Performance of *Bt* and non *Bt* cotton hybrids against American bollworm, *Helicoverpa armigera* (Hubner)

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ABSTRACT

Field trials were conducted in farmers' fields at Warangal district, Andhra Pradesh, India during 2005-06 and 2006-07 to monitor the population and fruiting body damaged caused by *H. armigera* in commercially released *Bt* cotton hybrids under unprotected conditions. In the present study it was found that there was no variability in egg laying among *Bt*, non *Bt* hybrids and Narasimha. However, the larval population and fruiting body damage was significantly lower in *Bt* hybrids than their corresponding non *Bt* hybrids. Seed cotton yield in *Bt* cotton hybrids were more than that of non *Bt* cotton hybrids.

Key words: *Bt* cotton, *Cry*1Ac, *H. armigera*

INTRODUCTION

Bollworms especially, American bollworm, *Helicoverpa armigera* (Hubner) and pink bollworm, *Pectinophora gossypiella* (Saunders), cause considerable damage in India to the cotton crop (Deore *et al.,* 2010). A loss of US $1.0 billion worth cotton has been accounted for the dreaded pest, *H. armigera* every year (Gujar *et al.*, 2000). The indiscriminate use of insecticides has resulted in the development of insecticide resistance in *Helicoverpa*. Growing commercialized *Bt* cotton offers an opportunity to manage the pest problem and increases productivity and provides benefits to farmers, consumers and environment. *Bacillus thuringiensis* (Berliner) is gram positive delta endotoxin producing bacterium. Using biotechnology tools, scientists have introduced genes from *B. thuringiensis* into cotton plant, leading to production of *Cry* protein which provides resistance to bollworm. The first generation transgenic cotton exhibited good level of resistance against the bollworms *viz.*, *H. armigera*, *P. gossypiella* and *Earias vittella* (Fabricius) under laboratory as well as field conditions (Khadi *et al*., 2001; Jeff Whitworth *et al.*, 2010). However, there is a need to monitor the resistance levels in the newly released hybrids. Hence, the present study was undertaken to assess the performance of newly released *Bt* hybrids and non-*Bt* cotton hybrids against *H. armigera.*

MATERIALS AND METHODS

Field experiments were conducted during 2005-06 and 2006-07 in farmers' field at Warangal district, Andhra Pradesh, India to evaluate five *Bt* Cotton hybrids along with their non *Bt* hybrids against *Helicoverpa armigera.* The experiment with 10 test hybrids *viz*., RCH 368 *Bt*, Bunny *Bt*, RCH 20 *Bt*, Mallika *Bt* and RCH-2 *Bt* and their non *Bt* hybrids along with local check variety, Narasimha was laid out with 11 treatments (each hybrid as treatment) replicated four times in a Randomized Block Design. The plot size was 10m x 10m with spacing of 1m x 1m.Cotton crop was raised following the recommended agronomic practices except for plant protection measures. The crop was protected up to 60 DAS from sucking pests by spraying with imidacloprid 17.5 SL (@0.25 mL/L) at 30 DAS and acetamiprid 20 SP (@ 0.2 g/L) at 45 and 60 DAS. Crop was not protected from bollworms with an aim to study the season long incidence of bollworm and its influence on yield of seed cotton.

Observations were recorded on 10 randomly selected plants per replication per plot avoiding border rows. The egg count was recorded on terminal growing shoot of the selected plants an while larval count of *H. armigera* was from the whole plant at weekly intervals. The damage to fruiting structures (squares/flowers/bolls) by *H. armigera* was recorded from whole plant at fortnightly intervals. Seed cotton yield data was recorded. The data were subjected to statistical analysis after suitable transformation.

