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A front-line demonstration on integrated pest management in cotton with special reference to pink boll worm, *Pectinophora gossypiella* (Saunders) and its economic analysis under farmer's field conditions

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Abstract
An Integrated Pest management for Pink Bollworm (PBW) in Cotton includes installing PBW pheromone traps (5acre^{-1}) after 45 DAS, release of *T. bactrae* @ 60000acre^{-1} thrice at weekly intervals between 60-90 DAS, spray of Quinalphos 20 EC 2mllitre^{-1}of water if 10% infested bolls with live larvae observed, were evaluated against PBW in Scarce rainfall zone of Anantapur district of Andhra Pradesh during *Kharif* March to September for three years (2019-20, 2020-21 and 2021-22). Observations on % Rosette flower and Locule damage was noted based on total number and damaged fruiting bodies in each plant taken from 10 IPM and 10 farmer's practice (FP) fields and results show IPM fields registered significantly less rosette flower damage compared to FP indicating the suitability of IPM components. Rosette flower damage was found lower of 5.23%, 3.07% and 3.48% with a mean of 3.92% in IPM as compared to FP (16.77%, 5.81% and 8.43%) with mean of 10.33, similarly, Locule damage of 7.07%, 2.48%, 3.95% with a mean of 4.50% in IPM as compared to 12.14%, 6.48% and 6.71% with a mean of 8.52% in FP during 2018–19, 2019–20, and 2020–21, respectively. The benefit-cost ratio shows that IPM practice gives more benefit, *i.e.* 2.58, 2.54, and 1.80, with mean of 2.30 compared to FP, 2.10, 2.27, and 1.50 with mean of 1.95 respectively, during 2019-20, 2020-21 and 2021-22, respectively.

Keywords: Pink boll worm, IPM practice, rosette damage

Introduction

One of the most significant commercial crops produced in tropical and subtropical areas of the world for feed, fiber, and oil is cotton (*Gossypium* sp.), sometimes known as "white gold" and grown primarily in Andhra Pradesh. It has an annual production of more than 6 million tonnes, where India is the world's largest producer of cotton (Anonymous, 2023). Cotton is cultivated over 13.285 million hectares across three agroecological zones in India (North, Central, and South), with an average lint production of 451.05 kg/ha in 2020-2121 (COCPC, 2022) [5]. It is grown by around 5.8 million farmers in India, and 40-50 million people make their living from cotton-related industries such as processing and commerce. However, India is one of the least productive nations due to a wide range of biotic and abiotic challenges that the crop faces during cultivation of the crop. Insect pest damage is one of the major sources of losses resulting from biotic stresses. The major pests of cotton belong to sucking pests *viz.*, cotton jassid (*Amrasca biguttula biguttula* (Ishida)), aphid (*Aphis gossypii* Glover), thrips (*Thrips tabaci* Linde, *Thrips palmi* Karny), whitefly (*Bemisiatabaci* Genn.), mirid bug (*Creontiades biseratense* Distant), mealybugs (*Phenacoccus solenopsis* Tinsley; *Paracoccus marginatus* Williams & Granara de Willink) and bollworms *viz.*, cotton bollworm (CBW) (*Helicoverpa armigera* (Hübner), spotted bollworms (SBW) (*Earias* spp.) and pink bollworm (*Pectinophora gossypiella* (PBW) (Saunders)) (Nagrare *et al.* 2022) [18]. Among all the insect pests, the Pink bollworm is the most destructive (Balakrishnan, 2010) [7]. Since its introduction, the fostering of *Bt* cotton has skyrocketed in India (Henneberry and Naranjo, 1998) [15].

