

**Potential of *Neoseiulus californicus* (Mc-Gregor) as a Biocontrol Agent of *Panonychus citri* (Mc-Gregor) (Phytoseiidae-Tetranychidae)**

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**ABSTRACT**

The life history and predation rate of the predatory mite, *Neoseiulus californicus* (Mc-Gregor) on the citrus red mite, *Panonychus citri* (Mc-Gregor) were studied under laboratory conditions at 25°C and 60–70% R.H. All movable stages of the predator were able to devour all different stages of *P. citri*. Average consumption rates of eggs, larvae, protonymphs, deutonymphs and adult males and females of *P. citri* by the predator larva were  $0.8 \pm 0.71$ ,  $0.7 \pm 0.32$ ,  $0.5 \pm 0.40$ ,  $0.3 \pm 0.23$ ,  $0.2 \pm 0.10$  and  $0.3 \pm 0.23$  prey individuals, respectively. These values increased with predator development from protonymph to adult. The predator adult female devoured  $7.8 \pm 1.12$ ,  $7.5 \pm 0.86$ ,  $5.0 \pm 1.30$ ,  $3.7 \pm 0.86$ ,  $2.5 \pm 3.20$  and  $5.1 \pm 0.86$  prey individuals; while those for male were  $5.5 \pm 0.72$ ,  $5.5 \pm 0.86$ ,  $4.3 \pm 1.40$ ,  $3.6 \pm 0.86$ ,  $3.0 \pm 2.4$  and  $4.0 \pm 0.86$  prey individuals for the previous prey stages, respectively. Thus, the predator adult female ate more than any other stage. In addition, the eggs and larvae, compared to other stages of *P. citri*, were the most consumed by all different predator stages; this raised the predator fecundity unlike the adult stage of the prey. Predation rate, life cycle, and oviposition periods varied depending on prey stages. The intrinsic rate of natural increase ( $r_m$ ) was higher on prey immatures and eggs than on prey adult females, which were 0.149, 0.092 and 0.042, respectively. Results indicated the effectiveness of *N. californicus* as an important biological control agent against *P. citri*.

**Key Words:** *Neoseiulus californicus*, Development, Life table, Predation, Citrus red mite, *Panonychus citri*.

**INTRODUCTION**

The agricultural sector occupies a prominent possession in the Egyptian national economy, of which orchards and mainly citrus production is considered one of the main objectives. The amount of Egyptian export of orange crops represented 9.1% from the total worldwide export during year 2011.

The citrus red mite, *Panonychus citri* (Mc-Gregor) is one of the most important worldwide pest species infesting over 80 plant species, including citrus species; but prefers sweet oranges. If population's low, *P. citri* is mainly found in the upper parts of trees, where there is strong sunlight; while when populations are high, *P. citri* can be found over the entire tree (Izquierdo *et al.*, 2002). *P. citri* and associated predaceous phytoseiid mites occurring on citrus are well documented (McMurtry 1985).

*Neoseiulus californicus* has proven its potential as biological control agent of the red spiders and eriophyids in Egypt (Mowafi *et al.*, 2009 and Ebrahim *et al.*, 2013). Its behavior suggests that it is opportunistic and capable of capturing several deferent types of prey (Takano-Lee and Hoddle, 2002). In addition, it was effective in reducing *P. citri* densities when released on citrus and the initial prey density is an important factor influencing their performance (Fadamiro *et al.*, 2013). *N. californicus* can survive periods of starvation in the laboratory (Xiao & Fadamiro 2010) and tolerates high field temperatures (McMurtry & Croft 2000, Blackwood *et al.*, 2001) and adapts to disturbed habitats, such as

intensively-managed orchards (McMurtry & Croft 1997). Therefore, this paper dealt with evaluation of *N. californicus* as a biocontrol agent of *P. citri*.

**MATERIALS AND METHODS**

The life history and predation rate of the predatory mite, *N. californicus* (Mc-Gregor) on the citrus red mite, *Panonychus citri* (Mc-Gregor) were studied under laboratory conditions at 25°C and 60–70% R.H. Petri dishes, with dimension 100 mm diameter x 15 mm H, as rearing units, were coated on its lower surface with a layer of moist cotton wool and put upside down in large plates, 120 mm diameter x 15 mm height, full with water to provide moisture continuously. Five small discoid pieces of mulberry leaves, *Morus alba* L. (about 2.5 cm diameter), were put upside down on the moist cotton.

