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Influence of Prey Type on the Biology and Life-Table Parameters of *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae)

A. S. Elhalawany, N. M. Abdel-Wahed, and Naglaa F. R. Ahmad
Fruit Trees Mites Dept., Plant Protection Research Institute, ARC, Dokki, Giza, Egypt.

ABSTRACT

Biological characteristics, life table parameters and predation rate of the predatory mite ***Neoseiulus californicus* (McGregor)** under the laboratory conditions of 25 ± 2°C, 75% R.H. and photoperiod of 12L: 12D was studied. Prey types were ***Brevipalpus phoenicis*** (Geijskes) motile stages, *Tetranychus urticae* Koch eggs and motile stages and *Tegolophus guavae* (Boczek) motile stages. The predator completed developmental stages on tested prey types with a life cycle of 7.02 to 10.25 days. Its developmental time was significantly affected by prey species as *T. urticae* motile stages shortened its development more than other ones. Female longevity ranged between 16.70 and 28.2 days. Longest female longevity and highest fecundity one was recorded on *T. urticae* motile stages (49.3 eggs/female), whereas lowest fecundity (12.6 eggs/female) was recorded on motile stages of *T. guavae.* The highest consumption rate of adult female was 496.2 individuals when fed on *T. guavae*; while the lowest was 161.2 individuals on *T. urticae* motile stages. Net reproduction rate of increase (R_o), intrinsic rate of natural increase (r_m) and finite rate of increase (λ) were highest on *T. urticae* motile stages as 35.59, 0.272 and 1.31, respectively.

Key words: *Neoseiulus californicus*, Biology, Life table, Consumption rate, *Brevipalpus phoenicis***,** *Tetranychus urticae*, *Tegolophus guavae*, Phytoseiidae.

INTRODUCTION

Guava *Psidium guaiava* L. (Murtacae) is widely grown all over the tropics and subtropics. The eriophyid, *Tegolophus guavae* (Boczek), the tenuipalpid, *Brevipalpus phoenicis* (Ceijskes) and the tetranychid, *Tetranychus urticae* Koch are the main pest mites infesting guava trees at Qualyubia governorate, Egypt. Population of *T. guavae* increased as leaves nutrient and temperature increased up to mid-Jun. followed by a dip during the hottest months and fruit maturity. The other two phytophagous mites increased up to mid-Jul. then decreased to the end of the year (Elhalawany and Abou-Setta, 2013).

Neoseiulus californicus (McGregor) (Acari: Phytoseiidae) is one of the main natural enemies of spider mites, feed on a wide range of foods such as spider and tarsonemid mites, small arthropods and pollens (Castagnoli *et al.*, 1999). *T. urticae* is a suitable prey for *N. californicus* enabling development to the adult stage (Gotoh *et al*., 2004). *N. californicus* feeds on range of spider mites and has been recommended as a biological control agent in various crops (Gotoh *et al*., 2006).

N. californicus is one of the major phytoseiid predators of spider mites and is associated with their dense webbing as it can cut through with its chelicerae (McMurtry *et al*., 2013).

Development of generalist phytoseiids can be affected by both their prey and the host plant on which its prey is feeding (Gotoh *et al.*, 2006). These phytoseiids can decrease spider mite population below economic threshold in the greenhouse and field, (e. g. on apple (Pringle and Heunis, 2006), and citrus (Katayama *et al.*, 2006)). Several studies have examined the effects of prey type and plants on development and reproduction of *N. californicus* (Castagnoli and Simoni 1991; El-Laithy and El-Sawi, 1998; Croft *et al.* 1998; Castagnoli *et al.*, 1999; Ali and El-Laithy, 2005; Gotoh *et al.*, 2004; 2006; and Taj & Jung, 2012).

This study was conducted to determine the impact of three different prey types under laboratory conditions on some biological characteristics and life-table parameters on *N. californicus*. The guava rust mite *T. guavae*; eggs and motile stages of the two spotted spider mite *T. urticae* and the tenuipalpid, *B. phoenicis,* were used as prey.

