Pakistan J. Zool., vol. 47(3), pp. 823-829, 2015.

Incidence of Insect Predators and Parasitoids on Transgenic Bt Cotton in Comparison to Non-Bt Cotton Varieties

Muhammad Arshad,[1]* Hafiz Azhar Ali Khan,[2*] Muhammad Abdul ur Rehman[1] and Noor Abid Saeed[3]
[1]*Department of Entomology, University of Agriculture, Faisalabad, Pakistan*
[2]*Institute of Agricultural Sciences, University of the Punjab, Lahore, Pakistan*
[3]*Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan*

Abstract.-Transgenic Bt (*Bacillus thuringiensis*) cotton (*Gossypium hirsutum* L.) genetically modified from and expressing delta-endotoxin protein has been increasingly preferred by Pakistani farmers due to high production potential and targeted control of bollworms. A field study was conducted to evaluate the impact of Bt cotton on insect predators and parasitoids population in comparison to conventional (non Bt) cotton varieties. The available non-Bt cotton varieties/line (AARI-FH- 942, NIBGE-NN3, NIAB-112) and Bt cotton varieties/line (AARI-FH-114, NIBGE-IR-3701, 4B-Tarzan-1) were sown during 2012-13 cotton season. Population of insect predators and parasitoids were observed from 1st week of July to 2nd week of November. The results revealed that the abundance of insect predators; *Chrysoperla carnea*, *Coccinella septempunctata, Geocoris* spp., *Menochilus sexmaculata*, and parasitoids: *Trichogramma* spp., *Apanteles* spp., did not differ significantly on non- Bt and transgenic Bt varieties. Their population almost equally distributed in both types of fields. The results conclude that transgenic Bt cotton have no adverse impact on population dynamics and distribution of insect predators and parasitoids under field conditions.

Key words: Insect predators, parasitoids, transgenic Bt cotton.

INTRODUCTION

Biological control has considered a reliable and long term solution of the insect pest problems due to self-perpetuating nature and environment friendly tactic (Bale *et al*., 2008). However, increasingly intensive farming strongly influences the population dynamics of insect predators and parasitoids and the activity by these natural enemies. The restricted use of pesticides and landscape biodiversity management help to conserve the bio-control agents in agro-ecosystems and favors the development of sustainable agriculture. The adoption of transgenic Bt cotton genetically modified through recombinant DNA from *Bacillus thuringiensis* (Bt) is increasing since its commercialization in 1996 and according to the report of ISAA (International Service for the Acquisition of Agr-Biotech Application), Pakistan planted 2.85 million hectares of Bt cotton in 2014 cotton season (James, 2014). Bt cotton (*Gossypium hirsutum* L.) is cultivated extensively and preferred by farmers due to higher production potential, less dependence on insecticides and targeted control of specific lepidopterous pests (Arshad and Suhail, 2011; Arshad *et al*., 2015). Cotton hosts the rich diversity of natural enemies (insect predators and parasitoids) that attack on different life stages of insect pests (egg, larval, pupal and adult stages) and provide natural balance.

Predators are essential biological control agents (Sathe and Bhosle, 2001; Sattar *et al*., 2007). Predators such as *Chrysoperla carnea*, *Coccinella septempunctata*, *Geocoris* spp., *Menochilus sexmaculatus*, and parasitoids *Trichogramma* spp and *Apanteles* spp. suppress the population of various cotton insect pests especially *Helicoverpa armigera*, *Spodoptera exigua*, *Aphis* spp. and *Bemisia tabaci*. *Tricogramma* spp. is reported an important egg parasitoid of lepidopterous pests (Ahmad *et al*., 1998). *Apanteles* spp. is a larval parasitoid and parasitizes larvae of lepidopteran pests (*S. exigua*, and *H. armigera*). Coccinellid predators (*C. septempunctata* and *M. sexmaculata*) are the important natural enemies of aphid and keep the aphid population below the economic threshold level (Wells *et al.*, 2001). *Geocorus* spp. and *C. carnea* are voracious feeders of cotton soft bodied insect pests (Mari *et al.*, 2007) and thus reduce the

*Corresponding author: arshaduaf@gmail.com, azhar_naturalist@yahoo.com
0030-9923/2015/0003-0823 $ 8.00/0

need of insecticides application.

