

## Intraguild Predation and Cannibalism between Two Phytoseiid Mites, *Neoseiulus californicus* and *Amblyseius andersoni*

H. Rahmani<sup>1,2\*</sup>, and N. Afshari<sup>1</sup>

### ABSTRACT

Intraguild predation and cannibalism (conspecific predation) of two generalist phytoseiid mites were determined in this study. Adult females and protonymphs of *Neoseiulus californicus* (McGregor) and *Amblyseius andersoni* Chant were considered as intraguild and cannibalistic predators, provided with eggs, eggs+larvae and protonymphs as intraguild or conspecific prey. A side from predator species and prey type (IG prey versus conspecific prey), females exhibited lowest predation rates on eggs. Not including prey type, the highest predation rate was recorded in *A. andersoni* and *N. californicus* when provided with eggs+ larvae. Female predators were not interested in the first nymphal stage of prey and there was no significant difference in consumption rates and oviposition when provided with conspecific or intraguild prey. Feeding on intraguild larval prey did not only increase mortality of *A. andersoni* immatures, but also decreased their consumption rates. For *N. californicus* immatures, predation on IG larval prey was higher than on conspecific larvae. Therefore, it seems that the predator species are able to survive on both con- and heterospecific prey.

**Keywords:** Acari, Cannibalistic predators, Conspecific prey, Interspecific predation.

### INTRODUCTION

The two-spotted spider mite, *Tetranychus urticae* is known as one of the economically most important pests in greenhouse production and field crops (Zhang, 2003). It has the highest pesticide resistance among arthropods (Van Leeuwen *et al.*, 2010). Repetitive applications of chemicals to control insect and mite pests lead to environmental pollution and serious health problems for consumers (Çalmaşur *et al.*, 2006). Therefore, biological agents and IPM Management (Integrated Pest Management) are taken into account to help or even to substitute the synthetic insecticides and acaricides.

Competition, cannibalism, and IntraGuild Predation (IGP) may influence the success of natural enemies including phytoseiid species in management methods, since they may co-occur in the environment or may be released simultaneously in greenhouse crops (Schausberger and Walzer, 2001). Knowledge on the strength and direction of competition and intraguild predation and their consequences at the population level is important to evaluate the success of pest control (Walzer and Schausberger, 1999a; Schausberger and Walzer, 2001; Walzer *et al.*, 2001). Some studies have indicated positive effects of combined release of phytoseiid mites in suppression of pests (Mori *et al.*, 1990; Schausberger and Croft, 2000 a,b;

<sup>1</sup> Department of Plant Protection, Faculty of Agriculture, University of Zanjan, Zanjan, Islamic Republic of Iran.

<sup>2</sup> Invertebrate and Weed Sciences, Agriculture Victoria Research, Agribio Center, La Trobe University Campus, Bandoora, Victoria, Australia.

\*Corresponding author: e-mail: hasan.rahmani@agriculture.vic.gov.au



Schausberger and Walzer, 2001; Walzer *et al.*, 2001; Onzo *et al.*, 2003; Hatherly *et al.*, 2005; Cakmak *et al.*, 2006, 2009; Walzer *et al.*, 2009), while others have shown that intraguild predation (IGP) may reduce the control of the target pests (Polis *et al.* 1989, Rosenheim *et al.* 1995; Holt and Polis, 1997; Arim and Marquet, 2004; Walzer *et al.* 2001; Hatherly *et al.* 2005; Negloh *et al.* 2012).

*Neoseiulus californicus* (McGregor) and *Amblyseius andersoni* Chant are predators of phytoseiid family, which are used commercially as biocontrol agents. *Neoseiulus californicus*, which is classified in type II group of Phytoseiidae (McMurtry *et al.*, 2013), can feed on spider mites, tarsonemid mites, small arthropods, pollen (Castagnoli *et al.*, 1999, Khanamani *et al.*, 2017), fungi (McMurtry *et al.*, 2013) and *Thrips tabaci* (Rahmani *et al.*, 2009). It is distributed around the world and considered as a cosmopolitan species (Gotoh *et al.*, 2004; Canlas *et al.*, 2006; McMurtry *et al.*, 2013; Barbosa and de Moraes, 2015). Efficient functional and numerical response to spider mites (Song *et al.*, 2016) is the other trait of this predator.

*Amblyseius andersoni* is a generalist predator; belongs to subtype III-b phytoseiid mites, that have the ability to feed on fungi. In addition, it is abundant as a predator of spider mites on grape varieties (McMurtry *et al.*, 2013). The red spider mite, *Panonychus ulmi* (Koch) was controlled effectively by this species (Koveos and Broufas, 2000). It is cosmopolitan but widespread in Europe (Tixier *et al.*, 2016).

At high prey densities, there is no problem about simultaneous use of predators, but predation may take place between different predatory mite species among various life stages within a guild (IGP) and/or within each species (cannibalism) in the absence of the main food. Consequence of these interactions is vital for having sustainable control (Walzer *et al.*, 2001).

There are many studies about interactions of *N. californicus* with other phytoseiids (Walzer and Schausberger, 1999a,b; Schausberger and Croft, 2000a; Schausberger and Walzer, 2001; Walzer *et al.*, 2004; Cakmak *et al.*, 2006,

2009; Rhodes *et al.*, 2006; Mendel and Schausberger, 2011; Farazmand *et al.*, 2015; Kazak *et al.*, 2015; Rahmani *et al.*, 2015). Some studies also assessed the interaction between *A. andersoni* and the other members of this family (Duso, 1989; Zhang and Croft, 1995; Schausberger, and Croft; 2000a,b; Ahmad *et al.*, 2015).

