Acarological Studies
Vol 5 (2): 52-57
doi: 10.47121/acarolstud.1234593

RESEARCH ARTICLE

Development and life table parameters of the *Phytoseius corniger* Wainstein (Acari: Phytoseiidae) feeding on the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) under laboratory conditions

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Received: 15 January 2023 Accepted: 15 March 2023 Available online: 31 July 2023

ABSTRACT: Phytoseiid mites are important for biological control of some pest species including phytophagous mites and small insects. The species, *Phytoseius corniger* Wainstein is one of the most abundant predatory mite in fruit orchards and urban green spaces in Razavi Khorasan province, Iran. Biological parameters of this predatory feeding on the two-spotted spider mite *Tetranychus urticae* Koch was studied for the first time under the laboratory conditions (25±2 ºC, 55±5 % RH and 16L: 8D photoperiod). The results indicated that the mean developmental periods for egg, larva, protonymph and deutonymph were 1.12±0.09, 0.73±0.03, 1.01±0.03, and 3.05±0.09 days for females, and 0.95±0.37, 0.67±0.39, 1.05±0.88, and 3.05±0.85 days for males, respectively. The pre-oviposition, oviposition, post-oviposition periods and adult longevity for females were 4.63±0.11, 11.63±0.16, 7.93±0.13 and 24.18±0.21 days, respectively. The females laid an average of 0.48 eggs per day, and 5.60 eggs during their life span. In addition, larvae of *P. corniger* may molt to the protonymph stage without feeding. Consumption rate during nymphal stage was 1.95 prey per day. The highest rate of prey consumption was recorded during the oviposition period, with an average of 3.35 prey items prey per day. Regarding life-history traits, the intrinsic rates of increase (r_m) of this predatory mite 0.064±0.02 (♀♀/♀/day) and its finite rate of increase (λ), net reproduction rate (R_0), generation time (T), and doubling time (DT) were 1.066±0.23 (day^{-1}), 3±0.07 (♀♀/♀/generation), 17.14±0.11 (days), and 10.83±0.65 (days), respectively. Further laboratory and field studies regarding its diet preference and predation capacity are needed.

Keywords: Demographic parameters, predatory mite, *Phytoseius corniger*.
Zoobank: https://zoobank.org/A592E6B4-62A2-441C-BB72-C2AD26BD0676

INTRODUCTION

The family Phytoseiidae (Acari: Mesostigmata) with more than 2800 described species (Demite et al., 2023) have diverse feeding habits, ranging from specializing on spider mites to general consumption of a wide variety of foods, including plant materials (McMurtry and Croft, 1997). According to the latest catalogue of Phytoseiidae fauna of Iran, so far, five species belonging to the genus *Phytoseius* have been reported in the country (Kazemi et al., 2022). Among them, *Phytoseius corniger* Wainstein, 1959 is mostly known in the Palearctic region and reported from India, Iran, Kazakhstan, Kyrgyzstan, Lebanon, Moldova, Pakistan, Serbia, Tajikistan and Turkmenistan (Demite et al., 2023). In Iran, this species has been the most abundant with wide distribution in both fruit orchards (Panahi Laeen et al., 2014) and in urban green spaces in Razavi Khorasan province (Namaghi, 2010). Despite being one of the most common predatory phytoseiids in the region, no study on its basic biological characteristics such as development, reproduction, and predation capacities have been carried out. However, the potential role of the generalist phytoseiids in suppressing spider mite densities has been reported by some researchers (McMurtry and Croft, 1997). According to Pappas et al. (2013) phytoseiid mites of the genus *Phytoseius* are natural enemies of tetranychid and eriophyid mites and they are mostly found on plants with pubescent leaves where they feed on prey, as well as on pollen. Nevertheless, the nutritional ecology and the role of these predators in biological control are only rarely addressed. The present study aimed to obtain preliminary information regarding the biology and life table parameters of *P. corniger* by feeding on the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae).

MATERIALS AND METHODS

Stock culture of the prey, *Tetranychus urticae*

The prey, *T. urticae* was originally collected from an infested cauliflower plants in vicinity of Mashhad and transferred to Department of Plant Protection at Faculty of Agriculture, Ferdowsi University of Mashhad, Iran. The stock culture of the prey, *T. urticae* was stablished on potted cauliflower plants (*Brassica oleracea* cv. Romanesco). The plants used in this study, were grown in plastic pots (25 cm diameter x 40 cm depth) filled with a commercial soil of Cocopeat: Perlit (60%: 40%) and kept at a greenhouse conditions set at 25±2°C, 50±10% RH and 16:8 (L: D) h photoperiod. The rearing of cauliflower plants started two months before the experiments.

