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Influence of pesticides and application methods on pest and predatory arthropods associated with cotton

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Abstract Incidence of sucking pests was studied in a transgenic (*Bt*) and non-transgenic cotton (non-*Bt*) agro ecosystem in 2008 and 2009. Simultaneously, the influence of different pesticides applied in two different methods on sucking pests and generalist predators was investigated on transgenic cotton. In stem application, the insecticides solutions prepared were painted directly on the middle portion of the plant stem but in foliar application the recommended dosages of the insecticides were sprayed on the cotton plant. The transgenic and non-transgenic cotton did not differ significantly in the population of sucking pests. The different pesticides when applied by foliar sprays reduced significantly more sucking pests than stem application. Among the different insecticides used, imidacloprid caused the maximum reduction of the leaf hopper population, acetamiprid caused the maximum whitefly reduction, and clothianidin caused the maximum thrips reduction under foliar application. *Via* stem application, acetamiprid and thiomethoxam were found better in suppression of the sucking pests' population, but the population of predators was significantly less disrupted by the stem application method. The foliar application was in general more effective; stem application may be more applicable early in the season when its efficacy was higher and when foliar sprays were particularly destructive to beneficial pests. In foliar application, all the systemic neonicotinoids like imidacloprid, clothianidin, admire, thiamethoxam and acetamiprid were found highly toxic to natural enemies in comparison with spirotetramat, buprofezin and fipronil.

Keywords Foliar sprays · *Gossypium* spp. · Natural enemies · Neonicotinoids · Stem application

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Introduction

Cotton (*Gossypium* spp.) is an important industrial crop in the world and is grown over an area of more than 34 million hectares (M-ha), of which approximately one third are in India. Cotton is a unique crop and grown commercially in ten states (divided into three zones, *i.e.,* north, central and south) of India by nearly 7.0 million farmers. The north zone, comprising Punjab, Haryana and Rajasthan, cultivates irrigated cotton over an area of 1.22 M-ha (>90% under transgenic cotton). *Bt* cotton, which confers resistance to bollworms of cotton, was first adopted in India as hybrids in 2002. The adoption of *Bt* cotton was very fast: in 2010, out of 11.0 M-ha under cotton, 9.4 M-ha (equivalent to 86%) was under *Bt* cotton. In 2011, out of an estimated total of 12 M-ha under cotton, the *Bt* cotton area shall cross the 10 M-ha mark.

About 184 insect pests have been recorded on cotton in India, causing a 30–80% loss to yield, and among them the bollworm complex was a major constraint (Patil 1998). Transgenic cotton is promising in the management of the bollworm population only (Fakrudin *et al*. 2003; Murugan *et al*. 2003). The genetically modified bollworm resistance cotton succumbs to yield losses due to the 'block' of sap feeders from seedling emergence to harvest (Vennila *et al*. 2004). Sap feeders, *viz*., leafhopper, *Amrasca devastans* (Dist.); aphid, *Aphis gossypii* (Glover); thrips, *Thrips tabaci* Lindeman; and whitefly, *Bemisia tabaci* (Gennadius), damage the cotton crop with regular occurrence at different growth stages, reducing the growth and yield. Hence, suitable techniques to manage the sucking pest population on transgenic cotton are needed. However, concern for the safety of predators has restricted the use of toxic insecticides for the management of sucking pests during the earlier part of the season. The commonly available predators like spiders, chrysopa and coccinellid preying upon the sucking pest complex of cotton, play an important role in the regulation of their population (Solangi *et al*. 2011).

