



Comparative Bollworm Infestation on BT and Non-BT Cotton

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Abstract: Field studies were carried out from 2nd July to 28th October 2013 to monitor population dynamics of *Earias* Spp., *Helicoverpa armigera* (Hub.) and *Pectinophora gossypiella* (Saund.) On cotton varieties K.D. 57, TH-112/105, Krish-342, Sindh-1, Shahbaz-95 and NIAB-78; and these varieties were compared with Sattari-BT for bollworm infestation.

The results indicated that the statistically population of boll worm complex varied significantly ($P < 0.05$) on different varieties. Cotton variety TH-112/105 was more infested (3.44%) by *Earias* spp. than Sindh-1, Shahbaz-95, KD-57 and Crish-342 with insect population of 3.40, 3.35, 3.18 and 3.08%. *Earias* population was recorded lower on NIAB-78 (1.79%) and lowest (0.93%) on Sattari-BT. The *H. armigera* population was highest (0.95%) on variety TH-112/105, while the pest population was 0.94, 0.92, 0.86 and 0.81% on cotton varieties Shahbaz-95, Sindh-1, KD-57 and Crish-342, respectively. *H. armigera* population was relatively lower on variety NIAB-78 (0.49%); while the lowest insect population (0.26%) was observed on variety Sattari-BT. *P. gossypiella* Saund. population also differed significantly ($P < 0.05$) on cotton varieties and highest population (3.21%) was observed on variety Sindh-1, while the pest population was 3.01, 2.94, 2.77 and 2.69% on cotton varieties KD-57, TH-112/105, Shahbaz-95 and Crish-342, respectively. The insect population was relatively lower on variety NIAB-78 (1.92%); while the lowest insect population (0.83%) was noted on variety Sattari-BT. *Earias* spp. population was at peak on 20th August, while *H. armigera* infestation reached its peak level on 27th August; and *P. gossypiella* population was at on 10th September. It was concluded that Bt variety Sattari showed considerable resistance to bollworm complex and bollworm infestation increased with increasing the number of bolls. Moreover, rising humidity instigated the development of bollworms population. The population of bollworms was negligible on variety Sattari-BT, and NIAB-78 also showed some resistance to bollworms.

Keywords: Field Studies, Bollworm, Infestation, BT and Non-BT Cotton

1. INTRODUCTION

The both developed and developing countries has reduced the pesticide use at the farm level after the development and increasing of Bt cotton (Qaim and Zilberman, 2003); The insect pest problem in cotton crop has solved after the development and improvement of resistant cotton varieties against several insect pests particularly. Singh and Lal (1993) and Singh *et al.*, (1996) studied comparative infestation of *Earias* spp., and *Helicoverpa armigera* on cotton varieties and reported that Bt cotton varieties were less attacked by the bollworms as compared to locally evolved cotton genotypes. The infestation of pink bollworm on local cotton varieties was higher than the Bt cotton (Jin *et al.*, 1999; Ahmad *et al.*, 2012).

The temporal and spatial variation in CryIAc protein levels in BT cotton was significant stated. Although Bt toxin in transgenic cotton has adverse effects on larval growth and survival of *Helicoverpa armigera*, *Earias insulana* and *Pectinophora gossypiella*, toxin level was dissimilar in various plant parts. Thus toxin level declined as the crop ripened and was very undetectable in squares (Bambawale *et al.*, 2004). Pakistan Agricultural Research Council (2007) stated that the toxin "Cry protein" in Bt cotton developed in

the country being highly variable. In the survey conducted by Pakistan Agricultural Research Council, where 10% and 19% samples from 126 locations in 21 districts were devoid of the toxin (PARC, 2008). The better development and growth of target pests, escaping direct or high doses of the toxin by the variability. Singh and Lal (1996) determined comparative resistance in numerous varieties against *Earias* spp., however resistance in cotton cultivars against *Helicoverpa armigera* has been assessed in the past (Jin *et al.*, 1999). In view of the economic significance of bollworm infestation on cotton, the present research was carried out to compare bollworm infestation on Bt and non-Bt cotton at Tandojam