Stock culture of the predatory mite, *Phytoseius corniger*

The adults of predatory mite were initially obtained from the hackberry tree (*Celtis* sp., Ulmaceae) in Ferdowsi University campus in August 2022 and transferred to rearing units consisting of clean succulent cauliflower leaves, in an incubator at 25±2 ºC, 55±5 % RH and 16L: 8D hour photoperiod. Clean leaf discs were placed underside facing up on a wet sponge layer in plastic containers (20 x 10 x 5 cm). The borders of leaf discs were surrounded with moistened tissue papers to provide water supply for phytoeiids and to prevent them from escaping. Every day, a mixture of all stages of *T. urticae* from the stock culture were supplied as food.

Biology, predation and life table parameters of *Phytoseius corniger*

This study was conducted using experimental units made of discs of cauliflower leaf discs (2 cm diameter) placed upside down on water saturated sponge in a plastic Petri dish (9 cm in diameter by 1.5 cm in height). The Petri dish was kept permanently open. Leaf discs were bordered with wet tissue paper strips to prevent mites from escaping. A total of 30 females from the stock colony were transferred to the individual arenas with the help of fine camel hair brush and left for 24 h to lay eggs. After egg deposition, females were removed and individual deposited eggs with less than 24 hours old were used for studying the biological attributes of the predator. The newly hatched protonymphs were supplied daily with prey at densities of 10-15 individuals of different motile stages of the two-spotted spider mite. The number of preys supplied to each rearing unit was determined according to preliminary experiments. Each day the number of consumed prey in each rearing unit was recorded and the unconsumed ones were removed and replaced by fresh prey. After the last molting, an adult male, randomly taken from the stock colony, was introduced to each leaf disc containing a newly emerged female. After copulation, males were transferred to stock culture. Mated females were observed to determine the pre-oviposition, oviposition, and post-oviposition periods as well as gathering data on fecundity. Observations on the development were done twice a day and reproduction, survival and prey consumption once a day. Every 4-5 days, the predator was transferred to new arenas, while its eggs were removed daily from the arenas. This procedure was continued until the last predatory mite died. The data obtained on surviving and duration of life stages were recorded and statistically analyzed to work out standard deviation. The fecundity was worked out by recording total number of eggs laid by individual females during their life span. Sex ratio was obtained based on rearing 27 eggs until reaching maturity.

Life table parameters including mean generation time (T), net reproduction rate (R_0), intrinsic rate of increase (r_m), finite rate of increase (λ), doubling time (DT) were estimated based on the age-stage and two-sex life table (Chi, 1988; Chi and Liu, 1985) using the computer program TWOSEX-MSChart (Chi, 2015, version 10.23). To take both sexes into consideration, the age-specific survival rate (l_x) and the age-specific fecundity (m_x) in the age-stage two-sex life table were calculated (Chi and Liu, 1985). Bootstrap method (Huang and Chi, 2012) was used to calculate Standard Errors (SE) of the life table parameters.

RESULTS

Developmental periods

Similar to the most of other phytoseiid species, the life cycle of *Phytoseius corniger* includes egg, larva, protonymph, deutonymph and adult stages. Individuals of the predatory mite, *P. corniger* were able to develop and reproduce on the two-spotted spider mite, but not on honey bee pollen. This is in contrast with our field observation on *P. corniger* on leaves of hackerberry tree (*Celtis* sp.) without any phytophagous mite as possible prey. Also, cannibalism was not noted when there was prey scarcity. The adult females and males of *P. corniger* had an average life span of 29.41±0.43 and 27.32±0.32 days, respectively. After 12-18 hours from the emergence, the adults mated and females start to oviposit after four days (Figure 2). The mean immature developmental time was 5.91 days for females and 5.70 days for males. Unmated females did produce eggs. Duration in days (Mean±SE) of the stages and reproductive parameters of *P. corniger* are given in Table 2.

The adults were shiny at the time of emergence. The males can be distinguished from the female by their more elongated body. The pre-oviposition, oviposition and post-oviposition periods includes 19.12%, 48.07% and 32.79% of female longevity, respectively.

