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Article

Life table analysis and predation efficiency of *Neoseiulus californicus* (Acari: Phytoseiidae) fed on diverse preys

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ABSTRACT

This study evaluated the biological traits and life table parameters of the predatory mite *Neoseiulus californicus* (McGregor) when fed on four prey species: the clover mite (*Bryobia praetiosa* Koch), the citrus brown mite (*Eutetranychus orientalis* Klein), the two-spotted spider mite (*Tetranychus urticae* Koch), and the acarid mite *Tyrophagus putrescentiae* (Schrank). Laboratory conditions were maintained at 27 ± 1 °C and 70 ± 5% relative humidity (RH). All prey types were suitable as food for *N. californicus*, but prey diet significantly influenced the predator's immature development and adult longevity in both sexes. The shortest developmental time (egg to adult) of predatory mite was 4.35 and 4.17 days for male and female when fed on *Te. urticae* motile stages. The shortest and longest oviposition periods were 12.53 and 19.07 days for *B. praetiosa* and *Te. urticae*, respectively. The highest fecundity per female was 39.60 eggs for *Te. urticae*, followed by 31.67 eggs for *E. orientalis*. The study found that *Te. urticae* had the highest net reproductive rates (R_0), intrinsic rate of increase (r), finite rate of increase (λ), and gross reproduction rate (*GRR*). Additionally, *Te. urticae* exhibited the shortest mean generation time (T) and doubling time (*DT*) compared to *B. praetiosa* and *Ty. putrescentiae*. Age-stage-specific fecundity (*fxj*) was highest for *Te. urticae*, followed by *E. orientalis*, *Ty. putrescentiae*, and *B. praetiosa*. A similar trend was observed in the age-stage-specific life expectancy (*exj*). Interestingly, the highest predation rates for both male and female *N. californicus* were observed when feeding on *Ty. putrescentiae* compared to the other prey species. The results obtained can be useful in the biological control of phytophagous mites on field crops. Further studies are needed to evaluate its effectiveness in combination with other parameters of a control program for managing pests affecting crops under field or greenhouse conditions.

KEYWORDS: Acaridae, consumption rate, phytophagous mites, predatory mites, Tetranychidae.

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INTRODUCTION

Phytophagous mites are among the most widespread and serious pests in agricultural ecosystems, causing significant economic losses to their host plants (Jeppson *et al.* 1975). Among these, *Eutetranychus orientalis* (Klein) (Tetranychidae), is a key pest of citrus, deciduous fruit trees, field crops, and ornamentals recorded on 269 host plant species worldwide. This mite feeds on the upper surfaces of leaves, causing leaf drop and the appearance of yellow-grey patches. Heavy infestations

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may result in fruit drop, top branch mortality, and significant damage to the following year's flowering (Elhalawany 2019; Migeon and Dorkeld 2024).

Moreover, the clover mite, *Bryobia praetiosa* Koch (Tetranychidae), has been recorded on more than 317 species of host plants including field crops, trees, various weed species and ornamental plants (Migeon and Dorkeld 2024). This mite is active during the spring and fall, emerging after the rainy season. It can also invade homes and buildings through cracks and small openings. *Bryobia praetiosa* causes small silver streaks on leaves and flowers, and large populations can turn lawns yellow or brown (Jeppson *et al.* 1975; Krantz and Walter 2009).

In addition, *Tetranychus urticae* Koch, is one of the most dangerous pests in different agricultural systems worldwide, feeding on about 1,586 host plant species (Migeon and Dorkeld 2024). *Tetranychus urticae* feeds on soft tissues on the lower leaf surface, resulting in yellow-brown stippling and webbing on the lower leaf surface (Vacante 2016). Heavy infestations cause leaves to turn yellow, eventually leading to leaf death and drop-off.

The astigmaid mite, *Tyrophagus putrescentiae* (Schrank) (Acaridae) is a cheese mite found in many habitats, including dry products, seeds, organic material, and mushroom beds (Eraky 1995). *Tyrophagus putrescentiae* reduces the growth rate of cereals by 20% to 70% and that of vegetables by 4% to 100% (Van Hage-Hamsten and Johansson 1992).

Phytoseiid mites are the most important natural enemies of phytophagous mites and play a critical role in integrated pest management (McMurtry and Croft 1997; Moraes *et al*. 2004). The development and performance of generalist phytoseiid mites such as *Neoseiulus californicus* are influenced by prey diets and the host plants on which prey depend (Gotoh *et al.* 2006).

The predatory mite *N. californicus* is commonly found on deciduous trees and many agricultural crops in many countries (Schausberger and Croft 2000). It has been described as a Type II selective predator of spider mites (McMurtry *et al.* 2013) and is considered a potential biological agent against *Te. urticae* and tarsonemid mites in both field and greenhouse crops (Cooping 2001). In Egypt, *N. californicus* has been successfully utilized to control *Te. urticae* on various crops in fields and greenhouses, *Panonychus ulmi* (Koch) on apple, *Panonychus citri* (McGregor) on citrus trees, *E. orientalis* on citrus trees, *Tegolophus guavae* (Boczek), *Brevipalpus phoenicis* (Geijskes), and *Te. urticae* on guava trees, *Frankliniella occidentalis* Pergande, *Bemisia tabaci* (Gennadius), *Polyphagotarsonemus latus* (Banks) on sweet pepper, and *Thrips tabaci* L. on onions (Ibrahim *et al.* 2010; Elmoghazy *et al.* 2011; Elhalawany *et al.* 2019, 2024a, b; El-Saiedy and Fahim 2021).

The impact of prey type on the growth and reproduction of *N. californicus* is studied by several researchers (Croft *et al.* 1998; Gotoh *et al.* 2004, 2006; Ali and El-Laithy 2005; El Taj and Jung 2012; Elhalawany *et al.* 2017, 2023; Gazoly *et al.* 2024). The primary objective of this research is to explore both new and previously studied prey types—*B. praetiosa*, *E. orientalis*, *Te. urticae*, and *Ty. putrescentiae*—to assess their suitability for the predatory mite *N. californicus* under laboratory conditions. While some prey, such as *Te. urticae*, have been extensively studied, our study aims to provide new insights by evaluating their effectiveness under different environmental conditions and using comprehensive life table analysis and predation rate metrics. Additionally, we place particular emphasis on the less-studied prey species, *B. praetiosa* and *Ty. putrescentiae*, to expand the existing knowledge base and explore their potential for large-scale rearing of *N. californicus*. This research not only validates previous findings but also seeks to complement and build upon them by incorporating new parameters and environmental conditions.