Neonicotinoids are a new generation of systemic insecticides used mostly as foliar sprays against sucking pests and widely used for seed treatments in transgenic cotton. Being effective against sucking pests, the neonicotinoids are used more frequently in cotton (Almand and Sweeden 2001; Greene and Capps 2002; Scott *et al*. 2000). Although the neonicotinoid insecticides, as a chemical class, have similar chemical structures, they vary greatly in certain characteristics, including water solubility, that influence movement into plants. Another potentially important difference may be how neonicotinoid systemic insecticides impact natural enemies or biological control agents such as predators and parasitoids. All neonicotinoid insecticides are used primarily to target phloem-feeding insects such as aphids, whiteflies and mealybugs. They may be applied as a foliar spray, drench or as a granule to the soil or growing medium, or as trunk injections (Mizell and Sconyers 1992; Tomizawa and Casida 2003). Besides neonicotinoids, buprofezin, spirotetramat (IGR) and fipronil (belonging to the class fiproles) were also used as foliar and stem applications. These insecticides are also effective against all sucking pests that appeared in cotton at different stages of crop growth (Papa *et al.* 2008; Patil *et al.* 2009; Udikeri *et al*. 2009; Vinoth Kumar *et al*. 2008).

The insecticides are used most of the time as foliar applications, which provide effective control. However, foliar application has a varying range of adverse impacts on natural enemies and there is a dearth of information regarding the impacts it has on predaceous arthropods in cotton when applied through different methods. In addition to the foliar application, seed dressing (Gupta *et al.* 1998), soil application, drenching through roots (Cloyd and Bethke 2010) or trunk injections (Tomizawa and Casida 2003) were found effective against pests and reported to be safe to predators. The stem application of insecticides prevalent in the central and southern zones of India (Durga Prasad *et al.* 2011) has been tried to manage the sucking pests and conserve the natural enemies in the study. In stem application of insecticides (new method), insecticides and water are mixed in a fixed ratio and applied to the middle portion of the stem. Stem application of insecticides differs from stem drenching because in stem application the insecticide solution is directly painted on the small middle portion of stem of the plant, but in stem drenching more than half of the solution is directed towards the root.

The primary aim of this study was to evaluate the difference in incidence of sucking pests in *Bt* and Non-*Bt* cotton and the efficacy of two different methods of application of insecticides against the sucking pests complex of cotton and their adverse impact on the generalist predators active in cotton. We hypothesized that different insecticides applied by different methods would result in a varying degree of efficacy against sucking pests and adverse impact to generalist predators under field conditions.

Materials and methods

Description of field experiments The experiments were conducted in Sirsa (Haryana) India (29 32′ 37.05 N, 75 02′19.53 E) where a cotton–wheat cropping system is generally followed. The experiment was conducted on cotton hybrid RCH-134 containing the bollgard gene expressing Cry I Ac and its non *Bt* isoline (obtained from Rasi Seeds, Tamilnadu, India).

The hybrid is of spreading habit with 180 days' duration and an average height of 160 cm. The crop was sown in May (12.05.2008 and 07.05.2009) at a spacing of 100×60 cm. The experiment was conducted under two sets. In the first set the transgenic and its non-transgenic counterparts were planted at similar seeding rates and three replications in 2008 and 2009 under unprotected conditions. In the second set only transgenic cotton alone was planted as the main plot and divided into two sub-plots: one subplot for foliar application and a second subplot for stem application; there were eight treatments including control in each method (Table 1). The second set was also replicated three times during both 2008 and 2009.

Insecticidal application methods in second set Treatments were initiated at 30 days after sowing (DAS) with four applications at 2-week intervals both in foliar and stem applications. The foliar applications were given at the recommended doses by using a volume of 375 *l* water ha^{-1} for thorough coverage of plants with spray material. In the stem application, the insecticides were diluted with water at ratios of 1:4 (spirotetramat, buprofezin and fipronil) and 1:20 (imidacloprid 200 SL, imidacloprid 70WG, clothianidin, thiamethoxam and acetamiprid), insecticide: water. The stem application of the insecticide was applied at 30, 45, 60 and 75 DAS when the average crop height was approx. 22 cm, 35 cm, 56 cm and 70 cm, respectively. The insecticides solution prepared for stem application was poured in a bottle fixed with sponge on the mouth for oozing out an equal amount of solution with each squeeze. With the help of this bottle, the insecticidal solution was applied only on the middle portion (2″) of the stem/trunk of the plant.

