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Research Article

Control of *Tetranychus urticae* by three predatory mites (Acari: Phytoseiidae) in a commercial greenhouse rose

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Abstract: The two-spotted spider mite (TSSM), *Tetranychus urticae* Koch (Acari: Tetranychidae) is a serious pest of many greenhouse crops such as bean, cucumber, rose and other products. The control of this important pest has been mainly based on the use of acaricides. Phytoseiid mites are used mostly for biological control of pest mites. In this study, control of TSSM by phytoseiid predatory mites, *Phytoseiulus persimilis* Athias-Henriot, *Amblyseius swirskii* Athias-Henriot and *Neoseiulus californicus* McGregor was evaluated on four rose varieties including Avalanche, Dolcevita, Samurai and Sorbet in a commercial rose greenhouse. The total number of motile stages and eggs of each studied species on a leaf were counted weekly, through a zigzag sampling pattern and using a hand lens. The sampling was carried out randomly and the leaves of a rose plant were taken from the canopy base (shoots bent over beds), the middle (area between base and top) and the top of the canopy (flowering shoots), which added up to a total of 30 leaves. The highest population density of TSSM per leaf was recorded on Samurai (17.96 ± 0.85) and the lowest population density was observed on Dolcevita (5.32 ± 0.39). Based on population fluctuation data of TSSM and its predators on four rose varieties, it was found that the predatory mite *P. persimilis* had the ability to reduce the high TSSM density and *N. californicus* also continued to operate in low TSSM density, but *A. swirskii* did not have a clear impact on TSSM density reduction.

Keywords: biological control, integrated mite management, population fluctuation, *Tetranychus urticae*, phytoseiid mite

Introduction

Cut roses are one of the most popular ornamental plants in the world (Alipour *et al.*, 2016). The major cut roses produced commercially in Iran are greenhouse roses. The two-spotted spider mite (TSSM), *Tetranychus urticae* Koch (Acari: Tetranychidae) is a serious pest of many greenhouse crops such as bean, cucumber, rose and many others (Maleknia *et al.*, 2016). Damage of this pest on ornamental plants reduces the flower's beauty, so that damage symptoms on leaves and petals can reduce the price of the product.

The control of spider mites has been mainly based on the use of acaricides (Khajehali *et al.*, 2011). The wide use of acaricides has developed acaricide resistance in mites and is one of the reasons for environmental concern (Escudero and Ferragut, 2005; Attia *et al.*, 2013). Also the increase of consumer demand for healthy products has influenced the use of pesticides in crop production and many growers have tended to deployment of the integrated pest management (IPM) (De Vis and Barrera, 1999;

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Nicetic *et al*., 2001; Opit *et al*., 2004; Casey *et al*., 2007; Holt *et al*., 2007). Biological control is an important part of IPM programs. For pest mites, the predators have been used more than other biological agents (Fathipour and Maleknia, 2016). It seems that the mite predators are impartible part of biological control programs in integrated mite management. Among these predators, phytoseiid mites are most used in the control of TSSM (Fathipour and Maleknia, 2016).The phytoseiid predator, *Phytoseiulus persimilis* Athias-Henriot is a specialist predator of TSSM which is often used as a periodic diffusion in biological control programs in greenhouse cut roses (Casey *et al*., 2007; McMurtry *et al*., 2013). *Amblyseius swirskii* Athias-Henriot is a generalist predator mainly used for augmentative biological control of mites, thrips and whiteflies for a range of greenhouse crop (Ragusa and Swirski, 1975; Buitenhuis *et al*., 2015). *Neoseiulus californicus* McGregor is one of the most important phytoseiid predators with a feeding preference for TSSM. These predators are used against TSSM in a range of greenhouse crops of temperate and subtropical regions around the world (Fathipour and Maleknia, 2016).

Although biological control is a safe and potentially effective method, it is usually not enough to protect the crop against pests alone (Gerson and Weintraub, 2007). One of the key elements for building a sustainable IPM program is the use of host plant resistance to pests (Khanamani *et al*., 2013), which can be used as a suitable replacement to broad-spectrum insecticides (Fathipour and Mirhosseini, 2017). One of the efficient strategies to manage TSSM is combination of biological control agents and resistant plants (Khanamani *et al*., 2014).