2. MATERIALS AND METHODS

The experiment was conducted at the experimental field of Entomology Section, Agriculture Research Institute, Tandojam during cropping session 2013, in a RCBD design and with 7 treatments, having 3 repeats each. Sowing of experimental crop was done on 25th April, 2013 by means of single coulter hand drill in rows. All the four varieties were sown in three replicates and channels and bunds were prepared to facilitate the irrigation process and further monitoring of the crop against any pest problem. All the sub-plots were equal

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in measurement as 7.5 ft x 18.0 ft. Seven cultivars of cotton including six non-Bt cotton varieties and one Bt cotton variety were examined to compare the bollworm infestation. The following *Gossypium hirsutum* L. varieties were included in this research:

Varieties:

1) K.D. 57 2) TH-112/105 3) Krish-342 4) Sindh-1 5) Shahbaz-95 6) NIAB-78 7) Sattari (Bt)

3.

RESULTS

Spotted bollworm (*Earias vittella* and *E. insulana*).

Spotted bollworms (*Earias vittella* and *E. insulana*) are devastating cotton insect pests and comparative population of *Earias* spp. on locally cotton varieties was monitored from 2nd July to 28th October 2013 and population dynamics were compared with Bt cotton. The data (**Table-1**) indicated that statistically the population of *Earias* spp. varied significantly ($P < 0.05$) on cotton varieties ($F = 129.564$, $P = 0.0000$, $DF = 6$), observation dates ($F = 161.079$, $P = 0.0000$, $DF = 17$) as well as their interaction ($F = 2.942$, $P = 0.0076$, $DF = 102$). The *Earias* spp. population was highest (3.44%) on cotton variety TH-112/105, while *Earias* spp. population was 3.40, 3.35, 3.18 and 3.08% on cotton varieties Sindh-1, Shahbaz-95, KD 57 and Crish-342, respectively. Relatively lower *Earias* spp. population was recorded on variety NIAB-78 (1.79%); while the minimum *Earias* spp. population (0.93/plant) was recorded on variety Sattari-BT. This indicates that Bt variety Sattari showed considerable resistance to *Earias* spp.; while the non-Bt cotton varieties suffered with relatively higher *Earias* spp. infestation than Bt cotton. It was further observed that the *Earias* spp. infestation on varieties KD-57, TH-112/105, Crish-342, Sindh-1 and Shahbaz-95 was almost equal ($P > 0.05$); while NIAB-78 showed some resistance to *Earias* spp., but the Sattar-Bt varieties was markedly effective to resist bollworm infestation. The *Earias* spp. infestation started early in these varieties, but on Bt-cotton, the bollworm started infestation in the last week of July. Regardless of varieties, the *Earias* spp. population started increasing with increasing day-temperature and found at its peak population when monitored on 20th August, 2013. However, later the *Earias* spp. population decreased gradually. However, the *Earias* spp. population remained below the economic injury level in Sattari-Bt varieties.

American bollworm (*Helicoverpa armigera* Hub.)

