Pakistan J. Zool., pp 1-8, 2021. DOI: https://dx.doi.org/10.17582/journal.pjz/20200512190543

Impact of Predators and Some Commercial Insecticides on *Thrips tabaci* Lindeman and *Amrasca biguttula* Ishida Populations in *Bt* Cotton under Arid Climate

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Article Information
Received 12 May 2020
Revised 23 June 2020
Accepted 20 July 2020
Available online 14 January 2021

Authors' Contribution
AAK conceived the experiments and wrote the manuscript. HK, SB and HT performed the experiment. JMS and ZH helped in writing manuscript and data analysis. AN, HMA and YI edited manuscript.

Key words
Cotton, Insect pests, Predators, Insecticides resistance, Economy

ABSTRACT

Insect pests and their vectored diseases are the most common factors which cause severe damage to the cotton crop. In this two year study, the effectiveness of Commando plus®, Oshin®, Talstar®, Radiant®, Movento® and Maximal® was evaluated against *Thrips tabaci, Amrasca biguttula* and their impact on bio-control agents in *Bt* cotton. More reduction in *T. tabaci* was observed with Radiant® and Talstar® for both years at the first application as compared to other treatments through 9 days after treatment. The second application of treatments also showed minimal differences from first application and again plots treated with Radiant® showed the best reduction in thrips population for both years. Generally, Radiant® found friendly toward predators as compared to other chemistries. The findings for tested chemicals showed that bio-based insecticides i.e. spinetoram (Radiant®) and nitenpyram (Maximal®) showed less impact on natural enemies in addition to suppression of *T. tabaci* and *A. bigutulla*.

INTRODUCTION

Insect pests are the most common factors which cause severe damages to field crops (37% reduction), additionally, viruses and pathogens can cause an 11% loss if they are kept untreated (Oerke and Dehne, 2004). Surveys indicate that a massive loss of cotton produce (up to 70%) may occur due to insect pest's infestation in the absence of any compatible control measure (Rehman *et al.*, 2017). Many insect pests including whitefly, mealybug, jassid, dusky cotton bug, and many lepidopterans are responsible for decreasing the profit and output of cotton crops. About 18.78% less has been observed in cotton yield due to infestation of jassid (Ali, 1992). Huge yield losses (40-50%) to cotton crops have also been recorded during a severe attack of thrips and jassid in cotton field plots (Naqvi, 1976). If these insects are not managed properly, they may cause damages to cotton from cotyledon to fiber formation. Farmers can reduce insect pests damage by the integration of different methods including chemical, biological, cultural, and agronomic practices (Abrantes *et al.*, 1978; Francis and Clegg, 1990).

By killing certain insect pests, Bt toxin can be helpful in minimizing the use of chemical insecticides (Wu *et al.*, 2008). The midgut of pests is disrupted by Bt toxin at target places which finally kills the insect (Morin *et al.*, 2003). Due to potentially high yield with low insect pest incidence, *Bt* cotton is grown over several million hectares. However, over time, many insect pests have developed resistance against Bt toxin which decreases its efficiency (Ferré and Rie, 2002; Tabashnik *et al.*, 2003, 2013). Moreover, *Bt* toxin helps control chewing insects especially the lepidopterans. Therefore, attention must be paid to manage a variety of sucking insect pests of cotton, for instance, jassids and thrips, which show 20-40% level of resistance against chemical insecticides (Smith, 2016). Insect pest's infestation is the major reason for huge losses in the production which could be up to 70% in the absence of pest control measures (Rehman *et al.*, 2017).

The integration of different pest control strategies including the use of biocontrol agents is the best choice for farmers to keep damages below the threshold level. The proper use of biological control results in limited chemical applications and a way to conserve bio-control agents in the agro-ecosystem. Also, these friendly insecticides ensure chemical free safe crop production (James, 2014).

