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Suitability of date palm pollen as an alternative food source for the predatory mite *Cydnoseius negevi* (Swirski & Amitai) (Acari: Phytoseiidae) at a low relative humidity

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ABSTRACT

The nutritional suitability of date palm pollen for the predatory mite *Cydnoseius negevi* (Swirski & Amitai) (Acari: Phytoseiidae) was tested by assessing the development and life table parameters of the predator at two relative humidity levels, 35 and 60 % RH, at 30 °C in the laboratory. *C. negevi* successfully developed and reproduced when fed on a fresh date palm pollen diet at both humidity levels. However, at 35 % RH, the incubation period and development of immatures were significantly longer, female longevity and fecundity significantly decreased, and all life table parameter values were negatively affected. The results obtained in this study were compared with those of some previously published studies in the same field. The date palm pollen could be a suitable food source for the mass production of *C. negevi*. Moreover, the successful reproduction and development of *C. negevi* fed date palm pollen at low RH (35 %) makes it a good alternate food source in the field to conserve the population of the predator under local arid environmental conditions.

Keywords Biology, life table parameters, *Cydnoseius negevi*, Phytoseiidae, biological control

Introduction

Phytoseiid mites (Mesostigmata: Phytoseiidae) play an important role as biocontrol agents in different agro-ecosystems throughout the world (Helle and Sabelis, 1985; Gerson *et al.* 2003; McMurtry *et al.* 2013). Many phytoseiid species have been successfully introduced in crops to control phytophagous mites especially spider mites and other small insect pests (McMurtry *et al.* 2013). The phytoseiid mite, *Cydnoseius negevi* (Swirski & Amitai), is a common species in the Middle East (Abou-Awad *et al.* 1998; Palevsky *et al.* 2009; Hountondji *et al.* 2010). It is also widely distributed in Saudi Arabia and has been found to be abundant in date palm orchards along with the date palm mite *Oligonychus afrasiaticus* (McGregor) (Acari: Tetranychidae) (Negm *et al.* 2012a,b; Alatawi *et al.* 2017). However, the ability of this predator to control the date palm mite and other pests in fields has not been studied yet.

As a generalist facultative (type III) phytoseiid predator (Momen *et al.* 2009; McMurtry *et al.* 2013), *C. negevi* is able to successfully develop and reproduce on a wide range of food sources *i.e.*, eriophyid and spider mites, thrips, and pollen of different plant species (Momen 1997; Momen *et al.* 2009; Negm *et al.* 2014; Hussein *et al.* 2016). Plant pollens contain high contents of proteins and essential amino acids and serve as high nutritional quality food for phytoseiid mites (Cook *et al.* 2003; Riahi *et al.* 2016, 2017). Therefore, plant pollens play an important role in the persistence and dynamics of many generalist predators (Hanna *et al.* 2005). The possibility of mass rearing a phytoseiid predator on alternative and more

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economical diet such as pollen could increase the interest in that predator as a biocontrol agent (Castagnoli and Simoni 1999).

The biology and life table of *C. negevi*, when feeding on pollen of different plant species and on some mites and insects under different temperatures and relative humidities in the laboratory have been investigated (Tables 4 and 5). However, the biological responses of *C. negevi* under low humidity, the general climate of Saudi Arabia (SA), have been poorly tested.

The biology and life table parameters of several phytoseiid mite species feeding on date palm pollen have been studied so far, e.g., *Amblyseius swirskii* Athias-Henriot, *Typhlodromus* (*Anthoseius*) *bagdasarjani* Wainstein & Arutunjan (Abou-Elella *et al.* 2013; Riahi *et al.* 2016; 2017), *Euseius scutalis* (Athias-Henriot) (Al-Shammery 2011; Abou-Elella *et al.* 2013; Abou-Elella *et al.* 2014; Fouly *et al.* 2013), *E. finlandicus* (Oudemans) (Abou-Elella *et al.* 2014), and *Proprioseiopsis asetus* (Chant) (Fouly 1997) (Table 4). Moreover, several studies have been conducted on *C. negevi* feeding on different preys, e.g., tetranychid and eriophyid mites, and small insects (Table 5) (Momen 1997; Abou-Awad *et al.* 1989; Negm *et al.* 2014; Metwally *et al.* 2015) (Table 5). All these biological studies were conducted at high relative humidity, *i.e.*, not less than 65 % RH.

