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Varietal Screening of Brinjal against Aphid (*Aphis gossypii* G.) Infestation and Population Fluctuation Plus Interaction between Aphid and Ladybeetle (*Coccinella septempunctata* L.) Populations

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Authors' Contribution
MA and QY conceived and designed the study, planted the crop and recorded the data. QY, MA and SS analysed the data and wrote the article.

Key words
***Aphis gossypii, Coccinella septempunctata,* Predator prey population dynamics, *Solanum melongena,* Varietal screening**

ABSTRACT

These studies were conducted in the field at Multan, Pakistan to investigate the population trend of the aphid, *Aphis gossypii* and the ladybeetle, *Coccinella septempunctata* on brinjal, *Solanum melongena,* during the 2013-14 and 2014-15 crop seasons. Brinjal varieties Round Black, Dilnasheen, Black Beauty, Hybrid Shilpa, Bemisal and Nirala were used in the experiment. The number of aphids and ladybeetles were recorded at weekly intervals from October 15 to March 1, both years. Aphid numbers were recorded on three leaves per plant and four plants per plot and averaged per leaf. Numbers of ladybeetles were recorded from the whole plant by sampling three plants per plot. Seasonal mean number of aphids per leaf was at the maximum on the variety Black Beauty and lowest on Nirala, during the 2013-14 growing season. During the 2014-15season the maximum number of aphids per leaf was recorded on the variety Round Black and lowest on Nirala. When sampling dates were compared, the highest and lowest aphid numbers/ leaf was noted on February 1 and March 1, respectively, during 2013-14. However, the maximum and minimum number was recorded on February 1 and January 1, respectively during 2014-15. The number of ladybeetles per plant was highest on December 1 and lowest on October 15, during both growing seasons. A significant positive correlation was found between aphid and ladybeetle populations during 2013-14, and correlation was positive but non-significant during the 2014-15 season. Findings from our study indicate that there exists a positive correlation between the two populations, but is not always significant. A positive correlation is expected between prey (aphid) and predator (ladybeetle). However, it's strength and consistency needs to be further investigated by repeating the study for more seasons and at more locations to clearly see the trend of the two populations.

INTRODUCTION

Brinjal or eggplant, (*Solanum melongena* L.), is a popular vegetable around the world. Although brinjal fruit does not have high caloric value it is a very rich source of minerals beneficial for human health (Zenia and Halina, 2008). Brinjal crop is attacked by a complex of insect pests from germination untill harvest, which results in economic losses by making fruit unfit for human consumption (Singh and Abrol, 2001). Some of its insect pests serve as vectors of several diseases (Russell, 1984). Important brinjal insect pests in Pakistan are the brinjal shoot and fruit borer, *Leucinodes orbonalis* G., the brinjal stem borer, *Euzophera perticella* R., the leaf roller, *Eublemma olivacea* W., a beetle, *Epilachna vigintioctopunctata* F. and an aphid, *Aphis gossypii* G. These aphids, *Aphis gossypii* G., or plant lice, are very important sucking insect pests (Berlendier and Sweetingham, 2003). *A. gossypii* attacks all ariaeal parts of the plant from early development stages to fruit maturation (Cruz and Bernardo, 1971; Sharma and Bhatangar, 2004). Its feeding results in plant stunting, twisting or yellowing of the foliage (Berlendier and Sweetingham, 2003) and small fruit size (Ghosh *et al*., 2004). Extreme infestations may destroy the plant completely (Sharma and Bhatangar, 2004).

Farmers prefer chemical insecticides for the control of insect pests due to their rapid action (Soomro

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et al., 2000; Razaq *et al*., 2013). Indiscriminate use of insecticides may result in health hazards for humans, insecticide resistance, resurgence of pests, environmental pollution and interruption of the natural balance in the ecosystem (Palumbo *et al*., 2001; Costa *et al*., 2003). Aphids have developed resistance to different groups of pesticides due to their extensive use (Wilde *et al*., 2001). Aphid populations have been increasing rapidly for the last few years and now have acquired the status of a regular pest in Pakistan (Aheer *et al*., 2008). Alternate methods for the control of these insect pests should be deployed to manage these insect pests (Soomro *et al*., 2000). Host plant resistance plays an important role and is compatible with various pest control strategies of integrated pest management (Hua and Hua, 2001; Khan *et al*., 2003). Host plant resistance tries to avoid crop damage by antibiosis, antixenosis or tolerance (Ellis and Farrel, 1995; Ellis *et al*., 1996), which may affect developmental time, or reproduction and survival rate of insects (Amjad and Peters, 1992). Resistant and tolerant plant varieties are a basic component of integrated pest management (IPM). Host plant resistance may contribute to IPM in two ways: reduces the rate of insecticide use and improves efficiency of natural enemies (Peterson *et al*., 2016). Even a low level of tolerance in plants may have a dramatic effect, which in fact reduces the need of insecticides (Srivastava, 1993).