The presence of a wide range of generalist predators has been reported in cotton field crops, which suppress

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0030-9923/2021/0001-0001 $ 9.00/0

the pest population in addition to the crop pollination facilitation (Isaacs *et al*., 2009). Most important predators found in cotton crop includes *Chrysopperla carnea*, *Coccinella septempunctata*, *Geocoris* spp., *Menochilus sexmaculatus*, parasitoids *Trichogramma* spp., *Apanteles* spp. and predatory spiders. *C. carnea* have excessive potential for the natural control of thrips (Khan *et al*., 2012; Rashid *et al*., 2012; Solangi *et al*., 2013; Sarwar, 2014). Certain predatory thrips are useful in decreasing the population of thrips. The predators of thrips include members of Anthocoridae, Lygaeidae, and mites. But their role in controlling thrips is limited, although there is no biological control of jassid due to its activity, but mites can control jassid to some extent and *C. carnea* is more effective for thrips (Zia *et al*., 2008).

The fluctuating scenario of spatiotemporal status of cotton requires alternate methods for pest control. Manipulation in cropping patterns of cotton, trap crops, crop rotation, and conservation tillage may limit the use of chemical insecticides. These practices also provide a space for the beneficial insects and farmer-friendly natural enemies of insect pests in cotton crops. However, integration of these practices with other applied solutions for pest management may also provide safer and effective pest control (Mari *et al*., 2007).

MATERIALS AND METHODS

Experimental layout plan and field preparation

Current research was conducted for two years consecutively during the summer season of 2017 and 2018 at the research farm of BZU, Bahadur Sub Campus Layyah (30° 57’ 53.1000” N and 70° 56’ 23.7624” E). The Bt cotton (FH-142) was sown on an area of 1012 m^2, further divided into 49 plots for seven treatments, with four replications for each treatment. The sowing was done on ridges through a hand-operated mini drill, keeping a distance of R×R 30 cm and P×P 75cm. A buffer zone of one meter was kept in between each treatment and two meters for each replication and walking path and water channels were adjusted in buffer zones. The experiment was made under Randomized Complete Block Design (RCBD). Irrigation was done every week or depending upon the soil condition and crop requirement. Fertilizer applications were made as recommended commercially and were applied in split doses i.e. at sowing, vegetative and flowering stage.

Field application of treatments

Before insecticides application (Table I), it was confirmed that the pest population (*Thrips tabaci* and *Amrasca biguttula*) reaches to economic injury level in each plot. Natural enemies (predatory spider and *C. carnea*) were observed twice a week pre and post-treatments. All the treatments were applied by using a hand-operated Knap Sack sprayer, which was calibrated before treatment application with a Turbo T-jet wide-angle spray tip nozzle. Treatments were applied three times in 2017 (10 July, 12 August) and 2018 (20 July, 22 August), while control plots were left untreated.

Data collection/sampling and analysis

Insect pest infestation appeared at the vegetative stage; the data regarding pests and bio-control agents was recorded. Five plants were selected for data collection from each plot. The richness of *T. tabaci*, *A. bigutulla*, lacewing, and spiders were observed by hand lens and visually examining leaves pre-treatment (24 h), post-treatment (24 h), 3, 6, and 9 days after treatment (DAT) of the last insecticide application until almost all the insects on each examined plant were observed.

The data for both years were analyzed separately. The normality of collected data was confirmed through the Kolmogorov-Simonov test. Analysis of variance (one-way) followed by Tukey’s test was used to discern the mean densities of tested arthropods among the experimental field plots for different treatments. The statistical package (Statistic 8.1®) was used for analyses of whole data.

Table I. List of synthetic chemical insecticides and their application rate used in the experimental field plots.

Treatments	Active ingredient	Chemical group	Brand name	Application rate	Company name
T1	Acephate	Organophosphate	Commando plus®	300gm/ac	FMC
T2	Necotinoid	Neonicotinoid	Oshin®	100gm/ac	Arysta life Sciences
T3	Bifenthrin	Pyrethroid	Talstar®	250ml/ac	FMC
T4	Spinetoram	Miscellaneous	Radiant®	100ml/ac	Dow Agrosciences
T5	Spirotetramate	Miscellaneous	Movento®	80ml/ac	Bayer crop science
T6	Nitenpyram	Miscellaneous	Maximal®	120gm/ac	FMC
T7	Control	----	untreated	----	----

Note: Commercially recommended insecticide dozes were used in experiment.

