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Effect of Different Predator: Prey Release Ratios of *Phytoseiulus persimilis* and *Typhlodromus bagdasarjani* (Acari: Phytoseiidae) on Reduction of *Tetranychus urticae* (Acari: Tetranychidae) on Cucumber under Microcosm Conditions

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ABSTRACT

Prey suppression by predators depends on effective predator: prey release ratios. The effectiveness of *Phytoseiulus persimilis* Athias-Henriot and *Typhlodromus bagdasarjani* Wainstein and Arutunjan was evaluated at different predator: prey release ratios for suppression of *Tetranychus urticae* Koch populations on cucumber plants in the microcosm condition based on three experiments. In the first experiment, 7 days after *T. urticae* releases, the most reduction in the different stages (densities) of *T. urticae* and the most increase in both *P. persimilis* and *T. bagdasarjani* were observed in predator: prey release ratio of 1:4 followed by ratios of 1:10 and 1:20. In the second experiment, one day after *T. urticae* release at predator: prey release ratio of 1:4, there was no significant difference between predators effect on the decline of *T. urticae* stages (densities). In this case, more *T. bagdasarjani* at all stages was observed on the plants in comparison with *P. persimilis*. According to the third experiment, 7 days after *T. urticae* release, there was no significant difference between predator: prey ratio of 1:4 of *P. persimilis* and 1:2 of *T. bagdasarjani* on *T. urticae* suppression. In this case, more *P. persimilis* was observed on plants in comparison with *T. bagdasarjani*. Our study demonstrates that the most suppression of *T. urticae* populations occurred in predator: prey ratio of 1:4 for both predators. Based on our findings, we suggest that *P. persimilis* and *T. bagdasarjani* can be released at a ratio of 1:4 for successful control of *T. urticae* on cucumber.

Keywords: Biological control, Predatory mites, Spider mites.

INTRODUCTION

The two-spotted spider mite, *Tetranychus urticae* Koch, is a serious pest of many commercial crops such as cucumber grown in greenhouses (Opit *et al*., 2004; Greco *et al*., 2005; Khalequzzaman *et al*., 2007). The chemicals application for management of *T. urticae* in greenhouses led to development of chemical-resistance populations of this pest as well as environmental concerns. As a result, with the aim of obtaining chemical-free crops, adoption of appropriate alternative strategies, such as biological control, to suppress pest populations is recommended (Park *et al*., 2000; Opit *et al*., 2004; Greco *et al*., 2005; Khalequzzaman *et al*., 2007). Biological control of spider mites on many crops has focused on the application of predaceous phytoseiid mites (Sabelis, 1985; Ganjisaffar *et al*., 2011a, b; McMurtry *et al*., 2013; Moghadasi *et al*., 2013, 2014; Farazmand *et al*., 2015; Khanamani *et al*., 2015). *Phytoseiulus persimilis* Athias-Henriot is a commercialized and highly specialized predator of *T. urticae* which is widely released in greenhouses to control spider mite

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populations (McMurtry and Croft, 1997; Park *et al*., 2000; Opit *et al*., 2004; Mohamed and Omar, 2011; McMurtry *et al*., 2013). *Typhlodromus bagdasarjani* Wainstein & Arutunjan is a generalist indigenous phytoseiid mite with a wide distribution in Iran; on the different plants infested by tetranychid and eriophyid mites, as well as insect pests such as thrips and whiteflies (Daneshvar and Denmark, 1982); Kamali *et al*., 2001; Faraji *et al*., 2007). This species is a useful biological control agent of *T. urticae* with well adaptation to warm weather such as summer months in the greenhouses (Ganjisaffar *et al*., 2011a, b; Moghadasi *et al*., 2013, 2014; Farazmand *et al*., 2015; Khanamani *et al*., 2015). This character could be the advantage of *T. bagdasarjani* in comparison with *P. persimilis* in controlling *T. urticae* in the warm conditions (Skirvin and Fenlon, 2003; Ganjisaffar e*t al*., 2011a, b). Also, *T. bagdasarjani* is considered as a generalist predator (Type III) that can feed and reproduce on pollen, plant exudates, as well as honeydew, which is the advantage of generalist predators in comparison with the specialists such as *P. persimilis* (McMurtry and Croft, 1997; McMurtry *et al*., 2013).

