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RESEARCH

Biology, Predation, and Life Table of *Cydnoseius negevi* and *Neoseiulus barkeri* (Acari: Phytoseiidae) on the Old World Date Mite, *Oligonychus afrasiaticus* (Acari: Tetranychidae)

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ABSTRACT. The old world date mite, *Oligonychus afrasiaticus* (McGregor) (Acari: Tetranychidae) is a severe spider mite pest of date palm in most of the Middle East and North Africa. Considering that nothing is known about the performance of phytoseiid predators against *O. afrasiaticus*, biology, predation, and life table parameters of *Cydnoseius negevi* (Swirski and Amitai) and *Neoseiulus barkeri* Hughes (Acari: Phytoseiidae), collected from date palm orchards, were studied under laboratory conditions (25, 35°C and 35 ± 10% RH) as a first step to understand their effectiveness against all mobile life stages of *O. afrasiaticus*. For both predators, oviposition period was significantly shorter at 35°C than at 25°C. The following parameters were obtained for *C. negevi* and *N. barkeri* at 25 and 35°C, respectively: female longevity, 31.8, 20.1, 35.7, 27.4 d; fecundity, 21.6, 38.0, 18.8, 34.8 eggs per female; oviposition period, 23.9, 13.7, 25.9, 18.1 d. Total predation of *C. negevi* and *N. barkeri* female was 246.0, 270.0, 227.6, 205.3 prey at 25 and 35°C, respectively. Rectal plugs were observed attached to the opisthosoma of some adult females of *N. barkeri*, which often cause the mite to stick to the surface. Life table parameters were estimated as net reproductive rate (R_0) 10.44, 17.35, 10.19, 13.84, intrinsic rate of increase (r_m) 0.14, 0.19, 0.13, 0.16 d^{-1}, finite rate of increase (λ) 1.15, 1.21, 1.12, 1.17 d^{-1}, generation time (T) 17.03, 15.17, 17.83, 16.61 d, doubling time (DT) 04.95, 03.64, 05.33, 04.33 d for *C. negevi* and *N. barkeri* at 25 and 35°C, respectively. The values of intrinsic rate of increase and net reproductive rate were higher in *C. negevi* than *N. barkeri* at both temperature regimes. Therefore, it could be concluded that *C. negevi* performance was better than *N. barkeri* against *O. afrasiaticus* and can be considered as a valuable addition to the existing methods for spider mites control.

Key Words: Phytoseiidae, biological control, Saudi Arabia, predator, Oligonychus afrasiaticus

Introduction

The old world date mite, *Oligonychus afrasiaticus* (McGregor 1939) (Acari: Tetranychidae) is a severe spider mite pest of date palm in arid regions and in most of North African and Middle Eastern countries (Calcat 1959; Hussain 1974; Zaher et al. 1982; Palevsky et al. 2003, 2004; Ben Chaaban et al. 2011).

Currently, controlling *O. afrasiaticus* on date palm mostly depends on using chemical pesticides (Al-Dosary 2010). Mite resistance to pesticides increases the worry about the impact of pesticide use on the environment and human health. The recently introduced sustainable agriculture programs to many countries, such as organic farming and biological control, will restrict the use of chemicals. Therefore, alternative management tactics for the control of spider mites and other pests of date palm need to be developed.

Biological control of spider mites has been proven to be effective in many agricultural crops (Helle and Sabelis 1985). The family Phytoseiidae includes potentially important predatory mites found throughout the world on many crops (Kostiainen and Hoy 1996, McMurtry and Croft 1997). Some phytoseiid species play an important role in controlling phytophagous mites and insects in North African and Middle Eastern countries (Momen and El-Laithy 2007, Momen et al. 2009, Palevsky et al. 2009, Hountondji et al. 2010, Jafari et al. 2010, Kreiter et al. 2010).