MATERIALS AND METHODS

Rearing of phytophagous mites

Bryobia praetiosa was collected from alfalfa (*Medicago sativa* L., Fabacae), *E. orientalis* from castor plant (*Ricinus communis* L., Euphorbiaceae), and *Te. urticae* from eggplant (*Solanum melongena* L., Solanaceae). Individuals of the three plant-fed mites (*B. praetiosa*, *E. orientalis*, *Te. urticae)* were transferred to clean castor bean leaves placed on a cotton layer in Petri dishes. Every three days, the castor bean leaves were inspected and replaced with new ones if yellowing or mite overcrowding was noted. Petri dishes were kept in a dark chamber at 25 ± 2 ℃ and 75 ± 10% RH.

Rearing of Tyrophagus putrescentiae

Individuals of *Ty. putrescentiae* were collected from stored cereals and cultured in plastic containers measuring 3 cm in diameter and 4 cm in depth, sealed with glass lids. Each container was filled with a dual mixture of gypsum and charcoal in a ratio of 9:1 to a maximum height of 0.7 cm. The mites were mass-reared in a 4:1 wt ratio on wheat bran and yeast and kept in a dark chamber at 25 ± 2 ℃ and 75 ± 10% RH. This method follows Elhalawany *et al.* (2022).

Colonies of predatory mite N. californicus

Individuals of *N. californicus* were collected during 2022 from crop plants and weeds at Qaha Station Plant Protection Research Institute, Qalubia Governorate, Egypt. The individuals of predatory mite *N. californicus* were identified according to the key provided by Abo-Shnaf and Moraes (2014). The mass rearing units consisted of mulberry leaves put on water saturated cotton layers placed in Petri dishes and feeding on *Phaseolus vulgaris* (L.) infested with *Te. urticae*. Water was added regularly to maintain the cotton humid and kept in a chamber at 27 ± 1 °C, 70 ± 5% RH and 16L: 8D.

Experimental unit

The study was conducted in an environmentally controlled room at 27 ± 1 °C, 70 ± 5% RH, and photoperiod of 16L: 12D. The experimental arenas consisted of a wet cotton pad on a sponge placed on foam dishes (15 × 20 cm). Mulberry leaf discs *Morus alba* L. (Moraceae) (3 cm in diameter) were placed in arenas. Water was added when necessary to prevent the escape of mites and to maintain the cotton humid.

Developmental time and predation rates

To examine the effects of prey type on the development and predation rates of *N. californicus*, 40 newly laid eggs from each group reared with the test prey were individually transferred to arenas (small leaf discs 3 cm in diameter) using a fine brush. The developmental stage and the number of immature stages consumed were counted twice daily until adulthood. One male was brought into each arena for mating for one day and then removed. Every day, the predators were given access to a diet of 20 immature stages of each prey type. Each arena was inspected daily and the numbers of eggs laid were recorded. Every three days, the leaf discs were replaced with new ones.

Life table analysis

In our study, we collected and utilized the following key data including total population size, duration in days, age-specific mortality rates, age-specific fecundity rates for females. Life table parameters were calculated according to the age-stage, two-sex life table theory (Chi and Liu 1985) and the method by Chi (1988) using the TWOSEX-MSChart program (Chi 2023). The net reproductive rate (R_0) represents the mean number of female offspring that an individual can produce during its lifetime, the mean generation time (T), the intrinsic rate of increase (r), the doubling time (DT), the gross reproduction rate (GRR), the finite rate of increase (λ), the age-specific survival rate (lx), the age-specific fecundity (m_x), age-stage-specific life expectancy (e_{xj}) is the time that an individual of age x and stage j is expected to be alive, the age-stage specific reproductive value (v_{xj}) defined as the contribution of individuals of age x and stage j to the future population (Fisher 1930) and calculated according to according to Huang and Chi (2011) and Tuan *et al.* (2014), and the age-stage fecundity (f_{xj}) gives the number of hatched eggs produced by adult females at age x were calculated. Excel 2013 was used to create S_{xj}, l_x, m_x, v_{xj} and e_{xj} curves.

Statistical analysis

The experiment was performed using a completely randomized design (CRD). The effect of prey diets on developmental times, survival rates, oviposition period, longevity and fecundity were evaluated using analysis of variance (one-way ANOVA) using a computer program (SAS Institute 2003). Differences between means were separated by Tukey's honestly significant difference test (Tukey's HSD test) at α = 0.05. The TWOSEX-MSChart software was also used to calculate means, standard errors, and variances of the population parameters were estimated using the bootstrap technique (100,000 samples), which is contained in the TWOSEX-MSChart program. The means were compared by the Paired Bootstrap test based on the confidence interval of difference ($P < 0.05$) (Huang and Chi 2013).

RESULTS

Developmental time of N. californicus

Individuals of *N. californicus* (females and males) successfully completed development from egg to adult stages on four prey diets: *B. praetiosa*, *E. orientalis*, *Te. urticae*, and *Te. putrescentiae* (Table 1). The egg period and the larva duration of females and males were not significantly different across the four prey diets ($P < 0.05$). The egg incubation period of *N. californicus* ranged from 1.13 to 1.23 days for females, and from 1.15 to 1.25 days for males. Protonymph was slightly different ($F = 3.75$, $P < 0.0158$) in female and ($F = 2.52$, $P < 0.0733$) in males. The deutonymph period was significantly different ($F = 15.32$, $P < 0.0001$) in female and ($F = 8.35$, $P < 0.0002$) in males, with the shortest immature stages occurring on *Te. urticae* and the longest on *B. praetiosa* in both females and males. The developmental time in both females and males, exhibited a significant difference across four prey diets ($F = 14.95$, $P < 0.0001$), ($F = 9.70$, $P < 0.0001$); it ranged from 4.17 to 5.77 days for females and 4.35 to 5.85 days for males on *Te. urticae* and *B. praetiosa*, respectively.