In the present study, we aimed to determine population fluctuation of TSSM and its predators *P. persimilis*, *A. swirskii* and *N. californicus* on four rose varieties (Avalanche, Dolcevita, Samurai and Sorbet) under greenhouse conditions. Specifically, our findings could be used for the implementation of IPM programs against TSSM in the rose greenhouses.

Materials and Methods

This study was conducted in a commercial rose greenhouse with an area of ten thousand square meters at Karaj, which was located at altitude of 1300-1500 m above sea level. This greenhouse had been covered by glass, and all bush roses were cultivated on raised beds in a hydroponic cultivation system. Four rose varieties including Avalanche, Dolcevita, Samurai and Sorbet were cultivated in this greenhouse. The biological control program has been carried out based on the experimental plan suggested by the Koppert Biological Systems and we only recorded the results of the mentioned control program.

Treatments against TSSM included the use of *P. persimilis*, *A. swirskii* and *N. californicus* obtained from Koppert Biological Systems. The time and rate of releasing the phytoseiid predators during the project (for 31 weeks) is presented in Table 1. The release of the predators on each release date was applied equally regardless of plant variety in the greenhouse, except for the release of *P. persimilis* in the seventeenth week, which was applied as a hot-spot treatment.

Table 1 Phytoseiid mite predators used in greenhouses rose.

Predatory mite	Application rate	Number per unit	Release date (Week)
P. persimilis	40 bottles	2000	3/8/2016 (1)
A. swirskii	2000 plus sachets	250	10/8/2016 (2)
P. persimilis	150 bottles	2000	23/8/2016 (3)
P. persimilis	70 bottles	2000	30/8/2016 (4)
P. persimilis	20 bottles	2000	6/9/2016 (5)
A. swirskii	5 bottles	5000	4/10/2016 (9)
N. californicus	4 bottles	25000	25/10/2016 (12)
P. persimilis	5 bottles	2000	30/11/2016 (17)
P. persimilis	23 bottles	2000	17/2/2017 (24)
P. persimilis	60 bottles	2000	2/3/2017 (26)
N. californicus	8 bottles	25000	2/3/2017 (26)

Abbreviations: *P*: *Phytoseiulus*; *A*: *Amblyseius*; *N*: *Neoseiulus*.

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The release of the predators was done on the bent stems by sprinkling the contents of a bottle on the leaves while the bottle was rotated regularly for the uniform distribution of the predatory mites. This work was done from the end of each row to the beginning of the rows. Also slow-release sachet of *A. swirskii* was used by hanging on the bent stems of roses.

To provide sufficient moisture and for better development of the predatory mites in greenhouse, for ten days after each release period, water was sprayed on the bushes daily. During the study period, the pruned leaves were kept for one day on planting bed near the bushes, so that the predatory mites on them were returned to bushes, so we tried to prevent predators from leaving the greenhouse.

Leaves were considered as the sampling units. For collecting leaf samples, a zigzag pattern was used. In this way, the samplings of the mites were done in the aisles between the rows of plants, from both sides of the aisle. In each sampling, 30 rose leaves were sampled from 30 bushes. The sampling was carried out randomly and the leaves of a rose plant were taken from the canopy base (shoots bent over beds), the middle of the canopy (area between base and top) and the top (flowering shoots). Total motile stages (combined adults and juveniles) and eggs of TSSM and its predators on a leaf were counted weekly using a hand lens. All counts were performed in the morning. Density of these mites was determined from 6th September 2016 to 4th April 2017.

One-way ANOVA was used to compare the mean density of total life stages (egg, nymphs and adults) of TSSM and its predators among rose varieties within each sampling date. Differences among the means were determined at a significance level of 5% using Tukey's test. All data were tested for normality before analysis and data were analyzed using Minitab software.