Phytoseiid mites generally require moderate to high humidity levels to be effective (Helle and Sabelis 1985). However, date palm trees are mostly grown in hot provinces where humidity is relatively low, that makes the performance of phytoseiids as control agents may not be adequate (Bakker et al. 1993). Therefore, searching for local phytoseiids adapted to the arid datepalm growing areas could provide more promising results for the control of *O. afrasiaticus*.

Cydnoseius negevi (Swirski and Amitai 1961) and *Neoseiulus barkeri* Hughes 1948 (Acari: Phytoseiidae) are common species found in the Middle East (Abou-Awad et al. 1989, Fouly and El-Laithy 1992, Abou-Awad et al. 1998, Palevsky et al. 2009, Hountondji et al. 2010, Jafari et al. 2010). The natural occurrence of these predators was reported in datepalm orchards at different provinces of Saudi Arabia (Negm et al. 2012a, b). *C. negevi* seemed particularly promising because it was found in different movable stages of development and over different localities in Saudi Arabia (Negm et al. 2012b). Furthermore, a preliminary trial to maintain a colony of *C. negevi* in the laboratory offering *O. afrasiaticus* as prey was very successful and encouraged further investigations.

No biological studies of phytoseiid mites have been conducted when they exposed to *O. afrasiaticus* as food source, except the work of Al-Shammery (2010) who studied the development and life table parameters of *Euseius scutalis* (Athias-Henriot).

Considering that nothing is known about the performance of *C. negevi* and *N. barkeri* against *O. afrasiaticus*, the objectives of the present study were to determine their biological traits including development, fecundity, predation, and life table parameters under laboratory conditions, as a first step in the determination of their suitability as control agents of *O. afrasiaticus.*

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Materials and Methods

Mite Sources

All three mite species used in this study were collected from date-palm orchards at Al-Imam Mohamed Bin Saud Islamic University, Riyadh city (24°49′014N, 46°42′663E, 657 m). *Cydnoseius negevi* was collected from sea purslanes, *Sesuvium* sp. (Aizoaceae) while *N. barkeri* was collected from bermuda grass, *Cynodon dactylon* (Poaceae) and *O. afrasiaticus* was collected from highly infested date palm trees.

Mite Colonies

The stock colony of each predator was maintained separately on rearing units made of common bean leaves, *Phaseolus vulgaris* L. (Fabaceae), in an incubator at 30°C and 70 ± 10% RH. Predators were transferred to new units every 5–7 d. Several young and fully expanded bean leaves were placed underside facing up on a wet cotton wool layer in plastic trays (150 by 80 mm). Cotton wool was provided with water when necessary to prevent mites from escaping and to maintain leaf freshness. Because of difficulty in maintaining colonies of the prey mite *O. afrasiaticus*, different stages of that species were directly brushed from infested date palm fruit strands to the predators in the stock colonies. The predatory mites were continuously fed a mixture of all stages of *O. afrasiaticus*. When over-population of predator was encountered, the old bean leaves were cut into several small pieces and then placed on a new stock culture.

Biology and Predation of *C. negevi* and *N. barkeri* on *O. afrasiaticus*

This study was conducted using experimental units made of discs of *P. vulgaris* leaflets (2 cm diameter) placed upside down on water saturated absorbent cotton wool in a plastic Petri dish (90 mm in diameter by 15 mm in height). The Petri dish was kept permanently open. Leaf discs were bordered with wet cotton strips to prevent mites from escaping. Experiments were conducted for *C. negevi* and *N. barkeri* against *O. afrasiaticus* at 25, 35°C and 35 ± 10% RH. Sixteen replications were run for each treatment.

Approximately 40 adult females of each predator species were transferred using a fine brush to leaf arenas. Newly deposited eggs (0–24 h old) of each predator were carefully transferred individually to each experimental unit using a fine brush. The number of preys supplied to each predator was determined according to preliminary observations of the consumption capacity. The newly hatched larvae were fed on a mixture of 10 preys of different mobile stages while each adult predator was fed on 15 individuals. Predation was recorded as the number of prey individuals consumed. Preys consumed were replaced by live ones to maintain an ample food supply. Daily observations were made at 12-h intervals to record: 1) development of immature and adult stages and 2) predatory efficiency of the different stages of each predator. An adult male, randomly taken from the stock colony, was introduced to each leaf disc containing a newly emerged female. Males were removed after copulation was observed in each leaf disc. Newly emerged mated females were observed to determine the pre-oviposition, oviposition, and post-oviposition periods as well as gathering data on fecundity.

