

Article

Demographic parameters of *Neoseiulus barkeri* (Acari: Phytoseiidae) fed on *Thrips tabaci* (Thysanoptera: Thripidae)

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Abstract

Thrips tabaci Lindeman is a serious pest of cucumber and onion in field and greenhouse conditions in Iran. *Neoseiulus barkeri* Hughes is an indigenous biological control agent in west of Iran on cucumber and maize that preys on spider mites and *T. tabaci* and can prevent the outbreak of them. In this study, the demographic parameters of the Iranian population of *N. barkeri* were determined using 1st instar larvae of *T. tabaci* as prey under laboratory conditions at 30±1°C, 65±5% RH and photoperiod 8:16 h (D:L). The results showed that *N. barkeri* successfully developed on 1st instars larvae of *T. tabaci*. The developmental times for egg, larva, protonymph, deutonymph and all immature stages were 1.37, 1.03, 1.54, 1.71 and 5.68 days, respectively. Also, 96.66% of eggs hatched and the survival rate for the movable immature stages were 100%. Total prey consumption by protonymphs, deutonymphs and adult female was 2.70, 3.57 and 75.85 individuals, respectively. Adult longevity of the male was recorded as 14.36 days while the females lived longer (20.17 days). The female ratio was 0.62%. The intrinsic rate of increase (r_m) and the net reproductive rate (R_0) were 0.252 day⁻¹ and 18.70 female offspring, respectively. Our results showed that *N. barkeri* could be considered as a biological agent for the control of *T. tabaci* on cucumber. Expanding knowledge on the biological parameters of this predatory mite can help to increase the use of this indigenous biological agent for the control of *T. tabaci* on cucumber.

Key words: *Neoseiulus barkeri*, *Thrips tabaci*, life history, population growth parameters

Introduction

Cucumber, *Cucumis sativus* L., is one of the most important vegetable crops that are planted in field and greenhouse conditions in Iran (Fathipour *et al.* 2006). Cucumber is infected by different pests such as fungi and arthropods. Since cucumber is eaten raw, the control of its pests with minimum use of chemical pesticides is very important, furthermore, interval between two harvests is short and therefore the danger of acute toxicity and pesticide residue is high.

The onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) are found worldwide and they have economically impacts on many agricultural crops (Pourian *et al.* 2009). Damage on cucumber is caused by feeding on the leaves and fruits and

transmission of plant pathogens. Both adults and larvae of *T. tabaci* suck the contents of sub-epidermal cells. This insect is a permanent pest throughout the year that has been reported from many provinces of Iran (Khanjani 2005). It is a major pest of cultivated plants in Iran, such as alliaceus and cucurbitaceous crops (Modarres Awal 2001). The control of *T. tabaci* is based on chemical pesticides; however, application of pesticides against this pest is not always successful. This pest is resistant mostly to applied pesticides because of sustainable use of insecticides, rapid rate of reproduction and overlapping the generations. Due to difficulties in chemical control of *T. tabaci* and for avoiding the negative effects of used broad-spectrum insecticide in recent years, many researchers have focused on development of integrated pest management, especially using biological control agents (Fekrat *et al.* 2009).

Some surveys for identification of predator mites of *T. tabaci* in western region of Iran have been conducted during 2011 and the phytoseiid mite *Neoseiulus barkeri* Hughes has been found in association with *T. tabaci* and *Tetranychus urticae* Koch on cucumber. This mite is belongs to the type III phytoseiids that in addition to mites can feed on thrips, eggs of *Bemisia tabaci* (Gennadius) and pollen (Bonde 1989; Gerson *et al.* 2003). Biological parameters of this predator on *T. urticae* (Karg *et al.* 1987; Jafari *et al.* 2010; 2011; Fouly & EL-Laithy 1992; Momen 1995) and *Aleuroglyphus ovatus* Toupeau (Acaridae) (Xia *et al.* 2012) were studied. Also, Beglyarov and Suchalkin (1983) and Bonde (1989) studied some biological traits of *N. barkeri* at 25°C on onion thrips, but the ability of Iranian population of this predator on *T. tabaci* has not been studied so far.