Augmentation and releases of natural enemies are successful implements to reduce pest populations in many greenhouse crops (Park *et al*., 2000; Colfer *et al*., 2003; Khalequzzaman *et al*., 2007). The efficacy of natural enemies is affected by many variables. One such variable is the ratio of prey to natural enemies, which is often used to determine the sufficient abundance of predators to control prey population (Hussey and Scopes, 1985; Park *et al*., 2000; Opit *et al*., 2004; Greco *et al*., 2005). Predators must be present in sufficient numbers to control the prey population (Opit *et al*., 2004; Greco *et al*., 2005). The levels of prey population suppression by predators depend on effective predator: prey release ratios and the knowledge about this ratio is very important to plan proper biological control program for pest management (Opit *et al*., 2004; Greco *et al*., 2005).

Miniaturized ecosystems i.e. microcosms, as called by Abbott (1966), despite not creating natural systems precisely–provide the advantages for researchers to investigate organism interactions under controlled conditions. In fact, laboratory microcosms are ecosystem models in which a part of the natural environment is enclosed and studied. Small-scale researches at this ecosystem model can lead to the development of practical application and act as a sample of natural environment (Benton *et al*., 2007; Grenni *et al*., 2012).

This study was conducted to investigate the ability of *P. persimilis* and *T. bagdasarjani* at different predator: prey release ratios to decrease the *T. urticae* abundance on plants and preserve them from obvious pest injury as well as to determine the most effective release ratio of these predators to suppress *T. urticae* population in the microcosm conditions.

MATERIALS AND METHODS

Plant Source

The cucumber plants (*Cucumis sativus* cv. Sultan) used in this study were planted in plastic pots (20 cm diameter and 40 cm depth) filled with the mixture of cocopeat: perlite (40: 60%) under greenhouse conditions (25±5°C, 50±20% RH and natural light duration).

Prey Source

Tetranychus urticae were originally collected from infested lima bean leaves in insect population ecology laboratory at the Department of Plant Protection, University of Tehran in Karaj, Iran, and reared on cucumber plants in a growth chamber at 25±2°C, 50±10% RH, and 16 L: 8 D hours photoperiod.

Predator Source

Typhlodromus bagdasarjani was collected from black mulberry trees at the campus of Tarbiat Modares University, Tehran, Iran. *Phytoseiulus persimilis* was initially obtained from laboratory stock culture reared in population ecology laboratory at the Department of Plant Protection, University of Tehran in Karaj, Iran. Each phytoseiid rearing unit included a piece of green hard plastic sheet (20×10 cm) on a water-saturated sponge in a plastic container (26×16×7 cm). The borders of sheet were covered with the moistened tissue papers not only to provide the predators with water but also to prevent them from escaping (Overmeer, 1985). Every three days, *T. urticae*-infested cucumber leaves, as well as some maize pollen as supplementary food, were added to the rearing unit. Rearing unit was maintained at 25±1°C, 75±5% RH, and 16 L: 8 D hours photoperiod in a growth chamber.

Experiments

The microcosms consisted of a cucumber plant with completely expanded six leaves enclosed in a cube cage (70×70×200 cm) covered with a fine mesh. These cages were placed in a room with controlled conditions at 25±2°C, 60±10% RH, and 16 L: 8 D hours photoperiod.

One day old mated *T. urticae* females and newly mated *T. bagdasarjani* and *P. persimilis* females were used for the experiments. Three types of experiments were designed. In the first experiment, based on preliminary findings, each cucumber plant was infested with 40 newly mated *T. urticae* females. After 7 days, newly mated *T. bagdasarjani* and *P. persimilis* females were released on plants separately in density of 10, 4, and 2 to achieve the 1:4, 1:10 and 1:20 predator: prey ratios, respectively. Plants without predators were considered as control. After 15 days, all leaves of the plants were collected and the number of eggs, immature stages including larva and nymphs, as well as adults of prey and predator were counted using binocular.

