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Management of Pink Bollworm (*Pectinophora gossypiella*) Through Mating Disruption: An Environment Friendly Technique

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ABSTRACT

Mating disruption through sex pheromones has a very significant role in any IPM program for pink bollworm (PBW) in cotton. The present investigation was conducted in 2021 at the experimental area of Nuclear Institute of Agriculture, Tandojam to evaluate the effectiveness of mating disruption technique through PB-ropes application against PBW. PB-ropes were installed @ 120 ropes per acre after 45 days of sowing of the crop. The results revealed that the block where PB-ropes were installed showed significantly lower adult moth catches of PBW in delta traps compared to the control block (where no treatment was applied). The overall mean moth catches of 4.33 per trap per night was observed in the PB-ropes block whereas moth catches in the control block were 16.03 moths per trap per night. The results also showed a lower percent infestation of PBW in the PB-ropes block compared to the control block. The overall mean percent infestation of 4.72 % was recorded in the PB-ropes block whereas the mean infestation in the control block was 9.65%. Furthermore, an overall reduction of 72.98% in moth catches and 51.08% in infestation of PBW was recorded in the PB-ropes block as compared to the control block during the whole study period. Therefore, it can be asserted that mating disruption is an optimal approach for the control of PBW, offering advantages such as species-specific, environment safety, and non-hazardous to beneficial insects.

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MUA and RM designed the study. MUA, MA and MS conducted the study. MUA and MS analyzed the data. MUA, RM and NHK wrote the manuscript.

Key words
Pink bollworm, PB-ropes, Cotton consumption, Gossyplure, Pheromone

INTRODUCTION

Cotton is recognized as white gold around the globe with more than 33 million hectares of agricultural land coming under cotton cultivation (FAO, 2020). In Pakistan, it is the second most important economic crop with a share of 0.80% of GDP. Pakistan is the 4th largest cotton producer, ranks 3rd in cotton consumption, and occupies 7th position in apparel production (Shuli *et al*., 2018). Bollworms are one of the leading threats to this gainful crop by causing 30-40% yield losses annually (Cororaton *et al*., 2008; Masood *et al*., 2011; Khan *et al*., 2012). Among the major chewing insect pests, pink bollworm (PBW) was more detrimental and caused a 10.7-59.2 % delay in the natural opening of bolls, 2.8-61% cotton seed yield losses as well as 2.1-47.1 % loss of oil (Patil, 2003). It feeds on the fruiting bodies of cotton plants with inconspicuous feeding behavior (Hussain *et al*., 2021; Naik *et al*., 2021; Rajashekhar *et al*., 2024). During 2015-16, approximately 4.5 million bales of cotton vanished due to the severe attack of PBW in Pakistan (Javed *et al*., 2020).

The PBW is considered the most injurious insect pest for cotton because it is very complicated to manage with synthetic insecticides. Females laid eggs on the sutures or beneath the bracteoles at the base of the boll particularly on bolls up to fourteen days old, so larvae immediately after hatching can enter the bolls or flowers within 20-30 min (Hutchison *et al*., 1988) or within 2 h (Ingram, 1994).

PBW management mainly relies on pesticide usage that leads to resistance evolution. Heavy insecticide applications are required to manage this pest effectively (Ahmad *et al*., 2002). At times frequent insecticide applications have been done that ultimately lead to secondary pest outbreak, otherwise managed by bio-control agents (Lykouressis *et al*., 2005). Annual expenditure of pesticides in Pakistan is approximately US$300 million, out of which 80% was sprayed on cotton for the control of bollworms (Arshad and Ahmad, 2011).

Pesticide sprays give safety from insect pests that

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can cause significant economic loss. However, their irrational use can lead to crop damage, poor control, high expenditure, and risks to health and the environment. Moreover, the population abundance of natural enemies has been greatly affected by the injudicious use of pesticides in the cotton fields. Also, they might accelerate the emergence of other cotton pests mostly mites and insects that develop resistance to some insecticides (Bassouiny, 2021). Bt technology provides effective bollworm control with target specificity and proved to be environment-friendly (Mendelsohn *et al*., 2003; Wu and Guo, 2005). But currently, PBW has developed resistance against transgenic cotton having *Cry1Ac* gene (Fabrick *et al*., 2014; Tabashnik *et al*., 2014).

Adult tendency to lay eggs in protected places, quick penetration of larvae into the bolls after hatching, internal feeding behavior, high reproductive potential, and considerable mobility of its moths are the significant obstacles to its control efforts. The effectiveness of synthetic insecticides reduced significantly against PBW because they camouflage themselves in rosette flowers and bolls (Hussain *et al*., 2021).