A layer of twirled wet cotton wool was placed around each leaf disc as barrier to confine the predator. About 5 Petri dishes were assigned for each developmental stage of *P. citri*. One egg of *N. californicus* was put on each disc for development to the adult stage and observed twice daily. When the *N. californicus* larvae hatched, a certain number of each developmental stage of *P. citri* were placed on each disc. Thus, one *N. californicus* larva was liberated on each disc, and the numbers of prey eaten during each of its larval, protonymphal, deutonymphal and adult female or male stages were recorded. Surplus food was provided whenever the supply became low.

The fecundity of *N. californicus* was determined

at 25°C. Three developmental stages of *P. citri* were assigned to estimate the life table parameters of *N. californicus* and these were egg, nymph and adult female. Before the final molt of the female deutonymph, one adult male was provided and was ensured to mate once. The male was then removed and observations were made twice a day until the first egg was laid. Thereafter, the number of laid eggs was recorded every 24 hours until the ovipositing female died. All resulting hatched larvae were transferred to new excised mulberry leaves and reared until adult stage to record the sex ratio of resultant progeny. Oviposition, pre- and post-oviposition periods were also recorded. The intrinsic rate of natural increase ( $r_m$ ) at 25°C was estimated according to the equation given by Birch (1948). The following life history parameters; net reproductive rate ( $R_o$ ), mean generation time ( $T$ ), and finite rate of increase ( $\lambda$ ) longevity and fecundity were determined.

## RESULTS AND DISCUSSION

The daily average consumption of *P. citri* developmental stages by those of *N. californicus* was listed in table 1. Daily average attacked eggs, larvae, protonymphs, deutonymphs, adult males and females of *P. citri* by *N. californicus* larva were  $0.8 \pm 0.71$ ,  $0.7 \pm 0.32$ ,  $0.5 \pm 0.40$ ,  $0.3 \pm 0.23$ ,  $0.2 \pm 0.10$  and  $0.3 \pm 0.23$  individuals, respectively. These values increased with predator development. Predator female was voracious as it devoured daily average  $7.8 \pm 1.12$ ,  $7.5 \pm 0.86$ ,  $5.0 \pm 1.30$ ,  $3.7 \pm 0.86$ ,  $2.5 \pm 3.20$  and  $5.1 \pm 0.86$  individuals; while male devoured  $5.5 \pm 0.72$ ,  $5.5 \pm 0.86$ ,  $4.3 \pm 1.40$ ,  $3.6 \pm 0.86$ ,  $3.0 \pm 2.4$  and  $4.0 \pm 0.86$  individuals from the previous prey stages, respectively.

Oviposition rates and periods of female adults of *N. californicus* at each of the three major developmental stages of *P. citri*, were estimated in days as listed in table 2. The average daily number of laid eggs per predator female was high when the immatures and eggs of the prey were provided as food, unlike the adult female of the prey, which were  $1.10 \pm 0.12$ ,  $0.70 \pm 0.14$  and  $0.40 \pm 0.09$  eggs, respectively. Also, the oviposition periods were longer when the adult female of the prey was provided as food and gradually became shorter when the eggs then immatures of the prey were provided as food, as follows  $20.26 \pm 1.50$ ,  $19.89 \pm 1.76$  and  $19.22 \pm 1.40$  days, respectively. The post-oviposition periods of the predator were longer when the eggs of the prey were provided as food and gradually became shorter when the immatures then adult females of the prey were provided as food, as follows  $13.43 \pm 4.75$ ,  $12.60 \pm 3.80$  and  $11.40 \pm 3.07$ , respectively.

The estimated values of *N. californicus* life table parameters are listed in table 3. The mean generation time ( $T$ , in days) of *N. californicus* was 19.61, 18.38 and 19.77 when eggs, immatures and adult females of *P. citri* were provided as food, respectively. The net reproductive rate ( $R_o$ ) was the highest with prey immatures, slightly lower and then lowest with prey eggs then adult females, which were 17.13, 11.28 and 5.19, respectively. Also, the intrinsic rate of natural increase ( $r_m$ ) was the highest with prey immature stages, slightly lower and then lowest with prey eggs and adult females and these were reflected on the finite rates of increase ( $\lambda$ ).