Along with host plant resistance natural enemies can play an important role in insect pest management. Among predators, *Coccinella septempunctata* L. is an important biocontrol agent of *Lipaphis erysimi* in crops (Sinha *et al*., 1982). It is known from many quantitative evaluations that have indicated coccinellids can substantially reduce aphid density (Michels *et al*., 2001; Snyder *et al*., 2004, 2008; Thies *et al*., 2011). Prey density is an important aspect of a coccinellid response (Nilsson and Brönmark, 2000). It has been reported that the ladybeetle response depends on initial aphid densities (Fan and Petitt, 1994) and distribution of the prey (Dixon and Agarwala, 1999). Not much work has been reported on simultaneous population fluctuations of aphids and ladybeetles on brinjal in Pakistan. Thus, the present study was carried out to investigate the population fluctuation of *C. septempunctata* in response to populations of *A. gossypii* on brinjal.

MATERIALS AND METHODS

The study was conducted in the fields at the Faculty of Agriculture, Baha ud Din Zakariya University, Multan, on spring planted crops from 2013 to 2015. Six brinjal varieties, i.e., Round Black, Dilnasheen, Black Beauty, Hybrid Shilpa, Bemisal and Nirala were utilizeds. Seeds of the varieties Dilnasheen, Bemisal, and Nirala were obtained from the Ayub Agricultural Research Institute, Faisalabad while those of other varieties were purchased from the local seed market at Faisalabad. Nurseries for all varieties were initiated by sowing seeds in 30 cm clay pots on July 25, 2014 and 2015. Seedlings were transplanted on September 10, 2013 and 2014 on one side of ridges, 5 meter long and spaced 50 cm, just after irrigation. The seedlings of each variety were transplanted on four rows keeping individual plant distance at 50 cm. The experiment was laid out in a randomized complete block design (RCBD) with six treatments (varieties) and four replications. Plots and replications were separated by one and two meter non-cropped areas, respectively. The agronomic practices were the same for all treatments. The crop was monitored weekly for insect pest infestation from October 1 to March 1, during the study period. Aphids appeared on the crop during early October and data recording was started on October 15, 2013, and 2014, when reasonable numbers were present on the leaves. Data were recorded from the middle two rows of each plot. Number of aphids per leaf was used as an indicator of resistance/susceptibility. The number of aphids (adults + nymphs) was counted early in the morning, when insects were less active, on the underside of three leaves from each plant by selecting two plants randomly from two middle rows in each plot. The three leaves selected were as follows; one from the upper one third, one from the middle one third and one from the lower one third of each sampled plant. The mean number of aphids per leaf was calculated for each plot. Number of lady beetle, *C. septempunctata* (adults and larvae, collectively) per whole plant was also recorded from two plants, randomly selected, from each of the middle two rows. Data recording was done fortnightly from October 15, 2013, to March 1, 2014. The same method was repeated for the second season, i.e., 2014-15. The data for aphid numbers on different varieties were analyzed by analysis of variance (ANOVA) and the least significance difference (LSD) was calculated, for comparisons of means using Statistix. v.8, statistical software. The correlation between the aphid and ladybeetle population was also calculated. For this purpose, the number of aphids was pooled for all varieties on different sampling dates so that a meaningful correlation between the two populations could be observed.

RESULTS AND DISCUSSION

Number of A. gossypii *per leaf recorded during 2013-14*

When the number of aphids per leaf was compared on different sampling dates (Table I) the variety Round Black had the highest (28.0±0.6) number followed by that on Dilnasheen and Black Beauty and Bemisal on October 15. Nirala had the lowest (6.2±1.0), but not-significantly

Table I. Number of aphid, *Aphis gossypii G.* (adults + nymphs) per leaf on different varieties of brinjal, *Solanum melongina* L. at Sahiwal during 2013-14 and 2014-15.

