J. Plant Prot. and Path., Mansoura Univ., Vol. 10 (1): 43- 47 , 2019

Biological Aspects and Life Table Parameters of the Predatory Mite, *Neoseiulus californicus* McGregor (Acari: Phytoseiidae) Reared on Different Diets

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ABSTRACT

The predator mite *Neoseiulus californicus* McGregor is an effective predator that is used to control the invasion of *Tetranychus urticae* Koch on crop plants. Experiments for rearing *N. californicus* on different food sources were carried out under laboratory condition (25±2ºC, 75+5 % RH). *N. californicus* was reared on three different food types; two types of phytophagous mites (*Tetranychus urticae* and *Brevipalpus phoenicis* Geijskes) and date palm pollens. In response to food type, the periods of *N. californicus* immature stages were 4.79, 8.14, and 11.79 days for females and 3.93, 6.71, and 10.71 days for males when fed on *T. urticae*, *B. phoenicis*, and date palm pollen, respectively. The developmental periods (life cycle) of both female and male individuals were longer when they fed on date palm pollen (14.07, 12.86 days for females and males respectively) compared with 6.93, 5.79 days for females and males in case of feeding on *T. urticae* and 10.29, 8.79 days for those reared on *B. phoenicis. N. californicus* males completed their developmental stages on the studied food types successfully ,however, *N. californicus* females were significantly affected by the type of food, which recorded the highest number of eggs per each female when fed on *T. urticae* (32.14 eggs), followed by females that fed on *B. phoenicis* and date palm pollen (13.29 and 3.86 eggs, respectively). Obtained results provide alternatives of *T. urticae* to rear *N. californicus* for mass production although the efficiency was not the same.

Keywords: Biological aspects, life table parameters, *Brevipalpus phoenicis,* date palm pollen**,** *Neoseiulus californicus*, *Tetranychus urticae.*

INTRODUCTION

Tetranychus urticae is one of the most harmful phytophagous mites among the pests threating crop production (20-45% were lost of the yield according to the season) as growth, chlorophyll contents and fruit size as well as quality are affected in severe mites infection (Rhodes *et al.*, 2006; Premalatha *et al.*, 2018). *T. urticae* has a high rate of fecundity and a short life cycle that can be seven days at high temperatures of about 32°C. *T. urticae* greatly affect strawberries (Rhodes *et al.*, 2006). The long term intensive use of acaricides leads to the dominance of resistant population that could not be affected by chemical pesticides and that would be reflected on plant yield (Fraulo and Liburd, 2007). Biological control the most important component of integrated pest management to decrease populations of phytophagous mites.

The biological control using phytoseid mites is an important approach to control phytophagous mites and insects in economical crops (Greco *et al.*, 2005; Khodayari *et al.*, 2013). *Neoseiulus californicus* McGregor (Acari: Phytoseiidae) is a representative example of such mites that could be used in augmentative biological control against various pests such as *Tetranychus urticae* (Cock *et al.*, 2010; Van Lenteren, 2012). In addition, *N. californicus* has been described as one of the major phytoseiid predators of spider mites and that associate with their dense webbing as it can cut through with its chelicerae (McMurtry *et al.*, 2013). Several reports indicated its use for the control of spider mites in field and greenhouse horticultural crops in North and South America and Europe (Swirski *et al.*, 1970; Castagnoli and Liguori, 1991; McMurtry and Croft, 1997; Jolly, 2000). *N. californicus* versatility as a biocontrol agent in its selective predation of spider mites with general habits in consuming various types of food such as eriophyid, tarsonemid, tydeid, insects, pollen and plant exudates (Castagnoli and Liguori, 1991; McMurtry and Croft, 1997; Castagnoli and Simoni, 1999). The possibility of mass rearing of *N. californicus* on alternative and more economical diet such as pollen increases the interest in this predator as a control agent (Castagnoli and Simoni, 1999). *Tetranychus urticae* is a suitable prey for *N. californicus* enabling its development to the adult stage (Gotoh *et al.*, 2006). *N. californicus* feeds on a wide range of spider mites and so it has been recommended as a biological control agent for these mites in various crops (Gotoh *et al.*, 2006).