From the previous results, it could be concluded that all moving stages of *N. californicus* predated on all developmental stages of *P. citri*. Also, the adult female devoured more than any other stages and deutonymph devoured more than both protonymph and larva. The prey eggs and larvae were eaten frequently. Thus, the ability of the predator to suppress the eggs and nymphs of *P. citri* was rapidly unlike adults, which agrees with Fadamiro *et al.*, 2013 who reached similar result. As the density of juvenile prey increased, predation likewise increased which agrees with the study of Canlas *et al.*, 2006. In addition, although our study indicated that the consumption rate of the predator for eggs and nymphs of *P. citri* were similarly equal, however Xiao and Fadamiro, 2010 indicated that the predator preferred nymphs than eggs of *P. citri*, and the nymphs were most often the first prey attacked by the predator.

Estimating life and fecundity tables of the predator and prey are essential to evaluate the efficiency and potentiality of a natural enemy on a definite pest (Gabre *et al.*, 2005; Ozman-Sullivan, 2006; Collier *et al.*, 2007; Reis *et al.*, 2007; Ferrero *et al.*, 2007; Broufas *et al.*, 2007). Our results revealed that at immature stages of *P. citri*, the net reproductive rate ( $R_o$ ) and Intrinsic rate of natural increase ( $r_m$ ) of *N. californicus* showed high values, unlike other stages and the mean generation time of predator showed low value when provided mobile immatures as prey. This agreed with Xiao and Fadamiro, 2010 who stated that the possibility of nutritional benefits of *P. citri* nymphs were higher than those of eggs. This contradicted with the results of Gotoh *et al.*, 2006 who stated that eggs of *P. citri* were found to be of high nutritional value for the special strain of *N. californicus*, because it resulted in short developmental times, high consumption rates and high  $r_m$  values. We think that this is one of the unique cases of *N. californicus* when devoured *P. citri* prey, in contrast with *T. urticae* where egg of the prey is the determining factor for the nutrition and increasing

Table (1): The daily average consumption of *P. citri* developmental stages by those of *N. californicus*.

Predator stage	No. of consumed <i>P. citri</i> (Mean±S.D.)					
	Eggs	Larvae	Protonymphs	Deutonymphs	Males	Females
Larva	0.8 ±0.71	0.7 ±0.32	0.5 ±0.40	0.3 ±0.23	0.2 ±0.10	0.3 ±0.23
Protonymph	4.6 ±0.70	4.5 ±0.90	3.2 ±1.20	2.6 ±0.64	1.9 ±0.70	2.4 ±0.90
Deutonymph	5.7 ±0.71	5.5 ±0.90	3.7 ±1.10	2.8 ±0.74	2.1 ±1.4	2.5 ±0.74
Female	7.8 ±1.12	7.5 ±0.86	5.0±1.30	3.7 ±0.86	2.5±3.20	5.1 ±0.86
Male	5.5 ±0.72	5.5 ±0.86	4.3 ±1.40	3.6 ±0.86	3.0 ±2.4	4.0 ±0.86

Table (2): Oviposition rates and periods of female adults of *N. californicus* at three major developmental stages of *P. citri* in days.

Parameter	Prey evolutionary stages		
	Egg	Immature	Adult female
No. of eggs/female	13.92±3.09	21.14±2.44	12.16±2.10
No. of ggs/female/day	0.70±0.14	1.10±0.12	0.40±0.09
Pre-oviposition period	1.68±0.72	1.67±0.46	1.64±0.62
Oviposition period	19.89±1.76	19.22±1.40	20.26±1.50
Post-oviposition period	13.43±4.75	12.60±3.80	11.40±3.07
Total adult longevity	35.00±4.52	33.49±3.60	33.30±2.91

Table (3): Life table parameters of *N. californicus* reared on three major developmental stages of *P. citri* at 25 ± 2°C and 70 ± 5% R.H.