RESULTS AND DISCUSION

The results of the study are presented in Table 1-4. Oviposition by *H. armigera* was first noticed at 46 DAS on all the cotton cultivars and declined thereafter during both the seasons. However, the cumulative data of 2005-06 and 2006-07 pertaining to seasonal mean oviposition by *H. armigera* reveals that there was no variability in egg laying among *Bt,* non *Bt* hybrids and Narasimha. Earlier studies on oviposition were not consistent. Though some researchers have reported significant differences in egg laying between *Bt* and non *Bt* cotton hybrids, there are other reports which concluded that there were no significant differences in egg laying between *Bt* and non *Bt* cotton hybrids. The results in the present study are in agreement with Kengegowda *et al*. (2005); Basavaraj *et al*. (2007); Li GuoPing *et al*. (2010); Arshad *et al*. (2011) who reported that there was no difference in oviposition between transgenic and non transgenic cotton. However, Wu *et al*. (2003) and Vennila *et al*. (2004) observed significant differences in egg laying.

H. armigera larval population increased slowly from 53 days after sowing to 102 days after sowing across the cotton cultivars and later decreased reaching a minimum at 130 DAS. However, season long larval incidence of American bollworm was very low in all the *Bt* hybrids compared to non *Bt* hybrids and Narasimha. Seasonal mean larval incidence revealed that all the *Bt* hybrids recorded significantly lower population of *H. armigera* than their corresponding non *Bt* hybrids and Narasimha (df=30; F=142.87, P=0.06). The present findings were in agreement with those of Wang and Xia (1997); Cui *et al*. (1998); Zhao *et al*. (1998); Cui and Xia (2000); Anonymous (2002); Srinivasa Rao (2004); Patil *et al*. (2004) and Arshad *et al*. (2011) who reported that the incidence of *H. armigera* larvae was very low on *Bt* cotton cultivars compared to their corresponding non *Bt* cultivars. Further, Srinivasa Rao (2004) reported that the larval population never crossed ETL in *Bt* cotton hybrids. Manjunatha *et al.* (2009) and Vijander *et al*. (2010) reported that larval incidence of American bollworm (*H. armigera*) was nil in all the *Bt* hybrids compared to non *Bt* hybrids.

Similarly, fruiting body damage also increased slowly from 65 DAS and damage was higher at 95 and 110 DAS and decreased thereafter. At peak activity of *H. armigera*, lowest fruiting damage were recorded in *Bt* hybrids, which are equal among themselves. However, non *Bt* hybrids recorded higher damage differed from their respective *Bt* counter parts but were equal among themselves (df=30; F=1062.19; P=0.10). The present findings are in confirmation with results of Krishnamurthy and Subramanian (2004); Patil *et al.* (2004) and Vennila *et al.* (2004); Thulasi Ram *et al.* (2006); Prasad and Rao (2008); Prasad *et al*. (2008), Manjunatha *et al.* (2009) who reported similar trend of low square damage and green boll damage in different *Bt* cotton cultivars compared to their corresponding non *Bt* cotton counterparts and check hybrid.

Seed cotton yield was equal among the *Bt* hybrids. However, *Bt* versions were superior over their non *Bt* versions and local check, Narasimha (df=30; F=6.17; P=423). The present findings are consistent with the findings of Benedict *et al.* (1996), Surilivelu *et al.* (2004), Khambhampati *et al*. (2006), Kumar (2006), Iyengar and Lalitha (2007), Bheemanna *et al.* (2008) and Manjunatha *et al.* (2009) who reported higher seed cotton yield in *Bt* hybrids compared non *Bt* hybrids. Radhika *et al*. (2006) observed that the yield differences among *Bt* hybrids was not significant, while *Bt* hybrids were significantly superior over their non *Bt* versions and checks. Hence the present study established that *Bt* hybrids recorded lower fruiting body damage and better in yield compared to non *Bt* hybrids.

Table 1. Mean oviposition of *H. armigera* on different cotton cultivars during 2005-2007 (Pooled data of two years)