Both *A. andersoni* and *N. californicus* are efficient biocotrol agents for spider mite species (Escudero and Ferragut, 2005; Jolly, 2000; Gotoh *et al.*, 2006; Amano and Chant, 1977; Duso, 1992) when used separately, but no study has been conducted on interaction between them at the simultaneous use. These two predators may co-exist in an environment, or may be deployed at the same time for better pest management at greenhouses. Therefore, the objective of this study was to compare predation of adult females and protonymphs of the two predator species when offered conspecific or IntraGuild (IG) prey. The hypothesis tested was predators consume more heterospecific than conspecific prey in a closed cage with no choice situation.

## MATERIALS AND METHODS

### Origin of Predatory Mites, Rearing, and General Methods

*Neoseiulus californicus* was obtained from a commercial producer (Koppert). *Amblyseius andersoni* was taken from the laboratory population in the University of Natural Resources and Life Sciences, Vienna, Austria. The colonies of each species were separately held on artificial arenas (half-filled plastic boxes containing water-saturated foam cubes with plastic tiles) and fed with mixed stages of *T. urticae*, by adding infested common bean leaves (*Phaseolus vulgaris* L.) on the arenas (Walzer and Schausberger 1999a, b).

Eggs, larvae, and protonymphs of the two predatory mite species were used as con- and heterospecific prey. For this purpose, even-aged cohorts were obtained by transferring gravid females from the rearing

units to 6 cm Petri-dishes containing detached bean leaves and fed with spider mites. After 24 h, newly laid eggs were collected and used for experiments or transferred to the separate arenas for having other required stages.

Closed cages were used as experimental units. Each cage consisted of rectangular pieces of an acrylic glass (6×3×0.6 cm) with circular cavities ( $\varnothing=2.0$  cm) closed at the bottom by gauze and covered with a microscope slide at the upper side. The microscope slide was fixed with a rubber band (Schausberger, 1997). Rearing and experimental units were maintained in a climate chamber at  $25\pm 2^\circ\text{C}$ ,  $70\pm 5\%$  RH and 16:8 L:D hours photoperiod.

### Experimental Procedures

Gravid females of both species were chosen randomly from rearing arenas and, after 24 hours starvation, used as IG predators. Each single female was placed into the experimental cage (one female predator, (*A. andersoni* or *N. californicus*) in each experimental cage) and provided with: (a) 6 eggs of < 24 hours age, (b) 4 eggs of 24 to 48 hours age+4 newly hatched larvae, and (c) 4 protonymphs of con- and/or heterospecifics at separate treatments (in each treatment just one type of mentioned prey was offered to a female predator). Every 24 hours, experimental units were observed and some parameters such as predation rates, survival and oviposition were recorded for 10 consecutive days. The eggs laid by the female predator were removed and predator was transferred to the new experimental cage with fresh food on daily basis. Replication was 16-20 times for each experiment and species.

In most phytoseiid mites, larvae reach the protonymphal stage without consumption, and protonymph is usually the first developmental stage starting to prey and act as IG predator (Walzer *et al.*, 2015) or cannibal. Larvae are facultative feeders in *N. californicus* (Schausberger and Croft, 1999) and *A. andersoni* (Zhang and Croft, 1995; Amano and Chant, 1977), hence, the first nymphal

stage of < 24 hours of each species was placed singly in the experimental cages as IG predator or cannibal. Six conspecific and/or six heterospecific larvae were regarded as prey (each prey offered to one protonymph in the experimental cage of each treatment). Dorsal shield of the predators (protonymphs) were marked with a tiny watercolor point in order to make them distinguishable from larva prey, which may enter the next stage. Predation, survival, and development of the predators were checked twice daily in intervals of 10 and 14 hours until the predator reached adulthood or died. Prey larvae were replenished daily. Each treatment (con- or heterospecific prey) was replicated 20 times for each experiment and species.

### Statistical Analysis

All data were analyzed using SPSS ver. 18.0.1. The number of preys consumed and number of laid eggs by adult females provided with either con- or heterospecific prey during 10 days were compared by one-way ANOVA for each predator, separately. Differences between treatments were compared using Tukey's multiple range tests. *t* tests were used to compare the predation rate and oviposition of female predators between conspecific and IG prey. The same method was used to analyze effects of con- or heterospecific larvae on developmental time of immatures and the juvenile predation rates. Mortality of immatures and adult females was analyzed for each species separately using Pearson Chi-square tests.

## RESULTS

### Adult Females Feeding on Con- and Heterospecific Eggs

Predation on eggs regardless of prey was very low for both predators (Tables 1 and 3). *Amblyseius andersoni* females consumed no conspecific eggs during 10 days, whereas

**Table 1.** Predation and oviposition (Mean±SE) of adult *A. andersoni* and *N. californicus* females caged singly and provided with conspecific or heterospecific prey for 10 consecutive days. <sup>a</sup>

Prey species	Stage	Predation		Oviposition	
		<i>A. andersoni</i>	<i>N. californicus</i>	<i>A. andersoni</i>	<i>N. californicus</i>
<i>A. andersoni</i>	Egg	0 <sup>a</sup> ±0	0.05 <sup>b</sup> ±0.050	0.3 <sup>b</sup> ±0.128	0.5 <sup>a</sup> ±0.170
<i>N. californicus</i>	Egg	0.15 <sup>a</sup> ±0.0820	0.45 <sup>a</sup> ±0.153	0.7 <sup>a</sup> ±0.147	0.4 <sup>a</sup> ±0.134
<i>A. andersoni</i>	Egg+Larva	3.53 <sup>b</sup> ±0.448	5.75 <sup>a</sup> ±0.479	1.16 <sup>a</sup> ±0.245	1.44 <sup>a</sup> ±0.223
<i>N. californicus</i>	Egg+Larva	7.80 <sup>a</sup> ±0.890	6.80 <sup>a</sup> ±0.565	1.4 <sup>a</sup> ±0.254	0.10 <sup>b</sup> ±0.069
<i>A. andersoni</i>	Protonymph	5.20 <sup>a</sup> ±0.592	6.45 <sup>a</sup> ±0.673	0.05 <sup>a</sup> ±0.050	0.23 <sup>a</sup> ±0.113
<i>N. californicus</i>	Protonymph	5 <sup>a</sup> ±0.465	4.48 <sup>b</sup> ±0.506	0.1 <sup>a</sup> ±0.069	0.22 <sup>a</sup> ±0.108

<sup>a</sup> Means followed by different letters are significantly different for each predator, between two types of prey, in each stage ( $P < 0.05$ ,  $t$  test).