RESULTS

There was no significant difference in the *T. tabaci* population for both years (2017 and 2018) before the application of any chemicals. All treatments provided a significant reduction in *T. tabaci* for both years compared to control 9 DAT except Talstar® 24h post-treatment (df = 6, F = 0.87, P = 0.5102) at the first application in the year 2018. However, Radiant® through 6 DAT (df = 6, F = 8.29, P ≤0.05) at first application and at 9 DAT (df = 6, F = 4.04, P = 0.0028) showed most significant difference among all the treatments at first application in 2018. More reduction in *T. tabaci* was observed with Radiant®, Talstar®, and Movento® at the first and second applications as compared to other treatments through 9 DAT during both years 2017 and 2018. The lowest population of *T. tabaci* post-treatment was found in Radiant® treated plots, followed by Movento® and Talstar® treated plots (Table II).

All treatments provided a significant reduction in the population of *A. bigutulla* post-treatment application of different insecticides, 9 DAT for both the years (2017 and 2018). However, Radiant® and Talstar® showed a maximum mortality of *A. biguttula*. The same trend was recorded for the proceeding year 2018 (Table III).

The preliminary analysis showed similar trend of predator's densities during 2017 and 2018, therefore data of both years were pooled. Most of the chemicals showed adverse effects toward *C. carnea* and Lycosids, more drastically than the Radiant® followed by Talstar®. Overall, there was a significant difference between densities of *C. carnea* (F = 6.09, P ≤0.05, df = 6), Lycosids (F = 6.45, P ≤0.05, df = 6) between treated and untreated plots. However, the post-hoc tests revealed that the fluctuation of the predator's densities was due to varying effects of chemical insecticides (Figs. 1 and 2).

The results regarding correlation between abiotic factors, predators (*C. carnea* and *Lycosidae* spp.), and insect pests (*A. biguttula* and *T. tabaci*) in the Bt cotton field plots are positively correlated and in a few cases, it was negative i.e. *A. bigutulla* with *C. carnea* and *T. tabaci* with Lycosids. This negative correlation between pests and predators is a good sign for biocontrol agents (Table IV).

DISCUSSION

A wide range of systemic pesticides are being utilized by cotton producers against sucking insect pests, but they are less useful, most probably because of field evolved resistance in these pests against most widely used synthetic conventional insecticides (Luttrell *et al*., 2015).

Table II. Effect of synthetic commercial insecticides on number (Mean±SEM) of *T. tabaci* per leaf on cotton field crop plants during 2017 and 2018. The data recorded pre-24 h, post-24 h and 3, 6, 9 days after treatment (DAT).

