Research Article

Management of Garlic Thrips, *Thrips tabaci* Linderman. (Thysanoptera: Thripidae) through Different Pest Management Techniques in Garlic Crop

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Abstract | Field efficacy of different management techniques were studied against thrips (*Thrips tabaci*) nymph and adult populations in garlic crop during the year 2017-18. The experiment was laid out in Randomized Complete Block Design having two factors with three replications and six treatments. Treatments Emamectin 1.9 EC @ 750 ml ha^{-1}, orange (*Citrus aurantium* L.) peel extract @ 5%, neem (*Azadirachta indica*) seed extract @ 5%, neem oil @ 3%, green lacewing, *Chrysoperla carnea* @ 3 eggs plant^{-1}, were applied three times. A total of 30 plants in each treatment were selected randomly for the data collection at 1, 2, 3, 6, 9 and 12 days intervals. Peak population of thrips (51.27 plant^{-1}) was noticed during the last week of April. Results regarding different treatments showed that Emamectin was effective exhibiting minimum mean number of *T. tabaci* (nymphs 1.74 plant^{-1} and adults 1.31 plant^{-1}) as compared to the rest of treatments. This was followed by orange peel extract and neem seed extract treated plots where 3.35 and 3.26 nymphs plant^{-1} and 2.60 and 2.69 adults plant^{-1} respectively were recorded. The data further showed that the plots treated with neem oil and *C. carnea* recorded mean number of 3.18 and 6.41 nymphs plant^{-1} and 2.52 and 5.68 adults plant^{-1}, respectively. Emamectin treated plots also showed promising results in terms of plant height and number of leaves by recording maximum plant height (84.2 cm) and maximum number of leaves (8.76 plant^{-1}). Neem seed extract and neem oil treated plots showed average plant height of 70.4 and 69.3 cm with average number of leaves of 8.24 and 8.18 plant^{-1}, respectively. Plots treated with Emamectin also resulted in maximum yield *i.e.* 19.3 tons ha^{-1}, while only 11.4 tons ha^{-1} was obtained from the control plots. It is obvious from the above results that the use of Emamectin along with botanical extracts are effective in controlling *T. tabaci* infestation, and hence may be used in garlic crop for managing this serious pest.

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Introduction

Garlic, *Allium sativum* L., is an important vegetable crop and is being used in Pakistan, China, Russia, United States, Egypt and India for more than 5000 years (Singh *et al*., 2014). Garlic is usually grown as vegetable crop and is cultivated on 9016 hectares in Pakistan with annual production of 80 thousand tones. In Khyber Pakhtunkhwa province, it is grown on about 2050 hectares with annual production of 22.50 thousand tones (FAO and Agric. Statistics of Pakistan, 2016). However, the production of garlic has been reduced to 10 to 40% from the previous few years, mostly because of insect pests and diseases incidence (Ahmad and Javed, 2001; Mohibullah, 1991).

Different types of insect pests attack on garlic crop. Among them onion thrips, *Thrips tabaci* Linderman. (Thysanoptera: Thripidae) is considered as major insect pest of garlic. In Pakistan, especially in Khyber Pakhtunkhwa and Balochistan provinces, *T. tabaci* is the most injurious pest of garlic and onion crops due to dry and warm climate conditions (Hussain *et al*., 1997; Hazara *et al*., 1999). Damage is done by both nymph and adult stages by their sucking and rasping type mouthparts (Nault and Huseth, 2016). Thrips are positively thigmotactic, preferring to be in close contact with plant surfaces and confined plant parts such as in tightly closed leaves, curled leaves or petals (Hauxwell, 2008). This behavior makes it difficult to find and control them. The life cycle of *T. tabaci* is between 10 and 30 days depending on the temperature and is faster at higher temperature. Adults have soft and sensitive fringed wings and are highly mobile. A female may lay eggs by inserting into the plant tissue making a small blister often visible along the leaf veins. Oviposition is done in batches of 50 to 200 eggs. Nymphs after hatching feed actively on the upper parts of the plants such as leaves, flowers, and while the adults feed well on the fruits. The pre-pupa and pupal instars are typically found in leaf litter or in soil and are non-feeding and inactive. Apart from direct damage, thrips are also vector of important plant pathogenic viruses, especially Tospo-viruses (Bunyaviridae) such as Capsicum Chlorosis Virus (CaCv), Tomato Spotted Wilt Virus (TSWV) and others. They also hinder the photosynthesis process that results in reduction in bulb size and yield of garlic (Kendall and Capinera, 1987).