In the second experiment, one day after release of *T. urticae* females, predators were released separately in density of 10 females on plants to create the predator: prey ratio of 1:4 (based on the first experiment results, this ratio provided the highest reduction in the *T. urticae* population densities). After 15 days, all leaves of plants were collected and the number of all stages of prey and predator were recorded.

In the third experiment, 7 days after release of *T. urticae*, females of *T. bagdasarjani* and *P. persimilis* were released separately in density of 20 and 10 females to create the predator: prey ratios of 1:2 and 1:4, respectively. After 15 days, the number of all stages of prey and predator on all leaves of plants were recorded. Each release ratio as well as control had eight replicates.

Data Analysis

All data were tested for normality with MINITAB 17 using the Ryan-Joiner method. The effects of different predator: prey ratios on the density of different stages of *T. urticae*, *T. bagdasarjani* and *P. persimilis* were analyzed by one-way ANOVA. Also, differences between means were compared by Tukey's range test (HSD) in SPSS 16. The t-test was performed to compare the number of all stages of predators in different predator: prey ratios between *T. bagdasarjani* and *P. persimilis* treatments using SPSS 16.

RESULTS

In the first experiment, one-way ANOVA indicated that the densities of different stages of *T. urticae* were significantly affected by predator: prey ratios of *P. persimilis* ($F_{3,31}$= 497.795, P< 0.0001; $F_{3,31}$= 103.378, P< 0.0001; $F_{3,31}$= 226.129, P< 0.0001; $F_{3,31}$= 651.158, P< 0.0001, for egg, immature stages (larva and nymph), adult and total stages, respectively; Table 1), and *T. bagdasarjani* ($F_{3,31}$= 448.58, P< 0.0001; $F_{3,31}$= 60.665, P< 0.0001; $F_{3,31}$= 86.614, P< 0.0001; $F_{3,31}$= 490.864, P< 0.0001, for egg, immature stages (larva and nymph), adult and total stages, respectively; Table 2). In addition, the results demonstrated the significant effect of predator: prey ratios on the different stages densities of *P. persimilis* ($F_{2,23}$= 684.804, P< 0.0001; $F_{2,23}$= 534.645, P< 0.0001; $F_{2,23}$= 763.607, P< 0.0001; $F_{2,23}$= 2335, P< 0.0001, for egg, immature stages (larva and nymph), adult and total stages, respectively; Table 1) and *T. bagdasarjani* ($F_{2,23}$= 164.472, P< 0.0001; $F_{2,23}$= 179.633, P< 0.0001; $F_{2,23}$= 318.5, P< 0.0001; $F_{2,23}$= 967.858, P< 0.0001, for egg, immature stages (larva and nymph), adult and total stages, respectively; Table 2).

Results showed that all predator: prey ratios had a significant effect on the pest density reduction (P< 0.0001, Tables 1 and 2). Only in the mean number of immature stages (larva and nymph) of *T. urticae* there was no significant difference between *T. bagdasarjani*: *T. urticae* ratio of 1:20 and the control (P> 0.05, Table 2).

The reduction percentage of different stages density of *T. urticae* at different predator: prey ratios after 15 days, was calculated by considering the difference between final number of prey stages in the control and predator: prey ratios after predators release (Table 3). According to the results, the most reduction in *T. urticae* different stages densities was observed in predator: prey ratio of 1:4 followed by predator: prey ratios of 1:10 and 1:20, for both predators. Predator stages (density) was positively affected by increasing the predator initial density at predator: prey release ratios from 1:20 to 1:4 (P< 0.0001, Tables 1 and 2).