Pests and predators sampling The sucking pests sampled were leafhopper (*Amrasca biguttula biguttula*), whitefly (*Bemisia tabaci*) and thrips (*Thrips tabaci*) per plant. From each plant three fully formed leaves were observed. From each plot, data were recorded from five plants, tagged and observed prior to and after each spray application. The major predators sampled included spiders, lady bird beetles and chrysopa per plant.

Data analysis Data for the first set (transgenic and non-transgenic) were analyzed with paired 't' test by online Graphpad Quickcalcs; the data recorded in the second set were analyzed with two-way ANOVA using the SPSS statistical package.

Results

Incidence of sucking pests on transgenic (Bt) and non-transgenic (non-Bt) cotton According to the data recorded for the incidence of sucking pests, no significant difference (t-calculated < t tab) was observed in *Bt* and non-*Bt* cotton for the incidence of sucking insect pests (*i.e.*, leafhopper, whitefly and thrip) and availability of the generalist predators (Table 2).

Table 1 Details of the insecticides treatments applied to transgenic cotton

Active ingredient	Trade name	Application rates		Mode of action	Remarks
		Foliar (g or ml ha^{-1})	Stem (insecticide: water)		
Imidacloprid 200 SL	Confidor	125	1:20	Systemic insecticide with contact and stomach action	Recommended for leafhopper and whitefly
Imidacloprid 70 WG	Admire	50	1:20		
Clothianidin 50% WDG	Dentotsu	75	1:20		
Thiomethoxam 25 WG	Actara	125	1:20		
Acetamiprid 20 SP	Pride	75	1:20		
*Spirotetramat 150 OD		1000	1:4	New systemic leaf insecticide	Recommended for mealybug and sucking pests
Buprofezin 20% SC	Applaud	1250	1:4	IGR, chitin inhibitor	
Fipornil 5% SC	Regent	800	1:4	Contact and stomach action	Recommended for sucking pests

* Spirotetramat procured directly from Bayer Crop Science

Table 2 Population of sucking pests and generalist predators on *Bt* and non-*Bt* cotton

Particulars	Mean*		SE(d)	t-cal	df	*P*-value	Significance (95% CI)
	Bt	Non-*Bt*					
Sucking pests per 3 leaves	7.89	8.05	0.086	1.8558	1	0.2046	n.s.
Natural enemies per plant	0.5867	0.5633	0.041	0.5754	1	0.6231	n.s.

*Mean of three replications; five plants from each replication during 2008 and 2009

Impact of insecticides and the application methods on sucking pests population The overall impact of different insecticides, *i.e.,* imidacloprid 200SL, imidacloprid 70WG, clothianidin, thiamethoxam, acetamiprid (all neonicotinoids), spirotetramat, buprofezin (IGRs) and fipronil applied by different methods, on transgenic cotton (*Bt*) for sucking pests was observed after four insecticidal applications applied during 2008 and 2009. Of the two methods of application, foliar application was found to be statistically superior to stem application. Foliar application reduced by 38.53%, 38.32% and 40.66% the populations of leafhopper, whitefly and thrips, respectively. Stem application reduced by 17.23%, 14.78% and 22.40% the populations of leafhopper, whitefly and thrips, respectively (Table 3).

The influence of individual insecticidal treatments applied by different methods on the population of sucking pests was also studied. With the foliar application method, imidacloprid 200 SL (1.69 per 3 leaves) and acetamiprid (1.81 per 3 leaves) recorded significantly lowest number of leafhopper population followed by imidacloprid 70WG (1.94 per 3 leaves). The maximum number of leaf hoppers was recorded in buprofezin (2.71 per 3 leaves) and spirotetramat (2.41 per 3 leaves), which were significantly on par with each other and equal to the control. With stem application, the maximum reduction of leafhopper population was achieved by acetamiprid (2.41 per 3 leaves) after four rounds of application applied during both years (Table 4). In general, the population of the sucking pests was greater in stem application as compared with foliar application.

