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Effect of management modules for pink bollworm, *Pectinophora gossypiella* (Saunders) in *Bt* cotton Cultivars

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Abstract
A field experiment was carried out for the management of pink bollworm in *Bt* Cotton using different modules at IPM plot of 62F during *kharif* 2018 and 2019. All the modules worked significantly well in comparison with control module as chemical module was at the top in PBW management. As least number of PBW larvae (32.5/25 green bolls) and locule damage (71/100 fully opened bolls) were recorded in chemical control module. Biological control module (47 larvae/25 green bolls; 102 damaged locules/100 fully opened bolls) proved second best module following by biological + chemical control module (52.5 larvae/25 green bolls; 105.5 damaged locules/100 fully opened bolls). Highest population of *P. gossypiella* larvae (locule damage (130.5 damaged locules/100 fully opened bolls) and 67 /25green bolls) was seen in module remain untreated. While, for benefit cost ratio recorded in chemical control module was highest as compared to other modules. The present study finished that for management of *P. gossypiella* insecticidal sprays at ETLs proved better than biological control and other methods.

Keywords: *P. gossypiella*, *Bt* cotton, pink bollworm, modules, management

1. Introduction
Cotton, *Gossypium spp*. is one of the major crop of Pakistan, and most important fiber crop grown commercially in whole the country (Aslam, *et al*., 2004) [1]. Cotton is also used for its plenty of bi products in textile and other industry of the country. Millions of the bales are produced every year all around the world including Pakistan (Ahmad, *et al*., 2002, Akhtar, *et al*., 2010) [2]. Plenty of the cotton insect pests attack on cotton plant. In these insect pests there are two basic types. One is sucking insect pests like jassid, whitefly, thrips, mealy bug, dusky cotton bug and red cotton bug (Ahmad, Ashraf, Hussain and Qureshi, 2002, Naik, *et al*., 2018) [3]. Second is the chewing insect pests in which the most notorious are American bollworm, spotted bollworm, armyworm and pink bollworm (Akhtar, Haidar, Khan, Ahmad, Sarwar, Murtaza and Aslam, 2010, Sarwar, 2017) [2, 9, 4, 5]. After release of the Bt cotton varieties attack of the spotted bollworm and American bollworm was managed. While this genetic modification is ineffective against Pink bollworm (*P. gossypiella* Saunders) (Akhtar, Haidar, Khan, Ahmad, Sarwar, Murtaza and Aslam, 2010, Sarwar, 2017) [2, 9, 4, 5]. Therefore, with passage of the time Pink bollworm (*P. gossypiella* Saunders) infestation is increasing and it has become a major threat to all *Bt* Cotton varieties (Aslam, Razaq, Saeed and Ahmad, 2004, Sarwar, 2017) [1, 4, 5]. From last three years it has been observed that it is causing considerable loss to Cotton. Even loss in terms of yields is two types quantitative and qualitative (Naik, Kumbhare, Kranthi, Satija and Kranthi, 2018, Amjad, *et al*., 2009) [3, 6].
It has been observed that in cotton growing areas last two months are seriously affect due to second generation attack of Pink bollworm. It was observed one to two dozen bolls on all kind of *Bt* Cotton hybrids was effected (Dhurua and Gujar, 2011, Tabashnik, *et al*., 2012) [7, 8]. This attack decreases a huge quantity of the bales every year in Pakistan (Aslam, Razaq, Saeed and Ahmad, 2004) [1]. Secondly that infested cotton has not good quality for ginning purpose especially its staple length and lint color. Early sown cotton field are also disturbed due to attack of first generation (March-April) of *Pectinophora gossypiella*. Even in some early (February) sown cotton fields in four weeks of April it was pest scouted that ninety percent cotton flowers were bearing larvae of *P. gossypiella* (Sarwar, 2017, Amjad, Bashir and Afzal, 2009) [6, 4, 5].