*N. californicus* females consumed more conspecific eggs than heterospecific ( $t$  tests for independent samples:  $N. californicus$ :  $T = -2.4$ ,  $df = 38$ ,  $P = 0.01$ ). Cannibalism was also significantly higher for *N. californicus* than *A. andersoni* (Table 1).

Oviposition was negligible for both predators and could be due to primary feeding (Tables 1 and 3). *Ambelyseius andersoni* females laid more eggs when fed on heterospecific eggs during 10 days ( $t$  tests for

independent samples:  $T = -2.05$ ,  $df = 38$ ,  $P = 0.04$ ) (Table 1). There was no significant difference in oviposition of *N. californicus* females fed on con- or heterospecific eggs ( $t$  tests for independent samples:  $T = 0.69$ ,  $df = 38$ ,  $P = 0.5$ ) (Table 1).

*A. andersoni* had higher survival on IG prey. Only 10 percent of *A. andersoni* females could not survive the experimental period when supplied with heterospecific eggs as prey ( $P < 0.05$ ) (Table 2). Percentage of

**Table 2.** Mortality of adult *A. andersoni* and *N. californicus* females caged singly and provided with conspecific or heterospecific prey for 10 consecutive days. <sup>a</sup>

Prey species	Stage	Mortality (percent)	
		<i>A. andersoni</i>	<i>N. californicus</i>
<i>A. andersoni</i>	Egg	25 <sup>a</sup>	20 <sup>a</sup>
<i>N. californicus</i>	Egg	10 <sup>b</sup>	15 <sup>a</sup>
<i>A. andersoni</i>	Egg+Larva	27 <sup>a</sup>	7 <sup>a</sup>
<i>N. californicus</i>	Egg+Larva	14 <sup>b</sup>	15 <sup>a</sup>
<i>A. andersoni</i>	Protonymph	25 <sup>a</sup>	31 <sup>a</sup>
<i>N. californicus</i>	Protonymph	30 <sup>a</sup>	32 <sup>a</sup>

<sup>a</sup> Means in columns (two prey for one predator in each stage) followed by the different letters are significantly different (Chi square test).

**Table 3.** Predation and oviposition (Mean±SE) of adult *A. andersoni* and *N. californicus* females caged singly and provided with conspecific or heterospecific prey for 10 consecutive days. <sup>a</sup>

Prey species	Stage	Predation		Oviposition	
		<i>A. andersoni</i>	<i>N. californicus</i>	<i>A. andersoni</i>	<i>N. californicus</i>
<i>A. andersoni</i>	Egg	0 <sup>c</sup> ±0	0.05 <sup>c</sup> ±0.050	0.3 <sup>c</sup> ±0.127	0.55 <sup>b</sup> ±0.169
<i>N. californicus</i>	Egg	0.15 <sup>c</sup> ±0.081	0.45 <sup>c</sup> ±0.153	0.7 <sup>bc</sup> ±0.146	0.4 <sup>b</sup> ±0.134
<i>A. andersoni</i>	Egg+Larva	3.53 <sup>b</sup> ±0.448	5.75 <sup>ab</sup> ±0.479	1.16 <sup>ab</sup> ±0.244	1.44 <sup>a</sup> ±0.223
<i>N. californicus</i>	Egg+Larva	7.80 <sup>a</sup> ±0.890	6.80 <sup>a</sup> ±0.565	1.4 <sup>a</sup> ±0.254	0.1 <sup>b</sup> ±0.069
<i>A. andersoni</i>	Protonymph	5.20 <sup>b</sup> ±0.592	6.45 <sup>a</sup> ±0.673	0.05 <sup>c</sup> ±0.050	0.23 <sup>b</sup> ±0.112
<i>N. californicus</i>	Protonymph	5 <sup>b</sup> ±0.464	4.48 <sup>b</sup> ±0.506	0.1 <sup>c</sup> ±0.068	0.22 <sup>b</sup> ±0.108

<sup>a</sup> Means in columns followed by different letters are significantly different at  $P < 0.05$  (ANOVA, Tukey).

mortality was similar for *N. californicus* females in both treatments (Table 2).

### Adult Females Feeding on Con- and Heterospecific Eggs+ Larvae

Mean predation rate of the two predators increased by adding larval stage of the prey (Tables 1 and 3). Consumption of IG eggs+larvae was greater in *A. andersoni* than cannibalism (*t* tests for independent samples:  $T = -4.5$ ,  $df = 32$ ,  $P = 0.000$ ) (Table 1), but oviposition rate was similar between the two types of prey (*t* tests for independent samples:  $T = -0.67$ ,  $df = 32$ ,  $P = 0.5$ ) (Table 1). Predation rate of con- and heterospecific eggs+larvae was similar for adult females of *N. californicus* (*t* tests for independent samples:  $T = -1.37$ ,  $df = 34$ ,  $P = 0.17$ ) (Table 1). These females laid more eggs while feeding on IG prey (*t* tests for independent samples:  $T = 6.27$ ,  $df = 34$ ,  $P = 0.000$ ) (Table 1).

Comparison of all treatments showed that adult *A. andersoni* and *N. californicus* consumed IG eggs+larvae and conspecific eggs+larvae, respectively, more than other foods during 10 days (Table 3).

Mortality percentage was higher in *A. andersoni* when fed on conspecific prey, but was similar to *N. californicus* females for the two types of prey (conspecific and IG prey) (Table 2).