Life Table Parameters

Life table parameters for both predators [mean generation time ($T = \text{Ln}\ R_0/r_m$), net reproduction rate ($R_0 = \sum l_x m_x$), intrinsic rate of increase ($r_m = \text{Ln}\ R_0/T$), finite rate of increase (λ), doubling time ($\text{DT} = \text{Ln}\ 2/r_m$)] were calculated according to Birch (1948) using a BASIC computer software program developed by Abou-Setta et al. (1986).

Statistical Analysis

To assess the development, adult longevity, fecundity, and predation of *C. negevi* and *N. barkeri* and the effect of temperature on these parameters, data were compared with one-way analysis of variance (ANOVA), using SAS computer program version 9.2 (SAS 2008). Means were separated by Duncan's Multiple Range Test (DMRT) at $P < 0.05$. Prior to ANOVA, data transformation was applied using square root (×).

Results

Biological and Behavioral Observations

Eggs of *C. negevi* were crystalline, oval, and with a sticky surface when newly deposited. Egg color changed to light whitish-yellow before hatching. Larvae were crystalline whitish and a little larger in size than the egg. Males were smaller than females and with the same brown coloration. Mating took place just as female reached maturity. Gravid-mated females became more spherical as the egg developed and opisthosoma enlarged. Eggs were deposited on the leaf disc's surface on the cotton fibers close to the wet cotton barrier. Both predators were easily disturbed in the arena when exposed to light after darkness. Moreover, motile immatures were seen capturing the adults of *O. afrasiaticus* from their legs. The nymphal stages were progressively larger than the larval stage with developing body color becoming increasingly brownish. All different motile stages of both predators were able to consume *O. afrasiaticus*.

Some adult females of *N. barkeri* showed an abnormal physical characteristic when fed on *O. afrasiaticus*. They had rectal plugs (red-brown in color) attached to the opisthosoma. These often caused the mite to be stuck to the surface of the plant leaf. The rectal plugs were most common in older females while immature stages and males rarely had these plugs. In some cases, the affected mites succeeded in eliminating these plugs through defecation and became normal again. Females of *C. negevi* that fed on the same prey were not affected.

Development of immatures, adult longevity and fecundity of *C. negevi* and *N. barkeri*

Cydnoseius negevi and *N. barkeri* successfully preyed on *O. afrasiaticus* and completed their development at the temperatures tested. The increase of temperature from 25 to 35°C enhanced faster immature development (Table 1). The total development time (egg–adult) of *C. negevi* females is decreased from 9.0 d at 25°C to 7.9 d at 35°C while for *N. barkeri* it decreased from 9.6 d at 25°C to 9.0 d at 35°C (Table 1).

The adult longevity and fecundity data of *C. negevi* and *N. barkeri* are shown in Table 2. Increasing temperature from 25 to 35°C had a significant effect on the female longevity and life span of *C. negevi* (Table 2) ($F = 11.45$; $\text{df} = 3, 20$; $P = 0.0002$). However, within that period, only oviposition period was significantly influenced by increasing temperature ($F = 9.14$; $\text{df} = 3, 20$; $P = 0.0008$). Female longevity was 31.8 and 20.1 d for *C. negevi* and 35.7 and 27.4 d for *N. barkeri* at 25 and 35°C, respectively (Table 2).

Total fecundity of both species was significantly higher at 35 than at 25°C (Table 2) ($F = 25.21$; $\text{df} = 3, 20$; $P = 0.0001$). The maximum value (38.0 eggs per female) was reported for *C. negevi* while it was 34.8 eggs per female for *N. barkeri*, both at 35°C. At both temperatures, *C. negevi* deposited more eggs than *N. barkeri* (Table 2). The progeny sex ratio of *C. negevi* and *N. barkeri* was female-biased and the maximum female-biased sex ratio was 70%, which was observed for *N. barkeri* at 35°C (Table 2).