Ouye and Butt (1962) demonstrated another alternative technique to control PBW that homogenized extract of mating pairs attracted the virgin males. Green *et al*. (1969) described "Hexalure" as an attractant to males but later on Hummel *et al*. (1973) identified "gossyplure" as the natural sex pheromone of PBW a 1:1 mixture of the Z, Z- and Z, E-isomers of 7, 11-hexadecadienyl acetate. Scientists used gossyplure both for monitoring (Qureshi *et al*., 1993; Buchelos *et al*., 1999) as well as for control purposes by mating disruption (Urquijo and Manzano, 2002; Lykouressis *et al*., 2005; Nadeem *et al*., 2023). Mating disruption is achieved mainly through dispersal of gossyplure at a high dose rate in cotton canopy resulting in minimum economic damage. Mating disruption using PB-ropes offers practically an ideal approach for PBW management in cotton (Patil *et al*., 2004; Tabashnik *et al*., 2021; Hussain *et al*., 2021; Babar *et al*., 2022; Nadeem *et al*., 2023).

None of the recent studies on mating disruption against PBW evaluated the efficiency of PB-ropes in the Sindh province of Pakistan. Therefore, the present study was initiated with an overall objective to evaluate the efficacy of PB-ropes against PBW in cotton under the climatic conditions of Tandojam, Sindh.

MATERIALS AND METHODS

The field experiment was conducted during Khairf, 2021 at the Experimental Farm of Nuclear Institute of Agriculture Tando jam on the cotton crop to appraise the effectiveness of PB-rope dispensers against PBW. The block of 8 acres of cotton was selected for the installation of PB-ropes and named as PB-ropes block while for control treatment an isolated block of 3 acres was selected where no treatment was applied against PBW during the entire study. This control block was at least 800 m away from the PB-ropes block. Recommended agronomic practices were adopted during the whole season in both blocks. PB-ropes were installed @ 120 ropes per acre after 45 days of sowing of the crop. These PB-ropes remain active in the field for 90-120 days. Pheromone baited delta traps were installed @ 1 per acre in both blocks (PB-ropes and control block) to monitor and evaluate the effect of PB-ropes on the adult moth catches of PBW. Traps were suspended on a stick 60 m apart and 1.25 m above ground level. Observation on moth catches was recorded weekly in each block from July to October. Delta traps with pheromone lures were also replaced weekly with new traps and lures. To determine the effect of PB-ropes on the infestation of PBW, larval presence or damage symptoms were recorded on the fruiting structures i.e. flowers and bolls of twenty four randomly selected plants in each block. Data on percent infestation were recorded from July to September for three months weekly. The percentage of infestation was calculated by comparing the total and damaged fruiting structures using the following formula:

$$\text{Infestation (\%)} = \frac{\text{No. of damaged fruiting parts}}{\text{Total No. of fruiting parts}}$$

Moth catches and percent infestation was compared between the PB-ropes block and control block. Data was subjected to analysis of variance (ANOVA) and means were compared through the LSD test at $P \leq 0.05$ by using statistix 8.1 software.

RESULTS

Effect on moth catches

The results revealed significant variation in PBW adult moth catches between the control block and PB-ropes block during different weeks of observation. Figure 1 clearly shows that mean moth catches in the PB-ropes treated block remained significantly low compared to the control block on all the dates of observation during the entire period of study. Mean moth catches in the PB-ropes treated block ranged from 0.03 to 12.51 per trap per night whereas in the control block, moth catches ranged from 1.47 to 24.71 per trap. In the control block adult male population of PBWW gradually started increasing from the 1st week of July and reached the highest peak in the third week of September with 27.71 moths per trap per night while the second highest peak was observed in the 2nd week

of October with 23.14 moths per trap. In comparison to the control block, adult moth catches in the PB-ropes block varied considerably and remained negligible during the all weeks of July and August. Afterward, the population in the treated block showed an upward trend, and peak captures were recorded in the 1st week of October with 12.51 moths per trap (Fig. 1).

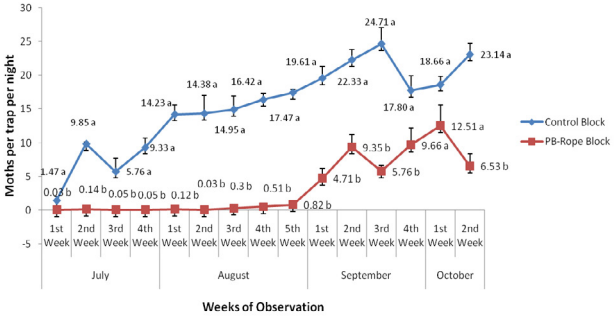

Fig. 1. Comparison of pink bollworm adult moth catches in PB-ropes and control block during different weeks of observation.