In all around the globe *P. gossypiella* has become economically the most destructive pest that responsible 2.8 to 61.9 per cent loss in seed cotton yield, 2.1 to 47.10 per cent loss in oil content and 10.70 to 59.20 per cent loss in normal opening of bolls (Naik, Kumbhare, Kranthi, Satija and Kranthi, 2018) [3]. Expected yield losses due to *P. gossypiella* in the developed countries like in U.S.A. range from 9 and 61 percent in chemically controlled and uncontrolled field (Sarwar, 2017) [4, 5]. If our farmers will be able to control or reduce only pink bollworm infestation from their fields then our per acre cotton yield will significantly raise (Ashfaq, *et al*., 2010, Lykouressis, *et al*., 2005) [9, 10].

Consequently to save quality and quantity of the cotton it is very important to check this pest (Lykouressis, Perdikis, Samartzis, Fantinou and Toutouzas, 2005) [10]. There is a need to manage this pest with multiple ways rather than using only chemicals (Naik, Kumbhare, Kranthi, Satija and Kranthi, 2018, Sarwar, 2017) [3, 4, 5]. Increase in the use of pesticides for this pest will case generation of insect resistance and our chemical tool will may become ineffective within few years as some insecticides are not killing this pest effectively in the field conditions (Ahmad, Ashraf, Hussain and Qureshi, 2002, Dhurua and Gujar, 2011) [7].

Therefore scientists are insisting on integrated pest management (IPM) to meet this notorious pest (Ahmad, Ashraf, Hussain and Qureshi, 2002, Sarwar, 2017, Dhurua and Gujar, 2011) [4, 5, 7]. We should apply all possible tactics like mechanical, cultural, environmental and chemical methods to keep this pest below economic threshold level (Sarwar, 2017) [4, 5]. Biological or natural control agents or not only environmentally safe, cost effective but also has been reported effectively managing the cotton insect pests (Ahmad, Ashraf, Hussain and Qureshi, 2002). In IPM of cotton the egg parasitoids, *Trichogrammatoidea spp*. have been successfully used for the management of pink bollworm and confirmed as good biological agents in the laboratory conditions (Ahmad, Ashraf, Hussain and Qureshi, 2002, Sarwar, 2017) [4, 5]. There is also need to exercise all these managing tools in the form of module under the existing environmental condition (Naik, Kumbhare, Kranthi, Satija and Kranthi, 2018) [3]. Therefore present study was designed to evaluate different management modules against Pink bollworm in Bt cotton in order to find out an effective and economic module.

2. Materials and Methods

Evaluation of different modules for control of Pink bollworm in Bt cotton was studied in Bt cotton hybrid "IUB2013" during *Kharif* seasons of 2018 and 2019 at IPM plot of 62F. The experiment was carried out with four modules, *viz*., Biological control module, Insecticide control module; Biological + Insecticidal control module and an untreated control module, each in 500 sq.m. area separated with 2m buffer distance. The crop was grown under irrigation area conditions in heavy soil at a spacing of 90 x 60 cm following all recommended agronomic practices except plant protection measures. Biological control module includes ecofriendly strategies and chemical control module comprised of chemical insecticidal sprays which are normally effective against Pink bollworm (Table1). Sowing was done on 02-7-2018 during 2018 and on 01-7- 2019 during 2019. In untreated control plot, no insecticidal sprays were taken up during both the seasons. The pest management interventions were carried out only when the pests crossed economic threshold level. In all the treatments, cotton seed treated with imidacloprid 70 WS were sown in order to manage the early sucking pests. Each plot was divided into four equal blocks to minimize the error while recording the data. The first block was treated with Trichogrammatoidea bactrae@ 20,000/ ha at 10 days interval if the moth catches exceed 8 per trap for 3 consecutive days and spraying of Neem oil @ 5ml/l was initiated. The tricho cards of *Trichogrammatoidea bactrae* (NBAII-MP-TRI-02) were procured from REDEC Vehari. The second block was treated with conventional insecticides, received a total of five sprays during the season. The third block received a combination of biological and chemical methods as soon as the moth catches reached an economic threshold level. The fourth block was untreated and served as a control. To record pink bollworm incidence 25 fruiting bodies per plot were plucked at 140, 150,160,170 and 180 days after sowing during *kharif* 2018 where the incidence was started at 140 DAS and 120, 130, 140, 150, 160, 170 and 180 days after sowing during *kharif* 2019 where incidence started early at 120 DAS. To record incidence of bollworms in fully opened bolls at harvest time, 100 opened bolls per plot were plucked randomly and were collected in polyethylene bags and estimated locule damage. The data of all the observations was pooled to arrive at seasonal means (Table 4 & 5). Cotton yield was recorded from each treatment and the data were presented as seed cotton yield in q/ha and benefit cost ratio of each treatment was worked out.