Varieties	Sampling dates									
	15-Oct-13	1-Nov-13	15-Nov-13	1-Dec-13	15-Dec-13	1-Jan-14	15-Jan-14	1-Feb-14	15-Feb-14	1-Mar-14
Year 2013-14										
Round Black	28.0±0.6a	22.8±2.0b	29.0±1.5bc	23.0±0.9bc	13.2±0.3b	12.3±1.8a	14.5±1.1b	33.7±0.8ab	21.2±1.6ab	6.5±0.3b
Dilnasheen	16.3±2.0b	19.8±0.9bc	27.0±1.3c	26.0±1.2b	12.7±1.5b	10.7±0.3ab	13.7±0.4b	32.0±2.4b	24.5±1.9a	7.7±1.0b
Black Beauty	18.8±0.4b	39.0±1.3a	35.3±1.9a	31.7±2.4a	16.7±1.6a	10.2±1.0ab	14.8±1.1b	35.7±1.7a	20.8±1.2ab	7.7±0.1b
Hybrid Shilpa	9.0±0.6c	13.3±0.7d	18.0±0.5d	20.0±1.4cd	10.8±0.6b	10.5±0.9ab	18.7±0.4a	25.7±0.4c	18.2±0.9bc	11.0±0.5a
Bemisal	19.0±1.2b	24.3±1.7b	32.3±1.7ab	23.0±1.4bc	11.0±0.4b	8.7±0.6b	14.2±1.4b	26.2±1.5c	14.7±1.0c	10.0±0.4a
Nirala	6.2±1.0c	15.0±1.4cd	16.2±0.4d	18.7±1.3d	13.5±1.3b	9.8±1.0ab	13.3±1.3b	17.0±1.0d	15.7±1.6c	9.5±0.7a
LSD	3.1	4.8	4.9	3.6	2.9	2.8	2.3	3.4	3.8	1.6
Year 2014-15										
Round Black	22.2±0.8a	28.5±1.3a	26.0±0.9ab	26.0±1.2c	22.2±1.1a	14.7±0.8a	18.2±1.0b	37.5±1.6a	28.0±0.9a	16.5±0.6bc
Dilnasheen	11.0±0.5c	15.5±1.3b	23.5±1.8b	33.7±1.9b	14.7±1.2b	6.0±0.4c	18.0±1.7b	24.2±1.2c	15.0±1.5d	12.2±0.7cd
Black Beauty	10.7±1.3c	26.2±2.0a	30.7±2.3a	27.2±2.5c	15.7±0.9b	8.2±0.9b	23.5±1.2a	27.5±0.8c	21.0±1.5b	18.0±2.2b
Hybrid Shilpa	6.2±0.3d	7.2±0.4c	14.5±1.8c	23.2±1.8c	14.0±0.5b	8.7±0.8b	23.2±1.9a	37.0±2.5ab	20.7±0.8bc	13.0±1.6cd
Bemisal	17.2±0.8b	19.7±1.9b	18.5±1.2c	41.0±2.0a	13.2±0.3b	8.2±0.4b	26.5±2.2a	33.0±1.3b	15.7±1.1d	25.2±2.5a
Nirala	6.5±0.3d	15.5±2.3b	25.2±0.9b	27.8±2.1c	15.7±1.6b	8.7±1.2b	16.2±1.4b	25.7±1.5c	17.2±1.8cd	9.0±0.5d
LSD	1.7	5.1	4.8	5.3	2.8	1.9	4.0	4.0	3.5	4.4

Means followed by the same letter in columns are not significantly different (LSD at P= 0.05).

different from that on Hybrid Shilpa but significantly lower than that on other varieties. On November 1, the highest number was recorded on Black Beauty (39.0±1.3) and lowest on Hybrid Shilpa, (13.3±0.7) which was not significantly different from that on Nirala but significantly different from all other varieties. A similar trend was observed on November 15. On December 1, the lowest number per leaf was recorded on Nirala (18.7±1.3), whereas the highest number was found on Black Beauty (31.7 ±2.4) All the other varieties had intermediate populations. On December 15, all the varieties had non-significantly different numbers of aphids per leaf, except Black Beauty, which had a significantly higher (16.7 ±1.6) number. On January 1, a significantly different population was recorded, being highest (12.3 ±1.8) and lowest (8.7 ±0.6) on Round Black and Bemisal, respectively. The other varieties had intermediate but non-significantly different populations from each other.