Treatments	Pre-24h		24h		3 DAT		6 DAT		9 DAT	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
First Application (July 10, 2017 and July 20, 2018)										
Control	3.63±0.15a	2.56 ± 0.25^{a}	7.04 ± 1.42^{a}	4.18 ± 0.68^{a}	4.75 ± 0.36^{a}	2.01 ± 0.27^{a}	3.08 ± 1.02^{a}	2.62 ± 0.1^{a}	4.22 ± 0.88^{a}	3.51 ± 0.32^{a}
Commando plus®	3.10 ± 0.09^{a}	2.92 ± 0.37^{a}	1.95 ± 0.36^{b}	1.22 ± 0.22^{c}	0.75 ± 0.31^{b}	1.03 ± 0.16^{b}	0.88 ± 0.20^{b}	0.92 ± 0.06^{b}	0.81 ± 0.18^{b}	1.00 ± 0.06^{bc}
Oshin®	2.99 ± 0.09^{a}	3.03 ± 0.23^{a}	1.56 ± 0.77^{b}	1.68 ± 0.47^{c}	0.96 ± 0.44^{b}	1.03 ± 0.15^{b}	1.00 ± 0.32^{b}	0.87 ± 0.11^{b}	0.87 ± 0.22^{b}	1.04 ± 0.14^{bc}
Talstar®	3.33 ± 0.10^{a}	3.64 ± 0.18^{a}	1.90 ± 0.57^{b}	2.93 ± 1.00^{b}	1.37 ± 0.52^{b}	1.29 ± 0.11^{b}	0.68 ± 023^{b}	1.00 ± 0.02^{b}	0.81 ± 0.35^{b}	0.96 ± 0.20^{c}
Radiant®	3.17 ± 0.10^{a}	2.99 ± 0.46^{a}	2.43 ± 0.47^{b}	1.31 ± 0.24^{c}	1.06 ± 0.30^{b}	0.58 ± 0.09^{c}	0.80 ± 0.40^{b}	0.36 ± 0.07^{c}	0.62 ± 0.26^{b}	0.67 ± 0.28^{c}
Movento®	3.38 ± 0.12^{a}	2.98 ± 0.36^{a}	1.97 ± 0.50^{b}	1.07 ± 0.39^{c}	0.95 ± 0.26^{b}	0.83 ± 0.23^{b}	0.87 ± 0.58^{b}	1.02 ± 0.05^{b}	1.31 ± 0.36^{b}	0.88 ± 0.21^{c}
Maximal ®	2.90 ± 0.09^{a}	2.84 ± 0.31^{a}	2.15 ± 0.40^{b}	2.06 ± 0.27^{bc}	0.97 ± 0.36^{b}	1.65 ± 0.27^{ab}	0.65 ± 0.30^{b}	1.17 ± 0.04^{b}	1.20 ± 0.26^{b}	1.34 ± 0.14^{b}
Second Application (August 12, 2017 & August 22, 2018)										
Control	3.60 ± 0.45^{a}	2.84 ± 0.31^{b}	3.81 ± 0.29^{a}	3.37 ± 0.34^{a}	2.01 ± 0.24^{a}	3.56 ± 0.38^{a}	3.20 ± 0.35^{a}	2.68 ± 0.43^{a}	3.43 ± 0.30^{a}	3.10 ± 0.20^{a}
Commando plus®	2.94 ± 0.31^{a}	2.82 ± 0.35^{b}	1.87 ± 0.29^{c}	1.47 ± 0.11^{b}	1.03 ± 0.23^{b}	1.12 ± 0.06^{b}	0.87 ± 0.12^{b}	0.96 ± 0.16^{c}	0.55 ± 0.10^{cd}	1.00 ± 0.27^{c}
Oshin®	3.21 ± 0.14^{a}	2.63 ± 0.41^{b}	2.13 ± 0.47^{c}	1.55 ± 0.17^{b}	0.87 ± 0.21^{b}	1.22 ± 0.12^{b}	1.00 ± 0.04^{b}	1.34 ± 0.14^{b}	0.77 ± 0.12^{cd}	1.05 ± 0.45^{b}
Talstar®	3.71 ± 0.29^{a}	2.48 ± 0.48^{b}	2.96 ± 0.42^{ab}	1.39 ± 0.10^{b}	1.02 ± 0.09^{b}	0.93 ± 0.07^{c}	0.83 ± 0.17^{ab}	1.06 ± 0.20^{bc}	0.94 ± 0.14^{c}	0.98 ± 0.27^{b}
Radiant®	3.53 ± 0.13^{a}	3.02 ± 0.46^{b}	2.11 ± 0.43^{c}	1.45 ± 0.12^{b}	0.68 ± 0.18^{bc}	0.92 ± 0.10^{c}	0.61 ± 0.13^{c}	0.77 ± 0.08^{c}	0.32 ± 0.10^{d}	0.42 ± 0.07^{c}
Movento®	3.62 ± 0.30^{a}	4.56 ± 0.29^{a}	0.66 ± 0.49^{d}	1.39 ± 0.07^{b}	1.75 ± 0.26^{a}	1.20 ± 0.08^{b}	1.37 ± 0.27^{ab}	1.19 ± 0.31^{b}	2.06 ± 0.19^{b}	1.33 ± 0.16^{b}
Maximal ®	3.56 ± 0.25^{a}	3.53 ± 0.16^{ab}	3.34 ± 0.36^{a}	1.38 ± 0.13^{b}	0.81 ± 0.23^{b}	1.22 ± 0.07^{b}	1.27 ± 0.28^{ab}	1.51 ± 0.22^{b}	1.43 ± 0.45^{b}	1.08 ± 0.28^{b}

Note: Values in columns having same superscript are non-significant at P≤0.05

Table III. Effect of synthetic commercial insecticides number (Mean±SEM) of *A. bigutulla* per leaf on cotton field crop plants during 2017 and 2018. The data recorded pre-24 h, post-24 h and 3, 6, 9 days after treatment (DAT).