Knowledge on the life history of local population of predator is necessary for use of them in biological control program, for example, Ferrero *et al.* (2007) stated that the finding of Moraes and McMurtry (1985) indicating South African population of *Phytoseiulus longipes* Evans is an ineffectiveness agent in controlling *Tetranychus evansi* Baker and Pritchard but tests conducted with the Brazilian strain by Furtado *et al.* (2006) suggested it to be very promising predator. The main objective of this study is to provide data on demographic parameters of a local population of *N. barkeri* at a constant temperature under laboratory condition on *T. tabaci*. This knowledge will be useful to design integrated pest management program to control *T. tabaci*. Also, information on the effects of the prey on life history of the predator is basic for assessing the efficacy of predator in biological control program.

Materials and methods

Thrips tabaci cultures

The individuals of *T. tabaci* were obtained from the fields of cucumber in Khorramabad region, in the west of Iran during July 2011 to provide the culture. Laboratory colonies of *T. tabaci* continuously reared on sown cucumber (var. Soltan) in chamber room at 30±1°C, 65±5% RH and a photoperiod of 8:16 h (D:L). After several generations, the 1st larvae of thrips were used as prey in all experiments. To obtain the first instar larvae of thrips, adult females of thrips were transferred to arenas consist a piece of cucumber leaves that put upside down on Petri dishes. After two days the females were removed on each arena and then transferred to new arenas. The new emerged first instar larvae were used as prey in all experiments.

Neoseiulus barkeri cultures

The individuals of *N. barkeri* were obtained from the fields of cucumber infected by *T. tabaci* and *T. urticae* in Khorramabad, Iran during July 2011 and maintained on planted

cucumber infested by *T. tabaci* in laboratory condition at $30\pm 1^{\circ}\text{C}$, $65\pm 5\%$ RH and 8:16 h (D: L) photoperiod. Also, the population of predator was maintained in arenas consist of Petri dishes (6 cm) with water saturated. The predators were fed for two day intervals by adding detached cucumber leaves which were infested by larvae of *T. tabaci*. To accomplish the experiments, a cohort consisting more than 250 individuals of *N. barkeri* was provided.

Experimental units and conditions

All experiments were carried out using arenas consisted of a piece of cucumber leaf (4 cm in diameter), placed upside down on water saturated foam mat covered with wet filter paper, inside plastic Petri dishes (6 cm in diameter) with a hole in its center (0.5 cm in diameter). To keep the leaves fresh and prevent mites from escaping, this arena was placed in the larger Petri dishes (9 cm) which filled with water to prevent mites from escaping. The lid of each Petri dish was covered by fine mesh for ventilation. The mites were transferred to new arenas every three or four days. The experiments were conducted at $30\pm 1^{\circ}\text{C}$, $65 \pm 5\%$ RH and a photoperiod of 16:8 h (L: D).

Development, reproduction and survival

To determine the developmental time a cohort consisted of 60 same-aged eggs was used. To obtain same-aged eggs, gravid females were transferred to 60 new experimental units and after 12 hours the females and surplus eggs were removed and only one egg remained in each unit and monitored during the developmental time. The movable predatory stages of *N. barkeri* were fed daily with 10–15 individuals of 1st larvae of *T. tabaci*. Since the previous study (Jafari *et al.* 2010) showed that the females require several times mating to produce maximum progeny, the dead or lost males were replaced by new ones picked up from the stock colony. The experimental units were daily monitored and any changes recorded until the death of the last female. The number of deposited eggs by each female was counted and consumed larvae by predator were replenished daily. This monitoring allowed us to determine the parameters of pre-oviposition, oviposition and post-oviposition periods, sex ratio, female and male longevity, fecundity and adult survival rate. The other reproductive parameters calculated according the mentioned data.

Predation

According to the preliminary test, the prey consumption potential of different stages of predator determined and for evaluation of the eaten preys by various stages of *N. barkeri*, the above mentioned experimental units were provided by 10 first instars larvae of *T. tabaci* as prey and introduced to larvae, protonymph, deutonymph and adult female of *N. barkeri*. The eaten preys were replenished once per day. Predation was assessed daily until the immature stages mites reached to adult stages and then until adults died.

