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Article

Assessing predation parameters of the predatory mite *Typhlodromus bagdasarjani* (Acari: Phytoseiidae) on different host plants

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ABSTRACT

It is important to use standard parameters for assessing the biological performance of natural enemies in biological programs. The predation parameters of *Typhlodromus bagdasarjani* Wainstein & Arutunjan (Acari: Phytoseiidae) fed on the immature stages of the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), reared on four different host plants including cucumber (cultivar 'Negin'), tomato (cultivar 'Isabella'), eggplant (cultivar 'Bell') and watermelon (cultivar 'Crimson') were determined under laboratory conditions at 25 ± 1 °C, 60 ± 5% R.H. and a photoperiod of 16:8 (L:D) h. Predation data were analyzed using the CONSUME MSChart. The lowest and highest estimated values for the net predation rate (C_0) were recorded on eggplant (35.12 prey/individual) and tomato (95.87 prey/individual), respectively. The lowest transformation rate from prey population to predator offspring (Q_p) (12.76 prey/egg) was recorded on cucumber which was not significantly different from those obtained on the others. The highest value for the stable predation rate (ψ) was recorded on the cucumber (2.49 prey/predator) and the lowest amount was recorded on the watermelon (1.93 prey/predator). The finite predation rate (ω) for *T. bagdasarjani* on the above-mentioned host plants was 2.73, 2.61, 2.03, and 2.04 (day^{-1}), respectively. Our findings revealed the predation parameters of *T. bagdasarjani* fed on immature stages of *T. urticae* on four different host plants and will be helpful for its sustainable management in different agro-ecosystems.

KEYWORDS: Biological control, different host plants, predation rate, spider mites, tri-trophic interactions.

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INTRODUCTION

As a cosmopolitan pest, the two-spotted spider mite, with a wide range of host plants, has been known to cause significant crop loss to different host plants such as eggplant (Khanamani *et al*. 2013), common bean (Ahmadi *et al*. 2007; Najafabadi *et al*. 2014), cucumber (Shoorooei *et al*. 2012; Maleknia *et al*. 2016; Razdoburdin and Kozlova 2016), strawberry (Karlec *et al*. 2017), tomato (Ferrero *et al*. 2011), soybean (Sedaratian *et al*. 2011), and rose (Moghadasi *et al*. 2013; Alipour *et al*. 2016). The feeding activities of *T. urticae* lead to both direct (sucking the leaf contents and decreasing chlorophyll content) and indirect (producing web nets on plant foliar and reducing light absorption for optimal photosynthesis) damages which drastically affect the quantity and quality of the yield (Alipour *et al*. 2016; Azadi-Qoort *et al*. 2019).

In addition to the environmental pollution, being hazardous to human health, and adverse effects

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on non-target organisms, the ability of *T. urticae* for developing resistance to different miticides has created several problems in its management programs (Dermauw *et al*. 2012; Rezaei *et al*. 2018). Accordingly, in recent years, considerable emphasis has been devoted on safe environmental practices for integrated management of spider mites (Abad-Moyano *et al*. 2010). Application of resistant host plants (Sedaratian *et al*. 2009) and biological agents (Poletti *et al*. 2007) have been noted as reliable alternatives.

Family Phytoseiidae contains the most promising predators of phytophagous mites in different cropping systems (Gerson *et al*. 1985). *Typhlodromus* (*Anthoseius*) *bagdasarjani* Wainstein & Arutunjan is a native species in the Middle East (Kamali *et al*. 2001) which is reported from plants infected with spider mites, eriophyoids, tydeids, thrips, and whiteflies (Farazmand *et al*. 2012). Members of this genus are categorized as type III phytoseiids (McMurtry *et al*. 2013). Laboratory studies have shown the compatibility of this predator with high temperatures (Ganjisaffar *et al*. 2011a, b). Functional response and mutual interference of *T. bagdasarjani* on *T. urticae* was evaluated by Farazmand *et al*. (2012). These researchers also studied the predation preference of *T. bagdasarjani* on heterospecific phytoseiid *Neoseiulus californicus* (McGregor) and *Scolothrips longicornis* Priesner (Farazmand *et al*. 2013) as well as intraguild predation among these three predators (Farazmand *et al*. 2015). In addition, the cannibalism behavior of predator *T. bagdasarjani* was also evaluated in a different study performed by Farazmand *et al*. (2014). Khanamani *et al*. (2014) reported that the reproductive performance and survivorship of this predatory mite can be affected by host plant chemistry. The possible effects of different pollen grains as supplementary food on the population parameters of *T. bagdasarjani* were estimated by Riahi *et al*. (2016).