Treatments	Pre-24h		24h		3 DAT		6 DAT		9 DAT	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
First application (July 10, 2017 & July 20, 2018)										
Control	2.95 ± 0.10^{a}	3.56 ± 0.25^{a}	3.01 ± 0.27^{a}	4.18 ± 0.68^{a}	3.10 ± 0.20^{a}	4.01 ± 0.27^{a}	2.56 ± 0.30^{a}	2.22 ± 0.17^{a}	2.74 ± 0.15^{a}	3.21 ± 0.2^{a}
Commando plus®	2.09 ± 0.17^{b}	1.92 ± 0.37^{b}	1.13 ± 0.17^{b}	1.22 ± 0.22^{c}	1.20 ± 0.27^{c}	0.93 ± 0.07^{c}	1.07 ± 0.27^{b}	1.02 ± 0.06^{b}	1.32 ± 0.23^{b}	1.16 ± 0.16^{c}
Oshin®	2.05 ± 0.74^{b}	3.03 ± 0.83^{a}	1.03 ± 0.13^{b}	2.68 ± 0.47^{b}	2.25 ± 0.45^{b}	1.03 ± 0.33^{b}	1.50 ± 0.25^{b}	0.99 ± 0.10^{b}	1.13 ± 0.05^{b}	2.34 ± 0.14^{b}
Talstar®	2.00 ± 0.58^{b}	3.64 ± 0.44^{a}	1.29 ± 0.11^{b}	0.93 ± 0.50^{d}	0.72 ± 0.27^{d}	0.29 ± 0.11^{d}	0.27 ± 0.06^{c}	0.42 ± 0.06^{c}	0.34 ± 0.14^{c}	0.56 ± 0.20^{d}
Radiant®	2.35 ± 0.35^{b}	4.02 ± 1.46^{a}	1.18 ± 0.09^{b}	1.31 ± 0.24^{c}	0.20 ± 0.03^{e}	0.28 ± 0.12^{d}	0.00 ± 0.00^{d}	0.22 ± 0.02^{d}	0.12 ± 0.01^{d}	0.00 ± 0.00^{e}
Movento®	2.14 ± 0.42^{b}	2.98 ± 0.96^{a}	0.43 ± 0.13^{c}	0.97 ± 0.29^{d}	0.33 ± 0.16^{e}	0.43 ± 0.23^{d}	1.09 ± 0.25^{b}	0.56 ± 0.08^{c}	1.00 ± 0.16^{b}	1.19 ± 0.31^{c}
Maximal ®	2.11 ± 0.27^{b}	2.84 ± 0.71^{a}	1.10 ± 0.06^{b}	2.06 ± 0.77^{b}	2.01 ± 0.27^{b}	1.65 ± 0.27^{b}	1.12 ± 0.47^{b}	1.27 ± 0.26^{b}	1.13 ± 0.35^{b}	1.32 ± 0.22^{c}
Second application (August 12, 2017 and August 22, 2018)										
Control	3.04 ± 0.28^{a}	3.78 ± 0.27^{a}	2.56 ± 0.15^{a}	3.37 ± 0.34^{a}	2.84 ± 0.29^{a}	3.56 ± 0.38^{a}	2.94 ± 0.37^{a}	2.68 ± 0.43^{a}	3.03 ± 0.25^{a}	3.10 ± 0.20^{a}
Commando plus®	2.33 ± 0.33^{a}	1.29 ± 0.24^{b}	1.13 ± 0.07^{c}	1.47 ± 0.11^{b}	1.37 ± 0.15^{b}	1.12 ± 0.06^{b}	1.46 ± 0.23^{b}	1.46 ± 0.16^{b}	1.81 ± 0.29^{b}	2 ± 0.27^{b}
Oshin®	1.83 ± 0.15^{b}	3.14 ± 0.54^{a}	1.05 ± 0.03^{c}	1.55 ± 0.17^{b}	1.50 ± 0.25^{b}	1.22 ± 0.12^{b}	1.13 ± 0.05^{b}	1.34 ± 0.14^{b}	1.95 ± 0.19^{b}	2.25 ± 0.45^{b}
Talstar®	0.99 ± 0.12^{c}	1.00 ± 0.42^{b}	1.12 ± 0.11^{c}	0.81 ± 0.10^{c}	0.27 ± 0.06^{c}	1.03 ± 0.07^{b}	0.54 ± 0.14^{c}	0.54 ± 0.20^{c}	0.43 ± 0.19^{c}	0.72 ± 0.27^{c}
Radiant®	0.32 ± 0.03^{d}	0.50 ± 0.04^{c}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}	0.03 ± 0.01^{d}	0.00 ± 0.00^{d}	0.12 ± 0.10^{d}	0.00 ± 0.00^{d}	0.36 ± 0.12^{c}	0.05 ± 0.03^{d}
Movento®	1.67 ± 0.16^{b}	1.19 ± 0.42^{b}	0.62 ± 0.22^{d}	0.39 ± 0.07^{d}	0.89 ± 0.25^{c}	0.41 ± 0.08^{c}	0.90 ± 0.16^{c}	0.29 ± 0.11^{c}	0.36 ± 0.08^{c}	0.33 ± 0.10^{c}
Maximal ®	2.10 ± 0.85^{a}	1.63 ± 0.12^{b}	2.01 ± 0.27^{b}	1.38 ± 0.13^{b}	2.56 ± 0.30^{a}	1.12 ± 0.07^{b}	1.74 ± 0.15^{b}	1.51 ± 0.22^{b}	1.81 ± 0.28^{b}	2.08 ± 0.28^{b}