### Adult Females Feeding on Con- and Heterospecific Protonymphs

*Amblyseius andersoni* consumed the same

amount of both protonymphs species (conspecific and IG prey) (*t* tests for independent samples:  $T = 0.26$ ,  $df = 38$ ,  $P = 0.7$ ) (Table 1). For *N. californicus*, mean predation of heterospecific protonymphs was higher than conspecific one (*t* tests for independent samples:  $T = 2.3$ ,  $df = 43$ ,  $P = 0.02$ ) (Table 1).

Oviposition rate of both female predators was not significantly different between conspecific and IG protonymphs (*t* tests for independent samples: *A. andersoni*:  $T = -0.58$ ,  $df = 38$ ,  $P = 0.56$ ; *N. californicus*:  $T = -0.63$ ,  $df = 43$ ,  $P = 0.9$ ) (Table 1).

Feeding protonymphal stage of the intraguild preys had negative effect on survival, as the number of both predators not completing the experimental period was higher compared to other types of prey. Almost 30 percent of female predators died when fed on either con- or heterospecific protonymphs (Table 2).

### Immatures Feeding on Con- and Heterospecific Larvae

Feeding on heterospecific larvae not only increased the mortality percentage of *A. andersoni* immatures, but also decreased the consumption rates (Table 4). Almost 50 percent of immatures died before reaching adulthood, which was significantly higher than other prey species (Table 4). Protonymph (*t* tests for independent samples:  $T = 0.46$ ,  $df = 38$ ,  $P = 0.6$ ), deutonymph (*t* tests for independent samples:  $T = -0.25$ ,  $df = 25$ ,  $P = 0.7$ ) and total developmental time of *A. andersoni* (*t* tests

**Table 4.** Predation and mortality of immature *A. andersoni* and *N. californicus* caged singly and provided with conspecific or heterospecific larvae over 10 days.<sup>a</sup>

Predator species	Prey	Parameters	
		Predation <sup>b</sup>	Mortality (Percent) <sup>c</sup>
<i>A. andersoni</i>	<i>A. andersoni</i>	0.6 <sup>a</sup> ±0.17	20 <sup>b</sup>
	<i>N. californicus</i>	0.25 <sup>a</sup> ±0.09	55 <sup>a</sup>
<i>N. californicus</i>	<i>A. andersoni</i>	1.3 <sup>a</sup> ±1.3	35 <sup>a</sup>
	<i>N. californicus</i>	0.8 <sup>a</sup> ±0.7	20 <sup>b</sup>

<sup>a</sup> Means followed by different letters are significantly different for each predator, between two types of prey.

<sup>b</sup> (Predation:  $P < 0.05$ , *t* test), <sup>c</sup> (Mortality: Chi-square test).



for independent samples:  $T= 1.3$ ,  $df= 38$ ,  $P= 0.1$ ) were not affected by prey type (conspecific larvae vs. heterospecific larvae) (Table 5).

Immatures of *N. californicus* consumed 1.30 heterospecific larvae during the experiment that was higher than predation on conspecific prey (0.8 larvae) (Table 4). Consumption of conspecific or IG larvae influenced protonymphal period ( $t$  tests for independent samples:  $T= 4.72$ ,  $df= 38$ ,  $P= 0.000$ ) and total developmental time ( $t$  tests for independent samples:  $T= 2.92$ ,  $df= 38$ ,  $P= 0.006$ ), but not deutonymphal period ( $t$  tests for independent samples:  $T= 0.81$ ,  $df= 28$ ,  $P= 0.4$ ) of *N. californicus*. Accordingly, total developmental times were two days shorter when feeding on IG prey vs. conspecific prey (Table 5).

## DISCUSSION

Walzer and Schausberger (1999a) demonstrated that adult females and immatures of *N. californicus* had higher IGP rates than cannibalism. *Neoseiulus californicus* also discriminate between con- and heterospecific prey and consume heterospecific larvae when it has a choice (Walzer and Schausberger, 1999b), whereas in this study, females fed more heterospecific protonymphs and conspecific egg+larva. Mean predation rate of *A. andersoni* was higher on egg+larva of *N. californicus* among different types of prey. Preferential predation on larva rather than

egg and nymph has been demonstrated in different species of Phytoseiidae (e.g. Croft and McMurtry, 1972; Schausberger, 1997; Walzer and Schausberger, 1999a, Ghasemloo *et al.*, 2016; Maleknia *et al.*, 2016). Protonymphs feature including bigger body size, more sclerotized tegument and better ability to escape or defense would force IG predators to ignore the probable more nutritional benefit of the first nymphal stage and select larval stage as prey (Schausberger, 1999; Schausberger and Croft 2000a; Meszaros *et al.*, 2007; Walzer and Schausberger, 2011; Moghadasi and Allahyari, 2017). It is in accordance with lower predation on both conspecific and IG protonymphal prey in *A. andersoni*, although for *N. californicus*, consumption of IG protonymphal prey was high. van der Hoeven and van Rijn (1990) demonstrated that capture success ratio of *Neoseiulus barkeri* Hughes was decreased by increasing size of the larval prey (*Frankliniella occidentalis* Pergande). This relation between ability of predation and prey size may be true for protonymphs and the reason of less predation on them in *A. andersoni* in this study.