Cotton cultivar	Mean number of eggs/plant											
	46 DAS	53 DAS	60 DAS	67 DAS	74 DAS	81 DAS	88 DAS	95 DAS	102 DAS	109 DAS	116 DAS	Mean
RCH 368 *Bt*	0.08± 0.01	0.30±0.06	0.58±0.05	0.40±0.06	0.45±0.01	1.05±0.04	1.58±0.03	1.38±0.08	0.30±0.02	0.18±0.03	0.00±0.00	0.57±0.01
RCH 368 non *Bt*	0.13± 0.02	0.43±0.04	0.68±0.06	0.33±0.02	0.48±0.01	1.40±0.09	1.95±0.07	1.05±0.04	0.13±0.02	0.15±0.02	0.03±0.01	0.58±0.01
Bunny *Bt*	0.05±0.01	0.55±0.07	0.50±0.09	0.45±0.09	0.60±0.01	1.00±0.05	1.53±0.06	1.20±0.09	0.30±0.05	0.20±0.06	0.03±0.01	0.58±0.01
Bunny non *Bt*	0.15± 0.02	0.30±0.05	0.83±0.04	0.40±0.03	0.55±0.02	1.35±0.10	2.28±0.04	1.20±0.06	0.23±0.01	0.10±0.02	0.05±0.01	0.67±0.01
RCH 20 *Bt*	0.13± 0.02	0.45±0.07	0.80±0.07	0.38±0.01	0.65±0.01	1.48±0.11	1.88±0.08	0.98±0.01	0.33±0.03	0.10±0.03	0.03±0.01	0.63±0.02
RCH 20 non *Bt*	0.18± 0.02	0.35±0.05	0.75±0.04	0.38±0.02	0.53±0.02	1.40±0.05	2.08±0.08	1.40±0.08	0.25±0.03	0.13±0.03	0.05±0.01	0.67±0.02
Mallika *Bt*	0.15±0.02	0.38±0.06	0.50±0.07	0.40±0.01	0.53±0.01	1.30±0.10	2.05±0.09	1.38±0.07	0.25±0.03	0.13±0.02	0.03±0.01	0.62±0.04
Mallika non *Bt*	0.01±0.00	0.45±0.06	0.80±0.04	0.35±0.01	0.53±0.03	1.30±0.10	1.63±0.08	1.35±0.07	0.33±0.03	0.18±0.02	0.03±0.01	0.62±0.03
RCH2 *Bt*	0.13±0.01	0.38±0.03	0.73±0.07	0.43±0.02	0.45±0.05	1.35±0.09	2.18±0.05	1.35±0.03	0.33±0.03	0.08±0.02	0.00±0.00	0.67±0.02
RCH2 non *Bt*	0.15±0.02	0.43±0.06	0.78±0.08	0.45±0.01	0.55±0.03	1.35±0.08	2.20±0.02	1.43±0.04	0.50±0.06	0.25±0.04	0.00±0.00	0.73±0.01
Narasimha	0.15±0.03	0.33±0.08	0.63±0.06	0.70±0.06	0.65±0.01	1.45±0.12	1.88±0.05	1.30±0.11	0.25±0.04	0.13±0.02	0.00±0.00	0.65±0.03
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.02	0.06	0.06	0.04	0.02	0.09	0.06	0.07	0.03	0.03	0.01	0.02
CD (P=0.05)	-	-	-	-	-	-	-	-	-	-	-	

DAS – Days after sowing; S – Significant; NS – Non Significant

Table 2. Mean larval incidence of *H. armigera* on different cotton cultivars during 2005-2007 (Pooled data of two years)