Field studies have been conducted to evaluate the impact of transgenic Bt cotton on the non-target arthropods which are natural enemies of important insect pests (Torres and Ruberson, 2006; Sisterson *et al*., 2007). Similarly, valuable laboratory studies reported negative impact of transgenic Bt cotton on predators and parasitoids (Hillbeck *et al*., 1999; Ponsard *et al*., 2002). However, in field studies typical minor effects of transgenic Bt cotton on non-target arthropods have been reported (Al-Deeb and Wilde, 2003; Naranjo, 2005). Studies on the cultivation of Bt cotton may (Hillbeck *et al*., 1999; Ponsard *et al*., 2002) or may not (Moar *et al*., 2002, Torres and Ruberson, 2006) affect the predators and parasitoids within cotton field. The present study was aimed at comparing the abundance and population dynamics of insect predators and parasitoids under field conditions of transgenic Bt cotton and conventional non-Bt varieties.

MATERIALS AND METHODS

The field experiment was laid out in a randomized complete block design (RCBD), and conducted at Plant Protection Division Research area, Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad. The experiment consisted of two treatments *i.e.,* sets of non-Bt and Bt cotton varieties each with three replications. In a set of three non-Bt cotton varieties/line *viz*., AARI-FH-942, NIBGE-NN3, NIAB-112 and three transgenic Bt cotton varieties/line *viz*., AARI-FH-114, NIBGE-IR-3701, 4B-Tarzan-1 were sown during the 1st week of April, 2012. Data collection regarding the abundance of population insect predators and parasitoids was initiated during 1st week of July and then taken fortnightly until 2nd week of November, resulting in 11 sampling collection dates. Sampling was done early in the morning because most of insects become active when temperatures is about 25-30^{o}C (Garcia *et al.,* 1982). Bag collection method was used for the sampling of canopy and foliage dwelling beneficial insects. A polythene plastic sheet bag (dimension: width 75 cm x length 75 cm) was used to collect beneficial insects by covering the plant, then shaking and arresting dropped insects in bag. Five samples were taken randomly per plot, so that a total of 15 samples per variety. The insect specimens were killed in cyanide jars and preserved for sorting, counting and identification with the help of available literature (Nagarkatti and Nagaraja, 1997; Whitfield *et al*., 2001) and comparison with reference insect collection present in National Insect Museum, NARC, Islamabad, Pakistan.

All data on population of insect predators and parasitoids in both fields were analyzed using the analysis of variance (ANOVA). Tucky's honestly significance difference (HSD) test was used to compare the means.

RESULTS AND DISCUSSION

The parasitoids recorded were *Apanteles* spp. and *Trichogramma* spp. Insect predators studied were *Chrysoperla carnea* (Stephens) *Geocoris* spp. *Coccinella septempunctata* (Linnaeus), *Menochilus sexmaculata* (Fabricius). Average mean seasonal population observed was for *Trichogramma* spp. (2.25) followed by *C. carnea* (2.21), *C. septempunctata* (1.83), *Geocoris* spp. (1.48), *M. sexmaculata* (0. 90 and *Apanteles* spp. (0.28) (Fig.1).

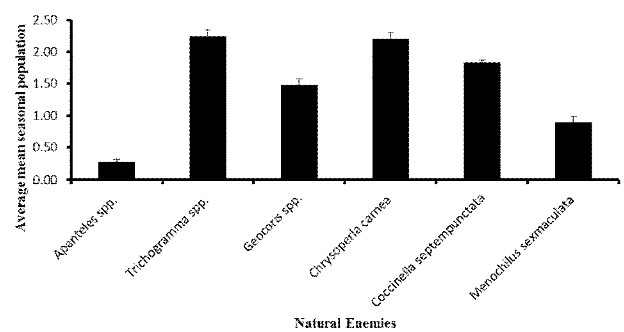

Fig. 1. Average means of predators and parasitoids during the study periods.