Population growth parameters

Using survivorship and fertility life table, population growth parameters including net reproductive rate (R_0 , mean number of female progeny produced by a female during its mean lifetime), mean life time (T , mean period between birth of the parents and that of the offspring), doubling time (DT , time for population to double), intrinsic rate of natural increase (r_m) and finite rate of increase (λ , the number of times the population

multiplies in a unit of time) were calculated using the methods recommended by Birch (1948) as follows:

$$\sum (e^{-r_m \cdot x} l_x m_x) = 1 \quad R_0 = \sum l_x m_x \quad DT = \frac{\ln 2}{r_m} \quad T = \frac{l_n R_0}{r_m} \quad \lambda = e^{r_m} \quad GRR = \sum_{x=\alpha}^{\beta} m_x$$

Data analysis

Statistical differences in demographic parameters were tested using jackknife procedure to estimate the variance for demographic parameters (Meyer *et al.* 1986). This procedure is mostly used to estimate variance and bias of estimators. It is based on repeated recalculation of the required estimator, missing out each sample in turn and it is used to quantify uncertainty associated with parameter estimates, as an alternative to analytical procedures, in cases for which the last ones require very complicated mathematical derivation (Maia *et al.* 2000). The obtained sex ratios of progeny were compared to expected ratio of 1:1 by a chi-square test (χ^2 , $P < 0.05$). To determine the significant different between the duration of immature stages of male and female the Student t-test was used.

Results

Developmental time and predation of immature stages

Results showed that the hatching rate of eggs was 96.66%. The developmental time of immature stages of females significantly longer than the males ($T = 5.33$; $P < 0.001$). Embryonic development lasted 1.37 ± 0.08 days. The larval stage period was 1.03 ± 0.02 days, the protonymph and deutonymph stages lasted 1.54 and 1.71 days, respectively. Immature development of females was 5.68 days (Table 1). The mean total eaten prey by protonymphs and deutonymphs were 2.70 and 3.57 of 1st instar larvae of *T. tabaci*, respectively (Table 1). Total consumed prey during the adult period was 75.85 ± 3.23 , of 1st instar larvae of *T. tabaci*. Each female consumed average 3.76 of 1st larvae of thrips per day.

Survival and reproduction parameters

The individual of *N. barkeri* successfully completed its development at $30 \pm 1^\circ\text{C}$ fed on 1st larvae of *T. tabaci*. The age-specific survival curve (l_x) of *N. barkeri* is presented in Fig. 1. The mortality began in third week and its intensity was after 26th day. Also, the age-specific fecundity of *N. barkeri* on 1st larvae of *T. tabaci* is presented in Fig. 1. The maximum of egg lying observed at 9th and 12th days of life time. Increasing of egg production was started when adults aged 4 days (≥ 1 egg/female/d) and decreased steadily from day 14. The mean duration of oviposition period and adult longevity of *N. barkeri* are given in Table 2.

Table 1. Developmental time (days \pm SE) and predation rate of immature stages of *Neoseiulus barkeri* feeding on the 1st larvae of *Thrips tabaci*.

	Egg	Larva	Protonymph	Deutonymph	Egg to Adult
Female	1.37 ± 0.08	1.03 ± 0.02	1.54 ± 0.08	1.71 ± 0.08	5.68 ± 0.11
Male	1.41 ± 0.11	0.93 ± 0.04	1.27 ± 0.10	1.18 ± 0.09	4.79 ± 0.12
Daily predation rate	-	-	2.70 ± 0.15	3.57 ± 0.16	6.32 ± 0.21

The average pre-oviposition, oviposition and post-oviposition period and life span of females were 2.08 ± 0.1 , 14.70 ± 0.19 , 3.43 ± 0.16 and 25.90 ± 0.28 days, respectively. The

net fecundity and net fertility rate were 35.17 and 34.00, respectively (Table 3). The total laid eggs were 36.40 (eggs/female). Offspring sex ratios were female biased (61.66% female) and has significant difference with expected ratio of 1:1 ($\chi^2= 5.438$; $df= 1$, $P< 0.05$).