Results

Population fluctuation of TSSM

The mean population density of TSSM per leaf of different rose varieties in each sampling date is shown in Table 2. The TSSM population density results showed a significant difference among different rose varieties at different dates. TSSM population density for the entire sampling period on each leaf for Avalanche, Dolcevita, Samurai and Sorbet varieties was record 14 ± 0.73, 5.32 ± 0.39, 17.96 ± 0.85 and 15.06 ± 0.90, respectively (Table 2).

In general, it was monitored from the beginning of the sampling period, the population density of TSSM gradually decreased on all the four rose varieties, and for the relatively long time (from the 10th to the 24th week) it was fluctuating at very low level, but from the twenty-fourth week onward, the population density increased (Table 2).

Population fluctuation of *P. persimilis*

The population of *P. persimilis* was monitored from the beginning of the first release during the first week (Table 3). The highest population density was recorded on Avalanche in overall dates, followed by Samurai, Sorbet and Dolcevita (0.92 ± 0.07, 0.88 ± 0.08, 0.56 ± 0.06, and 0.25 ± 0.03 mite/leaf, respectively). Due to the subsequent releases of this predator during the first, third, fourth and fifth weeks (Table 1), its population density increased gradually on all the four rose varieties, and when the population density of the predator peaked, with a steep slope decreased to lower levels (Table 3). With the release of this predator in the seventeenth week (Table 1), no predator was observed in any of the varieties examined but by the re-release on other dates, the predator population density gradually increased (Table 3).

Population fluctuation of *A. swirskii*

The population density of *A. swirskii* per leaf on all rose varieties at different dates is shown in Table 4. Mean density of *A. swirskii* until last date of its observation in the greenhouse (twelfth week) on overall dates for Avalanche, Dolcevita, Samurai and Sorbet varieties was record 0.10 ± 0.007, 0.05 ± 0.005, 0.04 ± 0.005, 0.07 ± 0.006 mite/leaf, respectively. Therefore, the highest population density of this predator per leaf was recorded on Avalanche (0.10 ± 0.007) and the lowest population density was observed on Samurai (0.04 ± 0.005).

Table 2 Population density of *Tetranychus urticae* on four rose varieties.