Cotton cultivar	Number of larvae/plant												
	53 DAS	60 DAS	67 DAS	74 DAS	81 DAS	88 DAS	95 DAS	102 DAS	109 DAS	116 DAS	123 DAS	130 DAS	Mean
RCH 368 *Bt*	0.00±0.00	0.05±0.01	0.05±0.02	0.15±0.03	0.23±0.01	0.35±0.01	0.48±0.04	0.63±0.03	0.40±0.02	0.25±0.01	0.03±0.01	0.03±0.01	0.22±0.01
RCH 368 non *Bt*	0.05±0.02	0.43±0.05	0.65±0.03	1.38±0.04	1.60±0.04	1.88±0.03	2.25±0.03	2.78±0.03	1.98±0.02	1.43±0.05	0.88±0.06	0.40±0.06	1.31±0.00
Bunny *Bt*	0.00±0.00	0.13±0.04	0.20±0.06	0.25±0.05	0.43±0.05	0.50±0.03	0.55±0.04	0.78±0.02	0.38±0.04	0.35±0.04	0.05±0.01	0.05±0.01	0.30±0.02
Bunny non *Bt*	0.40±0.09	0.43±0.05	0.80±0.04	1.55±0.02	1.73±0.03	2.00±0.01	2.58±0.04	3.30±0.05	2.13±0.04	1.68±0.06	1.15±0.07	0.70±0.05	1.54±0.01
RCH 20 *Bt*	0.00±0.00	0.03±0.09	0.05±0.02	0.15±0.01	0.18±0.01	0.28±0.02	0.43±0.01	0.63±0.03	0.30±0.02	0.15±0.01	0.05±0.01	0.05±0.01	0.19±0.00
RCH 20 non *Bt*	0.13±0.04	0.53±0.03	0.53±0.03	1.25±0.10	1.53±0.08	1.83±0.04	2.25±0.04	2.73±0.06	1.88±0.02	1.30±0.03	0.80±0.09	0.43±0.04	1.26±0.03
Mallika *Bt*	0.08±0.03	0.15±0.04	0.15±0.04	0.15±0.04	0.15±0.04	0.35±0.04	0.43±0.04	0.60±0.02	0.43±0.03	0.20±0.04	0.05±0.02	0.03±0.01	0.23±0.02
Mallika non *Bt*	0.18±0.04	0.43±0.01	0.78±0.02	1.50±0.04	1.58±0.03	1.78±0.03	2.55±0.04	2.90±0.04	1.95±0.04	1.33±0.04	0.88±0.05	0.38±0.05	1.35±0.00
RCH 2 *Bt*	0.00±0.00	0.03±0.01	0.03±0.01	0.13±0.03	0.10±0.02	0.33±0.02	0.40±0.03	0.53±0.02	0.25±0.02	0.13±0.02	0.00±0.00	0.03±0.01	0.16±0.01
RCH 2 non *Bt*	0.08±0.03	0.43±0.03	0.60±0.03	1.33±0.04	1.45±0.03	1.75±0.05	2.23±0.05	2.78±0.07	1.78±0.02	1.18±0.06	0.63±0.02	0.25±0.06	1.20±0.02
Narasimha	0.05±0.02	0.33±0.05	0.70±0.05	1.43±0.10	1.63±0.04	1.85±0.06	2.30±0.04	3.03±0.06	1.85±0.03	1.30±0.01	0.68±0.05	0.43±0.05	1.30±0.01
F-test	NS	S	S	S	S	S	S	S	S	S	S	S	S
SEm±	0.04	0.04	0.03	0.04	0.04	0.03	0.04	0.64	0.03	0.04	0.05	0.04	0.01
CD (P=0.05)	-	0.10	0.10	0.16	0.12	0.10	0.11	0.11	0.08	0.11	0.14	0.12	0.06

DAS – Days after sowing; S – Significant; NS – Non Significant

Table 3. Mean per cent fruiting body damage by *H. armigera* in different cotton cultivars during 2005-2007 (Pooled data of two years)

Cotton Cultivar	Fruiting body damage (%)						
	65 DAS	80 DAS	95 DAS	110 DAS	125 DAS	140 DAS	Mean
RCH 368 *Bt*	0.37±0.15	3.52±1.28	4.39±1.31	3.45±1.86	1.62±1.72	0.52±1.24	1.39±0.04
RCH 368 non *Bt*	4.29±0.77	15.96±3.99	19.83±2.10	19.99±3.13	11.58±2.93	5.75±2.02	15.01±0.04
Bunny *Bt*	0.48±0.47	4.14±1.14	4.61±1.17	3.94±0.85	2.08±0.92	0.66±0.97	2.14±0.03
Bunny non *Bt*	4.51±1.47	18.21±2.89	22.13±3.73	21.57±1.73	12.34±4.34	6.96±3.46	15.95±0.08
RCH 20 *Bt*	0.28±0.45	2.96±0.82	3.96±1.69	2.40±0.79	1.42±0.69	0.45±0.44	1.21±0.02
RCH 20 non *Bt*	5.14±1.78	15.59±4.36	19.39±3.00	19.35±3.04	9.79±3.53	5.37±2.65	9.41±0.03
Mallika *Bt*	0.37±0.44	4.25±1.33	3.61±0.85	3.56±1.74	1.50±1.31	0.43±0.24	0.97±0.01
Mallika non *Bt*	4.99±1.78	16.25±2.84	19.39±1.22	19.41±4.22	9.66±3.80	6.03±1.24	13.40±0.06
RCH 2 *Bt*	0.29±0.29	3.66±0.72	5.38±0.67	2.44±1.14	1.34±2.38	0.35±0.32	1.22±0.03
RCH 2 non *Bt*	4.92±1.95	17.19±3.63	19.11±2.83	19.06±3.49	8.61±2.79	4.64±0.94	10.57±0.06
Narasimha	5.21±2.08	17.52±4.25	21.13±3.13	20.89±4.12	9.42±2.71	6.14±1.56	10.97±0.07
F-test	S	S	S	S	S	S	S
SEm±	1.23	2.56	1.75	2.39	2.62	1.50	0.03
CD (P=0.05)	3.59	7.43	5.08	6.94	7.59	4.37	0.10