Table 2. The duration of oviposition periods and adult longevities of *Neoseiulus barkeri* on 1st larvae of *Thrips tabaci*.

	Pre-oviposition	Oviposition	Post-oviposition	Adult longevity	Life span
Female	2.08±0.10	14.70±0.19	3.43±0.16	20.17±0.25	25.90±0.28
Male	-	-	-	14.36±0.41	18.95±0.46

Population growth parameters

The estimated values of the population growth parameters of *N. barkeri* are given in Table 4. The intrinsic rate of increase (r_m) and the net reproductive rate (R_0) were 0.252 day⁻¹ and 18.70 female offspring, respectively, indicating a daily increase of 0.252% and an 18.7 fold increase from generation to generation. The population size is doubled in 2.75 days, while the mean generation time (T) was 11.62 days. Finite rate of increase (λ) was 1.286 day⁻¹, means the population from one generation to next is 1.286 times.

Table 3. Reproduction parameters of *Neoseiulus barkeri* fed on 1st larvae of *Thrips tabaci*.

Parameters	Value	Unit
Gross fecundity rate	36.40	Eggs/♀/Gen
Net fecundity rate	35.17	Eggs/♀/Gen
Gross fertility rate	35.18	Eggs/♀/Gen
Net fertility rate	34.00	Eggs/♀/Gen
Mean eggs per day	1.445	(Eggs/♀/day)
Mean fertile eggs per day	1.397	(Eggs/♀/day)

Table 4. Population growth parameters (± SE) of *Neoseiulus barkeri* fed on 1st larvae of *Thrips tabaci*.

Parameters	Value	Unit
Net reproductive rate (R_0)	18.70±0.28	(female offspring)
Gross reproduction rate (GRR)	22.44	(female offspring)
Intrinsic rate of increase (r_m)	0.252±0.002	(day ⁻¹)
Finite rate of increase (λ)	1.286±0.002	(day ⁻¹)
Doubling time (DT)	2.75±0.02	(days)
Mean generation time (T)	11.62±0.06	(days)

Discussion

Demographic information of insect may be useful in constructing population models and understanding interactions with other insect pests and natural enemies (Carey 1982). Although insects do not live in a stable environment without temperature fluctuation, nonetheless, the results of studies under constant temperatures are still very useful in understanding the population dynamics of various insects (Summers *et al.* 1984).

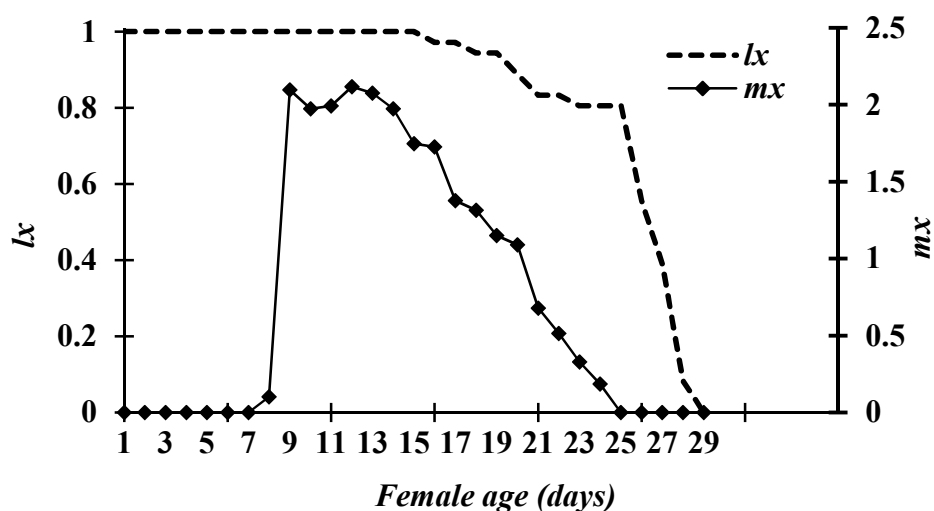


Figure 1. Age-specific survival rate (l_x) and age-specific fecundity (m_x) of *Neoseiulus barkeri* on 1st larvae of *Thrips tabaci*.

