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Validation of Pink Bollworm, *Pectinophora gossypiella* (Saunders) Management Strategies in Bt Transgenic Cotton

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ABSTRACT: During 2019-20 and 2020-21, a two-year field study was conducted on fifty cotton farmer fields in the Jalgaon District (MH) to validate pink bollworm management strategies in Bt cotton. Each farmer was assigned one acre as a demo plot where all of the prescribed pink bollworm management strategies were demonstrated, and five other farmers from each village were assigned as a check plot. The recommended pest management strategies were implemented once the pink bollworm reached economic threshold levels, *i.e.* eight to ten adult moth catches in pheromone traps for three consecutive days and 10% green boll observed during destructive sampling. A two-year study found that the average Pink bollworm infestation ranged from 4.50-20.70 percent in demonstration plots and 14.80-40.50 percent in farmer's practises (Check) plots. In the demonstration and control plots, the average number of insecticidal sprays for pink bollworm was 2.29 and 3.55, respectively. In the demonstration and control plots, the average seed cotton yields were 1719.70 and 1463.10 kg/ha, respectively. The cost-benefit ratios for the demonstration and check plots were 1:1.84 and 1:1.41, respectively. Pesticide use has been reduced by 32.13 percent. Critical inputs like insecticides, trichocards were supplied to the beneficiary farmers. Voice message were send to the farmers regarding management of pink bollworm in cotton. Standard meteorological week wise observation also records though large number of field visits.

Keywords: Boll damage, Cotton, Evaluation, IPM, field Pink bollworm, Management.

INTRODUCTION

Cotton is India's most important fibre and cash crop, and it is vital to the country's industrial and agricultural economies. It is the primary raw material for the cotton textile industry (cotton fibre). Cotton provides direct income to 6 million Indian farmers, and the cotton trade and processing industry employs 40-50 million people. Cotton is a kharif crop in many states, including Punjab, Haryana, Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, and parts of Andhra Pradesh and Karnataka. Pink bollworm, *Pectinophora gossypiella* (Saunders), is one of the most damaging insect pests of cotton, with a wide range that causes significant losses in cotton production across India (Dhurua and Gujar 2011; Naik *et al.,* 2018). *Pectinophora gossypiella* Saunders, the pink bollworm, is native to Asia and was first described in 1843 from larvae recovered from infested cotton bolls in India (Noble 1969). Pink bollworm (PBW) resistance to bollgard was first reported in 2010, followed by resistance to bollgard II in 2014. The infestation on Bt cotton was reported to cause 55% locule damage and a 35-90% reduction in seed cotton yield (Naik *et al.,* 2014). Sangareddy and Patil (1997) reported that incidence of PBW commenced from October onwards which gradually increased and reached to a peak during February and declined thereafter. The attraction of male moths of PBW started, at the beginning, of the first week of September and continued till the third week of April and also in the Farmer field whereas; in cotton ginning mills the activity seen throughout the year (Kumar *et al.,* 2022). The number of PBW moth trap catches increased gradually reaching its peak during the December's first fortnight (corresponding to 50th SMW/peak boll bursting) *i.e.* 376.4 moth/ trap/ fortnight and thereafter gradually declined (Rathod *et al.,* 2022). The significant contributors for breakdown of resistance are: extending crop beyond time, noncompliance of refuge, lack of timely and appropriate management initiatives, large number of hybrids with varying flowering and fruiting periods, cultivation of long duration hybrids, long term storage

of raw cotton in ginneries (seed cotton harbours PBW larvae), development of resistance to Cry1Ac and Cry2Ab proteins by Pink bollworm, etc. Pink bollworm adaptation to transgenic Bt-cotton expressing Cry1Ac (Bollgard) and Cry1Ac+Cry2Ab (BG-II) was assessed in India by ICAR-Central Institute for Cotton Research (ICAR-CICR), Nagpur during. In light of the disaster caused by the Pink bollworm on Bollgard II, the experiment was being carried out in five villages in Jalgaon District for the years 2019-20 and 2020-21.