The cotton growers have always found reporting

about their crop losses due to infestation of American bollworm (*Helicoverpa armigera* Hub.). The relative population of *H. armigera* on locally developed cotton varieties as well as on Bt cotton was monitored from 2nd July to 28th October. The data (**Table-2**) showed that statistically the population of *H. armigera* varied significantly ($P < 0.05$) on cotton varieties ($F = 107.90$, $P = 0.0000$, $DF = 6$), observation dates ($F = 247.02$, $P = 0.0000$, $DF = 17$) as well as their interaction ($F = 4.31$, $P = 0.0000$, $DF = 102$). The *H. armigera* population was highest (0.95%) on variety TH-112/105, while the pest population was 0.94, 0.92, 0.86 and 0.81% on cotton varieties Shahbaz-95, Sindh-1, KD-57 and Crish-342, respectively. *H. armigera* population was relatively lower on variety NIAB-78 (0.49%); while the lowest insect population (0.26/plant) was observed on variety Sattari-BT. The results clearly suggested Bt variety Sattari was considerably resistant to *H. armigera* infestation while the non-Bt cotton varieties received higher infestation of *H. armigera* when compared with Sattari-Bt. Similarity in infestation level ($P > 0.05$) was observed in case of cotton varieties TH-112/105, Sindh-1 and Shahbaz-95; while NIAB-78 also showed good resistance to *H. armigera*; however, Sattar-Bt proved to be highly resistant to *H. armigera* infestation. It was observed that *H. armigera* infestation started in the third of week of July in non-Bt varieties, while in Sattari-BT infestation started in the fourth week of July. The results also showed that rising temperature instigated the development of *H. armigera* population and the insect infestation was at its peak level on 27th August, 2013 in all the varieties; and decreased later. In Sattari-Bt and Niab-78, the *H. armigera* infestation was negligible Pink bollworm (*Pectinophora gossypiella* Saund.) is also an insect pest of economic importance in cotton. The population of *P. gossypiella* was compared in the field with the infestation on Bt from 2nd July 2013 to 28th October, 2013. The data (**Table-3**) indicated that statistically the population of *P. gossypiella* differed significantly ($P < 0.05$) on cotton varieties ($F = 222.59$, $P = 0.0000$, $DF = 6$), observation dates ($F = 308.93$, $P = 0.0000$, $DF = 17$) as well as their interaction ($F = 13.55$, $P = 0.0000$, $DF = 102$). The *P. gossypiella* population was highest (3.21%) on variety Sindh-1, while the pest population was 3.01, 2.94, 2.77 and 2.69% on cotton varieties KD-57, TH-112/105, Shahbaz-95 and Crish-342, respectively. *P. gossypiella* population was relatively lower on variety NIAB-78 (1.92%); while the lowest insect population (0.83%) was noted on variety Sattari-BT.

Table-2: Seasonal population of American bollworm *Helicoverpa armigera* (Hub.) on different cotton varieties in comparison with Bt-cotton Sattari-BT

Obs. Date	Varieties						
	KD-57	TH-112/105	Crish-342	Sindh-1	Shahbaz-95	Naib-78	Sattari-BT
2.7.13	0.00	0.00	0.20	0.00	0.20	0.00	0.00
9.7.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.7.13	0.25	0.27	0.23	0.27	0.26	0.14	0.00
23.7.13	0.47	0.51	0.44	0.50	0.49	0.27	0.14
30.7.13	0.69	0.76	0.65	0.74	0.73	0.39	0.21
6.8.13	1.40	1.52	1.31	1.50	1.47	0.80	0.43
13.8.13	1.72	1.87	1.61	1.84	1.81	0.98	0.53
20.8.13	2.16	2.36	2.03	2.32	2.28	1.23	0.67
27.8.13	2.29	2.50	2.15	2.46	2.42	1.31	0.71
3.9.13	1.50	1.63	1.41	1.61	1.58	0.85	0.46
10.9.13	1.40	1.52	1.31	1.50	1.47	0.80	0.43
17.9.13	1.27	1.39	1.19	1.36	1.34	0.72	0.39
24.9.13	1.12	1.22	1.05	1.20	1.18	0.64	0.35
1.10.13	0.45	0.50	0.43	0.49	0.48	0.26	0.14
7.10.13	0.35	0.38	0.33	0.38	0.37	0.20	0.11
14.10.13	0.34	0.37	0.32	0.37	0.36	0.19	0.00
21.10.13	0.00	0.28	0.00	0.00	0.43	0.08	0.00
28.10.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.86 b	0.95 a	0.81 b	0.92 a	0.94 a	0.49 c	0.26 d
	Variety (V)		Obs. Date (D)		V*D		
S.E.±	0.0364		0.0583		0.1544		
LSD 0.05	0.0717		0.1149		0.3040		
LSD 0.01	0.0944		0.1515		0.4007		

Table-3: Seasonal population of Pink bollworm (*Pectinophora gossypiella* Saund.) on different cotton varieties in comparison with Bt-cotton Sattari-BT