Sampling date (week)	Number of mites per leaf (Mean ± SE)				F	df	P
	Avalanche	Dolcevita	Samurai	Sorbet			
06/09/2016 (1)	52.2 ± 5.89[a]	21.13 ± 2.83[b]	52.8 ± 4.51[a]	16.6 ± 1.98[b]	54.87	3,119	0.001
13/09/2016 (2)	37.77 ± 5.71[a]	7.33 ± 2.13[b]	47.6 ± 5.55[a]	13.33 ± 1.49[ab]	38.28	3,119	0.001
20/09/2016 (3)	68.13 ± 5.38[a]	21.7 ± 0.54[b]	63.53 ± 5.01[a]	26.67 ± 1.41[ab]	45.21	3,119	0.001
27/09/2016 (4)	33.93 ± 3.70[ab]	8.77 ± 1.42[c]	43.17 ± 4.26[a]	16.97 ± 1.35[b]	35.51	3,119	0.001
04/10/2016 (5)	32.5 ± 2.89[a]	4.63 ± 1.12[c]	35.8 ± 4.10[a]	8.4 ± 0.79[b]	27.22	3,119	0.021
11/10/2016 (6)	30.73 ± 3.54[a]	0.07 ± 0.02[b]	27.2 ± 1.42[a]	2.07 ± 1.58[b]	74.68	3,119	0.001
18/10/2016 (7)	30.63 ± 2.60[a]	0.33 ± 0.11[c]	26.97 ± 3.02[a]	12.33 ± 2.52[b]	31.10	3,119	0.001
25/10/2016 (8)	12.5 ± 1.2[b]	0.03 ± 0.01[c]	27.27 ± 4.49[a]	0.77 ± 0.32[c]	9.12	3,119	0.014
01/11/2016 (9)	9.57 ± 2.1[a]	0.03 ± 0.01[b]	10.7 ± 1.85[a]	0	8	3,119	0.001
08/11/2016 (10)	4.07 ± 0.82[a]	0	0.2 ± 0.08[b]	0	11.51	3,119	0.001
15/11/2016 (11)	6.97 ± 1.40[a]	0	0	0	17	3,119	0.048
22/11/2016 (12)	0.6 ± 0.35[a]	0	0	0	8	3,119	0.012
29/11/2016 (13)	2.23 ± 0.81[a]	0	0	0	11	3,119	0.037
06/12/2016 (14)	1.83 ± 0.60[a]	0	0	0	6	3,119	0.041
13/12/2016 (15)	0	0	0	0	-	-	-
20/12/2016 (16)	0	0	0	0	-	-	-
27/12/2016 (17)	0	0	0.27 ± 0.12[a]	0.73 ± 0.43[a]	5.61	3,119	0.001
03/01/2017 (18)	0.37 ± 0.10[a]	0.17 ± 0.09[a]	0.87 ± 0.56[a]	2.07 ± 1.01[a]	12.30	3,119	0.001
10/01/2017 (19)	0.63 ± 0.23[b]	4.8 ± 0.93[a]	0.6 ± 0.47[b]	3.53 ± 1.06[a]	24.91	3,119	0.001
17/01/2017 (20)	0.33 ± 0.13[b]	0.30 ± 0.14[b]	5.7 ± 1.20[a]	5.73 ± 1.02[a]	12.20	3,119	0.034
24/01/2017 (21)	4.17 ± 0.60[a]	3.1 ± 0.60[a]	0.77 ± 0.50[b]	3.4 ± 1.5[a]	9	3,119	0.001
31/01/2017 (22)	0.07 ± 0.06[b]	0.03 ± 0.03[b]	0	3.6 ± 1.8[a]	11	3,119	0.001
07/02/2017 (23)	8.70 ± 2.70[a]	0.23 ± 0.23[c]	2.67 ± 0.41[b]	2.57 ± 0.43[b]	5	3,119	0.011
14/02/2017 (24)	2.93 ± 1.39[b]	6.97 ± 1.68[a]	0	6.73 ± 1.65[a]	4	3,119	0.041
21/02/2017 (25)	3.23 ± 1.2[c]	3.37 ± 0.47[c]	22 ± 1.01[a]	10.17 ± 1.54[b]	15	3,119	0.001
28/02/2017 (26)	5.27 ± 0.99[c]	15.67 ± 1.95[b]	35.67 ± 2.37[a]	32.53 ± 3.45[a]	17.31	3,119	0.001
07/03/2017 (27)	17.03 ± 4.07[b]	13.87 ± 2.52[b]	39.73 ± 3.03[a]	33.37 ± 2.83[a]	8	3,119	0.001
14/03/2017 (28)	15.43 ± 5.37[b]	24.93 ± 4.54[b]	39.57 ± 4.38[a]	37.6 ± 3.46[a]	12.11	3,119	0.048
21/03/2017 (29)	18.17 ± 2.97[c]	16.4 ± 2.87[c]	40.37 ± 4.84[b]	54.87 ± 5.37[a]	10.68	3,119	0.001
28/03/2017 (30)	21.9 ± 5.46[b]	10.67 ± 2.18[c]	15.27 ± 0.96[b]	69.2 ± 3.10[a]	5.62	3,119	0.001
04/04/2017 (31)	12.1 ± 2.06[c]	0.37 ± 0.19[d]	18.17 ± 0.78[b]	103.43 ± 2.58[a]	14.22	3,119	0.001
Overall dates	14 ± 0.73[b]	5.32 ± 0.39[c]	17.96 ± 0.85[a]	15.06 ± 0.90[b]	9.12	3,3479	0.001

Means within a row followed by different letters are significantly different (Tukey test, $P < 0.05$).