Assessing the biological performance of any natural enemy is crucial to evaluate both biological and behavioral attributes (Fathipour and Maleknia 2016). Although the life table parameters provide the most comprehensive information on the biological traits of pests and natural enemies, their connection with predation rates is important to describe and to compare the potential of biological agents in pest management programs (Tuan *et al*. 2015). Such studies generate standard parameters to determine the growth and development, stage differentiation, reproduction, and predatory rates effectively with regard to age, stage, and sex (Chi and Yang 2003; Yu *et al*. 2013). Biological performance of predators, however, cannot be properly described using the population parameters alone (Chi *et al*. 2011). Predation parameters are also useful indicators to reveal the capacity of natural enemies in certain circumstances. Several factors can influence the parameters mentioned, including the host plant (Khanamani *et al*. 2014), the quality of the diet (Perumalsamy *et al*. 2009; Farhadi *et al*. 2011; Negm *et al*. 2014; Solano *et al*. 2016), the availability of supplementary food (Riahi *et al*. 2016; Khanamani *et al*. 2017), the age of the prey (Madahi *et al*. 2015; Fathipour *et al*. 2017), and the predator's body size (Vangansbeke *et al*. 2016).

In tri-trophic systems, the nutritional quality of a host plant may indirectly affect the biological efficiency of the predator (negatively or positively) (Khanamani *et al*. 2014). Hence, in order to determine the precise quality of a natural enemy, descriptions of growth and development, survivorship, age structure, and fecundity as well as predation rate are urgently required. A review of literature clearly exhibited that our current information about possible effects of different host plants on the predation parameters of *T. bagdasarjani* is extremely limited. Accordingly, to fill this gap, the present study was designed to evaluate any possible effects of different host plants (cucumber (cultivar ‘Negin’), tomato (cultivar ‘Isabella’], eggplant (cultivar ‘Bell’) and watermelon (cultivar ‘Crimson’) on the predation parameters of this indigenous species. Such information could be helpful for successful application of *T. bagdasarjani* in biocontrol programs.

MATERIALS AND METHODS

Plant cultivation

The seeds of four different host plants including cucumber (cultivar ‘Negin’), tomato (cultivar

‘Isabella’), eggplant (cultivar ‘Bell’), and watermelon (cultivar ‘Crimson’) were obtained from Plant Protection Organization, Yasouj, Iran. Iranian farmers commonly grow these varieties in their greenhouses. The seeds were sown in plastic pots (20 cm diameter and 18 cm height) filled with fertilized field soil under greenhouse conditions (27 ± 5 ℃, 65 ± 15 R.H. and natural light period). During the experiments, all plants were irrigated at the same time (2-day intervals). Moreover, no chemical fertilizers or pesticides were utilized. These plants were used for the maintenance of mite colony and experimentations.

Mass rearing of prey and predator

The initial specimens of *T. urticae* were collected during 2015 from infected bean fields in Kohgiluyeh and Boyer Ahmad Province. The mite colony on each host plant (*i.e.* four mite colonies) was kept in mesh cages (200 × 70 × 100 cm) at a rate of 6–8 infected plants per each cage. Every week, the deceased hosts were replaced with new, healthy ones. The colonies were supplemented with the new mite samples to minimize any inbreeding effects.

To rear the laboratory colony of the predatory mite, the initial samples of *T. bagdasarjani* were obtained from the colony in the Department of Entomology, Faculty of Agriculture, Tarbiat Modares University. This sample was divided into four separate parts and transferred to the leaf discs (8 cm diameter) of each host plant. The immature stages (egg, larva, and protonymph) of *T. urticae* which were reared on each host plant were daily brushed into the related colony. The predators also were provided with maize pollen twice a week. Before the experiments, the mite colony was separately reared on different host plants for at least four generations. Predator colonies were maintained in four different growth chambers at 25 ± 1 ℃, R.H. of 65 ± 5%, and a photoperiod of 16L: 8D h.

