



E-ISSN: 2320-7078  
P-ISSN: 2349-6800  
JEZS 2017; 5(1): 27-35  
© 2017 JEZS  
Received: 05-11-2016  
Accepted: 06-12-2016

#### Maryam Rezaie

Zoology Research Department,  
Iranian Research Institute of  
Plant Protection, Agricultural  
Research, Education and  
Organization (AREEO), Tehran,  
Iran

#### Alireza Saboori

Department of Plant Protection,  
Faculty of Agriculture,  
University of Tehran, Karaj,  
Alborz, Iran

#### Valiollah Baniamerie

Agricultural Entomology  
Research Department, Iranian  
Research Institute of Plant  
Protection, Agricultural  
Research, Education and  
Organization (AREEO), Tehran,  
Iran

#### Ali Hosseini-Gharalari

Agricultural Entomology  
Research Department, Iranian  
Research Institute of Plant  
Protection, Agricultural  
Research, Education and  
Organization (AREEO), Tehran,  
Iran

#### Correspondence

#### Maryam Rezaie

Zoology Research Department,  
Iranian Research Institute of  
Plant Protection, Agricultural  
Research, Education and  
Organization (AREEO), Tehran,  
Iran

## The effect of strawberry cultivars on functional response and prey-stage preference of *Neoseiulus californicus* (Acari: Phytoseiidae) on *Tetranychus urticae* (Acari: Tetranychidae)

Maryam Rezaie, Alireza Saboori, Valiollah Baniamerie and Ali Hosseini-Gharalari

#### Abstract

*Neoseiulus californicus* (Acari: Phytoseiidae) is an effective predator of spider mites. The prey-stage preference of *N. californicus* was studied on different developmental stages of *Tetranychus urticae* on seven strawberry commercial cultivars ('Aliso', 'Chandler', 'Camarosa', 'Gavita', 'Sequia', 'Marak' and 'Yalova'). Functional response of adult female of *N. californicus* to egg and protonymph of *T. urticae* was determined. Experiments were carried out on strawberry leaflets in Petri dishes in the laboratory. The protonymph and deutonymph of *N. californicus* preferred *T. urticae* eggs to protonymph. However, the female predatory mite preferred protonymph *T. urticae*. The preference index on different strawberry cultivars was not different. The functional response to egg of *T. urticae* on 'Chandler', 'Gaviota' and 'Camarosa' was type II, whereas it was type III on protonymph of *T. urticae* on 'Sequia', 'Marak', 'Yalova' and 'Aliso'. The handling time are different among the cultivars (the highest value was reported for 'Marak' (1.06±0.035 hour) on egg of *T. urticae*, for 'Yalova' (1.45±0.05 hour) and for 'Camarosa' (1.44±0.13) on protonymph of *T. urticae*. The predation rate of different developmental stages of *N. californicus* on 'Chandler' was higher than the other cultivars (protonymph (2.6±0.3), deutonymph (3.8±0.2) and adult (9.5±0.6) in 24 hours) on egg of *T. urticae*, which might be due to least trichome or difference chemical and physical structure leaves. It is recommended to use this predatory mite to control different stages of *T. urticae*. However, the protonymph stage of *T. urticae* is the most suitable target stage.

**Keywords:** Prey-stage preference, strawberry, cultivars, functional response, predatory mite

#### 1. Introduction

*Tetranychus urticae* Koch (Acari: Tetranychidae) is a key pest of strawberry [23]. There are several methods to control this key pest. One of the environmentally friendly control methods is biological control using parasitoids and predators. *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae), is an important spider mite predator that is active in habitats with high temperature and low humidity [49] such as Mediterranean area [10]. This predator can successfully develop and reproduce on *T. urticae* up to 28 generations per year [22].

In order to reach an effective biological control when deploying a polyphagous predator, we need to know the prey preference of the predator. The functional response has been widely utilized to evaluate effectiveness of predacious insects and mites [14, 44, 11, 3, 43]. The functional response of *N. californicus* depends on prey species [7], temperature [22] and host plants [8]. Foraging efficiency and predation rate of predators are influenced by physical plant characteristics such as trichomes [33, 26, 8].

The objectives of this research were to 1) study the preference of different developmental stages of *N. californicus* to different stages of *T. urticae*, in the laboratory, 2) study the effect of seven strawberry cultivars on preference of *N. californicus* to *T. urticae* eggs, protonymphs and adults, and 3) study the effect of seven strawberry cultivars on functional response of predatory-female to different densities of *T. urticae* eggs and protonymphs.

#### 2. Materials and Methods

##### 2.1 Plant Material

Seven strawberry cultivars ('Marak', 'Yalova', 'Aliso', 'Gaviota', 'Sequoia', 'Camarosa' and

'Chandler') were obtained from the Faculty of Agriculture, University of Tehran (Alborz, Iran). Crowns were stored at 1–4 °C for three weeks, followed by planting in pots that were irrigated daily and were fertilized once every two weeks (NPK: 20:20:20) during 2010-2015.

## 2.2 Mite Colonies

*T. urticae* was reared for several generations on each of the above-mentioned strawberry cultivars. A stock of *N. californicus* was purchased from the 'Koppert Biological Systems' (Berkel en Rodenijis, the Netherlands) and was maintained on leaves of 'Gaviota' strawberry that were infested with different developmental stages of *T. urticae* as prey. The colony was also provided with pollen of sweet corn (27±1 °C, 70±5% RH, 16L: 8D). In order to obtain suitable predatory mites for the experiments, the predatory mites were reared on detached leaves of the above-mentioned strawberry cultivars. The leaves were placed upside down on a plastic sheet that was on a water-saturated sponge. Napkin tapes surrounded the plastic sheet, which was put into the water from the other side so that the predatory mites could drink water but could not escape.

## 2.3 Prey-Stage Preference

In this experiment, eggs, newly emerged protonymphs and 3-day-old females of *T. urticae* were used. Same-age eggs were reared separately to obtain 3-day old females. The eggs were obtained from the laboratory population that was reared on different strawberry cultivar, separately.

Newly emerged protonymphs, deutonymphs and 3-day-old mated females of *N. californicus* were used separately in prey-stage preference experiments. Each experiment had 10 replications. In order to study the prey-stage preference of *N. californicus* protonymphs and deutonymphs, they were offered with 10 eggs and 10 protonymphs of *T. urticae*. Equal number (20) of *T. urticae* eggs, newly emerged protonymphs and adults were offered to a 3-day-old mated female predator. The prey-stage preference was conducted in leaf arenas for each of the strawberry cultivars. Leaf arenas consisted of a leaflet of each of the strawberry cultivars (2×2 cm<sup>2</sup>) that was placed upside down on water saturated cotton balls. Each cultivar was tested separately from the other cultivars. After 24 hours, the number of preys consumed per predator was estimated.

