Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

J E Z S Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(6): 2118-2121

Received: 15-09-2017
Accepted: 20-10-2017

Prasun Karmakar
Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Soumita Pal
Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Correspondence
Prasun Karmakar
Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Impact of transgenic on biocontrol agents of major insect pests- A review

Prasun Karmakar and Soumita Pal

Abstract
Transgenic or genetically modified plants that express insecticidal proteins have become an important component in integrated pest management programmes worldwide. As insecticidal GM crops target insect pests, an important part of the environmental risk assessment is their potential impact on non-target arthropods including biocontrol agents. The review article summarizes previously published studies on the impact of transgenic on biocontrol agents of major insect pests. Biocontrol agents can be exposed to the plant-produced insecticidal proteins through various routes, but mainly by direct exposure as a result of herbivory on transgenic plant parts expressing insecticidal proteins or secondary exposure through feeding on target or non-target species fed upon transgenic plants. Till date, no direct detrimental effects of transgenic plants expressing insecticidal proteins on the abundance or efficiency of biocontrol agents have been reported. Indirect negative effects on developmental parameters of biocontrol agents have been largely due to early mortality, slow growth and poor nutritional quality of prey host fed upon transgenic plants.

Keywords: Transgenic, genetically modified plants, insecticidal proteins, biocontrol agents, transgenes

Introduction
Transgenic plants refer to genetically engineered plants expressing functional foreign gene or transgenes. With the advent of genetic transformation techniques, it has become possible to clone and insert genes into the crop plants to confer resistance to insect pests. Resistance to insect pests in genetically modified plants expressing genes for delta-endotoxin from soil bacterium, *Bacillus thuringiensis* (Berliner), protease inhibitors, amylase inhibitors, plant lectins and other novel genes such as chitinase has been reported [3-4, 6-7, 10-23]. Lots of concern has been raised vis-à-vis the possible impact of transgenic crops on non-target organisms including biocontrol agents.
The published literature available till date reveals no detrimental effects of transgenic plants on the abundance or efficiency of biocontrol agents [16, 18, 20, 22, 26, 27]. There is still no clear evidence of the direct effect of transgenes expressing insecticidal proteins on biocontrol agents. The *Bt* proteins produced in transgenic plants appear to have no direct effects on natural enemies due to their narrow spectrum of activity. Some indirect effects have been reported due to target prey-mediated responses to transgenes such as early mortality; slow growth and poor quality of prey host [14, 22, 25, 26]. However, small to marginal negative effects on developmental parameters of biocontrol agents were reported on GNA, Serine protease inhibitor and α-Amylase inhibitor fed artificial diet [17, 19]. There is still an urgent need to have a better understanding of tritrophic interactions which can help in assessing the impact of transgenic on biocontrol agents of major crop pests [25].
Furthermore, it has become clear that in crop systems where the deployment of GM crops has led to a decline in insecticide use, biological control organisms have benefited significantly. Use of transgenic crops for insect-pest control is environmentally safe, effective and eco-friendly approach which can be well suited in the IPM system.

Potential routes of arthropod natural enemy exposure to insecticidal proteins
1. Direct exposure as a result of herbivory
2. Indirect exposure when a natural enemy feeds or parasitizes a target herbivore containing the transgenic product
3. Indirect exposure when a natural enemy feeds or parasitizes a non-target herbivore containing the transgenic product [9]

In order to assess the impact of transgenics on the biocontrol agents, there is a need to conduct effective environmental risk assessment experiments. An effective environmental risk assessment includes:

Toxicological studies

1. Direct exposure of biocontrol agents to plant parts which express the insecticidal transgene proteins
2. Direct exposure of biocontrol agents to artificial diet incorporated with the transgene proteins

Tritrophic experiments involving the indirect exposure of biocontrol agents to

1. Target herbivore hosts
2. Non-target herbivore hosts

Community-based field experiments for assessing the impact of transgenic plants upon the relative abundance of biocontrol agents.