Fecundity and longevity of N. californicus

Data in Table 2 shows that similar to the immature development, pre-oviposition, oviposition periods, and longevity of *N. californicus* fed on four prey diets: *B. praetiosa*, *E. orientalis*, *Te. urticae*, and *Ty. putrescentiae* were significantly affected by food type ($P < 0.05$). The shortest pre-oviposition was 1.43 days on *Te. urticae*, while the longest was 2.00 days on *B. praetiosa*. The longest oviposition period and longevity of females were 19.07 and 22.28 days on *Te. urticae*, while the shortest was 12.53 and 16.63 days on *B. praetiosa*. Furthermore, the highest total number of eggs per female was 39.60 on *Te. urticae* while the lowest fecundity was 19.20 eggs/female on *B. praetiosa*. These values were significantly different among the four prey diets ($P < 0.05$).

Table 1. Effect of different prey species on the development of *Neoseiulus californicus* immature stages at 27 ± 1 °C, and 70 ± 5% RH.

Stages	*B. praetiosa*	*E. orientalis*	*Ty. putrescentiae*	*Te. urticae*
	Female			
Incubation period	1.23 ± 0.07a	1.20 ± 0.07a	1.17 ± 0.06a	1.13 ± 0.06a
Larva	0.63 ± 0.06a	0.60 ± 0.05a	0.70 ± 0.08a	0.60 ± 0.05a
Protonymph	1.37 ± 0.12a	1.23 ± 0.12 ab	1.10 ± 0.10 ab	0.90 ± 0.05b
Deutonymph	2.53 ± 0.11a	2.10 ± 0.11b	1.97 ± 0.08b	1.53 ± 0.11c
Immature stages	4.53 ± 0.22a	3.93 ± 0.13ab	3.77 ± 0.15b	3.03 ± 0.17c
Life cycle	5.77 ± 0.19a	5.13 ± 0.13ab	4.93 ± 0.17b	4.17 ± 0.18c
	Male			
Incubation period	1.25 ± 0.08a	1.20 ± 0.08a	1.15 ± 0.08a	1.15 ± 0.08a
Larva	0.65 ± 0.08a	0.65 ± 0.08a	0.70 ± 0.11a	0.65 ± 0.08a
Protonymph	1.40 ± 0.15a	1.30 ± 0.13a	1.20 ± 0.13a	0.95 ± 0.05a
Deutonymph	2.55 ± 0.14a	2.15 ± 0.15ab	2.00 ± 0.11bc	1.60 ± 0.15c
Immature stages	4.60 ± 0.21a	4.10 ± 0.15a	3.90 ± 0.19ab	3.20 ± 0.21b
Life cycle	5.85 ± 0.21a	5.30 ± 0.13ab	5.05 ± 0.23bc	4.35 ± 0.21c

Means (± SE) followed by the same letters in the same row are not significantly different by Tukey's HSD ($P < 0.05$).

Table 2. Fecundity (eggs/female) and longevity (days) of *Neoseiulus californicus* reared on four prey species at 27 ± 1 °C, and 70 ± 5% RH.

Parameters	*B. praetiosa*	*E. orientalis*	*Ty. putrescentiae*	*Te. urticae*
Pre-ovipostion	2.00 ± 0.10a	1.83 ± 0.11ab	1.77 ± 0.16ab	1.43 ± 0.12b
Ovipostion	12.53 ± 0.32d	16.00 ± 0.38b	14.00 ± 0.39c	19.07 ± 0.30a
Post-oviposition	2.23 ± 0.15a	2.07 ± 0.12a	1.81 ± 0.16 a	1.93 ± 0.11a
Longevity	16.63 ± 0.42c	19.89 ± 0.43b	17.65 ± 0.46c	22.28 ± 0.33a
Fecundity	19.20 ± 0.55d	31.67 ± 1.21b	26.80 ± 1.11 c	39.60 ± 0.93a
Daily rate (egg/♀)	1.53 ± 0.02 b	1.99 ± 0.08a	1.91 ± 0.04a	2.08 ± 0.05a
Life span	22.40 ± 0.49b	25.02 ± 0.48a	22.59 ± 0.48b	26.44 ± 0.39a

Means followed by the same letters in the same row are not significantly different by Tukey's HSD ($P < 0.05$).

Effect of prey type on life table parameters of N. californicus

Two-sex life table parameters of *N. californicus* fed on four prey diets are presented in Table 3. The net reproductive rate (R_0) was 23.80 females/female/generation, and the gross reproductive rate (*GRR*) was 24.15 offspring/individual, the highest intrinsic rate of increase (r = 0.279 day^{-1}), finite rate of increase (λ = 1.32 day^{-1}), fed on the mobile stages of *Te. urticae*, and these values are significantly different from those on *B. praetiosa* and *Ty. putrescentiae*. The shortest mean generation time (T = 11.14 days) was observed on mobile stages of *Ty. putrescentiae*, while the doubling time (*DT* = 2.48 days) occurred on mobile stages of *Te. urticae*.

Table 3. Life table parameters of *Neoseiulus californicus* reared on four prey species at 27 ± 1 °C, and 70 ± 5% RH.

Parameter	*B. praetiosa*	*E. orientalis*	*Ty. putrescentiae*	*Te. urticae*
Gross reproductive rate (*GRR*)[d]	12.03 ± 1.9b	19.60 ± 3.1a	16.29 ± 2.17b	24.15 ± 3.93a
Net reproductive rate (R_0)[b]	11.84 ± 1.9b	19.08 ± 3.2ab	16.04 ± 2.70b	23.80 ± 3.94a
Intrinsic rate of increase (r)[c]	0.209 ± 1.56b	0.244 ± 1.69b	0.249 ± 1.83ab	0.279 ± 1.95a
Finite rate of increase (λ)[c]	1.23 ± 1.91b	1.27 ± 2.14b	1.28 ± 2.34b	1.32 ± 0.025a
Mean generation time (T)[a]	11.82 ± 0.18ab	12.06 ± 0.23a	11.14 ± 0.30b	11.35 ± 0.29ab
Doubling time (*DT*)[a]	3.31 ± 0.27a	2.83 ± 0.21ab	2.78 ± 0.22ab	2.48 ± 0.18b

[a] Day, [b] females/female/generation, [b] individuals/female/day, [d] offspring/individual.
Means followed by the same letters in the same row are not significantly different (Paired bootstrap test, $P \leq 0.05$).