Preference Index was estimated based on Manly (1974) [30]:

$$\beta_1 = \frac{\log\left(\frac{e_1}{A_1}\right)}{\log\left(\frac{e_1}{A_1}\right) + \log\left(\frac{e_2}{A_2}\right)}$$

where,  $\beta_1$  is the preference to prey 1 (egg, protonymph or adult *T. urticae*),  $e_1$  and  $e_2$  are the number of prey '1' and '2' remaining after the experiment, respectively, and  $A_1$  and  $A_2$  are the number of prey '1' and '2' presented to the predator. If the preference index is close to 1, the predator prefers prey '1', and if it is close to 0, it prefers prey '2'. An index close to 0.5 shows no preference, indicating that predation is random [51]. Preference Index and Predation Rate were subjected to

analysis of variance in SPSS [41].

## 2.4 Functional Response

The setup was similar as mentioned above. Similar to the previous experiments, leaflets of seven strawberry cultivars were used. Eight different densities of *T. urticae* nymphs and eggs (2, 4, 8, 16, 32, 45, 60 and 70 per arena) were offered to 3-day-old female *N. californicus*. After 24 hours, the numbers of consumed prey were estimated. Each density was replicated 10–15 times.

Type of the functional response was determined by logistic regression analysis (PROC CATMOD) [38]. Attack Rate ( $a$ ) and Handling Time ( $T_h$ ) were estimated by fitting data to Disc equation [19] or Rogers Random Predator equation [11,43], using non-linear least square technique (PROC NLIN) [38].

$$N_a = a \times T \times N_t \times \frac{P}{1} + \dot{a} \times T_h \times N_t$$

Where,  $N_a$  is the number of consumed prey,  $N_t$  is the initial number of prey,  $T$  is the experiment duration. After determining the type of functional response,  $T_h$  and  $a$  (for type II) or  $b$  (for type III) must be estimated. Non-linear least square regression (PROC NLIN) was used to estimate the parameters of the Holling's disk equation. Comparison between the two functions was performed using:

$$N_a = \frac{[b + D_b(j)]N_0^2 T_t}{1 + [b + D_b(j)]N_0^2 [T_h + D_{Th}(j)]}$$

The parameters  $D_b$  or  $D_a$  and  $D_{th}$  estimate the difference between the value of the parameter  $b$  or  $a$  and  $T_h$ , respectively. In order to detect difference between two handling times, it must be proved that  $D_{Th}$  is a significantly different from zero. If  $D_{th}$  is not significantly different from zero, then the difference between  $T_h$  and  $D_{th}$  is not significant and the two handling time is equal [25].

In order to study the leaf surface structure of the strawberry cultivars, density and length of non-glandular trichomes on leaf surface were determined under a binocular microscope (X40). Data were subjected to analysis of variance (PROC GLM).

## 3. Results

**3.1 Preference Index:** Preference Index was different among all cultivars. On all of the cultivars, the Preference Index was higher on *T. urticae* eggs compared to *T. urticae* nymphs, indicating that they prefer eggs to nymphs (Table 1). However, the Preference Index of the predatory mite at protonymph and deutonymph stages on the prey eggs and protonymphs was not different among the cultivars (ANOVA: predator protonymph on prey egg:  $F_{6,63}=2.17$ ,  $P=0.0598$ , predator protonymph on prey protonymph:  $F_{6,63}=2.17$ ,  $P=0.0595$ , predatory deutonymph on prey egg:  $F_{6,63}=1.82$ ,  $P=0.1125$ , predator deutonymph on prey protonymph:  $F_{6,63}=1.83$ ,  $P=0.1125$ ).

**Table 1:** Prey-stage Preference Index of three stages of *Neoseiulus californicus* (protonymph, deutonymph and 3-day-old female adult) when offered eggs, nymphs and adults of *Tetranychus urticae*, on seven strawberry cultivars, during 24 h in the laboratory.

Predacious stage of <i>N. californicus</i>	Strawberry cultivars	Preference Index ( $\beta$ ) on different growth stages of <i>T. urticae</i>			F	P
		Egg	Protonymph	Adult		
Protonymph <sup>†</sup>	'Aliso'	0.67±0.03 <sup>a</sup>	0.33±0.03 <sup>b</sup>	-	7.32	0000
	'Marak'	0.60±0.08 <sup>a</sup>	0.39±0.09 <sup>b</sup>	-	1.67	0000
	'Chandler'	0.88±0.05 <sup>a</sup>	0.12±0.05 <sup>b</sup>	-	10.92	0000

	‘Gaviota’	0.84±0.07 <sup>a</sup>	0.15±0.06 <sup>b</sup>	-	7.18	0000
	‘Camarosa’	0.80±0.08 <sup>a</sup>	0.20±0.08 <sup>b</sup>	-	5.20	0000
	‘Yalova’	0.74±0.06 <sup>a</sup>	0.26±0.06 <sup>b</sup>	-	5.50	0000
	‘Sequoiua’	0.79±0.06 <sup>a</sup>	0.20±0.07 <sup>b</sup>	-	5.68	0000
Deutonymph <sup>††</sup>	‘Aliso’	0.75±0.03 <sup>a</sup>	0.25±0.03 <sup>b</sup>	-	10.27	0000
	‘Marak’	0.79±0.04 <sup>a</sup>	0.27±0.04 <sup>b</sup>	-	15.09	0000
	‘Chandler’	0.73±0.05 <sup>a</sup>	0.27±0.04 <sup>b</sup>	-	9.13	0000
	‘Gaviota’	0.76±0.03 <sup>a</sup>	0.24±0.04 <sup>b</sup>	-	10.72	0000
	‘Camarosa’	0.77±0.04 <sup>a</sup>	0.23±0.04 <sup>b</sup>	-	9.63	0000
	‘Yalova’	0.66±0.03 <sup>a</sup>	0.34±0.03 <sup>b</sup>	-	6.59	0000
Female	‘Sequoiua’	0.68±0.03 <sup>a</sup>	0.32±0.03 <sup>b</sup>	-	8.08	0000
	‘Aliso’	0.34±0.01 <sup>b</sup>	0.56±0.02 <sup>a</sup>	0.09±0.01 <sup>c</sup>	248	0000
	‘Marak’	0.30±0.03 <sup>b</sup>	0.54±0.03 <sup>a</sup>	0.17±0.01 <sup>c</sup>	54.39	0000
	‘Chandler’	0.34±0.03 <sup>b</sup>	0.50±0.01 <sup>a</sup>	0.15±0.02 <sup>c</sup>	74.71	0000
	‘Gaviota’	0.37±0.03 <sup>b</sup>	0.52±0.03 <sup>a</sup>	0.10±0.01 <sup>c</sup>	66074	0000
	‘Camarosa’	0.39±0.04 <sup>b</sup>	0.54±0.04 <sup>a</sup>	0.06±0.01 <sup>c</sup>	79.60	0000
	‘Yalova’	0.35±0.01 <sup>b</sup>	0.54±0.03 <sup>a</sup>	0.10±0.02 <sup>c</sup>	106.80	0000
	‘Sequoiua’	0.33±0.02 <sup>b</sup>	0.58±0.03 <sup>a</sup>	0.09±0.01 <sup>c</sup>	101.48	0000

\*Means within a row followed by same letter were not significantly different based on Tukey test ( $\alpha=5\%$ ).