Predation of *C. negevi* and *N. barkeri*

Predation data of *C. negevi* and *N. barkeri* immature and adult stages are presented in Table 3. Immature females of *C. negevi* significantly consumed a higher number of preys (20.4 at 25°C and 15.9 at 35°C) than *N. barkeri* (9.6 at 25°C and 9.1 at 35°C) ($F = 18.10$; $\text{df} = 3, 28$; $P = 0.0006$). Also, at 35°C, *C. negevi* significantly consumed more prey (216.4) than *N. barkeri* (166.0) during the oviposition period (Table 3) ($F = 15.3$; $\text{df} = 3, 20$; $P = 0.0092$). The highest number of prey consumed during the adult longevity was reported for *C. negevi* females at 35°C (270.0 prey) while for *N. barkeri* it was 205.3 preys.

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Table 1. Mean duration in days (±SE) of the immature stages of *C. negevi* and *N. barkeri* on *O. afrasiaticus* at 25, 35°C and 35 ± 10% RH

Temperature (°C)	Predator species	Sex	Development of immature stages (days)			
			Egg	Larva	Nymph	Total immature
25	*C. negevi*	♀	2.57 ± 0.20a	1.00 ± 0.15a	5.43 ± 0.23a	9.00 ± 0.35a
		♂	2.25 ± 0.14a	00.88 ± 0.24a	5.13 ± 0.24a	8.26 ± 0.46a
	N. barkeri	♀	3.13 ± 0.26a	1.19 ± 0.19a	5.31 ± 0.34a	9.63 ± 0.33a
		♂	3.00 ± 0.46a	1.13 ± 0.24a	5.13 ± 0.52a	9.26 ± 0.60a
35	*C. negevi*	♀	2.14 ± 0.30a	1.00 ± 0.15a	4.79 ± 0.34a	7.93 ± 0.42a
		♂	1.80 ± 0.25a	1.10 ± 0.29a	4.60 ± 0.48a	7.50 ± 0.46a
	N. barkeri	♀	2.86 ± 0.26a	1.14 ± 0.14a	5.00 ± 0.38a	9.00 ± 0.46a
		♂	2.50 ± 0.58a	00.83 ± 0.17a	5.17 ± 0.60a	8.50 ± 0.50a

Means followed by different letters within the same column are significantly different (ANOVA followed by Duncan's MRT: $P < 0.05$).

Table 2. Mean duration in days (±SE) of different periods of the adult phase, longevity, fecundity, and sex ratio (% females) of *C. negevi* and *N. barkeri* on *O. afrasiaticus* at 25, 35°C and 35 ± 10% RH

Temperature (°C)	Predator species	Sex	Adult lifetime (days)				Lifespan (egg to death/days)	Total fecundity (eggs/female)	Daily fecundity (eggs/female/day)	Sex ratio (% females)
			Preoviposition period	Oviposition period	Postoviposition period	Longevity				
25	*C. negevi*	♀	3.67 ± 0.28a	23.90 ± 1.21a	4.10 ± 0.4a	31.80 ± 0.93a	40.08 ± 1.44a	21.60 ± 2.62b	1.50 ± 0.06a	63.6
		♂				27.83 ± 1.59ab	35.33 ± 1.80ab			
	N. barkeri	♀	4.17 ± 0.17a	25.92 ± 0.71a	5.58 ± 0.47a	35.67 ± 0.91a	44.67 ± 1.12a	18.80 ± 1.39b	1.00 ± 0.07a	66.6
		♂				30.33 ± 0.06a	38.58 ± 0.88ab			
35	*C. negevi*	♀	3.33 ± 0.54a	13.67 ± 3.1b	3.10 ± 0.71a	20.10 ± 2.87b	29.10 ± 3.54b	38 ± 0.86a	2.77 ± 0.33a	58.3
		♂				18.50 ± 1.50b	26.75 ± 1.25b			
	N. barkeri	♀	3.60 ± 0.46a	18.10 ± 1.11b	5.70 ± 0.46a	27.40 ± 1.48ab	37.03 ± 1.67ab	34.80 ± 2.03a	1.92 ± 0.07a	70
		♂				24.25 ± 1.75ab	27.42 ± 5.83b			

Means followed by different letters within the same column are significantly different (ANOVA followed by Duncan's MRT: $P < 0.05$).