Adult females of *Typhlodromus pyri* and *Kampimodromus aberrans* are able to distinguish con- and heterospecific larvae and protonymphs and they prefer to feed on heterospecifics when given the choice (Schausberger, 1997). *Iphiseius degenerans* is another example for having this ability (Montserrat *et al.*, 2006). *Amblyseius andersoni* is also among the same type of

**Table 5.** Developmental times (days) (Mean±SE) of *A. andersoni* and *N. californicus* caged singly and provided with conspecific or heterospecific larvae. <sup>a</sup>

Prey species	Stage	Predators	
		<i>A. andersoni</i>	<i>N. californicus</i>
<i>A. andersoni</i>	Protonymph	3.6 <sup>a</sup> ±0.24	2.9 <sup>b</sup> ±0.15
<i>N. californicus</i>	Protonymph	3.4 <sup>a</sup> ±0.02	4 <sup>a</sup> ±0.16
<i>A. andersoni</i>	Deutonymph	3.75 <sup>a</sup> ±0.29	4 <sup>a</sup> ±0.26
<i>N. californicus</i>	Deutonymph	3.86 <sup>a</sup> ±0.3	4.41 <sup>a</sup> ±0.39
<i>A. andersoni</i>	Total <sup>b</sup>	6.57 <sup>a</sup> ±0.5	5.52 <sup>b</sup> ±0.51
<i>N. californicus</i>	Total <sup>b</sup>	5.55 <sup>a</sup> ±0.6	7.75 <sup>a</sup> ±0.56

<sup>a</sup> Means followed by different letters are significantly different for each stage, between two types of prey ( $P < 0.05$ ,  $t$  test). <sup>b</sup> (Protonymph+Deutonymph).

phytoseiid mite group (MCMurtry *et al.*, 2013) and the same behavior is expected. In no choice situation, adult females of *A. andersoni* had more predation on other species egg and egg+larva, but predation on protonymphs was higher on conspecific (predation was slightly greater on conspecific prey and there was no significant difference between consumption of con- or heterospecific protonymphs for this predator).

Both females of phytoseiid species had the lowest amount of predation on IG eggs. This observation agrees with Farazmand *et al.* (2015) who determined the predation rate of *N. californicus* and *T. bagdasarjani* on IG prey eggs, larvae, and protonymphs on cucumber leaf discs. The same result was reported for *A. swirskii* and *N. cucumeris* (Buitenhuis *et al.*, 2010), however, *P. persimilis* and *T. bagdasarjani* preferred egg stage and consumed more heterospecific eggs when placed singly on cucumber leaf discs in both absence and presence of extraguild prey, *T. urticae* (Moghadasi and Allahyari, 2017).

Oviposition rate of the two predatory mite species was higher when feeding on egg+larva (both con- and heterospecific). It seems that piercing eggs and overwhelming protonymphs is difficult for adult females and predation on them was only for survival and not producing offspring. (Schausberger and Croft, 2000b; Meszaros *et al.*, 2007). Momen and Abdel-Khalek (2009) indicated that cannibalizing *Amblyseius swirskii* females did not lay eggs, whereas in our study both female predators sustained oviposition on conspecific prey.

Developmental duration of immature could be affected by consumption. Total developmental period of immature *N. californicus* when fed on *T. urticae* was reported almost 3 (Uddin *et al.*, 2016) and 6 days (Escudero and Ferragut, 2005) at 25°C, but cannibalism and intraguild predation increased developmental period and adults emerged after 10 and 7 days, respectively. Moreover, in the presence of preferred prey, 93% of *N. californicus* could survive to adulthood (Uddin *et al.*, 2016; Escudero and Ferragut, 2005), whereas in the present study,

80 and 65% of *N. californicus* immatures could reach adulthood by feeding conspecific prey and IG prey, respectively. Amano and Chant (1977) stated that adult *A. andersoni* reached adulthood after 7 days. It was longer in our study (9 and 8 days) for nymphs that consumed con- and heterospecific prey. Overall, short pre-adult period, higher predation, and mortality were the consequences of IGP for *N. californicus*. It is similar to what we have found for *A. andersoni*, although mean predation rates of immatures were higher on conspecific prey.

Some phytoseiid mites could lay eggs and survive when fed with heterospecific prey. For example, Farazmand *et al.* (2015), Ghasemloo *et al.* (2016), and Moghadasi and Allahyari (2017) reported oviposition by *T. bagdasarjani* on intraguild prey stages. Also, adult females of *K. aberrans*, *T. pyri*, *A. andersoni*, and *Phytoseius finitimus* were able to survive and oviposit when fed with heterospecific larvae (Ahmad *et al.*, 2015). It seems that generalist phytoseiids are stronger predators than specialists on intraguild predation and can outcompete them (Schausberger, 1997; Walzer and Schausberger, 1999a; Hatherly *et al.* 2005; Meszaros *et al.* 2007; Momen and Abdel-Khalek, 2009; Moghadasi and Allahyari, 2017).

In this study, two phytoseiid species could survive and feed on conspecific prey as well as on IG prey. Since they were given no choice, this may affect their ability to distinguish between preys and avoid cannibalism. Moreover, predators might have different behavior in the small experimental units compared to situations in greenhouses or the field. As a result, additional choice experiments are needed in natural condition and at the population level.