Various IPM techniques such as cultural control, bio-control agents, use of resistant varieties, biorational insecticides and various botanical extracts are being used against thrips, but growers mostly prefer pesticides application in garlic crop. However, extensive and recurrent use of synthetic insecticides against thrips has resulted in thrips resistance to these chemical insecticides (Soler *et al*., 2011). This issue of insecticides resistance can be addressed with appropriate rotation of insecticides from other pesticides classes. Many researchers have reported that chemical insecticides like spinosad and abamectin are the most effective insecticides against many pests including *T. tabaci* and are least toxic to natural enemies/ defender of the crop (Trdan *et al*., 2005). Similarly, extracts of various plants are also useful in controlling *T. tabaci* (Dodia *et al*., 2008). Among these, chrysanthemum *(Chrysenthemum cinerariaefoliumy*, neem *(Azadirachta indica)* and tobacco *(Nicotiana tabacum)* have been widely used against various insects species including thrips (Stoll, 2000). Ayalew (2005) tested the neem seed extract powder against *T. tabaci* population and reported the treated insects showed sign of abnormal and retarded growth. In addition to these measures, experts are also trying to use natural enemies of thrips belonging to various families for the control of *T. tabaci*. Larvae of green lacewing, *Chrysoperla carnea* is most useful biocontrol agent which can feed on thrips (Dirimanov and Dimitrov, 1975). Therefore, this study was conducted to observe the population trend of *T. tabaci* in garlic crop and to find out the impact of emamectin, different botanicals extracts and a biocontrol agent, *C. carnea* larvae, on the nymphs and adults of *T. tabaci* and their effect on the yield of garlic crop.

Materials and Methods

Efficacy of a synthetic insecticide along with botanical extracts and biocontrol agent in garlic variety (Swat 1) was tested against *T. tabaci* at Agriculture Research Institute (ARI), Tarnab Farm Peshawar, Khyber Pakhtunkhwa, during the year 2017-18. The total experimental area in this study was 225 m^2 which was divided into 3 blocks; each block was then sub-divided into six plots (each with 5×2.5 m^2) with one-meter buffer zone. The plant to plant and row to row distances were kept about 15 and 30 cm respectively. Same agronomic practices were applied as per crop requirement. There were 6 treatments and each treatment was repeated thrice. Emamectin® 1.9 EC @ 750ml ha^{-1} (T1), orange (*Citrus aurantium* L.) peel extract @ 5% (T2), neem (*A. indica*) seed extract @ 5% (T3) and neem oil @ 3% (T4) were applied using knapsack sprayer, while the bioagent *C. carnea* @ 3 eggs $plant^{-1}$ (T5) was applied manually. At the control (check) plots (T6), only tap water @220 L ha^{-1} was applied. The experimental lay out used in the study was RCBD (Randomized Complete Block Design). The experimental plots were observed on regular basis for *T. tabaci* population from first week of February till the harvesting of crop in these treatments were applied as per above mentioned rates after the pest reached to certain economic threshold level (*i.e.* 15 thrips plant^{-1}). Post treatments applications, *T. tabaci* (nymphs and adults) population data were recorded after 1, 2, 3, 6, 9 and 12 days intervals from randomly ten selected plants in each treatment as well as control plot. Similarly, plant height data (from soil surface to the top of tallest leaf) was measured by randomly selecting ten plants in each plots in each replication with the help of measuring tape and was then converted into mean plant height (cm). These selected plants were also checked for the total number of leaves per plant and the mean number of leaves number was recorded. After harvesting, ten garlic plants were randomly selected from each plot and the bulb size of garlic plant was recorded (in cm) by measuring diameter using Vernier-caliper, and then percent bulb size was worked out. For obtaining yield, the weight of all bulbs in treated and those of non-treated sub-plots in each replication was first determined in kilograms (Kg) and then converted into tons ha^{-1} at the time of crop harvest. After harvesting, average yield data for each treatment were calculated and the percent increase in yield over control plot was measured using formula.

$$\textit{Percent increase in yield} = T\text{-}C/C \times 100$$

Where;
T= Treated plot yield; C= Control plot yield.

Statistical analysis

Raw data collected for various parameters were analyzed using Statistical Software Program (Statistix 8.1). Treatments means and their interactions were compared using Least Significant Difference (LSD) test.