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Table 3 Population density of *Phytoseiulus persimilis* on four rose varieties**.**

Sampling date (week)	Number of predatory mites per leaf (Mean ± SE)				F	df	P
	Avalanche	Dolcevita	Samurai	Sorbet			
06/09/2016 (1)	0.23 ± 0.10$_{a}$	0.27 ± 0.12^{a}	0.23 ± 0.09^{a}	0.1 ± 0.06^{a}	8	3,119	0.011
13/09/2016 (2)	0	0.07 ± 0.04^{a}	0.03 ± 0.03^{a}	0	9.11	3,119	0.035
20/09/2016 (3)	0.13 ± 0.08^{ab}	0.07 ± 0.05^{b}	0.17 ± 0.09^{ab}	0.47 ± 0.17^{a}	6	3,119	0.00
27/09/2016 (4)	0.93 ± 0.20^{a}	0.23 ± 0.12^{b}	0.33 ± 0.16^{ab}	0.73 ± 0.23^{ab}	4	3,119	0.00
04/10/2016 (5)	1.20 ± 0.25^{ab}	0.47 ± 0.18^{b}	0.7 ± 0.24^{ab}	1.4 ± 0.31^{a}	8.12	3,119	0.013
11/10/2016 (6)	2.10 ± 0.30^{a}	0.53 ± 0.15^{b}	0.43 ± 0.15^{b}	0.83 ± 0.19^{b}	14	3,119	0.00
18/10/2016 (7)	3.93 ± 0.46^{a}	0.83 ± 0.22^{c}	2.1 ± 0.30^{b}	1.87 ± 0.40^{b}	12	3,119	0.00
25/10/2016 (8)	2.53 ± 0.31^{b}	0	4.53 ± 0.65^{a}	1.6 ± 0.32^{c}	5	3,119	0.00
01/11/2016 (9)	2.37 ± 0.29^{b}	0	5.67 ± 1.05^{a}	0.1 ± 0.06^{c}	6.71	3,119	0.00
08/11/2016 (10)	0.83 ± 0.22^{a}	0	0.57 ± 0.18^{a}	0	8.21	3,119	0.00
15/11/2016 (11)	0.3 ± 0.15^{a}	0	0.17 ± 0.11^{a}	0	8.25	3,119	0.028
22/11/2016 (12)	0.63 ± 0.22^{a}	0	0	0	7	3,119	0.016
29/11/2016 (13)	0.37 ± 0.16^{a}	0	0	0	9.31	3,119	0.032
06/12/2016 (14)	0.27 ± 0.15^{a}	0	0	0	4.96	3,119	0.041
13/12/2016 (15)	0	0	0	0	-	-	-
20/12/2016 (16)	0	0	0	0	-	-	-
27/12/2016 (17)	0	0	0	0	-	-	-
03/01/2017 (18)	0	0	0	0	-	-	-
10/01/2017 (19)	0	0	0	0	-	-	-
17/01/2017 (20)	0	0	0	0	-	-	-
24/01/2017 (21)	0	0	0	0	-	-	-
31/01/2017 (22)	0	0	0	0	-	-	-
07/02/2017 (23)	0	0	0	0	-	-	-
14/02/2017 (24)	0	0	0	0	-	-	-
21/02/2017 (25)	0.03 ± 0.00^{a}	0	0	0	5	3,119	0.048
28/02/2017 (26)	0.17 ± 0.00^{a}	0	0	0	5.81	3,119	0.033
07/03/2017 (27)	0	0.2 ± 0.12^{a}	0	0.13 ± 0.09^{a}	9	3,119	0.010
14/03/2017 (28)	0.23 ± 0.11^{ab}	0.43 ± 0.16^{a}	0.3 ± 0.15^{ab}	0.07 ± 0.05^{b}	12	3,119	0.036
21/03/2017 (29)	2.1 ± 0.37^{a}	2.43 ± 0.38^{a}	1.53 ± 0.31^{ab}	0.3 ± 0.14^{b}	13.84	3,119	0.00
28/03/2017 (30)	7.8 ± 0.85^{a}	0.73 ± 0.18^{c}	3.37 ± 0.36^{b}	2.77 ± 0.45^{b}	7.62	3,119	0.00
04/04/2017 (31)	2.43 ± 0.44^{b}	1.5 ± 0.38^{c}	7.2 ± 0.64^{a}	6.93 ± 0.81^{a}	14	3,119	0.00
Overall dates	0.92 ± 0.07^{a}	0.25 ± 0.03^{c}	0.88 ± 0.08^{a}	0.56 ± 0.06^{b}	7.3	3,2519	0.00

Means within a row followed by different letters are significantly different (Tukey test, $P < 0.05$).

