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Cost Benefit Analysis of Integration of Biocontrol Agents with Insecticides and Plant Extracts for the Management of *Thrips tabaci* Lin. in Bt Cotton Ecosystem

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SA, MWS and MSN designed the field experiments. MWS conducted the field experiments. MWS, SA, AA and AR conducted the data analysis. SA, RRK, AA and AR wrote the main manuscript text.

Key words
Thrips, Predators, Cotton, Ecosystem, Botanicals, Insecticides.

ABSTRACT

In order to find out the integration of biocontrol agents with plant chemical and insecticide against *Thrips tabaci* L. (Thripidae: Thysanoptera), release of *Coccinella septempunctata* and *Chrysoperla carnea*, spray of Neem Seed Kernel Extract (NSKE) 5% and spinosad 240 SL (Tracer) were integrated in all possible combinations, thus, making a total of 15 treatments including separate application of each above and a control where none was applied except water only. Results showed significant difference amongst treatments (p <0.05). Application of spinosad alone and in combination with other control methods proved to be the most effective treatment. Releases of bio-agents *viz*., *C. septempunctata* and *C. carnea* resulted in 4.72 and 4.51 thrips leaf^{-1}, respectively, and also did not differ significantly with each other. Application of bio-agents in combination was less effective with 4.37 thrips leaf^{-1} and differed significantly from all other treatments. Application of NKSE resulted in 4.00 thrips leaf^{-1} and found superior from those treatments where bio-agents were released alone and in combination. However, the highest yield was observed where all the control methods were integrated together showing 30.976 kg plot^{-1} seed cotton and it did not differ significantly in treatments where spinosad was present. The lowest seed cotton yield was recorded to be 23.393, 23.984 and 24.104 kg plot^{-1} in those plots (T_1, T_2 and T_5) where only bio-agents were released and these three treatments did not show significant difference among them. On the basis of these interventions, the maximum cost benefit ratio was calculated to be 1: 15.19 in those plots of FH-118 where spinosad alone was sprayed. The minimum cost benefit ratio was recorded in T_5, *i.e.* 1: 1.02 where both the biological agents were released together. Results have been discussed in the light of these cost benefit ratios, and concluded that deliberate use of predators may be expensive for the management of thrips on Bt cotton.

INTRODUCTION

Traditional (organophosphates and carbamates) and new chemistry insecticides (mostly neonicotinoides) are usually recommended for control of thrips (Aslam *et al*., 2004; Asi *et al*., 2008; Sadozai *et al*., 2009). Indiscriminate and injudicious use of insecticides has been complicated in the development of resistance in insects (Mallah, 2007; Desneux *et al*., 2007). The cotton researchers have tried biorational insecticides to reduce insect populations but with variable success. The use of plant chemicals and predators are options that have been considered in many studies. Lacewings (*Chrysoperla carnea* (Neuroptera: Chrysopidae) are being used in insect management programs in Pakistan (Zia *et al*., 2008; Solangi *et al*., 2011).

The integration of lacewings with insecticides and/or plant chemicals has been reported to be promising for the management of many insect pests of the crops (Hasan *et al*., 2007; Hussain *et al*., 2010). Coccinellids especially seven spotted ladybird beetle *Coccinella septempunctata* (Coleoptera: Coccinellidae) were not only used to control but also reported important factor in population of thrips (Deligeorgidis *et al*., 2005; Li *et al*., 2007). *Trichogramma* species is another agent used in integration with chemicals against cotton insect pests (Thangavel *et al*., 2012). Addition of biocontrol agents mainly predators in integrated pest management program has proved economical not in terms of net return but also was cost effective (Ranga Rao *et al*., 2007; Godhani *et al*., 2010).

Few studies have reported no significant differences in thrips abundance on conventional and Bt cotton varieties (Li *et al*., 2007; Kumar *et al*., 2014). However, the introduction of Bt cotton in various types of ecosystem

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has brought a change in pest pressure and insecticide application regime, the release of mass reared insects/ predators may prove expensive in integration program on basis of rearing cost and net profit gain though bio-intensive management combined with Bt cotton (Rasi 2 Bt) has proved promising and ideal for high net profit (Patel *et al*., 2010). In order to test this hypothesis, the present study was conducted to integrate natural enemies with chemicals on a selected resistant Bt cotton genotype (FH-118).