Leaf disc preparation

To evaluate predation parameters of *T. bagdasarjani* on different host plants, the leaf disc method was used (Sedaratian *et al*. 2009, 2011). This arena was built from Petri dishes (6 cm diameter and 1.5 cm height). This arena was built from Petri dishes (6 cm diameter and 1.5 cm height) and the leaves of each host plant at the beginning of reproductive stage. Rings were cut from randomly picked material with a diameter of 5.5 cm. The rings were placed upside down on the water-soaked cotton bed in the above-mentioned discs, and a cotton strip was wrapped around the edges to prevent any predators from escaping. After this, the prepared dishes were put inside larger ones (8 cm diameter and 1.5 cm height). The lid of larger discs had a ventilation hole in its center (1.5 cm diameter) which was covered with a fine mesh net. To keep the cotton bed saturated and the leaves fresh, adequate water was daily added to the larger discs.

Experimental setup

All experiments were performed under laboratory conditions at 25 ± 1 ℃, 65 ± 5% R.H., and a photoperiod of 16L: 8D h. Fifty same-aged (< 24 h) adult predators (♀ + ♂) were randomly selected from the colonies, which established on each host plant and transferred onto leaf discs. An adequate number of immature stages of *T. urticae* (> 1000 prey) were brushed daily on the leaf surface for predator feeding. The laid eggs of the two first days were removed. On the third day of oviposition, sixty same-aged eggs (< 12 h) were carefully harvested from the rearing arenas and used for the experiments. These were separately transferred onto a leaf disc and monitored daily. After egg hatching, forty prey (larva + protonymph) were added daily into each arena for feeding. During daily observations, the number of preys eaten was carefully recorded. After counting, the mite carcasses were removed from the arenas and replaced by new ones. In addition to the daily predation, development to the subsequent stages and survivorship of all individuals tested were also documented. After adult emergence, the female predators were coupled with male individuals reared on the same host. The pairs were then moved onto the new discs. Each couple was supplied daily with 60 preys and predation was monitored. Female fecundity was also recorded until the death of the last individual. During the experiments, the predators were also fortified by the supplementary food (pollen maize) as previously described.

Data analysis

The data gathered on the daily predation of different life stages of predatory mite *T. bagdasarjani* feeding on the immature stages of *T. urticae*, together with some outputs of the age-stage two-sex life table of this predator (unpublished data), were used to estimate the predation parameters using the CONSUME-MSChart software (Chi 2016a).

In this procedure, the following parameters were calculated (Chi and Yang 2003). The age-stage-specific predation rate (c_{xj}) is the mean number of preys consumed by predators at age x and stage j. The mean number of consumed preys at age x (age-specific predation rate [k_x]) was estimated according to the following equation:

$$k_x = \frac{\sum_{j=1}^{\beta} s_{xj} c_{xj}}{\sum_{j=1}^{\beta} s_{xj}}$$

where b is the number of life stages and s_{xj} is the age-stage-specific survival rate. The age-specific net predation rate (q_x) was calculated as $q_x = k_x l_x$, where l_x is the age-specific survival rate.

Another parameter was net predation rate (mean number of preys consumed by an individual during its life span [C_0]) calculated as:

$$C_0 = \sum_{x=1}^{\&} \sum_{j=1}^{\beta} s_{xj} c_{xj}$$

The ratio of the net predation rate (C_0) to the net reproduction rate (R_0) has been considered as transformation rate (Q_p) from the prey population to predator offspring and estimated as $Q_p = C_0/R_0$.

Furthermore, the stable predation rate (total predation capacity of a stable population [ψ]), and finite predation rate (predation potential of *T. bagdasarjani* population by combining its growth rate (λ), age-stage predation rate (c_{xj}), and stable age-stage structure (a_{xj}) [ω]) were also calculated according to Chi and Yang (2003) as:

$$\varphi = \sum_{x=0}^{\infty} \sum_{j=1}^{\beta} a_{xj}\, c_{xj}$$

and

$$\omega = \lambda\varphi = \lambda \sum_{x=0}^{\infty} \sum_{j=1}^{\beta} a_{xj}\, c_{xj}$$

To calculate the variance and standard error (SE) of the predatory parameters, the bootstrap procedure was applied with 100,000 resampling (Huang and Chi 2012). The mean grouping was performed using a paired bootstrap test at TWOSEX-MSChart (Chi 2016b). All graphs were prepared by the Excel (2016).