The results regarding monthly and overall mean moth catches (Table I) revealed that traps in the PB-ropes block captured a lower population compared to the control block. Mean moth catches in the PB-ropes block were 0.07, 0.36, 7.37, and 9.52 per trap per night compared to 6.60, 15.49, 21.11, and 20.90 in the control block during July, August, September, and October, respectively. A significant difference was recorded in overall mean moth catches for the entire period of observations. An overall mean moth catches of 4.33 per trap per night was recorded in the PB-ropes treated block compared to the control block with 16.03 moths per trap.

Table I. Comparison of mean moth catches with overall reduction percentage in different months.

Months	Moth catches/trap/night		Reduction % in moth catches over control block
	Control block	PB-ropes block	
July	6.60a±0.77	0.07b±0.05	98.93 %
August	15.49a±0.10	0.36b±0.09	97.67 %
September	21.11a±3.46	7.37b±1.01	65.08 %
October	20.90a±0.64	9.52b±2.35	54.44 %
Overall mean	16.03a±0.99	4.33b±0.74	72.98 %

Means sharing similar letter in rows are significantly different at p<0.05.

The results in Figure 2 demonstrate a significant percent reduction in adult moth catches in the PB-ropes block during all weeks of observation compared to the control block. More than a 90 percent reduction was recorded in all the weeks of July and August. However, in September highest reduction was observed in the 3rd week followed by the 1st week with percent reductions of 76.66 and 75.97 %, respectively. The mean percent reduction of 98.93, 97.67, 65.08, and 54.44 % was recorded during July, August, September, and October, respectively. An overall mean percent reduction of 72.98% was recorded during the study period in the PB-ropes treated block compared to the control block (Table I).

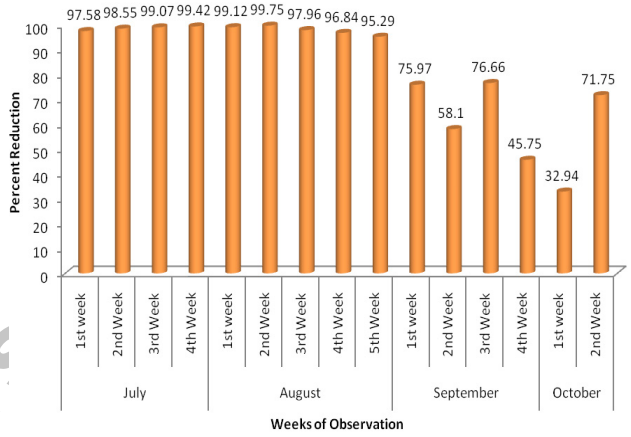

Fig. 2. Percent reduction of moth catches in PB-ropes block over control block.

Effect on percent infestation

The results regarding the percent infestation of PBW in control and PB-ropes blocks varied significantly during different weeks of observation. Figure 3 clearly shows that the percent infestation in the PB-ropes treated block remained significantly low compared to the control block on all the dates of observation during the entire period of study. The mean percent infestation in PB-ropes treated block ranged from 1.21 to 21.75 % whereas in control block percent infestation ranged from 0.25 to 34.31 percent. In the control block, infestation gradually started increasing from the 3rd week of July and reached the highest peak in the 4th week of September with a percent infestation of 34.31%. However, the percent infestation in the PB-ropes block varied significantly and remained low during the all weeks of July and August. Infestation in the PB-ropes block was observed for the first time in 2nd week of August and showed a considerable increase in September with 7.8 % infestation in the 1st week of observation and attained the highest peak of 21.75 % infestation in the 4th week which was the last observation week (Fig. 3).

Table II. Comparison of mean percent infestation with overall reduction percentage in different months.

Months	Mean percent infestation		Reduction % in percent infestation over control block
	Control block	PB-ropes block	
July	0.46a±0.07	0.00b±0.00	100 %
August	7.80a±0.54	1.71b±0.83	78.07 %
September	20.68a±0.76	12.46b±1.22	39.74 %
Overall mean	9.65a±0.18	4.72b±0.57	51.08 %

Means sharing similar letter in rows are significantly different at p<0.05.

