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The Potential of Predatory Mites, *Neoseiulus cucumeris* (Ouds.) For Biological Control Corresponding to *Brevipalpus phoenicis* (Acari: Tenuipalpidae) and *Panonychus citri* (Acari: Tetranychidae)

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ABSTRACT

The life history and consumption rate of *Neoseiulus cucumeris* (Ouds.) feeding on two phytophagous mites *Panonychus citri* and *Brevipalpus phoenicis* was conducted in the laboratory at constant temperatures of 25 °C and relative humidity of 70 ± 5 %. At this temperature studied, the development time and prey average consumption of the predatory mite *N. cucumeris* were affected by prey species. The life cycle of the adult female predatory mite, *N. cucumeris* was 11.91 ± 0.46 and 13.13 ± 0.26 when fed on *P. citri* and *B. phoenicis*, respectively. While, the life cycle of the adult male of the predatory mite, *N. cucumeris* recorded 11.83 ± 0.78 and 12.87 ± 0.55 days to develop from egg to adult when fed on the same phytophagous mites, respectively. The female of *N. cucumeris* recorded the highest fecundity when fed on *P. citri*, which was 27.73 ± 0.18 eggs unlike, *B. phoenicis* which was 25.75 ± 1.02 days. On the other hand, the average daily consumption of *N. cucumeris* when feeding on *P. citri* showed a higher value ranging from 1.6 to 2 moving stages unlike *B. phoenicis*, which ranged from 1.1 to 1.4 moving stages. The current study indicated that *N.* cucumeris can play a good role in the control of *P. citri* and *B. phoenicis* and can reduce its population densities as a generalist species.

INTRODUCTION

Phytoseiidae is the most important family of plants inhabiting predatory mites. The stuff of this family is extensively used as biological control of mites and insects in both greenhouses and open fields. The predatory mites *Neoseiulus cucumeris* (Ouds.) is belonging to the family Phytoseiidae, which has been the focus of many studies for controlling the spectrum of pests like spider mites (Easterbrook et al. 2001), whiteflies (Zhang *et al.*, 2011), aphids, tomato russet mite (Brodeur *et al.,* 1997) and thrips (Broadsgaard and Hansen 1992, Van Houten *et al.*, 1995, Arthurs *et al.*, 2009, Kakkar *et al.*, 2016). Thus, *N. cucumeris* is considered one of the most easily adaptable and belonged to type III predators because of its broad host range and survival on plant pollen in the absence of selected prey (McMurtry and Croft 1997). Although *N. cucumeris* belonged to generalist predators of spider mites and can feed on thrips, the characteristic of the host plant has an important role in the success of biological control (Ramakers 1988; 1990). The temperature and relative humidity are a profound effect on the developmental rates of the predatory mite, *N. cucumeris*. The low

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development and high both reproduction and prey consumption rate occurred at increasing temperatures and relative humidity when fed on Tetranychus urticae. Al-Azzazy et al., 2018 reported that the maximum reproduction was 3.91, and 3.09 eggs/day at 35 °C and 65% RH, while it decreased to reach 2.12, and 1.90 eggs/day at 25 ± 1 °C and 55 ± 5% RH. when the predatory mite, *N. cucumeris* fed on A. lycopersici and T. urticae, respectively.

Brevipalpus phoenicis and *Panonychus citri* are among the most important worldwide distribution that attacks citrus trees. The aggravation of the damage to citrus trees did not attribute to Brevipalpus feeding on leaves lonely, which causes low citrus yield; it's about transmitting leprosis diseases. Childers *et al.*, 2003 stated demonstrated that the longevity of the genus Brevipalpus is two to three times greater than the corresponding longevities of various tetranychid mites. The life cycle of either Brevipalpus phoenicis or Panonychus citri has four active stages (i.e., larva, protonymph, deutonymph, and adult). There is a quiescent developmental stage between each active stage. Both temperature and relative humidity are a profound effect on the developmental rates of the two species (Morishita, 1954; Haramoto, 1969; Chandra and Channa Basavanna, 1974; Lal, 1978, Goyal *et al.*,1985). Both life cycle duration and developmental stages are considerably longer for *B. phoenicis* unlike P. citri (McGregor) by Beavers and Hampton (1971) and Saito (1979).
This study examines the predatory mite, *N. cucumeris* potential as a predator against *B. phoenicis* and *P. citri*

MATERIALS AND METHODS

Arenas of detached leaves were used in this study to assess the productivity of the predatory mite, *N. cucumeris* when fed on two phytophagous mites, *P. citri* and *B. phoenicis.* Numbers of Petri dishes were coated with a thin layer of moist cotton wool at their lower surface. These Petri dishes were placed upside-down in large Petri dishes saturated with water to provide moisture continuously. Five small pieces discs of citrus leaves (about 2.5 cm diameter), were put upside down on the moist cotton. A thin layer of tanglefoot was painted around each arena as a barrier to confine the mites to a defined area. Twenty arenas for each treatment of *P. citri* and *B. phoenicis* were used. Each arena was provided with one egg of *N. cucumeris* for development to the moving stage.