MATERIALS AND METHODS

During the years 2019-20 and 2020-21, a field study was conducted on fifty farmers' fields in the Maharashtra district of Jalgaon to validate pink bollworm *Pectinophora gossypiella* (Saunders) management strategies in Bt cotton. Each farmer was assigned one acre to serve as a demonstration plot for all of the prescribed pink bollworm management strategies (Table 1), and five other farmers from each village were assigned to serve as a check plot (Table 2). After catching eight to ten adult moths in pheromone traps for three days in a row and observing 10% green boll during destructive sampling, the recommended insecticides were sprayed in the recommended dosages as prescribed by Agricultural University. From fifty demonstration and control plots, data on pheromone trap catches (weekly standard), percent rosette flower, green boll damage, locule damage, number of insecticidal sprays, volume of insecticide applied, yield, and B: C ratio were collected and averaged.

Table 1: Crop stage wise Pink bollworm management strategies adopted.

Operation	Pink bollworm management strategies adopted in demonstration plots
Sowing	Timely sowing *i.e.* July month wherever applicable Use jassid tolerant, short duration Varieties/BGII hybrids recommended for the region.
Refugia	Refuge planting (120 g non Bt) around Bt cotton or separate as strip if supplied with seed packet or cultivation of Bt cotton provided with refuge- in-built.
Monitoring	Install pheromone traps @ 5/acre for monitoring pink bollworm moth activity at 45 DAS.
Pesticide	Spray neem seed extract 5% + Neem oil 5 ml/ litre of water at 50-60 DAS, At boll formation stage, farmers are advised to inspect presence and damage of PBW by plucking 20 green bolls from different plants randomly (one boll per plant). ETL at this stage is 10% damaged green bolls (at least two bolls having white or pink larvae). Thiodicarb 75% WP 15 g or Chlorpyriphos 20% EC 25 ml or 20 g per 10 lit water. At 90 Days after sowing release of the egg parasitiod *Trichogramma bactrae* @ 60,000 eggs /acre. After 120 Days after sowing spray of Cypermethrin 10% EC 10 ml or Lambdacyhalothrin 5%EC 10ml per 10 lit water.
Crop termination	After 180 days after sowing termination and Uprooting of the crop not extending the cotton crop beyond 180 DAS. Cleaning up fields of residual stalks and partially opened bolls.

Table 2: Farmer's practices recorded in check plots.

Operation	Pink bollworm management strategies not adopted in check plots
Sowing	No timely sowing, may be done in may having irrigation facilities Sowing time- 15 May to 30 July
Refugia	No use of refugia
Monitoring	No Regular Monitoring was done and also no ETL was recorded. Negligible use of pheromone traps.
Pesticide	Spray neem seed extract 5% + Neem oil 5 ml/ litre of water at 50-60 DAS. Thiodicarb 75% WP 15 g or Chlorpyriphos 20% EC 25 ml or 20 g per 10 lit water. After 120 Days after sowing spray of Cypermethrin 10% EC 10 ml or Lambdacyhalothrin 5%EC 10ml per 10 lit water. Use of some systemic insecticides.
Crop termination	No termination of crop in December. Ratooning was preferred

RESULTS AND DISCUSSION

During 2019-20, the range of pink bollworm infestation in demonstration plots was 15-21.7%, while the range of infestation in check plots was 35-40.10%. In demonstration plots, the average number of insecticidal sprays for sucking pests and boll worms was 2.04 and 2.24, for a total of 4.28, whereas in check plots, the average number of insecticidal sprays for sucking pests and boll worms was 2.80 and 3.60, for a total of 6.40. In terms of sucking pest population, The population of leaf hoppers was 7.67/3 leaves in demonstration plots versus 13.33/3 leaves in check plots, the population of whiteflies was 18.67/3 leaves in demonstration plots versus 26.33/3 leaves in check plots, and the population of thrips was 9.67/3 leaves in demonstration plots versus 21.0/3 leaves in check plots. The average

additional profit in the demonstration plot was Rs. 10704.46, with a benefit cost ratio of 1.90:1, whereas the B: C ratio recorded in the control plots was 1.49:1. The reduction in pesticide usage in the demonstration plot was 34.53%. The demonstration plots yielded 1644.5 kg/ha of seed cotton, while the check plots yielded 1461.2 kg/ha.