Age-stage, two-sex life table of N. californicus

The results illustrated in Figure 1 proved that the age-stage survival curves (s_{xj}) show the probability of a newly hatched *N. californicus* individual surviving to age x and stage j. Differences in developmental rates lead to overlaps between the different developmental stages on the four prey diets. The highest survival rates for females and males were 0.60 and 0.40, respectively, on the four prey diets. Male adults emerged earlier but survived shorter periods of time than female adults on the four prey diets.

The age-specific survival rate (*lx*), age-specific fecundity rates (m_x), and mean number of offspring produced by *N. californicus* individuals of the age x and stage j per day, shown with the age-stage-specific fecundity (f_{xj}), were greatly influenced by prey diets (Fig. 2). The age-specific survival rate (*lx*) exhibited a comparable pattern of gradual decline throughout development on four prey diets, but (*lx*) declined faster on *B. praetiosa* and *Ty. putrescentiae* compared to the other two prey diets, *Te. urticae* and *E. orientalis*. The first oviposition occurred on the days 6th, 5th, 4th, and 5th on *B. praetiosa*, *E. orientalis*, *Te. urticae*, and *Ty. putrescentiae*, respectively. The maximum values of *mx* and f_{xj} were 1.32 and 2.2 eggs/female/day on *B. praetiosa*, and that occurred at the age of 10, and 1.56 and 2.6 eggs/female/day on *E. orientalis*, and that occurred at the age of 11 for *N. californicus*, followed by *Te. urticae* (1.64 and 2.73 eggs/female/day) at the age of 9, and finally *Ty. putrescentiae* (1.4 and 2.33 eggs/female/day) at the age of 9 days (Fig. 2).

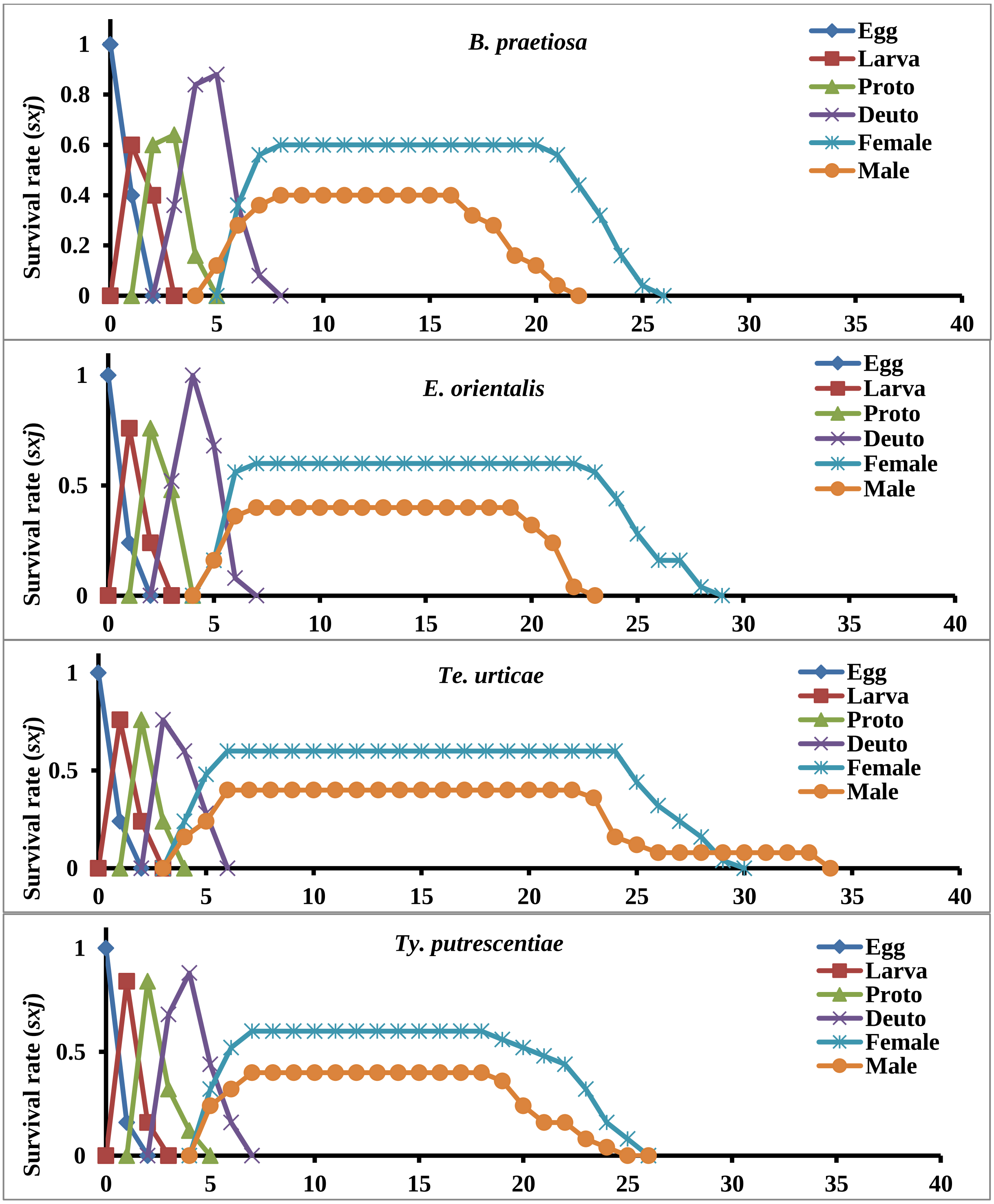

Figure 1. Age-stage specific survival rate (s_{xj}) of *Neoseiulus californicus* reared on four prey species at 27 ± 1 °C.