MATERIALS AND METHODS

Experiments were conducted at Qaha Agriculture Research Station (ARC), Qualyubia governorate, Egypt. Four prey types for *N. californicus* were used (i.e. motile stages of *B. phoenicis*, eggs of *T. urticae*, motile stages of *T. urticae* and *T. guavae*).

Stock cultures of the predatory mite:

The predatory mite *N. californicus* was collected from different plants especially strawberry and cucumber plants. The colonies were maintained at room temperature under laboratory conditions in large plastic boxes (70x30x40 cm). Water was added when needed. Excised bean leaves highly infested with *T. urticae* were provided every day as prey source for the predatory mite.

Stock culture of *T. urticae*:

The stock colony of *T. urticae* was obtained from colonies that had been in a greenhouse, reared on bean plants, *Phaseolus vulgaris* L. in plastic pots (15 cm in diameter). Adult mites were transferred to clean mulberry, *Morus alba* L leaves with the lower surface up, placed on moistened cotton pads resting on sponges in the foam dish (15x20 cm). The mulberry leaves were examined every three days and replaced with fresh ones when over-crowding of mites and yellow leaves were observed.

Stock culture of *T. guavae*:

This eriophyid mite was collected from guava trees at Qualyubia Governorate. Due to the difficulty in transferring the different stages of eriophyoids, 1.0 cm in diameter of heavily infested leaves with all mite stages was carefully examined and the non-target organisms were removed then added as prey source to the predatory mite. The total number of prey was recorded before introducing them and one day later to estimate consumption.

Stock culture of *B. phoenicis*:

This tenuipalpid mite was collected from fruits and leaves of guava trees. Motile stages were used as separated diet for our experiments. The total number of motile stages was recorded before introducing them into the arena every day to estimate consumption.

The study was conducted in an incubator at 25 ± 2°C, 75% R.H. and photoperiod of 12L: 12D. Experimental unit was consisted of moistened cotton pads rested on sponges over a foam dishes (15x20 cm). Mulberry leaf discs (3 cm in diameter) were placed upside down on the experimental units. Water was added, as required to prevent mites from escaping and to keep the culture healthy.

Biological aspects and consumption rates:

To study the effect of prey types on development and prey consumption of *N. californicus*, four groups of 40 newly deposited eggs were singly transferred with a fine brush to arena (small leaf discs 3cm in diameter). Developmental stage and the number of eggs consumed were recorded twice a day until adult stage. A male was introduced for one day to each arena for mating and then removed. Every replicate was observed daily to record the number of eggs laid and the number of prey eggs consumed until the female died. Every two days the leaf disc with prey eggs and motile stages in each arena was replaced with a new one.

Life-table parameters:

Life-table parameters as defined by (Birch, 1948) were calculated using a BASIC computer program (Abou-Setta *et al.* 1986). Sex ratio from each experiment was determined by visual observation and life tables were constructed from the data obtained for developmental time of immatures and adult characteristics.

Statistical analysis:

To compare the influence of prey species, developmental time, prey consumption, fecundity and duration of adult female reproductive stages was analyzed by one-way ANOVA and means were compared by using student's least significant difference. Significance level was $P < 0.05$. Analysis was conducted using SAS statistical software (SAS Institute, 2010).

RESULTS AND DISCUSSION

Developmental time and consumption rate of *N. californicus*:

N. californicus completed its development on the studied prey types (i.e. *B. phoenicis*, *T. guavae* and *T. urticae* eggs and motile stages). Developmental period (from egg to adult) of females and males was significantly affected by prey type (Table 1). Incubation period of eggs ranged from 1.2 to 1.6 days under laboratory conditions of 25°C and 75% R.H. Developmental periods of both female and male *N. californicus* were longer when they fed on *T. guavae* motile stages than on motile stages of *T. urticae*. Mean developmental periods of *N. californicus* varied from 7.02 to 10.25 days for females and from 6.8 to 9.19 days for males.