The population of *A. swirskii* was monitored from the beginning of the first release during the second week. The population density of this predator increased on all four rose varieties, but it was dramatically reduced after a few weeks. Finally, after the twelfth week, no density of this predator was observed on any of the studied varieties (Table 4).

Population fluctuation of *N. californicus*

The mean population density of *N. californicus* per leaf of different rose varieties on each sampling date is shown in Table 5. There was a significant difference in density of *N. californicus* among different rose varieties at different dates. The population density of this predator during the overall date for Avalanche, Dolcevita, Samurai and Sorbet varieties was obtained 0.04 ± 0.007, 0.07 ± 0.01, 0.01 ± 0.004, 0 and 0.05 ± 0.008 mite/leaf, respectively.

The *N. californicus* population was monitored from the beginning of its release during the twelfth week that after six weeks, the first individuals were observed in samurai variety. Subsequently, the predator population was observed very sparse and found at very low levels on different varieties (Table 5). After the second release of this predator in the twenty-sixth week (Table 1), there was an increasing trend but fluctuation was observed in the predator's population (Table 5).

Table 4 Population density of *Amblyseius Swirskii* on four rose varieties.

Sampling date (week)	Number of predatory mites per leaf (Mean ± SE)				F	df	P
	Avalanche	Dolcevita	Samurai	Sorbet			
06/09/2016 (2)	0.067 ± 0.05[a]	0	0	0.03 ± 0.03[a]	9.00	3,119	0.046
13/09/2016 (3)	0.13 ± 0.08[a]	0.03 ± 0.03[a]	0.07 ± 0.07[a]	0.17 ± 0.08[a]	13.20	3,119	0.034
20/09/2016 (4)	0.13 ± 0.08[a]	0.27 ± 0.13[a]	0.07 ± 0.05[a]	0.13 ± 0.08[a]	6.44	3,119	0.011
27/09/2016 (5)	0.17 ± 0.08[a]	0.23 ± 0.1[a]	0.23 ± 0.11[a]	0.2 ± 0.14[a]	8.10	3,119	0.00
04/10/2016 (6)	0.37 ± 0.11[a]	0.03 ± 0.03[b]	0	0.1 ± 0.07[b]	7.98	3,119	0.014
11/10/2016 (7)	0.27 ± 0.11[a]	0	0	0.067 ± 0.06[a]	9.33	3,119	0.00
18/10/2016 (8)	0	0.03 ± 0.03[a]	0.1 ± 0.07[a]	0	5.55	3,119	0.029
25/10/2016 (9)	0	0	0.03 ± 0.03[a]	0	6.39	3,119	0.017
01/11/2016 (10)	0	0	0	0.03 ± 0.03[a]	7.14	3,119	0.031
08/11/2016 (11)	0.03 ± 0.03[a]	0	0	0	8.00	3,119	0.024
15/11/2016 (12)	0	0	0	0.07 ± 0.06[a]	5.21	3,119	0.042
Overall dates	0.10 ± 0.007[a]	0.05 ± 0.005[b]	0.04 ± 0.005[b]	0.07 ± 0.006[b]	12.06	3,1319	0.047

Means within a row followed by different letters are significantly different (Tukey test, P< 0.05).

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Table 5 Population density of *Neoseiulus californicus* on four rose varieties.