Table 3 Overall reduction (%) in population of sucking pests due to different insecticidal treatments applied by foliar and stem application methods during 2008 and 2009. (Significant difference at 0.05% between the two methods of application)

Particulars	Mean percent reduction*	
	Foliar application	Stem application
Leafhoppers	38.53	17.23
Whitefly	38.32	14.78
Thrips	40.66	22.40
Coccinellid	53.71	24.40
Chrysopa	58.08	26.91
Spider	49.88	21.10

* The average population reduction after four spray applications of all insecticidal treatments applied by foliar and stem application methods in three replications during 2008 and 2009

The whitefly population was significantly influenced by different insecticidal treatments applied in two methods. The minimum number of whiteflies was recorded in imidacloprid 200SL (2.99 per 3 leaves) followed by acetamiprid (3.33 per 3 leaves) in foliar application and acetamiprid (5.07 per 3 leaves) followed by imidacloprid 200 SL (5.29 per 3 leaves) in stem application. Buprofezin was found effective in reducing the whitefly population when applied through foliar application (3.98 per 3 leaves) but in stem application (6.21 per 3 leaves) it was not effective due to poor translocation.

The thrips population was also significantly influenced by the different treatments. Acetamiprid (6.09 per 3 leaves) and clothianindin (6.33 per 3 leaves) were the best treatments, and recorded the minimum thrips population among foliar applied treatments. In stem application, the minimum number of thrips was recorded in thiamethoxam (7.43 per 3 leaves) followed by clothianidin (7.89 per 3 leaves). Maximum thrips population was found in spirotetramat (9.67 per 3 leaves) and buprofezin (11.67 per 3 leaves) both in foliar and stem application, respectively (Table 4). All the other treatments were found to be superior to the untreated control for all the insect pests.

Impact of insecticides and application methods on the predatory arthropod population The two methods used for application of insecticides for the control of sucking pests differed significantly in their deleterious effect on the predator populations. The foliar application of insecticides reduced the predatory arthropods population more than did stem application (t-cal > t-tab). The stem application method had low adverse impact on the predatory arthropods population. The foliar methods of

Table 4 Effect of different insecticides and their methods of application on the population (per three leaves) of sucking pests in transgenic cotton (*Bt*) [z]