† Degrees of freedom for ANOVA=18

†† Degrees of freedom for ANOVA=27

On all of the cultivars, Preference Index of *N. californicus* adult was different among *T. urticae* eggs, protonymphs and adults (Table 1). Female *N. californicus* preferred *T. urticae* protonymph stage to egg and adult stages. The Preference Index of *N. californicus* on egg stage of *T. urticae* was not different among the cultivars ( $F_{6,63}= 1.30, P= 0.2658$ ), a similar result was observed for the protonymph stage of *T. urticae* ( $F_{6,63}= 0.80, P= 0.5698$ ). However, Preference Index of female predatory mite, when provided with *T. urticae* adults, was different among cultivars, with highest preference on ‘Marak’ and ‘Chandler’ ( $F_{6,63}= 5.96, P= 0.0012$ ).

**3.2 Predation Rate:** The predation rate of *N. californicus* at

protonymph stage was different among the cultivars, when they were offered *T. urticae* egg ( $F_{6,63}= 3.91, P=0.0001$ ) and *T. urticae* protonymph ( $F_{6,63}= 2.94, P= 0.0001$ ). The highest predation rate of *T. urticae* egg was observed on ‘Chandler’ and ‘Aliso’, while the highest predation rate of *T. urticae* protonymph was observed on ‘Marak’ and ‘Aliso’ (Table 2). The predation rate of *N. californicus* at deutonymph stage was different among the cultivars, when they were offered *T. urticae* egg ( $F_{6,63}= 2.50, P=0.0342$ ), and the highest predation rate was observed on ‘Chandler’ ( $3.80\pm 0.25$ ). However, the predation rate of the predatory mite at deutonymph stage on *T. urticae* protonymph was not different among the cultivars ( $F_{6,63}= 2.02, P=0.0689$ ) (Table 2).

**Table 2:** Mean ( $\pm$ SE) number of *Tetranychus urticae* eggs, nymphs and adults consumed by three growth stages of *Neoseiulus californicus* (protonymph, deutonymph and 3-day-old female adult), on seven strawberry cultivars, during 24 h in the laboratory.

Predacious stage of <i>N. californicus</i>	Growth stages of <i>T. urticae</i> , as prey	Mean ( $\pm$ SE) number of <i>T. urticae</i> killed							F <sup>†</sup>	P
		‘Gaviota’	‘Marak’	‘Chandler’	‘Camarosa’	‘Aliso’	‘Yalova’	‘Sequoiua’		
Protonymph	Egg	1.4±0.2 <sup>b</sup>	1.8±0.3 <sup>b</sup>	2.6±0.3 <sup>a</sup>	1.4±0.2 <sup>b</sup>	2.2±0.3 <sup>ab</sup>	1.8±0.3 <sup>b</sup>	1.8±0.1 <sup>b</sup>	2.91	0.0001
	Protonymph	0.4±0.2 <sup>b</sup>	1.1±0.2 <sup>a</sup>	0.4±0.2 <sup>b</sup>	0.6±0.3 <sup>ab</sup>	1.1±0.1 <sup>a</sup>	0.5±0.2 <sup>b</sup>	0.7±0.2 <sup>ab</sup>	2.94	0.0001
Deutonymph	Egg	2.8± 0.2 <sup>cb</sup>	3.3 ±0.2 <sup>ab</sup>	3.8± 0.2 <sup>a</sup>	3.0± 0.2 <sup>cb</sup>	3.7± 0.6 <sup>ab</sup>	2.9± 0.1 <sup>abc</sup>	2.6± 0.2 <sup>c</sup>	2.50	0.0342
	Protonymph	1.0± 0.1	1.1± 0.2	1.6± 0.2	1.0± 0.2	1.3± 0.1	1.5± 0.2	1.6± 0.2	2.02	0.0689
Adult (Female)	Egg	11.3± 0.5 <sup>a</sup>	6.9±0.8 <sup>c</sup>	9.5± 0.6 <sup>b</sup>	9.1± 0.3 <sup>b</sup>	9.1± 0.6 <sup>b</sup>	9.1± 0.5 <sup>a</sup>	9.5± 0.4 <sup>b</sup>	5.34	0.0020
	Protonymph	13.0± 0.5	10.7± 0.2	11.9± 0.6	10.6± 0.9	12.5± 0.6	13.2± 0.6	12.6± 0.6	2.70	0.0621
	Adult	4.3± 0.4 <sup>a</sup>	4.3± 0.4 <sup>a</sup>	4.3± 0.5 <sup>a</sup>	2.1± 0.4 <sup>c</sup>	2.94±0.4 <sup>cb</sup>	3.1± 0.4 <sup>bc</sup>	3.4± 0.5 <sup>bc</sup>	4.98	0.0050

\*Means within a row followed by same letter(s) were not significantly different based on Tukey test ( $\alpha=5\%$ ).

† Degrees of freedom for ANOVA=63

The predation rate of adult *N. californicus* was different among cultivars, when they were offered *T. urticae* eggs ( $F_{6,63}= 5.34, P=0.0020$ ) and adults ( $F_{6,63}= 4.98, P=0.0050$ ). The highest predation rate of adult *N. californicus* was observed on ‘Gaviota’, when they were offered *T. urticae* eggs. Meanwhile, the predation rate was higher on ‘Gaviota’,

‘Marak’ and ‘Chandler’, when they were offered *T. urticae* adults (Table 2). The maximum number of eggs and protonymph of *T. urticae* consumed by the predatory mite was not different among the cultivars ( $F_{6,63}= 1.30 P=0.2623$  and  $F_{6,63}= 1.45 P=0.2302$ , respectively) (Table 3).

**Table 3:** Maximum ( $\pm$ SE) number of *Tetranychus urticae* eggs, nymphs consumed by *Neoseiulus californicus* female on seven strawberry cultivars, during 24 h in the laboratory.

	‘Aliso’	‘Gaviota’	‘Camarosa’	‘Sequoiua’	‘Marak’	‘Chandler’	‘Yalova’	F <sup>†</sup>	P
Predation rate on egg of <i>T. urticae</i>	29.70±2.61	28.50±1.00	24.20±4.30	31.90±2.21	22.30±2.10	27.91±2.52	30.60±4.73	1.30	0.2623
Predation rate on protonymph of <i>T. urticae</i>	22.70±1.92	19.20±1.81	16.00±1.60	17.60±2.22	20.90±1.24	18.42±2.51	18.91±1.72	1.45	0.2302

\*Means within a row followed by same letter(s) were not significantly different based on Tukey test ( $\alpha=5\%$ ).