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## REFERENCES

1. Ahmad, S., Pozzebón, A. and Duso, C. 2015. Predation on Heterospecific Larvae by Adult Females of *Kampimodromus aberrans*, *Amblyseius andersoni*, *Typhlodromus pyri* and *Phytoseius finitimus* (Acari: Phytoseiidae). *Exp. Appl. Acarol.*, **67**: 1-20.
2. Amano, H. and Chant, D. A. 1977. Life History and Reproduction of Two Species of Predacious Mites, *Phytoseiulus persimilis* Athias-Henriot and *Amblyseius andersoni* Chant (Acarina: Phytoseiidae). *Can. J. Zool.*, **55**: 1978-1983.
3. Arim, M. and Marquet, P. A. 2004. Intraguild Predation: A Widespread Interaction Related to Species Biology, *Ecol. Lett.*, **7**: 557-564.
4. Barbosa, M. F. C. and de Moraes, G. J. 2015. Evaluation of Astigmatid Mites as Factitious Food for Rearing Four Predaceous Phytoseiid Mites (Acari: Astigmata; Phytoseiidae). *Biol. Control.*, **91**: 22-26.
5. Buitenhuis, R., Shipp, L. and Scott-Dupree, C. 2010. Intra-Guild vs. Extra-Guild Prey: Effect on Predator Fitness and Preference of *Amblyseius swirskii* (Athias-Henriot) and *Neoseiulus cucumeris* (Oudemans) (Acari: Phytoseiidae). *Bull. Entomol. Res.*, **100**: 167-173.
6. Çakmak, I., Janssen, A. and Sabelis, M. W. 2006. Intraguild Interactions between the Predatory Mites *Neoseiulus californicus* and *Phytoseiulus persimilis*. *Exp. Appl. Acarol.*, **38**: 33-46.
7. Çakmak, I., Janssen, A., Sabelis, M. W. and Baspinar, H. 2009. Biological Control of an Acarine Pest by Single and Multiple Natural Enemies. *Biol. Control.*, **50**: 60-65.
8. Çalmaşur, Ö., Aslan, İ. and Şahin, F. 2006. Insecticidal and Acaricidal Effect of Three Lamiaceae Plant Essential Oils against *Tetranychus urticae* Koch and *Bemisia tabaci* Genn. *Ind. Crop. Prod.*, **23**: 140-146.
9. Canlas, L. J., Amano, H., Ochiai, N. and Takeda, M. 2006. Biology and Predation of the Japanese Strain of *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae). *Syst. Appl. Acarol.*, **11**: 141-157.
10. Castagnoli, M., Simoni, S. and Biliotti, N. 1999. Mass-Rearing of *Amblyseius californicus* (McGregor) (Acari: Phytoseiidae) on Two Alternative Food Sources. In: "Ecology and Evolution of the Acari", (Eds): Bruin, J., van der Geet, L. P. S. and Sabelis, M. W. Kluwer Academic Publishers, Dordrecht, PP. 425-431.
11. Croft, B. A. and McMurtry J. 1972. Comparative Studies of four Strains of *Typhlodromus occidentalis* Nesbitt (Acarina. Phytoseiidae) VI. Life History Studies. *Acarologia*, **13**: 460-470.
12. Duso C. 1989. Role of the Predatory Mites *Amblyseius aberrans* (Oud.), *Typhlodromus pyri* Scheuten and *Amblyseius andersoni* (Chant) (Acari, Phytoseiidae) in Vineyards. I. The Effects of Single or Mixed Phytoseiid Population Releases on Spider Mite Densities (Acari, Tetranychidae). *J. Appl. Entomol.*, **107**: 474-492.
13. Duso, C. 1992. Role of *Amblyseius aberrans* (Oud.), *Typhlodromus pyri* Scheuten and *Amblyseius andersoni* (Chant) (Acari, Phytoseiidae) in Vineyards: III. Influence of Variety Characteristics on the Success of *A. aberrans* and *T. pyri* Releases. *J. Appl. Entomol.*, **114**: 455-462.
14. Escudero, L. A. and Ferragut, F. 2005. Life-History of Predatory Mites *Neoseiulus californicus* and *Phytoseiulus persimilis* (Acari: Phytoseiidae) on Four Spider Mite Species as Prey, with Special Reference to *Tetranychus evansi* (Acari: Tetranychidae). *Biol. Control.*, **32**: 378-384.
15. Farazmand, A., Fathipour, Y. and Kamali, K. 2015. Intraguild Predation among *Scolothrips longicornis* (Thysanoptera: Thripidae), *Neoseiulus californicus* and *Typhlodromus bagdasarjani* (Acari: Phytoseiidae) under Laboratory Conditions. *Insect. Sci.*, **22**: 263-272.
16. Ghasemloo, Z., Pakyari, H. and Arbab, A. 2016. Cannibalism and Intraguild Predation in the Phytoseiid Mites *Phytoseiulus persimilis* and *Typhlodromus bagdasarjani* (Acari: Phytoseiidae). *Internat. J. Acarol.*, **42**: 149-152.
17. Gotoh, T., Yamaguchi, K. and Mori, K. 2004. Effect of Temperature on Life History of the Predatory Mite *Amblyseius (Neoseiulus) californicus* (Acari: Phytoseiidae). *Exp. Appl. Acarol.*, **32**: 15-30.
18. Gotoh, T., Tsuchiya, A. and Kitashima, Y. 2006. Influence of Prey on Developmental Performance, Reproduction and Prey Consumption of *Neoseiulus californicus*