The aim of this study was to investigate the suitability of date palm pollen as an alternate food source for *C. negevi* at relatively low humidity level (35 % R.H.). This study could be used in predicting *C. negevi* colonization ability when date palm pollen provided as alternative food source at the time of releasing the predator in date palm orchards where relative humidity is low.

Materials and methods

Predator and prey diet source

Cydnoseius negevi was collected from the bermuda grass, *Cynodon dactylon* L. (Poaceae), under the date palm trees, *Phoenix dactylifera* L. at Alammariah, Riyadh, SA, 24°48.354'N, 46°29.937'E, during September 2014. The *C. negevi* colony was then maintained in small arenas as described by Marafeli *et al.* (2011), placed in an incubator in the laboratory at 27 ± 2 °C and 65 ± 10 % RH and was fed on mostly date palm pollen and rarely on the two prey species, *Tetranychus urticae* Koch and *O. afrasiaticus*. The populations of *O. afrasiaticus*, collected from highly infested date palm trees and *T. urticae* collected from egg plants at King Saud University (KSU), were maintained on different grasses and common bean, *Phaseolus vulgaris* L. (Fabaceae) plants respectively in a growth chamber at the Department of Plant Protection, College of Food and Agriculture Sciences, (KSU), Riyadh. Fresh date palm pollen was directly collected from male date palm trees, at KSU from March to April 2014. The open flowers of the male date palms were dried in the laboratory at 25°C and 30 % RH, shaken on a white paper, and the pollen was collected in small glass vials and stored in a refrigerator until their use (Al-Shammery 2011).

Biology of *Cydnoseius negevi* fed on fresh date palm pollen in the laboratory

The experiment was conducted during August–September 2015 in a climate controlled chamber (BINDER®, Germany) at 30 ± 2 °C, two relative humidity levels, 35 % ± 5 and 60 % ± 5, RH, 14 L:10 D in small experimental units following Marafeli *et al.* (2011), with a few modifications. The experimental units consisted of a black plastic lid (3 cm diameter) placed on a petri dish (9 cm diameter) without a cover. Wet cotton wool wrapped around the lid and distilled water was provided continuously in the Petri dish to prevent the mites from escaping. Wisps of cotton wool were placed on the arena to provide oviposition sites for the predator. Seventy-four replicates for each RH level were made. Two *C. negevi* eggs were transferred from the stock colony to each experimental cell using a fine brush. After hatching, each larva was kept in

the experimental cell separately and each fed with equal amount of date palm pollen. Older pollen was replaced with fresh date palm pollen under a stereomicroscope (SZX10, Olympus, Tokyo, Japan) using a fine brush each 3 - 4 days. A male from the stock colony was introduced to each experimental unit for 12 hours when the female deutonymph stage appeared. After mating, males were removed from the cells. The mated females were individually confined in experimental units and date palm pollen was supplied until their death. The biological parameters, *i.e.*, eggs incubation period, duration of larval, protonymphal, and deutonymphal stages, and lifespans of female (including pre-oviposition, oviposition, post-oviposition, and fecundity) and male predators were observed and recorded at 12-h intervals until their death. The sex ratio of the progeny was also recorded.

Statistical Analysis

Data were analyzed using a one way ANOVA to compare the developmental period of different immature stages, adult longevity and life span of male and female and female fecundity of *C. negevi* according to the two RH tested. Means were compared using Fishers LSD test at $P < 0.05$. All analyses were run using the SAS computer program version 9.2 (SAS Institute®, 2008).

