Journal of Ornamental Plants
Available online on: www.jornamental.iaurasht.ac.ir
ISSN (Print): 2251-6433 ISSN (Online): 2251-6441
Research Paper

Life-History of the Predatory Mite *Amblyseius swirskii* (Athias-Henriot) (Acari: Phytoseiidae) on *Tetranychus urticae* Koch (Acari: Tetranychidae), *Carpoglyphus lactis* Linnaeus (Acari: Carpoglyphidae) and *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae)

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Received: 08 January 2020 Accepted: 23 May 2020
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Abstract

The predatory mite *Amblyseius swirskii* Athias-Henriot is one of the most common biological-control agent of different mites and insect pests, such as two-spotted spider mite and greenhouse whitefly. To evaluate *A. swirskii* potential role in controlling three pest species, the present survey investigated the life history of this predatory mite when fed on eggs of *Tetranychus urticae, Trialeurodes vaporariorum* and *Carpoglyphus lactis* under laboratory conditions (25 ± 1°C, 70 ± 5% RH and 16 L: 8D). Results showed that the predator mite is able to feed and complete its development on the above mentioned pest species. The predator displays particularly high capacity for population growth when fed on *T. urticae* and *C. lactis*, therefore it be able to provide an effective control of these pests in the gardens and the greenhouses. When *T. vaporariorum* was fed, significantly, increase in development and pre-oviposition times, and a reduction in oviposition period and fecundity were observed. In addition, the estimated life table parameters of *A. swirskii* including r, λ and R_0 significantly descended when the predator fed on the whitefly. Our results showed that this predatory mite has an effective ability as an effective biological control agent for *T. urticae*, *C. lactis* and *T. vaporariorum* in greenhouse.

Keywords: *P*redatory mite, The dried fruit mite, The greenhouse whitefly, Tow-spotted spider mite.

INTRODUCTION

The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae) and the dried fruit mite, *Carpoglyphus lactis* (Linnaeus), (Acari: Carpoglyphidae) are considered as serious pests reported from many host species, including the economically important crops in farms, greenhouses and stored commodities (Chmielewski, 1970; Xu *et al*., 2012; McKenzie *et al*., 2014; Javadi Khederi *et al*., 2014 & 2019; Hosseininia *et al*., 2017).

The population of *Tetranychus urticae* has significantly increased in crop-producing areas of Iran and this pest can produce about 20 generations per year under suitable conditions (Khanjani and Hadad Irani-Nejad, 2009; Javadi Khederi *et al*., 2014; Shahbaz *et al*., 2019; Osman *et al*., 2019). This mite infests both sides of the leaves where it produces much webbing and it causes yellow chlorotic spots on the leaves. Severe infestation causes the leaves become brown and dies, resulting in decreased fruit yield and reduced fruit quality (Martinez–Ferrer *et al*., 2006). The greenhouse whitefly, *Trialeurodes vaporariorum*, removes a large amount of phloem sap from plants, causing chlorosis in the infected leaves, decreasing fruit yield and quality (Bi and Toscano, 2007; Hosseininia *et al*., 2017; Javadi Khederi *et al*., 2019). Also, they excrete honeydew, which promotes the growth of sooty mold fungi, and affects plant physiology (Bi *et al*., 2001; Hosseininia *et al*., 2017). The dried fruit mite, *Carpoglyphus lactis*, is not a stored product mite infesting saccharide-rich stored commodities, including dried fruits, candied fruits, sweet drinks and different sweets (Chmielewski, 1970; Ji *et al*., 2015). As in many other agricultural areas in the world, control of *T. urticae* and *T. vaporariorum* in Iran has been heavily dependent on repeated applications of chemical insecticides (Javadi Khederi *et al*., 2014; Hosseininia *et al*., 2017). The high reproductive potential of the above mentioned pests along with their short life cycles, and frequent use of synthetic pesticides result in rapid resistance to pesticides in the mite and whitefly populations (Khalaf *et al*., 2010; Hosseininia *et al*., 2017; Javadi Khederi *et al*., 2019).