Treatment	Leafhopper [y]				Whitefly[y]				Thrips[y]			
	Pre-Application		After 7 days		Pre-Application		After 7 days		Pre-Application		After 7 days	
	Foliar	Stem	Foliar	Stem	Foliar	Stem	Foliar	Stem	Foliar	Stem	Foliar	Stem
Imidacloprid 200SL	3.92 (2.22)	3.87 (2.21)	1.69 $(1.64)^{d}$	3.11 $(2.03)^{bc}$	6.93 (2.82)	6.87 (2.81)	2.99 $(2.00)^{g}$	5.29 $(2.51)^{d}$	11.74 (3.53)	9.33 (3.21)	7.52 $(2.93)^{e}$	8.01 $(3.00)^{de}$
Imidacloprid 70WG	3.98 (2.23)	3.46 (2.11)	1.94 $(1.71)^{d}$	2.81 $(1.95)^{bc}$	7.13 (2.85)	7.40 (2.90)	4.04 $(2.24)^{f}$	6.11 $(2.67)^{cd}$	12.67 (3.70)	11.80 (3.58)	7.86 $(2.98)^{e}$	9.12 $(3.18)^{cd}$
Clothianidin 50%	4.02 (2.24)	3.33 (2.08)	2.15 $(1.77)^{cd}$	2.79 $(1.95)^{bc}$	7.07 (2.84)	8.13 (3.02)	3.33 $(2.08)^{g}$	5.62 $(2.57)^{d}$	12.42 (3.66)	11.73 (3.57)	6.33 $(2.71)^{f}$	7.89 $(2.98)^{e}$
Thiomethoxam 25	4.11 (2.26)	3.67 (2.16)	2.36 $(1.83)^{cd}$	2.86 $(1.96)^{bc}$	7.47 (2.91)	7.67 (2.94)	3.81 $(2.91)^{b}$	5.67 $(2.58)^{d}$	13.25 (3.77)	10.80 (3.44)	8.54 $(3.09)^{de}$	7.43 $(2.90)^{e}$
Acetamiprid 20 SP	4.19 (2.28)	3.19 (2.05)	1.81 $(1.68)^{d}$	2.41 $(1.85)^{cd}$	8.00 (3.00)	8.00 (3.00)	3.33 $(2.08)^{g}$	5.07 $(2.46)^{de}$	13.45 (3.80)	12.13 (3.62)	6.09 $(2.66)^{f}$	8.92 $(3.15)^{cd}$
Spirotetramat 150OD	3.56 (2.14)	3.71 (2.17)	2.41 $(1.85)^{cd}$	3.41 $(2.03)^{bc}$	7.20 (2.86)	7.26 (2.87)	4.63 $(2.37)^{e}$	7.01 $(2.83)^{bc}$	13.97 (3.87)	10.67 (3.42)	9.67 $(3.27)^{c}$	10.52 $(3.39)^{bc}$
Buprofezin 20%	3.71 (2.17)	3.39 (2.10)	2.71 $(1.93)^{c}$	3.11 $(1.98)^{bc}$	7.40 (2.90)	7.67 (2.94)	3.98 $(2.23)^{f}$	6.21 $(2.69)^{cd}$	11.89 (3.59)	13.20 (3.77)	8.72 $(3.12)^{d}$	11.67 $(3.56)^{a}$
Fipornil 5% SC	3.60 (2.14)	3.66 (2.16)	2.19 $(1.79)^{cd}$	3.18 $(1.97)^{bc}$	7.20 (2.86)	6.93 (2.82)	5.31 $(2.51)^{d}$	6.61 $(2.76)^{c}$	12.76 (3.71)	10.13 (3.34)	6.27 $(2.70)^{e}$	9.36 $(3.22)^{cd}$
Control	3.33 (2.08)	3.67 (2.16)	3.45 $(2.11)^{ab}$	4.01 $(2.24)^{a}$	8.5 (3.08)	7.60 (2.93)	8.50 $(3.08)^{a}$	7.60 $(2.93)^{b}$	11.60 (3.55)	10.73 (3.43)	10.65 $(3.41)^{b}$	11.32 $(3.51)^{ab}$
SE(d)	0.131		0.086		0.157		0.061		0.348		0.066	
CD (*P*=0.05)	n.s.		0.17		n.s.		0.120		n.s.		0.13	

[z] Mean of three replications; five plants /treatment from each replication and population recorded after four insecticidal sprays during both the years (2008 and 2009); in parentheses is transformed value $\sqrt{1+x}$

[y] Within any sucking pest population and column, means followed by a common letter do not differ significantly at *P*=0.05

application reduced significantly more the population of predators, *i.e.,* ladybird beetle (53.71%), chrysopa (58.08%) and spiders (49.88%). Unlike foliar application, stem application resulted in less population reduction of ladybird beetle (24.40%), chrysopa (21.10%) and spiders (26.91%) (Table 3).

The influence of individual insecticidal treatments applied by two different methods on generalist predators was also studied. Among the different insecticides used in the study, imidacloprid was found more toxic to ladybird beetle (56.00% and 19.00% reduction under foliar and stem application, respectively) but spirotetramat (32.00% and 10.82% reduction in foliar and stem application) and buprofezin (37.24% and 9.00% reduction in foliar and stem application) were found to be safer to these generalist predators. For chrysopa, imidacloprid 70WG (55.00% and 18.33% reduction in foliar and stem applications, respectively) followed by thiomethoxam and imidacloprid 200SL were highly toxic but buprofezin (18.44% and 8.09% reduction in foliar and stem applications, respectively) and spirotetramit were found safer or least toxic. Thiomethoxam with 54.76% and 20.94% reduction in spider population under foliar and stem applications was highly toxic, followed by clothianidin, whereas buprofezin (24.13% and 11.52% reduction in foliar and stem applications, respectively) was found safer (Table 5). Results indicated that the neonicotinoids differ in their activity towards the predaceous arthropods when applied by different methods. The insecticides spirotetramat, fipronil and buprofezin were found safer than the neonicotinoids to the generalist predators both under foliar and stem applications.