Table 1: Treatment details of different modules in *Bt* Cotton

Treatments	
Module 1	1. Installation of Pheromone traps @ 10 per hectare at 45 DAS for monitoring Release of Trichogrammatoidea bactrae @ 20,000/ ha at 10 days interval if the moth catches exceed 8 per trap for 3 consecutive days 2. Spraying of Neem seed kernel extract @ 5% or Neem oil @ 5ml/l 3. Collection and destruction of Rosette flowers
Module 2	1. Spraying of Triezophos @ 1.5g/l 2. Spraying of Deltamethrin @ 2.0 ml/l 3. Spraying of Gamma cyhalothrin @ 0.3 ml/l 4. Spraying of Bifenthrin @ 1ml/l 5. Spraying of Lambda cyhalothrin @ 1ml/l Insecticidal sprays arrived at using the male catches (ETL) in the pheromone traps
Module 3	1. Installation of Pheromone traps @ 10 per hectare at 45 DAS for monitoring 2. Release of Trichogrammatoidea bactrae @ 20,000/ ha at 10 days interval if the moth catches exceed 8 per trap for 3 consecutive days 3. Spraying of Neem seed kernel extract @ 5% or Neem oil @ 5ml/l 4. Collection and destruction of Rosette flowers

	5. Spraying of Bifenthrin @ 1ml/l 6. Spraying of Lambda cyhalothrin @ 1ml/l Insecticidal sprays arrived at using the male catches (ETL) in the pheromone traps
Module 4	Control

3. Results

In order to manage the pink bollworm infestation different modules were applied at field in *Bt* cotton during *kharif* 2018 and 2019. In two seasonal researches as depicted in table 4 showing that all the modules are effective in comparison with untreated control (module 4) during kharif 2018 and 2019. Chemical management module remains at the top with respect to Pink bollworm infestation control as compare to other module in both years.

In the present investigation, it was revealed that through destructive sampling the least number of *P. gossypiella* larvae was observed in module 2 followed by module 1, module 3 while, the highest was noticed in module 4 during 2018-19. In term of number of *P. gossypiella* larval strength infestation, response against modules was similar as last year but comparatively low in intensity during 2019-2020 as given in table 2. Where, chemical module remains highly effective following by module 1, module 3 and module 4 showing the influence of insecticidal interventions over biological and other modules. Number of PBW larvae per 25 green bolls through destructive sampling at different days of crop growing period during 2018-19 should comparatively high results were observed but rate of number for module 1 and two was slow as compared to the others as given in table 3. After last picking of the experimental treatments locule damage was recorded from 100 fully opened bolls and *P. gossypiella* infested locules were counted. The data showed that highest locule damage was recorded against module 3 while in module 2 with biological control agents was less damaged. The chemical management module 2 was the highly effective and recorded little locule damage due to *P. gossypiella* infestation as showed in the table 4. As compared to first three modules data recorded from 100 fully opened bolls proved the highest locule damage was noticed in module 4 untreated controls during both years. The present findings proved that among all treatments, chemical are the best which was followed by botanical, botanical + chemical, intercrop + Trichogramma + botanical, biological control for control of bollworms in cotton. To find the effect of different modules on seed cotton yield was significantly observed that seed cotton was more in quantity where maximum integrated pest management tactics were applied and vice versa as showed in table 5. Overall the whole study proved that the major factors like yield, income from crop, gross income and cost benefit ration were at optimum level where maximum integrated pest management tactics were applied as given in table 6. Therefore integrated pest management tool played good role for high yield.