Prey stage	Mean generation time (T, days)	Net reproductive rate (Ro)	Intrinsic rate of natural increase ( $r_m$ /day)	Finite rate of increase ( $\lambda$ )	Sex ratio (F:M) <sup>a</sup>
Egg	19.61	11.28	0.092	1.09	2.1:0.9
Immatures	18.38	17.13	0.149	1.15	2.1:0.9
Adult female	19.77	5.19	0.042	1.04	2.1:0.9

fertility of the predator (Burnett, 1971; Croft & McMurtry, 1972; McMurtry & Rodriguez, 1987 and Gotohet *al.*, 2006). Our study revealed that the maximum intrinsic rate of natural increase value of *N. californicus*, obtained when provided *P. citri* immatures as food, reached 0.149. Actually, the intrinsic rate of natural increase of *N. californicus* presented lower value with *P. citri* compared with *T. urticae*. The intrinsic rate of natural increase of *N. californicus*, with *T. urticae* provided as food, reached values between 0.19 and 0.274 (Mesa *et al.*, 1990; Castagnoli & Simoni 1991; Rencken & Pringle 1998; Castagnoli *et al.*, 1999 and Gotoh *et al.*, 2004). Therefore, our study indicated that the effect of successive release of *N. californicus* in the open field will be more convenient for controlling *P. citri*, instead of single release, to compensate the low value of the intrinsic rate of natural increase of *N. californicus*. This agreed with Fadamiro *et al.*, 2013 who stated that 2 releases of *N. californicus*, at a rate of 200 per tree per release, effectively maintained *P. citri* at low densities (< 1.5 motiles per

leaf) throughout the duration (56 d) of the experiment.

Xiano and Fadamiro, 2010 stated that the mean number of eggs laid per day by *N. californicus* female when fed on *P. citri* was 0.3 eggs. This value differed from that obtained by Gotoh *et al.*, 2006 who stated that the number of eggs laid per female per day of the alien strain of predatory mite, *N. californicus*, (which was provided by Arista Life Science Co., Ltd., Tokyo, in July 2001) ranged from 3.03 to 2.95 when fed on eggs of *P. citri* and reared on sour orange (*Citrus aurantium*) and Cherry, respectively. This disagreed with our study that indicated different values of mean number of eggs laid per day by *N. californicus*, which were 0.70, 1.10 and 0.40 when the predator fed on eggs, immatures and adult females of *P. citri*, respectively. Accordingly, these differences in the intrinsic rate of natural increase of *N. californicus* may be attributed to presence of certain substances, probably hormones or with hormone like effect, which either increase fertility and laying eggs with *T. urticae*, or suppress fertility and laying eggs with *P.*

*citri*. These substances may be an integral component of the prey or obtained from the plants they feed on. The same explanation can be applied to the finding of high values of intrinsic rate of the natural increase of *N. californicus* obtained with the immature phase followed by eggs, as compared to lower values with the adult individuals of *P. citri* as prey. Also, it can be concluded that alien strain of the predatory mite, *N. californicus*, (which was provided by Arista Life Science Co., Ltd., Tokyo, in July 2001) have been reared and adapted on *P. citri*, reflected on the increasing values of the average number of eggs laid per day. *Phytoseiulus persimilis* and subsequently *N. californicus* need to spend several generations on this host for adaptation (Drukker *et al.*, 1997, Castagnoli *et al.*, 1998; 1999).

In conclusion, the current study indicated that *N. californicus* can play a good role in the control of *P. citri* (Xiao & Fadamiro 2010 and Fadamiro *et al.*, 2013) and can reduce its population densities as a generalist tetranychid predator (McMurtry & Rodriguez 1987; McMurtry & Croft 1997 and Croft *et al.*, 1998). This species can survive and reproduce on different mites, insect species and pollens (Castagnoli & Falchini, 1993; Sabelis & Van Rijn, 1997 and Croft *et al.*, 1998). It's ability to survive a few to several days of food deprivation in the field may be an important survival strategy for predacious mites, in particular those species with specialized diets (Pratt *et al.*, 1999; Blackwood *et al.*, 2001 and Xiao & Fadamiro, 2010).

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