The purpose of this study was to monitor the biological aspects and life table parameters of *N. californicus* in response to feed on date palm pollen and two types of phytophagous mites, as a contribution to its mass rearing to enable its use in the biological control of *T. urticae* in the greenhouse.

MATERIALS AND METHODS

Pollen collection

The pollens of date palm, *Phoenix dactylifera* L.*,* were collected from date palm orchard in Belkas, Dakahlia governorate. The pollens were oven-dried at 37°C for 48 h and then refrigerated at 4°C for up to two weeks during the experiment.

Phytophagous mites cultures

Brevipalpus phoenicis Geijskes and *T. urticae* mites were collected from Date palm trees in Belkas, Dakahlia governorate, and reared continuously in pure cultures on mulberry leaves in Petri-dishes at 25±2 ºC and 75±5 % R.H. Both types of mites have been authenticated in Plant Protection Research Institute, Dokki, Giza.

Predatory mite cultures

The collection of *N. californicus* was obtained from strawberry infested leaves with its pray *T. urticae* from Belkas, Dakahlia governorate. *N. californicus* has been identified in Plant Protection Research Institute, Giza. The pure culture was made by using leaf discs of *Ricinus communis* placed in Petri dishes (9 cm in diameter) containing cotton soaked in tap water and changed routinely every 2-3 days.

Experimental design

50 deposited eggs of *N. californicus* were transferred individually to one square inch leaf discs of *R. communis* leaves placed on cotton soaked in tap water (Khanamani *et al.*, 2017). These eggs (50 eggs for each treatment) were checked twice daily and the incubation period was recorded. After the emergence of larval predators, the pollen (0.05mg per experimental unit), immature stages of *T.urticae* and *B. phoenicis* were offered as food to *N. californicus* and the biological aspects were checked twice daily using a stereomicroscope ,and the development and survivorship of the different immature stages were monitored. Upon emergence of adults, females and males were coupled. The couples were kept together up to the end of the study; when a male died, it was replaced with a new one. The duration of pre-oviposition, oviposition and post-oviposition periods as well as longevity and fecundity were recorded. The daily observations continued until the death of the last individual. In pollen treatment, fresh pollen was offered in seven-day intervals, removing the older pollen to avoid contamination with fungi.

Life table parameters such as r_m values for *N. californicus* females were calculated according to the equation described previously (Birch, 1948; Childers, 1986);

$$\Sigma e^{-rmx} l_x m_x = 1$$

Where x is the age interval, l_x is the age-specific survival rate and m_x is the average number of female progeny.

The net reproductive rate ($R_0 = \Sigma l_x m_x$), the average generation time ($t_G = \ln R_0/r_m$) and the finite rate of increase $\lambda = e^{rm}$ was calculated with the corresponding formula. Doubling time ($t_D = \ln 2/r_m$) was calculated as described by (Mackauer, 1983).

RESULTS AND DISCUSSION

Developmental periods:

The developmental periods (from egg to adult) of *N. californicus* females and males were significantly affected by food type as shown in Table 1. Incubation period of eggs ranged from 1.86 to 2.29 days under laboratory conditions of 25°C and 75% R.H. on *T. urticae* and pollen, respectively. While the Mean periods of *N. californicus* immature stages was 4.79, 8.14, and 11.79 days for females and 3.93, 6.71, and 10.71 days for males when fed on *T. urticae*, *B. phoenicis*, and date palm pollen, respectively.

Table 1. Mean durations (per days) of *N. californicus* reared on different food types at 25 ± 2°C, 75% R.H.