Table 3. Predation (number of preys consumed per stage) (mean ± SE) by different stages of *C. negevi* and *N. barkeri* on *O. afrasiaticus* at 25, 35°C and 35 ± 10% RH

Temperature (°C)	Predator species	Sex	Predation rate at different stages							Total predation during lifespan
			Immatures			Adult				
			Larva	Nymph	Total immature	Preoviposition period	Oviposition period	Postoviposition period	Longevity	
25	*C. negevi*	♀	9.0 ± 0.44a	11.43 ± 1.34a	20.43 ± 1.34a	27.67 ± 1.84ab	202.5 ± 3.23ab	15.83 ± 1.82a	246.00 ± 05.22a	266.33 ± 05.78a
		♂	8.5 ± 0.29a	11.5 ± 0.66a	20 ± 0.71a				194.33 ± 03.84b	214.33 ± 03.84ab
	N. barkeri	♀	3.13 ± 1.16b	6.5 ± 0.91b	09.63 ± 1.74b	22.6 ± 1.36b	189.8 ± 3.57b	15.8 ± 1.93a	227.6 ± 3.65ab	240.40 ± 5.12ab
		♂	1.75 ± 1.03b	4.75 ± 1.38b	6.54 ± 1.55bc				138.33 ± 45.37b	146.87 ± 44.73b
35	*C. negevi*	♀	7.57 ± 0.75a	8.29 ± 0.75ab	15.86 ± 1.03a	30.67 ± 3.01a	216.4 ± 06.25a	22.2 ± 2.52a	270.00 ± b11.50a	285.80 ± 11.96a
		♂	5.6 ± 1.33ab	6.20 ± 1.24b	11.8 ± 1.98b				201.33 ± 7.62ab	213.13 ± 8.97ab
	N. barkeri	♀	3.14 ± 0.88b	6 ± 0.87b	09.14 ± 1.01b	21.33 ± 2.12b	166.0 ± 29.63b	18 ± 1.73a	205.33 ± 33.91ab	216.47 ± 34.06ab
		♂	1.33 ± 0.88b	4 ± 1.53b	5.33 ± 0.88bc				123 ± 53.16b	130.86 ± 7.51b

Means followed by different letters within the same column are significantly different (ANOVA followed by Duncan's MRT: $P < 0.05$).

Effect of *O. afrasiaticus* on life table parameters of *C. negevi* and *N. barkeri*

Life table parameters of *C. negevi* and *N. barkeri* fed on *O. afrasiaticus* at the two temperature regimes are presented in Table 4. Net reproductive rate (R_0) was 10.44 and 17.35 females per female for *C. negevi* and 10.19 and 13.84 for *N. barkeri*, at 25 and 35°C, respectively (Table 4). As temperature increased, the intrinsic rate of increase (r_m) of both predators increased from 0.14 to 0.19 females per female per day for *C. negevi* and 0.13 to 0.16 for *N. barkeri*. Mean generation time (T) and doubling time (DT), for each predator, were slightly longer at 25 than at 35°C (Table 4). Generally, *C. negevi* at 35°C gained the highest values of the intrinsic rate of increase (r_m) and net reproductive rate (R_0) and reported the shortest values of mean generation time (T) and doubling time (DT).

Discussion

This study was the first to evaluate the biology and predatory efficiency of the phytoseiid predators, *C. negevi* and *N. barkeri*, against *O. afrasiaticus* as prey. However, many research works have been conducted on both predators when fed on various arthropod preys (insects and mites) and food types such as plant pollen (Tables 5 and 6). In this study, both predators *C. negevi* and *N. barkeri* developed and reproduced when fed on *O. afrasiaticus* at the temperatures and relative humidity tested.