Life table parameters of *Cydnoseius negevi* adult female

The life history data of the adult females were used to develop the life table parameters. The life table parameters (*i.e.*, net reproductive rate (R_0), intrinsic rate of increase (r_m), finite rate of increase (λ), mean generation time (T), and doubling time (DT)) were calculated according to Birch (1948) using a software program developed by Abou-Setta *et al.* (1986).

Results

Biology of *Cydnoseius negevi* feeding on fresh date palm pollen under different humidity levels

Cydnoseius negevi successfully completed its development when fed on date palm pollen at both 35 % and 60 % RH levels and 30 °C. The immature developmental time, total life span, and longevity of male and female and different reproductive parameters of the female are shown in Tables 1 and 2.

The total duration of the immature stage development of both *C. negevi* females and males were significantly lower at 60 % RH (3.30 and 4.45 days, respectively) than at 35 % RH (5.33 and 6.01 days, respectively) ($F_{3,70} = 16.72$; $P < 0.0001$). At both 35 % and 60 % RH, the duration of the developmental stage of *C. negevi* immature males was longer than that of

Table 1 Means duration in days ($\pm$ SE) of the immatures of *Cydnoseius negevi* fed on date palm pollen at 35 $\pm$ 5 % and 60 $\pm$ 5 % RH and 30 $\pm$ 2 °C.

Humidity % RH.	Sex	Development of immature stages (days)				
		Egg	Larva	Protonymph	Deutonymph	Total immature
35	♀	1.89 $\pm$ 0.12a	0.77 $\pm$ 0.04a	1.23 $\pm$ 0.09a	1.44 $\pm$ 0.1a	5.33 $\pm$ 0.3a
	♂	2.05 $\pm$ 0.15a	1.13 $\pm$ 0.13b	1.75 $\pm$ 0.14b	1.13 $\pm$ 0.13a	6.05 $\pm$ 0.35a
60	♀	0.81 $\pm$ 0.05b	0.54 $\pm$ 0.02c	0.74 $\pm$ 0.06c	1.20 $\pm$ 0.12a	3.30 $\pm$ 0.14b
	♂	1.14 $\pm$ 0.15b	0.73 $\pm$ 0.08a	1.18 $\pm$ 0.15a	1.41 $\pm$ 0.22a	4.45 $\pm$ 0.35c

Means followed by different letters within the same column are significantly different (ANOVA) followed by LSD test: $P < 0.05$.

Table 2 Means duration in days ($\pm$ SE) of different periods of the adult phase longevity, life span, fecundity and sex ratio (%females) of *Cydnoseius negevi* fed on date palm pollen at $35 \pm 5\%$ and $60 \pm 5\%$ RH and $30 \pm 2\%$ °C.

Humidity % RH.	Sex	Adult Life Time (days)				Lifespan (egg to death)(days)	Total fecundity (Eggs/female)	Daily fecundity (Eggs/female/day)	Sex ratio (%females)
		Pre- oviposition	Oviposition	Post- oviposition	Longevity				
35	♀	1.89 $\pm$ 0.16a	11.47 $\pm$ 1.6a	3.75 $\pm$ 0.6a	17.11 $\pm$ 1.9a	22.43 $\pm$ 1.74a	14.00 $\pm$ 1.63a	1.66 $\pm$ 0.14a	71%
	♂				10.7 $\pm$ 2.7a	16.75 $\pm$ 2.4a			
60	♀	2.81 $\pm$ 0.5a	16.06 $\pm$ 1.8a	4.33 $\pm$ 0.5a	23.20 $\pm$ 1.74b	26.50 $\pm$ 1.8a	20.30 $\pm$ 1.71b	1.55 $\pm$ 0.14a	73%
	♂				14.45 $\pm$ 1.8a	18.91 $\pm$ 2.05b			

Means followed by different letters within the same column are significantly different (ANOVA followed by LSD test: $P < 0.05$)

females (Table 1). The incubation period ($F_{3,70} = 24.11$; $P < 0.0001$), duration of the larval ($F_{3,70} = 11.12$; $P < 0.0001$) and protonymphal stages ($F_{3,70} = 10.32$; $P < 0.0001$) were significantly higher at 35 % RH than at 60 % RH. However, the developmental duration of the deutonymphs of both sexes was not influenced significantly at both RH levels (Table 1).