Developmental stages	Sex	*Tetranychus urticae*	*Brevipalpus phoenicis*	Date palm pollen	L.S.D. 0.05%
Egg	♀	2.14±0.38 [a]	2.14±0.38 [a]	2.29±0.49 [a]	0.47
	♂	1.86±0.38 [a]	2.07±0.35 [a]	2.14±0.38 [a]	0.41
Larva	♀	1.14±0.24 [b]	1.43±0.35 [ab]	1.79±0.39 [a]	0.37
	♂	1.07±0.19 [b]	1.29±0.39 [ab]	1.57±0.35 [a]	0.36
Protonymph	♀	1.93±0.35 [c]	2.79±0.27 [b]	4.64±0.56 [a]	0.46
	♂	1.57±0.45 [c]	2.29±0.39 [b]	4.71±0.70 [a]	0.60
Deutonymph	♀	1.71±0.39 [c]	3.93±0.53 [b]	5.36±0.56 [a]	0.56
	♂	1.29±0.39 [c]	3.14±0.48 [b]	4.43±0.35 [a]	0.46
Immature stages	♀	4.79±0.64 [c]	8.14±0.85 [b]	11.79±0.99 [a]	0.95
	♂	3.93±0.45 [c]	6.71±0.99 [b]	10.71±0.81 [a]	0.88
Life cycle	♀	6.93±0.93 [c]	10.29±1.04 [b]	14.07±0.84 [a]	1.05
	♂	5.79±0.70 [c]	8.79±1.22 [b]	12.86±0.90 [a]	1.08
APOP		1.93±0.61 [b]	2.14±0.69 [b]	4.93±1.67 [a]	1.24
TPOP		8.86±0.99 [c]	12.43±0.98 [b]	19±1.12 [a]	1.16
Oviposition		17.57±1.43 [a]	10.21±1.04 [b]	3.36±1.07 [c]	1.34
Fecundity		32.14±1.95 [a]	13.29±1.38 [b]	3.86±1.57 [c]	1.86
Adult longevity	♀	27.07±1.69 [a]	17.64±1.75 [b]	18.71±1.85 [b]	1.98
	♂	20.71±2.46 [a]	13.57±2.15 [b]	8.64±0.90 [c]	2.20
life span	♀	34.00±2.36 [a]	27.93±2.01 [b]	32.79±1.85 [a]	2.34
	♂	26.50±3.06 [a]	22.36±3.18 [b]	21.50±1.73 [b]	3.07

APOP= Adult preoviposition period, TPOP= Total preoviposition period

The developmental periods of both female and male individuals were longer when they fed on date palm pollen (14.07, 12.86 days for females and males, respectively) compared with 6.93, 5.79 days for females and males in case of feeding on *T. urticae* and 10.29, 8.79 days for those reared on *B. phoenicis*. The same results were reported previously by Ali and El-Laithy, (2005) when *N. californicus* developmental time was 7.8 days when fed on *T. urticae* immatures, but the longest period (13.9 days) was recorded when *N. californicus* was fed on *T. cucurbitacearum* adults. In the same context, feeding on pollens of date palm and castor bean significantly elongated the life cycle of *N. californicus* females compared with *T. urticae* nymphs diet (El-Laithy and El-Sawi, 1998). These differences might be attributed to the response of *N. californicus* for different food supplies (Kustutan and Cakmak, 2009)

Female reproductive period and fecundity:

Egg laying of *N. californicus* females was significantly affected by the type of food, which recorded the highest number of eggs per female when fed on *T. urticae* (32.14 eggs) followed by 13.29 eggs in case of *B. phoenicis* and the lowest number of eggs was obtained when females fed on date palm pollen (3.86 eggs) (Fig. 1). The mean oviposition period for each female, also significantly affected by the type of food which was 17.57, 10.21 and 3.36 days when fed on *T. urticae*, *B. phoenicis* and date palm pollen, respectively as shown in Table 1.