Predation rate

Predation data of *P. corniger* immature and adult stages is given in Table 3. Larvae of *P. corniger* molt to protonymph stage without feeding. The predation rate during nymphal stage was 1.95 prey per day. Adult females consumed more prey than adult males. The highest rate of prey consumption was recorded during the oviposition period, with the female consuming an average of 3.35 prey per day. The higher prey consumption by females compared to males on *T. urticae* has been reported in several cases for other phytoseiid species (e.g., Rasmy et al., 1991; Naher et al., 2005; Khalequzzaman et al., 2007).

Population parameters

Life table parameters are appropriate indexes of population growth under a defined set of conditions that provide a valuable tool to determine the potential of a biocontrol agent under different local and seasonal conditions. The population parameters of *P. corniger* were calculated based on a cohort of 27 individuals. The calculated parameters (Mean±SE) are shown in Table 4. The population of *P. corniger* reared on *T. urticae* in a controlled environment could complete a generation within 17.14±0.08 days. The probability that an individual will survive to age *x* and stage *j* is shown by the parameter s_{xj} (Figure 1). There was clear overlapping in the age-stage survival curves between successive stages, demonstrating the variable developmental rates occurring among *P. corniger* individuals of both sexes. The age-specific survival rate (lx), fecundity (mx) of *P. corniger* are plotted in Figure 2. It was observed that the survival rate (lx) and fecundity (m_x) of *P. corniger* decreased with as the age increased.

Table 1. Duration in days (Mean±SE) of various life stages of *Phytoseius corniger* reared on the two-spotted spider mite, *Tetranychus urticae* under laboratory conditions (25±2 ºC, 55±5 % RH and 16L: 8D h photoperiod).

Developmental stages	Sex[1]	N[2]	Minimum	Maximum	Mean (±SE)
Egg	Female	16	0.83	2	1.12±0.09
	Male	8	0.83	1	0.95±0.365
Larva	Female	16	0.5	1	0.73±0.03
	Male	8	0.62	0.75	0.67± 0.39
Protonymph	Female	16	0.5	1.16	1.01±0.03
	Male	8	1	1.16	1.05±0.88
Deutonymph	Female	16	2.5	4.50	3.05±0.09
	Male	8	2.91	3.25	3.05±0.85
Egg-Adult	Female	16	4.33	8.66	6.495±0.06
	Male	8	5.36	6.16	5.76±0.33
Longevity	Female	16	19.25	27.75	24.18±0.21
	Male	8	20.75	22.75	21.60±0.21

[1]Sex ratio (female: male) was approximately 2: 1 and obtained based on rearing 27 eggs which 24 of them (88.9%) developed successfully to the adult stage. [2]N = Number of specimens observed.

Table 2. Duration in days (Mean±SE) of the stages and egg production of *Phytoseiuus corniger* at 25 ± 2 °C, 55 ± 5% RH, and 16L: 8D h photoperiod, when fed *Tetranychus urticae.*

Stages and reproductive parameters	N[1]	Minimum	Maximum	Average (±SE)
Pre-oviposition period (Days)	16	3.25	6.00	4.62±0.11
Oviposition period (Days)	16	11.00	12.50	11.62 ±0.16
Post-oviposition period (Days)	16	5.00	9.25	7.93±0.13
Number of eggs per female	16	2.70	7.00	5.06±0.38

[1]N = Number of specimens observed.

Table 3. Predation of the predatory phytoseiid mite, *Phytoseius corniger* on *Tetranychus urticae* at laboratory conditions (25±2 ºC, 55±5 % RH and 16L: 8D h photoperiod)

Life stage	Sex	Minimum	Maximum	Mean±SE
Larvae	Female	0.00	0.00	0.00
	Male	0.00	0.00	0.00
Protonymph	Female	1.00	3.00	2±0.191
	Male	0.00	3.00	1.68±0.21
Deutonymph	Female	3.00	8.00	5.85±0.37
	Male	3.00	8.00	5.85±0.34
Pre oviposition		4.00	13.00	8.05±0.64
Oviposition		18.00	46.00	39.35±1.59
Post oviposition		14.00	31.00	25.95±1.22

Table 4. Population parameters (Mean±SE) of *Phytoseius corniger* reared on *Tetranychus urticae* under laboratory conditions (25±2 ºC, 55±5 % RH and 16L: 8D h photoperiod).