In addition, the environmental pollution, food contamination and effect on biological agents are the other scenarios that need serious concern and attention (Desneux *et al*., 2007; Horowitz *et al*., 2007; Liang *et al*., 2012; Guedes *et al*., 2016; Javadi Khederi *et al*., 2019). Thus, it is important to search the innovative practices for control of these pests, with lowest risks and compatibility with the environment, such as biological control methods.

Among predaceous that can suppress pest population, the phytoseiid mites, which considered as important biological control agents against different kinds of pests, are commercially used on various greenhouse crops worldwide (Nomikou *et al*., 2001; Gerson and Weintraub, 2012). *Amblyseius swirskii* (Acari: Phytoseiidae) is a very efficient biocontrol agent of whiteflies (Calvo *et al*., 2011; Zhang *et al*., 2015), thrips (Calvo *et al*., 2011; Juan-Blasco *et al*., 2012), and several phytophagous mites, such as two-spotted spider mites and the dried fruit mite (van Houten *et al*., 2007; Zhang *et al*., 2015; Ji *et al*., 2015 and Seiedy *et al.*, 2016).

Moreover, numerous studies of the life table of *A. swirskii* have been reported on various prey species (Park *et al*., 2010 & 2011; Fouly *et al*., 2011; Ji *et al*., 2015; Seiedy *et al*., 2016). It is necessary to assay whether *A. swirskii* is able to suppress the populations of three major pests, including *T. urticae*, *C. lactis* and *T. vaporariorum* as well as their impact on *A. swirskii* life history and success of the population. It is necessary to assay whether *A. swirskii* is able to suppress the populations of three major pests, including *T. urticae*, *C. lactis* and *T. vaporariorum* as well as their impact on *A. swirskii* life history and success of the population. Thus, we evaluated the life table parameters of *A. swirskii* on the eggs of the above mentioned preys under laboratory conditions.

MATERIALS AND METHODS

Plants, preys and the predatory mite

Rose bare-root seedlings (*Rosa hybrid* cv. Apollo) were planted in 2.6-L pots filled with a 1.3:1 sand: peat moss mixture (by volume) in a greenhouse located at the experimental site of the National Ornamental Plant Institute, Mahallat, Iran. The samples collected from mites and whiteflies were first identified and then purified, and after ensuring the desired species, they were bred and used in experiments. The initial population of *T. vaporariorum* was established using nymph-infested foliage collected from rose greenhouses, Mahallat vicinity, Iran. Briefly, the leaves bearing nymphs and pupae were brought to the laboratory and placed with rose plants in insect rearing cages at 25 ± 1 °C, 70 ± 5% RH and photoperiod of 16:8 h (L:D). Then, 40 female adults of *T. vaporariorum* were confined in a clip cage (2 cm diameter, 1 cm high) on the lower side of leaves for 24 h for oviposition. Mite specimens of *T. urticae* were collected from a greenhouse at Mahallat, Iran, and then were reared on rose plants under laboratory conditions(at 25 ± 5 °C, 50 ± 5% RH and 14:10 h (L:D)). At the first step, 20 pairs of adults were transferred to leaf disks of rose with a camel hair brush. In order to collect the same age eggs, the adults of *T. urticae* were removed after 6 h and then the eggs were individually used in the experiment. For the dried fruit mite, the specimens of *C. lactis* were reared on dry yeast. The predatory mite, *A. swirskii*, were initially obtained from a colony maintained in the Lab of Predatory Mites, National Ornamental Plant Institute, Mahallat, Iran.

Life table study

Petri dishes, containing a sponge placed on filter paper and a piece of rose leaf about 2 cm^2 on the top of the sponge, were prepared as experimental units. To obtain eggs of the same age, about 40 specimens of mated females of *A. swirskii* transferred from the source colony to a series of Petri dishes. The females were allowed to lay eggs for 12 h and then were removed. For each prey, including *T. urticae*, *C. lactis* and *T. vaporariorum*, 30 eggs were used for investigating life tables of the predator. The eggs were transferred to the experimental units with a tiny hair brush. The development times of the immature stages of *A. swirskii* that fed on the eggs of the above mentioned preys, were counted every 12 h until the adult stage was emerged. After completing immature stages, males and females were paired and the female fecundity was recorded daily and the population parameters were calculated considering both sexes. Petri dishes were kept in the growth chamber and almost 30 eggs of each prey were supplied daily from the stock colonies of pests as food source for each experimental unit.