4. Discussion

Pink bollworm is a serious threat to cotton crop that cause a huge loss in the developing countries (Sarwar, 2017) [4, 5]. Cultural practices like timely sowing, deep ploughing, animal grazing and destruction of the effected bolls at the end of the final picking (Sarwar, 2017) [4, 5]. It has been recommended that in IPM programme, cultural controls with the use of Bt cotton along with sex pheromone trap and suitable sprays of good formulations are very important against this cotton pest (Sarwar, 2017) [4, 5]. It has been coded that with increase in the moth per night in trap incorporation of chemical management can be useful to control this pest (Sarwar, 2017) [4, 5]. Management module is important as insect resistance has been reported in some studies (Tabashnik, Wu and Wu, 2012) [8]. Pink bollworm can be control with the help of pheromone traps by male disruption technique as a major tool of integrated pest management played good role for high yield (Sarwar, 2017) [4, 5]. Implementation of pheromone traps to control the pink bollworm is a major economical tool (Maruti, *et al*., 2020) [11]. Another study revealed that use of biocontrol agents like Tricogramma cards and proper agronomic practices played key role in the management and enhanced the cotton yield (Sarwar, 2017) [4, 5]. Use of pesticide not only kill the beneficial pests but also harmful for the environment and enhance the cost benefit ratio (Henneberry and Naranjo, 1998) [12].

Table 2: Number of PBW larvae per 25 green bolls through destructive sampling at different days of crop growing period during 2019-20

Treatments	Days after sowing					Mean
	140 days	150 days	160 days	170 days	180 days	
Module 1	3	30	33	37	69	34.4
Module 2	1	18	15	28	31	18.6
Module 3	5	35	41	64	80	45
Module 4	11	51	59	73	93	57.4

Table 3: Number of PBW larvae per 25 green bolls through destructive sampling at different days of crop growing period during 2018-19

Treatments	Days after sowing							Mean
	120 days	130 days	140 days	150 days	160 days	170 days	180 days	
Module 1	7	28	62	67	93	79	75	58.71
Module 2	11	30	52	52	66	58	63	47.43
Module 3	16	34	47	66	92	65	117	62.43
Module 4	20	41	66	92	110	81	113	74.71

Table 4: Effect of different modules on *Pectinophora gossypiella* (Saunders) for 2018-19 and 2019-20

Treatments	No. of PBW larvae/25 green bolls		Pooled	No. of damaged locules/100 fully opened bolls		Pooled
	2018-19	2019-20		2018-19	2019-20	
Module 1	33	55	43	62	142	98
Module 2	16	44	30.5	51	97	77
Module 3	40	63	42.5	101	121	112.5
Module 4	65	76	62	113	132	136.5

Table 5: Effect of different modules on seed cotton yield (q/ha) for the year 2018-19 and 2019-20

Treatments	Seed cotton yield (q/ha)		Pooled
	2018-19	2019-20	
Module 1	19.88	16.11	18.99
Module 2	28.17	16.99	21.78
Module 3	18.90	16.53	15.67
Module 4	11.67	11.42	11.57

Table 6: Economics of different modules applied against management of *Pectinophora gossypiella* (Saunders) for 2018-19 and 2019-20

Particular	2018-19				2019-20			
	Module 1	Module 2	Module 3	Module 4	Module 1	Module 2	Module 3	Module 4
Yield (q/ha)	16.91	21.17	15.90	12.87	16.11	17.82	14.65	12.47
Income from crop (Rs./ha)	77,345	1,01,678	70,104	56,699	72,915	81002	70928	57190
Gross income (Rs./ha)	77,533	1,01,607	70,109	56,699	72,515	80,302	71,028	57,190
Total Cost of cultivation (Rs./ha)	63,110	67,545	64,235	57,650	65,060	65,025	63,635	57,250
Benefit: Cost ratio	1.20	1.42	1.02	0.91	1.10	1.11	1.00	0.92

5. Conclusion

After application of complete module it was concluded that biological module + chemical module was least effective but chemical control module was at the top for the best management of Pink bollworm in *Bt* Cotton. It was also found that application of biological control module was second best strategy of the module.

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