† Degrees of freedom for ANOVA=63

**3.3 Functional Response:** Logistic regression analysis showed that the functional response of *N. californicus* on *T. urticae* eggs was type II on ‘Chandler’, ‘Gaviota’, ‘Camarosa’ and ‘Aliso’, While on the other cultivars, it was type III. On all cultivars, the functional response on *T. urticae* protonymph was type III, (Table 4). Attack rate of *N. californicus* to eggs of *T. urticae* was between 0.008 h<sup>-1</sup> to 0.016 h<sup>-1</sup> on ‘Sequia’, ‘Marak’ and ‘Yalova’, whereas it was between 0.112 h<sup>-1</sup> to 0.149 h<sup>-1</sup> on ‘Chandler’, ‘Gaviota’, ‘Camarosa’ and ‘Aliso’.

Handling time of *N. californicus* on *T. urticae* eggs was between 0.61 h to 1.06 h (Table 5). The functional response parameters of *N. californicus* on *T. urticae* protonymph are shown in Table 5. The attack rate was between 0.05 h<sup>-1</sup> to 1.81 h<sup>-1</sup> and handling time was 1.149 h to 3.350 h. The handling time was different among the cultivars, i.e. ‘Aliso’ vs. ‘Sequia’, ‘Aliso’ vs. ‘Camarosa’, ‘Sequia’ vs. ‘Yalova’, ‘Gaviota’ vs. ‘Camarosa’ and ‘Yalova’ vs. ‘Camarosa’ (Table 6).

**Table 4:** Logistic regression analysis of rate of prey consumed by *Neoseiulus californicus* in proportion to initial number of preys (eggs or nymphs of *Tetranychus urticae*) on seven strawberry cultivars.

Prey	Strawberry cultivars	Parameters	Estimate (±SE)	X <sup>2</sup>	P	
<i>T. urticae</i> Eggs	‘Aliso’	Constant	2.29±0.24	93.72	0.0010	
		Linear	-0.036±0.01	6.75	0.0094	
		Quadratic	-0.0005±0.00018	0.08	0.7800	
	‘Gaviota’	Constant	3.54±0.50	49.11	0.0101	
		Linear	-0.216±0.05	15.25	0.0010	
		Quadratic	0.006±0.017	13.13	0.0003	
		Cubic	-0.0006±0.000016	14.82	0.0001	
		‘Chandler’	Constant	5.05± 0.69	53.29	0.0001
			Linear	-0.28± 0.069	17.35	0.0001
	Quadratic		0.006± 0.002	9.28	0.0001	
	Cubic		-0.00005± 0.00002	6.97	0.0001	
	‘Sequia’	Constant	0.06±0.28	0.05	0.8101	
		Linear	0.21±0.04	31.53	0.0010	
		Quadratic	0.008±0.001	34.95	0.0010	
		Cubic	0.00072±0.000013	30.94	0.0010	
	‘Marak’	Constant	0.53±0.31	2.97	0.0840	
		Linear	0.197± 0.042	21.53	0.0001	
		Quadratic	-0.008±0.001	32.54	0.0001	
		Cubic	0.0008±0.00001	31.90	0.0001	
	‘Camarosa’	Constant	7.51± 0.82	82.89	0.0001	
		Linear	-0.65±0.66	65.89	0.0001	
		Quadratic	0.01 ± 0.002	64.03	0.0001	
		Cubic	-0.00017±0.00002	66.01	0.0001	
	‘Yalova’	Constant	1.65±0.36	21.44	0.0010	
Linear		0.05± 0.04	1.34	0.2400		
Quadratic		-0.004± 0.0015	6.55	0.0100		
Cubic		0.000042±0.00001	8.80	0.0300		
<i>T. urticae</i> nymphs	‘Aliso’	Constant	-0.31± 0.50	0.38	0.5268	
		Linear	0.48± 0.11	18.76	0.0001	
		Quadratic	-0.03± 0.0065	21.19	0.0001	
		Cubic	0.000064± 0.00014	18.94	0.0001	
	‘Gaviota’	Constant	0.88±0.32	7.73	0.0050	
		Linear	0.11±0.04	7.32	0.0050	
		Quadratic	-0.005± 0.0001	15.03	0.0001	
		Cubic	0.0005±0.00001	14.36	0.0002	
	‘Chandler’	Constant	1.68± 0.52	10.43	0.0010	
		Linear	0.03± 0.10	0.10	0.7500	
		Quadratic	-0.002± 0.006	0.18	0.6701	
		Cubic	7.67± 0.00007	0.00014	0.8520	
	‘Sequia’	Constant	-0.18±0.44	0.17	0.6820	
		Linear	0.49±0.10	23.40	0.0001	
		Quadratic	-0.033± 0.006	28.74	0.0001	
		Cubic	0.00007± 0.0001	26.95	0.0001	
	‘Marak’	Constant	0.39± 0.40	0.68	0.0410	
		Linear	0.35± 0.10	10.99	0.0009	
		Quadratic	-0.02± 0.006	11.20	0.0080	
		Cubic	0.004± 0.0001	7.65	0.0005	
	‘Camarosa’	Constant	2.46± 0.69	12.69	0.0004	
		Linear	0.17± 0.12	1.97	0.1600	
		Quadratic	-0.02± 0.006	11.74	0.0006	
		Cubic	0.00064± 0.0001	18.08	0.0001	
‘Yalova’	Constant	-1.87± 0.40	21.44	0.0001		
	Linear	0.64± 0.09	45.56	0.0001		
	Quadratic	-0.037± 0.005	40.98	0.0001		
	Cubic	0.00007± 0.0001	35.30	0.0001		

**Table 5:** Estimated parameters for the random predator equation (Roger) for *Neoseiulus californicus* feeding on eggs or nymphs of *Tetranychus urticae*, on seven strawberry cultivars.

Prey	Strawberry cultivars	Parameters	Estimate	Asymptotic SE	Asymptotic 95% CI	
					Lower	Upper
Egg of <i>T. urticae</i>	'Sequoiua'	$\beta$	0.008	0.0015	0.0056	0.0116
		$T_h$	0.74	0.03	0.691	0.8010
	'Chandler'	a	0.128	0.030	0.069	0.1900
		$T_h$	0.678	0.062	0.550	0.8010
	'Camarosa'	a	0.112	0.041	0.030	0.1910
		$T_h$	0.668	0.110	0.450	0.8920
	'Marak'	$\beta$	0.016	0.004	0.078	0.2100
		$T_h$	1.06	0.035	0.990	1.1300
	'Aliso'	a	0.145	0.034	0.005	0.0160
		$T_h$	0.632	0.059	0.515	0.7500
	'Yalova'	$\beta$	0.009	0.003	0.003	0.01
		$T_h$	0.84	0.057	0.73	0.95
	'Gaviota'	a	0.149	0.035	0.079	0.22
		$T_h$	0.612	0.03	0.40	0.72
Nymph of <i>T. urticae</i>	'Sequoiua'	$\beta$	0.014	0.005	0.004	0.023
		$T_h$	1.368	0.068	1.232	1.504
	'Chandler'	$\beta$	0.016	0.004	0.007	0.024
		$T_h$	1.238	0.04	1.151	1.324
	'Camarosa'	$\beta$	0.013	0.004	0.005	0.020
		$T_h$	1.445	0.780	1.290	1.600
	'Marak'	$\beta$	0.015	0.005	0.006	0.024
		$T_h$	1.276	0.059	1.159	1.394
	'Aliso'	$\beta$	0.013	0.005	0.002	0.023
		$T_h$	1.11	0.062	0.989	1.238
	'Yalova'	$\beta$	0.011	0.003	0.004	0.018
		$T_h$	1.45	0.052	1.040	1.394
	'Gaviota'	$\beta$	0.016	0.006	0.004	0.027
		$T_h$	1.149	0.054	1.042	1.255