The variety Hybrid Shilpa had the most aphids per leaf (18.7 ±0.4) on January 15. All other varieties had non-significantly different populations among themselves but significantly lower than that on Hybrid Shilpa. The variety Black Beauty had the highest number of aphids per leaf (35.7 ±1.7) followed by Black Beauty and Round Black on February 1. The significantly lowest number (17.0 ±1.0) was recorded on Nirala. On February 15, Dilnasheen had the highest (24.5 ±1.9) number per leaf but was not significantly different from Round Black or Black Beauty. Hybrid Shilpa, Bemisal and Nirala had significantly lower populations than the other varieties. On March 1, the number of aphids per leaf was not significantly different among Hybrid Shilpa, Bemisal and Nirala. These three varieties had the highest number of aphids per leaf. The remaining varieties had lower but non-significantly different numbers among themselves.

When overall seasonal means (total number of aphids recorded on all sampling dates / number of sampling dates) were considered, all varieties showed a significant difference for number of aphids per leaf, except Dilnasheen and Bemisal which had numbers non-significantly different from each other (Fig. 1). The significantly highest number (23.1 ±0.6) was recorded on Black Beauty and significantly lowest (13.5 ±0.4) on Nirala. These findings partly confirmed the results of a previous study by Habib *et al*. (2015), who recorded the highest overall mean density of *A. gossypii* on Black Beauty and a lower population on variety Pear Long.

Populations were sampled during the growing season on different dates and averaged over varieties, on the basis of number of aphids per leaf. This showed

that populations started to build from mid October (35 days after transplanting) with the significantly highest populations recorded on February 1, 2014 followed by those on November 15, 2013 (Fig. 2). Populations declined to the lowest level on March 1, 2014. In the present study maximum aphid populations were observed in February which was similar to the findings of Shakeel *et al*. (2014) and Hassan *et al*. (2004), who concluded that populations of aphids were maximum in February.

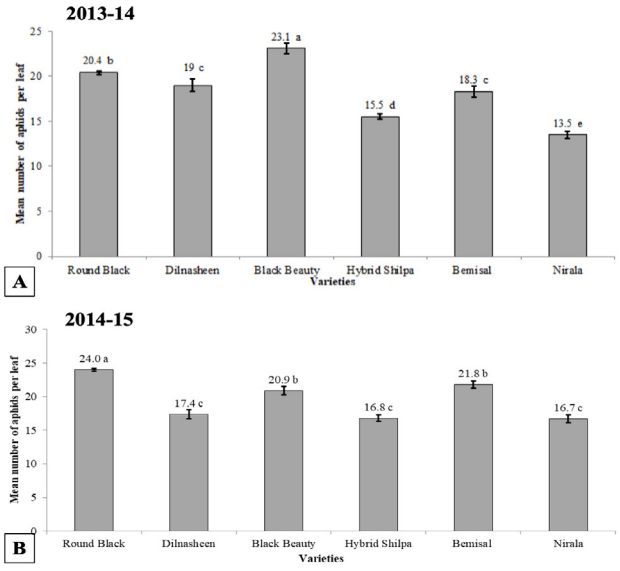

Fig. 1. Mean seasonal (total aphids counted/ number of sampling dates) number of aphids, *Aphis gossypii* (adult+nymphs) per leaf on different brinjal varieties at Sahiwal during 2013-14 (A) and 2014-15 (B).

Number of A. gossypii *per leaf recorded during 2014-15*

Aphid populations per variety on different sampling dates is presented in Table I. The variety Round Black had the highest (22.2±0.8) population followed by that on Bemisal on October 15. Variety Nirala and Hybrid Shilpa had non-significantly different populations from each other, but significantly lower than that on other varieties. On November 1, varieties Round Black and Black Beauty had non-significantly different numbers of aphids. However, these two varieties had significantly higher numbers of aphids per leaf than that on other varieties tested. The significantly lowest population was noted on Hybrid Shilpa (7.2 ±0.4). On November 15, the highest number was recorded on Black Beauty followed by that on Round Black. Numbers of aphids on Hybrid Shilpa and Bemisal was not significantly different from each other, but significantly lower than that on other varieties. Lowest number of aphids per leaf (14.5 ±1.8) was noted on Hybrid Shilpa. The aphid population on Bemisal was highest (41.0 ±2.0) followed by that on Dilnasheen on December 1. All other varieties had non-significantly different numbers of aphids per leaf among themselves but significantly lower than that on Bemisal and Dilnasheen. On December 15, all varieties had non-significantly different populations except that on Round Black, which had the significantly highest number (22.2 ±1.1) of aphids per leaf. On January 1, the significantly highest (14.7 ±0.8) and lowest (6.0 ±0.4) populations were noted on Round Black and Dilnasheen, respectively. All other varieties tested had non-significantly different numbers of aphids. On January 15, the number of aphids on Black Beauty, Hybrid Shilpa and Bemisal was not significantly different. However, these varieties had significantly higher numbers of aphids than other varieties, which were also not significantly different from one another. On February 1, populations were highest (37.5 ±1.6) on Round Black followed by those on Bemisal. The varieties Dilnasheen, Black Beauty and Nirala had the lowest number of aphids per leaf. On February 15, again the significantly highest population (28.0 ±0.9) was recorded on Round Black. Lowest populations were recorded on Dilnasheen (15.0 ±1.5) and Bemisal (15.7±1.1). On March 1, the significantly highest population was recorded on Bemisal (25.2±2.) followed by that on Black Beauty. The lowest number of aphids per leaf was noted on Nirala and Dilnasheen.