When the egg of *N. cucumeris* hatched to the larval stage, a small piece of citrus leaves with a counted number of *P. citri* and *B. phoenicis* were placed separately on each disc. Thus, one *N. cucumeris* larva was liberated on each disc, and the numbers of prey eaten during its larval, protonymphal, deutonymphal and adult female or male were recorded. Surplus food was provided whenever the supply became low or the citrus leaves need to change. The fecundity of *N. cucumeris* was determined at 25ºC and relative humidity of 70 ± 5 %. 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 the observations were continued twice a day as far as the first egg was laid. Thereafter, the number of laid eggs was recorded every 24 hours as far as the oviposition female died. For recording the sex ratio of resultant progeny, larvae of *N. cucumeris* were transferred to the new excised citrus leaves and the larvae reared as far as the adult stage. Oviposition, pre--oviposition and post-oviposition periods were recorded as well.

Statistical Analysis:

One-way ANOVA was calculated by using SPSS program. In addition, LSD (Fisher’s Significant Difference Test) was chosen to identify the significant difference.

RESULTS AND DISCUSSION

Effects of prey species on the duration of incubation period and immature stages of predator *N. cucumeris*:-

Data of the average duration of the immature stages of *N. cucumeris* when fed on two phytophagous mites, *P. citri* and *B. phoenicis* at temperature degrees, 25 ± 2ºC and 70 ± 5% R.H is presented in table 1 which, indicated that the duration of different stages of *N. cucumeris* was affected by prey species as follows:

1- Incubation Period: Significant differences were recorded between incubation periods of *N. cucumeris* females and males when fed on the three preys. The incubation periods for females were 3.90 ± 0.13 and 4.20 ± 0.12 days while the incubation period for males was 3.85 ± 0.10 and 4.12 ± 0.14 days when fed on *P. citri* and *B. phoenicis*, respectively.

2- Larva: The period of the larval stage of the predatory mite, *N. cucumeris* was affected by prey species where it was spent 2.40 ± 0.06 and 2.85 ± 0.03 days in terms of females while in the case of males it was 2.20 ± 0.01 and 2.60 ± 0.04 days when fed on *P. citri* and *B. phoenicis*, respectively.

3- Protonymph: The period of protonymphal stage of the predatory mite, *N. cucumeris* was affected by prey species where it was 2.64 ± 0.04 and 2.92 ± 0.02 days in terms of females while it was 2.76 ± 0.06 and 3.06 ± 0.07 days when fed on *P. citri* and *B. phoenicis*, respectively.

4- Deutonymph: The deutonymphal stage period was affected by prey species where it was 2.97 ± 0.09 and 3.16 ± 0.07 days in terms females, while it was 3.02 ± 0.04 and 3.09 ± 0.03 days in terms of males when fed on *P. citri* and *B. phoenicis*, respectively.

Although the statistical analysis showed that, significant differences were recorded in the duration of the deutonymphal female stage of the predator mite, the deutonymphal male stage of the predator mite showed no significant differences when fed on the same prey.

5- Total Immature: The duration of total immature females has been affected by species of prey where it was 8.01 ± 0.26 and 8.93 ± 0.37 days and the male was 7.98 ± 0.17 and 8.75 ± 0.31 when fed on *P. citri* and *B. phoenicis*, respectively.

Effects of Prey Species on the Life Cycle Duration of the Predator *N. cucumeris*: -

The adult female of the predatory mite, N. cucumeris needed 11.91 ± 0.46 days to develop from egg to adult when fed on *P. citri*. While it required 13.13 ± 0.26 days to develop from egg to adult when fed on *B. phoenicis*. On the other hand, the adult males of predacious mite needed 11.83 ± 0.78 and 12.87 ± 0.55 days to develop from egg to adult when fed on *P. citri* and *B. phoenicis*, respectively. Statistical analysis recorded significant differences among the period of the life cycle for predatory mite, *N. cucumeris* when fed on *P. citri* and *B. phoenicis*.