In the second experiment, the effect of *P. persimilis* and *T. bagdasarjani* predator: prey ratio of 1:4 –the best ratio of both predators provided the highest reduction in the *T. urticae* population densities based on the first experiment results– on the densities of *T. urticae* different stages was studied. According to the results of one-way ANOVA analysis, the densities of *T. urticae* different stages were significantly affected by predators release ($F_{2,23}$= 1952, P< 0.0001; $F_{2,23}$= 354.55, P< 0.0001; $F_{2,23}$= 584.87, P< 0.0001; $F_{2,23}$= 2184, P< 0.0001, for egg, immature stages (larva and nymph), adult and total stages, respectively; Table 4). In other words, the release of predators at predator: prey ratio of 1:4, one day after release of *T. urticae* females, led to significant reduction in *T. urticae* population after 15 days. Also, the results showed that there was no significant difference between predators effect on the reduction of *T. urticae* different stages densities (Table 4).

The number of predator stages at predator: prey ratio of 1:4 is shown in Table 5. Fifteen days after predators release, more *T.*

Table 1. Number of different stages of *Tetranychus urticae* and *Phytoseiulus persimilis* (Mean±SE) at different predator: prey ratios recorded 15 days after predator release in the first experiment.[a]

Prey stage	Predator: Prey ratios			
	1:4	1:10	1:20	Control
Egg	114.25±9.22 d	2290.4±39.75 c	6548.5±212.93 b	10930±370.41 a
Larva+Nymph	108.5±3.81 d	387.75±28.77 c	1064.5±68.59 b	1301±81.15 a
Adult	87.25±7.94 d	446.5±25.83 c	624.25±26.07 b	894.38±24.81 a
Total stages	310±25.28 d	3141.6±64.87 c	8237.2±180.5 b	13125±399.62 a
Predator stage				
Egg	66.5±0.94 a	35.37±0.71 b	25.25±0.79 c	-
Larva+Nymph	66.5±1.61 a	33.75±0.25 b	22.12±0.55 c	-
Adult	60.87±1.08 a	30.62±0.59 b	20.62±0.46 c	-
Total stages	193.88±1.89 a	99.75±0.79 b	68±1.13 c	-

[a] Means followed by the same letters within rows are not significantly different (P< 0.05, Tukey`s HSD).

bagdasarjani at all stages was observed on the plants in comparison with *P. persimilis*. This difference was more visible in the adult

Table 2. Number of different stages of *Tetranychus urticae* and *Typhlodromus bagdasarjani* (Mean±SE) at different predator: prey ratios recorded 15 days after predator release in the first experiment.[a]

Prey stage	Predator: Prey ratios			
	1:4	1:10	1:20	Control
Egg	372.62±14.05 d	3827.8±212.38 c	6686±95.15 b	10290±322.48 a
Larva+Nymph	146±4.27 c	708.12±37.09 b	1161.9±55.65 a	1404.2±125.42 a
Adult	227.12±9.31 d	545.62±37.73 c	720.5±26.25 b	829.88±31.63 a
Total stages	744.75±8.74 d	5081.5±178.34 c	8581.8±67.55 b	12524±410.77 a
Predator stage				
Egg	22.62±0.88 a	13.25±0.45 b	7.12±0.35 c	-
Larva+Nymph	22.12±0.51 a	12.62±0.56 b	8.87±0.44 c	-
Adult	17.62±0.32 a	10.87±0.48 b	5.25±0.16 c	-
Total stages	62.37±0.93 a	36.75±0.53 b	21.25±0.45 c	-

[a] Means followed by the same letters within rows are not significantly different (P< 0.05, Tukey`s HSD).

Table 3. The percentage of reduction in different stages density of *Tetranychus urticae* at different predator: prey ratios recorded 15 days after *Phytoseiulus persimilis* and *Typhlodromus bagdasarjani* release in the first experiment.

Predator species	*T. urticae* stage	Predator: Prey ratios		
		1:4	1:10	1:20
Phytoseiulus persimilis	Egg	98.95%	79.04%	40.09%
	Larva+Nymph	91.7%	70.25 %	18.21%
	Adult	90.27%	50.11%	30.2%
	Total stages	97.64%	70.07%	37.24%
Typhlodromus bagdasarjani	Egg	96.37%	62.8%	35%
	Larva+Nymph	89.6%	49.57%	17.25%
	Adult	72.63%	34.25%	13.18%
	Total stages	94.05%	59.42%	31.47%

Table 4. Number of different stages of *Tetranychus urticae* (Mean±SE) at predators release ratio of 1:4 and the control recorded 15 days after predators release in the second experiment.[a]