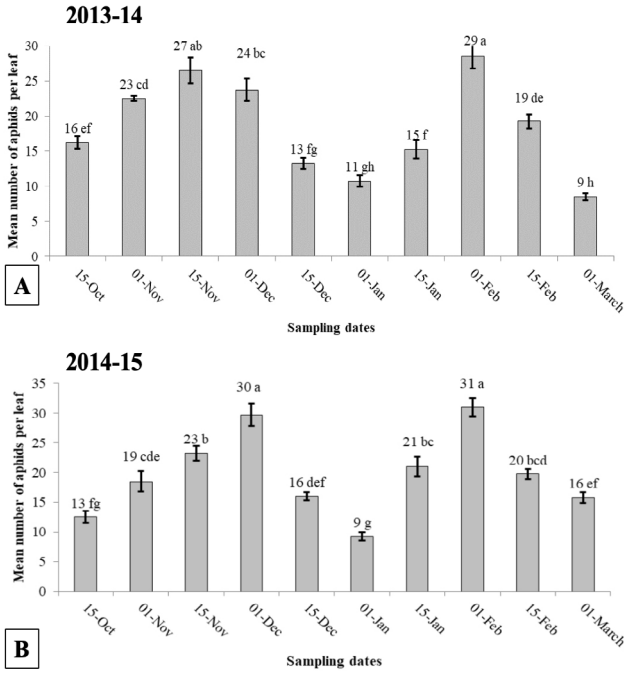

Fig. 2. Number (averaged over varieties) of *Aphis gossypii* (adult+nymphs) per leaf of brinjal at Sahiwal during 2013-14 (A) and 2014-15 (B).

When overall seasonal means (total number of aphids recorded on all sampling dates / number of sampling dates) were considered, the highest population was found on Round Black followed by those on Bemisal and Black Beauty, which did not have a significantly different number of aphids per leaf from each other (Fig. 1). Varieties Nirala, Hybrid Shilpa and Dilnasheen had the lowest (but non-significant) number of aphids. The lowest population was recorded on Nirala (16.7 ±0.6). Javed *et al*. (2011) determined the highest number of trichomes per leaf, leaf lamina hair density and shoot hair density on Nirala among seven tested brinjal varieties. More trichomes on leaves are usually responsible for lower insect pest infestation (Hossain, 2002; Traw and Dawson, 2002; Agrawal, 2004).

When population dynamics were observed during the growing season on different sampling dates averaged over varieties (Fig. 2) on the basis of number of aphids per leaf, there were two peaks, i.e., on December 1, 2014 and February 1, 2015. The lowest population was recorded on October 15, 2014 and January 1, 2015. After January 1, 2015, a sharp increase in aphids was observed, reaching a peak on February 01 and then the populations started declining.

C. septempunctata *population and its correlation with aphid populations during 2013-14*

Coccinella septempunctata populations (averaged over all varieties) started to build up from October 15 to December 1, then started declining afterwards until March 1 (Table I). From January 1 to February 15, the population showed an increasing trend but then a declining trend was noted until reaching the lowest level (3/plant), which was not-significantly different from that on October 15. It was observed that the lady beetle population increased when aphid populations did and declined with decrease in aphid populations. The trend in aphid and lady beetle populations on different sampling dates is shown in Figure 3. A significant positive correlation was found between numbers of aphids per leaf and lady beetles per plant (r=0.65, p =0.047) (Table II). These findings are in accordance with those reported by Ali *et al*. (2012) and Singh *et al*. (2013), who observed a significantly positive correlation between aphid and coccinellid populations. Soleimani and Madadi (2015) also reported a significant positive relationship between the population densities of *Coccinella septempunctata* and *Aphis pisum* (r= 0.41, p = 0.049) in 2013 (r = 0.38, p = 0.03) in alfalfa.