MATERIALS AND METHODS

Study area and experimental design

The study on bio-intensive management of thrips was conducted on a previously selected resistant genotype of Bt cotton cv FH-118 under field conditions during year 2014 at a farmer's field at Chak No. 60/RB, Shahbazpur, Faisalabad (214 m altitude; 31° 25´N, 73° 06´E). FH-118 was obtained, and sown on May, 2014 following agronomic practices recommended by Directorate of Cotton Research Institute from Ayub Agriculture Research Institute (AARI), Faisalabad. Net plot size was 70 m^2 where row to row and plant to plant distances were 0.76 m and 1 m, respectively.

Various treatments including biological agents (2nd instar larvae of *C. septempunctata* and *C. carnea* were released per plant), spray of neem seed kernel extract (NSKE, Neemasol 510 SC) and spinosad 240 SL (Tracer), respectively, @ 1.5 L ha^{-1} and 125 ml ha^{-1} were arranged in randomized complete block design (RCBD), replicated thrice. Biocontrol agents mentioned above were released at weekly intervals for six times starting from 21st June to 26th October, 2014. NSKE and spinosad were sprayed three times at fifteen days interval. Spray was done with the help of Matabi hand operated sprayer fitted with control flow valve (CFV) and an imported hollow cone nozzle with a discharge rate of 0.80 L min^{-1} at 2.4 bar pressure keeping in view leaf area index (LAI) of cotton. Spray was done during day time with temperature averaging 30-35°C at 5.7 km/hr^{-1} North West wind.

All the above treatments were applied on target pest at economic threshold level (Govt. Punjab, PWQCP, Lahore, Pakistan). The treatments were applied singly and in all their possible combinations. Data on the population of thrips from upper, middle and bottom leaves of 20 cotton plants were recorded at seven days interval from 15th June to 2nd week of August, 2014.

Yield and cost benefit ratio

Seed cotton yields for all treatment plots were also recorded on the basis of first and second pickings as per agronomic standards. Cost benefit ratio was calculated in comparison with values in control treatment; using the formula:

Cost benefit ratio = Total income or benefits / Total costs

Statistical analysis

Test of significance on the data regarding thrips population statistically analyzed by Duncan's Multiple Range Test at p=0.05. Means of treatments were separated by Least Significant Difference (LSD).

RESULTS

Analysis of variance data regarding population of thrips in different treatments and interaction between treatments and leaf positions revealed significant difference (Table I). Means comparison showed that application of spinosad resulted in significant control of the thrips showing 1.75 thrips $leaf^{-1}$ and did not differ significantly from T_7, T_9, T_{10}, T_{11}, T_{13} and T_{14} with 1.78, 1.78, 1.81, 1.69, 1.74 and 1.71 thrips population $leaf^{-1}$, respectively (Table I). These results apparently conclude that application of spinosad alone and in combination with other control methods proved to be the most effective treatments. Release of bio-agents *viz. C. septempunctata* and *C. carnea* resulted in 4.72 and 4.58 thrips $leaf^{-1}$, respectively, which did not differ significantly with each other. *C. septempunctata* and *C. carnea* in combination was less effective with 4.37 thrips $leaf^{-1}$ and differed significantly from all the other treatments. NKSE resulted in 4.00 thrips $leaf^{-1}$ and found superior from the treatments where bio-agents were released alone and in combination. Both treatments T_6 and T_{12} did not show significant difference with each other having 3.27 and 3.39 thrips $leaf^{-1}$, respectively. Furthermore, the effectiveness of treatments in descending orders was as follows; $T_{11} > T_{14} > T_{13} > T_4 > T_7 = T_9 > T_{10} > T_6 = T_{12} > T_8 > T_3 > T_5 > T_1 = T_2 > T_{15}$.

The interaction response between leaf position and treatments relating the population of thrips $leaf^{-1}$ revealed the significant variations. It is evident from the results that highest control of thrips was recorded in those treatments where spinosad alone and in combination with other control methods was applied at all the leaf positions whereas lowest control was observed in the release of *C. septempunctata* and *C. carnea* when applied separately as well as together. Spray of NSKE was found intermediate between insecticide and biocontrol agents regime in controlling thrips population when applied singly and in combination with bio-agents. The trend was, however, found to be the similar on upper, middle and bottom leaves in effectiveness of treatments.

Table I.- Mean thrips population density per upper, middle and bottom leaves in various treatments of cotton field trials during 2014 in Faisalabad.