Obs. Date	Varieties						
	KD-57	TH-112/105	Crish-342	Sindh-1	Shahbaz-95	Naib-78	Sattari-BT
2.7.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.7.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.7.13	0.00	0.00	0.00	0.47	0.00	0.00	0.00
23.7.13	1.88	1.43	2.11	1.86	2.78	0.66	0.00
30.7.13	1.62	2.92	1.82	1.61	1.50	0.92	0.39
6.8.13	2.36	5.12	2.65	2.34	2.18	1.55	0.56
13.8.13	3.22	5.36	3.62	3.19	2.98	2.12	0.77
20.8.13	4.09	5.45	4.60	4.06	3.79	2.70	0.98
27.8.13	4.44	5.48	5.86	4.41	4.12	2.93	1.06
3.9.13	5.53	5.73	4.86	9.01	5.12	3.65	1.32
10.9.13	6.68	4.68	5.56	6.63	6.19	4.40	2.00
17.9.13	4.33	5.12	3.69	4.30	4.01	2.86	1.17
24.9.13	4.20	4.68	3.38	4.17	3.89	2.77	1.38
1.10.13	3.85	1.38	2.68	3.82	3.57	2.54	1.38
7.10.13	4.22	1.16	2.12	4.19	3.91	2.78	1.64
14.10.13	2.96	1.77	3.01	2.94	2.74	1.95	1.24
21.10.13	2.51	1.58	2.35	2.49	2.33	1.66	0.60
28.10.13	2.29	1.16	0.17	2.27	0.73	1.01	0.43
Mean	3.01 b	2.94 b	2.69 c	3.21 a	2.77 c	1.92 d	0.83 e
	Variety (V)		Obs. Date (D)		V*D		
S.E.±	0.0793		0.1271		0.3363		
LSD 0.05	0.1561		0.2503		0.6624		
LSD 0.01	0.2058		0.3299		0.8729		

Pink bollworm (*Pectinophora gossypiella* Saund.)

The results showed that Bt variety Sattari-BT showed remarkable resistance to *P. gossypiella* and the other non-Bt cotton varieties were infested heavily when compared with Bt cotton. Similarity in infestation level ($P>0.05$) was observed in case of cotton varieties KD-57 and TH-112/105, Crish-342 and Shahbaz-95. NIAB-78 showed considerable resistance to *P. gossypiella*, but the resistance level of Sattari-BT *P. gossypiella* infestation was highest and so promising. It was observed that *P. gossypiella* infestation started in the last week of July in non-Bt varieties, while in Sattari-BT, infestation started almost in the first week of August. However, environmental effects on pest development were clear and with rising the humidity, the pest infestation increased simultaneously and *P. gossypiella* population was at peak in the second week of September. Moreover, the bollworm infestation level was also associated with the development of bolls on cotton plants.

4.

DISCUSSION

Cotton crop in Pakistan is ravaged by many insect pests at its different growth stages. The bollworms have always been a threat to cotton production and studies showed that the bollworms can destroy cotton crop even no harm to the crop foliage by damaging the bolls. The studies have proved that Bt cotton is less infested by the insect pests particularly the bollworms, such as spotted bollworm *Earias* spp., American bollworm *Helicoverpa armigera* (Hub.) and pink bollworm *Pectinophora gossypiella* (Saund.). The criterion for distinguishing varieties has been comparison of infestation level and very few studies revealed difference in other biological parameters such as life history characteristics (Somashekara *et al.*, 2011). Hence, the present research was carried out to compare bollworm infestation on Bt and non-Bt cotton.