C. septempunctata *population and its correlation with aphid populations during 2014-15*

The number of lady beetles per plant and aphids per leaf on different sampling dates is presented in Table I. Populations started to build up from November 1 and reached a peak (25/plant) on December 1. After that, the lady beetle population started declining till January 15, and then increased until February 15. The lowest number of lady beetles per plant was observed on March 1. Trends for aphid and lady beetle populations on different sampling dates is shown in Figure 3. A non- significant but positive correlation was observed between aphid and lady beetle populations (r=0.52, p=0.123). Our results confirmed the findings of previous researchers. A study for finding correlation between aphid numbers and the population of lady beetles on plants revealed that egg and larval density was positively correlated to aphid numbers (Rana, 2006; Majumder and Agarwala, 2013). Soleimani and Madadi (2015) reported a non-significantly positive correlation between *Aphis gossypii* and *Hippodamia variegate* populations i.e., r = 0.21, p = 0.33 and r = 0.09, p = 0.66 for 2012 and 2013, respectively.

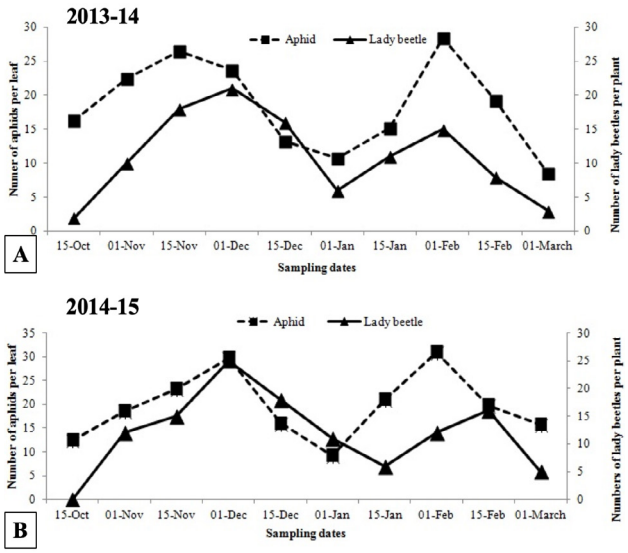

Fig. 3. Population fluctuation of *Coccinella septempunctata* (adult+larvae) per plant and *Aphis gossypii* (Adult+nymphs) per leaf on brinjal during 2013-14 (A) and 2014-15 (B) at Sahiwal.

Results of this study revealed that the seasonal mean number of aphids per leaf was highest on the brinjal variety Black Beauty and lowest on Nirala during the 2013-14 growing season. During the 2014-15 season, the maximum number of aphids per leaf was recorded on the variety Round Black and lowest on Nirala. The number of ladybeetles per plant was highest during December and lowest in October, both growing seasons. A significant positive correlation was found between aphid and ladybeetle populations during 2013-14, and the correlation

was positive but non-significant during the 2014-15 season. The findings of our study indicate that there exists a positive correlation between the two populations, but not always statistically significant. Our findings are also confirmed by those of Mukhtar et al. (2018) who found a positive correlation between the populations of predatory spiders *Cyrtophora citricola* and *Drosophila melanogaster* in citrus orchards.

Table II. Number of *Coccinella septempunctata* (adult+larvae) per plant and *Aphis gossypii* (adults + nymphs) per leaf on brinjal during 2013-14 and 2014-15 at Sahiwal.

Sampling dates	*C. septempunctata*/plant	*A. gossypii*/leaf
Year 2013-14		
15-Oct	2 g	16 ef
01-Nov	10 d	23 cd
15-Nov	18 b	27 ab
01-Dec	21 a	24 bc
15-Dec	16 c	13.25 fg
01-Jan	6 f	11 gh
15-Jan	11 d	15 f
01-Feb	15 c	29 a
15-Feb	8 e	19 de
01-March	3 g	9 h
LSD	1.82	1.63
Year 2014-15		
15-Oct	0 f	13 g
01-Nov	12 cd	19 cde
15-Nov	15 bc	23 b
01-Dec	25 a	30 a
15-Dec	18 b	16 def
01-Jan	11 d	9 g
15-Jan	6 e	21 bc
01-Feb	12 cd	31 a
15-Feb	16 b	20 bcd
01-March	5 e	16 ef
LSD	3.087	1.83

Means followed by the same letter in columns are not significantly different (LSD at P= 0.05).

Statement of conflict of interest

The authors declare that they have no conflict of interests.

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