Direct exposure of biocontrol agents to plant parts which express the insecticidal transgene proteins

Studies conducted to assess the effect of Cry1C or Cry2A containing transgenic rice pollen on the fitness of *Propylea japonica* (Thunberg) using dietary-exposure experiments [14]. It was reported that the larval developmental time of *P. japonica* was significantly longer when fed pollen from *Bt* rice lines rather than control pollen but other life table parameters were not significantly affected. The prolonged larval development in the first experiment was likely attributable to unknown differences in the nutritional composition of *Bt* rice pollen. The study indicated that Cry1C or Cry2A transgenic rice pose a negligible risk to *P. japonica*. No significant impact on the survival and development of adult Green Lacewing, *Chrysoperla carnea* (Stephens) as a result of consumption of transgenic maize pollen containing Cry 1Ab or Cry 3Bb1 [13]. No significant effects were reported as a result of consumption of pollen of transgenic *Bt*-CpTI cotton on the survival and reproduction of the parasitoid wasp *Trichogramma chilonis* (Hymenoptera: Trichogrammatidae) in the laboratory [8].

Direct exposure of biocontrol agents to artificial diet incorporated with the purified insecticidal transgene proteins

There was no adverse effect on the larval development and survival of *C.carnea* in bioassay studies involving feeding of high concentrations of the Cry 1Ab toxin directly to the predator [20]. The results of these feeding studies revealed no direct toxic effect of Cry1Ab on *C. carnea* larvae. Negative effects were observed upon the survival and developmental parameters of adult parasitic wasps' viz. *Aphidius colemani* Viereck, *Trichogramma brassicae* Bezdenko and *Cotesia glomerata* L. when the wasps were reared on the artificial diet expressing snowdrop lectins (GNA). It was found that an increasing concentration of GNA in artificial diet had a significant impact on the fitness of these adult wasps [19]. Adverse effects were recorded on the survival of bruchid parasitoids, *Eupelmus vuilleti* Crawford and *Anisopteromalus calandrae* Howard reared on artificial diet incorporated with wheat alpha-amylase inhibitor and Soyabean Kunitz Trypsin Inhibitor (SKTI) [17].

Tritrophic experiments involving the indirect exposure of biocontrol agents to target herbivore hosts

Studies were conducted to assess the effect of Cry2Aa protein in rice on *Chrysoperla sinica* (Tjeder) larvae by using a target herbivore *Chilo suppressalis* (Walker) as prey revealed that *C. suppressalis* larvae were sensitive to Cry2Aa at concentrations exceeding the levels that the larvae may encounter in *Bt* rice fields [14]. However, detrimental effects in *C. sinica* reared on *Bt* rice-fed *C. suppressalis* as prey were attributed to the decreased prey quality due to the sensitivity of *C. suppressalis* larvae to Cry2Aa.

A significant reduction in cocoon formation and adult emergence was observed for the ichneumonid parasitoid, *Campoletis chlorideae* Uchnida when reared on *Helicoverpa armigera* (Hübner) larvae fed on the leaves of transgenic cotton before and after parasitization [22]. Survival and development of *C. chlorideae* were also poor when *H. armigera* larvae were fed on the leaves of cotton hybrid Mech 184. However, no *Bt* toxins were detected in *H. armigera* larvae and the parasitoid cocoons with enzyme-linked immunosorbent assay. The adverse effects of transgenic cotton on survival and development of *C. chlorideae* were largely due to early mortality and possibly poor nutritional quality of *H. armigera* larvae due to toxic effects of the transgene [22]. *Helicoverpa* eggs from a moth reared on *Bt* maize were of poor quality for the egg parasitoid *T. brassicae* resulting in a low performance of F1 females. *H. armigera* was sublethally affected when feeding on *Bt*-maize resulting in a mortality of 79% to late instars [26].

Tritrophic studies on *Bt* maize and cotton revealed reduced development, reproduction and survival of parasitoids when exposed to *Bt* plants than those of high-quality hosts, where parasitoid development and survival were equivalent on hosts exposed or not exposed to *Bt* proteins. There was a slight increase in reproductive performance when parasitoids were provided with high-quality hosts exposed to *Bt* proteins, compared with non-*Bt* controls. In case of predators, studies revealed slightly lower survivorship when provided low-quality prey exposed to *Bt* proteins, but slightly faster developmental rates when provided unsusceptible (high-quality) prey exposed to *Bt* proteins. All other predator life history characteristics were unaffected by *Bt* proteins regardless of prey quality [25].