Decreasing humidity levels from 60 % to 35 % had a significant effect on the mean total fecundity and longevity of *C. negevi* females (Table 2). *Cydnoseius negevi* females deposited fewer eggs (14) at 35 % RH than at 60 % RH (20.3) ($F_{1,57} = 7.11$; $P < 0.01$), although the oviposition period and total life span of the females did not significantly differ ($F_{1,57} = 3.56$; $P < 0.06$) at the two RH levels (Table 2). The sex ratio of *C. negevi* progeny was female-biased and not affected by RH (71 % and 73 % of females, for 35 % and 60 % RH, respectively) (Table 2).

Life table parameters of *Cydnoseius negevi*

C. negevi females successfully reproduced when fed on date palm pollen at both 35 % and 60 % RH levels and 30 °C; life table parameters are presented in Table 3. However, when humidity decreased from 60 % to 35 % RH, “net reproductive rate (R_0)”, “intrinsic rate of increase (r_m)” and “finite rate of increase (λ)” also decreased (Table 3). The duration of mean generation time (T) and doubling time (DT) were longer at 35 % than at 60 % RH (Table 3). At 60 % and 35 % RH, the population of this species could multiply 18 and 14 times ($R_0 = 18.16$ and 13.99 females/female) with the generation time ranging from 11.5 to 13.05 days, respectively. Furthermore, the intrinsic rate of increase (r_m) decreased from 0.25 to 0.20 individuals/female/day and the finite rate of increase (λ) decreased from 1.28 to 1.22 at 60 % and 35 % RH, respectively.

Table 3 Life table parameters of *Cydnoseius negevi* on date palm pollen at $35 \pm 5\%$ and $60 \pm 5\%$ RH and $30 \pm 2\%$ °C RH.

Humidity % RH	R_0 (females/ female)	T (days)	r_m (females/female/ day)	(λ) (females/female/ day)	DT (days)
35	13.99	13.03	0.20	1.22	3.48
60	18.16	11.50	0.25	1.28	2.88

Parameters: R_0 – net reproductive rate; T – mean generation time; r_m – intrinsic rate of increase; (λ) – finite rate of increase; DT – Doubling time.

Discussion

The purpose of this study was to evaluate the biology and life table parameters of *C. negevi*, fed on date palm pollen at a low humidity level (35 % RH). *Cydnoseius negevi* reproduced successfully at both 35 % and 60 % RH levels. Previous studies showed that *C. negevi* reproduced and developed successfully when fed on pollens of different plant species such as date palm *Phoenix dactylifera* L, maize, *Zea mays* L. (Hussein *et al.* 2016), and castor bean, *Ricinus communis* L. (Abou-Awad *et al.* 1989; Momen *et al.* 2009) at the humidity level 65 % RH (Table 4). Negm *et al.* (2014) also showed that *C. negevi* successfully preyed on the date palm mite, *O. afrasiaticus*, and completed its development under low relative humidity 35 % RH. The ability of *C. negevi* to develop and reproduce at a relatively low humidity (35 %) as well as feed on different small pests and variety of plant pollen (Table 4 and 5), could thus explain its survival in arid areas.

In the present study, eggs incubation period and the total immature developmental duration of *C. negevi* increased as relative humidity decreased from 60 % to 35 %. This probably explains the differences in the total duration of the immature stage development at the different humidity levels tested (Table 1). Similar trends were recorded when *Typhlodromus aripo* De Leon was reared under low humidity conditions feeding on cassava green mite *Mononychellus progresivus* Doreste, (Mutisya *et al.* 2014).