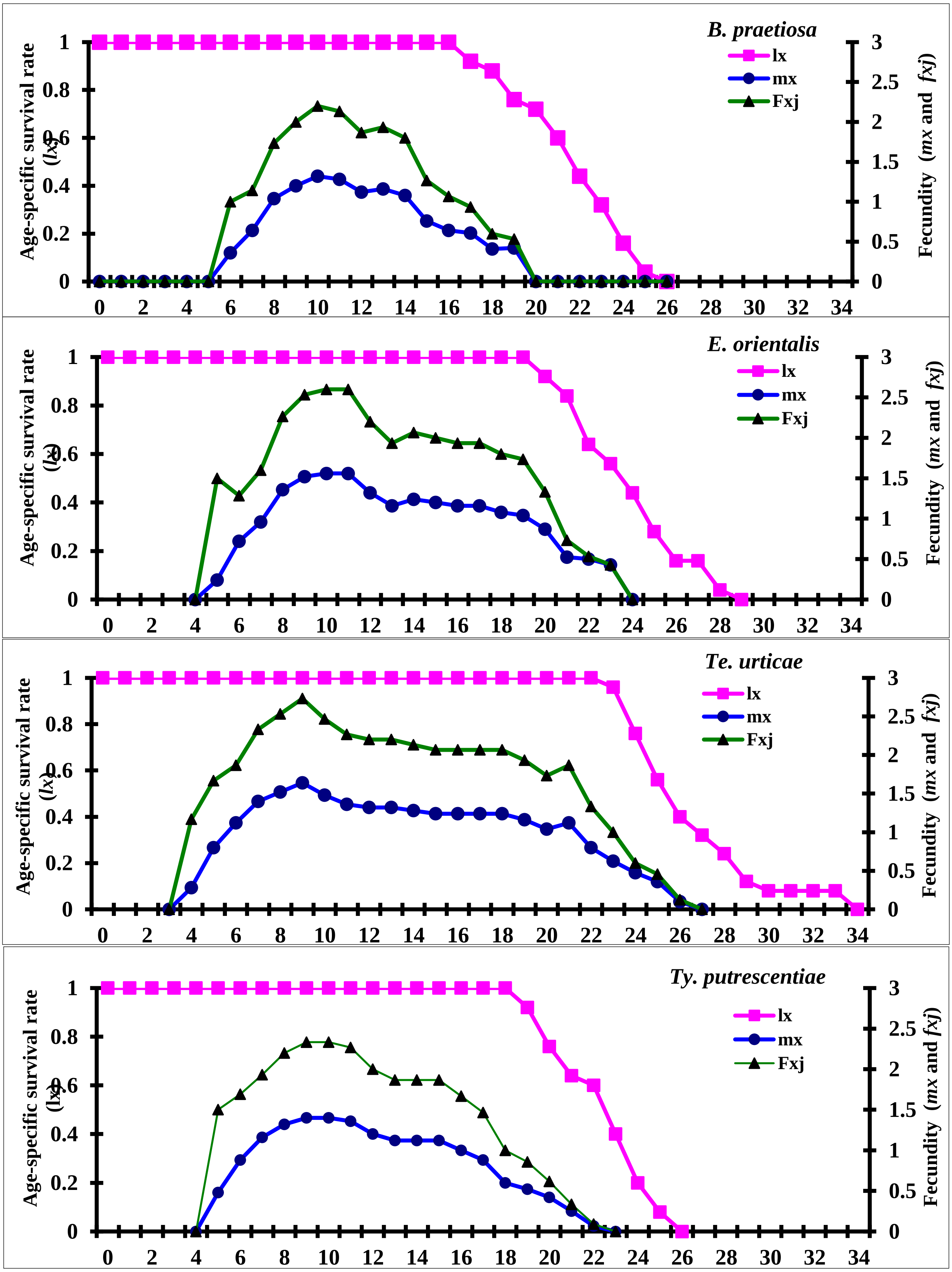

Figure 2. Age-specific survival rate (l_x), age-specific fecundity rate (m_x) and age-stage specific fecundity of female (f_{xj}) of *Neoseiulus californicus* reared on four prey species at 27 ± 1 °C.