In our previous studies, we found that local population of *N. barkeri* adapted to 30°C and higher temperatures fed on *T. urticae* (Jafari *et al.* 2010 and 2011). The results of the present study also showed that 30°C is suitable temperature for development of *N. barkeri* on *T. tabaci*. Successful development at high temperatures is critical factor for this predator to be accepted as a biological control agent especially during summer on cucumber.

Present study showed that the 1st larvae of *T. tabaci* is suitable prey for the *N. barkeri* and this predator can be used as a biological control agent, as integrated with other methods in IPM program for the control of this pest. The survival rate for the movable immature stages of *N. barkeri* fed on 1st larvae of *T. tabaci* was 100%. These results are important in comparison with reported results by Rahmani *et al.* (2009) in which they found that the *Neoseiulus californicus* (McGregor) (an exotic introduced predator) fed on 1st larvae of *T. tabaci* was 83% juvenile mortality. Also the high juvenile mortality was reported for other phytoseiid mites reared on thrips (Wimmer *et al.* 2008; Walzer *et al.* 2004).

The obtained developmental time of *N. barkeri* in present study was 5.68 days. Developmental time of *N. barkeri* recorded by Bonde (1989) (6.2 days) and Beglyarov & Suchalkin (1983) (5.98 days) fed on *T. tabaci* at 25°C that are slightly greater than our results at 30°C. In previous study this parameter for this population fed on *T. urticae* was 4.59 days (Jafari *et al.* 2011). The discrepancy can be ascribed by the diet type, also differences in experimental conditions and source of populations perhaps led to this little difference.

The adult longevity in present study was 20.17 days, which is shorter than that reported by Jafari *et al.* (2011) (as 25.45 days) fed on *T. urticae*. Uckan and Ergin (2002) stated that when food quality was low, longevity of a female parasitoid was increased presumably due to an adaptation for a parasitoid species to maintain its generation.

The sex ratio in present study was female biased (61.66%). Similarly Momen (1995) reported the female ratio of *N. barkeri* on *T. urticae* as 60%. In another study Xia *et al.* (2012) reported the sex ratio for this predator to be 60.87% and 59.26% at 28 and 32°C, respectively. Furthermore, Jafari *et al.* (2010) reported this parameter for *N. barkeri* fed on *T. urticae* as 60% at 30°C. It could be concluded that the sex ratio of this predator is

female biased at least at optimum temperatures without attention to kind of diet. Sabelis (1985) stated that the sex ratio of phytoseiid mites is characterized by female bias, which is a value that varies within and between species.

Bonde (1989) reported daily and total fecundity of *N. barkeri* as 2.3 eggs/female/day and 47.1 eggs/female on *T. tabaci* at 25°C. The mentioned parameters in present study were 2.48 eggs/female/day and 36.40 eggs/female, respectively. Also, the present study were in agreements with those reported by Jafari *et al.* (2010) (2.57 eggs/female/day and 38.62 eggs, respectively) fed on *T. urticae*. Xia *et al.* (2012) reported the daily and total fecundity for this predator on *Aleuroglyphus ovatus* at 32°C, 1.83 eggs/female/day and 20.52 eggs/female (also at 28°C mentioned parameters reported as 1.56 and 30.85, respectively). It may be due to inappropriate feeding conditions and also may also be related to the geographical population.

Post-oviposition period in this study (3.43 days) was shorter than the reported periods by Jafari *et al.* (2010) (9.25 days at 30) and Xia *et al.* (2012) (8.65 and 7.84 days at 28 and 30°C, respectively) but near to that reported by Bonde (1989) at 25°C as 1.3 days.