T. urticae stage	Treatment		
	P. persimilis	*T. bagdasarjani*	Control
Egg	4±1.65 b	69.87±2.06 b	6112.4±137.48 a
Larva+Nymph	2.12±0.81 b	68.75±2.66 b	775.88±39.34 a
Adult	1.75±0.67 b	33.50±2.73 b	531.12±21.16 a
Total stages	7.87±3.07 b	172.12±2.59 b	7419.4±156.83 a

[a] Means followed by the same letters within rows are not significantly different (P< 0.05, Tukey`s HSD).

Table 5. Number of different stages of *Phytoseiulus persimilis* and *Typhlodromus bagdasarjani* (Mean±SE) at predators release ratio of 1:4 recorded 15 days after predators release in the second experiment.

Predator stage	Predator species		
	P. persimilis	*T. bagdasarjani*	*t*
Egg	1±0.33	11.75±0.49	-18.22*
Larva+Nymph	0.62±0.37	13.37±0.56	-18.80*
Adult	0	15.12±1.46	-10.38*
Total stages	1.62±0.53	40.75±2.23	-17.09*

* Significant difference at *P*< 0.001 (df= 14)

stages of predators (zero adult of *P. persimilis* versus 15 adults of *T. bagdasarjani*).

Since in the second experiment there was no significant difference between predator: prey ratio of 1:4 of the two predators, in the third experiment, we compared the effect of predator: prey ratio of 1:4 of *P. persimilis* and predator: prey ratio of 1:2 of *T. bagdasarjani*, 7 days after release of *T. urticae* on plants. According to the results of one-way ANOVA analysis, predator: prey ratios of both predators led to significant reduction in the different stages densities of *T. urticae* after 15 days ($F_{2,23}$= 2027, P< 0.0001; $F_{2,23}$= 488.09, P< 0.0001; $F_{2,23}$= 580.3, P< 0.0001; $F_{2,23}$= 2386, P< 0.0001, for egg, immature stages (larva and nymph), adult and total stages, respectively; Table 6). On the other hand, the results indicated no significant difference between predators presence effect on the reduction of *T. urticae* population (Table 6).

The number of predator stages at the above mentioned predator: prey ratios is shown in Table 7. As shown in this table, 15 days after predator release, there were more *P. persimilis* at all stages in comparison with *T. bagdasarjani*.

DISCUSSION

Predator initial density in prey-predator interactions is an effective parameter on population dynamic (Greco *et al*., 2005). The successful control of pests by predators depends on maintaining the correct balance between densities of predator and pest. In this regard, investigation of appropriate predator: prey release ratio is necessary to improve the biological control in order to achieve the fastest pest suppression and the least plant damage without a need to release a large number of predators (Hussey and Scopes, 1985; Alatawi *et al*., 2011).The release of great number of predators cause the fast pest population extermination and, as a result, the fast fade out of predators (Hussey and Scopes, 1985).

Our results indicated that the most

Table 6. Number of different stages of *Tetranychus urticae* (Mean±SE) at *Phytoseiulus persimilis* release ratio of 1:4 and *Typhlodromus bagdasarjani* release ratio of 1:2 as well as the control recorded 15 days after predators release in the third experiment. [a]

T. urticae stage	Treatment		
	P. persimilis	*T. bagdasarjani*	Control
Egg	103.5±2.91 b	129.62±2.2 b	10674±234.46 a
Larva+Nymph	103±2.68 b	49.5±2.03 b	1183.8±50.06 a
Adult	85.75±4.54 b	65.5±1.8 b	954.5±36.16 a
Total stages	292.25±6.59 b	244.62±2.78 b	12813±256.72 a

[a] Means followed by the same letters within rows are not significantly different (P< 0.05, Tukey`s HSD).

Table 7. Number of different stages of *Phytoseiulus persimilis* at release ratio of 1:4 and *Typhlodromus bagdasarjan* at release ratio of 1:2 (Mean±SE) recorded 15 days after predators release in the third experiment.