Data analysis

All individuals life history data were analyzed based on the age-stage, two sex life table theories (Chi and Liu, 1985; Chi, 1988) using the TWOSEX-MSChart program (Chi, 2017). The differences of life table bootstrap-values among the treatments were compared using the paired bootstrap test (Chi, 2017), while the differences of biological parameters of the predator were compared using Tukey-Kramer procedure ($P < 0.05$) (SAS, 2004). The age-specific survival rate (l_x), age-specific fecundity (m_x), and population parameters: intrinsic rate of increase (r); net reproductive rate (R_0); the gross reproductive rate (GRR) and mean generation time (T) were calculated accordingly.

The intrinsic rate of increase is estimated using iterative bisection method:

$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1$$

with age indexed from 0 (Goodman, 1982). The following formulas were used to obtain l_x

and m_x:

$$l_x = \sum_{j=1}^{k} s_{xj}$$

and

$$m_x = \frac{\sum_{j=1}^{k} s_{xj} f_{xj}}{\sum_{j=1}^{k} s_{xj}}$$

Where k is the number of stages (Chi and Liu, 1985). As calculating the life table is extremely time consuming and replication is impractical, we used bootstrap method to calculate the standard errors of the life table parameters with 100,000 replications. The mean generation time is defined as the time length that a population needs to increase to R_0-fold of its size (i.e., $e^{rT} = R_0$ or $l^T = R_0$) at the stable age–stage distribution. The mean generation time is calculated as $T = \ln R_0/r$. The TWOSEX–MS Chart program is available at http://140.120.197.172/ecology (Chi, 2017). All graphs were plotted by Sigma Plot version 11.0 (Systat Software Inc. 2008).

RESULTS

Development time and total life span

Amblyseius swirskii successfully completed its developmental feeding on the three prey species, including *T. urticae*, *C. lactis* and *T. vaporariorum* (Table 1). The highest egg incubation period of this predator in females and males were 1.79 and 2.01 days, respectively, which were recorded for the mites when fed on *T. vaporariorum* ($F_{2, 66}$ = 5.87, P < 0.054; $F_{2,42}$ = 4.83, P < 0.025) (Table 1). Larval durations of both sexes of *A. swirskii* reared on *T. urticae* and *C. lactis* were not significantly different while these periods were increased when the predator reared on *T. vaporariorum* ($F_{2, 66}$ = 5.66, P = 0.049; $F_{2,42}$ = 8.60, P < 0.0001) (Table 1). No significant differences were attained in protonymphal period of females and males of *A. swirskii* feeding on the three prey species ($F_{2, 69}$ = 0.51, P = 0.86; $F_{2,39}$= 0.48, P = 0.89). However, the shortest deutonymph duration of both sexes was observed *T. urticae* ($F_{2, 65}$ = 0.51, P < 3.86; $F_{2,44}$ = 0.60, P < 2.90) (Table 1). The immature time of females and males ranged from 6.03 to 7.21 and 5.83 to 7.45 days, respectively ($F_{2, 66}$ = 15.73; $F_{2,47}$ = 24.89, both P < 0.0001). The shortest and longest life span of both sexes were recorded on *T. vaporariorum* and *T. urticae* ($F_{2, 66}$ = 78.23; $F_{2,47}$ = 33.74, both P < 0.0001), respectively (Table 1).