Results and Discussion

Population trend of T. tabaci in garlic crop during the year 2017-18

T. tabaci remained a consistent pest on garlic throughout the cropping season. The data in Figure 1 showed that *T. tabaci* population started to build up in 4th week of January and continued till the last week of May. Its population increased from 1.24 to 4.87 per plant during the month of February 2018. In March 2018, the population of *T. tabaci* increased from 6.95 to 29.63 thrips plant^{-1}. The peak population of 51.27 thrips plant^{-1} was observed in the last week of April. At the end of May 2018, *T. tabaci* population declined to 2.78 thrips plant^{-1} as crop started to mature (Figure 1).

Table 1: *Effect of different treatments against Thrips tabaci (L.) on plant height and number of leaves plant^{-1} in garlic crop at ARI Tarnab, Peshawar during 2017-18.*

Treatment	Plant height (cm)	Number of leaves plant^{-1}
Emamectin 1.9 EC	84.2 a	8.76 a
Orange peel extract	72.1 b	8.24 bc
Neem seed extract	70.4 bc	8.37 c
Neem oil	69.3 c	8.18 b
C. carnea	65.2 d	7.56 d
Control	57.4 e	6.93 e

LSD for plant height= 2.2872; LSD for number of leaves= 0.3871; Means followed by a different letter (s) are significantly different from one another at (P≤0.05), using LSD test.

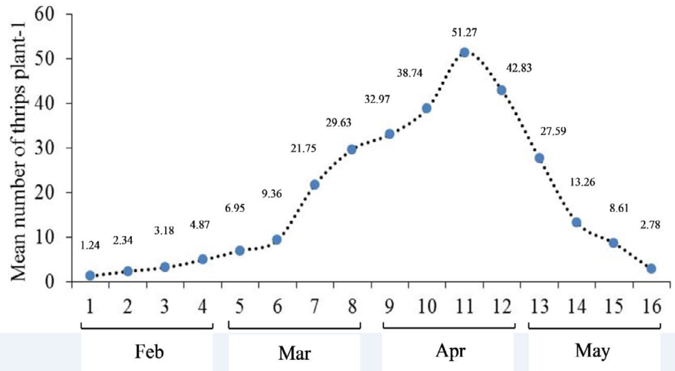

Figure 1: *Population trend of Trips tabaci (L.) in garlic crop during 2017-18 at ARI Tarnab, Peshawar.*

T. tabaci nymph population after 1st application of different treatments on garlic crop

T. tabaci nymph population trend after 1st application of different treatments on garlic crop is shown in Figure 2. Data showed that plots treated with the emamectin had the lowest mean number of nymphs plant^{-1} in all time intervals (3.43), followed by orange peel extract (5.20), neem seed (5.26) and neem oil (5.32). Plots treated with *C. carnea* eggs had 8.08 mean number of nymphs per plant, while highest number of thrips nymph per plant was observed in control (15.84). Data regarding time interval showed that mean number of thrips per plant were on the decreasing trends with increased time of exposure i.e day-1 (6.84), day-2 (6.72), day-3 (6.64) and day-6 (6.55), and were statistically different from each other following application of various treatments except for day-9 and day-12 where mean number of thrips were (7.42 and 8.33) respectively. Interaction of data between treatments and time intervals revealed that minimum number of nymphs per plant was noticed in plots treated with Emamectin (2.12) after day-1. Data recorded for intervals of day-1, day-2, day-3 and day-6 were found statistically similar to each other. At day-12 of application of treatments, it was observed that the highest nymphs population was in control plot (17.34) followed by *C. carnea* (8.58).

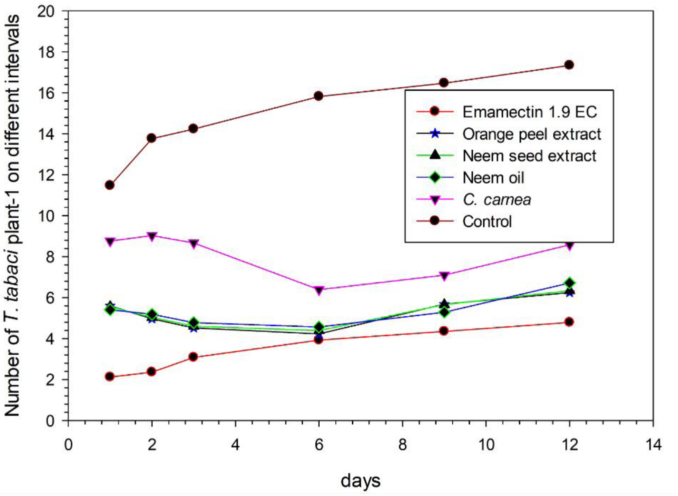

Figure 2: *First spray application of different treatments against Trips tabaci nymphs at different time intervals in garlic crop at ARI Tarnab, Peshawar during 2017-18.*