Tritrophic experiments involving the indirect exposure of biocontrol agents to non-target herbivore hosts

Tritrophic experiments revealed no adverse effects on development and survival of parasitoid, *Aphidius ervi* Haliday developing on aphid hosts and *Encarsia formosa* Gahan parasitizing the whitefly nymphs fed on *Bt* eggplants (Cry3B) as compared to the isogenic control line. Experiments revealed that the different physiological traits during the growing stages of these plant varieties had an indirect effect on the herbivore-parasitoid-system [26]. No adverse effect was observed on the endoparasitoid, *Diadegma insulare* Cresson upon the exposure of parasitized Cry1C resistant *Plutella xylostella* L. larvae to the biologically active form of Cry protein in *Bt* plants [16].

Studies on impact of Cry2Aa on *Chrysoperla sinica* (Tjeder) larvae in rice by using a non-target *Laodelphax striatellus* Fallén as prey revealed that *C. sinica* larvae when fed with *L. striatellus* nymphs (reared on either *Bt* or control rice plants) were not sensitive to Cry2Aa at concentrations exceeding the levels that the larvae may encounter in *Bt* rice fields [15]. *Bt* cotton was reported not to affect the survival of parasitoid, *E. formosa* but it affected development time of the adult parasitoids. Parasitoid took a longer time to develop on *Bt* cotton than non-*Bt* cotton [2]. The negative impact of transgenic cotton on parasitoid development may be attributable to the variation in host whitefly quality among *Bt* and non-*Bt* plants.

Small to marginal negative effects were observed on the rate of host suitability, number of cocoons and adult parasitoids emerging per host, percent cocoons yielding parasitoids, and sex ratio and adult lifespan of parasitoids of *Cotesia flavipes* Cameroon, a parasitoid of *Diatraea saccharalis* (F.) fed on artificial diet containing transgenic sugarcane tissue [21]. In contrast, differences were not detected between diet treatments in rates of host acceptance, egg load of females, and egg to adult developmental periods. The negative effects of transgenic sugarcane on *C. flavipes* detected in this study are important because GNA levels in the diet (≈0.49% of total protein content) containing transgenic sugarcane tissue were ≈50% of the level expressed in transgenic sugarcane plants [21].

Studies were conducted to determine the effects of *Bt*-tomato (Cry3Bb) on generalist predator *Macrolophus caliginosus* Wagner, an endoparasitoid wasp, *A. ervi* and non-target aphid, *Macrosiphum euphorbiae* (Thomas) under laboratory conditions [18]. Experiments revealed that there were no significant differences between performances of *M. euphorbiae* on *Bt* tomato (line UC82*Bt*) with respect to their near-isogenic control line (line UC82). Immunoassays did not detect Cry3Bb protein in *M. euphorbiae* developing on *Bt*-tomato. Similarly, no significant differences were reported on the longevity and prey consumption of *M. caliginosus* when fed aphids reared on UC82*Bt* or on UC82. Moreover, the genetic modification did not affect the attractiveness of uninfested tomato plants toward *A. ervi*. It was observed that *Bt* tomato had no adverse effects on the biological parameters of *M. caliginosus*, *A. ervi* and *M. euphorbiae* [18].

Tritrophic experiments were conducted to assess the adverse effects of *Bt* canola (Cry1Ac) on *Diaeretiella rapae* McIntosh of mealy cabbage aphid, *Brevicoryne brassicae* L. [26]. Studies revealed that the foraging efficiency and oviposition behaviour of this parasitoid species were not significantly influenced by *Bt* canola plants and expression of Cry1Ac had no detrimental effects on the development of the parasitoid larvae. Furthermore, the *Bt* canola variety did not impact the development of the parasitoids.

Studies were conducted to assess the effects of transgenic cotton on predator *Cryptolaemus montrouzieri* Mulsant by comparing its development, survival and body weight on non-target mealybug, *Ferrisia virgata* (Cockerell) fed with transgenic cotton leaves expressing Cry1Ac (Bt toxin) + CpTI (Cowpea Trypsin Inhibitor) with those on its near-isogenic non-transgenic line [27]. No significant differences were observed in the physiological parameters of the predator *C.montrouzieri* offered *F. virgata* reared on transgenic cotton or its near-isogenic line. Cry1Ac and CpTI proteins were detected in transgenic cotton leaves, but no detectable levels of both proteins were present in the mealybug or its predator when reared on transgenic cotton leaves. Thus, bioassay studies indicated that transgenic cotton poses negligible risk to the predatory coccinellid *C. montrouzieri* via its prey, the mealybug *F. virgata.*

Community-based field experiments for assessing the impact of transgenic plants upon the relative abundance of biocontrol agents. No significant differences were observed with respect to the relative abundance of predators, viz., spiders, chrysopids and coccinellids on *Bt* and non-*Bt* cotton genotypes [1, 5, 24].