S.N.	Treatments	Mean thrips population density			Means (LSD=0.159, SE=0.057)
		Upper leaves	Middle leaves	Bottom leaves	
T_1	*C. septempunctata*	8.57 b	4.17 h	1.42 m	4.72 b
T_2	*C. carnea*	8.18 c	4.08 h	1.48 m	4.58 b
T_3	NSKE	7.20 e	3.42 i	1.39 m	4.00 d
T_4	Spinosad	3.35 ij	1.59 lm	0.32 o	1.75 g
T_5	$T_1 + T_2$	7.82 d	3.97 h	1.33 m	4.37 c
T_6	$T_1 + T_3$	5.80 g	3.03 k	0.98 n	3.27 f
T_7	$T_1 + T_4$	3.38 i	1.57 lm	0.76 o	1.78 g
T_8	$T_2 + T_3$	6.97 e	3.45 i	0.93 n	3.78 e
T_9	$T_2 + T_4$	3.42 i	1.50 m	0.42 o	1.78 g
T_{10}	$T_3 + T_4$	3.37 i	1.66 lm	0.40 o	1.81 g
T_{11}	$T_1 + T_2 + T_4$	3.28 ijk	1.49 m	0.32 o	1.69 g
T_{12}	$T_1 + T_2 + T_3$	6.21 f	3.06 jk	0.92 n	3.39 f
T_{13}	T1 + T3 + T4	3.53 i	1.49 m	0.19 o	1.74 g
T_{14}	$T_1 + T_2 + T_3 + T_4$	3.31 ijk	1.64 lm	0.18 o	1.71 g
T_{15}	Control	11.30 a	6.14 f	1.84 l	6.42 a
Means (LSD=0.071, SE=±0.025)		5.71 a	2.82 b	0.83 c	

Means in column for leaf position sharing common letters are not different at $p < 0.05$ (LSD test). NSKE, Neem Seed Kernel Extract commercially available as Neemasol 5%. Spinosad 240 SL marketed with title as Tracer in Pakistan.

Table II.- Cost benefit ratio analysis of biocontrol agents (*C. septempunctata* and *C. carnea*), plant extract (Neem Seed Kernel Extract, NSKE) and insecticide (Spinosad-Tracer) alone and in combination with each other in cotton field trials during 2014 in Faisalabad.

S.N.	Treatments	Seed cotton yield		Increase in seed cotton yield (Kg ha^{-1})	Cost benefit ratio
		Kg $plot^{-1}$	Kg ha^{-1}		
T_1	*C. septempunctata* (T_1)	23.393 e	3357.363	137.779	1:1.16
T_2	*C. carnea* (T_2)	23.984 e	3442.183	222.599	1:1.18
T_3	NSKE (T_3)	26.183 d	3757.784	538.200	1:4.61
T_4	Spinosad (T_4)	29.270 abc	4200.830	981.460	1:15.19
T_5	$T_1 + T_2$	24.104 e	3459.406	239.822	1:1.02
T_6	$T_1 + T_3$	27.602 cd	3961.439	742.055	1:3.16
T_7	$T_1 + T_4$	29.319 abc	4207.862	988.278	1:5.40
T_8	$T_2 + T_3$	26.409 d	3790.219	570.635	1:2.42
T_9	$T_2 + T_4$	29.173 b	4186.908	967.054	1:5.29
T_{10}	$T_3 + T_4$	28.369 c	4071.518	851.934	1:4.70
T_{11}	$T_1 + T_2 + T_4$	30.209 a	4335.596	1116.012	1:3.70
T_{12}	$T_1 + T_2 + T_3$	26.436 d	3794.094	574.510	1:1.62
T_{13}	$T_1 + T_3 + T_4$	28.913 bc	4149.593	930.009	1:3.10
T_{14}	$T_1 + T_2 + T_3 + T_4$	30.974 a	4445.388	1225.804	1:2.93
T_{15}	Control	22.433 e	3219.584	-	-
LSD ± SE			1.600 ±0.552		

Means in columns sharing common letters are not different at $p < 0.05$ (LSD test). NSKE, Neem Seed Kernel Extract commercially available as Neemasol 5%. Spinosad 240 SL marketed with title as Tracer in Pakistan.

Seed cotton yield revealed significant difference ($p \leq 0.01$) among treatments (Table II). Highest yield was observed in T_{14} where all the control methods were integrated together showing 30.974 Kg plot^{-1} seed cotton yield and did not differ significantly with those of recorded in T_{11}, T_7 and T_4 having, respectively 30.209, 29.319 and 29.270 Kg plot^{-1} seed cotton yield. Lowest seed cotton yield was recorded to be 23.393, 23.984 and 24.104 Kg plot^{-1} in those plots where T_1, T_2 and T_5 were applied and did not show significant difference among themselves. Seed cotton yield in T_8 (26.409) did not differ significantly from T_{12} (26.436), T_6 (27.602) and T_3 (26.183 Kg plot^{-1}). A non-significant difference also existed between T_9 and T_{13} showing 29.173 and 28.913 Kg plot^{-1}, respectively. T_{10} (28.369 Kg plot^{-1}) did not differ significantly from T_{13}, T_7, T_6 and T_4. Furthermore, results regarding increase in seed cotton yield in different treatments over control revealed that the highest increase in seed cotton yield (1225.804 Kg ha^{-1}) was observed in T_{14} whereas lowest in T_1 (137.779 Kg ha^{-1}).