However, at both 35 and 60 % RH, the developmental time of *C. negevi* immature females feeding on date palm pollen was shorter in the present study than that of *C. negevi* fed on the date palm pollen (Hussein *et al.* 2016), pollens of castor bean and maize (Abou Awad *et al.* 1989; Momen *et al.* 2009). Likewise, when fed on date palm pollen, the immature stages of the phytoseiid mite, *Euseius scutalis* Athias-Henriot, completed its development in a significantly shorter time than when fed on citrus and castor bean pollens (Al-Shammery 2011). These results could indicate that date palm pollen may accelerate the development of immature stages. Results in this study showed that the developmental period of *C. negevi* was a little longer for immature males than for females at both 35 and 60 % RH. Similarly, the immature developmental time of the phytoseiid mites, *A. swirskii* and *Neoseiulus californicus* (McGregor) was longer for the males than for the females when fed on pollen of *Betula pendula* Roth and castor beans (Goleva and Zebitz 2013; Marafeli *et al.* 2014).

In addition, in this study, total mean fecundity and longevity of *C. negevi* females significantly declined when humidity levels decreased from 60 to 35 %. Similar trends were reported by Mutisya *et al.* (2014) while studying biology of *T. aripo* feeding on cassava green mite, *M. progresivus* Doreste. However, the total mean fecundity and adult longevity of *C. negevi* fed on date palm pollen, even at 60 % RH, was recorded greatly lower in the present study as compared when it fed on castor bean pollen, *Ricinus communis* L at 70–75 % RH (Abou Awad

Table 4 Reproduction and life table parameters of some phytoseiid mites feeding on date palm pollen and other different plant sources from different studies under different lab condition.

Phytoseiid mite species	Food Type (pollen)	Duration (Days)		Reproduction Values			Lab conditions			Life table parameters		References
		Total Immature	Longevity	Total Fecundity	Sex Ratio	Tem.	%RH	Ro	T	r _m	(λ)	
<i>C. negevi</i>	Date palm	5.33	17.11	14.00	71	30	35	13.99	13.03	0.20	1.22	Present study
		3.30	23.20	20.30	73	30	60	18.16	11.50	0.25	1.28	
		6.17	31.33	9	74	27	65	6.82	12.36	0.16	1.17	Hussein <i>et al.</i> , 2016
	Maize/Corn	6.16	36.47	29.53	79	27	65	18.93	13.17	0.22	1.25	
	Castor bean	6.33	37	32.93	88	28	70-75	29.04	12.39	0.27	1.31	Momen <i>et al.</i> , 2009
<i>Amblyseius swirskii</i>	Date palm	10.50	42.30									Abou-Elella <i>et al.</i> , 1989
<i>A. swirskii</i>	Date palm	6.31	32.75	37.06	65	27	75	24.17	13.85	0.23	1.26	Abou-Elella <i>et al.</i> , 2013
<i>Typhlodromus bagdasarjani</i>	Date palm	7.3	46.0	8.7	-	25	65	6.06	22.41	0.08	0.08	Riahi <i>et al.</i> , 2017
<i>Euseius finlandicus</i>	Date palm	8.69	14.53	0.82	25	25	65	0.24	16.48		0.9170	Riahi <i>et al.</i> , 2016
<i>Euseius scutalis</i>	Date palm		40.80	5.50	50	28	70-80	0.99	9.65	-	0.99	Abou-Elella <i>et al.</i> , 2014
<i>Proprioseiopsis asetus</i>	Date palm	5.2	21.50	31.93		26	75	17.88	12.39	0.23	1.26	Fouly <i>et al.</i> , 2013
		5.75	20.00	37.06	70	27	75	25.94	12.29	0.27	1.30	Abou-Elella <i>et al.</i> , 2013
		6.54	18.22	42.62	64	26	70	34.93	17.19	0.21	1.22	Al shammery, 2011
<i>Phytoseius plumifer</i>	Date palm	6.52	29.53		26	26	70	29.28	13.39	0.25	1.28	Fouly, 1997
		10.5	32	16.6	62	29.5						Zaher <i>et al.</i> , 1969

Table 5 Reproduction and life table parameters of the predatory phytoseiid mite *Cydnoseius negevi* feeding on different prey reported from different studies under different lab condition.