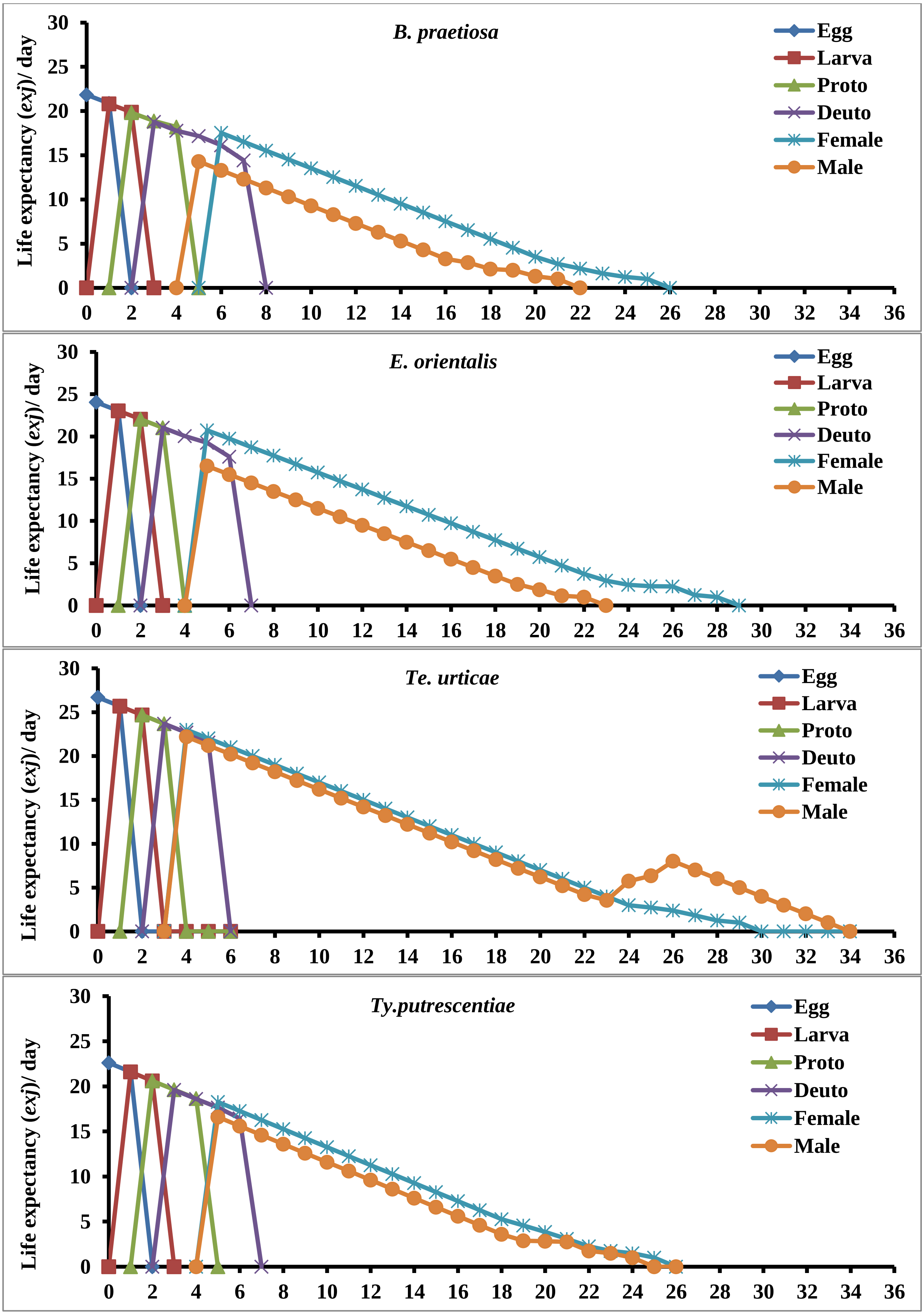

Figure 3. Age-stage life expectancy (e_{xj}) of *Neoseiulus californicus* reared on four prey species at 27 ± 1 °C.

The results illustrated in Figure 3 show the age-stage-specific life expectancy (e_{xj}). The peaks of e_{xj} of *N. californicus* female and male were 23.0 and 22.2 days, both on day 4 for *Te. urticae*, followed by 20.73 and 16.5 days for both sexes for *E. orientalis*. Furthermore, the maximum e_{xj} of *N. californicus* female and male were 17.53 and 14.3 days, respectively, on days 6 and 5 in the case of *B. praetiosa*.

The highest age-stage-specific reproductive values (v_{xj}) of *N. californicus* were 8.70, 10.21, 9.71, and 9.09 on the 8^{th} day when fed on *B. praetiosa*, *E. orientalis*, *Te. urticae*, and *Ty. putrescentiae*, respectively (Fig. 4). Consequently, these days clarified the age at which females feeding on the previously indicated prey demonstrated the greatest contribution to the future population.

Predation rate of Neoseiulus californicus

Table 4 shows the influence of prey diet on the predation rate of *N. californicus*. The prey diets had a substantial ($p < 0.05$) impact on the rate of consumption of *N. californicus* by its prey. In general, adult females of *N. californicus* significantly consumed a much greater number of prey diets than male adult stages. The highest consumption rate was 139.13 individuals with female longevity (adult stages) of *Ty. putrescentiae,* whereas the lowest consumption rate was 121.47 individuals with *B. praetiosa*. Total prey consumption for male during its life span was 110.5, 111.0, 117.5, and 96.4 when fed on *B. praetiosa*, *E. orientalis*, *Ty. putrescentiae*, and *Te. urticae*, respectively, with significantly different diets between the four prey diets ($P < 0.05$). Therefore, the highest rate of longevity and life span consumption for both males and females when fed on *Ty. putrescentiae* were more than three prey types.

Table 4. The predation rates of *Neoseiulus californicus* reared on four prey species at 27 ± 1 °C, and 70 ± 5% RH.

Stages	*B. praetiosa*	*E. orientalis*	*Ty. putrescentiae*	*Te. urticae*
		Female		
Larva	1.53 ± 0.13ab	1.40 ± 0.13b	2.00 ± 0.17a	1.47 ± 0.13ab
Protonymph	2.53 ± 0.17a	2.33 ± 0.13a	2.73 ± 0.21a	2.53 ± 0.17a
Deutonymph	3.40 ± 0.29a	3.27 ± 0.25a	3.93 ± 0.40a	3.33 ± 0.27a
Preoviposition	15.20 ± 0.65a	14.27 ± 0.48a	16.40 ± 0.73a	15.20 ± 0.65a
Oviposition	89.87 ± 3.70b	104.40 ± 1.70a	101.87 ± 2.34a	100.40 ± 3.53ab
Postoviposition	16.40 ± 1.13b	12.73 ± 0.53c	20.87 ± 0.52a	17.40 ± 1.06b
Longevity	121.47 ± 4.20b	131.40 ± 2.18ab	139.13 ± 2.82a	133.0 ± 4.01ab
Life span	128.93 ± 4.53b	138.40 ± 2.33ab	147.80 ± 3.06a	140.33 ± 4.30ab
		Male		
Larva	2.6 ± 0.16a	1.8 ± 0.29ab	2.0 ± 0.21ab	1.4 ± 0.16b
Protonymph	2.8 ± 0.20a	2.4 ± 0.16a	2.7 ± 0.26a	2.50 ± 0.17a
Deutonymph	3.70 ± 0.37a	3.00 ± 0.30a	3.30 ± 0.30a	2.90 ± 0.28a
Longevity	101.4 ± 5.69ab	103.8 ± 2.08ab	109.5 ± 3.27a	89.6 ± 5.88b
Life span	110.5 ± 5.70ab	111.0 ± 2.46ab	117.5 ± 3.54a	96.4 ± 6.18b

Means followed by the same letters in the same row are not significantly different by Tukey's HSD ($p < 0.05$).

DISCUSSION

The objective of this study was to evaluate the two-sex life and biological characteristics of *N. californicus* when fed on four different prey diets: *B. praetiosa*, *E. orientalis*, *Te. urticae*, and *Ty. putrescentiae* at 27 ± 1 °C. Both sexes of *N. californicus* successfully completed developmental stages with the prey species. As a specialized predator of spider mites, *N. californicus* is classified as a Type II predator (McMurtry *et al*. 2013). The results of this study showed that the development and reproduction of *N. californicus* were influenced by the prey species. The shortest life cycle (from egg to adult) was recorded when *N. californicus* fed on *Te. urticae* (4.17 days), while the longest life cycle was observed when it fed on *B. praetiosa* (5.77 days).

