as voltage-gated sodium channel modulators, were applied at 105 DAS. Regardless of the specific chemical pesticides used, a regimen of four sprays at 15-day intervals starting from 65 DAS, guided by Economic Threshold Levels (ETL) determined by moth trap catches, proved highly effective in mitigating pink bollworm infestations and associated damage in Bt-cotton. This approach, combining ETL monitoring and prophylactic spraying of various insecticides with diverse modes of action at different timings, demonstrated success in pink bollworm management.

Conclusion

In summary, the findings indicate that both treatments, regardless of the chemicals' distinct modes of action, applied at 15-day intervals four times from 65 days after sowing (DAS), and chemical pesticides guided by Economic Threshold Levels (ETL) based on moth trap catches, were successful in controlling pink bollworm infestation. This resulted in decreased damage to green bolls, along with higher yields of seed cotton and net profits.

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

Sl. No.	Treatments	g *a.i.* /ha	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	Profenofos 50 % EC (65 DAS)	750	1500
	Emamectin benzoate 5 % SG (95 DAS)	11	229
	Bifenthrin 10 % EC (110 DAS)	80	800
T_3	Profenofos 50 % EC (65 DAS)	750	1500
	Chlorantraniliprole 18.5 % SC (80 DAS)	30	150
	Bifenthrin 10 % EC (110 DAS)	80	800
T_4	Profenofos 50 % EC (65 DAS)	750	1500
	Chlorantraniliprole 18.5 % SC (80 DAS)	30	150
	Emamectin benzoate 5 % SG (95 DAS)	11	229
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	Profenofos 50 % EC (65 DAS)	750	1500
	Spinetoram 11.7 % SC (95 DAS)	56	470
	Fenpropathrin 10 % EC (110 DAS)	75	750
T_7	Profenofos 50 % EC (65 DAS)	750	1500
	Chlorantraniliprole 18.5 % SC (80 DAS)	30	150
	Fenpropathrin 10 % EC (110 DAS)	75	750
T_8	Profenofos 50 % EC (65 DAS)	750	1500
	Chlorantraniliprole 18.5 % SC (80 DAS)	30	150
	Spinetoram 11.7 % SC (95DAS)	56	470
T_9	Chlorantraniliprole 9.3 % +Lambda-cyhalothrin 4.6 % ZC (ETL based spray)	37.50	250
T_{10}	Untreated control	--	--

DAS - Days After Sowing

Table 2. Effect of different treatments on incidence of pink bollworm and green boll damage in cotton

Treatments	Larvae per 10 Bolls					% Green boll damage				
	PC	15 DALS	130 DAS	Mean	% ROC	PC	15 DALS	130 DAS	Mean	% ROC
T_1	3.16 (1.91)	3.25 (1.94) ^{a}	2.25 (1.66) ^{a}	2.75	77.75	26.25 (30.82)	22.5 (28.32) ^{a}	20.00 (26.57) ^{a}	21.25	72.13
T_2	3.12 (1.90)	6 (2.55) ^{bcd}	4.75 (2.29) ^{bcd}	5.38	56.54	26.25 (30.82)	35 (36.27) ^{bc}	32.50 (34.76) ^{bc}	33.75	55.74
T_3	3.04 (1.88)	5.5 (2.45) ^{b}	4.25 (2.18) ^{b}	4.88	60.58	27.5 (31.63)	32.5 (34.76) ^{b}	30.00 (33.21) ^{b}	31.25	59.02
T_4	3.04 (1.88)	6.5 (2.65) ^{bcdef}	5.25 (2.40) ^{bcdef}	5.88	52.50	25 (30.00)	37.5 (37.76) ^{c}	35.00 (36.27) ^{cd}	36.25	52.46
T_5	3.00 (1.87)	3.5 (2.00) ^{a}	2.5 (1.73) ^{a}	3.00	75.73	26.25 (30.82)	25 (30.00) ^{a}	22.50 (28.32) ^{a}	23.75	68.85
T_6	3.04 (1.88)	6.25 (2.60) ^{bcde}	5.0 (2.35) ^{bcde}	5.63	54.52	30 (33.21)	35 (36.27) ^{bc}	35.00 (36.27) ^{cd}	35	54.10
T_7	3.12 (1.90)	5.75 (2.50) ^{bc}	4.5 (2.24) ^{bc}	5.13	58.56	26.25 (30.82)	32.5 (34.76) ^{b}	32.50 (34.76) ^{bc}	32.5	57.38
T_8	3.12 (1.90)	6.75 (2.69) ^{bcdef}	5.75 (2.50) ^{cdef}	6.25	49.47	26.25 (30.82)	37.5 (37.76) ^{c}	35.00 (36.27) ^{cd}	36.25	52.46
T_9	3.16 (1.91)	3.25 (1.94) ^{a}	2.5 (1.73) ^{a}	2.88	76.74	25 (30.00)	22.5 (28.32) ^{a}	22.50 (28.32) a	22.5	70.49
T_{10}	3.12 (1.90)	10.25 (3.28) ^{g}	14.5 (3.87) ^{g}	12.38	0.00	27.5 (31.63)	70 (56.79) ^{d}	82.50 (65.27) e	76.25	0.00
S. Em (±)	NS	0.10	0.10	0.10		NS	0.71	0.76	0.73	
CD @ p=0.05		0.31	0.30	0.30			2.13	2.29	2.21	