Conclusion

Use of transgenic crops for insect-pest control is environmentally safe, effective and eco-friendly approach which can be well suited in the IPM system. No clear evidence of the direct effect of transgenes expressing insecticidal proteins on biocontrol agents has been yet reported. There is still an urgent need to have a better understanding of tritrophic interactions which can help in assessing the impact of transgenic on biocontrol agents of major crop pests.

Acknowledgement

Both the authors have contributed equally and have no conflict of interest. Authors are grateful to Dr. Parminder Singh Shera and Dr. Sudhendu Sharma, Punjab Agricultural University, Ludhiana for providing necessary advice to carry out the review work.

References

1. Arshad M, Arif MJ, Gogi MD, Abdul ur Rehman M, Abdin ZMJ, Wakil W *et al*. Seasonal abundance of non-target natural enemies in transgenic *Bt* and conventional cotton. Pakistan Entomologist. 2014; 36:115-118.
2. Azimi S, Ashouri A, Tohidfar M, Hasanlouei RT. Effect of Iranian *Bt* cotton on *Encarsia formosa*, parasitoid of *Bemisia tabaci*. International Research Journal of Applied and Basic Sciences. 2012; 3:2248-2251.
3. Benedict JH, Ring DR. Transgenic crops expressing Bt proteins: Current status, challenges and outlook. In: *Transgenic crop Protection: Concepts and Strategies.* O Koul and G S Dhaliwal (Eds) Science publishers, inc., Enfield (NH) U.S.A. 2004, 15-84.
4. Benedict JH, Sachs ES, Altman DW, Deaton DR, Kohel RJ, Ring DR *et al*. Field performance of cotton expressing Cry1A insecticidal crystal protein for resistance to *Heliothis virescens* and *Helicoverpa zea*. Journal of Economic Entomology. 1996; 89:230-238.
5. Dhillon MK, Sharma HC. Comparative studies on the effects of *Bt*-transgenic and non-transgenic cotton on arthropod diversity, seed cotton yield and bollworms control. Journal of Environmental Biology. 2013; 34:67-73.
6. Ding X, Gopalakrishnan B, Johnson LB, White FE, Wang X, Morgan TD *et al*. Insect resistance of transgenic tobacco expressing an insect chitinase gene. Transgenic Research. 1998; 7:77-84.
7. Franco OL, Rigden DJ, Melo MR, Grossi-De-Sa MF. Plant alpha amylase inhibitors and their interaction with insect alpha amylases. European Journal of Biochemistry. 2002; 269:397-412.
8. Geng JH, Shen ZR, Song K, Zheng L. Effect of pollen of regular cotton and transgenic *Bt* + CpTI cotton on the survival and reproduction of the parasitoid wasp *Trichogramma chilonis* (Hymenoptera: Trichogrammatidae) in the laboratory. Environmental Entomology. 2006; 35:1661-1668.
9. Head GP, Brown CR, Groth ME, Duan JJ. Cry1Ab protein levels in phytophagous insects feeding on transgenic corn: implications for secondary exposure risk assessment. Entomologia Experimentalis et Applicata. 2001; 99:37-45.
10. Hilder VA, Boulter D. Genetic engineering of crop plants for insect resistance: A critical review. Crop Protection. 1999; 18:177-191.
11. Kaur S, Gujar GT. Contemporary approaches for