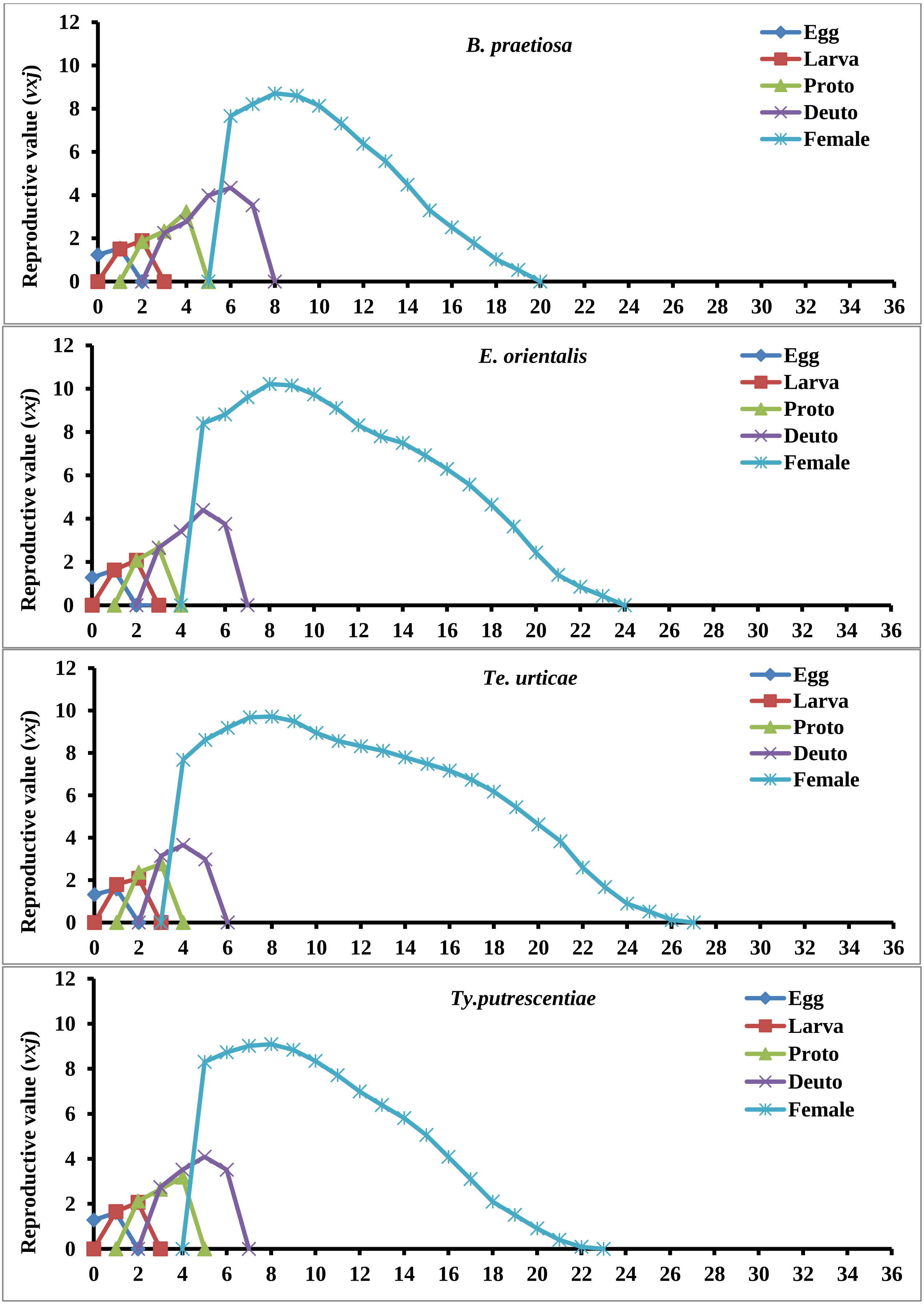

Figure 4. Age-stage specific reproductive value (v_{xj}) of *Neoseiulus californicus* reared on four prey species at 27 ± 1 °C.

Similar findings were mentioned for *N. californicus* when fed on motile stages of *Te. urticae*; the developmental periods of both females and males were shorter as 7.02 and 6.8 days (Elhalawany *et al.* 2017), and it was 5.97 and 5.85 days (Elhalawany *et al.* 2023) at 25 °C, respectively. Gotoh *et al.* (2004) found that the life cycle lasted 4.3 days when the female *N. californicus* fed on *Te. urticae*, and laid 38.4 eggs at 25 °C. Similar results by El-Nahas *et al.* (2020) reported the life cycle of *N. californicus* male and female to be 6.65 and 7.05 days when fed on *Te. urticae* at 27 °C. In contrast, Rezaie *et al.* (2017) revealed that on seven strawberry varieties, the developmental period for males and females were 6.60 and 10.06 days, respectively.

Our results reveal that the immature development, pre-oviposition, oviposition periods, and longevity of *N. californicus* fed on four prey diets were significantly influenced by food type. Females' oviposition periods and longevity were longer on *Te. urticae*. The highest fecundity was 39.60 eggs per female with daily rate of 2.08 eggs/female for *Te. urticae*, followed by 31.67 eggs per female with daily rate of 1.99 eggs/female for *E. orientalis*. These results are lower than the study of Croft *et al.* (1998) who reported that when *N. californicus* fed on *Te. urticae*, the daily rate of females was 3.45 eggs/day. This aligns with Elhalawany *et al.* (2017) who found that feeding this mite on *Te. urticae* motile stages resulted in the maximum fecundity (49.3 eggs/female). The highest fecundity rate was 42.60 eggs/female with daily rate of 2.21 eggs/female when *N. californicus* fed on *Te. urticae* at 27 °C El-Nahas *et al.* (2020). Gazoly *et al.* (2024) finding that there were substantial differences in the fecundity of female predators *N. californicus* between the two prey species tested *Panonychus citri* and *E. orientalis*, being higher when fed *P. citri* during a 14-day oviposition period (34 eggs/female) than when fed *E. orientalis* during an 18-day oviposition period (29.42 eggs/female).

Life tables can be used to better understand the overall effects of different factors on population increase of *N. californicus*. Results of this research indicated that *Te. urticae* had the highest R_0, r, λ, T and DT were 23.80, 0.279, 1.32, 11.35, and 2.48, respectively, compared to *B. praetiosa* and *Ty. putrescentiae*. Similar findings by Ali and El-Laithy (2005) and Elhalawany *et al.* (2017, 2023) showed higher values for R_0, r_m, and λ on *Te. urticae* motile stages. Also, similar results were reported for *N. californicus* fed on *P. citri* mobile stages reported by Gazoly *et al.* (2024). In this way, the ability to multiply from one unit of time to the next is shown by the intrinsic rate of increase and net reproductive rates. The doubling time determined (DT = 2.48 days on *Te. urticae*) in the present study, is also longer than that reported for *N. californicus* (2.37 days) by El Taj and Jung (2012).