**Table 6:** Parameters estimated by an equation with an indicator variable for comparison of functional response parameters of *Neoseiulus californicus* on seven strawberry cultivars

Prey	Strawberry cultivarss	Parameter	Estimate	Std Error	Approximate 95% confidence limits	
					Lower	Upper
<i>T. urticae</i> Egg	Gavita& Chandler	$D_a$	0.021	0.046	-0.070	0.111
		$D_{th}$	-0.067	0.085	-0.235	0.102
	Camarosa & Gaviota	$D_a$	0.030	0.048	0.065	0.124
		$D_{th}$	-0.060	0.089	-0.237	0.115
	Camarosa & Chandler	$D_a$	0.017	0.053	-0.089	0.122
		$D_{th}$	0.010	0.125	-0.237	0.257
	Aliso & Chandler	$D_a$	-0.017	0.049	-0.114	0.080
		$D_{th}$	0.046	0.094	-0.140	0.231
	Aliso & Gaviota	$D_a$	-0.004	0.052	-0.010	0.107
		$D_{th}$	-0.021	0.088	-0.195	0.153
	Aliso & Camarosa	$D_a$	-0.033	0.057	-0.14	0.079
		$D_{th}$	0.035	0.124	-0.208	0.279
	Sequoia & Marak	$D_\beta$	0.0082	0.041	-0.072	0.088
		$D_{th}$	-0.229	0.270	-0.768	0.310
	Sequoia & Yalova	$D_\beta$	0.0064	0.047	-0.087	0.10
		$D_{th}$	-0.129	0.208	-0.539	0.281
Marak & Yalova	$D_\beta$	0.0082	0.041	-0.072	0.088	
	$D_{th}$	-0.229	0.273	-0.768	0.310	
<i>T. urticae</i> Nymph	Aliso & Sequia	$D_\beta$	0.001	0.007	-0.013	0.015
		$D_{th}$	0.253	0.096	0.064	0.443
	Aliso & Gaviota	$D_\beta$	0.003	0.008	-0.012	0.019
		$D_{th}$	0.035	0.082	-0.127	0.197
	Aliso & Marak	$D_\beta$	0.002	0.007	-0.011	0.016
		$D_{th}$	0.163	0.087	-0.009	0.335
	Aliso & Yalova	$D_\beta$	-0.001	0.006	-0.013	0.11
		$D_{th}$	0.032	0.081	-0.128	0.192
	Aliso & Camarosa	$D_\beta$	0.0005	0.006	-0.012	0.013
		$D_{th}$	0.332	0.104	0.126	0.540
	Aliso & Chandler	$D_\beta$	0.003	0.007	-0.010	0.016
		$D_{th}$	0.124	0.076	-0.026	0.275
	Sequia & Gaviota	$D_\beta$	0.002	0.007	-0.012	0.017
		$D_{th}$	-0.218	0.088	-0.393	1.510

Sequia & Marak	D <sub>β</sub>	0.001	0.007	-0.012	0.014
	D <sub>th</sub>	-0.09	0.09	-0.269	0.087
Sequia & Yalova	D <sub>β</sub>	-0.0002	0.006	-0.014	0.009
	D <sub>th</sub>	-0.222	0.057	-0.391	-0.053
Sequia & Camarosa	D <sub>β</sub>	-0.0006	0.006	-0.012	0.011
	D <sub>th</sub>	0.079	0.103	-0.125	0.282
Sequia & Chandler	D <sub>β</sub>	0.002	0.006	-0.100	0.014
	D <sub>th</sub>	-0.129	0.078	-0.284	0.025
Gaviota & Marak	D <sub>β</sub>	-0.0009	0.007	-0.016	0.014
	D <sub>th</sub>	0.128	0.080	-0.031	0.287
Gaviota & Yalova	D <sub>β</sub>	-0.004	0.007	-0.018	0.009
	D <sub>th</sub>	-0.004	0.075	-0.151	0.144
Gaviota & Camarosa	D <sub>β</sub>	-0.003	0.007	-0.016	0.011
	D <sub>th</sub>	0.296	0.096	0.106	0.486
Gaviota & Chandler	D <sub>β</sub>	-0.003	0.007	-0.014	0.014
	D <sub>th</sub>	0.089	0.070	-0.049	0.227
Marak & Yalova	D <sub>β</sub>	-0.003	0.006	-0.015	0.008
	D <sub>th</sub>	-0.131	0.079	-0.286	0.024
Marak & Camarosa	D <sub>β</sub>	-0.002	0.006	-0.014	0.009
	D <sub>th</sub>	0.168	0.098	-0.025	0.360
Marak & Chandler	D <sub>β</sub>	0.0005	0.006	-0.012	0.013
	D <sub>th</sub>	-0.039	0.073	-0.182	0.105
Yalova & Camarosa	D <sub>β</sub>	0.002	0.005	-0.008	0.012
	D <sub>th</sub>	0.299	0.093	0.116	0.484
Yalova & Chandler	D <sub>β</sub>	0.004	0.005	-0.007	0.015
	D <sub>th</sub>	0.093	0.068	-0.041	0.226
Camarosa & Chandler	D <sub>β</sub>	0.002	0.006	-0.009	0.014
	D <sub>th</sub>	-0.207	0.086	-0.378	0.370

**3.4 Leaf Trichomes:** The number of trichomes/cm<sup>2</sup> on lower surface of leaves was different among the cultivars ( $F_{6,63}=57.93$ ,  $P=0.0012$ ). The lowest number of trichomes was

observed on 'Chandler' (Table 7). The length of trichomes on lower surface of leaves was not different among the cultivars ( $F_{6,63}=8.90$ ,  $P=0.1798$ ) (Table 7).