Oviposition period, fecundity and adult longevity

The highest pre-oviposition period of *A. swirskii* was recorded on *T. vaporariorum* ($F_{2,66}$ = 12.32, P < 0.0001). The mean oviposition period was significantly reduced feeding on *T. vaporariorum* and *C. lactis*, respectively ($F_{2,66}$ = 97.48, P < 0.0001). In addition, the maximum value for post-ovipositionwas was attained on *C. lactis* and *T. urticae*, respectively ($F_{2,66}$ = 41.37, P<0.0001) (Table 2). Based on the present result, the highest and lowest total fecundity were obtained on *T. urticae* and *T. vaporariorum*, respectively ($F_{2,66}$ = 63.97, P < 0.0001) (Table 2). Also, the highest longevities of the females and males of the predatory mite were recorded as 20.49 and 18.59 days, respectively, which were obtained on the two spotted spider mite ($F_{2, 69}$ = 73.75; $F_{2, 44}$ = 6.35, both P < 0.0001) (Table 2).

Table 1. Mean (±SE) development time, longevity and total life span (days) of *Amblyseius swirskii* females and males reared on *Tetranychus urticae*, *Carpoglyphus lactis* and *Trialeurodes vaporariorum.*

Preys	Incubation	Larva	Protonymph	Deutonymph	Immature	Life span
Females						
T. urticae	1.42 ± 0.25^{b}	0.95 ± 0.18^{b}	1.83 ± 0.19^{a}	1.94 ± 0.13^{b}	6.03 ± 0.24^{b}	26.52 ± 0.55^{a}
C. lactis	1.49 ± 0.24^{b}	1.24 ± 0.27^{ab}	1.79 ± 0.210^{a}	2.00 ± 0.18^{b}	6.41 ± 0.30^{a}	23.88 ± 0.33^{b}
T. vaporariorum	1.79 ± 0.23^{a}	1.39 ± 0.25^{a}	1.94 ± 0.22^{a}	2.20 ± 0.23^{a}	7.21 ± 0.28^{a}	23.53 ± 0.47^{b}
Males						
T. urticae	1.50 ± 0.25^{b}	1.20 ± 0.17^{b}	1.89 ± 0.22^{a}	1.57 ± 0.24^{b}	5.83 ± 0.27^{b}	24.42 ± 1.32^{a}
C. lactis	1.75 ± 0.25^{b}	1.15 ± 0.26^{b}	1.88 ± 0.23^{a}	1.68 ± 0.79^{a}	6.39 ± 0.35^{b}	23.79 ± 1.25^{a}
T. vaporariorum	2.01 ± 0.28^{a}	1.68 ± 0.31^{a}	1.95 ± 0.23^{a}	1.81 ± 0.26^{a}	7.45 ± 0.36^{a}	19.28 ± 0.95^{b}

*In each column, means with the similar letters are not significantly different (P<0.05) using the Tukey's test.

Table 2. Mean (± SE) reproductive period (day) and total fecundity (offspring) of *Amblyseius swirskii* females and males reared on *Tetranychus urticae*, *Carpoglyphus lactis* and *Trialeurodes vaporariorum.*

Preys	Pre-oviposition	Oviposition	Post-oviposition	Total fecundity	Females longevity	Males-longevity
T. urticae	2.13 ± 0.27^{b}	9.95 ± 0.1^{a}	5.41 ± 0.23^{a}	25.21 ± 0.53^{a}	20.49 ± 0.39^{a}	18.59 ± 1.26^{a}
C. lactis	2.54 ± 0.24^{ab}	7.36 ± 0.36^{b}	5.89 ± 0.43^{a}	21.46 ± 0.29^{b}	19.47 ± 0.45^{b}	17.40 ± 0.83^{a}
T. vaporariorum	2.89 ± 0.24^{a}	6.04 ± 0.16^{c}	4.24 ± 0.33^{b}	14.87 ± 0.45^{c}	16.32 ± 0.36^{c}	11.83 ± 0.84^{b}

*In each column, means with the similar letters are not significantly different (P<0.05) using the Tukey's test.

Population parameters

The intrinsic rate of increase (r) ranged from 0.127 to 0.181 day^{-1}, which was the lowest in *T. vaporariorum* and the highest on *T. urticae*. The net reproductive rate (R_0) was significantly higher on *T. urticae* and *C. lactis* than *T. vaporariorum*. The mean generation time (T) parameter had a significantly difference in preys and (T) of *A. swirskii* was observed to have the highest value on *T. vaporariorum*. Moreover, the finite rate of increase (λ) varied from 1.139 to 1.192 day^{-1} and concerning the highest value of this parameter, was observed on *T. urticae* (Table 3).