The present research showed that variety TH-112/105 was more infested (3.44% by *Earias* spp. than Sindh-1, Shahbaz-95, KD-57 and Crish-342 with insect population of 3.40, 3.35, 3.18 and 3.08%. Lower *Earias* population on NIAB-78 (1.79/plant) was observed and lowest (0.93%) on Sattari-BT. The *H. armigera* population was highest (0.955) on variety TH-112/105, while the pest population was 0.94, 0.92, 0.86 and 0.81% on cotton varieties Shahbaz-95, Sindh-1, KD-57 and Crish-342, respectively. *H. armigera* population was relatively lower on variety NIAB-78 (0.49%); while the lowest insect population (0.26%) was observed on variety Sattari-BT. *P. gossypiella* Saund. population also differed significantly ($P<0.05$) on cotton varieties and highest population (3.21%) was observed on variety Sindh-1, while the pest population was 3.01, 2.94, 2.77 and 2.69% on cotton varieties KD-57, TH-112/105,

Shahbaz-95 and Crish-342, respectively. The insect population was relatively lower on variety NIAB-78 (1.92%); while the lowest insect population (0.83%) was noted on variety Sattari-BT. *Earias* spp. population was at peak on 20th August, while *H. armigera* infestation reached its peak level on 27th August; and *P. gossypiella* population was at on 10th September. It was concluded that Bt variety Sattari showed considerable resistance to bollworm complex and bollworm infestation increased with increasing the number of bolls. Moreover, rising humidity instigated the development of bollworms population.

The population of bollworms was negligible on variety Sattari-BT, and NIAB-78 also showed some resistance to bollworms. These results are in accordance with those of Spotted bollworm attack on cotton crop at early stage causes top boring. The larva enters into the bolls and eats all its contents (Bariola and Lingern, 1984). Varietal resistance and chemical control has been mostly relied upon for the control of spotted bollworm on cotton (Wahla *et al.*, 1998). The both developed and developing countries has reduced the pesticide use at the farm level after the development and increasing of Bt cotton (Qaim and Zilberman, 2003). Singh *et al.*, (1996) studied comparative infestation of *Earias* spp., and *Helicoverpa armigera* on cotton varieties and reported that Bt cotton varieties were less attacked by the bollworms as compared to locally evolved cotton genotypes.

Although Bt toxin in transgenic cotton has adverse effects on larval survival and development of *Helicoverpa armigera*, *Earias insulana* and *Pectinophora gossypiella*, toxin level was different in various plant parts. Thus toxin level decreased as the crop matured and was very low or undetectable in squares (Bambawale *et al.*, 2004). Zhang and Tang (2009) recommended that the resistance to bollworm is not pertinent to be created if the transgenic Bt insect-resistant cotton varieties are introduced in the regions except in the Xinjiang cotton region. Xiao *et al.*, (2011) divulged that the transgenic cotton cultivars did not change the resistance grade of phase-sensitive strains determination of four insect-resistant. The self-bred lines from CCRI 29, Nankang-3, and Kemian-1 was decreased by one in resistance grade of these transgenic varieties.

The self-strain and hybrid strain in the resistance ratio to Bt preparations was 9.3876 and 2.5215, respectively. Ahmed *et al.*, (2012) reported that the activities of nonspecific esterases were high in larvae reared on Bt varieties whereas total proteases were low on these varieties. Wan *et al.*, (2012) revealed that Bt cotton decreased significantly population density of

pink bollworm. The BT cotton decreased of 91% for eggs and 95% for larvae on non-Bt cotton after 11 years of Bt cotton practice. The sprays of insecticide targeting pink bollworm and American bollworm reduced by 69%. The evolution of pink bollworm resistance to Bt cotton in China has elevated concerns that if unchecked, such resistance could eventually eliminate the benefits of Bt cotton in the early stages. The results described that the percentage of Bt cotton lower than the economic injury level, these causes were sufficient regional pest overthrow and diminishes the risk of resistance. Jin *et al.*, (2013) showed the resistance in other strains of *H. armigera*, the resistance in the strains characterized be especially difficult to suppress.

5. CONCLUSION

Cotton variety TH-112/105 was more infested (3.44%) by *Earias* spp. than rest of varieties.