Life table parameters	Mean±SE
Net reproductive rate (R_0)	3.00±0.07*
Mean generation time (T)	17.14±0.11
Intrinsic rate of increase (r)	0.06±0.02
Finite rate of increase (λ)	1.07±0.23
Doubling time (DT)	10.83±0.45

Note: R_0, net reproductive rate (♀♀/♀/generation); T, mean generation time (days); r, intrinsic rate of increase (♀♀/♀/day); λ, finite rate of increase (day^{-1}); DT, Doubling time (days); *-the number of observed individuals were 27.

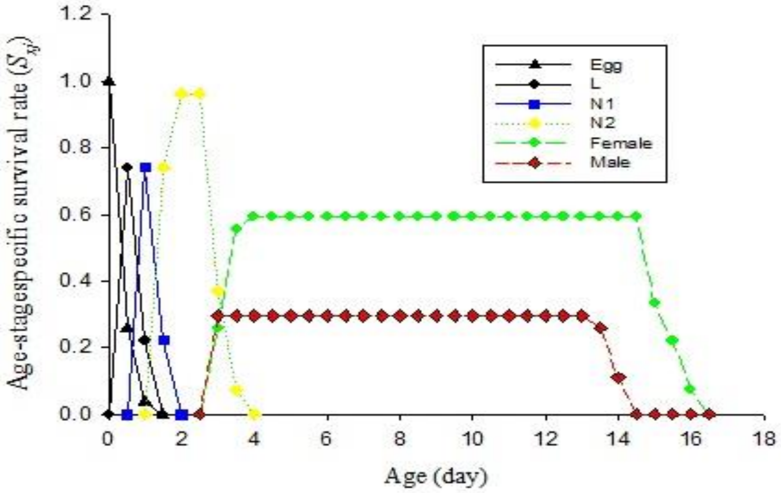

Figure 1. Age-stage specific survival rate (s_{jx}) of the parent cohort of bisexual *Phytoseius corniger* fed on *Tetranychus urticae* under laboratory conditions (25 ± 2 °C, 55 ± 5% of RH, and 16L: 8D h photoperiod). Note: L stands for larva, N1 for protonymph, and N2 for deutonymph, respectively.

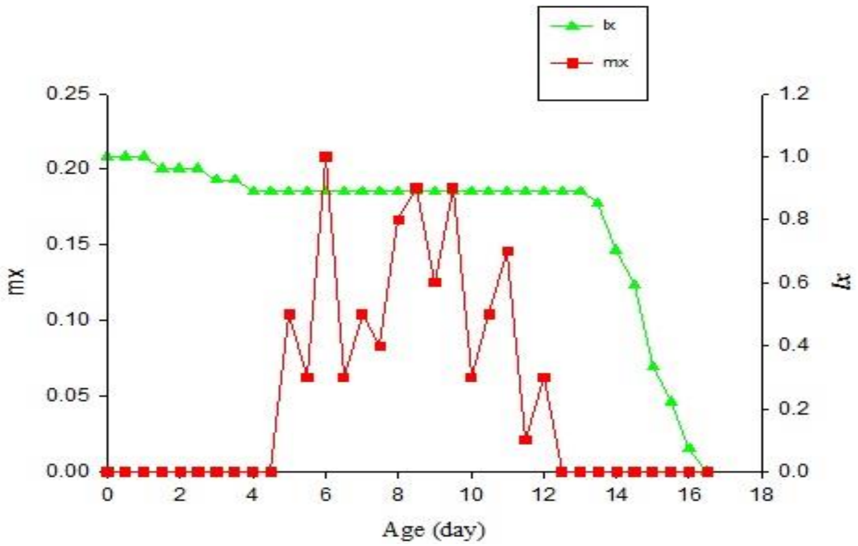

Figure 2. The age-specific survival rate (lx), and fecundity (m_x) of *Phytoseius corniger* fed on *Tetranychus urticae* under laboratory conditions (25 ± 2 °C, 55 ± 5% of RH, and 16L: 8D h photoperiod).