Table 3. Mean (± SE) population parameters of *Amblyseius swirskii* reared on *Tetranychus urticae*, *Carpoglyphus lactis* and *Trialeurodes vaporariorum.*

Preys	r (day^{-1})	λ (day^{-1})	R_0 (eggs/individual)	T (day)
T. urticae	0.181 ± 0.009^{a}	1.192 ± 0.019^{a}	13.35 ± 1.34^{a}	14.35 ± 1.43^{b}
C. lactis	0.164 ± 0.018^{b}	1.173 ± 0.017^{ab}	12.95 ± 0.89^{ab}	15.61 ± 0.36^{ab}
T. vaporariorum	0.127 ± 0.013^{c}	1.139 ± 0.017^{c}	7.30 ± 0.73^{c}	15.74 ± 1.37^{a}

*In each column, means with the similar letters are not significantly different (P<0.05) using the Tukey's test.

Age-specific survival rate (lx) and age-specific fecundity (m_x)

The predator mortality was increased and its longevity was reduced significantly when *A. swirskii* fed on *T. vaporariorum.* Furthermore, the survival rate (l_x) of this predator was more affected on the *T. vaporariorum*, in which the survivorship rate (l_x) of *A. swirskii* was reduced more sharply than the other preys (26 d). In addition, the maximum longevity for the females was observed when they fed on *T. urticae* (34 d) followed by that for the dried fruit mite *C. lactis* (30 d) (Fig. 1). The highest value of the daily age-specific fecundity (m_x) of *A. swirskii* was 2.32 eggs/individual on day 14 of the life span for the mites fed on *T. urticae*. Moreover, the maximum values of age specific fecundity of mites reared on *C. lactis* and *T. vaporariorum* were recorded as 1.91 and 1.50 eggs/individual, which attained on days 11 and 12 of the life span, respectively (Fig. 1).