Our data indicate that consumption rate of *N. californicus* for its prey was affected by prey diets. The mean number of *Te. urticae* consumed by *N. californicus* male and female was 89.6 and 96.4, 133.0 and 140.33 motile stages during longevity and life span, respectively. This result is similar to previous studies where the greatest consumption rate of adult females on *Te. urticae* motile stages was 161.2 individuals, according to Elhalawany *et al.* (2017). Also, El-Nahas *et al.* (2020) found that *N. californicus* female when fed on *Te. urticae* consumed 198.40 individuals, while the male consumed 153.10 individuals during its life span at 27 °C. In addition, Elhalawany *et al.* (2023) reported the total number of prey consumed by the female was 143.87 and 138.07 when fed on *Ty. putrescentiae* and *Te. urticae* motile stages, respectively. In contrast, Kaur and Zalom (2019**)** expressed that *N. californicus* preferred to consume *Eotetranychus lewisi* (McGregor) than *Te. urticae*.

The study indicated the age-stage-specific life expectancy (e_{xj}) of *N. californicus* female and male shows peaks on day 4 for *Te. urticae*, *E. orientalis*, and *B. praetiosa*. The highest age-stage-specific reproductive values (v_{xj}) are 8.70, 10.21, 9.71, and 9.09 on the 8th day when fed on these preys, indicating the greater contribution of females to the future population. These results are slightly lower than those reported by Rezaie *et al.* (2017) on seven strawberry varieties. The life expectancy of a newly hatched *N. californicus* egg varied from 7.94 to 11.43 days.

CONCLUSION

It could be concluded that the four phytophagous mites, *B. praetiosa*, *E. orientalis*, *Ty. putrescentiae* and *Te. urticae*, are significantly affected the developmental and reproductive properties of the predatory mite *N. californicus*. The study found that the prey diet had a notable influence on the biological performance of *N. californicus*, with *Te. urticae* supporting the highest reproductive rates, intrinsic rate of increase (*r*), finite rate of increase (λ), and gross reproduction rate (GRR). Among the tested prey, *Te. urticae* had the highest fecundity and life expectancy values, while *B. praetiosa* had the lowest. Age-specific fecundity followed the order, *Te. urticae* > *E. orientalis* > *Ty. putrescentiae* > *B. praetiosa*. These findings highlight the potential of *N. californicus* as an effective biological control agent for managing phytophagous mites, especially when *Te. urticae* is present. However, further research is recommended to evaluate the effectiveness of *N. californicus* in combination with other biological control strategies and environmental parameters.

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تجزیه و تحلیل جدول زندگی و کارایی شکارگری *Neoseiulus californicus* (Acari: Phytoseiidae) تغذیه شده از طعمه‌های گوناگون

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چکیده

این بررسی ویژگی‌های زیستی و فراسنجه‌های جدول زندگی هرنای شکارگر *Neoseiulus californicus* (McGregor) را در هنگام تغذیه از چهار گونه شکار ارزیابی می‌کند: هرنای شبدر (*Bryobia praetiosa* Koch)، هرنای قهوه‌ای مرکبات (*Eutetranychus orientalis* Klein)، هرنای تارتن دو لکه‌ای (*Tetranychus urticae* Koch) و هرنای آکارید *Tyrophagus putrescentiae* (Schrank). شرایط آزمایشگاهی در دمای ۱ ± ۲۷ درجه سلسیوس و رطوبت نسبی ۵ ± ۷۰ درصد (RH) حفظ شد. همه انواع شکار به عنوان غذا برای *N. californicus* مناسب بودند، اما رژیم غذایی شکار به مقدار زیادی بر رشد مراحل نابالغ شکارگر و طول عمر بالغ در هر دو جنس تأثیر گذاشت. کوتاه‌ترین زمان رشد (تخم تا بالغ) هرنای شکارگر ٤/۳۵ و ٤/۱۷ روز برای نر و ماده بود که از مراحل متحرک *Te. urticae* تغذیه می‌شد. کوتاه‌ترین و طولانی‌ترین دوره تخم‌گذاری به ترتیب برای *B. praetiosa* و *Te. urticae* ۱۲/۵۳ و ۱۹/۰۷ روز بود. بیشترین باروری در هر ماده ۳۹/٦۰ تخم برای *Te. urticae*، به دنبال آن ۳۱/٦۷ تخم برای *E. orientalis* بود. این مطالعه نشان داد که *Te. urticae* بیشترین میزان خالص تولیدمثل (R_0)، میزان ذاتی افزایش (r)، میزان متناهی افزایش (λ) و میزان ناخالص تولیدمثل (GRR) دارد. افزون بر این، *Te. urticae* کمترین میانگین زمان تولید (T) و زمان دو برابر شدن (DT) را در مقایسه با *B. praetiosa* و *Ty. putrescentiae* نشان داد. باروری سنی ویژه (f_{xj}) برای *Te. urticae*، به دنبال آن برای *E. orientalis*، *Ty. putrescentiae*، و *B. praetiosa* بیشترین بود. روند مشابهی در امید به زندگی در مرحلهٔ سنی ویژه (e_{xj}) مشاهده شد. جالب توجه است که بیشترین میزان شکار برای هر دو نر و ماده *N. californicus* هنگام تغذیه از *Ty. putrescentiae* در مقایسه با گونه‌های دیگر شکار مشاهده شد. نتایج به‌دست‌آمده می‌تواند در مهار زیستی هرناهای گیاهخوار محصولات زراعی مفید باشد. مطالعات بیشتری برای ارزیابی اثربخشی آن در ترکیب با سایر فراسنجه‌های برنامه کنترل برای مدیریت آفات مؤثر بر محصولات در شرایط مزرعه‌ای یا گلخانه‌ای مورد نیاز است.

واژگان کلیدی: Acaridae، میزان مصرف، هرناهای گیاهخوار، هرناهای شکارگر، Tetranychidae.

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