**Table 7:** Mean ( $\pm$ SE) number and length of trichomes on lower surface of seven strawberry cultivars

Parameters	'Chandler'	'Camarosa'	'Yalova'	'Aliso'	'Gaviota'	'Sequoia'	'Marak'	F	P
Number of trichomes (mm)	227.1 $\pm$ 2.95 <sup>b</sup>	293.7 $\pm$ 1.87 <sup>a</sup>	292.00 $\pm$ 2.43 <sup>a</sup>	291.9 $\pm$ 8.68 <sup>a</sup>	290.6 $\pm$ 3.01 <sup>a</sup>	289.3 $\pm$ 4.04 <sup>a</sup>	287.4 $\pm$ 4.43 <sup>a</sup>	57.93	0.0012
Length of trichomes (mm)	1.8 $\pm$ 0.06 <sup>a</sup>	1.6 $\pm$ 0.05 <sup>a</sup>	1.5 $\pm$ 0.06 <sup>a</sup>	1.6 $\pm$ 0.040 <sup>a</sup>	1.6 $\pm$ 0.05 <sup>a</sup>	1.7 $\pm$ 0.05 <sup>a</sup>	1.5 $\pm$ 0.06 <sup>a</sup>	8.90	0.1798

\*Means within a row followed by the same letter (s) were not significantly different based on Duncan test ( $\alpha=5\%$ ). Degrees of freedom for ANOVA=26

## 4. Discussion

### 4.1 Preference Index

Female *N. californicus* had a higher predation rate on active stages of spider mite. However, *N. californicus* protonymphs and deutonymphs had a higher predation rate on *T. urticae* eggs compared to *T. urticae* protonymphs. Blackwood *et al.* (2001) reported that adult female *N. californicus* has no prey-stage preference between *T. urticae* eggs and nymphs [4]. Xia & Fadamiro (2010) reported that female predatory mites prefer nymphs to eggs of *Panonychus citri* (McGregor) [50]. Phytoseiid mites often prefer feeding on immature stages and eggs [37]. Some studies showed that adult female phytoseiid mites prefer *T. urticae* that are in egg stage rather than other developmental stages [5, 9, 32, 4]. However, there are other reports indicating that *T. urticae* developmental stages other than egg stage are preferred by phytoseiid mites [48, 46]. Difference between our results and other reports might be due to difference in prey: predator size proportions or leaf structure. In our study, *N. californicus* protonymph and deutonymph preferred *T. urticae* eggs, however, adults preferred the nymphal active stage.

### 4.2 Predation Rate

In this study, the maximum number of prey consumed by *N. californicus* was higher than reported by Canlas *et al.* (2006) and Ahn *et al.* (2009) [6, 1]. The maximum number of *T.*

*urticae* egg and protonymph consumed by the predatory mite in 24 hours, on different cultivars, were 22.3 to 31.9 and 16.0 to 22.7, respectively. These estimates were higher than estimates of Canlas *et al.* (2006) and Ahn *et al.* (2009) [6, 1]. Canlas *et al.* (2006) reported that the maximum number of *T. urticae* eggs and protonymphs consumed by *N. californicus* were 20.91 and 12.57, respectively [6]; while, Ahn *et al.* (2009) reported that the maximum number of *T. urticae* eggs and protonymphs consumed by *N. californicus* were 17.14 and 11.81, respectively [1]. Gotoh *et al.* (2004) reported that the average daily consumption rate of adult female *N. californicus*, during the first 20 days after emergence, at 25 °C, was 13.4 eggs of *T. urticae* [32]. However, Marafel *et al.* (2011) reported that maximum number of *T. urticae* consumed protonymphs was 60 individuals [31]. The difference between the estimates of different studies may be due to laboratory conditions or host plants.

### 4.3 Functional Response

Our study showed that *N. californicus* had type II and, sometimes, type III functional response on *T. urticae* eggs and protonymphs. Similar results have been reported by Gotoh *et al.* (2004) and Castagnoli & Simoni (1999) [32, 7]. Some researchers observed type II functional response for *N. californicus* on male *T. urticae* [28] and *T. urticae* eggs in red form [17]. Xia & Fadamiro (2010) showed that *N. californicus*

had type II functional response on *P. citri* nymphs<sup>[50]</sup>.

In type II functional response, the proportion of consumed prey declines monotonically as the prey density increases. In type III functional response, the proportion of consumed prey is positively density-dependent over some region of the prey density range<sup>[24]</sup>. Predators which exhibit type III functional response are efficient biological control agents<sup>[16, 45]</sup>.

The functional response of phytoseiid mites are type II, e.g. *Phytoseiulus longipes* Evans on different developmental stages of *Tetranychus pacificus* McGregor<sup>[2]</sup>, *Neoseiulus barkeri* Hughes on different developmental stages of *T. urticae*<sup>[15]</sup> and type III, e.g. *P. persimilis* on *T. pacificus* protonymph<sup>[13]</sup>.

The attack rate of *N. californicus* was more on *T. urticae* nymph than *T. urticae* egg. It might be due to size or movement of the prey. Holling (1961) showed that it takes more time for a predator to capture and kill a large prey than a small one<sup>[20]</sup>. Castagnoli and Simoni (1999) showed that the attack rate of *N. californicus* on *T. urticae* eggs ranged between 1.36 to 2.19 day<sup>-1</sup><sup>[7]</sup>, while it ranged between 0.89 to 6.75 day<sup>-1</sup> on *T. urticae* protonymph ('Honehoye' strawberry cultivar). In our study, comparison of functional response parameters of *N. californicus*, observed on seven strawberry cultivars, indicated that the attack rate of treatments were close to each other and there was no significant difference in the attack rate of different time-interval treatments. The time needed for *N. californicus* to capture and kill prey was similar on all seven strawberry cultivars, and the host plants did not influence this activity.

Our results showed that the handling time for *T. urticae* protonymph was more than *T. urticae* egg. Similar result was reported by Ahn *et al.* (2009)<sup>[1]</sup>. Castagnoli and Simoni (1999) showed that the handling time of *N. californicus* on *T. urticae* eggs ranged between 0.02 to 0.07 day<sup>[7]</sup>, while it ranged between 0.015 to 0.27 day on *T. urticae* protonymph ('Honehoye' strawberry cultivar). In our study, the estimated handling time was different among the seven strawberry cultivars. It is suggested that possible differences in chemical properties of the seven strawberry cultivars might have affected the searching capabilities of *N. californicus*.

#### 4.4 Leaf Trichomes

Difference in leaf trichome density of the strawberry cultivars did not affect prey-preference by *N. californicus*. However, the predation rate was different among the cultivars, i.e. it was higher on 'Chandler' than other strawberry cultivars. This difference might be due to lower density of trichomes or chemical and physical structure of leaves. 'Chandler' leaves were smoother than other cultivars. The trichomes protect the prey from predation.