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

DALS - Days After Last Spray, DAS - Days After Spray, PC - Pre Count, ROC - Reduction Over Control

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

Table 3. Effect of different treatments on yield parameters and seed cotton yield

Treatments	Good Opened Bolls (%)	Bad Opened Bolls (%)	Locule damage (%)	Yield (q/ha)	% Yield increase over control
T_1	79.75 (63.26)^{a}	20.25 (26.74)^{a}	20.21 (26.71)^{a}	18.20 (4.32)^{a}	145.88
T_2	73.60 (59.08)^{bcd}	26.40 (30.92)^{bcd}	33.92 (35.62)^{bcd}	12.89 (3.66)^{bc}	74.12
T_3	74.25 (59.51)^{b}	25.75 (30.49)^{b}	32.26 (34.61)^{b}	13.03 (3.68)^{b}	76.01
T_4	70.80 (57.29)^{cdef}	29.20 (32.71)^{cdef}	35.15 (36.36)^{cdef}	12.54 (3.61)^{bcde}	69.39
T_5	79.25 (62.90)^{a}	20.75 (27.10)^{a}	20.76 (27.10)^{a}	18.12 (4.32)^{a}	144.86
T_6	73.42 (58.96)^{bcde}	26.58 (31.04)^{bcde}	34.08 (35.71)^{bcde}	12.77 (3.64)^{bcd}	72.57
T_7	74.04 (59.37)^{bc}	25.96 (30.63)^{bc}	32.56 (34.79)^{bc}	12.93 (3.66)^{bc}	74.66
T_8	70.41 (57.04)^{def}	29.59 (32.96)^{def}	35.82 (36.76)^{def}	12.51 (3.61)^{bcde}	68.99
T_9	79.15 (62.83)^{a}	20.85 (27.17)^{a}	20.92 (27.22)^{a}	18.10 (4.31)^{a}	144.53
T_{10}	22.99 (28.65)^{g}	77.01 (61.35)^{g}	80.44 (63.75)^{g}	7.40 (2.81)^{f}	--
S. Em (±)	0.70	0.70	0.58	0.18	
CD @ p=0.05	2.12	2.12	1.74	0.56	

Values in parenthesis are arcsine transformed (Except yield which is $\sqrt{x+0.5}$ transformed)

Table 4. Cost economics of different treatments imposed against pink bollworm

Treatments	Cotton Yield (q/ ha)	Cost of production (Rs. / ha)	Cost of Protection (Rs.)	Total Cost of Cultivation (Rs.)	Market Value (Rs. / q)	Gross returns (Rs. / ha)	Net Returns (Rs. / ha)	B: C Ratio
T_1	18.20	58000	6433	64433	5500	100073	35639	1.55
T_2	12.89	58000	3691	61691	5500	70868	9177	1.15
T_3	13.03	58000	5465	63465	5500	71638	8172	1.13
T_4	12.54	58000	5016	63016	5500	68943	5927	1.09
T_5	18.12	58000	11034	69034	5500	99660	30626	1.44
T_6	12.77	58000	8291	66291	5500	70235	3944	1.06
T_7	12.93	58000	4898	62898	5500	71088	8190	1.13
T_8	12.51	58000	10184	68184	5500	68778	594	1.01
T_9	18.10	58000	9995	67995	5500	99523	31528	1.46
T_{10}	7.40	58000	0	58000	5500	40700	-17300	0.70

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

Figure 1. Good opened boll

Figure 2. Bad opened boll