A maximum cost-benefit ratio was calculated to be 1: 15.19 in those plots where spinosad was sprayed alone minimum (1:1.02) ratio was recorded where both the biological agents were released together (Table II).

DISCUSSION

Results of present studies revealed significant differences among treatments and in comparison to control regarding thrips population leaf^{-1} as well as in seed cotton yield Kg plot^{-1}. Spray of spinosad singly and integrated with biocontrol agents resulted in maximum reduction of the pest and proved to be the most effective. The present findings cannot be compared with those of Kannan *et al.* (2004) where they used imidacloprid @ 5 g Kg^{-1} of seed as seed treatment and reported that this application kept the population below ETL up to 40 days after sowing. In the present study, the application of biological agents singly showed minimum reduction in number of the pest. The application of neem seed kernel extract (NSKE) was found intermediate in registering the pest reduction. Present findings are in partial conformity with those of Fiaz *et al.* (2012) who reported the efficacy of bakain (*Melia azadirachta*) leaf extract, neem oil and neem leaf extract, for the significant control of thrips population. In the present investigation, the bio-agents and neem seed kernal extract when integrated with spinosad resulted in encouraging trend towards pest mortality. On an average basis, the maximum reduction of the pest was 73.67% in those plots where the biological agents were integrated with the spinosad and was at par with those where spinosad was the addition. Integration of all the control methods yielded maximum output i.e. 30.974 Kg plot^{-1} and did not differ significantly with those of where biological agents were integrated with spinosad *i.e.* 30.209 Kg plot^{-1}. Furthermore, maximum increase in seed cotton yield was recorded to be 1225.804 Kg ha^{-1} in those plots where all the control methods were integrated together. The minimum increase in yield was recorded to be 137.779 Kg ha^{-1} in those plots where *C. septempunctata* was applied. The maximum cost benefit ratio was recorded in those plots where spinosad alone was sprayed resulting in 1:15.19 CBR and found to be the best treatment. The present findings cannot be compared with those of Shanmugam *et al.* (2006) who reported that biointensive IPM could reduce insecticide usage but they did not evaluate cost of biocontrol agents. Present results are partially supported with findings of Hasan *et al.* (2007) who reported that integration of bio-control agents such as *C. carnea* and *T. chilonis* (Hymenoptera; Trichogrammatidae) individually as well as jointly with insecticides proved as effective as chemical control using recommended insecticides against sucking insect pest. They further reported that integrated control proved economical but in the present study, application of biocontrol agents did not show encouraging results in both the pest reduction and increase in seed cotton yield. Application of spinosad singly and integrated with other control methods showed good results since spray of spinosad alone showed maximum cost benefit ratio. Increase in expenditures affected CBR and resulted in minimum CBR in other treatments. Biradar and Vennila (2008) highlighted the importance of conservation of biological agents for the control of aphid, jassid, thrips and whiteflies in Bt-cotton and reported that the diverse groups of predators have greater potential to offer natural control against emergence of sucking insects. Hasan *et al.* (2007) reported effective integration of bio-control agents like *C. carnea* and *T. chilonis* individually as well jointly with insecticides. Present findings can partially be compared with those of Hanumantharaya *et al.* (2008) who integrated intercropping lucerne + two sprays of NSKE on cotton + release of *C. carnea* at the rate of 0.075 and 0.1 million ha^{-1} and found the significant reduction of sucking pests and increased seed cotton yield from 5.2 q ha^{-1} in untreated check to 9.0 q ha^{-1} in treated plots. Furthermore, Udikeri *et al.* (2008) and Kumar *et al.* (2011) cannot be also compared with the present results because they compared integrated pest management modules with recommended package of practices on Bt-cotton.

CONCLUSION

Though earlier studies have revealed high profit in fields where predators and parasitoids were released in integration with plant chemicals and synthetic insecticides (Rahman *et al*., 2003; Ranga Rao *et al*., 2007; Godhani *et al*., 2010; Patel *et al*., 2010), yet our results have shown that dependence on natural enemies alone or in combination was expensive. Further studies are required to evaluate cheap option for rearing and release of predators/parasitoids in cotton fields.

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Statement of conflict of interest

There is no conflict of interests regarding the publication of this article.

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