Sampling date (week)	Number of predatory mites per leaf (Mean ± SE)				F	df	P
	Avalanche	Dolcevita	Samurai	Sorbet			
22/11/2016 (12)	0	0	0	0	-	-	-
29/11/2016 (13)	0	0	0	0	-	-	-
06/12/2016 (14)	0	0	0	0	-	-	-
13/12/2016 (15)	0	0	0	0	-	-	-
20/12/2016 (16)	0	0	0	0	-	-	-
27/12/2016 (17)	0	0	0	0	-	-	-
03/01/2017 (18)	0	0	0.1 ± 0.07[a]	0	6.05	3,119	0.027
10/01/2017 (19)	0	0.03 ± 0.01[a]	0	0	10.44	3,119	0.012
17/01/2017 (20)	0.07 ± 0.04[a]	0.07 ± 0.02[a]	0	0	6.12	3,119	0.023
24/01/2017 (21)	0	0	0	0	-	-	-
31/01/2017 (22)	0	0	0.03 ± 0.01[a]	0	9.11	3,119	0.035
07/02/2017 (23)	0	0	0	0	-	-	-
14/02/2017 (24)	0	0	0	0.03 ± 0.01[a]	5.08	3,119	0.039
21/02/2017 (25)	0	0	0	0	-	-	-
28/02/2017 (26)	0.07 ± 0.04[a]	0.07 ± 0.07[a]	0	0	7.81	3,119	0.042
07/03/2017 (27)	0.03 ± 0.01[b]	0.53 ± 0.16[a]	0.03 ± 0.01[b]	0.43 ± 0.15[ab]	5.69	3,119	0.00
14/03/2017 (28)	0.23 ± 0.10[a]	0.13 ± 0.06[ab]	0	0	13.04	3,119	0.00
21/03/2017 (29)	0	0.17 ± 0.14[a]	0.03 ± 0.03[a]	0.1 ± 0.07[a]	11.23	3,119	0.00
28/03/2017 (30)	0.03 ± 0.01[a]	0.3 ± 0.13[a]	0	0.1 ± 0.07[a]	9.00	3,119	0.00
04/04/2017 (31)	0.33 ± 0.14[a]	0.13 ± 0.08[b]	0.07 ± 0.06[b]	0.43 ± 0.15[a]	14.21	3,119	0.00
Overall dates	0.04 ± 0.007[ab]	0.07 ± 0.01[a]	0.01 ± 0.004[b]	0.05 ± 0.008[ab]	9.85	3,1319	0.038

Means within a row followed by different letters are significantly different (Tukey test, $P< 0.05$).

Discussion

Different plant varieties have a different effect on the biological parameters of herbivorous species and their predators (Khanamani *et al*., 2014). In this study, the differences observed in population density of TSSM and its predators are probably due to the leaf structure, growth characteristics, and the defense mechanisms of the rose varieties. This means that four rose varieties significantly affected the biology of TSSM. The effect of leaf structure or growth characteristics of the rose varieties on population density of TSSM and its predators was not examined in this study. Thus further work is necessary to determine whether the differences observed in population density of TSSM and its predators are due to the leaf structure or caused by growth characteristics of the plants. Skirvin and Williams (1999) reported that morphological structure of rose varieties can affect the population density of TSSM. Similar conclusions were also made by other researchers (Agrawal, 2000; Balkema-Boomstra *et al*., 2003; Biswas *et al*., 2004; Peralta and Tello, 2011; Schmidt, 2014).

The results showed that the population of *P. persimilis* was increased consistently in all four varieties with decreasing population of TSSM (Tables 2 and 3). A severe decline in predator density immediately after peak population was observed on four rose varieties, which indicates that there is not sufficient prey to feed the predator (Table 3). Due to the fact that *P. persimilis* is a specialized predator of TSSM, its density is reduced significantly in the absence of sufficient prey. These results were similar to results obtained by Blumel and Walzer (2002) on other varieties of this host plant. Also Gacheri *et al*. (2015) and Chacón-Hernández *et al*. (2016) reported that a severe decline occurs in density of predator by decreasing the density of TSSM. Hot-spot applications of *P. persimilis* in the seventeenth week was not effective in decreasing density of TSSM (Tables 1 and 3). Therefore, it is concluded that although *P. persimilis* has been successful in controlling the high density of TSSM, it does not have the ability to control the population of the pest in lower densities. This disagrees with that concluded by Gacheri *et al*. (2015) in rose farms in Kenya.