Prey species	duration (days)		Reproduction values		Lab conditions			Life table parameters				References
	Total immature	Longevity	Total Fecundity	Sex Ratio (♀%)	°C	%RH	Ro	T	r _m	(λ)	DT	
<i>O. afrasiaticus</i>	9.00	31.80	21.6	63.6	25	35	10.44	17.03	0.14	1.15	4.95	Ngem <i>et al.</i> , 2014
	7.93	20.10	38	58.3	35	35	17.35	15.17	0.19	1.21	3.6	
<i>Tuta absoluta</i>		21.37	2.5	62	30	70 – 75						Metwally <i>et al.</i> , 2015
<i>Bemisia tabaci</i>	6.07	32.20	21.2	85	28	70 – 75	18.02	12.26	0.24	1.27		Momen <i>et al.</i> , 2009
<i>Insulaspis pallidula</i>	7.70	16.82	10.23	80	28	70 – 75	8.14	14.84	0.14	1.15		
<i>Phoenicoccus marlatt</i>	7.81	14.37	6.44	55	28	70 – 75	3.61	13.59	0.09	1.09		
<i>Aculus fockeui</i>	8.64	34.78	32.35	58	28	75	16.29	17.03	0.16	1.18		Momen, 2009
<i>Eriophyes ficus</i>	8.39	36.23	35.77	85.7	27	65 – 75	30.87	15.04	0.23	1.26		Abou-Awad <i>et al.</i> , 1998
<i>Tetranychus urticae</i>		66.9	39.7		28	70 – 80						Momen, 1997
<i>Eutetranychus orientalis</i>	10.40	38.5										Abou-Awad <i>et al.</i> , 1989
<i>T. urticae</i>	11.00	49.74										

et al. 1989; Momen *et al.* 2009) and on maize pollen, *Zea mays* L. at 65 % RH (Hussein *et al.* 2016) at almost the same temperature. Furthermore, among the different plant pollen tested, the highest fecundity and longevity were reported when *C. negevi* females fed on castor bean pollen (Abou Awad *et al.* 1989; Momen *et al.* 2009) (Table 4). Among all prey and diets tested (table 4 and 5), the highest total fecundity and longevity of *C. negevi* were recorded for females reared on the two spider mite species, *T. urticae* (Momen 1997).

Often, fecundity, oviposition period, and longevity of phytoseiid mites were found to be higher and longer at high humidity than at low (Kumari and Sadana 1991; Schausberger 1998; Mutisya *et al.* 2014) as found in this study. However, total mean fecundity values were higher in three previous studies conducted at 70-75 % RH when *E. scutalis* fed on date palm pollen than recorded in the present study even at high RH (65%), but the longevity found was the same (Al-Shammery 2011; Abou-Ellella *et al.* 2013; Fouly *et al.* 2013) (Table 4). Interestingly, Hussein *et al.* (2016) found that total mean fecundity of *C. negevi* females fed on date palm pollen at 65 % RH was very low (9 eggs/ female for all its life) although female longevity was longer than what was observed in the present study (Table 4).

In the present study, the sex ratio (female %) was not significantly affected by humidity. Similarly, females of *E. alstoniae* showed insignificant difference in the sex ratio at a constant temperature (30 °C) with different relative humidity levels (50, 70 and 90 %) (Kumari and Sadana 1991). Under relatively high humidity (65–80 % RH) and different diets consumed by *C. negevi*, the female proportion ranged from 55 to 88 % (Table 4 and 5). In the present study, *C. negevi* female proportion was recorded almost the same (71 %, 73 %) at both 35 % and 60 % RH. Among the different plant pollens tested previously, the highest *C. negevi* female proportion was recorded when individuals were fed on castor bean pollen (88 %) (Momen *et al.* 2009). This suggests that diet can be one of the main factors affecting the sex ratio as pollens from different plant species have different nutritional values (Todd and Bretherick 1942; Stanley and Linskens 1974; Schmidt and Buchmann 1985; Atrouse *et al.* 2004; Nicolson 2011). However, Abou-Setta *et al.* (1997) found that the proportion of females (56–58 %) within the species *Proprioseiopsis rotundus* (Muma) was not affected when fed with different kinds of food.