This indicates that Bt variety Sattari showed considerable resistance to *Earias* spp.; while the non-Bt cotton varieties suffered with relatively higher *Earias* spp. infestation. The bollworm infestation was also associated with development of bolls. It was observed that *H. armigera* infestation started in the third week of July in non-Bt varieties, while in Sattari-BT infestation started in the fourth week of July. Rising temperature and humidity instigated the development of *H. armigera* population and the insect infestation was at its peak level on 27th August, 2013 in all the varieties. In Sattari-Bt and Niab-78, the *H. armigera* infestation was negligible. Sattari-BT showed remarkable resistance to *P. gossypiella* and the other non-Bt cotton varieties were infested more than Bt cotton. *P. gossypiella* population was at peak in the second week of September.

REFERENCES:

Ahmad, Z., (1980). Incidence of major cotton pests and diseases in Pakistan with special reference to pest management, Int'l consultation on cotton production. Res. with focus on the Asian Region, Manila, Philippines 17, 156-179. (WHAT IS NAME OF JOUR.)

Ahmed, S., M. K. Iqbal, M. Shahid and R. R. Khan. (2012). Comparison of antibiosis of spotted bollworm, *Earias vittella* (Fab.), on Two Bt- nd One Non Bt-Cotton Varieties. Pak. J. Zool. 44, 463-468.

Ali, A., and M. Ahmad, (1982). Biophysical resistance in different varieties of cotton against insect pests. Pak. Entomol. 4, 27-32.

Bambawale, O.M., A. Singh, O.P. Sharma, B.B. Bhosle, R. C. Lavekar, A. Dhandapani, V. Kanwar, R. K. Tanwar, K. S. Rathod, N.R. Panange, and V. M. Pawar, (2004). Performance of Bt cotton (Mech-162) under

integrated pest management in farmers' participatory field trials in Nanded district, Central India. Curr. Sci. 86, 1628-1623.

Bariola, L.A., and P. D. Lingern, (1984). Comparative toxicities of selected insecticides against pink boll worm (Lepidoptera: Gelechiidae.) moths. J. Econ. Entomol. 77, 207-210.

Castle, J. C., N. Prabhaker, and T. J. Henneberry, (1999). Insecticide resistance its management in cotton insects", ICAC Review Article on Cotton Production Research, 55-56.

Chaudhry, M.R., and M. Arshad, (1989). Varietal resistance to cotton insects. The Pakistan Cottons 33, 44-55.

Dhaka, S. R., and B. L. Pareek, (2007). Seasonal incidence of natural enemies of key insect pests of cotton and their relationship with weather parameters. J. Plant Prot. Res. 47, 418-419.

Gahukar, R.T., (2006). Improving the conservation and effectiveness of arthropod parasitoids for cotton pest management. Outlook on Agric. 35, 41-49.

GOP, 2(013). Area, production and yield of cotton in Pakistan. Economic Survey of Pakistan, 2012-13, Government of Pakistan, Islamabad.

Halcomb, K. L., J. H. Benedict, B. Cook, and D. R. Ring, (1996). Survival and growth of bollworm and tobacco budworm on non-transgenic and transgenic cotton expressing a cry 1A insecticidal protein (Lepidoptera: Noctuidae). Environ. Entomol. 25, 250-255.

Huque, H., (1994). Insect pests of fibre crops. In: A. A. Hashmi (Ed.), Insect Pest Management, Cereal and Cash Crops. Vol. 1, Pakistan Agricultural Research Council, Islamabad, 193-260.

Jackson, R. E., J. R. Bardley, A. D. Burd, and D. J. W. Van, (2000). Field and greenhouse performance on bollworms on Bollgard II cotton genotypes. Proceedings of Beltwide Cotton Conference, San Antonio, USA, 4-8 January, 2, 1048-1051.

Jin, Z. Q., G. D. Cao, S. S. Luo, J. M. Hong, and Y. Q. Hung, (1999). Insect resistance and yield of different insect resistant hybrid cotton cultivars. Zhejiang Nongye Kexue 3, 142-144.