Predator stage	Predator species		
	P. persimilis	*T. bagdasarjani*	*t*
Egg	58.62±2.1	16.87±0.48	19.13*
Larva+Nymph	57.25±1.3	15±0.46	30.49*
Adult	54.87±2.08	17.12±0.55	17.53*
Total stages	170.75±4.19	49±0.91	28.42*

* Significant difference at *P*< 0.001 (df= 14).

reduction in *T. urticae* densities occurred in predator: prey ratio of 1:4, followed by predator: prey ratios of 1:10 and 1:20 for both predators. At all of these release ratios, a significantly decreased density of *T. urticae* was observed 15 days after predator release. Janssen and Sabelis (1992) explained that adequate predator: prey release ratios of phytoseiids –both specialists and generalists– for the control of tetranychid mites are usually between 1:60 and 1:20, at which ratios the phytoseiids growth rates need not be as high as that of tetranychids. In order to compensate the lower growth rate of phytoseiids in comparison with their tetranychid prey, they referred to the release of the larger quantities of phytoseiids with small *r* (the intrinsic rate of increase). Accordingly, in current research, the greatest reduction in *T. urticae* populations occurred at predator release ratios of 1:2 and 1:4 –greater quantities in comparison with the mentioned ratios in Janssen and Sabelis (1992) study – not only one day, but also 7 days after release of *T. urticae* females on plants. Moreover, our results support the findings of Opit *et al*. (2004) who showed the ability of *P. persimilis* in control of *T. urticae* at predator: prey ratios of 1:20 and 1:4 on ivy geranium. Also, Greco *et al*. (2005) referred to prey: predator ratio of 1:5 as the most effective ratio on the reduction density of *T. urticae* using *Neoseiulus californicus* (McGregor) on strawberry. Furthermore, Hamlen and Lindquist (1981) explained that the adequate predator: prey ratios for releasing phytoseiids to eliminate the tetranychid populations are between 1:20 and 1:60 for vegetables and between 1:4 and 1:20 for ornamentals in greenhouses.

Based on our results, the decrease in *T. urticae* densities and consequently the reduction in plant damage were obvious 15 days after predator releases. In this regard, Hussey and Scopes (1985) explained that infestation of every five-leaf cucumber plant with 20 *T. urticae* females and then release of one and two *P. persimilis* on every plant could lead to the successful control of spider mites within 6 and 3 weeks, respectively.

According to our experiments, predator populations were influenced by the predator initial densities at different predator: prey release ratios. One day after release of *T. urticae* and subsequently 15 days after predator releases (at the predator: prey release ratio of 1:4), more *T. bagdasarjani* was observed on the plants in comparison with *P. persimilis* (Table 5). This difference is more visible in the adult stages of predators, as the reproductive population. In other words, when only one day is available for *T. urticae* to increase their population, *T. bagdasarjani* is able to establish more population than *P. persimilis*. This could be due to the higher ability of generalist predators to establish their population in the absence of prey by feeding on pollen and plant exudates as alternative food (McMurtry and Croft, 1997; McMurtry *et al*., 2013; Khanamani *et al*., 2017; Riahi *et al*., 2017). In this study, using the cucumber plants could provide these alternative foods for *T. bagdasarjani*. When 7 days was available for *T. urticae* for reproduction, more *P. persimilis* (at release ratio of 1:4) was observed in comparison with *T. bagdasarjani* (at release ratio of 1:2) 15 days after predators release (Table 7). *Phyoseiulus persimilis* –as a specialist predator of *T. urticae* – shows the strong tendency to remain and reproduce in *T. urticae* patches. *Phytoseiulus* species have the highest potential for population increase among Phytoseiidae (McMurtry and Croft, 1997; McMurtry *et al*., 2013). This could be due to the more increase in population of *P. persimilis* compared with *T. bagdasarjani* in the presence of higher *T. urticae* density after 7 days in comparison with lower density of *T. urticae* after one day.