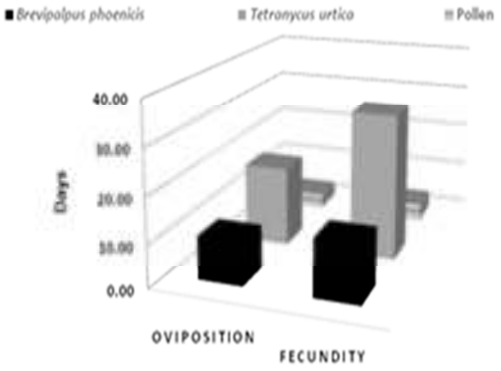

Figure 1. Female reproductive period and fecundity of *N. californicus* reared on different food types at 25 ± 2°C, 75% R.H.

Adult longevity:

N. californicus females and males completed their developmental stages successfully on the studied food type (*T. urticae, B. phoenicis* and date palm pollen). *N. californicus* adult longevity for the tested food was 27.07, 17.64 and 18.71 days for Females respectively. For males, the longevity was 20.71, 13.57 and 8.64 days for the testes food mentioned before, (Table 1). From the obtained data, it is clear that females of *N. californicus* reared on *T. urticae* had a significantly longer adult longevity than (27.07 days) those feed on other tested food due to it has the longest oviposition period (17.57 days). Respectively

Prey consumption:

The predatory mite *N. californicus* fed successfully on the tested preys. Female of *N. californicus* consumed a significantly higher number of *B. phoenicis* than the other one, as shown in Table 2. The consumption rate for both preys increased through the developmental stages.

Table 2. Prey consumption of *N. californicus* when fed on *Brevipalpus phoenicis, Tetranychus urticae* at 25±2°C& 75±5% R.H.

Developmental stages	Sex	*T. urticae*	*B. phoenicis*	L.S.D. at 0.05%
Larva	♀	2.29±0.76 [a]	0.86±0.69 [b]	0.84
	♂	2.43±0.53 [a]	1.14±0.69 [b]	0.72
Protonymph	♀	4.29±1.11 [a]	3.43±1.27 [a]	1.39
	♂	3.86±1.57 [a]	2.57±1.27 [a]	1.67
Deutonymph	♀	5.86±1.57 [a]	4.86±0.90 [a]	1.49
	♂	5.71±1.50 [a]	4.57±1.13 [a]	1.55
Preoviposition		18.86±3.85 [a]	21.14±2.41 [a]	3.74
Oviposition		109.86±13.72 [b]	137.57±11.41 [a]	14.70
Postoviposition		17.14±3.34 [a]	20.29±3.82 [a]	4.18
Adult longevity	♀	145.86±13.80 [b]	179.00±8.79 [a]	13.48
	♂	92.14±7.63 [a]	102.29±10.93 [a]	10.98

Females consumed higher numbers than males throughout all developmental stages of the predator. The consumption of prays during the oviposition period was significantly higher than the pre- and post-oviposition periods. Females of *N. californicus* consumed a higher number of *B. phoenicis* (137.57 individuals) during the oviposition period and adult longevity (179 individuals) than other diets. This result indicates the ability of the used *N. californicus* strain to adapt itself for new elective pray (Castagnoli and Simoni, 1999), although it takes several generation from other predator strains to efficiently adapt to new prays (Castagnoli *et al.*, 1999). During adult longevity, female and male consumed an average number of *Tetranychus urticae* (145.86) and (92.14) individuals under laboratory conditions for females and males, respectively (Table 2).

Life table parameters

The calculated life table parameters were constructed using the survival data of a specific age (Lx) and the female offspring produced per female in each age (Mx), the net reproductive rate (Ro), the mean generation time (T_c), the intrinsic rate of increase (r_m) and the finite rate of increase (e^{rm}) (Table3).

The mean generation time (T) of predator mite, *N. californicus* was significantly affected by the type of food. The longest time needed for one generation (18.02 days) was recorded when the mite fed on date palm pollen, whereas, the shortest period was (15.04 days) on *T. urticae*. The net reproductive rate (R_o) was (24.75, 7.89 and 1.51) per generation when fed on mentioned diets, respectively. On the other hand, when the values of r_m was converted to the finite rate of increase (e^{rm}), it was clear that population of predator had capacity to multiply about (1.24, 1.13 and 1.02) times/female/day when it fed on the mentioned diets, respectively. These results are similar to those obtained by previous studies (Gotoh *et al.*, 2004; Canlas *et al.*, 2006; El Taj and Jung, 2012; Saber, 2012). The r_m values are affected not only by the food type but also by the type of the host plant of the prey (Kustutan and Cakmak, 2009).