The pink bollworm, *Pectinophora gossypiella* (Saunders), is now regarded as one of the most dangerous insect pests of cotton crops, this is because it has recently developed resistance to Bt technology and started attacking fruiting bodies hence potentially causing indirect yield losses as well as degrading the fibre quality. Hence the administration of insecticides from various groups in certain sequences, together with the timing of application and interval spraying, are essential components of a successful cotton bollworm control program (Abd El-Mageed *et al.*, 2007) [1]. According to reports, the percentage of cotton lost to bollworms, sucking pets, and both combined is 11.60%, 44.50%, and 52.10%, respectively (Dhawan and Sindu, 1986) [12]. Dilnur *et al.* (2019) [13] found that bollworms alone might result in yield reductions of up to 85%. Cotton farmed areas increased significantly after the introduction of genetically modified cotton (*Bt* cotton) BG-I in 2002 and BG-II in 2006 (Qaim 2020) [22]. Large-scale Bt cotton farming can subject bollworms to constant and high selection pressure, which can result in the development of toxin tolerance (Hardee, 2001) [14]. The emergence of Pink bollworm resistance to Cry 1 Ac and Cry 2 Ab toxins has recently been reported in India (Naik, 2018) [10]. Since the Pink Bollworm is an interior feeder, controlling it with insecticides alone is quite challenging. Adoption of integrated pest management tactics is therefore a potential solution that is crucial. In order to effectively manage the complex of pests in cotton, which range from sucking pests to bollworms including pink bollworms recently a variety of techniques must be used in combination. The selection of pesticides and other management strategies will depend on where the pest is found. The use of integrated pest management, which entails a number of preventative measures (cultural, physical, mechanical, biological, and chemical methods), is crucial, appropriate, and sustainable in this situation for the production of cotton (CICR, 2017) [3]. Feedback received after Bt cotton was commercialized has shown that the knowledge is not a fix-all for insect issues and that an integrated strategy is required to maximize benefits and maintain the technology (Bambawale *et al.*, 2010) [8]. As a result, the practical effectiveness of the developed IPM module was assessed in farmer field circumstances using front-line demonstrations.

Materials and Methods

ICAR- Krishi Vigyan Kendra, Kalyandurg, has performed ten front-line demonstrations in natural rainfed conditions throughout the Kharif season (June-October) for three consecutive years, 2019-20, 2020-2021, and 2021-2022, in various villages within the Krishi Vigyan Kendra operational region. From each farmer 0.4ha (one acre) was selected as demonstration plot and all IPM practices were imposed and an adjacent field was treated as check.

Crop rotation, clean cultivation Sowing in June along with a refuge, at 0-60DAS, Pest monitoring at weekly intervals by using a field scout, installation of PBW pheromone traps (5acre^{1}) after 45 days of sowing at squaring and flowering stage for presence of PBW larvae within flowers, if moth catch crosses ETL, spraying crop with Neem oil 5ml + NSKE 50ml + 1gm detergent powder litre^{-1} of water at 50-60 DAS. At 60-90DAS, initiate pink bollworm monitoring starting from flowering stage, observe for rosette flowers, remove from the plant and destroy them. Assess ETL by plucking 20 green bolls from randomly selected plants across one acre and if ETL at this stage is 10% or crossed damaged green bolls, spray Quinalphos 20EC 2ml lit^{-1} of water, mandatorily, release of *T.bactrae* @ 60000 acre^{-1} thrice at weekly intervals between 60-90 DAS, at 120 DAS or more, on 10% infested bolls with live larvae of Pink bollworm spray Fenvalerate 20% EC 1 ml or Cypermethrin 10% EC 1 ml or LamdaCyhalothrin5% EC 1 ml 10 lit^{-1} of water against PBW, termination of crop by end of December and destruction of crop residues (CICR, 2019) [4].

Observations on insect pests PBW damage: - A total of ten IPM fields and ten farmer's practice (FP) fields were used to collect data on rosette flowers (%) and locule damage (%). Based on the overall quantity and damaged fruiting bodies in each plant, the damage to fruiting bodies (squares) was noted. To determine the percentage of damage, the fruiting bodies (squares), both shed and intact on the plants, were considered. Over the course of three pickings, the seed cotton yield for every plot was noted. Cost of cultivation, including plant protection, yield, and benefit cost ratios, was also calculated for economic analysis.

Results and Discussion

Data reveal that IPM fields had considerably less fruiting body damage (Rosette and Locule) than FP fields, showing the effectiveness of IPM components (Table 1). Rosette flower damage was found to be lower in IPM fields (5.23%, 3.07%, and 3.48%, with a mean of 3.92%) than in FP fields (16.77%, 5.81%, and 8.43%), with a mean of 10.33% during 2019-20, 2020-21, and 2021-22, respectively. Similarly, locule damage was much lower in IPM fields (7.07%, 2.48%, 3.95%) with a mean of 4.50% than in farmer's practice fields (12.14%, 6.48%, and 6.71%) with a mean of 8.52% in 2019-20, 2020-21, and 2021-22, respectively.