Effects of Prey Species on the Duration of Various Adult Periods of Predator *N. cucumeris*:

Data in the Table (2) indicated that the average duration of longevity (pre-oviposition, oviposition and post-oviposition) for females and males were affected by prey species as follows:

1- Pre-oviposition Period: The adult females of the predatory mite, *N. cucumeris* were needed 1.54 ± 0.02 and 1.79 ± 0.01 days to lay the first egg when fed on *P. citri* and *B. phoenicis*, respectively. Statistical analysis recorded no significant differences among the pre-oviposition period of predator mites when fed on *P. citri* and *B. phoenicis*

2- Oviposition Period: The oviposition period was the longest (12.54 ± 0.13days) when the predator mite *N. cucumeris* fed on *P. citri*, while it was (11.95 ± 0.13) *B. phoenicis*.

Statistical analysis recorded significant differences between the oviposition period when the predator fed on *P. citri* and *B. phoenicis.*

3- Post-oviposition Period: The adult female of *N. cucumeris* was lived after stopping laying eggs for 8.15 ± 0.36 and 9.00 ± 0.48 days when fed on *P. citri* and *B. phoenicis*, respectively.

Statistical analysis recorded significant differences between the post- oviposition period when the predator fed on *P. citri* and *B. phoenicis*.

Table 1: Average duration of the immature stages of *N. cucumeris* when fed on two phytophagous mites *P. citri* and *B. phoenicis* at a temperature degree of 25 ± 2ºC and 70 ± 5% R.H.

Developmental stages		Moving stages of	
		P. citri	*B. phoenicis*
Incubation period	Female	3.90 ± 0.13	4.20 ± 0.12
	Male	3.85 ± 0.10	4.12 ± 0.14
Larva	Female	2.40 ± 0.06	2.85 ± 0.03
	Male	2.20 ± 0.01	2.60 ± 0.04
Protonymph	Female	2.64 ± 0.04	2.92 ± 0.02
	Male	2.76 ± 0.06	3.06 ± 0.07
Deutonymph	Female	2.97 ± 0.09	3.16 ± 0.07
	Male	3.02 ± 0.04	3.09 ± 0.03
Total immature	Female	8.01 ± 0.26	8.93 ± 0.37
	Male	7.98 ± 0.17	8.75 ± 0.31
Life cycle	Female	11.91 ± 0.46	13.13 ± 0.26
	Male	11.83 ± 0.78	12.87 ± 0.55

Table 2: Average duration of various adult periods and generation of *N. cucumeris* and the number of eggs laid by the adult females when fed on two phytophagous mites *P. citri* and *B. phoenicis* at temperature degrees, 25 ± 2ºC and 70 ± 5% R.H.

Predator stage		Moving stages of	
		P. citri	*B. phoenicis*
Generation	Female	13.45 ± 0.03	14.92 ± 0.04
	Male	-	-
Pre-oviposition	Female	1.54 ± 0.02	1.79 ± 0.01
	Male	-	-
Oviposition	Female	12.54 ±0.13	11.95 ± 0.13
	Male	-	-
Post-oviposition	Female	8.15 ± 0.36	9.00 ± 0.48
	Male	-	-
Adult longevity	Female	22.24 ± 0.34	22.74 ± 0.47
	Male	21.72 ± 0.22	22.29 ± 0.36
Life span	Female	34.15 ± 0.34	35.87 ± 0.47
	Male	33.70 ± 0.27	35.36 ± 0.32
No. of eggs/female		27.73 ± 0.18	25.75 ± 1.02
No. of eggs/female/day		2.21 ± 0.02	2.15 ± 0.07
Sex ratio (female: male)		2.4 : 0.6	2.3 : 0.7

Effects of Prey Species on the Generation Period of *N. cucumeris*;

Data in Table (2) indicated that likewise the generation period was affected by species of prey where it was 13.45 ± 0.03 and 14.92 ± 0.04 days when fed on *P. citri* and *B.*

phoenicis, respectively. No significant differences were recorded in the generation periods when fed on *P. citri* and *B. phoenicis*.

Effects of Prey Species on the Duration of Longevity:

The average duration of the longevity of the predator mite was 22.24 ± 0.34 and 22.74 ± 0.47 when the predator fed on *P. citri*, while the duration of longevity was 21.72 ± 0.22 and 22.29 ± 0.36 days when the predator fed on *B. phoenicis*, for females and males, respectively. Significant differences were recorded in the duration of longevity when fed on different preys.