Generally, the population density of TSSM decreased from the beginning of sampling period and reached near zero per leaf in the tenth week and this trend continued for relatively long time (until the 24th week) (Table 2). The low density of the TSSM population from the 10th to the 24th week could mainly be due to the *N. californicus* activity in this period (Tables 2 and 5). Due to the prey preferences of *N. californicus* on TSSM (Fathipour and Maleknia, 2016) and according to Tables 2 and 5, it seems that the low density of TSSM in different varieties from the 10th to the 24th week has prevented its population growth. Therefore, it is a good option for TSSM control in low density, and seems that its release is very suitable. Blumel and Walzer (2002) reported that *N. californicus* has the ability to survive in low prey density, but the lack of prey prevents its population density growth.

We did not find a definite cause for reduction of *A. swirskii* population (Table 4). It is probable that the *A. swirskii* has not been able to compete with the *P. persimilis* and it is possible that the feeding patch has left. This is a general predator and may have changed the feeding patch in search for another food source, such as thrips and whitefly (Messelink and Janssen, 2008; van Maanen *et al*., 2012).

In conclusion, the obtained results showed that the predatory mite *P. persimilis* had the ability to reduce the high TSSM density and *N. californicus* also continued to operate in low TSSM density, but *A. swirskii* did not have a clear impact on reducing TSSM density.

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کنترل *Tetranychus urticae* با استفاده از سه گونه شکارگر فیتوزیید در یک گلخانه تجاری رز

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چکیده: کنه تارتن دولکه‌ای *Tetranychus urticae* Koch (Acari: Tetranychidae) یک آفت جهانی برای بسیاری از گونه‌های گیاهی مانند خیار، سویا، رز و غیره می‌باشد. کنترل کنه‌های تارتن عمدتاً بر اساس استفاده از آفت‌کش‌های شیمیایی صورت می‌گیرد. شکارگرهای فیتوزیید برای کنترل کنه‌های آفت و هم-چنین برخی از حشرات استفاده شده‌اند. در این مطالعه، کنترل کنه تارتن دولکه‌ای با استفاده از کنه‌های شکارگر فیتوزیید *Phytoseiulus persimilis* Athias-Henriot، *Amblyseius swirskii* Athias-Henriot و *Neoseiulus californicus* McGregor روی چهار رقم رز شامل Avalanche، Dolcevita، Samurai و Sorbet ارزیابی شد. مجموع تعداد تخم و کل مراحل متحرک هر یک از کنه‌های مورد مطالعه با استفاده از یک لنز دستی در واحد برگ و به‌صورت هفتگی شمارش شد. نمونه‌برداری به‌صورت تصادفی انجام گرفت و برگ‌های یک بوته رز از تاج پوشش تحتانی (شاخه‌های خم شده)، تاج پوشش‌میانی (بین شاخه‌های پایینی و بالایی) و تاج پوشش بالایی (شاخه‌های گل‌دهنده) انتخاب شدند. در مجموع تعداد ۳۰ نمونه برگ در هر بار نمونه-برداری جمع‌آوری شد. بیش‌ترین میانگین جمعیت کنه تارتن دولکه‌ای به‌ازای هر برگ روی رقم Samurai (۰/۸۵ ± ۱۷/۹۶) و کم‌ترین تراکم آن روی رقم Dolcevita (۰/۳۹ ± ۵/۳۲) ثبت گردید. بر اساس داده‌های حاصل از تغییرات جمعیت کنه تارتن دولکه‌ای و شکارگرهای آن روی چهار رقم رز، شکارگر *P. persimilis* به-عنوان یک عامل بیولوژیک مؤثر در کاهش تراکم بالای کنه تارتن دولکه‌ای شناخته شد. هم‌چنین شکارگر *N. californicus* توانایی حفظ دوام خود در جمعیت پایین کنه تارتن دولکه‌ای را داشت اما شکارگر *A. swirskii* تأثیر آشکاری بر کنترل کنه تارتن دولکه‌ای نداشت.

واژگان کلیدی: شکارگرهای فیتوزیید، کنه تارتن دولکه‌ای، پویایی جمعیت، مدیریت تلفیقی کنه آفت

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