Geocoris spp. observed first on from June 16, reached highest peak on September 02 (3.44/15 bags) and then declined onward till November 16 (0.28/15 bags) (Fig. 2). Seasonal mean population was recorded as 1.48/15 bags (Fig. 1). Similar to our findings, Khuhro *et al*. (2002) reported the population of *Geocoris* spp. in cotton and higher population in 4th week of July, mean population 0.30/15 sweeps from June to September. Hafeez *et al*. (2006) recorded maximum population of *Geocoris* spp. 7.2/25 plants in cotton belt from Vehari. Solangi *et al*. (2008) found *Geocoris punctipes* (1.28/plant) from June to September in cotton fields. We found non-significant difference of *Geocoris* spp. population on both types of cotton (non-Bt and Bt) during all assessment dates (Table I). The seasonal mean population did not differ significantly (P = 0.73) although slightly higher numbers in Bt varieties (1.51) with comparison to non-Bt varieties (1.46) (Fig. 3). Our results did not differ significantly of *Geocoris* spp. population level in both types of fields (non-Bt and Bt). Similar to our findings, Moar *et al*. (2002) reported greater number of natural enemies in their evaluation in transgenic cotton then non-transgenic cotton for insects (parasitic wasps, *Nabis* spp., *Orius* sp., green lacewings, *Geocoris* spp. and spiders). Torres and Ruberson (2006) observed no lethal or sub-lethal effects of transgenic Bt cotton on development and reproduction of *Geocoris punctipes* through feeding on prey. However, in contrast to our findings, Ponsard *et al*. (2002) observed the adverse impact of Bt toxin on development and biology of insect predators under laboratory conditions by consumption of Bt-intoxicated host. Head *et al*. (2005) reported non-significantly negative impacts of Bt toxin on population of insect predators (*Geocoris* spp., *Orius* spp., spiders and lady beetles) in comparison with non-Bt cotton treated with insecticides.

Population of *C. carnea* was observed from 1st week of August which gradually increased and peaked on September 16 (4.11/15 bags) and then these numbers declined till 1st week of November (0.94/15 bags) (Fig. 2). The seasonal mean population observed was 2.21/15 bags (Fig. 1). Khuhro *et al*. (2002) found higher numbers of *C. carnea* in 4th week of June and mean population 0.23/15 sweeps from June to September in cotton crop. Solangi *et al*. (2008) reported *Chrysoperla* spp. in cotton crop from June to September (2.07/plant). A non-significant difference of *C. carnea* population was observed in non-Bt varieties with respect to Bt varieties during all sampling dates (Table I). The seasonal mean population difference recorded non-significantly (P = 0.38) relatively greater numbers in non-Bt varieties (2.29) then Bt varieties (2.13) (Fig.3). Our results showed that although relatively higher population in Bt varieties but statistically non-significant difference. *C. carnea* do not preferred either non-Bt or Bt varieties. Their population was almost equally distributed in both types of fields (non-Bt and Bt). Similar to our studies, Dutton *et al*. (2002), under laboratory condition reported no adverse impact of Bt toxin on biology of *C. carnea* through Bt intoxicated prey (aphids) reared on transgenic maize. Contrary to our results, Sharma *et al.* (2007) reported higher population of predators (chrysopids, coccinellids and spiders) in transgenic Bt cotton.

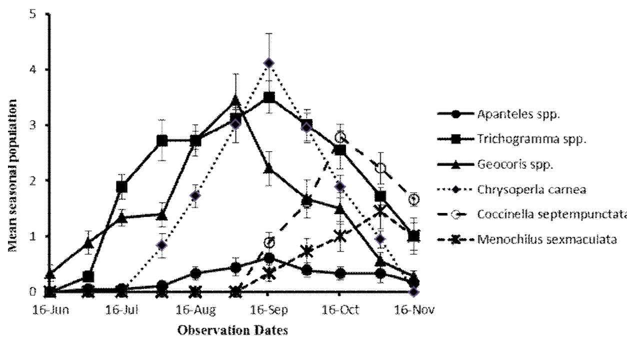

Fig. 2. Fifteen days interval population of predators and parasitoids on overall Bt and non-Bt cotton varities.

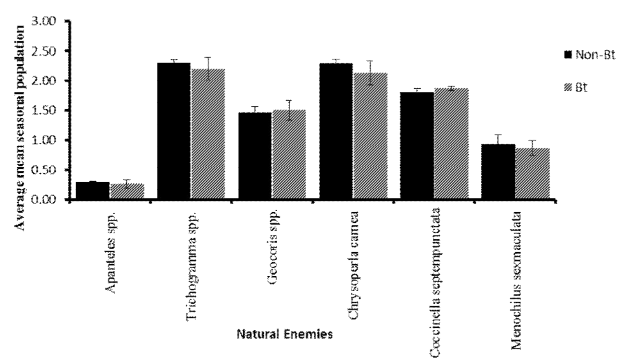

Fig. 3. Average mean of predators and parasitoids on non Bt and Bt cotton during the study periods.