In 2020-21, the range of pink bollworm infestation in demonstration plots was 18.0-22.3%, while the range in Check plots was 35.0-39.9. In demonstration plots, the average number of insecticidal sprays for sucking pests and boll worms was 2.36 and 2.34, for a total of 4.7, whereas in farmers fields (Check), the average number of insecticidal sprays for sucking pests and boll worms was 2.80 and 3.50, for a total of 6.30. In terms of sucking pest population, Leaf hopper population was 8.66/3 leaves in demonstration plots whereas check plots population was 12.33/3 leaves, whiteflies population was 11.33/3 leaves in demonstration plots whereas check plots population was 18.0/3 leaves, thrips population was 8.67/3 leaves in demonstration plots whereas farmers field (Check) population was 22.67/3 leaves. An additional profit of Rs 12227 was recorded in demonstration plots with a benefit-cost ratio of 1.77:1, whereas farmers field (Check) plots had a benefit-cost ratio of 1.34:1, and pesticide usage was reduced by 29.74% as a result of demonstrative practises. In the demonstration plots field, a seed cotton yield of 1795 kg/ha was recorded, whereas in the farmers field, very little yield was recorded (1465kg/ha) (Table 3-7). The findings above show that simply using chemical insecticides to control the Pink Bollworm will not produce satisfactory results. Instead, combining chemical insecticides with a bio intensive model that includes spraying botanicals such as neem oil and applying semiochemicals such as pheromone traps, using egg parasitoids such as *Trichogramma bactrae*, and spraying recommended insecticides with proper dosages on a community level will effectively control the Pink Bollworm. El-Hafez *et al* finding's in the year 2000, determining the role of boosting Trichogramma bactrae in the IPM programme for controlling *Pectinophora gossypiella* in Egypt, agreed with the results obtained during the field investigation.

Table 3: Impact of bio intensive module vs. farmer's practices on green boll damage during 2019-20 & 2020-21.

Year	Demonstration Plot				Farmers Practice Plots (Check)			
	% flower infestation	% green bolls infestation	% Locule damage	Average Infestation	% flower infestation	% green bolls infestation	% Locule damage	Average Infestation
2019-20	4.00	40.90	20.20	21.70	14.60	59.90	45.80	40.10
2020-21	5.00	40.70	21.20	22.30	15.00	58.00	46.10	39.90
Mean	**4.50**	**40.80**	**20.70**	**22.00**	**14.80**	**58.95**	**45.95**	**40.50**

Table 4: Average number of insecticidal sprays and seed cotton yield in Kg/ha in demonstration plots and farmers practice plots during the years 2019-20 & 2020-21.

Year	Average number of insecticidal sprays						seed cotton yield in Kg/ha	
	Demonstration Plot			Farmers Practice Plots (Check)			Demonstration Plot	Farmers Practice Plots (Check)
	Sucking Pest	Bollworm	Total	Sucking Pest	Bollworm	Total		
2019-20	2.04	2.24	4.28	2.80	3.60	6.40	1644.50	1461.20
2020-21	2.36	2.34	4.70	2.80	3.50	6.30	1795.00	1465.00
Mean	**2.20**	**2.29**	**4.49**	**2.80**	**3.55**	**6.35**	**1719.70**	**1463.10**

Table 5: Sucking pests infestation in demonstration plots and farmers practice plots during the years 2019-20 & 2020-21.

Year	Jassids		Whiteflies		Thrips	
	Demonstration Plot	Farmers Practice Plots (Check)	Demonstration Plot	Farmers Practice Plots (Check)	Demonstration Plot	Farmers Practice Plots (Check)
2019-20	7.67	13.33	18.67	26.33	9.67	21.00
2020-21	8.66	12.33	11.33	18.00	8.67	22.67
Mean	**8.17**	**12.83**	**10.00**	**22.17**	**9.17**	**21.84**

Table 6: Impact of bio intensive module on the Benefit Cost ratio during the years 2019-20 & 2020-21.