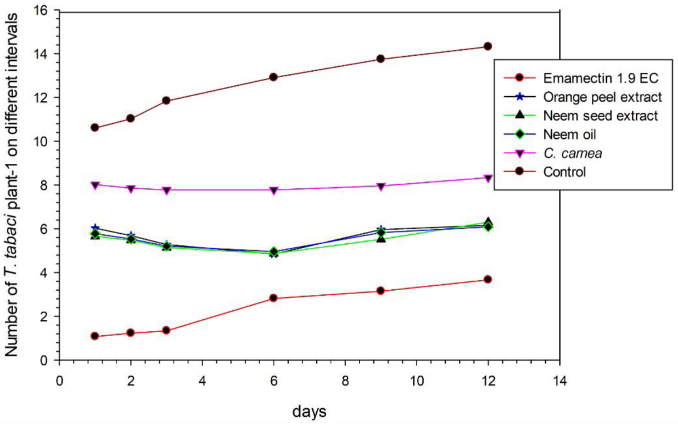

Figure 3: *First spray application of different treatments on Trips tabaci adults at different time intervals in garlic crop at ARI Tarnab, Peshawar during 2017-18.*

First spray application effect of different treatments on T. tabaci adult population in garlic crop

Data presented in Figure 3 regarding application of difference treatment on the number of adult populations showed significant difference between the treatments i.e. $P<0.05$. Data showed that plots treated with Emamectin resulted in minimum number of mean adult population of 2.21 thrips plant^{-1}, this was followed by neem seed, neem oil and orange peel where 5.49, 5.56 and 5.66 mean number of thrips per plant were recorded. Plots treated with *C. carnea* eggs treated plots received a mean number of 7.95 adults plant^{-1}, while 12.41 mean number of thrips per plant was recorded in control. Mean population of adults thrips observed at different time intervals revealed that maximum adult population was seen on day-12 (7.48) and day-9 (7.03) of treatments application, while lowest population of adult thrips was observed on day-3 (6.09) that was statistically similar with data recorded after day-1 (6.19), day-2 (6.13) and day-6 (6.35).

Second spray application effect of different treatments against T. tabaci nymph population in garlic crop

Mean population of nymphs after 2nd spray application of different treatments has been shown in Figure 4. Mean data for treatments showed that Emamectin (4.18) performed better in managing nymph population which was followed by neem seed (7.15), orange peel (7.24) and neem oil (7.32). The plots treated with *C. carnea* had 9.69 mean number of nymphs per plant after 2nd spray application. All the treatments data showed significance difference as compared with the control. Mean data for various time intervals showed statistically significant effect and maximum mean population of (11.17) nymphs plant^{-1} was recorded on day-12 of spray application followed by day-9 (9.66) and day-2 (9.19). While the lowest mean population of nymphs plant^{-1} was observed after day-06 (8.47) followed by day-3 (8.95) and day-1 (9.03). These intervals were found statistically similar to one another.

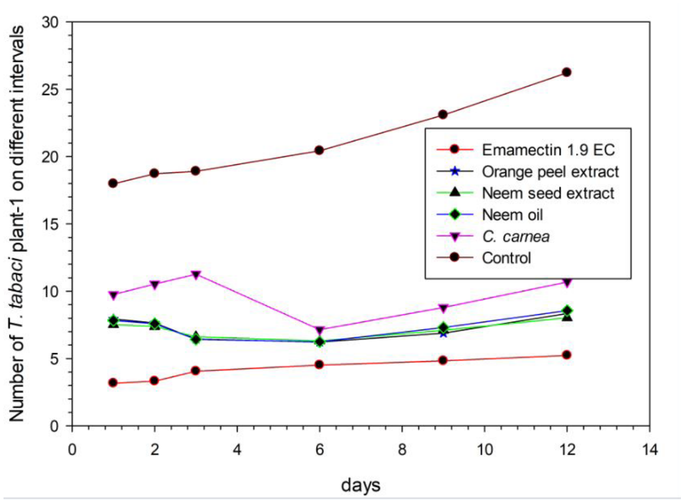

Figure 4: *Second spray application of different treatments on Trips tabaci nymph population at different time intervals in garlic crop at ARI Tarnab, Peshawar during 2017-18.*