The coccinellid beetles, *M. sexmaculata* and *C. septempunctata* were observed from September

Table I.- Population of insect predators per 15 bags on Bt and non-Bt cotton at NIAB – Faisalabad Pakistan during crop year 2012.

Insects	Treatments	Dates of observations										
		16/06/2012	2/7/2012	16/07/2012	2/8/2012	16/8/2012	2/9/2012	16/09/2012	2/10/2012	16/10/2012	2/11/2012	16/11/2012
Chrysoperla carnea	Bt varieties	-	-	-	0.56±0.29	1.67±0.38	3.33±0.51	3.56±0.48	3.11±0.29	1.78±0.22	0.89±0.11	-
	Non-Bt varieties	-	-	-	1.11±0.29	1.78±0.22	2.67±0.38	4.67±0.96	2.78±0.48	2.00±0.38	1.00±0.33	-
	P-Value	-	-	-	0.44	0.82	0.07	0.46	0.66	0.74	0.68	-
	Tukey HSD	-	-	-	-	-	-	-	-	-	-	--
Geocoris spp.	Bt varieties	0.44±0.22	0.78±0.29	1.56±0.11	1.11±0.11	2.89±0.11	3.56±0.78	2.67±0.51	1.67±0.69	1.22±0.29	0.44±0.29	0.22±0.11
	Non-Bt varieties	0.22±0.22	1.00±0.33	1.11±0.22	1.67±0.38	2.56±0.29	3.33±0.69	1.78±0.11	1.67±0.33	1.78±0.48	0.67±0.19	0.33±0.19
	P-Value	0.66	0.42	0.26	0.29	0.42	0.53	0.20	1.00	0.12	0.42	0.42
	Tukey HSD	-	-	-	-	-	-	-	-	-	-	-
Menochilus sexmaculata	Bt varieties	-	-	-	-	-	-	0.56±0.22	0.33±0.19	0.56±0.40	1.67±0.51	1.22±0.29
	Non-Bt varieties	-	-	-	-	-	-	0.11±0.11	1.11±0.29	1.44±0.11	1.22±0.40	0.78±0.40
	P-Value	-	-	-	-	-	-	0.270	0.19	0.09	0.18	0.54
	Tukey HSD	-	-	-	-	-	-	-	-	-	-	-
Coccinella septempunctata	Bt varieties	-	-	-	-	-	-	0.89±0.40	1.78±0.11	2.56±0.48	2.22±0.56	1.89±0.11
	Non-Bt varieties	-	-	-	-	-	-	0.89±0.11	1.44±0.11	3.00±0.00	2.22±0.29	1.44±0.11
	P-Value	-	-	-	-	-	-	1.00	0.22	0.45	1.00	0.18
	Tukey HSD	-	-	-	-	-	-	-	-	-	-	-

Table II.- Population of insect parasitoids per 15 bags on Bt and non-Bt cotton at NIAB – Faisalabad Pakistan during crop year 2012.

Insect pests	Dates of observations										
	Treatments	2/7/2012	16/07/2012	2/8/2012	16/8/2012	2/9/2012	16/09/2012	2/10/2012	16/10/2012	2/11/2012	16/11/2012
Apanteles spp.	Bt varieties	0.11±0.11	0.00±0.00	0.11±0.11	0.33±0.19	0.11±0.11	0.56±0.40	0.56±0.22	0.33±0.19	0.44±0.29	0.11±0.11
	Non-Bt varieties	0.00±0.00	0.11±0.11	0.11±0.11	0.33±0.19	0.78±0.22	0.67±0.19	0.22±0.11	0.33±0.19	0.22±0.22	0.22±0.11
	P-Value	0.42	0.42	1.00	1.00	0.73	0.83	0.22	1.00	0.18	0.42
	Tukey HSD	-	-	-	-	-	-	-	-	-	-
Trichogramma spp.	Bt varieties	0.33±0.19	1.78±0.29	2.44±0.59	2.78±0.59	3.22±0.29	3.11±0.48	3.00±0.51	2.56±0.48	1.89±0.11	0.89±0.40
	Non-Bt varieties	0.22±0.11	2.00±0.38	3.00±0.51	2.67±0.19	3.00±0.19	3.89±0.22	3.00±0.38	2.56±0.59	1.56±0.29	1.11±0.59
	P-Value	0.73	0.77	0.46	0.85	0.68	0.36	1.00	1.00	0.42	0.79
	Tukey HSD	-	-	-	-	-	-	-	-	-	-