DAS – Days after sowing; S – Significant; NS – Non Significant

Table 4. Seed cotton yield in different cotton cultivars

Cotton cultivar	2005-06	2006-07	Mean
	Yield (kg/ha)	Yield (kg/ ha)	Yield (kg/ ha)
RCH 368 *Bt*	2467±405	2517±238	2492±309
RCH 368 non *Bt*	1809±88	1834±91	1821± 89
Bunny *Bt*	2270 ±55	2345±55	2307±41
Bunny non *Bt*	1734±132	1739 ±50	1736±78
RCH 20 *Bt*	2554 ±173	2679±77	2616±119
RCH 20 non *Bt*	1616±131	1914±38	1765±72
Mallika *Bt*	2329±162	2404±88	2366±126
Mallika non *Bt*	1791±127	1886±134	1828±126
RCH 2 *Bt*	2780 ±336	2505 ±180	2643±256
RCH 2 non *Bt*	1824±158	1874±157	1849±156
Narasimha	1950 ±189	1908±124	1929±147
F-test	S	S	S
SEm±	192	115	146
CD (P=0.05)	558	335	423

This is mainly due to ability of *Bt* hybrids to resist infestation from American bollworm as evident from low larval incidence and lower fruiting body damage.

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REFERENCES

Annapurve, S. N., Deshmukh, G. S., Kausale, S. P. and Kale, U. V. 2007. Correlation study of yield contributing characters in American cotton. *Journal of Cotton Research and Development*, **21**(1): 16-20.

Anonymous. 2002. *Annual Report*, Regional Agricultural Research station, Lam, Guntur, Andhra Pradesh.

Arshad M, Sushail A, Zain-ul-Abdin and Dildar gogi M 2011 Efficacy of transgenic *Bt* cotton against H. armigera (Lepidoptera : Noctuidae) in the Punjab. *Pakistan Entomologist*, **33** (2): 119-123.

Basvaraj, V. P., Bheemanna, M. and Shivanand, G. H. 2007. Insect pest status and Economics of *Bt* cotton cultivation under irrigated Ecosystem. *WCRC-4 cotton nature's High-Tech fiber*, 10-14 September.

Benedict, J. H., Sachs, E. S., Altman, D. W., Deaton, W. R., Kohel, R. J., Ring, D. R. and Berberich, S. A. 1996. Field performance of cottons expressing transgenic *Cry*1Ac insecticidal proteins for resistance to *Heliothis virescens* and *Helicoverpa zea* (Lepidoptera:Noctuidae). *Journal of Economic Entomology*, **89**: 230-238.

Bheemanna, M., Patil, B. V., Hanchinal, S. G., Hosamani, A. C. and Bansi, A. B. 2008. Comparative performance and economics of Bollgard II *Bt* cotton under irrigated conditions. *Journal of Cotton Research and Development*, **22**(1): 118-121.