Second spray application effect of different treatments on T. tabaci adult population in garlic crop

Figure 5 data showed that time intervals differ significantly from each other. After day-12 of the treatments application, the adult population was maximum (10.64) followed by day-9 (9.53) and day-1 (9.17) while minimum mean data was recorded on day-6 (8.52), day-3 (8.75) and day-2 (9.09). Mean data for treatments showed that different insecticides had a significant effect on adults population of *T. tabaci* (P<0.05). Control plots received significantly increased mean number of adult population (18.48), followed by *C. carnea* (9.88). While the lowest mean number of adults was observed in treatment Emamectin (5.31) followed by orange peel (7.24), neem seed (7.33) and neem oil (7.45). Interaction data showed that maximum adult population was on day-12 in control (21.67) while minimum adult population was recorded in emamectin (4.68) on day-1.

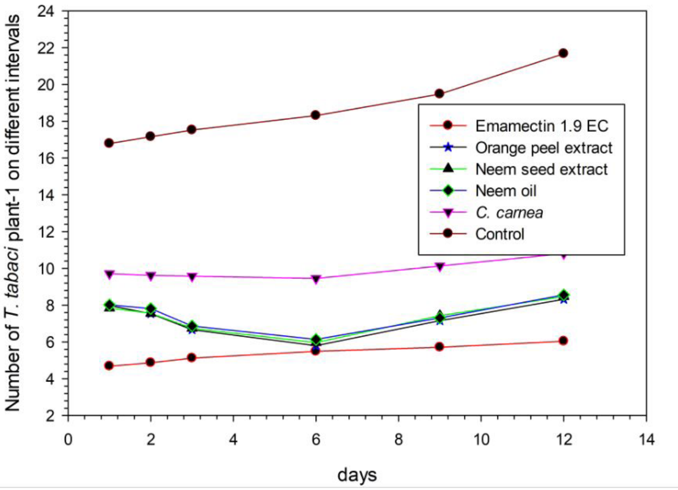

Figure 5: *Second spray application effect of different treatments on Trips tabaci adult population at different time intervals in garlic crop at ARI Tarnab, Peshawar during 2017-18.*

Third spray application effect of different treatments on T. tabaci nymph population in garlic crop

Data presented in Figure 6 showed 3rd spray application effect on mean number of nymphs in garlic crop. All the treatments performed better in reducing nymph population and were found significantly effective except control plot. The plots treated with emamectin had lowest mean number of nymph population (1.74), this was followed by neem oil, neem seed and orange peel where 3.18, 3.26 and 3.35 mean number of nymphs were recorded. The plots treated with *C. carnea* eggs had 6.41 mean number of nymphs, significantly high number of nymph population (17.72) was observed in the control plots. Mean data for time interval indicated that maximum population was recorded on day-12 (5.43) while minimum number of nymphs were observed on day-06 (4.21) followed by day-3 (4.72), day-9 (4.83) and day-2 (4.96).

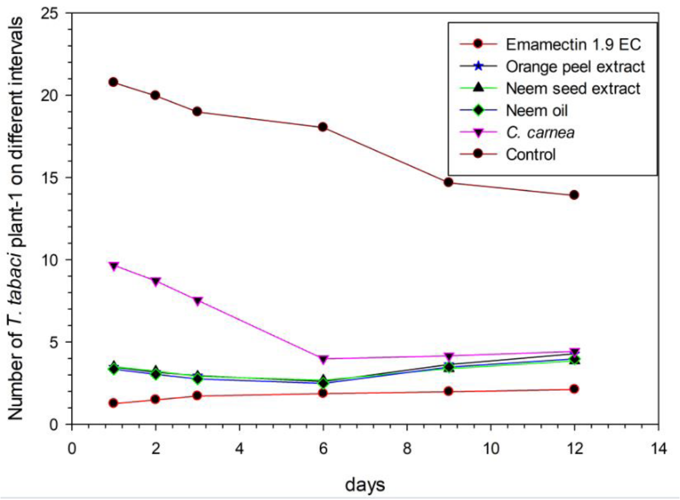

Figure 6: *Third spray application effect of different treatments against Trips tabaci nymph population at different time intervals in garlic crop at ARI Tarnab, Peshawar during 2017-18.*