Jin, L., Y. Wei, L. Zhang, Y. Yang, B. E. Tabashnik and Y. Wu, (2013). Dominant resistance to Bt cotton and minor cross-resistance to Bt toxin Cry2Ab in cotton

- bollworm from China. *Evolutionary Applications* 6, 1222–1235.
- Kalsy, H.S., B. Singh, and H. R. Garg, (1985). Comparative incidence of pink bollworm on some cultivars of *hirsutum* cotton. *Crop Improvement* 12, 195-196.
- Lohar, M.K., (2001). *Text Book of Applied Entomology*. 2nd Ed. Pub. Kashif Publ. Hyderabad, 242-244
- Noonari, A. M., A. D. Shah, T. K. Jugtani, and M. K. Lohar, (1994). Efficacy of different insecticides against gram pod borer, *Heliothis armigera* Hub. on gram crop under field conditions. *Sarhad J. Agric.* 12, 183-186.
- PARC, (2008). Status of cotton harboring Bt gene in Pakistan. Instt. Agri-Biotechnol Genetic Resources, National Agricultural Research Centre, Pakistan Agricultural Research Council, Islamabad.
- Qaim, M., and D. Zilberman, (2003). Yield effects of genetically modified crops in developing countries. *Sci.* 299, 900-902.
- Raqib, A., K. Ullah, M.S. Khan, and F. Shah, (1985). Incidence of pink bollworm on different cultivars of cotton. *The Pakistan Cottons* 30, 25-28.
- Razaq, M., M. Aslam, S. A. Shad, M. Naeem, M. Aslam, and N. A. Saeed, (2004). Evaluation of some new promising cotton strains against bollworm complex. *J. Research Sci.* 15, 313-318.
- Satpute, U. S., D. N. Sarnaik, and P. D. Bhalerao, (1988). Assessment of avoidable field losses in cotton yield due to sucking pests and bollworms. *Indian J. Plant Protect.* 16, 37-39.
- Singh, J., R. S. Gill, A. P. S. Brar, and B. S. Sandhu, (1996). Evaluation of some exotic cotton hybrids against insect pests. *Crop Improvement* 23, 275-277.
- Singh, M., and C. B. Lal, (1996). Breeding for resistance to jassid and bollworms (*Earias* spp.) in Egyptian cotton. *Indian J. Agri. Sci.* 63, 547–50
- Singh, M., and C. B. Lal, (1993) Breeding for resistance to jassid and bollworms (*Earias* Spp.) in Egyptian cotton. *Ind. J. Agric. Sci.* 63, 547-550.
- Somashekara, R., S. S. Udikerl, S. B. Patil, and K. Basavanagoud, (2011). Food consumption indices for spotted bollworm *Earias vitella* (Fab) on transgenic cottons expressing one or more Bt genes. *Karnatka J. Agric. Sci.* 24, 140-142.
- Soomro, B. A., M. A. Chang, G. H. Nachnani, and A. Razaque, (1986). Analysis of national coordinated varietal trails in Sindh. *The Pakistan Cottons* 30,7-16.
- Wan, P., Y. Huang, B.E. Tabashnik, M. Huang and K. Wu. (2012). The Halo Effect: Suppression of Pink Bollworm on No,n-Bt Cotton by Bt Cotton in China. *PLoS ONE*. 7, 42-44.
- Wahla, M., A. M. Tufail, and P. Iqbal, (1998). The comparative effectiveness of different doses of confidor SL 200 and Tamaraon 600 SL against the cotton thrip, *Thrips tabaci* Lind. on FH-682, cotton. *Pakistan Entomologist* 19, 8-10.
- Xiao, L., H. S. Hou-jun, L. Bai, (2011). Studies on Resistance Evolution of Cotton Bollworm to Bt Transgenic Cotton in Artificial Simulating "Refuges" and "Non-refuges Conditions. *Cotton Sci.* 23, 52-57.
- Zhang, T., and C. Tang, (2009). Commercial production of transgenic Bt insect-resistant cotton varieties and the resistance management for bollworm (*Helicoverpa armigera* Hubner). *Chinese Science Bulletin* 45, 1249-1257.