Year	Cost of spray (Rs/ha)		Cost of cultivation (Rs/ha)		Gross Return		Additional profit (Rs/ha) in A	Net profit in B	Benefit Cost Ratio	
	A	B	A	B	A	B			A	B
2019-20	4681.06	7149.60	44176.30	49289.80	84190.30	73645.20	10704.46	40014.06	1.90	1.49
2020-21	4651.96	6620.60	44242.00	49213.00	78081.00	65943.00	12227.40	33839.00	1.77	1.34
Mean	**4666.51**	**6885.10**	**44209.15**	**49251.40**	**81135.65**	**69794.10**	**11465.93**	**36926.53**	**1.84**	**1.41**

Note: A-Demonstration plots; B- Farmers Practice Plots (Check)

Table 7: Reduction in pesticide usage in IRM Vs non-Demonstration plots (in terms of cost).

Year	Cost of spray in Demonstration plots in Rs (A)	Cost of spray in Farmers Practice Plots in Rs (B)	Difference (C) in Rs A-B	% Reduction in usage C/Bx100
2019-20	4681.06	7149.60	2468.54	34.53

2020-21	4651.96	6620.60	1968.64	29.74
Mean	**4666.51**	**6885.10**	**2218.59**	**32.13**

Patil *et al.* (2011) discovered that adopting pink bollworm strategies resulted in a reduction in sucking pest populations while using fewer insecticides than recommended plant protection techniques. According to the findings, the IRM technique outperformed the current farmer practise of excessive insecticide application and little monitoring, resulting in a significant increase in cotton yield, similar to the findings of Agarwal *et al.* (2006). Non-Bt crops provide a safe haven for pests that do not produce Bt proteins. Insects sensitive to Bt proteins can survive in refuge, reducing the possibility of two resistant insects mating and producing resistant offspring. This method is particularly effective at delaying opposition. Eminent scientists working on IRM strategies generally agreed that this approach was consistent with Liu and Tabashnik (1997); Liu *et al.* (1997). The efficacy of pheromone traps such as sleeve trap and yellow funnel was well demonstrated by some researchers. Similar results were obtained in agreement with Sandhyarani *et al.* (2010) who reported that pheromones at higher dosages or frequency of lures can also be used in mass trapping and to confuse mating. A good correlation was obtained between pheromone trap catches and larval incidence in the field, which was also in agreement with Beroza (1960). Some workers also demonstrated pink bollworm management through mass trapping. Graham *et al*. (1960) reported that the adaptability of IPM modules integrated with Bt cotton genotypes proved superior by recording the lowest percentage of infestation and higher seed cotton yield with higher net returns. According to Krishna *et al*. (2020) Bt cotton pink bollworm can be effectively managed by implementing integrated pest management (IPM) strategies based on insecticide resistance management (IRM). According to Krishna, it is not sustainable to control pink bollworm with chemical insecticides alone because doing so increases cultivation costs and decreases net returns (2020). Krishna *et Al.* (2020) conducted two year field study on validation of pink bollworm management strategies in Bt cotton in nearly fifty cotton farmer fields during 2018-19 and 2019-20 in selected villages of Kurnool district under IRM-Pink bollworm management project sponsored by Central institute for cotton Research, Nagpur. During the year 2018-19 Pink bollworm infestation ranged from 30-55% in IRM demo plots where as in farmers practice infestation ranged from 31-57%. Average Number of insecticidal sprays in IRM fields was 5.0 where as in farmers practice it was 7.3. IRM demo fields had registered a benefit-cost ratio of 1.9:1 where as in farmers practice it was 1.2:1. During the year 2019-20 IRM farmers had registered a green boll damage of 19-32% where as in farmers practice it was 20-70%, number of average insecticidal sprays in IRM farmer fields were 4.66 where as in farmers practice it was 7.2, IRM farmer had registered a benefit-cost ratio of 2.17:1 where as in farmers practice it was 1.3:1, results are in confirmation with present studies.

CONCLUSION

According to the study mentioned above, the bio-intensive module-based pink bollworm management strategies mentioned above can be used to manage the pink bollworm in Bt cotton effectively. Chemical insecticides are ineffective against the pink bollworm on their own because they increase cultivation costs, harm ecosystems, leave behind more pesticide residues, and have lower net returns.

FUTURE SCOPE

Additional research on new PBW management techniques, such as matting disruption techniques, will help farmers better manage PBW on their fields and stop pink bollworm from developing resistance.

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Conflict of Interest. None.

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