16 and their number gradually increased and peaked on November 02 (1.44/15 bags) and October 16 (2.78/15 bags) respectively and then decline during following dates (Fig. 2). The mean seasonal population of *M. sexmaculata* and *C. septempunctata* recorded were 0.90/15 bags and 1.83/15 bags, respectively (Fig. 1). In similar field conditions, Khuhro *et al*. (2002) reported *Coccinellids* from June to September with maximum population on 3rd week of July. Ashfaq *et al*. (2011) observed maximum population of *C. septempunctata* 1.42/leaf on August 10. We found non-significant difference of beetles' population (*M. sexmaculata* and *C. septempunctata*) throughout cotton season (Table I). A non-significantly higher population of *M. sexmaculata* in non-Bt varieties (0.93) then Bt varieties (0.87) while *C. septempunctata* was non-significantly (P = 0.5) higher in Bt varieties (1.87) with respect to non-Bt varieties (1.80) (Fig. 3). Our studies showed that Bt cotton have no negative impact on population and distribution of both beetles (*M. sexmaculata* and *C. septempunctata*). Similar to our studies, Head *et al*. (2005) observed equal distribution and abundance of population dynamics of *coccinellid* beetles in non-Bt and transgenic Bt cotton. Mellet and Schoeman (2007) reported that cultivation of transgenic Bt-cotton had no adverse impact on abundance of *coccinellids* spp. However, Naranjo (2005) reported typically minor effects of Bt toxin on beneficial insects (*C. carnea*, *G. punctipes Coccinellids* and *Aphelinids* parasitoids) compared to alternative use of insecticides.

Trichogramma spp. was first observed during 1st week of July and higher numbers were observed on September 16 (3.50/15 bags), then low population was recorded till November 16 (1.00/15 bags) (Fig. 2). The seasonal mean population was 2.25/15 bag (Fig. 1). In similar field conditions, Ahmad *et al*. (1998) reported *Trichogramma* spp. population from Aug to Oct. In our present study a non-significant difference was observed in *Trichogramma* spp. population of both field types (non-Bt and Bt cotton) during all observation dates (Table II). The seasonal mean population difference was non-significant (P = 0.59) in non-Bt (2.30) and Bt varieties (2.20) (Fig. 3). A similar trend of population was observed in both types of fields of cotton (non-Bt and Bt). Similarly Fernandes *et al*. (2007) reported no adverse impact of transgenic Bt maize on the population of ladybird beetles and *Trichogramma* wasps. Wu and Guo (2005) found higher population of parasitoids (*Trichogrammatids*, *Microplitis* and *Campoletis*) in non-Bt as compared to transgenic Bt cotton.

Apanteles spp. population was noted from 1st week of July and maximum number on September 16 (0.61/15bags) then numbers declined till November 16 (0.17/15 bags) (Fig.2). The seasonal mean population recorded were 0.28/15 bag (Fig. 1). Almost similar to our findings, Hafeez *et al*. (2006) reported maximum population of *Apanteles* spp. 0.6/25 plants from August to October during cotton season. We found non-significant difference of *Apanteles* spp. population throughout the cotton season on all observed dates (Table II). A non-significant difference of seasonal mean population (P = 0.68) of *Apanteles* spp. recorded slightly higher in non-Bt varieties (0.30) in comparison to Bt varieties (0.27) (Fig. 3). Our findings showed that population of *Apanteles* spp. did not differ significantly in non-Bt with respect to the Bt varieties. Almost a similar trend of *Apanteles* spp., was present throughout cotton season in both types of cotton fields (non-Bt and Bt). Similar to our findings, Schuler *et al*. (1999) showed no negative impact of Bt toxin on development and biology of parasitoids. Similarly, Dhillon and Sharma (2013) noted no adverse impact of Bt toxin on diversity of arthropods. Contrary to our results Pilcher *et al*. (2005) reported higher population of parasitoids in non-Bt as compared to transgenic Bt cotton. Men *et al*. (2003) reported decreased diversity of natural enemies (predators and parasitoids) in transgenic crops as compared to non-transgenic crops.