RESULTS

Age-specific predation rate, age-specific net predation rate, and age-specific survival rate

The age-specific predation rate (k_x) and age-specific net predation rate (q_x) of the predatory mite *T. bagdasarjani* fed on immature stages of *T. urticae* on different host plants are illustrated in Figure

1. Our findings revealed that the bottom-up effects of different hosts significantly affected the predation parameters of *T. bagdasarjani* and these parameters had a host-dependent pattern. Considering the effects of age-specific survival rate (l_x), the values estimated for the age-specific net predation rate (q_x) were different from those calculated for the age-specific predation rate (k_x) on the same host (Fig. 1). With increase of the age of predator, the values estimated for the age-specific predation rate were increased and reached their peak at ages 50, 35, 48, and 48 days as 6.0, 9.3, 14.5, and 11.5 preys on the cucumber, eggplant, tomato, and watermelon, respectively (Fig. 1). The downward trend of age-specific survival rate (l_x) had a considerable effect on the age-specific net predation rate and caused its differences from the k_x (Fig. 1). In addition, the survivorship of *T. bagdasarjani* was lower on the eggplant and watermelon than other hosts indicated by the steepest slope of the age-specific survival rate curve in the first days (Fig. 1).

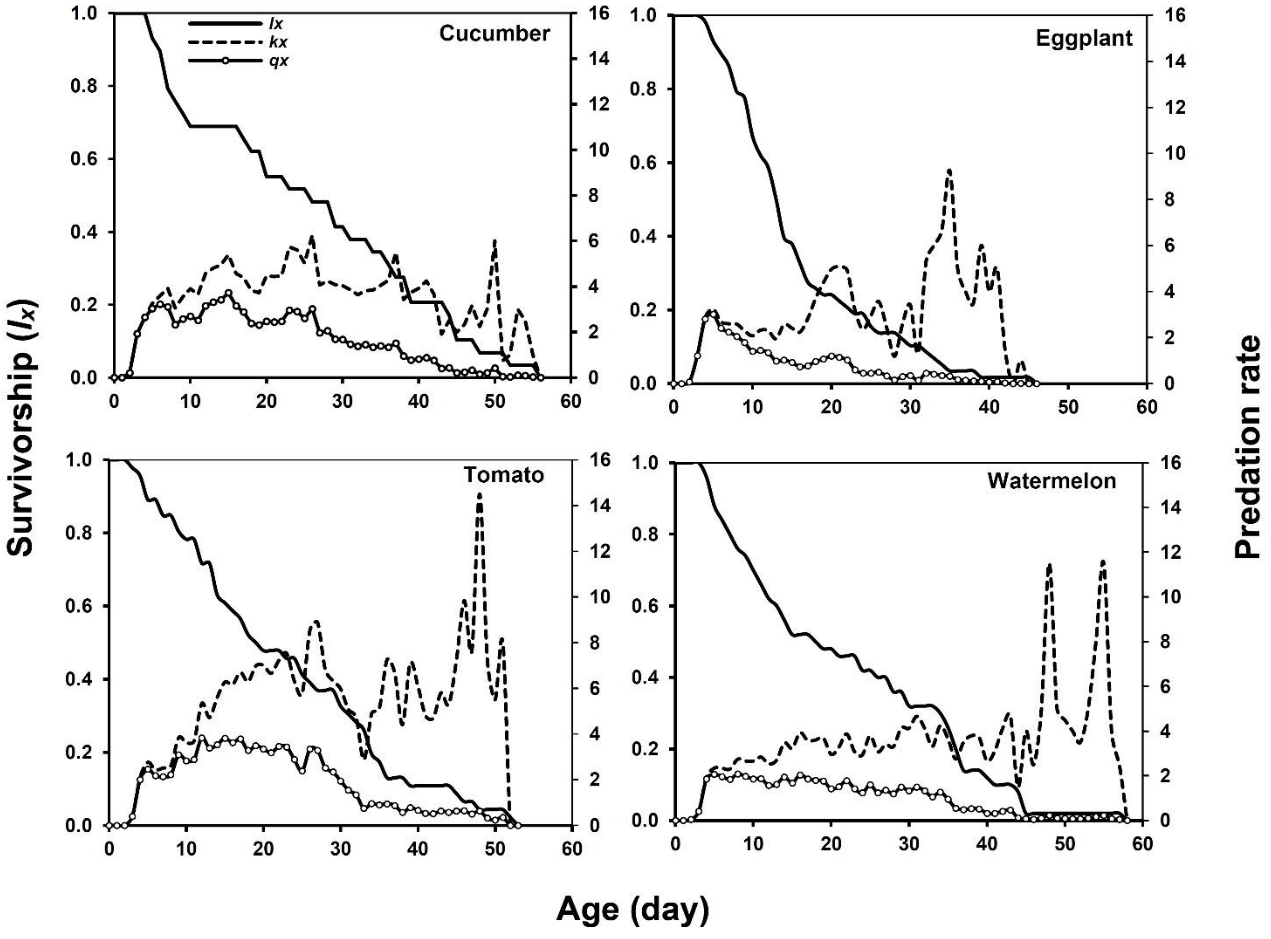

Figure 1. The age-specific survival rate (l_x), age-specific predation rate (k_x), age-specific net predation rate (q_x) of predatory mite *Typhlodromus bagdasarjani* fed on immature stages of *Tetranychus urticae* reared on different host plants.

Age-stage-specific predation rate

Figure 2 exhibits the age-stage-specific predation rate (c_{xj}) for different life stages of the predatory mite *T. bagdasarjani* when fed with immature stages of *T. urticae* reared on different host plants. This parameter reflects the average number of preys consumed by the predatory mite at age *x* and stage *j* on the host plants tested. Because the eggs had no feeding activity and the negligible predation of larvae, the recorded values for immature development in this figure are mostly related to the protonymphs and deutonymphs. In the case of adult predators, the female individuals had relatively more predation than male ones on all hosts tested. On watermelon, due to the shorter life span of female predators, a higher consumption at the late ages was documented for the male individuals (Fig. 2). The maximum number of consumed preys by the female predators was 6.45, 9.25, 9.75, and 6 at the ages 26, 35, 39, and 39 on the cucumber, eggplant, tomato, and watermelon, respectively.