In an evaluation of the development of *C. negevi* at 28°C on a pollen diet of castor bean, *Ricinus communis* and eggs of three insect species, the shortest life cycle was observed when the predator fed on *Bemisia tabaci* eggs (Momen et al. 2009). The developmental time of female immatures of *C. negevi* fed on *Eriophyes ficus* and *Tetranychus urticae*

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Table 4. Life table parameters of *C. negevi* and *N. barkeri* on *O. afrasiaticus* at 25, 35°C and 35 ± 10% RH

Temperature (°C)	Predator species	$R_{0\ (females/female)}$	*T* (d)	$r_{m\ (females/female/day)}$	λ (females/female/day)	DT (d)
25	*C. negevi*	10.44	17.03	0.14	1.15	4.95
	N. barkeri	10.19	17.83	0.13	1.12	5.33
35	*C. negevi*	17.35	15.17	0.19	1.21	3.64
	N. barkeri	13.84	16.61	0.16	1.17	4.33

Parameters: R_0, net reproductive rate; *T*, mean generation time; r_m, intrinsic rate of increase; λ, finite rate of increase; DT, doubling time.

Table 5. Summary of reported values of reproduction and life table parameters of *C. negevi*

Prey	R_0	r_m	*T*	λ	Temperature (°C)	Relative humidity (%)	Daily fecundity	Total fecundity	References
Oligonychus afrasiaticus	10.44	0.14	17.03	1.15	25	35	1.5	21.6	Present study
O. afrasiatcius	17.35	0.19	15.17	1.21	35	35	2.78	38	Present study
Aculus fockeui	16.29	0.16	17.03	1.18	28	75	1.22	32.35	Momen (2009)
Bemisia tabaci	18.02	0.24	12.26	1.27	28	70–75	0.83	21.2	Momen et al. (2009)
Insulaspis pallidula	8.14	0.14	14.84	1.15	28	70–75	0.74	10.23	Momen et al. (2009)
Phoenicoccus marlatti	3.61	0.09	13.59	1.09	28	70–75	0.61	6.44	Momen et al. (2009)
Ricinus communis	29.04	0.27	12.39	1.31	28	70–75	1.13	32.93	Momen et al. (2009)
Tetranychus urticae					28–30	70–80	2.4	–	El-Banhawy et al. (1999)
T. urticae	23.07	0.16	19.16	1.18	27	65–75	1.31*	25.64	Abou-Awad et al. (1998)
Eriophyes ficus	30.87	0.23	15.04	1.26	27	65–75	1.35*	35.77	Abou-Awad et al. (1998)
T. urticae					28	70-80	1.6	39.7	Momen (1997)
Eutetranychus orientalis							1.3		Abou-Awad et al. (1989)
T. urticae							1		Abou-Awad et al. (1989)

Parameters: R_0, net reproductive rate (females/female); *T*, mean generation time (day); r_m, intrinsic rate of increase (females/female/day); λ, finite rate of increase (females/female/day); DT, doubling time (day).

Table 6. Summary of reported values of reproduction and life table parameters of *N. barkeri*

Prey	R_0	r_m	*T*	λ	Temperature (°C)	Relative humidity (%)	Daily fecundity	Total fecundity	References
Oligonychus afrasiaticus	10.19	0.13	17.83	1.12	25	35	1	18.8	Present study
O. afrasiaticus	13.84	0.16	16.61	1.17	35	35	1.92	34.8	Present study
Aleuroglyphus ovatus	11.45	0.17	14.75	1.18	32	85	1.47	20.52	Xia et al. (2012)
Tetranychus urticae	22.02	0.221	13.95	1.25	25	65	1.97	36.8	Jafari et al. (2010)
Ephestia kuehniella	32.88	0.14	25.03	1.15	27	70–75	1.7	50.4	Momen and El-Laithy (2007)
T. urticae					25	70–75	1.88	54.84	Momen (1995)
Eriophyes dioscoridis					25	70–75	1.3	44.21	Momen (1995)
T. urticae					26	60	1.02	13.2	Fouly and El-Laithy (1992)
Thrips tabaci	27.78	0.22	19.1	1.25	25	75-95	2.3	47.1	Bonde (1989)
T. tabaci					25		1.99		Beglyarov and Suchalkin (1983)