DISCUSSION

Despite the extensive practical use of phytoseiids for biological control of some phytophgous mites, the microhabitat and food preference of vast majority of the species still remains to be unknown (McMurtry et al., 2013). Although, several studies have been reported about the association of *Phytoseius* species with tetranychid, eriophyid, tarsonemid and tenuipalpid mites (Vassiliou et al., 2012; McMurtry et al., 2013), there has been no study on the biology, predation and life table parameters of the *P. corniger* feeding on *T. urticae*. So, the preliminary results obtained from this study are not comparable to the other studies on other species of the genus *Phytoseius*. Among the few works carried out on predation capacity of the species of the genus *Phytoseius*, Duso and Vettorazzo (1999) stated that *Phytoseius finitimus* (Ribaga) is a potentially useful for the control of *Panonychus ulmi* Koch on grape. In laboratory experiments, Pappas et al. (2013) observed that *P. finitimus* may feed and reproduce on larvae of *T. urticae*, as well as on crawlers of the greenhouse whitefly, *Trialeurodes vaporariorum* Westwood. Also, the phytoseiid *Phytoseius plumifer* (Canestrini and Fanzago) have been mentioned as predator of tetranychid and eriophyid mites on various crops in Iran (Hajizadeh et al., 2002; Nadimi et al., 2009; Gorji et al., 2012; Khodayari et al., 2013). In a study on the life table parameters of *P. plumifer* on *T. urticae*, Gorji et al. (2012) showed that the net reproduction rate (R_0) was 29.6 females/female and the finite rate of increase (λ) was noted to be the highest at 30°C (1.29 day^{-1}). Results of a study by Al-Azazzy and Alhewairini (2020) suggest that *P. plumifer* has the ability to maintain eriophyid and tetranychid mite densities below damaging levels. In the present study, the net reproductive rate (R_0) of *P. corniger* was 3.00±0.07 which is very lower than those reported by Gorgi et al. (2012) and Al-Azazzy and Alhewairini (2020) for *Phytoseius plumifer*, respectively. It seems that *P. plumifer* has higher fecundity *P. corniger*. This difference, could be explained by differences in rearing conditions such as a higher temperature and differences in diet preference of these conspecies. It is more likely that other preys such as tydeoid mites maybe more preferred than *T. urticae* by *P. corniger*. The temperature and the type of food are the main factors that affects the population parameters considerably such as development, fecundity and efficiency of predatory mites.

Based on our field observations as well as the laboratory experiments, it is suggested that *P. corniger* is a generalist predator and belongs to the subtype IIIa, since it was found frequently on pubescent leaves of hackerberry tree (*Celtis* sp.) where there were no or only a few tydeoid mites per leaf. Observing 4-5 individuals of *P. corniger* on a leaf of hackerberry tree suggests that this phytoseiid mite might be able to feed on pollen or can utilize plant exudates and honeydew as survival food in the absence of prey, or as complementary food, as has been stated by McMurtry and Croft (1997).

Feeding *P. corniger* on *T. urticae* resulted into an intrinsic rate of increase of 0.18 (females/female/day). The r_m is a value that is one of the basic criteria for evaluating the effectiveness of a biological control agent on their prey. Theoretically, when a predator has a population growth rate higher than its prey, it can regulate the population of its prey. As the present study did not measure the r_m value of the prey, *T. urticae* at the same experimental conditions, it is not possible to judge on the effectiveness of *P. corniger* against *T. urticae* population. Further studies will reveal more details regarding its diet preference and predatory potential of this phytoseiid mite.

Authors' contributions

Leili Baghlani: Investigation, data curation, writing original draft. **Hussein Sadeghi Namaghi:** Supervision, Analyzing data, writing-original draft, review editing. **Lida Fekrat:** Supervision, methodology, analyzing data. The present study is a part of the M.Sc. thesis of the first author.

Statement of ethics approval

Not applicable.

Funding

This research was supported by Ferdowsi University of Mashhad, Iran (Grant number: 3/566020).

Conflict of interest

The authors declares that there is no conflict of interest.

Acknowledgements

This study was supported by Ferdowsi University of Mashhad, which is greatly appreciated.

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Edited by: İsmail Döker
Reviewed by: Three anonymous referees

Citation: Baghlani, L., Sadeghi Namaghi, H. and Fekrat, L. 2023. Development and life table parameters of the *Phytoseius corniger* Wainstein (Acari: Phytoseiidae) feeding on the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) under laboratory conditions. Acarological Studies, 5 (2): 52-57.