Similar results were mentioned for *N. californicus*. Shortest developmental time was 7.8 days when fed on *T. urticae* immatures. Longest (13.9 days) was on adults of *Tetranychus cucurbitacearum* (Ali and El-Laithy, 2005). Pollens of date palm and castor bean significantly elongated the life cycle of *N. californicus* females compared with *T. urticae* nymphs (El-Laithy and El-Sawi, 1998). The total number of eggs laid per *N. californicus* female was 54.5 and 35.5 eggs when reared on *T. urticae* and *Panonychus ulmi* (Koch), respectively (Croft *et al.*, 1998).

Effect of prey types on longevity, fecundity and consumption rate of *N. californicus*:

Adult females consumed higher numbers than males (Table 3). The consumption rate from *B. phoenicis*, *T. guavae* and *T. urticae* (eggs and motile stages) increased through the developmental stages. Predatory larvae, nymphs and female of *N. californicus* consumed a significantly higher number of *T. guavae* than other ones (Table 3).

The pre-oviposition period differed with all food tested (Table 2). Females of *N. californicus* reared on

T. urticae motile stages had a significantly longer oviposition period and adult longevity than on other food tested (19.8 and 28.2 days) (Table 2). Females during the oviposition period consumed a significantly higher number of preys than the pre- and post- oviposition periods. Females of *N. californicus* consumed a higher number of *T. guavae* (382.6 individuals) during the oviposition period and adult longevity (496.2 individuals) than other diets (Table 3).

Table (1): Mean durations (days) of *Neoseiulus californicus* reared on different prey types at 25 ± 2°C, 75% R.H. and 12L: 12D photoperiod.

Developmental stages	Sex	*B. phoenicis* motile stages	*T. guavae* motile stages	*T. urticae* eggs	*T. urticae* motile stages	L.S.D. at 5%
Egg	♀	1.45^{ab}	1.6^{a}	1.32^{b}	1.5^{ab}	0.21
	♂	1.3^{a}	1.38^{a}	1.2^{a}	1.4^{a}	0.33
larva	♀	1.4^{bc}	2.1^{a}	1.55^{b}	1.2^{c}	0.28
	♂	1.4^{bc}	2.00^{a}	1.7^{ab}	1.1^{c}	0.47
Protonymph	♀	2.62^{b}	3.1^{a}	2.47^{b}	2.1^{c}	0.31
	♂	2.2^{a}	2.75^{a}	2.45^{a}	2.1^{a}	0.61
Deutonymph	♀	3.1^{b}	3.45^{a}	3.0^{b}	2.27^{c}	0.34
	♂	2.55^{b}	3.06^{a}	3.1^{a}	2.2^{b}	0.49
Immatures	♀	7.12^{b}	8.65^{a}	7.0^{b}	5.55^{c}	0.53
	♂	6.15^{b}	7.81^{a}	7.25^{a}	5.4^{c}	0.72
Life cycle	♀	8.57^{b}	10.25^{a}	8.3^{b}	7.02^{c}	0.60
	♂	7.45^{b}	9.19^{a}	8.45^{a}	6.8^{b}	0.84
Longevity	♀	18.0^{c}	16.70^{c}	24.3^{b}	28.2^{a}	1.54
	♂	13.4^{c}	14.9^{c}	17.8^{b}	20.8^{a}	2.46
Life span	♀	26.5^{c}	26.95^{c}	32.6^{b}	35.2^{a}	1.54
	♂	20.85^{c}	23.5^{b}	26.25^{ab}	27.6^{a}	2.65

Means within rows followed by the same letter were not significantly different at the 5% level.

Table (2): Longevity and fecundity of *Neoseiulus californicus* female reared on different prey types**.**

Developmental stages	*B. phoenicis* motile stages	*T. guavae* motile stages	*T. urticae* eggs	*T. urticae* motile stages	L.S.D. at 5%
Preoviposition	2.1^{c}	2.80^{b}	4.4^{a}	2.97^{b}	0.46
Oviposition	10.55^{c}	7.7^{d}	15.0^{b}	19.8^{a}	1.30
Postoviposition	5.3^{ab}	6.20^{a}	5.0^{b}	5.5^{b}	0.73
Longevity	18.0^{c}	16.70^{c}	24.3^{b}	28.2^{a}	1.54
Fecundity	16.7^{c}	12.60^{c}	40.1^{b}	49.3^{a}	4.18
Daily rate	1.6^{b}	1.65^{b}	2.7^{a}	2.5^{a}	0.24

Means within rows followed by the same letter were not significantly different at the 5% level.