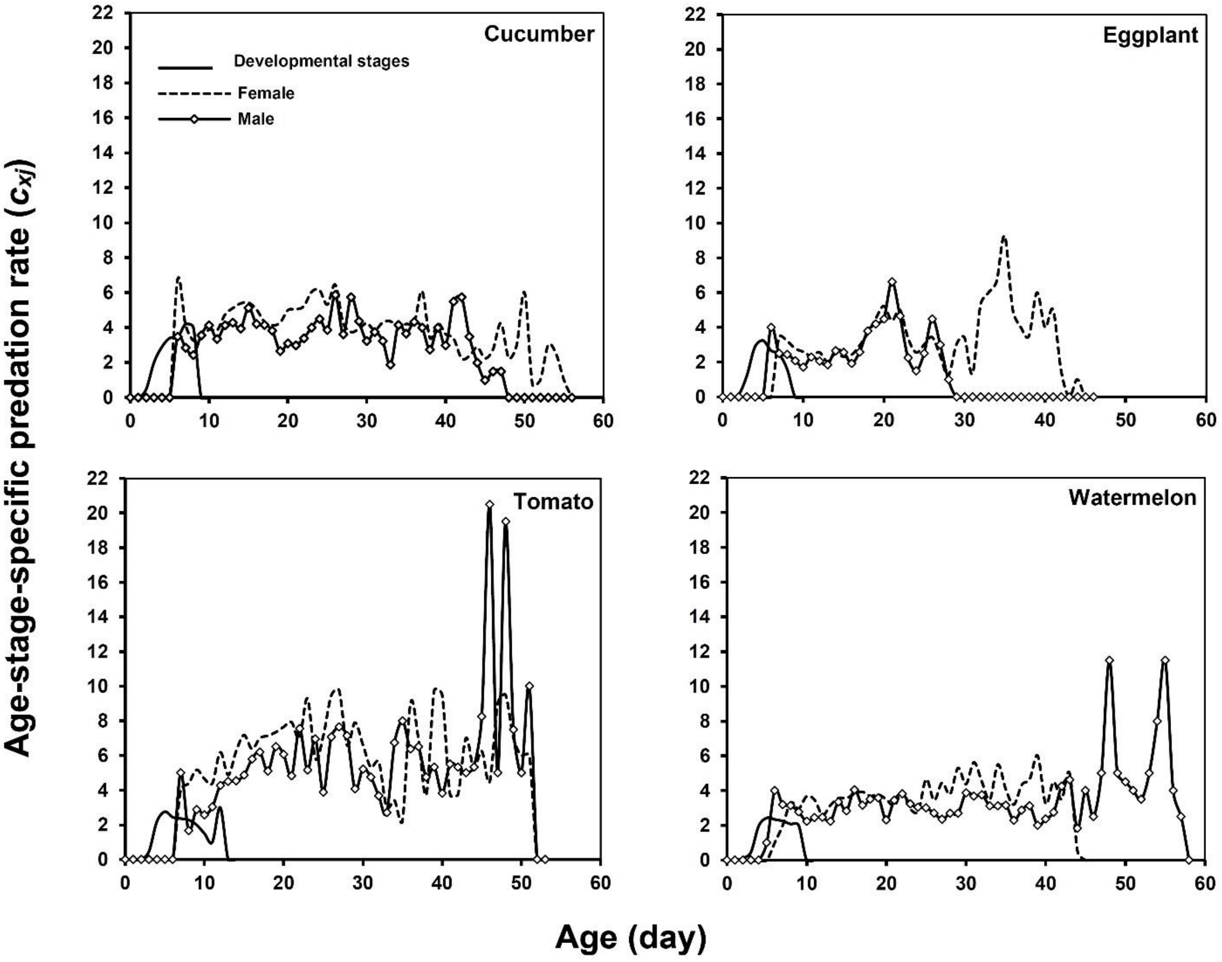

Figure 2. Age-stage-specific predation rate (c_{xj}) of predatory mite *Typhlodromus bagdasarjani* fed on immature stages of *Tetranychus urticae* on different host plants.

Predation parameters

Table 1 presents predation parameters of *T. bagdasarjani* on different host plants. The highest value of the net predation rate (C_0) was recorded on the tomato (95.87 prey/individual) and cucumber (91.52 prey/individual), and the lowest value of this parameter was observed on the eggplant (35.12 prey/individual). Although there was no significant difference among the estimated values of transformation rate (Q_p) on host plants tested, the highest value of this parameter (16.43 prey/egg) was recorded on the eggplant. In the case of stable predation rate (ψ) significant differences were also detected, and the highest values were as 2.49 and 2.37 (prey/predator) on the cucumber and tomato, respectively. Similar outputs were also observed for the finite predation rate (ω) on different host plants; having the highest values on the cucumber and tomato (2.73 and 2.61 day^{-1}, respectively) and the lowest ones on the eggplant and watermelon (2.03 and 2.04 day^{-1}, respectively) (Table 1).

Table 1. Predation parameters of predatory mite *Typhlodromus bagdasarjani* on different host plants feeding immature stages of *Tetranychus urticae*.

	Different host plants			
	Cucumber	**Eggplant**	**Tomato**	**Watermelon**
Net predation rate (C_0) (prey/individual)	91.524 ± 13.579^a	35.121 ± 4.882^b	95.870 ± 12.875^a	56.990 ± 7.543^c
Transformation rate (Q_p) (prey/egg)	12.761 ± 2.600^a	16.427 ± 8.470^a	14.554 ± 3.035^a	15.157 ± 4.427^a
Stable predation rate (ψ) (prey/predator)	2.487 ± 0.192^a	1.961 ± 0.124^b	2.370 ± 0.147^a	1.927 ± 0.112^b
Finite predation rate (ω) (day^{-1})	2.734 ± 0.237^a	2.032 ± 0.157^b	2.605 ± 0.182^a	2.042 ± 0.135^b

* The same letters in each row do not differ significantly (Paired bootstrap test, $P < 0.05$).