This data show that treating pink bollworm with just chemical pesticides will not produce good outcomes. However, IPM, along with need-based spraying of prescribed pesticides at appropriate doses on a community basis, efficiently controls pink bollworm. The results obtained during the field investigation were consistent with the findings of Patil *et al.* (2011) [19], which reveal that the adoption of IRM-based IPM modules resulted in a reduction in the population of sucking pests above recommended plant protection techniques with fewer usage of pesticides. The results showed that the IPM technique outperformed the current farmer practice of using pesticides excessively and with little monitoring, resulting in a considerable increase in cotton output (Aggarwal *et al.*, 2006) [2]. Some researchers have established the efficacy of pheromone traps such as sleeve traps and yellow funnels (Sandhya *et al.*, 2010) [24]. Pheromones at increased concentrations or frequency of lures can also be employed in mass trapping as well as to confused mating. Maruti *et al.* (2020) [17] demonstrated pink bollworm management through mass trapping which was in consistent with previous research, which found that the adaptability of an IPM module integrated with cotton was higher, as evidenced by the lowest percentage of pest or PBW infestation and higher seed cotton yield with higher net returns. Prasad and Ashwini, 2021 [24] reported that the lowest number of PBW larvae per 10 green bolls was observed with reduction up to 61.9% incidence during both the years of study.

Table 1: Incidence of PBW damage (Rosette and Locule) and its Economic analysis of Cotton in Farmers Practice and IPM fields over three consecutive years (2019-20, 2020-21, 2021-22).

Parameters	2019-2020		2020-2021		2021-2022		Pooled		% inc/dec in IPM over FP
	FP	IPM	FP	IPM	FP	IPM	FP	IPM	
Rosette flowers (%)	16.77	5.23	5.81	3.07	8.43	3.48	10.33	3.92	37.90
Locule damage (%)	12.14	7.07	6.48	2.48	6.71	3.95	8.44	4.50	54.02
Seed cotton Yield (kg/ha)	1022	1147	1464	1565	1450	1625	1311	1446	9.33
Percent Increase in yield over control(%)	-	12.23	-	6.90	-	12.07		10.40	-
Cost of cultivation (Rs./ha)	21,824	19,932	35,450	33,874	55,346	51,655	37540	35157	6.77
Gross returns (Rs./ha)	45,990	51,615	80,520	86,075	83,027	93,047	69846	76912	9.18
Net returns (Rs./ha)	24,166	31,683	45,070	52,201	27,681	41,392	32306	41759	22.63
Benefit Cost ratio (B: C)	2.10:1	2.58:1	2.27:1	2.54:1	1.50:1	1.80:1	1.95:1	2.30:1	15.21

FP: Farmers Practice; IPM: Integrated Pest Management Demo Plot

Economics of IPM

The three-year pooled data on yield and economics demonstrated that IPM deployment resulted in a 10.40% improvement in yield over FP (Table 1). The benefit-cost ratio for IPM was 2.30, whereas for FP it was 1.95. Increased production in IPM areas was mostly due to effective agricultural techniques that helped sustain plant Vigour under insect attack, allowing plants to adjust for pest damage.

Previous studies (Kumar *et al.*, 2011, Dahiya *et al.*, 2015 [11], Patil *et al.*, 2014, Chandi *et al.*, 2015) [16, 11, 20, 9] demonstrated that the use of IPM components, clean agriculture, and judicious pesticide usage offered optimal circumstances for natural enemy proliferation and enhancement. Sain *et al.* (2021) [23] also found that IPM technologies such as timely sowing of recommended cotton hybrids, weed removal as an alternate host, proper plant nutrition, use of neem-based pesticides, conservation of natural enemies by avoiding insecticides that harm natural enemies, and judicious use of safer pesticides were effective in managing cotton pests. Shankar *et al*., 2022 [25] found that the demonstration plot (2234.0 kg ha-1) produced 16.9% more cotton than the farmers' practice (1910.5 kg ha-1).

Conclusion

Cotton IPM was validated on a large scale in farmer fields for three years, which resulted in higher yields with fewer inputs and pesticide application at a high benefit-cost ratio. Thus, the study concludes that using IPM tactics in cotton can help manage PBW efficiently. The verified IPM technique is environmentally safe, economically feasible, and easily implementable in farmer fields, and it is very effective in managing PBW and other cotton pests in the country's southern region.

Data availability statement

The public access to raw data is subject to legal constraints. However, authors have the entire right to transfer or share raw data upon request, subject to following the terms of the original consents and research project. Furthermore, data access must ensure that the user complies with their ethical and legal duties as data controllers to enable for secondary use of the data outside of the original research.

Authors' Contribution

Conceptualization of research, designing of the experiments, Execution of field experiments and data collection Contribution of experimental materials, Analysis of data and interpretation, Preparation of manuscript: All authors were contributed equally.

Declaration

The authors declare that they have no conflict of interests.

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