Table (3): Number of prey consumed (Mean ± S.D.) by *Neoseiulus californicus* female and male reared on different diets.

Developmental stages	*B. phoenicis* motile stages	*T. guavae* motile stages	*T. urticae* eggs	*T. urticae* motile stages	$L.S.D._{5\%}$
Female					
Larva	1.2^{c}	7.2^{a}	3.25^{b}	$2.2b^{c}$	1.08
Protonymph	3.9^{b}	13.45^{a}	4.25^{b}	4.2^{b}	1.63
Deutonymph	5.5^{c}	19.6^{a}	8.9^{b}	6.85^{bc}	2.28
Preoviposition	24.5^{b}	58.0^{a}	26.1^{b}	19.1^{c}	4.49
Oviposition	149.4^{bc}	382.6^{a}	153.8^{b}	116.8^{c}	34.0
Postoviposition	29.3^{b}	55.6^{a}	29.3^{b}	25.3^{b}	4.59
Adult longevity	203.2^{b}	496.2^{a}	209.2^{b}	161.2^{c}	40.0
Male					
Larva	1.5^{b}	9.5^{a}	3.3^{b}	2.2^{b}	1.83
Protonymph	3.1^{b}	12.9^{a}	4.7^{b}	4.2^{b}	1.97
Deutonymph	5.0c	17.9^{a}	8.4^{b}	$6.4b^{c}$	2.99
Adult longevity	117.9^{b}	300^{a}	127.1^{b}	131.4^{b}	38.65

Means within rows followed by the same letter were not significantly different at the 5% level.

Table (4): Life-table parameters of *Neoseiulus californicus* reared on different prey types.

Parameter	*B. phoenicis* motile stages	*T. guavae* motile stages	*T. urticae* eggs	*T. urticae* motile stages
Mean generation time (T_G)[a]	12.45	13.57	13.88	13.11
Survival rate %	0.9	0.86	0.92	0.95
50% mortality	20	18	23	28
Sex ratio (females/total)	0.7	0.75	0.72	0.76
Net reproductive rate (R_o)[b]	10.45	6.74	26.86	35.59
Intrinsic rate of increase (r_m)[c]	0.188	0.14	0.236	0.272
Finite rate of increase (λ)	1.2	1.15	1.26	1.31
Doubling generation (DT)[a]	5.12	6.88	4.08	3.54

[a] Day, [b] per generation, [c] individuals/female/day

$R_o = \Sigma(l_x \times m_x)$; $T = \Sigma(x \times l_x \times m_x) / \Sigma(l_x \times m_x)$; $r_m = \ln(R_o)/T$; $DT = \ln(2)/ \mathbf{r_m}$ and $\lambda = \exp(\mathbf{r_m})$

The mean total and daily fecundity of *N. californicus* fed on various diets are given in (Table 2). The highest mean total egg production of *N. californicus* was on *T. urticae* motile stages (49.3 eggs/♀) with daily rate of (2.5 eggs/♀/day), and the lowest on motile stages of *T. guavae* and *B. phoenicis* (12.6 and 16.7 eggs/ ♀), respectively. All diets showed statistically different results. Individuals of *T. guavae* were unsuitable for egg laying of the predator *N. californicus*. Total prey consumption for male during its longevity was 117.9, 300, 127 and 131.4 when fed on *B. phoenicis, T. guavae,* egg of *T. urticae* and motile stages of *T. urticae,* respectively (Table 3).