Note: Values in columns having same superscript are non-significant at $P\geq0.05$.

Table IV. Correlation matrix of insect pests, natural enemies and abiotic factors during cropping season of year 2017.

	Temperature	*C. carnea*	RH°	*A. bigutulla*	Lycosids
C. carnea	-0.0723				
P =	0.8327				
RH°	-0.8179	0.3045			
P =	0.0021	0.3625			
A. bigutulla	-0.3857	-0.0877	0.2335		
P =	0.2414	0.7976	0.4896		
Lycosid	0.0316	-0.0307	0.0045	0.0803	
P =	0.9265	0.9286	0.9895	0.8144	
T. tabaci	-0.3259	0.3997	0.5487	0.0647	-0.5706
P =	0.3281	0.2233	0.0805	0.8501	0.0668

Moreover, environmental contamination and non-target effects on beneficial fauna, including insect predators (ants, coccinellid beetles and green lacewings) and parasitoids (wasps), are other contemporary issues of these irrationally used broad-spectrum insecticides (Simon-Delso *et al*., 2015). Therefore, there is a need to evaluate and screen out more target-specific pesticide formulations against sucking insect pests which would be relatively safer for insect natural enemies. It is likewise important to lessen the utilization of synthetic chemicals and to improve the utilization of natural control because new chemical insecticides are unsafe for bio-control agents (Raees *et al*., 2017). Recently, Haider *et al*. (2017) proposed that biological control is eco-friendly control of insect pests than the use of synthetic pesticides. Along these lines, there is a need to lessen the utilization of synthetic concoctions to keep the environment safe and to save the number of inhabitant's natural enemies (Huang *et al*., 2018). The current study was directed to assess the efficacy of some new chemical insecticides (Radiant®, Movento® and Maximal®) and conventional insecticide formulations (Talstar®, Commando Plus® and Oshin®) against the above-mentioned sucking insect pest and their natural enemies under field conditions.

Current results showed that all used insecticides provided a significant reduction in thrips and jassids population as compared to untreated control plants indicating that they all were very useful in reducing sucking insect pests' populations. However, the exception