Table 3. Effect of different foods on the life table parameters of phytoseiid mite *N. californicus* at 25±2 °C and 75±5% R.H.

Parameters	*T. urticae*	*B. phoenicis*	Pollen
Life cycle	6.93	10.29	14.06
Oviposition period [a]	17.57	10.21	3.36
Mean total fecundity(egg/♀)	32.14	13.29	3.86
Daily rate (egg/♀/day)	1.83	1.30	1.14
Sex ratio (females/total)	0.73	0.69	0.61
Mean generation time (T_c) [a]	15.04	16.59	18.02
Net reproductive rate (R_o) [b]	24.75	7.89	1.51
Intrinsic rate of increase (r_m) [c]	0.21	0.12	2.28
Finite rate of increase (e^{rm})	1.24	1.13	1.02

[a] Days, [b] Per generation, [c] Individuals/female/ day.

It could be generally concluded that *T. urticae* and *B. phoenicis* was the most suitable diets more than date palm pollen for the development and reproduction of predatory mite, *N. californicus*. The results demonstrate that the populations of *N. californicus* are able to feed and complete their development when reared on the three tested diets. In conclusion, this study presents alternative diets for mass rearing of *N. californicus* that could used in case of absence of its common pray *T. urticae*,.

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الخواص البيولوجيه وجداول الحياة للاكاروس المفترس*Neoseiulus californicus* (اكاري: فيتوسيدي) عند تربيه علي انواع غذاء مختلفه

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المفترس الاكاروسي (McGregor) *Neoseiulus californicus* هو مفترسا فعالا يستخدم للتحكم في زياده اعداد العنكبوت الاحمر *Tetranychus urticae* (Koch) على نباتات المحاصيل. ولقد أجريت تجارب لتربية *N. californicus* علي مصادر غذائية مختلفة تحت ظروف المختبر (25 ± 2 درجة مئوية ، 75 ± 5 ٪ رطوبه نسبيه) على ثلاثة أنواع مختلفة من الغذاء, نوعين من الاكاروسات نباتيه التغذيه *Brevipalpus phoenicis*, *Tetranychus urticae* و لقاح نخيل التمر لدراسه الاستجابة لنوع الطعام ، كانت المراحل غير الناضجة من المفترس *N. californicus* هي 4.79 ، 8.14 ، و 11.79 يوم للإناث و 3.93 ، 6.71 ، و 10.71 يوم للذكور عند التغذية على *T. urticae*، *B. phoenicis* ، و حبوب لقاح النخيل ، على التوالي. كانت فترات النمو(دوره الحياه) لدى كل من الإناث والذكور أطول عند إطعامهم على حبوب لقاح النخيل (14.07 ، 12.86 يوم للإناث والذكور على التوالي) مقارنة مع 6.93 ، 5.79 أيام للإناث والذكور في حالة التغذية على *T. urticae* و 10.25 ، 8.79 أيام لأولئك الذين تم تربيتهم في *B. phoenicis*. أكملت ذكور المفترس مراحل نموها على أنواع الطعام المدروسة بنجاح ، إلا أن انثي *N. californicus* تأثرت بشكل كبير بنوع الطعام ، الذي سجل أعلى عدد من البيض لكل أنثى عند تغذيتها على *T. urticae* (32.14 بيضة). ، تليها الإناث التي تتغذى على *B. phoenicis* و حبوب لقاح النخيل (13.29 و 3.86 بيض ، على التوالي). توفر النتائج الممثلة تغذيات بديله غير للعنكبوت الاحمر *T. urticae* للمفترس *N. californicus* وزياده اعداده على الرغم من أن الكفاءة لم تكن هي نفسها.