Parameters: R_0, net reproductive rate (females/female); *T*, mean generation time (day); r_m, intrinsic rate of increase (females/female/day); λ, finite rate of increase (females/female/day); DT, doubling time (day).

(Abou-Awad et al. 1998) were close to the present findings against *O. afrasiaticus*. A longer life cycle (9.5 days) was recorded when *C. negevi* fed on *T. urticae* eggs (Momen 1999).

On the other hand, development of *N. barkeri* immature females was relatively longer in our study (9.6 days at 25°C) than reported when fed on *Aleuroglyphus ovatus* (7.8 d at 24°C) (Xia et al. 2012). These results show that *A. ovatus* provides *N. barkeri* with higher reproductive capability than does *O. afrasiaticus*. Therefore, we assumed that it is worth studying *C. negevi* on *A. ovatus* for mass rearing purposes which may give promising results. Development of *N. barkeri* female immatures on *T. urticae* at 25°C was 8.4 d when estimated by Fouly and El-Laithy (1992) and 6.3 d by Jafari et al. (2011). These values are shorter than obtained in the current study (9.6 at 25°C) and show the preference of *T. urticae* for this predator as prey.

Many biological studies have been conducted on *C. negevi* and *N. barkeri* to test their development against various food sources (Bonde 1989; Zhang and Fan 2005; Momen and El-Laithy 2007). The results of these studies indicate the wide feeding range for these predators under different temperature regimes.

Adult female longevity of *C. negevi* is similar to the data obtained when fed on individuals of *E. ficus*, *T. urticae* eggs, *B. tabaci* eggs, and *R. communis* pollen (Abou-Awad et al. 1998; Momen 1999; Momen et al. 2009). When *E. scutalis* was evaluated against *O. afrasiaticus* (Al-Shammery 2010), adult female longevity was shorter (19.4 d) than that of *C. negevi* (31.8 d). This could be due to the higher humidity level applied for *E. scutalis*. Adult female longevity for *N. barkeri* (35.6 at 25°C and 27.4 at 35°C) against *O. afrasiaticus* was close to that reported against *A. ovatus* (34.6 at 24°C and 23.7 at 32°C) (Xia et al. 2012).

Total fecundity of *C. negevi* fed on *O. afrasiaticus* at 35°C is higher than the same values reported in previous studies (ranged from 6.4 to 35.8 eggs), with one exception (39.7 eggs, on *T. urticae* as prey; Table 5). However, total fecundity of *C. negevi* against *O. afrasiaticus* at 25°C (21.6 eggs/female) was the same as that obtained against *B. tabaci* at 28°C (Momen et al. 2009). Fecundity of females mated more than once is much higher than females mated only once (Saber and Momen 2000). This indicates that single-mated females live longer than multiple-mated ones (Momen 1997). However, phytoseiid mites

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require multiple matings to attain their maximum reproductive potential (Amano and Chant 1977). Therefore, the low fecundity in the present study might be due to both single-mating incidence and the low humidity level applied (35%). Total fecundity value of *N. barkeri* against *O. afrasiaticus* at 25°C, with one exception (13.2 eggs) when offered *T. urticae* as prey, is lower than the range reported for other food sources (36.8–54.8 eggs) (Table 6). Fouly and El-Laithy (1992) stated that females of *N. barkeri* only accepted coupling once.

The sex ratio of phytoseiid mites is characterized by a female bias (Amano and Chant 1977; Tanigoshi 1982). This agrees with the present findings of *C. negevi* and *N. barkeri* as well as other previous literature (Momen 1997, Momen et al. 2009).