The population growth parameters provide population growth rate of an insect in the current and next generations (Frel *et al.* 2003). The r_m value is most important intrinsic parameter that indicates the potential of predator for growth, reproduction and survival fed on prey, also is influenced by pre-imaginal developmental time. This parameter reflects the overall effects of temperature and food on development, reproduction, and survival (Southwood 1978). The value of this parameter in present study was 0.252 day⁻¹ that in agreements with the reported value by Bonde at 25°C (as 0.22 day⁻¹). However this value was greater than that reported by Xia *et al.* (2012) fed on *A. ovatus* at 28 and 30°C (as 0.166 and 0.165 day⁻¹ respectively). It seems the low value of fecundity in Xia *et al.* (2012) study lead to this difference, which indicates the important of fecundity in r_m value. Helle and Sabelis (1985) stated that two parameters that have greater effects on determining the r_m value are developmental time and oviposition rate.

With regards to the previous studies by Jafari *et al.* (2010) who indicated that the local population of this predator can develop and reproduce on *T. urticae* and comparisons with results of this research, it seems both *T. urticae* and *T. tabaci* are suitable food for this predator and this predator can help us to control of this pest in cucumber crop.

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***Neoseiulus barkeri* (Acari: Phytoseiidae) شکارگر کنه شکارگر پارامترهای دموگرافیک کنه شکارگر *Thrips tabaci* (Thysanoptera: Thripidae) با تغذیه از**

شهریار جعفری، ندا عباسی و فرشته بحیرایی

چکیده

تریپس پیاز (*Thrips tabaci* Lindeman)، یکی از آفات مهم و کلیدی خیار و پیاز در شرایط مزرعه‌ای و گلخانه در ایران است. کنه شکارگر *Neoseiulus barkeri* Hughes یکی از عوامل کنترل بیولوژیک

بومی در کشور است که روی محصولات زراعی مانند خیار و ذرت وجود دارد و در جلوگیری از طغیان کنه‌های تارتن و تریپس‌ها نقش مهمی دارد. از آنجایی که در مورد ویژگی‌های زیستی جمعیت بومی این کنه شکارگر با تغذیه از *T. tabaci* اطلاعات چندانی وجود نداشت، در این پژوهش ویژگی‌های زیستی و پارامترهای رشد جمعیت این کنه شکارگر با تغذیه از لاروهای سن یکم تریپس جالیز در دمای ۳۰ درجه سلسیوس بررسی شد. نتایج نشان داد که این کنه شکارگر به طور موفقیت‌آمیزی با تغذیه از لاروهای سن یکم تریپس جالیز با حداقل تلفات، رشد و نمو می‌کند. میزان ۹۶/۶۶ درصد از تخم‌ها تفریخ شدند و نرخ بقای مراحل نابالغ ۱۰۰ درصد بود. زمان رشد و نمو مراحل تخم، لارو، پوره سن یکم، پوره سن دوم و کل مراحل نابالغ به ترتیب ۱/۳۷، ۱/۰۳، ۱/۵۴، ۱/۷۱ و ۵/۶۸ روز بود. میزان کل مصرف طعمه توسط پوره سن یکم، پوره سن دوم و بالغین به ترتیب ۲/۷۰، ۳/۵۷ و ۷۵/۸۵ بود. میانگین طول عمر افراد بالغ و کل طول عمر ماده‌ها به ترتیب ۲۰/۱۷ و ۲۵/۹۰ روز تعیین شد. نسبت تعداد نتاج ماده‌ها به کل نتاج ۶۱/۶۶ بود. نرخ ذاتی افزایش جمعیت (r_m) و نرخ تولید مثل خالص (R_0) به ترتیب ۰/۲۵۲ و ۱۸/۷۰ تعیین شد. نتایج این بررسی نشان داد که این کنه شکارگر می‌تواند به کمک سایر روش‌های کنترل به عنوان یک عامل کنترل بیولوژیک بومی برای کنترل تریپس جالیز مورد استفاده قرار گیرد. شناخت ویژگی‌های زیستی این کنه شکارگر می‌تواند در افزایش استفاده عملی از این عامل بیولوژیک در شرایط گلخانه و مزرعه بسیار موثر باشد.

واژگان کلیدی: پارامترهای رشد جمعیت، چرخه زیستی، *Thrips tabaci*، *Neoseiulus barkeri*

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