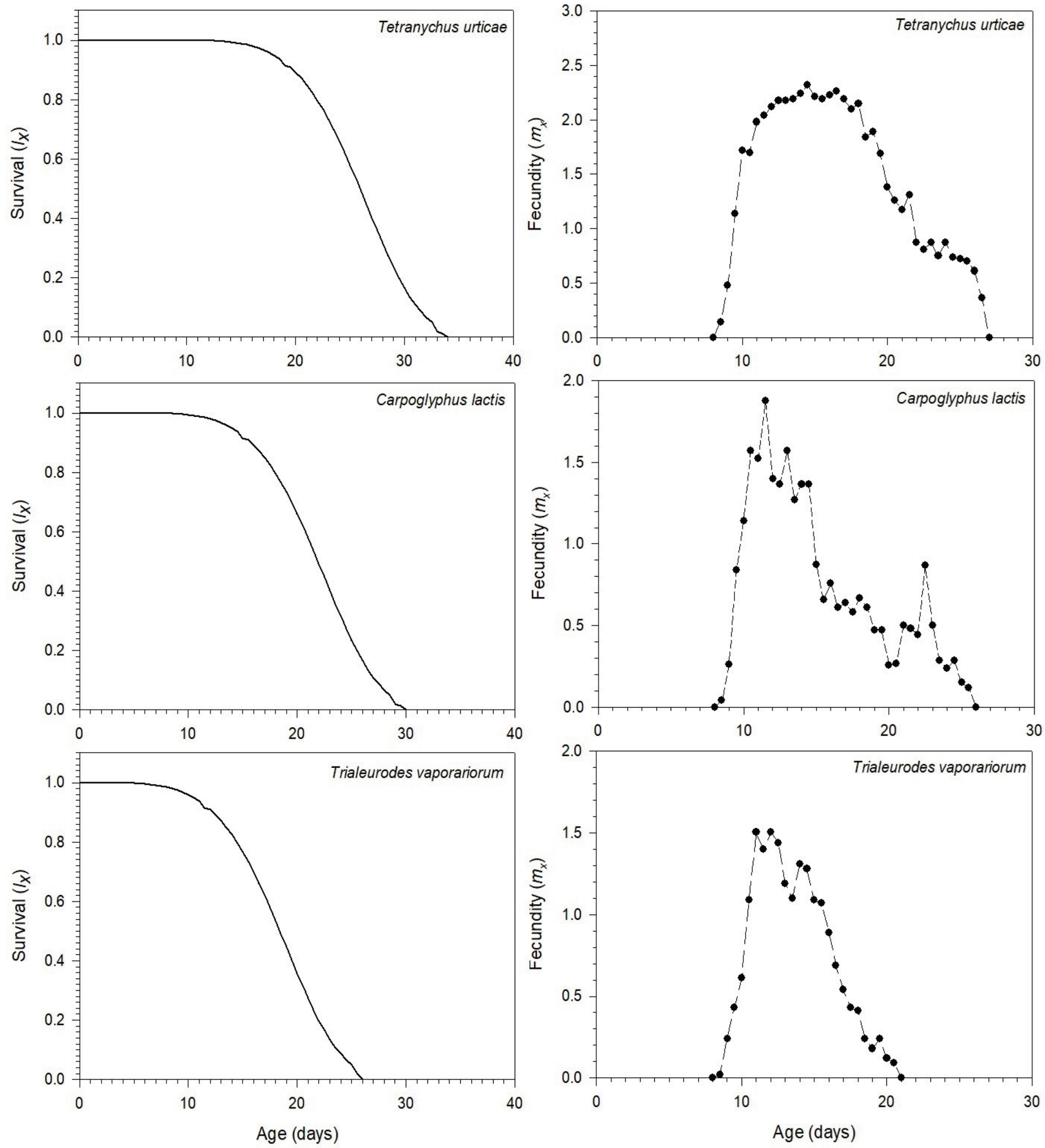

Fig.1. Age-specific survival rate (l_x) and age–specific fecundity (m_x) of *A. swirskii* reared on *T. urticae*, *C. lactis* and *T. vaporariorum.*

DISCUSSION

The results showed that *A. swirskii* populations are capable to feed and complete their developments upon the three prey species, including *T. urticae*, *C. lactis* and *T. vaporariorum.* The predatory mite may have a high potential for population growth when fed on *T. urticae* and *C. lactis*, therefore it may be possible to provide an e□ective control of spider mite in the rose greenhouse. Furthermore, *C. lactis* can be a more suitable prey for mass-production of *A. swirskii.* However, when *A. swirskii* fed on *T. vaporariorum*, its performance was weak. Our results demonstrated a significant increase in development and pre-oviposition times, and a reduction in oviposition period and fecundity. In comparison, less capacity of the predator for population increase on *T. vaporariorum* suggests poor ability of the *A. swirskii* to control of the whitefly populations on the rose plant. The better ability of phytoseiid mites to growth upon tetranychid mites than whiteflies have been already demonstrated for *Amblyseius orientalis* (Ehara) and *A. swirskii* (Zhang *et al*., 2015; Seiedy *et al*., 2016). The mentioned studies have shown that none of the assayed phytoseiid mites were efective (i.e. low oviposition and survival rate) predators of *Bemisia tabaci* Gennadius. Different kinds of food can have variable effects on the life history of this predatory mite. Various factors, including host plants, temperature, rearing methods, availability of food, prey species and other experimental conditions, have been reported to cause a difference in the developmental time of mites (Escudero and Ferragut, 2005; Park *et al*., 2010; Lee and Gillespie, 2011; Javadi Khederi *et al*., 2014; Javadi Khederi and Khanjani, 2014; Seiedy *et al*., 2016). For example, Seiedy *et al*. (2016) suggested that *A. swirskii* grows faster when fed on *T. urticae* rather than on *B. tabaci*. Moreover, various results were recorded on *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae) and *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), respectively (Onzo *et al*., 2012; Kumar *et al*., 2014).