CONCLUSION

Our findings conclude an equal abundance of observed parasitoids and predators in both transgenic Bt and non-Bt cotton varieties throughout the cotton season. Therefore beneficial insect community is not affected by the cultivation of transgenic Bt cotton.

REFERENCES

AHMAD, N., ASHRAF, M., FATIMA, B. AND NASRULLAH, 1998. Potential of *Trichogramma chilonis* to parasitize eggs of pink, spotted and spinny bollworms of cotton. *Pakistan J. Zool*., **30**: 39-40.

AL-DEEB, M.A. AND WILDE, G.E., 2003. Effect of Bt corn expressing the Cry3Bb1 toxin for corn rootworm control on above ground non-target arthropods. *Environ. Ent*., **32**: 1164-1170.

ARSHAD, M. AND SUHAIL, A., 2011. Field and laboratory performance of transgenic Bt cotton containing Cry1Ac against beet armyworm larvae (Lepidoptera: Noctuidae). *Pakistan J. Zool*., **43**: 529-535.

ARSHAD, M., ZAIN-UL-ABDIN, GOGI, M.D., ARIF, M.J. AND KHAN, R.R., 2015. Seasonal pattern of infestation by spotted bollworm, *Earias insulana* (Boisd.) and pink bollworm, *Pectinophora gossypiella* (Saund.) in field plots of transgenic Bt and non-Bt cottons. *Pakistan J. Zool*., **47**: 177-186

ASHFAQ, S., KHAN, I.A., SALJOQI, A.U.R., AHMAD, S., MANZOOR, F., SOHAIL, K., HABIB, K. AND SADOZAI, A., 2011. Population dynamics of insect pests of cotton and their natural enemies. *Sarhad J. Agric*., **27**: 251-253.

BALE, J.S., VAN LENTEREN, J.C. AND BIGLER, F., 2008. Biological control and sustainable food production. *Phil. Trans. R. Soc. B.*, **363**: 761-776.

DHILLON, M.K. AND SHARMA, H.C., 2013. Comparative studies on the effects of Bt-transgenic and non-transgenic cotton on arthropod diversity, seed-cotton yield and bollworms control. *J. environ. Biol*., **34**: 67-73.

DUTTON, A., KLEIN, H., ROMIES, J. AND BIGLER, F., 2002. Uptake of Bt toxin by herbivores feeding on transgenic maize and consequences for the predators *Chrysoperla cornea. Ecol. Ent*., **27**: 441-447.

FERNANDES O.A., FARIA, M., MARTINELLI, S., SCHMIDT, F., CARVALHO, V. F. AND MORO, G., 2007. Short-term assessment of Bt maize on non-target arthropods in Brazil. *Sci. Agric*. (Piracicaba, Braz.), **64**: 249-255.

GARCIA, A., GONZALEZ, D. AND LEIGH, T.F., 1982. Three methods for sampling arthropod numbers on California cotton. *Environ. Ent.*, **11**: 565-572.

HAFEEZ, F., ARIF, M.J., GOGI, M.D., ZIA, K., KARA, H. AND ARSHAD, M., 2006. Survey of Entomophagous insects in cotton belt of Punjab, Pakistan. *Pakistan J. biol. Sci*., **9**: 1375-1380.

HEAD, G., MOAR, M., EUBANKS, M., FREEMAN, B., RUBERSON, J., HAGERTY, A. AND TURNIPSEED, S., 2005. A multiyear large scale comparison of arthropod population on commercially managed Bt and non-Bt cotton fields. *Enviorn. Ent*., **34**: 1257-1267.

HILLBECK, A., MOAR, W.J., PUSZTAI-CAREY, M., FILIPPINI, A. AND BIGLER, F., 1999. Prey mediated effects of Cry1Ac toxin and Cry2Ac protoxin on the predator *Chrysoperla carnea. Ent. Exp. Appl*., **91**: 305-316.

JAMES, C., 2014. *Global status of commercialized biotech/GM crops:* 2014. ISAAA brief no. 49, International Service for the Acquisition of Agri-Biotech Applications.

KHUHRO, R.D., NIZAMANI, I.A. AND TALPUR, M.A., 2002. Population abundance of predators in Alfalfa and cotton fields at Tandojam. *Pakistan J. appl. Sci*., **2**: 300-303.

MARI, J.M., NIZAMANI, S.M. AND LOHAR, M.K., 2007. Population fluctuation of sucking insect pests and predators in cotton ecosystem. *Afr. Crop Sci. Conf. Proc*., **8**: 929-934.