Cui, J. J. and Xia, J. Y. 2000. Effects of *Bt* cotton *Bacillus thurigiensis* transgenic cotton on the dynamics of pest population and their enemies. *Acta Phytophylacica Sinica*, **27**(2): 141-145

Cui, J. J., Xia, J. Y., Cui, J. J., Xia, J. Y. 1998. Effects of early seasonal strain of *Bt* transgenic cotton on population dynamics of main pests and their natural enemies. *Acta Gossypii Sinica*, **10**(5): 225-262

Deore, J. S., Borikar, P. S., Yadav, G. A. and Dhumal, M. S. 2010. Efficacy of newer insecticides against bollworm complex in cotton. *Pestology*, **34** (2):12-17

Gujar, G. T., Archana Kumari, K. V. and Chandra Shekar, K. 2000. Spatial and temporal variation in susceptibility of American bollworm, *Helicoverpa armigera* (Hubner) to *Bacillus thuringiensis* var. *kurstaki*. *Current Science*, **78**: 995-1001

Giri, A. N. and Kapse, P. S. 2007. Performance and economics of *Bt* cotton hybrids at farmers field in Maharashtra state. *Journal of Cotton Research and Development*, **21**(1): 128-130.

Ismael, Y., Bennett, R. and Morse, S. 2002. Farm level economic impact of biotechnology small holder *Bt* cotton farmers in South Africa. *Outlook on Agriculture*, **31**(2): 107-111.

Iyengar, S. and Lalitha, N. 2007. GM cotton in Gujarat general madness or genuine miracle. *Asian Biotechnology and Department Review*, **9**(2): 45-81.

Jeff Whitworth, R., Michaud, J. P., Holly Davis and Phillip,E. Sloderbeck. 2010 In: Cotton Insect Management 2010, Kansas State University, February 2010. 1 – 7 **PP.**

Kengegowda, N., Patil, P. V. and Bheemanna, M. 2005. Population dynamics of Insect pest on *Bt*, non *Bt* and popular hybrid cotton in Tungabhadra Project Area of Karnataka State. *Karnataka Journal of Agricultural Sciences*, **18**(2): 383-388.

Khadi, B. M., Kulkarni, V. N., Katageri, I. S. and Vamadevaiah, H. M. 2001. Role of transgenics in improving quality and quantity of cotton. *National Journal of Plant Improvement*, **3**: 11-23.

Khambhampati, U., Morse, S., Bennett, R. and Ismael, Y. 2006. Farm level performance of genetically modified cotton A frontier analysis of cotton production in Maharashtra. *Outlook on Agriculture*, **35**(4): 291-297.

Krishnamurthy, S. V. and Subramanian, S. 2004. Evaluation of transgenic *Bt* cotton hybrids. In: *National symposium on changing world order cotton Research*, Development and Policy in context August 10-12, 2004, ANGRAU, R. Nagar, Hyderabad 35 **P**.

Kumar, Y. 2006. Experiences with *Bt* cotton in Gujarat. In: *Proceedings of national seminar on transgenic crops in Indian Agriculture: status, risks and Acceptance: Souvenir*, Extended summaries and Abstracts (Sethi, S.K., Siwach, S. S. and Yadav, R. K. eds.), 28-29Jan, 2006, CCS HAU, Hisar, 32-35 **PP**.

Li GuoPing, Feng HongQiang, Chen PeiYu, Wu ShaoYing, Liu Bing and Qiu Feng. 2010. Effect of transgenic *Bt* cotton on the population density, oviposition behaviour, development, and reproduction of a non target pest, *Adelphocoris suturalis* (Hemiptera : Mididae). *Environmental Entomology*, **39**(4): 1378-1387.

Manjunatha, R., Predeep, S., Sridhara, S., Manjunatha., Naik, M.I., Shivanna, B. K. and Venkatesh Hosamani. 2009. Comparative performance of *Bt* and non-*Bt* cotton against bollworm complex. *Karnataka Journal of Agricultural Sciences*, **22**(3): 646-647.

Mehta, A. K., Saharan, H. S., Thakral, S. K. and Jagdish Beniwal, 2009. Performance of *Bt* cotton hybrids at farmers' field in Harayana. *Journal of Cotton Research and Development*, **23** (2): 243-246.

Patil, B. V., Bheemanna, M., Hanchinaland, S. G. and Kengegowda, N. 2004. Performance and economics of *Bt* cotton cultivation in irrigated ecosystem. In: *Proceedings of National symposium on strategies for sustainable* *cotton production,* A global vision 23-25, November, 2004, UAS, Dharwad,139-142 **PP**.