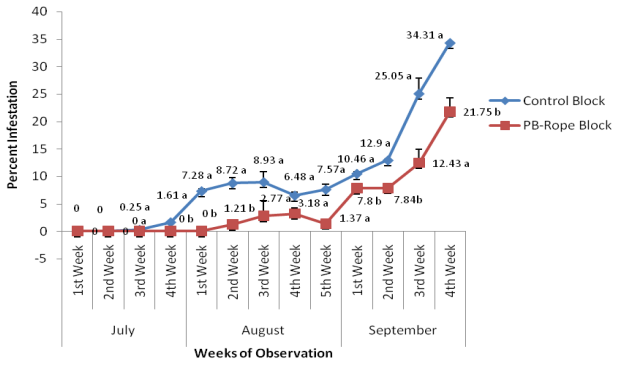

Fig. 3. Comparison of pink bollworm infestation in PB-ropes and Control Block during different weeks of observation.

The results regarding monthly and overall mean percent infestation of PBWW (Table II) revealed that the PB-ropes block harbored lower infestation as compared to the control block during all the months. Mean percent infestation in the PB-ropes block were 0.00, 1.71, and 12.46 % compared to 0.46, 7.80, and 20.68 % in the control block during July, August, and September, respectively. A Significant difference was recorded in the overall mean percent infestation for the entire period of observations. An overall mean percent infestation of 4.72 % was recorded in the PB-ropes treated block compared to the control block with 9.65 % infestation.

The results in Figure 4 demonstrate a significant reduction in the percent infestation of PBWW in the PB-ropes block during all weeks of observation compared to the control block. 100 % reduction was recorded in the 3rd and 4th week of July and in 1st week of August. Afterward, a peak reduction in percent infestation was recorded in the 2nd and 5th week of August with a percent reduction of 86.03 and 81.87 %, respectively. However, in September a decline in the reduction percentage was observed with an increase in percent infestation. The highest reduction was observed in the 3rd week of September followed by the 2nd week with a percent reduction of 50.34 and 39.18 %, respectively. The mean percent reduction in infestation of PBWW was 100 and 78.07 and 39.74 % during July, August, and September, respectively. An overall mean percent reduction of 51.08 % was recorded in infestation of PBWW during the entire study period in the PB-ropes treated block compared to the control block (Table II).

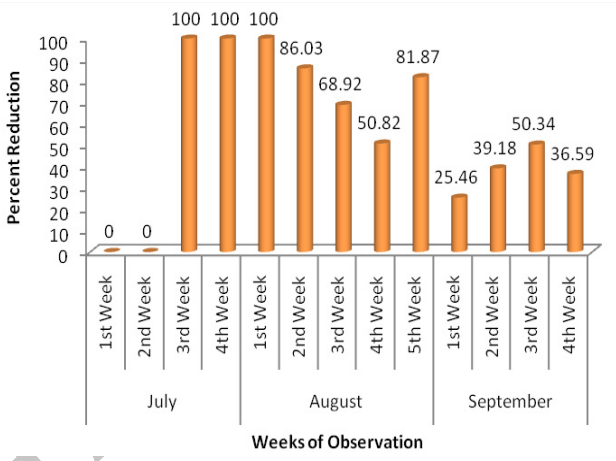

Fig. 4. Percent reduction of PBW infestation in PB-ropes block over control block.

DISCUSSION

Our data on moth catches per trap per night in the PB-ropes treated block and control block indicated significant suppression of PBW adult male catches in the PB-ropes block. The decline in trap catches is primarily due to disruption in mating among adults by averting and confusing males from finding females. This results in lower fertile egg production which ultimately reduces the population abundance of PBW (Hussain *et al*., 2021). These results are in accordance with Babar *et al*. (2022) who reported a 68.24 and 72.52 % reduction in the moth population in PB-ropes block over control during the two year study. They also observed a 53.63 and 50.26 % reduction in the larval population with significantly less population in treated block. Lykouresis *et al*. (2005) reported that the application of pheromone was very efficient in reducing the number of PBWW caught in traps compared to repeated insecticide sprays in control fields. The reduction in trap catches is a sign of a sufficient quantity of pheromones in the field that is required for male disorientation resulting in reduced mating success and oviposition rate. 95-100 % mating suppression was reported in Israel due to PB-Rope dispensers (Kehat *et al*., 1999).