MELLET, M.A. AND SCHOEMAN, A.S., 2007. Effect of Bt-cotton on chrysopids, ladybird beetles and their prey: Aphids and Whiteflies. *Indian J. exp. Biol*., **45**: 554-562.

MEN, X.Y., GE, F., LIU, X.H. AND YARDIM, E.N., 2003. Diversity of arthropod communities in transgenic Bt cotton and non-transgenic cotton agro ecosystems. *Environ. Ent*., **32**: 270-275.

MOAR, W.J., EUBANKS, M., FREEMAN, B., TURNIPSEED, S., RUBERSON, J. AND HEAD, G., 2002. Effect of Bt cotton on biological control agents in the Southern United States. *Ist Int. Symp. on Biological Control of Arthropods, Honolulu, Hawaii, U.S. Department of Agriculture, Forest Service, Morgantown, West Virginia, USA*., 14-18 January, 2002.

NAGARKATTI, S. AND NAGARAJA, H., 1997. Biosystematics of *Trichogramma* and Trichogrammatoidea species. *Annu. Rev. Ent*., **22**: 157-176.

NARANJO, S.E., 2005. Long-term assessment of the effects of transgenic Bt cotton on the abundance of non-target arthropod natural enemies. *Environ. Ent*., **34**: 1193-1210.

PILCHER, C.D., RICE, M.E. AND OBRYCKI, J.J., 2005. Impact of transgenic *Bacillus thuringiensis* corn and crop technology on five non-target arthropods. *Environ. Ent.*, **34**:1302-1316.

PONSARD, S., GUTIERREZ, A.P. AND MILLS, N.J., 2002. Effects of Bt toxin (Cry1Ac) in transgenic cotton on the adult longevity of four heteropteran predatore *Environ. Ent.*, **31**: 1197-1205.

SATHE, T.V. AND BHOSLE, Y.A., 2001. *Insect pest predators*. Daya publishing house. pp.1-69.

SATTAR, M. AND ABRO, G.H., 2011. Mass Rearing of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) adults for integrated pest management programmes. *Pakistan J. Zool.*, **43**: 483-487.

SCHULER, T.H., POTTING, R.P.J., DENHOLM, I. AND POPP, G.M., 1999. Parasitoid behaviour and Bt_plants.

Nature, **400**: 825–826.

SHARMA, H.C., ARORA, R. AND PAMPAPATHY, G., 2007. Influence of transgenic cottons with *Bacillus thuringiensis Cry1Ac* gene on the natural enemies of *Helicoverpa armigera*. *Bio Control.*, **52**: 469-489.

SISTERSON, M.S., CARRIÈRE, Y., DENNEHY, T.J. AND TABASHNIK, B.E., 2007. Non-target effects of transgenic insecticidal crops: implications of source-sink population dynamics. *Environ. Ent.*, **36**: 121-127.

SOLANGI, G.S., MAHAR, G.M. AND OAD, F.C., 2008. Presence and abundance of different insect predators against sucking insect pest of cotton. *J. Entomol*., **5**: 31-37.

TORRES, J.B. AND RUBERSON, J.R., 2006. Interactions of Bt-cotton and the omnivorous big-eyed bug *Geocoris punctipes* (Say), a key predator in cotton fields. *Biol. Contr.,* **39**: 47-57.

WELLS, M.L., MCPHERSON, R.M., RUBERSON, J.R. AND HERZOG, G.A., 2001. Coccinellids in cotton: Population response to pesticide application and feeding response to cotton aphid (Homoptera: Aphididae). *Environ. Ent*., **30**: 785-793.

WHITFIELD, J.B., CAMERON, S.A., RAMIREZ, S.R., ROESCH, K., MESSINGER, S., TAYLOR, O.M. AND COLE, D., 2001. Review of the Apanteles species (Hymenoptera: Braconidae) attacking Lepidoptera in Bombus (Fervidobombus) (Hymenoptera: Apidae) colonies in the new World, with description of a new species from South America. *Annls. entomol. Soc. Am.*, **94**: 851-857.

WU, K.M. AND GUO, Y.Y., 2005. The evolution of cotton pest management practices in China. *Annu. Rev. Ent*., **50**: 31-52.