- (Acari: Phytoseiidae). *Exp. Appl. Acarol.*, **40**: 189-204.
19. Hatherly, I. S., Bale, J. S. and Walters, K. F. A. 2005. Intraguild Predation and Feeding Preferences in Three Species of Phytoseiid Mite Used for Biological Control. *Exp. Appl. Acarol.*, **37**: 43-55.
  20. Holt, R. D. and Polis, G. A. 1997. A Theoretical Framework for Intraguild Predation. *Am. Nat.*, **149**: 745-764.
  21. Jolly, R. L. 2000. The Predatory Mite *Neoseiulus californicus*: It's Potential as a Biocontrol Agent for the Fruit Tree Red Spider Mite *Panonychus ulmi* in the UK. In: "The BCPC Conference: Pests and Diseases", 13-16 November, Brighton, UK, PP. 487-490.
  22. Kazak, C., Karut, K. and Doker, I. 2015. Indigenous Populations of *Neoseiulus californicus* and *Phytoseiulus persimilis* (Acari: Phytoseiidae): Single and Combined Releases against *Tetranychus urticae* (Acari: Tetranychidae) on Greenhouse Eggplant. *Internat. J. Acarol.*, **41**: 108-114.
  23. Khanamani, M., Fathipour, Y., Talebi, A. and Mehrabadi, M. 2017. How Pollen Supplementary Diet Affect Life Table and Predation Capacity of *Neoseiulus californicus* on Two-Spotted Spider Mite. *Syst. Appl. Acarol.*, **22**: 135-147.
  24. Koveos, D. S. and Broufas, G. D. 2000. Functional Response of *Euseius finlandicus* and *Amblyseius andersoni* to *Panonychus ulmi* on Apple and Peach Leaves in the Laboratory. *Exp. Appl. Acarol.*, **24**: 247-256.
  25. Maleknia, B., Fathipour, Y. and Soufbaf, M. 2016. Intraguild Predation among Three Phytoseiid Species, *Neoseiulus barkeri*, *Phytoseiulus persimilis* and *Amblyseius swirskii*. *Syst. Appl. Acarol.*, **21**: 417-426.
  26. McMurtry, J. A., Moraes, G. J. D. and Sourassou, N. F. 2013. Revision of the Lifestyles of Phytoseiid Mites (Acari: Phytoseiidae) and Implications for Biological Control Strategies. *Syst. Appl. Acarol.*, **18**: 297-320.
  27. Mendel, D. and Schausberger, P. 2011. Diet-Dependent Intraguild Predation between the Predatory Mites *Neoseiulus californicus* and *Neoseiulus cucumeris*. *J. Appl. Entomol.*, **135**: 311-319.
  28. Meszaros, A., Tixier, M. S., Cheval, B., Barbar, Z. and Kreiter, S. 2007. Cannibalism and Intraguild Predation in *Typhlodromus exhilaratus* and *T. phialatus* (Acari: Phytoseiidae) under Laboratory Conditions. *Exp. Appl. Acarol.*, **33**: 37-43.
  29. Moghadasi, M. and Allahyari, H. 2017. Effect of Prey and Pollen on Interactions between *Typhlodromus bagdasarjani* and *Phytoseiulus persimilis* (Acari: Phytoseiidae) on Cucumber (Cucurbitaceae). *Can. Ent.*, **149**: 581-591.
  30. Momen, F. M. and Abdel-Khalek, A. 2009. Cannibalism and Intraguild Predation in the Phytoseiid Mites *Typhlodromus swirskii*, *Euseius scutalis* and *Typhlodromus athiasae* (Acari: Phytoseiidae). *Acarina*, **17**: 223-229
  31. Montserrat, M., Janssen, A., Magalhães, S. and Sabelis, M.W. 2006. To Be an Intraguild Predator or Cannibal: Is Prey Quality Decisive? *Ecol. Entomol.*, **31**: 430-436.
  32. Mori, H., Saito, Y. and Nakao, H. 1990. Use of Predatory Mites for Controlling Spider Mites (Acarina: Tetranychidae) in Japan. *FFTC-NARC International Seminar on 'The Use of Parasitoids and Predators to Control Agricultural Pests'*, Tukuba Science City, Ibarakiken, Japan.
  33. Negloh, K., Hanna, R. and Schausberger, P. 2012. Intraguild Predation and Cannibalism between the Predatory Mites *Neoseiulus neobaraki* and *N. paspalivorus*, Natural Enemies of the Coconut Mite *Aceria guerreronis*. *Exp. Appl. Acarol.*, **58**: 235-246.
  34. Onzo, A., Hanna, R. and Sabelis, M. W. 2003. Interactions in Acarine Predator Guild: Impact on *Typhlodromalus aripo* Abundance and Biological Control of Cassava Green Mite in Africa. *Exp. Appl. Acarol.*, **31**: 225-241.
  35. Polis, G. A., Myers, C. A. and Holt, R. D. 1989. The Ecology and Evolution of Intraguild Predation: Potential Competitors that Eat Each Other. *Annu. Rev. Ecol. Syst.* **20**: 297-330.
  36. Rahmani, H., Daneshmandi, A. and Walzer, A. 2015. Intraguild Interactions among Three Spider Mite Predators: Predation Preference and Effects on Juvenile Development and Oviposition. *Exp. Appl. Acarol.*, **67**: 493-505.
  37. Rahmani, H., Fathipour, Y. and Kamali, K. 2009. Life History and Population Growth Parameters of *Neoseiulus californicus* (Acari: Phytoseiidae) Fed on *Thrips tabaci* (Thysanoptera: Thripidae) in Laboratory Condition. *Syst. Appl. Acarol.*, **14**: 91-100.