DISCUSSION

Realizing the incredible role of host plants in multitrophic interactions is a key factor in our ability to assess the strength of top-down effects on phytophagous populations. The quality of host plants consumed by phytophagous pests could affect the population dynamics of natural enemies. As previously proven, herbivores on different host plants often differ in their susceptibility to natural enemies (Lill *et al*. 2002; Zvereva and Rank 2003). Host plants serve as the first level of the tri-trophic system of the plant-herbivore-predator, and their traits influence the stability of prey-predator complexes occurring on the plants (Messina and Hanks 1998). In a tri-trophic system, secondary biochemicals in the plant tissues can directly affect the fitness of phytophagous organisms (Soleimannejad *et al*. 2010; Soufbaf *et al*. 2010; Karimi *et al*. 2012), and they can indirectly affect the biological performance of the insect predators/parasitoids (Sedaratian-Jahromi 2021). The negative impacts of host plant chemistry on the biological efficiency of natural enemies include reducing their survivorship, body size, and fecundity (Ode 2006). Accordingly, it is crucial to evaluate any possible interactions between different host plants and biocontrol agents prior to their simultaneous application in the integrated management programs. As a critical need to accurately evaluate the effect of predation in a prey-predator system, there is a vital demand for assessing both the growth potential and predation capacity because it is possible that a predator shows a variety of predation behaviors on different host plants (Khanamani *et al*. 2014; Alipour *et al*. 2016).

Our findings revealed that different host plants can affect predation parameters of indigenous species *T. bagdasarjani* and the value of net predation rate (C_0) for this predator on tomato and cucumber was significantly higher than other hosts. This may be due to the smaller size of *T. urticae* on these hosts than on the eggplant and cucumber so that the predator needs to consume more prey items for its growth and development (Cogni *et al*. 2002). These results are in agreement with those previously discussed by Khanamani *et al*. (2015) for this predatory mite on different cultivars of the eggplant. In addition to body size, increased movement of phytophagous pests on some host plants increases their exposure to their natural enemies (Kaitaniemi 2004). The morphological traits of host plants (specifically the height and density of trichomes) have also been suspected as possible factors which could have prevented the prey from feeding on the leaf surface and hence promoted its movement (Kaplan and Thaler 2010). However, more attention should be devoted to accurately assess such effects.

The results presented herein clearly show the negative effects of the two-spotted spider mites reared on the eggplant and watermelon on the predation capacity of *T. bagdasarjani*. Such differences could be interpreted in light of possible variations in biochemical profiles and morphological traits of the host plants. These characters play an important role in the host suitability for the growth and development of *T. urticae* which are frequently noted by several researchers (e.g., Ahmadi *et al*. 2007; Sedaratian *et al*. 2009, 2011; Najafabadi *et al*. 2014; Azadi-Qoort *et al*. 2019). Khanamani *et al*. (2015) stated that the concentrated secondary biochemicals in the prey are also toxic for predatory mite *T. bagdasarjani* and affected the biological efficiency of this predator. The same reports were also published by Moghadasi *et al*. (2016) in the case of *Phytoseiulus persimilis* Athias-Henriot and Alipour *et al*. (2016) for *P. persimilis* and *Amblyseius swirskii* Athias-Henriot on different rose cultivars.

The transformation rate from *T. urticae* population reared on different host plants to *T. bagdasargani* offspring (Q_p) was varied from 12.76 on cucumber to 16.43 on eggplant. The Q_p gives a demographic estimation for the relationship between the reproduction rate (R_0) and predation rate (C_0) of the predator (Farhadi *et al.* 2011) and indicates the transformation rate from prey population to predator offspring. For example, on cucumber, *T. bagdasarjani* requires approximately 13 preys to produce one egg while this value is 16.43 on eggplant reflecting the lower quality of mites reared on this host. The lower transformation rate on the cucumber and tomato could be due to the adequate essential nutrients for egg production in the prey reared on these hosts.