Host plants may affect predation efficiency of phytoseiid mites, e.g. predation rate of *Amblyseius andersoni* Chant on *Panonychus ulmi* Koch was lower on peach leaves than apple leaves<sup>[27]</sup>. *Phytoseiulus persimilis* Athias-Henriot predation rate is more on plant species with smooth leaves<sup>[39]</sup>. The effect of trichomes on predation efficiency has been studied<sup>[34, 26, 21, 12]</sup>. Shipp & Whitfield (1991) found that predation efficiency of *Neoseiulus cucumeris* (Oudemans) on *Frankliniella occidentalis* (Pergande) was higher on sweet pepper than on cucumber leaves which was due to higher trichome density of cucumber leaves<sup>[40]</sup>.

Some researchers studied the effect of host plants on the functional response of phytoseiid mites<sup>[27]</sup>. Leaf hairs and trichomes have a major impact on the searching ability of natural enemies<sup>[47, 42]</sup>. Ahn *et al.* (2009) showed that differences in trichome density of the abaxial leaf surface of

strawberry cultivars affect the functional response of adult female *N. californicus* on immature stages of *T. urticae*<sup>[1]</sup>. The predation rate of *P. persimilis* was lower at high trichome density than low trichome density on gerbera, when prey densities were low<sup>[26]</sup>. Madadi *et al.* (2007) suggested that difference in trichome density among cucumber, sweet paper and eggplant affected the functional response of *N. cucumeris*. Kovveos & Broufas (2000) reported that due to the dense trichomes covering the lower surface of apple leaves compared to peach leaves, *E. finlandicus* movement decreases on apple leaves compared to peach leaves, resulting in prey handling time increase<sup>[27]</sup>. However, Ahn *et al.* (2009) reported that non-glandular trichome of abaxial leaf surface of strawberry cultivars (Mae hyang & Sulhyang varieties) did not affect functional response of adult female *N. californicus*, preying on immature stage of *T. urticae*<sup>[1]</sup>. Some studies showed that low handling time of phytoseiid mites is due to low trichome densities on host plants<sup>[40, 27, 39]</sup>. Shipp & Whitfield (1991) found that lower handling time of *N. cucumeris* on *F. occidentalis* on sweet pepper compared to cucumber, was due to differences in trichome densities<sup>[40]</sup>. Cedola *et al.* (2001) reported that the attack rate and the handling time of *N. californicus* were similar between two tomato cultivars with different densities of glandular hair<sup>[8]</sup>.

#### 5. Reference

1. Ahn JJ, Kim KW, Lee JH. Functional response of *Neoseiulus californicus* (Acari: Phytoseiidae) to *Tetranychus urticae* (Acari: Tetranychidae) on strawberry leaves. Journal of Applied Entomology.2009; 134:98-104.
2. Badii MH, McMurtry GA. Effect of prey density on functional and reproductive response of the predatory mite *Phytoseiulus longipes* (Acari: Phytoseiidae). International Journal of Acarology.1988; 14:61-69.
3. Badii MH, Ortiz EH, Flores AE, Landeros J. Prey stage preference and functional response of *Euseius hibisci* to *Tetranychus urticae* (Acari: Phytoseiidae, tetranychidae). Experimental Applied Acarology. 2004; 34:263-273.
4. Blackwood JS, Schausberger P, Croft BA. Prey- stage preference in generalist and specialist phytoseiid mite (Acari: Phytoseiidae) when offered *Tetranychus urticae* (Acari: Tetranychidae) eggs. Environmental Entomology. 2001; 30:1104-1111.
5. Burnett T. Prey consumption in acarine predator-prey populations reared in the greenhouse. Canadian Journal Zoology. 1971; 49:903-913.
6. Canlas L, Amano H, Ochiai N, Takeda M. Biology and predation of the Japanese strain of *Neoseiulus californicus* (Acari: Phytoseiidae). Systematic and Applied Acarology. 2006; 11:141-157.
7. Castagnoli M, Simoni S. Effect of long-term feeding history on functional and numerical response of *Neoseiulus californicus* (Acari: Phytoseiidae). Experimental Applied Acarology. 1999; 23:217-234.
8. Cedola CV, Sanchez NE, Lijesthrom G. Effect of tomato hairiness on functional and numerical response of *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae). Experimental Applied Acarology. 2001; 25:819-831.
9. Croft BA, McMurtry JA. Comparative studies on four strains of *Typhlodromus occidentalis* Nesbitt (Acari: Phytoseiidae). IV. Life history studies. Acarologia. 1972; 13:460-470.
10. de Moraes GJ, McMurtry JA, DenMarak HA, Campos CB. A revised catalog of the mite family Phytoseiidae.