Table 5 Percent reduction in population of predators in transgenic cotton (*Bt)* after multiple application of insecticides[z]

Treatment	Coccinellids[y]		Chrysopa[y]		Spider[y]	
	Foliar	Stem	Foliar	Stem	Foliar	Stem
Imidacloprid 200 SL	56.00[a]	19.00[a]	52.32[b]	17.26[c]	47.78[c]	18.89[c]
Imidacloprid 70 WG	53.29[b]	18.92[a]	55.00[a]	18.33[b]	51.08[b]	19.58[c]
Clothianidin 50% WDG	50.79[c]	17.11[b]	52.80[b]	24.93[a]	49.68[bc]	16.79[d]
Thiomethoxam 25 WG	51.37[c]	16.80[b]	51.08[bc]	19.03[b]	54.76[a]	20.94[b]
Acetamiprid 20 SP	50.31[c]	19.36[a]	50.16[c]	15.38[d]	48.37[bc]	19.42[c]
Spirotetramat 150 OD	32.00[f]	10.82[d]	25.90[e]	11.27[e]	25.69[e]	13.90[e]
Buprofezin 20% SC	37.24e	9.00[e]	18.44[f]	8.09[f]	24.13[e]	11.52[f]
Fipornil 5% SC	39.00[e]	15.69[c]	38.33[d]	18.81[b]	28.64[d]	24.09[a]
Control	0.00[g]	0.00[f]	0.00[g]	0.00[g]	0.00[f]	0.00[g]
SE(d)	0.798	0.318	0.949	0.364	1.455	0.439
CD (*P*=0.05)	1.58	0.63	1.88	0.72	2.88	0.87

[z] Mean of three replications: five plants per treatment from each replication and four insecticidal sprays during both years (2008 and 2009)

[y] Within each natural enemy and column of percent reduction, data followed by a common letter do not differ significantly at *P*=0.05

Discussion

The cotton crop is attacked by sucking pests with the onset of the season (May–November). In the present study the population of sucking pests was statistically similar under both *Bt* and non-*Bt* regimes. Dhillon and Sharma (2009a) also observed non-significant differences in numbers of leafhoppers, whiteflies, aphids, green bugs, red and dusky bugs in *Bt* and non-*Bt* cotton. Earlier large scale studies had also confirmed the negative effects of broad spectrum insecticides on insect communities both under *Bt* and non-*Bt* crops (Dhillon and Sharma 2009b; Naranjo 2009; Whitehouse *et al.* 2005). The farmers used a wide variety of neonicotinoids and other insecticides to manage the sucking pests. Due to the early season spray, the non-target effects of these insecticides are very common (Turnipseed and Sullivan 1998).

Only the foliar application method is prevalent among the farmers in the north zone of India. The stem application practiced in the south zone (Durga Prasad *et al*. 2011) was tried in the north zone in the present study but was not found effective in reducing the population of the sucking pests. Another drawback to stem application is the drudgery involved and increase in the quantity of insecticides applied as compared with the foliar method of application. If the individual stem application is considered then only the first stem application applied after 30 DAS was found effective in comparison with other successive stem applications, as the canopy of the crop was less developed (only 22 cm) at the time of the first stem application. The systemic insecticides like imidacloprid, thiomethoxam, acetamiprid and clothianidin were found better in stem application due to their more rapid translocation than other insecticides like spirotetramat, buprofezin and fipronil.