Effects of Prey Species on the Duration of the Life Span:

The time of life span of *N. cucumeris* was 34.15 ± 0.34 and 35.87 ± 0.47 days for females and 33.70 ± 0.27 and 35.36 ± 0.32 days for males when fed on *P. citri* and *B. phoenicis*, respectively.

In addition, significant differences were found in life span time when fed on *P. citri* and *B. phoenicis*.

Effects of Prey Species on the Fecundity of Females;

The female of *N. cucumeris* oviposited 27.73 ± 0.18 and 25.75 ± 1.02 eggs, with a daily rate of 2.21 ± 0.02 and 2.15 ± 0.07 eggs when fed on *P. citri* and *B. phoenicis*, respectively. Significant differences were found in the numbers of eggs laid when fed on *P. citri* and *B. phoenicis.*

Effects of Prey Species on Sex Ratio;

The sex ratio (female: male) of *N. cucumeris* was 2.4: 0.6 and 2.3: 0.7 when fed on *P. citri* and *B. phoenicis*, respectively.

The number of prey consumed by different postembryonic stages of *N. cucumeris* females when fed on two phytophagous mites *P. citri* and *B. phoenicis* at temperature degrees 25 ± 2ºC and 70 ± 5% R.H.in table 3 shows that the average consumption of moving stages of *P. citri* and *B. phoenicis* by the larvae female of the predatory mite, *N. cucumeris* was 1.25 ± 0.79 and 1.05 ± 0.62 individuals, respectively while the larvae male consumed 1.10 ± 0.64 and 0.89 ± 0.65 individuals, respectively. These values increased with the predator protonymph females with an average of 3.10 ± 1.21 and 2.10 ± 0.56 individuals while the protonymph male consumed 2.45 ± 0.83 and 1.68 ± 0.58 individuals from previous preys, respectively. The consumption of prey by the predator deutonymph female averaged 4.85 ± 0.75 and 3.45 ± 1.05 individuals while the deutonymph male consumed 3.85 ± 1.09 and 2.52 ± 0.69 individuals from previous preys, respectively. Therefore, the total consumption of prey during immature females averaged 9.20 ± 1.64 and 6.60 ± 1.09 individuals while the immature male consumed 7.40 ± 1.76 and 5.10 ± 1.15 individuals from previous preys, respectively. These values greatly increased with the predator adult female during Pre-oviposition periods with reached 9.45 ± 1.57 and 6.85 ± 1.226 individuals from moving stages of *P. citri* and *B. phoenicis*, respectively. The average consumption of *P. citri* and *B. phoenicis* during the oviposition period of the predatory mite likewise greatly increased to reach 19.60 ± 2.98 and 13.95 ± 2.63 individuals, respectively. The consumption of prey by the predator during the post-oviposition period averaged 14.70 ± 3.42 and 10.45 ± 2.67 individuals from previous preys, respectively. Accordingly, the average consumption of prey during adult longevity of predator female was 43.75 ± 5.29 and 31.25 ± 3.95 individuals, while the predator male consumed 39.50 ± 3.78 and 30.47 ± 3.72 individuals from previous preys, respectively. Similarly, the average consumption of prey during the Life span of the predator female was 52.95 ± 4.93 and 37.85 ± 4.24 individuals, while the predator male consumed 47.55 ± 4.01 and 38.00 ± 4.35 individuals from previous preys, respectively.

Table 3: Number of preys consumed by different postembryonic stages of *N. cucumeris* females when fed on two phytophagous mites *P. citri* and *B. phoenicis* at temperature degrees 25 ± 2ºC and 70 ± 5% R.H.