Results in the current study are in agreement with those Gotoh *et al.*, 2006, indicated that the developmental periods of immature *N. californicus* females and males were significantly affected by the prey species fed on. The developmental period of *N. californicus* was shorter on eggs of two *Tetranychus* species than on eggs of *Panonychus ulmi*. Immature females had a higher predation rate than immature males. Pre-oviposition period, oviposition period and number of eggs laid per female were not significantly affected by either the plants or the type of prey eggs. Total consumption by *N. californicus* adults was lower for eggs of *P. ulmi* than for eggs of the other four species, apparently because of the shorter post-oviposition period when fed on eggs of *P. ulmi*. Also, Taj and Jung (2012) reported lifetime fecundity (63.9 eggs at 25°C) fed on *P. ulmi* that noticeably was greater than the similar studies.

The reported daily oviposition rate of *N. californicus* fed on *P. ulmi* by Gotoh *et al*. (2006) was 3.0–3.2 eggs/female/day at 25°C; while we found a lower number 1.91eggs/female/day. On the other hand, at 25°C and a diet of *T. urticae*, the Japanese strain gave (3.3–3.4 eggs/female/day (Gotoh *et al*., 2006)) and the Korean strain (3.2 eggs/female/day (Taj & Jung, 2012)) was almost similar together.

Effect of prey type on life table parameters:

The sex ratio (female/ total) of predator varied from 0.72 to 0.76%. The highest value of the intrinsic rate of natural increase r_m (0.272) individuals/♀/day for *N. californicus* was reached when fed on *T. urticae* motile stages; while the lowest one of (0.14) was on motile stages of the eriophyid *T. guavae*. The finite rate of increase (λ) was the highest 1.31 when predator females continuous consumed *T. urticae* motile stages, whereas was the lowest 1.2 when continuously eriophyid *T. guavae*. The time for population doubling (DT) was shortest on *T. urticae* motile stages 3.54 days; while the longest one on the eriophyid *T. guavae*, 6.88 days (Table 4). Results in the current study are in agreement with (Ali and El-Laithy 2005) who indicated that the highest value of the intrinsic rate of natural increase (r_m) 0.24 for *N. californicus* was reached when fed on *T. urticae* immature; while the lowest one of 0.13 was on eggs of *T. urticae* or adult of *T. cucutbitacearum*. In addition, the net reproductive rate (R_o) of *N. californicus* was highest at 25°C (22.92 females/female) and lowest at 30°C (16.74 females/female). The mean generation time (T) decreased from 20.61 to 16.79 days with increasing temperature up to 30°C. The intrinsic rate of natural increase (r_m) ranged from 0.162 to 0.285, and was maximal at 25°C (Canlas *et al*., 2006) (Table 5).

There are many reports on the life-history traits of predatory mites in relation to their importance as biological control agents (Gotoh *et al.*, 2004). The r_m-value of *N. californicus* in present study was 0.237 day $^{-1}$ at 25°C which is close to the obtained values for Korean strain (Taj & Jung 2012) and the Japanese strain (Gotoh *et al*., 2004) (Table 5). The value of r_m when *N. californicus* was reared on *T. urticae* eggs and maize pollen was 0.17 and 0.23 day^{-1}, respectively (Saber, 2012).

The age-stage-specific survival rate (*lx*), probability that a newly hatched *N. californicus* mite will survive to age *x* and age specific fecundity (*mx*), (Figure 1) shows the survivorship and stage differentiation, as well as the variable developmental rate. Total survival of *N. californicus* immature on four diets was 0.9, 0.86, 0.92 and 0.95; while the 50% mortality of adult female of the predatory mite was 20, 18, 23 and 28 days on *B. phoenicis*, *T. guavae*, *T. urticae* eggs and motile stages, respectively (Table 4).

Table (5): Summary of life table parameters for predatory mite *Neoseiulus californicus* at 25°C.