Overall, life table parameters of *C. negevi* were influenced negatively when humidity levels decreased from 60 to 35 %. In previous studies, life table parameters of *C. negevi* were only studied at high RH (>65 %) except in Negm *et al.* (2014) at 35 % RH (Table 4). The net reproductive rate (*R*₀) and mean generation time (*T*) of *C. negevi*, when fed on date palm pollen were comparatively lower (13.91 and 13.03) at 35 % RH and 30 °C in this study than when fed

on *O. afrasiaticus* (17.37 and 15.17) at same RH but 35 °C respectively (Negm *et al.* 2014). On the opposite, at 35 % RH, there was no significant difference in the doubling time (DT), intrinsic rate of increase (r_m) and finite rate of increase (λ) of *C. negevi* feeding on either date palm pollen in the present study or *O. afrasiaticus* (Negm *et al.* 2014) (Table 5). Among the different plant pollens tested, including date palm pollen in the present study, the highest net reproductive rate (R_0) of *C. negevi* was recorded when fed on castor bean pollen (Momen *et al.* 2009). The mean generation time (T) of *C. negevi* was almost the same when fed either on date palm pollen in the present study or on pollens of castor bean, maize and date palm in previous studies even at different RH levels (Momen *et al.* 2009; Hussein *et al.* 2016). However, AL-Shammery (2011) reported that the date palm pollen shortened the mean generation time of *E. scutalis* as compare when it fed on the pollen of other plant species *i.e.* citrus, alfalfa, and castor bean and simultaneously resulted in the highest values of net reproductive rates, intrinsic and finite rates of increase. Recently, the life table parameters for *T. bagdasarjani* and *A. swirskii* fed on date palm pollen were determined in two independent studies (Riahi *et al.* 2016; 2017) (Table 4 and 5). Both phytoseiid species exhibited longer mean generation times (T) compared to *C. negevi* in the present study on the same food. Also the net reproductive rate (R_0) of both species when fed on date palm pollen were lower than for *C. negevi* in the present study. However, both species exhibited higher values for net reproductive rate (R_0), intrinsic rate of increase (r), and finite rate of increase (λ) when fed on almond pollen (Riahi *et al.* 2016, 2017).

The date palm mite *O. afrasiaticus* is usually found in association with *C. negevi* in fields on the date palm trees and grasses (Alatawi *et al.* 2017). The population of date palm mite greatly decline in off date fruit period especially in winter (Palevsky *et al.* 2003). Therefore, the provision of date palm pollen during winter and off fruit period on date palm trees and underground grasses may enhance the population of the predators especially *C. negevi*. In the augmentative releases of natural enemies, the provision of pollen on the plant surface may enhance or sustain the population growth of predatory mites, which will ultimately result in enhanced biocontrol conditions (Nomikou *et al.* 2002).

Cydnoseius negevi successfully developed and reproduced when fed date palm pollen at a relatively low humidity (35 % RH). Thus, we would recommend it as a biocontrol agent of the date palm mite under arid environmental conditions. Moreover, date palm pollen could be used as a suitable diet for the augmentation and conservation of *C. negevi* in date palm orchards (grass and date palm leaves) as well as for its survival as a biocontrol agent on date fruits before early infestation of date palm mites. When *N. californicus* (a generalist predator) is released on perennial crops prior to spider mite infestation and in the presence of artificial food (pollen), with exceptions, it could persist and maintain the pest population at a level lower than the economic threshold level (Schausberger and Walzer 2001).

Further field-based studies are required for a better understanding of the potential use of *C. negevi* with date palm pollen in the field where systems are likely to be more complex than laboratory conditions. No study on the release of this predator has been applied in the field yet.

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