(Received 10 February 2015, revised 4 April 2015)

Table I.- **Population of insect predators per 15 bags on Bt and non-Bt cotton at NIAB – Faisalabad Pakistan during crop year 2012.**

Insects	Treatments	Dates of observations										
		16/06/2012	2/7/2012	16/07/2012	2/8/2012	16/8/2012	2/9/2012	16/09/2012	2/10/2012	16/10/2012	2/11/2012	16/11/2012
Chrysoperla carnea	Bt varieties	-	-	-	0.56±0.29	1.67±0.38	3.33±0.51	3.56±0.48	3.11±0.29	1.78±0.22	0.89±0.11	-
	Non-Bt varieties	-	-	-	1.11±0.29	1.78±0.22	2.67±0.38	4.67±0.96	2.78±0.48	2.00±0.38	1.00±0.33	-
	P-Value	-	-	-	0.44	0.82	0.07	0.46	0.66	0.74	0.68	-
	Tukey HSD	-	-	-	-	-	-	-	-	-	-	--
Geocoris spp.	Bt varieties	0.44±0.22	0.78±0.29	1.56±0.11	1.11±0.11	2.89±0.11	3.56±0.78	2.67±0.51	1.67±0.69	1.22±0.29	0.44±0.29	0.22±0.11
	Non-Bt varieties	0.22±0.22	1.00±0.33	1.11±0.22	1.67±0.38	2.56±0.29	3.33±0.69	1.78±0.11	1.67±0.33	1.78±0.48	0.67±0.19	0.33±0.19
	P-Value	0.66	0.42	0.26	0.29	0.42	0.53	0.20	1.00	0.12	0.42	0.42
	Tukey HSD	-	-	-	-	-	-	-	-	-	-	-
Menochilus sexmaculata	Bt varieties	-	-	-	-	-	-	0.56±0.22	0.33±0.19	0.56±0.40	1.67±0.51	1.22±0.29
	Non-Bt varieties	-	-	-	-	-	-	0.11±0.11	1.11±0.29	1.44±0.11	1.22±0.40	0.78±0.40
	P-Value	-	-	-	-	-	-	0.270	0.19	0.09	0.18	0.54
	Tukey HSD	-	-	-	-	-	-	-	-	-	-	-
Coccinella septempunctata	Bt varieties	-	-	-	-	-	-	0.89±0.40	1.78±0.11	2.56±0.48	2.22±0.56	1.89±0.11
	Non-Bt varieties	-	-	-	-	-	-	0.89±0.11	1.44±0.11	3.00±0.00	2.22±0.29	1.44±0.11
	P-Value	-	-	-	-	-	-	1.00	0.22	0.45	1.00	0.18
	Tukey HSD	-	-	-	-	-	-	-	-	-	-	-

Table II.- **Population of insect parasitoids per 15 bags on Bt and non-Bt cotton at NIAB – Faisalabad Pakistan during crop year 2012.**

Insect pests	Dates of observations										
	Treatments	2/7/2012	16/07/2012	2/8/2012	16/8/2012	2/9/2012	16/09/2012	2/10/2012	16/10/2012	2/11/2012	16/11/2012
Apanteles spp.	Bt varieties	0.11±0.11	0.00±0.00	0.11±0.11	0.33±0.19	0.11±0.11	0.56±0.40	0.56±0.22	0.33±0.19	0.44±0.29	0.11±0.11
	Non-Bt varieties	0.00±0.00	0.11±0.11	0.11±0.11	0.33±0.19	0.78±0.22	0.67±0.19	0.22±0.11	0.33±0.19	0.22±0.22	0.22±0.11
	P-Value	0.42	0.42	1.00	1.00	0.73	0.83	0.22	1.00	0.18	0.42
	Tukey HSD	-	-	-	-	-	-	-	-	-	-
Trichogramma spp.	Bt varieties	0.33±0.19	1.78±0.29	2.44±0.59	2.78±0.59	3.22±0.29	3.11±0.48	3.00±0.51	2.56±0.48	1.89±0.11	0.89±0.40
	Non-Bt varieties	0.22±0.11	2.00±0.38	3.00±0.51	2.67±0.19	3.00±0.19	3.89±0.22	3.00±0.38	2.56±0.59	1.56±0.29	1.11±0.59
	P-Value	0.73	0.77	0.46	0.85	0.68	0.36	1.00	1.00	0.42	0.79
	Tukey HSD	-	-	-	-	-	-	-	-	-	-