- Magnolia Press. Auckland. 2004, 494.
11. de Clercq P, Mohaghegh J, Tirry L. Effect of host plant on the functional response of the predator *Podisus nigrispinus* (Heteroptera: Pentatomidae). *Biological Control*. 2000; 18:460-470.
  12. Drukker B, Bruin J, Jacobs G, Kroon A, Sabelis MW. How predatory learn to cope with variability in volatile plant signals in the environmental of their herbivorous prey. *Experimental Applied Acarology*. 2000; 24:881-895.
  13. Eveleigh ES, Chant DA. Experimental studies on acarine predatory prey interactions elect of predator age and leeding history on the prey consumption and functional response (Acarina: Phytoseiidae). *Canadian Journal Zoology*. 1981; 59:1387-1406.
  14. Everson P. The relative activity and functional response of *Phytoseiulus persimilis* (Acarina: Phytoseiidae) and *Tetranychus urticae* (Acarina: Tetranychidae), the effect of temperature. *Canadian Journal Zoology*. 1980; 112: 17-24.
  15. Fan YQ, Petitt FL. Functional response of *Neoseiulus barkeri* on two-spotted spider mite (Acari: Tetranychidae). *Experimental Applied Acarology*. 1994; 18:613-621.
  16. Fernandez– Arhex V, Corly JC. The functional response of parasitoids and its implications for biological control. *Biocontrol Science and Technology*. 2003; 13:403-413.
  17. Friese DD, Gilstrap FE. Influence of prey availability on reproduction and prey consumption of *Phytoseiulus persimilis*, *Amblyseius californicus*, and *Metaseiulus occidentalis* (Acarina: Phytoseiidae). *International Journal of Acarology*. 1982; 8:85-89.
  18. Enkegaard A, Brodsgaard HF, Hansen DL. *Macrolophus caliginosus*: Functional response to whiteflies and preference and switching capacity between whiteflies and spider mites. *Entomologia Experimentalis et Applicata*. 2001; 101:81-88.
  19. Holling CS. Some characteristics of simple types of predation and parasitism. *Canadian Journal Zoology* 1. 1959; 91:385-398.
  20. Holling CS. Principles of insect predation. *Annual Review Entomology*. 1961; 6:163-182.
  21. Gillespie DR, Quiring DJM. Reproduction and longevity of the predatory mite, *Phytoseiulus persimilis* (Acari: Phytoseiidae) and its prey, *Tetranychus urticae* (Acari: Tetranychidae) on different host plants. *Journal of the Entomological Society of British Columbia*. 1994; 91:3-8.
  22. Gotoh T, Mitsuyoshi N, Yamaguchi K. Prey consumption and functional response of three acarophagous species to eggs of the two- spotted spider mite in the laboratory. *Applied Entomology & Zoology*. 2004; 39:100-108.
  23. Jeppson LR, Keifer HH, Baker EW. Mite injurious to economic plants. University of California. Berkley, CA. USA, 1975.
  24. Juliano SA. Nonlinear curve fitting, predation and functional response curves. In: Scheiner, S. M., Gurevitch, J. (Eds.) *Design and Analysis of Ecological Experiments*. Chapman & Hall. New York. 1993, 159-182.
  25. Juliano SA. Nonlinear curve fitting: predation and functional response curves. In: *Design and Analysis of Ecological Experiments*, 2nd edn. Ed. by Cheiner, S. M.; Gurven, J New York: Chapman & Hall. 2001, 159-182.
  26. Krips OE, Willems PEL, Gols R, Posthumus MA, Dicke A. The response of *Phytoseiulus persimilis* to spider mite-induced volatiles from gerbera, influence of starvation and experience. *Journal of Chemical Ecology*. 1999; 25:2623-2641.
  27. Koveos DS, Broufas GD. Functional response of *Euseius finlandicus* and *Amblyseius andersoni* to *Panonychus ulmi* on apple and peach leaves in the laboratory. *Experimental Applied Acarology*. 2000; 24:247-256.
  28. Laing JE, Osborn JAL. The effect of prey density on functional and numerical response of three species of predatory mites. *Entomophaga*. 1974; 19:267-277.
  29. Madadi H, Enkegaard A, Brodsgaard HF, Kharrazi-Pakdel A, Mohaghegh J, Ashouri A. Host plant effects on the functional response of *Neoseiulus cucumeris* to onion thrips larvae. *Journal of Applied Entomology*. 2007; 131:728-733.
  30. Manly BFJ. A model types of selection experiments. *Biometrics*. 1974; 30:281-294.
  31. Marafel PP, Reis PR, Silveira EC, Toledo MA, Souza-Pimentel GC. *Neoseiulus californicus* preying in different life stages *Tetranychus urticae* (Acari: Phytoseiidae, Tetranychidae). *Acarologia*. 2011; 51:499-506.
  32. McMurtry JA, Rodriguez JC. Nutritional ecology of phytoseiid mites. In: Sbusky, E., Rodriguez, J. C. (Eds.) *Spider & Related Invertebrates*. John Wiley & Sons. New York. USA. 1987: 606-644.
  33. Messina FJ, Hanks JB. Host plant alters the shape of functional response of an aphid predator (Coleoptera: Coccinellidae). *Environmental Entomology*. 1998; 27:1196-1202.
  34. Rasmy AH, El- Banhawy EM. Behaviour and bionomics of the predatory mite, *Phytoseius plumifer* (Acarina: Phytoseiidae) as affected by physical surface features of host plants. *Entomophaga*. 1974; 19:255-257.
  35. Reis PR, Sousa EO, Teodoro AV, Pedro Neto M. Effect of prey density on the functional and numerical responses of two species of predaceous mites (Acari: Phytoseiidae). *Neotropical Entomology*. 2003; 23:461-467.
  36. Reis PR, Teodoro AV, Eto MV, Silva EV. Life History of *Amblyseius herbicolus* (Chant) (Acari: Phytoseiidae) on Coffee Plants. *Neotropical Entomology*. 2007; 36:282-287.
  37. Sabelis MW. Reproductive strategies: In: Helle, W. & Sabelis, M.W. (Eds.), *Spider Mites, Their Biology, Natural Enemies and Controls*. Elsevier. Amsterdam. 1985; 1A:265-278.
  38. SAS Inc. version 9.1. SAS Institute Inc. Cary. Nc. 2003.USA.
  39. Skirvin DJ, Fenlon JS. Plant species modifies the functional response of *Phytoseiulus persimilis* (Acari: Phytoseiidae) to *Tetranychus urticae* (Acari: Tetranychidae): implications for biological control. *Bulletin of Entomological Research*. 2001; 91:61-67.
  40. Shipp JL, Whitfield GH. Functional response of the predatory mite, *Amblyseius cucumeris* (Acari: Phytoseiidae), on western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae). *Environmental Entomology*. 1991; 20:694-699.
  41. SPSS Inc. IBM SPSS Statistics for Windows, version 21.0. 2012. Armonk, NY: IBM Crop.
  42. Sutterlin S, van Lenteren JC. Influence of hairness of *Gerbera jamesonii* leaves on the searching efficiency of the parasitoid *Encarsia Formosa*. *Biological Control*. 1997; 9:157-168.
  43. Timms JE, Oliver TH, Straw NA, Leather SR. The effects of host plant on three coccinellid functional response. Is the conifer specialist *Aphidecta obliterate*

- (L.) (Coleoptera: coccinelidae) better adapted to spruce than the generalist *Adalia bipunctata* (L.) (Coleoptera: Coccinelidae)? *Biological Control*. 2008; 47:273-281.
44. Trexler JC, McCulloch CE, Travis J. How can the functional response best be determined? *Oecologia*. 1988; 76:206-214.
  45. Pervez A, Omkar A. Functional responses of coccinellid predators: an illustration of a logistic approach. *Journal of Insect Science*. 2005; 5:1-6.
  46. Popov SY, Kondryakov AV. Reproductive tables of predatory phytoseiid mites (*Phytoseiulus persimilis*, *Galendromus occidentalis* and *Neoseiulus cucumeris*). *Entomological Review*. 2008; 88:658-665.
  47. van Haren R, Steenhuis M, Sabelis MW, de Ponti O. Tomato stem trichomes and dispersal success of *Phytoseiulus persimilis* relative to its prey *Tetranychus urticae*. *Experimental Applied Acarology*. 1987; 3:115-121.
  48. Zaher MA, Shehata KK. Biological studies on the predator mite *Typhlodromus pyri* Sch. (Acarina Phytoseiidae) with the effect of prey and non-prey substances. *Zeitschrift für Angewandte Entomologie*. 1971; 67:389-394.
  49. Weintraub P, Palevsky E. Evaluation of the predatory mite, *Neoseiulus californicus*, for spider mite control on greenhouse sweet pepper under hot arid weld conditions. *Experimental Applied Acarology*. 2008; 45:29-37.
  50. Xiao Y, Fadamiro HY. Functional responses and prey-stage preferences of three species of predacious mites (Acari: Phytoseiidae) on citrus red mite, *Panonychus citri* (Acari: Tetranychidae). *Biological Control*. 2010; 53:345-352.
  51. Xu X, Enkegaard A. Prey preference of the predatory mite *Amblyseius swirskii* between first instar western flower thrips *Frankliniella occidentalis* and nymphs of the two-spotted spider mite *Tetranychus urticae*. *Journal of Insect Science*. 2009; 149:1-11.