Based on our findings, there was no significant difference between predators effect on reduction of *T. urticae* densities not only at predator: prey release ratio of 1:4 of two predators, but also at release ratios of 1:4 of *P. persimilis* and 1:2 of *T. bagdasarjani*. As a result, both predators were able to control *T. urticae* on cucumber under microcosm conditions of this research. We found no significant difference in decline of *T. urticae* populations between *T.urticae-P. persimilis* and *T. urticae-T. bagdasarjani* interactions. This fact suggests that the effectiveness of these predators –one specialist and the other generalist– is similar in this research conditions. But, from another viewpoint, there are different features between these two predators. The strong dependence of *P. persimilis* on *T. urticae* for survival and reproduction has led to fade out this predator in the lack of its food and, consequently, the growers have to reintroduce this predator into the greenhouses (Overmeer, 1985; McMurtry and Croft, 1997; McMurtry *et al*., 2013). On the other hand, *T. bagdasarjani* –as a generalist predator– can survive and reproduce not only on tetranychid mites but also on some other prey species as well as plant exudates and pollen (Ganjisaffar *et al*., 2011a, b; Moghadasi *et al*., 2013, 2014; Farazmand *et al*., 2015; Khanamani *et al*., 2015). This trait can lead to the better establishment of *T. bagdasarjani* in comparison with *P. persimilis* in reduction or elimination of *T. urticae* population.

Our study predicates on the assessment of different *P. persimilis*/*T. bagdasarjani*: *T. urtice* release ratios in decreasing *T. urticae* populations and, consequently, decreasing plant damage. The results demonstrated that the most suppression of *T. urticae* populations occurred in predator: prey ratio of 1:4 in both predators. Based on our findings, we suggested that *P. persimilis* and *T. bagdasarjani* can be released at a ratio of 1:4 for successful control of *T. urticae* on cucumber. Since this study was done under microcosm conditions in a short period, further studies based on long-term experiments are required to satisfy control of *T. urticae* on cucumber.

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تأثیر نسبت‌های مختلف رهاسازی شکار: شکارگر در دو کنه شکارگر *Phytoseiulus persimilis* و *Typhlodromus bagdasarjani* بر کاهش جمعیت کنه تارتن *Tetranychus urticae* روی خیار در شرایط میکروکازم

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چکیده

میزان کاهش جمعیت شکار توسط شکارگر به رهاسازی نسبتهای موثر شکار: شکارگر بستگی دارد. در این پژوهش، کارآیی نسبتهای مختلف رهاسازی (شکار:شکارگر) دو کنه شکارگر *Typhlodromus bagdasarjani* Wainstein & Arutunjan و *Phytoseiulus persimilis* Athias-Henriot در کاهش جمعیت مراحل نموی کنه *Tetranychus urticae* Koch روی خیار در شرایط میکروکازم و بر اساس سه آزمایش، بررسی شد. در آزمایش نخست، بیشترین کاهش جمعیت در *T. urticae* و بیشترین افزایش جمعیت در *P. persimils* و *T. bagdasarjani* در نسبت رهاسازی ۱:۴ و متعاقب آن به ترتیب در نسبتهای ۱:۱۰ و ۱:۲۰ مشاهده شد. در آزمایش دوم در نسبت رهاسازی ۱:۴، تفاوت معنی‌داری بین تاثیر دو کنه شکارگر بر کاهش جمعیت T. urticae وجود نداشت. در این آزمایش تعداد بیشتری *T. bagdasarjani* در مقایسه با *P. persimilis* روی گیاهان وجود داشت. در آزمایش سوم، تفاوت معنی‌داری بین تاثیر *P.persimilis* در نسبت ۱:۴ و *T. bagdasarjani* در نسبت ۱:۲ بر کاهش جمعیت *T. urticae* مشاهده نشد. در این آزمایش تعداد بیشتری *P.persimilis* در مقایسه با *T. bagdasarjani* روی گیاهان دیده شد. نتایج این پژوهش نشان داد که بیشترین میزان کاهش جمعیت *T. urticae* در هر دو شکارگر در نسبت رهاسازی ۱:۴ بوده است. بر این اساس، به منظور کنترل موفق *T. urticae*، رهاسازی هر دو کنه شکارگر به نسبت ۱:۴ قابل توصیه است.