Cydnoseius negevi immature females consumed 20.4 prey of *O. afrasiaticus* while they consuming 27 individuals of *Eutetranychus orientalis* and 34 of *T. urticae*, respectively (Abou-Awad et al. 1989), and 166.4 individuals of *E. ficus* and 133.1 eggs of *T. urticae*, respectively (Abou-Awad et al. 1998). The larger consumption of *E. ficus* and *T. urticae* is related to the smaller size of the prey species/stages. Results obtained from predation of *N. barkeri* immatures on *T. urticae* at 26°C (Fouly and El-Laithy 1992) are close to that reported in the present study against *O. afrasiaticus*.

Rectal plugs attached to the opisthosoma of some adult females of *N. barkeri* resemble those described for other phytoseiids. Hess and Hoy (1982) hypothesized that these symptoms are indicative of pathological reasons. Their investigations of *Typhlodromus occidentalis* tissues revealed the presence of an intracellular symbiotic association between the mite and certain microorganisms. Moreover, a blockage was observed at the alimentary canal near the anal opening of both sexes in *Amblyseius hibisci* (Tanigoshi et al. 1981). Similar symptoms were observed for *Neoseiulus fallacis*, however, it seems that the symptoms are regarded to undigested food materials that for unknown reasons accumulated in the alimentary canal and become difficult for the mite to expel (Allawi 1983). May be the prey (*O. afrasiaticus*) is considered unsuitable food for *N. barkeri* (G. J. de Moraes, personal communication). Schutte and Dicke (2008) reported unidentified microorganisms in association with some phytoseiids. Bacteria and microsporidia have been published by different authors. *Acaricomes phytoseiuli*, is a bacterium reported in association with *Phytoseiulus persimilis*. The infection with *A. phytoseiuli* affected the predator efficiency against the spider mite prey (Gols et al. 2007). Wu and Hoy (2012) detected the bacterium *Wolbachia* in *Metaseiulus occidentalis* and some other phytoseiid predators. They suggested that *Wolbachia* may cause cytoplasmic incompatibilities to the predator which will further affect its fecundity.

The life table parameters reported for *C. negevi* in this study at 35°C are close to that provided by Momen et al. (2009). They evaluated this predator on *B. tabaci* eggs ($R_0 = 18.20$, $T = 12.25$, $r_m = 0.23$, $\lambda = 1.26$) and *Insulaspis pallidula* eggs ($T = 14.84$, $\lambda = 1.15$) as preys at 28°C. The values of R_0 and r_m of *C. negevi* at 25°C and 35% RH are slightly lower than reported for *E. scutalis* against the same prey at 25°C and 70% RH (Al-Shammery 2010). *Euseius scutalis* performed better on *O. afrasiaticus* than *C. negevi*, and this could be due to the higher humidity level used. Abou-Awad et al. (1998) reported a higher net reproduction rate (23.1 and 30.8) when *E. ficus* and *T. urticae* were used as prey at 27°C, respectively.

In case of *N. barkeri* against *Thrips tabaci* at 25°C, the life table parameters (R_0, T, r_m, DT) values were 27.78, 19.10, 0.22, 3.15, respectively (Bonde 1989), on *A. ovatus*, at 24°C, the parameters were 20.14, 20.07, 0.14, 5.10 (Xia et al. 2012) and on *T. urticae* 22.02, 13.95, 0.22, 3.13 (Jafari et al. 2010) while in the present study they were 10.44, 17.30, 0.14, 4.95. This indicates that *N. barkeri* performs better on thrips, as a generalist phytoseiid predator, than on other mite prey. The unsuitability of *O. afrasiaticus* as prey for *N. barkeri* also appeared from the abnormal physical phenomenon resulted from the feeding process. Results obtained from life table study show that *C. negevi* performs better than *N. barkeri* when *O. afrasiaticus* was offered as prey. They encourage the evaluation of the functional response of *C. negevi* as well as the evaluation of methods for its mass rearing.

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