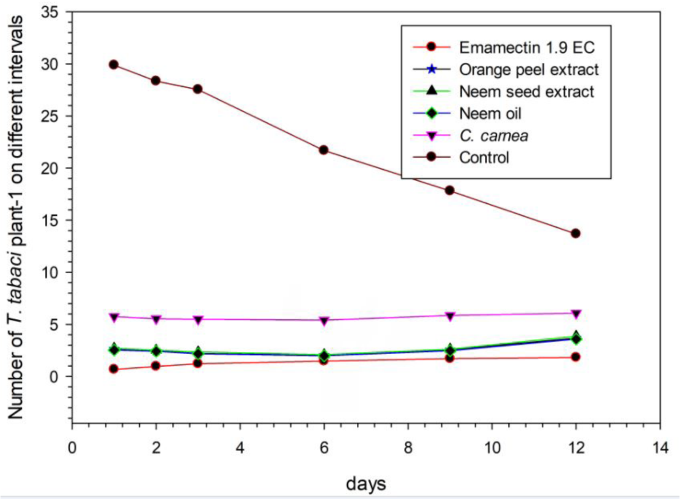

Figure 7: *Third spray application effect of different treatments on Trips tabaci adult population at different time intervals in garlic crop at ARI Tarnab, Peshawar during 2017-18.*

Third spray application effect of different treatments on T. tabaci adult population in garlic crop

Data presented in Figure 7 showed 3rd spray application effect of different treatments on mean number of adults in garlic crop. All the treatments performed better in reducing adult population and were found significantly effective except control plot. Treatment emamactin managed the adult population effectively with minimum mean number of adult population (1.31), this was followed by neem oil, neem seed and orange peel where 2.52, 2.69 and 2.60 mean number of nymphs were recorded. Time interval data showed that minimum adults population of *T. tabaci* was recorded on day-2 (6.83) followed by day-1 (7.36), day-3 (6.83) and day-6 (5.78). Maximum adult population was recorded on day-12 (5.45) followed by day-9 (5.50). Interaction for data between treatments and time intervals showed that maximum thrips adult population was in control on day-12 (13.68) while minimum population plant^{-1} was on day-1 (0.68) in treatment emamactin.

Effect of different treatments on average plant height and number of leaves plant^{-1}

Plant height and number of leaves plant^{-1} data presented in Table 1 indicate that plots treated with emamectin gained maximum plant height (84.2 cm). This was followed by orange peel (72.1), neem seed (70.4) extracts and neem oil (69.3). The lowest plant height was recorded in control plots (57.4), followed by *C. carnea* (65.2). The data further showed that tested treatments proved significant effect on reducing *T. tabaci* population which resulted in significant differences in number of leaves plant^{-1}. Emamectin treated plots showed maximum number of leaves (8.76), followed by other treatments (orange peel extract, neem seed extract and neem oil) where mean number of leaves per plants were 8.24, 8.37 and 8.18, respectively.

Effect of different treatments on garlic bulb size

The data regarding the percent bulb sizes of garlic (cm) after each treatment application indicated in Table 2 showed that all the treatments resulted in significantly increased bulb size of garlic in comparison with control. Lowest percent of bulbs having size less than 5cm were recorded in treatment emamectin (35.80) followed by orange peel (41.60) and neem seed extract (42.60). While the highest percent of less than 5cm was noted in control plot (48.60) followed by *C. carnea* (43.70) and neem oil (43.30). Garlic bulbs having size between 5-6cm, the recorded data indicated that the highest percent was in control plot followed by orange peel (32.50) and neem seed (32.30). And the least percentage of bulbs was recorded in emamectin (25.20), *C. carnea* (27.10) and neem oil (30.20) respectively. Orange peel and neem seed were statistically similar to each other. In above 6cm bulb size, the highest percentage was recorded in treatment emamectin (39.0) followed by *C. carnea* (29.20), and neem oil (26.50). While the lowest percent of above 6cm bulb size were found in control (14.40), neem seed (25.10) and orange peel (25.90), respectively. Treatments including orange peel, neem seed and neem oil in above 6cm bulb size were statistically significant to each other while non-significant with remaining treatments.

Mean yield and percent increase in yield recorded for each treatment in garlic crop

Data regarding the yield of garlic in different treatments in Table 3 showed significantly increased yield as compared to control plots due to the fact that application of various treatments have decreased the *T. tabaci* population in treated plots and resulted in significantly different yield of garlic crop. Emamectin treated plots showed maximum yield (19.3 tons ha^{-1}) followed by orange peel (15.6 tons ha^{-1}), neem seed (15.0 tons ha^{-1}) and neem oil (14.7 tons ha^{-1}) while in control only 11.4 tons ha^{-1} yield was recorded. The plots treated with emamectin showed highest percent increase in yield (40.73%), followed by orange peel extract (26.79%), neem seed extract (24.02%), neem oil (22.58%) and 16.78% increase in yield with *C. carnea* in comparison with control plot.