Prey	Parameters			
	R_o	r_m	T_G	References
T. urticae (all stages)	29.90	0.19	17.40	Mesa *et al.* (1990)
T. urticae (all stages)	36.6	0.26	13.90	Castagnoli & Simoni (1991)
T. urticae (all stages) on lima bean	28.6	0.27	15.30	Gotoh *et al.* (2004)
T. urticae egg	24.2	0.32	9.8	Ali and El-Laithy 2005
T. urticae immature stages	43.58	0.36	10.2	Ali and El-Laithy 2005
T. urticae (all stages) on kidney bean	22.9	0.21	17.5	Canlas *et al.* (2006)
T. urticae egg on common bean	32.95	0.31	11.23	Gotoh *et al.* (2006)
T. kanzawai egg on tea	33.94	0.30	11.5	Gotoh *et al.* (2006)
P. ulmi (all stages) on apple	28.81	0.31	11.02	Gotoh *et al.* (2006)
T. citri (egg stages) on orange	31.02	0.29	11.68	Gotoh *et al.* (2006)
P. ulmi (all stages) on apple	49.24	0.25	15.31	Taj & Jung (2012)
P. ulmi (all stages) on apple	31.64	0.23	14.54	Maroufpoor *et al.* (2013)

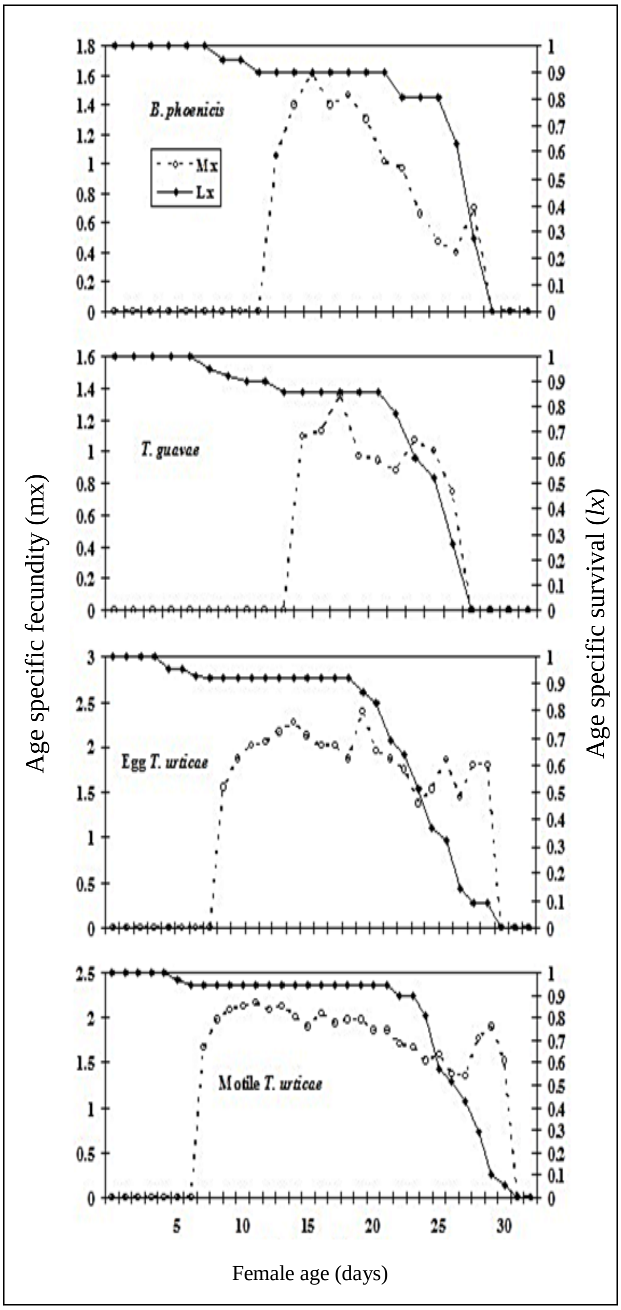

Fig. (1): Age-specific survival (*lx*) and age-specific decundity (*mx*) of predatory mite *N. californicus* reared on different diets.

It can be concluded that feeding predator on motile stages of *T. urticae* is better for long-term preservation of *N. californicus* females than other preys due to a shorter developmental duration, a higher egg production and more favorable life table values.

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