In the current study, the developmental time of *A. swirskii* fed on *T. urticae* and *C. lactis* eggs (6.03 and 6.39 days, respectively) was shorter than that calculated on *Aculops lycopersici* (Massee) (Acari: Eriophyidae) at 25 °C (Park *et al*., 2011), western flower thrips (*Frankliniella occidentalis* (Pergande)) and onion thrips (*Thrips tabaci* Lindeman) at 25 °C (Wimmer *et al*., 2008). In this case, the differences in local strains of *A. swirskii*, diets availability and quality as well as effects of various test conditions, such as temperature and relative humidity, cannot be excluded.

The shortest and longest developmental time of *A. swirskii* were observed when they fed on eggs of *T. urticae* and *T. vaporariorum* respectively. The eggs may be a more profitable prey stage than nymphs for the predatory mite *A. swirskii* (Seiedy *et al*., 2016). This profitability may be due to the larger effective prey eggs mass, more nutrient composition and a shorter time to food digest and attacking the prey (Sabelis, 1985; Javadi Khederi *et al*., 2019). Although, the recorded developmental time for *A. swirskii* fed on *T. urticae* at 26 °C (El-Laithy and Fouly, 1992) and *B. tabaci* at 28 °C (Momen *et al*., 2013) was shorter than that reported in our study. When the predatory mite fed upon *T. vaporariorum*, there was a significant increase in immature development time. Similarly, the duration of the immature stages for the females of *Typhlodromus bagdasarjani* Wainstein & Arutunjan and *A. swirskii*, when fed on *Cenopalpus irani* Dosse (Acari: Tenuipalpidae), was reported as 7.6 days at 27 °C and 7.48 days at 25 °C, respectively, which is close to our findings (7.21 days) (Jafari and Bazgir, 2015; Bazgir *et al*., 2018). The differences between our finding and studies by other researchers may be due to differences in prey species. However, differences in local strains development times or the effects of different test conditions, such as temperature and relative humidity, cannot be excluded.

The longevity and total life span of both sexes as well as oviposition and fecundity of *A. swirskii* were decreased when it fed upon *T. vaporariorum*. Similarly, Zhang *et al*. (2018) reported that *A. orientalis* (Ehara) fed on *B. tabaci* eggs, as prey, had the shortest oviposition duration and longevity, and the lowest fecundity compared with eggs of the carmine spider mite *Tetranychus cinnabarinus* (Boisduval). In addition, the same results were obtained by Seiedy *et al*. (2016) on *T. urticae* and *B. tabaci*. Based on our findings, the total fecundity of *A. swirskii* on *T. urticae* (25.21 offspring) and *C. lactis* (21.46 offspring) were significantly higher than that on *T. vaporariorum* (14.87 offspring). Our values on *T. urticae* and *C. lactis* were higher when compared with the mites that fed on *B. tabaci* (19.22 eggs per female at 25 °C) (Seiedy *et al*., 2016), and *Rhynacaphytoptus ficifoliae* Kiefer (Acari: Diptilomiopidae) (20.4 eggs per female at 29 °C) (Abou-Awad *et al*., 1999). Although, some author observations for the same predator fed on *A. lycopersici* (38.1 eggs per female at 25 °C), *T. urticae* (37.1 eggs per female at 25 °C) and *C. lactis* (29.03 eggs per female at 23 °C), respectively, were higher than the present values (Park *et al*., 2011; Nguyen *et al*., 2013 & 2014). These findings demonstrated that kinds of food offered to the predatory mites as well as the experimental conditions greatly affected the fecundity during the ovipositional period.