Predator stage		Moving stages of	
		P. citri	*B. phoenicis*
Larva	Female	1.25 ± 0.79	1.05 ± 0.62
	Male	1.10 ± 0.64	0.89 ± 0.65
Protonymph	Female	3.10 ± 1.21	2.10 ± 0.56
	Male	2.45 ± 0.83	1.68 ± 0.58
Deutonymph	Female	4.85 ± 0.75	3.45 ± 1.05
	Male	3.85 ± 1.09	2.52 ± 0.69
Total immature	Female	9.20 ± 1.64	6.60 ± 1.09
	Male	7.40 ± 1.76	5.10 ± 1.15
Pre-oviposition	Female	9.45 ± 1.57	6.85 ± 1.226
	Male	-	-
Oviposition	Female	19.60 ± 2.98	13.95 ± 2.63
	Male	-	-
Post-oviposition	Female	14.70 ± 3.42	10.45 ± 2.67
	Male	-	-
Adult longevity	Female	43.75 ± 5.29	31.25 ± 3.95
	Male	39.50 ± 3.78	30.47 ± 3.72
Life span	Female	52.95 ± 4.93	37.85 ± 4.24
	Male	47.55 ± 4.01	38.00 ± 4.35

DISCUSSION

The present results revealed that both development time and prey average consumption of the predatory mite *N. cucumeris* were affected by prey species. Furthermore, although all research concerned the predatory mite preferred *T. urticae* in terms of increasing the egg production, growth and longevity, the predator accepted *P. citri* and *B. phoenicis* as alternative foods.

The average daily consumption of *N. cucumeris* when feeding on *P. citri*, showed a higher value ranging from 1.6 to 2 moving stages unlike *B. phoenicis*, which ranged from 1.1 to 1.4 moving stages. These values are unlike preferred prey as *T. urticae*, which ranged from 3 to 4 individuals/day (Blaeser and Sengonca, 2001). Hence, *N. cucumeris* mite can feed on *P. citri* and *B. phoenicis* in the case of food shortage under natural conditions. Thus the polyphagous *N. cucumeris* can be effectively implemented in biological control programs. In addition, unlike *P. citri*, *B. phoenicis*'s inability to produce a sticky and dense web of spider mites may provide a comparative advantage to the predatory mite, *N. cucumeris* to suppress the population numbers of *B. phoenicis*, because the predatory mite's inability to cope with a sticky and dense web of spider mites (Sabelis & Bakker 1992; Li and Zhang, 2020).

As a matter of fact, *N. cucumeris* belonged to a generalist predator, which can be fed on varieties of food sources, including pollen, thrips, spider mites, tarsonemid mites, and acarid mites (McMurtry *et al.*, 2013). Accordingly, during the biological control program, *N. cucumeris* should be released in the early season. This may clarify that the preventive release of *N. cucumeris* was shown to be effective against *Tetranychus* species on cotton during the early season in Xingjiang, China (Zhang *et al.*, 2006). In addition, *N. cucumeris* may achieve long-term control on *P. citri* and *B. phoenicis* as far as *N. cucumeris* is likely to remain much longer than specialists, it can inhibit the resurgence of both *P. citri* and *B. phoenicis*. Thus the polyphagous *N. cucumeris* can be effectively implemented in biological control programs.

Obtained results showed that *N. cucumeris* developed from eggs to adults in 11.91 days (25°C) when fed on *P. citri*, faster than 13.13 days when fed on *B. phoenicis*. Whether the value of the life cycle of *N. cucumeris*, when fed on P., *citri*, was slightly shorter than fed with and *B. phoenicis* and subsequently, what Kolodochka (1985) indicated that this value was (6.25 days) when fed on *T. urticae* eggs at 25°C, these values of life cycle differences of *N. cucumeris* may be differences that result from carbohydrates, lipids, amino acids and other forms of proteins content of *P. citri, B. phoenicis* and *T. urticae*. These nutrients facilitate the sexual maturation of females and ovogenesis (Coll and Guershon 2002; Lundgren 2009). Alternatively, these differences in the development period and life cycle of *N.* cucumeris may be attributed to the presence of certain substances, probably hormones or hormone-like effects, which either increase fertility and laying eggs with *T. urticae*, or suppress fertility and laying eggs with *P. ciri*. These substances may be an integral component of the prey or obtained from the plants they feed on (Ebrahim et al., 2014)

In conclusion, the current study indicated that *N.* cucumeris can play a good role in the control of *P. citri* and *B. phoenicis* and can reduce its population densities as a generalist tetranychid predator (McMurtry and Croft 1997; McMurtry et al. 2013; Li and Zhang 2016; Zheng *et al.,* 2017). This species can survive and reproduce on different mites, insect species and pollen (Gerson & Weintraub 2007; van Lenteren 2012; McMurtry *et al.*, 2013; Kakkar et al. 2016; Li and Zhang, 2020. Accordingly, in field conditions, predators can have access to supplementary diets such as alternative prey and plant-provided food (Al-Shammer 2011; Huang *et al.,* 2011; Vantornhout *et al.*, 2005).

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