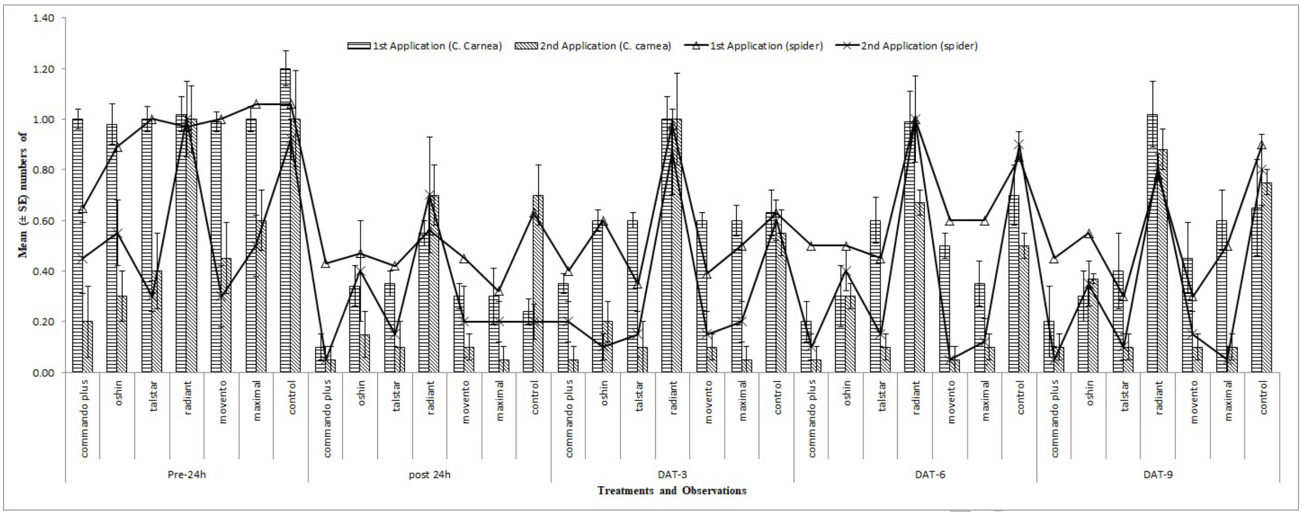

Fig. 1. Effect of different insecticides numbers Mean (±SE) of *C. carnea* and predatory spider per plant in *Bt* cotton field on July 10, 2017 and August 12, 2017 observed at 24h, 3 DAT, 6 DAT and 9 DAT (day after treatment) at (P ≤ 0.05).

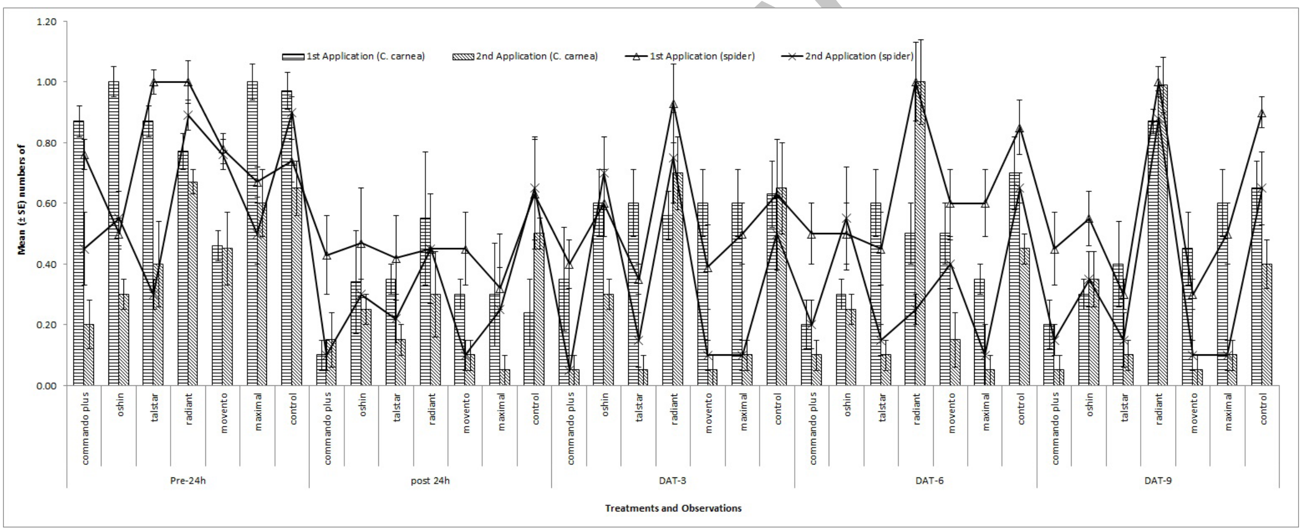

Fig. 2. Effect of different insecticides numbers Mean (±SE) of *C. carnea* and predatory spider per plant in *Bt* cotton field on July 20, 2018 and August 22, 2018, observed at 24h, 3 DAT, 6 DAT and 9 DAT (day after treatment) at (P ≤ 0.05).