Predatory insects may be negatively affected by neonicotinoid systemic insecticides under the following circumstances: (i) when they feed on pollen or nectar, or plant tissue contaminated with the active ingredient; (ii) when they consume the active ingredient while ingesting plant sap; (iii) when they feed on hosts that have consumed leaves contaminated with the active ingredient; (iv) when they consume hosts that have ingested the active ingredient (Tillman and Mullinix 2004). The influence of individual insecticidal treatment—applied by two methods—on the generalist predator was studied. The foliar application of systemic insecticides was effective in suppressing the pest population, but found to be detrimental to the establishment and extended survival of natural enemies. The foliar method of application reduced significantly the population of predators, *i.e.,* ladybird beetle (53.71%), chrysopa (49.88%) and spiders (58.08%), as compared with the stem application method. This might be due to direct toxicity of insecticides to the predators in foliar application along with the possibility of intake of intoxicated hosts (prey). In stem application, the possibility of direct toxicity is minimized because in stem application the insecticide was applied to only a very small portion of the stem, where the activity of predators is presumed very low. These results are in agreement with the earlier reports of Cloyd and Bethke (2010), Grafton-Cardwell and Gu (2003) and Kim *et al.* (2006), who stated that the soil application or drenching of systemic neonicotinoids and IGR's reduced the exposure of natural enemies to insecticides and thus reduced the toxic effect. Impacts of neonicotinoid (clothianidin, dinotefuran and thiamethoxam) insecticides on natural predators through the soil were less detrimental than foliar applications (Cloyd *et al*. 2009).

The negative impact of insecticides on beneficial arthropods in cotton has been well documented in the USA (Kilapatrick *et al*. 2005) and Israel (Devine *et al.* 1998). Among the different insecticides used in this study imidacloprid, admire (imidacloprid 70WG) and thiamethoxam, acetamiprid, clothianiidin were found more toxic to ladybird beetle, lace wing and spiders but buprofezin, spirotetramit and fipronil were found to be somewhat safer to these generalist predators. The insecticides had a variable effect on the different predator species: thiamethoxam was the most toxic compound to spiders in the present study and was also reported to be highly toxic to all predators (Al-Kherb 2011) followed by imidacloprid and acetamiprid. In this study chrysopa, *Chrysoperla* sp. and Coccinella spp. were found highly susceptible to all the neonicotinoids, particularly imidacloprid. Imidacloprid and acetamiprid were also determined as highly toxic to *Chrysoperla carnea* by Elbert *et al*. (1998) and Delbeke *et al*. (1997). The mild effect of buprofezin, spirotetramit and fipronil on the generalist predators in the present study is supported by the earlier report where fipronil was selective to predators (*Scymnus* sp., *Geocoris ventralis*, *Cycloneda sanguinea* and *Doru lineare*) under field conditions (Soares and Carlos 2000). Use of selective insecticides such as insect growth regulators help in the conservation of beneficial arthropods in cotton crops (Naranjo *et al*. 2002, 2003) than more traditional, broad spectrum and over-reactive approaches to pest management. The insect growth regulators buprofezin and spirotetramat used in the present studies were also found more conservative to generalist predators in comparison with the neonicotinoids.

Transgenic and non-transgenic cottons do not differ in their susceptibility to the sucking pests as studied in near isolines. The two methods used for the application of insecticides differ in their efficacy against the sucking pests: the stem application having poor efficacy against the sucking pests was comparatively good when applied in the earlier stage of crop growth, when foliar application is harmful due to more disruptions to the generalist predators. Stem application, throughout the period of its application, was found safer to natural enemies than foliar application. The different treatments applied differ in their efficacy against sucking pests and adverse impacts on the generalist predators. The neonicotinoids are more toxic to the predators then buprofezin, spirotetramit and fipronil. *Chrysoperla carnea* was more sensitive to the neonicotinoids than were the ladybird beetle and spiders.

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