genetically engineered insect resistant transgenic crops. In: Host Plant Resistance to Insects: Concepts and Applications, G S Dhaliwal and R Singh (Eds) Panima publishing corporation, New Delhi. 2004, 492-516.
12. Lepte JC, Bonade BM, Augustin S, Pilate G, Le Tan VD, Delpanque A *et al*. Toxicity to *Chrysomela tremulae* of transgenic poplars expressing a cysteine proteinase inhibitor. Molecular Breeding. 1995; 1:319-328.
13. Li Y, Meissle M, Romeis J. Consumption of *Bt* maize pollen expressing Cry1Ab or Cry3Bb1 does not harm adult green lacewings, *Chrysoperla carnea* (Neuroptera: Chrysopidae). PLoS One, 2909, 3. doi:10.1371/journal.pone.0002909. 2008.
14. Li Y, Wang Y, Romeis J, Liu Q, Lin K, Chen X *et al*. Consumption of *Bt* rice pollen containing Cry1C or Cry2A does not pose a risk to Propylea japonica (Thunberg). Scientific Reporter. 2015; 5:76-79.
15. Li Y, Wang Y, Romeis J, Liu Q, Lin K, Chen X *et al*. *Bt* rice expressing Cry2Aa does not cause direct detrimental effects on larvae of *Chrysoperla sinica*. Ecotoxicology. 2013; 22:1413-1421.
16. Liu X, Chen M, Onstad D, Roush R, Shelton AM. Effect of *Bt* broccoli and resistant genotype of *Plutella xylostella* (Lepidoptera: Plutellidae) on development and host acceptance of the parasitoid *Diadegma insulare* (Hymenoptera: Ichneumonidae). Transgenic Research. 2010; 20:887-897.
17. Lüthi C, Álvarez-Alfageme F, Romeis J. The potential of transgenic legumes in integrated bruchid management: assessing the impact on bruchid parasitoids. In: Proceedings of the 10th International Working Conference on Stored Product Protection Berlin, Julius-Kühn-Archiv. 2010, 979-984.
18. Maria CD, Raffaele S, Maria GDL, Luigi I, Maurilia M, Raffaella S *et al*. Interactions between *Bt*-expressing tomato and non-target insects: the aphid *Macrosiphum euphorbiae* and its natural enemies. Journal of Plant Interactions. 2012; 7:71-77.
19. Romeis J, Babendreier D, Wackers FL. Consumption of snowdrop lectin (GNA) causes direct effects on adult parasitic wasps. Oecologia. 2003; 134:528-536.
20. Romeis J, Dutton A, Bigler F. *Bacillus thuringiensis* toxin (Cry1Ab) has no direct effect on larvae of the green lacewing *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Journal of Insect Physiology. 2004; 50:175-183.
21. Setamou M, Bernal JS, Legaspi JC, Mirkov TE. Effects of snowdrop lectin (*Galanthus nivalis* Agglutinin) expressed in transgenic sugarcane on fitness of *Cotesia flavipes* (Hymenoptera: Braconidae), a parasitoid of the non target pest, *Diatraea saccharalis* (Lepidoptera: Crambidae). Annals of the Entomological Society. 2001; 95:75-83.
22. Sharma HC, Arora R, Pampapathy G. Influence of transgenic cottons with *Bacillus thuringiensis cry1Ac* gene on the natural enemies of *Helicoverpa armigera*. Biological Control. 2007; 52:469-489.
23. Sharma OP, Sehgal M, Jeswani MD, Trivedi TP, Garg DK, Srivastava CP *et al*. Pigeonpea. In: Validated IPM Technologies for Selected Crops, A Singh, H R Sardana and N Sabie (eds) National Center for Integrated Pest Management, New Delhi. 2004, 77-89.
24. Shera PS, Arora R, Singh P. Comparative susceptibility of trasgenic *Bt* cotton hybrids to *Earias* spp. and other non-target insects. Crop Protection. 2015; 71:51-59.
25. Steven EN. Impacts of *Bt* crops on non-target invertebrates and insecticide use patterns. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 2009; 4:011. DOI: 10.1079/PAVSNNR20094011.
26. Tobias F, Frank C. Effects of *Bt* transgenes on herbivorous insect-parasitoid interactions. A PhD Dissertation, zur Erlangung des Doktorgrades, der Fakultät für Agrarwissenschaften, der Georg-August-Universität Göttingen. 2004.
27. Wu H, Zhang Y, Liu P, Xie J, He Y. Effects of Transgenic Cry1Ac + CpTI Cotton on Non-Target Mealybug Pest *Ferrisia virgata* and Its Predator *Cryptolaemus montrouzieri*. PLoS ONE, 9: e95537. doi:10.1371/journal.pone.0095537. 2014.