Table 2: *Different treatments effect on Thrips tabaci on mean yield and percent increase in yield in garlic crop at ARI Tarnab, Peshawar during 2017-18.*

Treatment	Yield in tons ha^{-1}	% Yield increase over control
Emamectin 1.9 EC	19.3 a	40.73
Orange peel extract	15.6 b	26.79
Neem seed ectract	15.0 bc	24.02
Neem oil	14.7 c	22.58
C. carnea	13.7 d	16.78
Control	11.4 e	

LSD value for yield= 0.7780; Means followed by a different letter (s) are significantly different from one another at (P≤0.05), using LSD test.

Table 3: *Different treatments effects against Thrips tabaci (L.) on bulb size of garlic crop at ARI Tarnab, Peshawar during 2017-18.*

Treatment	% Bulb size (cm)		
	Below 5cm	5-6cm	Above 6cm
Emamectin 1.9 EC	35.80 e	25.20 e	39.00 a
Orange peel extract	41.60 d	32.50 b	25.90 c
Neem seed extract	42.60 c	32.30 b	25.10 c
Neem oil	43.30 bc	30.20 c	26.50 bc
C. carnea	43.70 b	27.10 d	29.20 b
Control	48.60 a	37.00 a	14.40 d
LSD	0.73	1.16	3.25

Means followed by a different letter (s) are significantly different from one another at (P≤0.05), using LSD test.

Field efficacy of different pest management techniques against nymph and adult population of *T. tabaci* were studied under field conditions in garlic crop at Agriculture Research Institute Tarnab, Peshawar during the year 2017-18. Different management techniques including emamectin 1.9 EC @ 750 ml ha^{-1}, orange peel extract @ 5%, neem seed extract @ 5%, neem seed oil @ 3% and *C. carnea* @ 3 eggs $plant^{-1}$ were applied. *T. tabaci* remained a consistent pest on garlic and was observed in early February till end of May. Maximum number of thrips population (51.27 thrips $plant^{-1}$) was observed during the last week of April. Same population trend of *T. tabaci* was also observed by Deligeogidis *et al*. (2006) who studied the population trend of *T. tabaci* on tomato and cucumber crops. These results also confirmed the findings of Ullah *et al*. (2010) who reported initial thrips infestation in February which reached to maximum in April. Hyder and Sharif (1987) also recorded the same trend and reported that *T. tabaci* population began in early January and reached to maximum in month of April. The effectiveness of different insecticides used in this experiment showed that best control was achieved with all applications of treatments. Mean data for treatments showed that synthetic insecticides emamectin significantly managed thrips population followed by botanical extracts (orange peel, neem seed, and neem oil) and *C. carnea* as compared with control plots.

Our data regarding mean number of thrips for time intervals showed that post treatment effect of plant extracts remained consistent with the increase in time interval up to one week. Same results were obtained by Khaliq *et al*. (2014), who studied the effect of different botanical extracts and chemical insecticides against *T. tabaci* and reported significant reductions (50-70%) in thrips population and (60%) control was caused due to botanicals. Our results confirm the findings of Fitiwy *et al*. (2015) who observed that synthetic insecticides gave better results against *T. tabaci*. Our results also showed similarities with the findings of Azam *et al*. (2008) who stated that neem oil performed better against *T. tabaci* as compared with other treatments and was suggested as economically viable and environment friendly bio-pesticide. The orange peel extract showed significant results in our experiment which were in line with Kiran and Magaji (2017), who reported that these extracts can be effectively use as optional source to control *Musca domestica*. Nagaraj *et al*. (2017) also evaluated neem products against *Scirtthrips dorsalis* on grapes and recommended neem seed extract as better option for management of thrips in grapes. Hazara *et al*. (1999) also recorded botanical extracts with good effectiveness against *T. tabaci* in field condition. Usman *et al*. (2012) also suggested botanical extracts favorable for organic farming and non-hazardous for human health as well as for environment. Solangi *et al*. (2014) also studied effect of different botanical extracts against *T. tabaci* and reported that plant extracts can be used effectively against thrips infestation.