of reduced effectiveness of the treatments was observed and Radiant® showed the most significant differences among all the treatments through 6 DAT and 9 DAT at first application in 2018. All treatments significantly reduced *T. tabaci* for both years compared to control through 9 DAT except Talstar®, 24h post-treatment, which might be due to the environmental factor and due to the growth stage at which treatment was applied. Radiant® showed the most significant differences among all the treatments through 6 DAT and at 9 DAT at first application in 2018. More reduction was observed in *T. tabaci* with Radiant®, Talstar®, and Movento® at the first and second applications as compared to others through 9 DAT during both years 2017-2018. Talstar® and radiant showed no significant difference among the population of insects after the application of insecticides. The same results were stated by Nault *et al*. (2012) in the field plots where spinetoram shows low thrips larval population compared to the plots treated with spirotetramat.

In the experimental results of 2018, the maximum mortality was recorded in plots treated with Radiant® after 24h (0.91, 1.31) to 9 DAT (0.81, 2.00) respectively. Dripps *et al*. (2008) and Sparks *et al*. (2008) described that spinetoram is a semi-synthetic active ingredient demonstrating the spinosyn chemical class of insecticides. This molecule has demonstrated higher levels of efficacy compared to that of spinosad against lepidopterous pests, thrips, and leaf miners in a broad range of horticultural and crops. Waters and Walsh (2010) found that spinetoram was effective against onion thrips; however, only spirotetramat provided adequate control of thrips. Subramanian *et al*. (2010) evaluated the efficacy of chemical insecticides and botanicals against thrips and reported that all tested synthetic insecticides and botanicals were effective. All treatments provided significant mortality in the *A. bigutulla* population post-treatment of different insecticides through 9 DAT for the both years (2017 and 2018). However, Radiant® and Talstar® showed a maximum mortality of *A. biguttula*. These results are similar to those who reported that acephate was efficient control against jassid (Stefanov and Dimetrov, 1986). These results also support the discoveries that acephate was found the most effective against sucking pests (Wahla *et al*., 1997).

Chemical control is one of the quick strategies and takes a vital role in IPM strategy to decrease the pest of cotton crop (Gogi *et al*., 2006). In the present study, we noticed better results of these pesticides against all insects. It was observed that transgenic cultivars were attacked by the sucking complex particularly jassids which were observed on the cotton crop (Zia *et al*., 2013). Regarding the effect of insecticides on non-target insect species, most of the insecticide formulations tested caused more than 50% reduction of all beneficial insect fauna. However Radiant was more friendly towards all biocontrol agents under the current study. This is not in agreement with the results of a recent study done by Sarwar (2014) which reported no significant effect of endosulfan 35% EC and monocrotophos 36% SL on cotton insect pests and natural enemies complex. Many new insect growth regulators such as pyriproxyfen and buprofezin have been demonstrated as very target specific and with least residual effects on non-target species of insect predators and regulators (Naranjo *et al*., 2004; Messelink *et al*., 2014).

Results with regard to the correlation of natural enemies and abiotic factors demonstrated that there was a correlation among all insects including natural enemies of insect pests with abiotic factors. The above conclusions regarding green lacewing and predatory spiders were in conformity with those of Boda and Ilyas (2017). Mahmood *et al*. (1990) showed that low temperature was associated with the pest population. Moreover, humidity, temperature, and rainwater effect the thrips and leafhopper population. Thrips are less incredible and adversely associated with an increase in the temperature. Thrips decrease their activities in hot condition since temperature variance impacts the thrips population.

CONCLUSIONS

For keeping the populations of *T. tabaci* and *A. bigutulla* under check, the repeated use of insecticides during the vegetative stage of cotton is of much importance. However, to safeguard the environment and farmer's friendly arthropods, the use of safe chemicals is needed. The findings for tested chemicals showed that bio-based insecticides i.e. spinetoram (Radiant®) and nitenpyram (Maximal®) showed less impact on natural enemies in addition to suppression of *T. tabaci* and *A. bigutulla*. These milder new insecticides may be more suitable for integrated pest management programs and for habitats where conventional insecticides are not allowed or appropriate such as organic farming and urban peri-urban areas. The evidence of pests' resistance to some commonly used broad-spectrum insecticides including neonicotinoid and acephate also indicate the need for reduced use of strong chemical insecticides and their integration with other milder chemicals.

Statement of conflict of interest
The authors have declared no conflict of interest.

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