38. Rhodes, E. M., Liburd, O. E., Kelts, C., Rondon, S. I. and Francis, R. R. 2006. Comparison of Single and Combination Treatments of *Phytoseiulus persimilis*, *Neoseiulus californicus*, and Acramite (Bifenazate) for Control of Two Spotted Spider Mites in Strawberries. *Exp. Appl. Acarol.*, **39**: 213-225.
39. Rosenheim, J. A., Kaya, H. K., Ehler, L. E., Marois, J. J. and Jaffee, B. A. 1995. Intraguild Predation among Biological-Control Agents: Theory and Evidence. *Biol. Control*, **5**: 303–335.
40. Schausberger, P. 1997. Inter- and Intraspecific Predation on Immatures by Adult Females in *Euseius finlandicus*, *Typhlodromus pyri* and *Kampimodromus aberrans* (Acari: Phytoseiidae). *Exp. Appl. Acarol.*, **21**: 131–150.
41. Schausberger, P. and Croft, B. A. 1999. Activity, Feeding, and Development among Generalist and Specialist Phytoseiid Mites. *Environ. Entomol.*, **28**:322–329.
42. Schausberger, P. and Croft, B. A. 2000a. Cannibalism and Intraguild Predation among Phytoseiid Mites: Are Aggressiveness and Prey Preference Related to Diet Specialization? *Exp. Appl. Acarol.*, **24**: 709–725.
43. Schausberger, P. and Croft, B. A. 2000b. Nutritional Benefits of Intraguild Predation and Cannibalism among Generalist and Specialist Phytoseiid Mites. *Ecol. Entomol.*, **25**: 473–480
44. Schausberger, P. and Walzer, A. 2001. Combined *versus* Single Species Release of Predaceous Mites: Predator–Predator Interactions and Pest Suppression. *Biol. Control.*, **20**: 269–278.
45. Song, Z. W., Zheng, Y., Zhang, B. X. and Li, D. S. 2016. Prey Consumption and Functional Response of *Neoseiulus californicus* and *Neoseiulus longispinosus* (Acari: Phytoseiidae) on *Tetranychus urticae* and *Tetranychus kanzawai* (Acari: Tetranychidae). *Syst. Appl. Acarol.*, **21**: 936–946.
46. Tixier, M. S., Allam, L., Douin, M. and Kreiter, S. 2016. Phytoseiidae (Acari: Mesostigmata) of Morocco: New Records, Descriptions of Five New Species, Redescriptions of Two Species, and Key for Identification. *Zootaxa*, **4067**: 501-551.
47. Uddin, M., Alam, M., Miah, M., Uddin, R., Mian, M. and Hossain, I. 2016. Life Table Parameters of an Indigenous strain of *Neoseiulus californicus* McGregor (Acari: Phytoseiidae) when Fed *Tetranychus urticae* Koch (Acari: Tetranychidae). *Entomol. Res.*, **47**: 84-93.
48. Van der Hoeven, W. A. D., and Van Rijn, P. C. J. 1990. Factors Affecting the Attack Success of Predatory Mites on Thrips Larvae. *Proc. Exper. Appl. Entomol.*, **1**: 25–30.
49. Van Leeuwen, T., Vontas, J., Tsagkarakou, A., Dermauw, W. and Tirry, L. 2010. Acaricide Resistance Mechanisms in the Two-Spotted Spider Mite *Tetranychus urticae* and Other Important Acari: A Review. *Insect. Biochem. Mol. Biol.*, **40**: 563–572.
50. Walzer A., Lepp N. and Schausberger, P. 2015. Compensatory Growth Following Transient Intraguild Predation Risk in Predatory Mites. *Oikos*, **124**:603–609.
51. Walzer, A. and Schausberger, P. 1999a. Cannibalism and Interspecific Predation in the Phytoseiid Mites *Phytoseiulus persimilis* and *Neoseiulus californicus*: Predation Rates and Effects on Reproduction and Juvenile Development. *Biol. Control.*, **43**: 457–468.
52. Walzer, A. and Schausberger, P. 1999b. Predation Preferences and Discrimination between Con and Heterospecific Prey by the Phytoseiid Mites *Phytoseiulus persimilis* and *Neoseiulus californicus*. *Biol. Control.*, **43**: 469–478.
53. Walzer, A. and Schausberger, P. 2011. Threat-Sensitive Anti-Intraguild Predation Behaviour: Maternal Strategies to Reduce Offspring Predation Risk in Mites. *Anim Behav.*, **81**: 177–184.
54. Walzer, A., Blümel, S. and Schausberger, P. 2001. Population Dynamics of Interacting Predatory Mites, *Phytoseiulus persimilis* and *Neoseiulus californicus*, Held on Detached Bean Leaves. *Exp. Appl. Acarol.*, **25**:731–743.
55. Walzer, A., Moder, K. and Schausberger, P. 2009. Spatiotemporal within-Plant Distribution of the Spider Mite *Tetranychus urticae* and Associated Specialist and Generalist Predators. *Bull. Entomol. Res.*, **99**:457–466.
56. Walzer, A., Paulus, H. and Schausberger, P. 2004. Ontogenetic Shifts in Intraguild Predation on Thrips by Phytoseiid Mites: the Relevance of Body Size and Diet

- Specialization. *Bull. Entomol. Res.*, **94**: 577-584.
57. Zhang, Z. Q. and Croft, B. A. 1995. Interspecific Competition and Predation between Immature *Amblyseius fallacis*, *Amblyseius andersoni*, *Typhlodromus occidentalis* and *Typhlodromus pyri* (Acari: Phytoseiidae). *Exp. Appl. Acarol.*, **19**: 247-257.
58. Zhang, Z. Q. 2003. *Mites of Greenhouses: Identification, Biology, and Control*. Wallingford, Oxon, UK: CAB International, 235 PP.

### شکارگری درون گونه‌ای و همخواری بین دو کنه شکارگر فیتوزیید، *Neoseiulus californicus* و *Amblyseius andersoni*

ح. رحمانی، و ن. افشاری

#### چکیده

در این مطالعه به شکارگری درون گونه‌ای و همخواری (تغذیه از هم گونه) در دو کنه شکارگر از خانواده فیتوزییده پرداخته شده است. کنه‌های ماده بالغ و پوره‌های سن اول دو کنه *Neoseiulus californicus* و *Amblyseius andersoni* به عنوان شکارگر در آزمایش‌ها مورد استفاده قرار گرفتند. از تخم، تخم+ لارو و پوره سن اول هم گونه و غیر هم گونه نیز به عنوان طعمه استفاده شد. صرف نظر از نوع گونه شکارگر و طعمه مورد استفاده (طعمه درون گونه‌ای و یا هم گونه)، کمترین و بیشترین میان شکارگری کنه‌های ماده به ترتیب از تخم و تخم+لارو ثبت شد. پوره سن اول هم گونه و غیر هم گونه مورد توجه کنه‌های ماده نبوده و تفاوت معنی‌داری در تغذیه از آن در تیمارها مشاهده نشد. تغذیه از طعمه درون گونه‌ای (مرحله لاروی) باعث افزایش مرگ‌ومیر و کاهش نرخ شکارگری در نابالغین کنه *A. andersoni* شد. در خصوص کنه *N. californicus*، میزان تغذیه نابالغین از لارو غیر هم گونه بیش تر از لارو هم گونه بود. بنابراین این طور به نظر می‌رسد که هر دو کنه شکارگر قادر به زنده ماندن هنگام تغذیه از طعمه هم گونه و غیر هم گونه می‌باشند.