Patil *et al*. (2007) recorded 0.8 moths per trap per

night where PB-ropes were installed @ 200/hectare compared to the control treatment where 2.6 moths were trapped. Likewise, Mohamed *et al*. (2016) concluded that PBW moths abundance reduced to nearly 100% compared to control. Shrinivas *et al*. (2019) reported a significant decrease in the PBWW population as a result of specialized pheromone and lure application technology (SPLAT) that confuses the adults in the field and is recommended as a substitute for harmful insecticide. Harter *et al*. (2010) concluded that PB-ropes resulted in reduced mating and ultimately decline in insect abundance. Nadeem *et al*. (2023) recorded 96.30 % control over the PBW population due to PB-ropes application in the field followed by delta traps (85.03%) and light traps (75.13%).

The present results showed a gradual rise in population from July and a peak gained in September and October, the peak season of the cotton crop with a maximum quantity of fruiting bodies. These results are consistent with previous reports on the population dynamics of PBW (Khuhro *et al*., 2015; Ali *et al*., 2016; Asif *et al*., 2017; Asif *et al*., 2022).

The results also revealed that the PB-ropes treated block significantly harbored a lower percent infestation of PBW compared to the control block during the entire period of study. Similarly, Lykouresis *et al*. (2005) reported much higher percent damage in control treatment compared to PB-ropes treated fields during the two years of study. Maruti *et al*. (2020) mentioned that pheromones play a significant task in the mating disruption and mass trapping of PBW moths under field conditions by minimizing the infestation percentage. Bassouiny (2021) concluded that combined treatment of pheromones with parasitoids provided a 90% decline in PBW infestation compared to insecticides (80-87%) in cotton. Unlu and Mezreli (2011) and Mohamed *et al*. (2016) concluded that larval population and green boll percent infestation were much inferior in treated plots as compared to control plot, and it is the main indicator of the effectiveness of PB-rope dispensers. Radhika and Reddy (2006) reported minimum damage with higher yields in pots where PB-ropes were installed.

An area-wide mating disruption program for PBW management was initiated in Parker Valley, Arizona. The crop losses were reduced from 9.91% to 0.02% and the control cost was reduced from US$ 10.7.50 per ha to US$ 72.00 per ha in five years (Antilla *et al*., 1996). In central Greece, a 99.1% reduction in male trap catches was recorded in PB-ropes treated plots and crop losses were considerably less than in pesticide treated control plots (Sarfraz *et al*., 2006).

Previous studies also revealed a low abundance of other pests such as aphids and whiteflies and a decrease in sprays required for their control in PB-ropes treated block. These positive indirect effects might be due to the presence of beneficial insects in relatively greater numbers and their effective action in PB-ropes treated cotton fields (Lykouressis and Perdikis, 1997; Lykouressis *et al*., 1999). This positive impact of mating disruption in other pest population regulation has also been included in the main advantage of this method (Boguslawski and Basedow, 2001). Similarly, Staten *et al*. (1987) mentioned that this technique significantly contributes in minimizing the chances of late outbreaks of secondary pests.

Several environmental factors including temperature and wind velocity have a significant influence on the effectiveness of mating disruption programs. The pheromone release rate increases in high temperatures and could bring down the longevity of a disruptant indicating that increased pheromone-loading is required in warmer regions (Gut *et al*., 2004). The efficiency of mating disruption techniques in declining moth catches relied upon the orientation of cotton rows relative to the direction of the prevailing wind in that particular area. Moth catches were lower in treated fields where cotton rows were perpendicular to the wind direction compared to the parallel rows. However, the damage percentage on the plants appeared to be not affected by the prevailing wind direction (Lykouressis *et al*., 2005).

PBW ropes are typically applied in a cotton field at the "pinhead square" growth stage, which is usually around 40-45 days after sowing; this is considered the optimal time for maximum effectiveness against the pest. This approach provides effective control of PBW for 90-120 days (Rana, 2020). Timing of application, optimum rope density, and spacing can significantly impact their effectiveness. This technique provides efficient protection from PBW with an advantage over the pesticides in being species-specific, non-hazardous, non-polluting, environment friendly, and does not disturb natural/beneficial fauna. An additional benefit of mating disruption will be its positive effect on the environment through a significant reduction in pesticide usage.

CONCLUSION

The present study revealed the high effectiveness of PB-ropes application in cotton against PBWas expressed by the significant reduction in adult moth catches and lowering the percent infestation. Therefore, it can be concluded that mating disruption through PB-ropes is a very successful technique and could provide efficient control of PBW menace in cotton.

DECLARATIONS

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IRB approval

This study was approved by the Institutional Review Committee of NIA Tandojam, Pakistan.

Generative AI and AI-assisted technology statement

The authors have declared that no generative AI or AI-assisted technologies were used to create this manuscript.

Statement of conflict of interest

The authors have declared no conflict of interest.

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