It is impossible to correctly interpret the biological efficiency of natural enemies without information on both life table and predation parameters. In other words, to precisely evaluate the effect of predation in biocontrol programs, we need not only to assess the growth potential of natural enemies but also to evaluate their predation capacity (Chi *et al*. 2011). The finite predation rate (ω) takes several parameters such as the finite rate of increase (λ), age-stage-specific structure (a_{xj}) and the age-stage predation rate (k_x) of a predator population into account, and hence can be considered as a reliable parameter for describing and comparing the predation potential of natural enemies (predator/parasitoid) applied in biocontrol programs (Riahi *et al*. 2017). Based on the present information, due to the higher finite predation rate of *T. bagdasarjani* on cucumber and tomato, the performance of this predator on these hosts is higher than those observed on eggplant and watermelon. Our previous report on susceptibility of these host plants to *T. urticae* in which cucumber and tomato had the lowest and highest resistance to this mite pest, respectively (Azadi-Qoort *et al*. 2019); present results illustrate compatibility of *T. bagdasarjani* with different host plants. Such interactions facilitate the simultaneous application of these control strategies and should be considered as a positive point for sustainable management of spider mite populations in different agro-ecosystems as well as possible financial investment in this indigenous phytoseiid in the future.

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ارزیابی آماره‌های شکارگری کنهٔ شکارگر *Typhlodromus bagdasarjani* (Acari: Phytoseiidae) روی میزبان‌های مختلف گیاهی

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چکیده

به‌عنوان یک نیاز اساسی، استفاده از آماره‌های استاندارد به‌منظور ارزیابی میزان کارایی دشمنان طبیعی در برنامه‌های مهار زیستی بسیار ضروری است. در پژوهش حاضر، آماره‌های شکارگری کنه شکارگر *Typhlodromus bagdasarjani* Arutunjan & Wainstein (Acari: Phytoseiidae) با تغذیه از مراحل نابالغ کنهٔ تارتن دولکه‌ای، *Tetranychus urticae* Koch (Acari: Tetranychidae)، پرورش یافته روی چهار میزبان گیاهی مختلف شامل خیار (رقم «نگین»)، گوجه‌فرنگی (رقم «ایزابلا»)، بادمجان (رقم «بل») و هندوانه (رقم «کریمسون») و در شرایط آزمایشگاهی با دمای ١ ± ٢٥ درجهٔ سلسیوس، رطوبت نسبی ٥ ± ٦٠ درصد و دورهٔ نوری ١٦ ساعت روشنایی و ٨ ساعت تاریکی مورد مطالعه قرار گرفت. داده‌های شکارگری با استفاده از نرم‌افزار آماری CONSUME MSChart تجزیه و تحلیل و مورد بررسی قرار گرفتند. کمترین و بیشترین مقادیر محاسبه شده نرخ خالص شکارگری (C_0) به‌ترتیب روی بادمجان (٣٥/١٢ طعمه/فرد شکارگر) و گوجه‌فرنگی (٩٥/٨٧ طعمه/فرد شکارگر) محاسبه شد. پایین‌ترین میزان نرخ تبدیل از جمعیت طعمه به نتاج شکارگر (Q_p) (١٢/٧٦ طعمه/تخم) روی خیار به‌دست آمد که اختلاف معنی‌داری با مقادیر ثبت شده این آماره روی سایر میزبان‌های گیاهی مورد مطالعه نداشت. بالاترین میزان نرخ پایدار شکارگری (ψ) روی خیار (٢/٤٩ شکار/شکارگر) و پایین‌ترین میزان این آماره (١/٩٣ شکار/شکارگر) نیز روی هندوانه به‌دست آمد. نرخ نامتناهی شکارگری (ω) برای کنهٔ شکارگر *T. bagdasarjani* روی میزبان‌های گیاهی ذکر شده در بالا به‌ترتیب برابر با ٢/٧٣، ٢/٦١، ٢/٠٣ و ٢/٠٤ (بر روز) ثبت شد. یافته‌های پژوهش حاضر در ارتباط با آماره‌های شکارگری کنهٔ شکارگر *T. bagdasarjani* با تغذیه از مراحل نابالغ کنه تارتن *T. urticae* روی چهار میزبان گیاهی مختلف، به‌منظور مدیریت پایدار این آفت در بوم‌سامانه‌های مختلف کشاورزی بسیار مفید خواهند بود.

واژگان کلیدی: مهار زیستی، میزبان‌های مختلف گیاهی، میزان شکارگری، کنه‌های تارتن، برهم‌کنش سطوح سه‌گانه غذایی.

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