Prasad, N. V. V. S. D. and Rao, N. H. P. 2008. Field evaluation of *Bt* cotton hybrids against insect and complex under rainfed conditions. *Indian Journal of Entomology*, **70**(4): 330-336.

Prasad, N. V. V. S. D., Mahalakshmi, M. S. and Rao, N. H. P. 2008. Monitoring of cotton boll worm through pheromone traps and impact of a biotic factors on trap catch. *Journal of Entomological Research*, **32**(3): 187-192.

Radhika, P., Sudhakar, K., Mohiddin, S. B. and Reddy, B. S. 2006. Relative incidence of pest complex on *Bt* and non-*Bt* cotton hybrids under protected and unprotected conditions in scarce rainfall zone of Andhra Pradesh. *Journal of Applied Zoological Researches*, **17**(2) : 158-161.

Reddy, M. C., Reddy, K. V. S. and Reddy, A. N. 2005. Performance of *Bt* cotton in Andhra Pradesh. *Journal of Research ANGRAU*, **33**(4): 79-81.

Srinivasa Rao, N. 2004. Performance of transgenic *Bt* cotton on the seasonal incidence and management of bollworms compared to local bunny through the joint toxic action of novaluron, a new chitin inhibitor. In: *Ph.D. Thesis*, Acharya N G Ranga Agricultural University, Rajendranagar, Hyderabad.

Surilivelu, T., Sumathi, E., Mathiarjan, G. and Rajendran, T. P. 2004. Temporal distribution of pink bollworm in *Bt* cotton hybrids. In: *Proceedings of National Symposium on Strategies for Sustainable Cotton Production*, A global vision 23-25, November, 2004, UAS, Dharwad 86-88 **PP**.

Sesha Mahalakshmi, M. 2007. Impact of *Bt* cotton on the incidence and management of bollworm complex. In: *Ph.D. Thesis* Acharya NG Ranga Agicultural University, Rajendranagar, Hyderabad.

Vennila, S., Biradar, V. K., Gadpayle, J. G., Panchbhai, P. R., Ramteke, M. S., Deole, S. A. and Karanjkar, P. P. 2004. Field evaluation of *Bt* transgenic cotton hybrids against sucking pests and bollworms. *Indian Journal of Plant Protection*, **32**(1): 1-10.

Vennila, S., Biradar, V. K., Gadpayle, J. G., Panchbhai, P. R., Ramteke, M. S., Deole, S. A. and Karanjkar, P. P. 2004. Field evaluation of *Bt* transgenic cotton hybrids against sucking pests and bollworms. *Indian Journal of Plant Protection*, **32**(1): 1-10.

Vennila, S., Panchbhai, P. R. and Biradar, V. K. 2006. Growth and survival of *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Fab.) on transgenic *Bt* cotton. *Journal of Cotton Research and Development*, **20**(1): 131-133.

Vijender, P., Sharma, P, D., Rahul Chouhan and Jat, S. L. 2010. Relative incidence of American bollworm, *Helicoverpa armigera* (Hubner) in *Bt* and their corresponding non *Bt* cotton genotypes. *Journal of Cotton Research and Development*, **24**(2): 253-255.

Wang, C. Y. and Xia, J. Y. 1997. Differences of population dynamics of bollworms and population dynamics of major natural enemies between *Bt* transgenic cotton and conventional cotton. *China cottons*, **24**(6): 13-15.

Wu, K. M., Peng, Y. F. and Jia, S. R. 2003. What we have learnt on impacts of *Bt* cotton on non target organisms in China. *Agriculture Biotech Network*, **5**: 1-4.

Yousouf, I., Bennett, R. and Morse, S. 2001. Farm level impact of *Bt* cotton in South Africa. *Biotechnology and Development monitor*, **48**: 15-19.

Zhao, J. Z., Lu, M. G., Fan, X. L. and Xie, F. Z. 1998. Survival and growth of different instar larvae of *Helicoverpa armigera* (Hubner) on transgenic. *Acta Entomologica Sinica*, **41**(4): 354-358.

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