During this research, synthetic insecticide (emamectin) was found effective in controlling *T. tabaci* population. These results were quite similar to the previous research work that used chemical insecticides for managing *T. tabaci* population and got a considerable effect. Hussain *et al*. (1997) used abamectin and spinosad against *Tribolium castaneum* and concluded that these chemicals had most toxic effect in managing thrips population. Another study conducted by Ullah *et al*. (2010) reported that synthetic insecticides *i.e.* Confidor, Tracer and Thiodon can effectively control thrips population. Sadozai *et al*. (2009) also reported that synthetic insecticides had a knockdown effect on thrips population. Similarly, the insecticide Spinosad was also tested by other scientists against western flower thrips and its associated natural enemies and documented that the Spinosad was effective in controlling the thrips population both in lab and under field conditions. They also found Spinosad with least toxic effect against defender (Jones *et al*., 2005). Sadozai *et al*. (2009) also reported that synthetic insecticides Thiodan effectively control the thrips population in garlic crop. *C. carnea* used in our research study had an impact on nymph population but showed less or no effect against adults of *T. tabaci*. Bharpoda *et al*. (2013) studied the effectiveness of *C. carnea* and synthetic insecticides against sucking insect pest in cotton and found *C. carnea* as effective predator of sucking pests. Another study conducted by Zia *et al*. (2008) also confirmed *C. carnea* as a successful bio-control agent against *Bemisia tabaci* in cotton and reported that use of *C. carnea* are gaining popularity in pest management programs in Pakistan. Our findings are in similarity with Sattar *et al*. (2007) who studied the predatory potential of *C. carnea* larvae against mealy bug and reported that *C. carnea* could be used as bio-pesticide technique in reduction of mealy bug population. Results pertaining to yield and its components i.e. plant height, number of leaves $plant^{-1}$ and bulb size given in the (Tables 1, 2 and 3) showed effectiveness of different treatments on these parameters. Plots treated with emamectin yielded maximum plant height (84.2cm) which was followed by orange peel extract (72.1), neem seed extract (70.4), neem oil (69.3) and *C. carnea* (65.2) as compared to control plots where mean plant height of 57.4 cm was observed. Also the plots treated with emamectin resulted in maximum number (8.76 leaves plant^{-1}) followed by neem seed extract (8.37), orange peel (24), neem oil (8.18) and *C. carnea* (7.56). While least number of leaves plant^{-1} was noted in control plots (6.93). Data regarding bulb size of garlic showed that emamectin treated plots, highest percent of above bulb size (6cm) was recorded (39.0) while in control the lowest percent of only 14.4 was recorded. The yield data realizes that maximum yield in tons ha^{-1} was obtained from Emamectin treated plots (19.3) which was followed by orange peel (15.6), neem seed (15.0), neem oil (14.7) and *C. carnea* (13.7) while in control 11.4 tons ha^{-1} was recorded. Shah (2015) also reported maximum yield in synthetic insecticides followed by botanical extracts. Similarly, Kambou and Guissaou (2011) and Hussain *et al.* (2016) also tested different synthetic and botanical insecticides against onion thrips and harvested maximum yield in plots treated with synthetic insecticides.

Conclusions and Recommendations

It is concluded from the above data that *T. tabaci* is serious pest of onion and its activity remained throughout the cropping season. The synthetic insecticide and all the botanical extracts significantly reduced thrips population. *C. carnea* was least effective in managing *T. tabaci* population in field condition as compared to the other treatments but showed better performance as compared to control plot. Maximum yield was obtained from synthetic insecticide treated plot followed botanical extracts and *C. carnea.* Minimum yield was recorded from untreated plot (control). To avoid or minimize the use of synthetic insecticide, botanical insecticides should be incorporated in management programs because they have less or no impact on environment as well as on natural ecosystem. The incorporation of *C. carnea* in the thrips management programs is suggested for long term management of thrips. However, further studies are recommended regarding the assessment of non-target effects of these botanical extracts and emamectin on natural enemies of insect pests.

Novelty Statement

This study highlights the importance of different pest management techniques including synthetic and botanical extracts along with biocontrol agent (*C. carnea*) against *T. tabaci* in garlic crop. The research results indicate that *T. tabaci* is serious pest of onion and its activity remained throughout the cropping season. The synthetic insecticide (emamectin) and all the botanical extracts significantly reduced thrips population.

Author's Contribution

Ahmad Ur Rahman Saljoqi: Supervised the whole research.
Muhammad Salim: Analyzed the data and wrote the article.
Iftikhar Ahmad: Conducted the research trial, compiled the data.

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

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