The life table parameters are a good tool to understand the potential of population growth under climatic and nutritional conditions, as a reflection of the overall effects of temperature and food on the growth, survival, reproduction and increase rate of an arthropod (Javadi Khederi and Khanjani, 2014). The intrinsic rate of increase (r) has been used as an index of the insect and mite population performance and it is important in studies of different arthropod population growth (Sabelis, 1985). The parameter (r) integrates the effects of mortality and fecundity into a single value, so, it was greatly affected by the wide range of variables consisted of preimaginal survival, developmental rate, longevity of females, fecundity schedule and sex ratio, which all of them are affected by climatic and nutritional conditions (Javadi Khederi and Khanjani, 2014). The population growth parameters were more suitable for *A. swirskii* when fed upon *T. urticae* and *C. lactis* compared with *T. vaporariorum*. This is confirmed by the intrinsic rate of increase (r) which were 0.181 and 0.164 day^{-1} on *T. urticae* and *C. lactis*, respectively, while it was 0.127 day^{-1} on *T. vaporariorum*. The reported intrinsic rate of increase (r) for *A. swirskii* on *Aceria ficus* (Cotte) (Acari: Eriophyidae) (0.155 day^{-1} at 29 °C) and *R. ficifoliae* (0.122 day^{-1} at 29 °C) (Abou-Awad *et al*., 1999), *Cenopalpus irani* (0.140 day^{-1} at 26 °C) (Bazgir *et al*., 2018) and *B. tabaci* (0.120 day^{-1} at 25 °C) (Seiedy *et al*., 2016) was lower than that attained in present finding when *A. swirskii* fed on *T. urticae* and *C. lactis*. The reported values of this parameter for *A. swirskii* on *Eotetranychus frosti* (McGregor) (Acari: Tetranychidae) (0.179 day^{-1} at 26 °C) (Bazgir *et al*., 2018), *C. lactis* (0.175 day^{-1} at 23 °C) and *T. urticae* (0.167 day^{-1} at 26 °C) (El-Laithy and Fouly, 1992) were consistent with our results. In addition, our findings demonstrated significant differences in mean generation times (T), the net reproductive rate (R_0) and finite rate of increase (λ) ($P < 0.05$) among the three prey species, shows that *A. swirskii* is well-adapted to *T. urticae* and *C. lactis* compared to *T. vaporariorum*. The changes in various growth parameters can be related to the effects of different climatic conditions, such as temperatures and relative humidity, as well as food quality (Duek *et al*., 2001), since the study of life tables is set in controlled conditions with the same temperatures and food as the factors that could cause variation in growth parameters of an arthropod (Javadi Khederi and Khanjani, 2014).

The age-specific survival rate (lx) and age specific fecundity (m_x) curves indicated that *T. vaporariorum* prey decreases the survival and fecundity of *A. swirskii* compared with the other two preys. In addition, the day of maximum reproduction in mites fed on whiteflies has decreased, as compared with *T. urticae* and *C. lactis*, which may lead to constraints of reproduction and survivorship. According to Zhang *et al*. (2015), the peak oviposition period of *A. orientalis* on *T. cinnabarinus* protonymphs was higher than that when feeding on *B. tabaci* eggs, which was close to our findings.

Present findings demonstrated that *T. urticae* and *C. lactis* are suitable prey compared to

T. vaporariorum for *A. swirskii*. Therefore, this phytoseiid species can be useful in the management of *T. urticae* in rose greenhouse. However, complementary studies should be carried out to assess the effects of different factors, such as climatic and host plant on *A. swirskii* biological life table. Moreover, according to biological aspect of this predator on *C. lactis*, this prey seems very suitable for mass production of *A. swirskii*.

ACKNOWLEDGMENT

We thank Dr. Saeed Javadi Khedri, Dr. Bahman Asali Fayaz and Dr. Mohammad Reza Amin for their cooperation in implementing this project. We would also like to thank the Ornamental Plants Research Center in Iran (Mahallat) which provided us with the funding and equipment for this research.

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How to cite this article:

Hosseininia, A., Khanjani, M., Asadi, M. and Soltani, J. 2020. Life-history of the Predatory Mite *Amblyseius swirskii* (Athias-Henriot) (Acari: Phytoseiidae) on *Tetranychus urticae* Koch (Acari: Tetranychidae), *Carpoglyphus lactis* Linnaeus (Acari: Carpoglyphidae) and *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae). *Journal of Ornamental Plants,* 10(3), 155-166.

URL: http://jornamental.iaurasht.ac.ir/article_675417_c3ae0ca13399c33a4879b0f71d818b0c.pdf