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Effect of host plants on predation, prey preference and switching behaviour of *Orius albidipennis* on *Bemisia tabaci* and *Tetranychus turkestani*

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Abstract. The anthocorid bug *Orius albidipennis* Reuter is a generalist predator that feeds on the whitefly *Bemisia tabaci* Gennadius and the strawberry spider mite *Tetranychus turkestani* Ugarov & Nikolski in greenhouse crops. There are no previous studies on the potential efficacy of the predatory bug against these pests on greenhouse crops. We report on the efficacy and the prey preference of the predator to control these pests on different host plants under laboratory conditions. In a laboratory experiment, we estimated the predation rates of *O. albidipennis* at different densities of each prey after 24 h on cucumber and sweet pepper leaves. Predation rates of the predatory bug to *T. turkestani* and *B. tabaci* were significantly higher on sweet pepper leaf than on cucumber leaf. We studied the effect of plant species on prey preference and switching of *O. albidipennis* to *B. tabaci* and *T. turkestani* using Manly's α index values and Murdoch's no-switch line, respectively. Our results show that *O. albidipennis* prefers *T. turkestani* to *B. tabaci* on both host plants but its preference for *T. turkestani* on sweet pepper is significantly greater than on cucumber. Moreover, on sweet pepper, preference values are completely fitted by Murdoch's no-switch line. The findings suggest that morphological defence traits of plants, such as hairy leaves of cucumber, may effectively change prey preference and reduce predation success of *O. albidipennis*.

Key words: Flower bug, strawberry spider mite, sweet potato whitefly, predation rate, Manly's α index, Murdoch's no-switch

Introduction

The whitefly *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) and the strawberry spider mite *Tetranychus turkestani* Ugarov & Nikolski (Acari: Tetranichidae) are economically important pests of greenhouse and field vegetables such as sweet pepper and cucumber around the world (Stansly and Natwick, 2010). The sweet potato whitefly, *B. tabaci*, attacks numerous plant species that are found in tropical and warm temperate regions of the world (Breene *et al.*, 1992; Stansly and Natwick, 2010). *Bemisia tabaci* transmits viruses and can cause direct damage through feeding and indirect damage by honeydew excretion that creates favourable conditions for the rapid growth of sooty mould fungi (Breene *et al.*, 1992). *Tetranychus turkestani* is a polyphagous cosmopolitan pest (Jeppson *et al.*, 1975; Mossadegh and Kocheili, 2003). This mite is one of the best-known pests

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in tropical ecosystems, causing significant damage to cucurbitaceous, leguminous and other field and horticultural plants (Jeppson *et al.*, 1975; Kamali *et al.*, 2004).

Control of *B. tabaci* and *T. turkestani* depends mainly on pesticide application. Concerns over pesticide risk has led to research into alternative pest control measures, including biological control agents (Ashley, 2003). Insect generalist predators attack various prey species, because they have the plasticity to adapt their biology to different prey (Sobhy *et al.*, 2010). Species of predatory bugs of genus *Orius* are an important group of insects predating on economically important pests (Lattin, 1999) such as thrips (Tommasini and Nicoli, 1996), mites and aphids (Akramovskaya, 1978; Yasunaga, 1997), eggs of pentatomids (Pericart, 1972) and whiteflies (Stansly and Natwick, 2010). *Orius albidipennis* Reuter is a common predator in many regions of Iran, and it has been shown to have the potential of being a biological control agent under field and greenhouse conditions (Dehghani Zahedani *et al.*, 2011). However, generalist predators may exhibit prey preference in the presence of mixed prey species (Dicke *et al.*, 1989; Nordlund and Morrison, 1990; Cheng *et al.*, 2010) so the use of *O. albidipennis* for biological control might be complicated in a situation where both *B. tabaci* and *T. turkestani* are found on the same plant (Stansly and Natwick, 2010). Prey preference by biological control agents can affect their ability to effectively control target pests (Nordlund and Morrison, 1990; Cheng *et al.*, 2010). Prey switching may be frequency-dependent if the predator preferentially consumes the most common type of prey. 'Positive switching' occurs when the abundance of two prey species in the diet of a predator increase proportionately faster than in the environment that could influence the stability of the prey populations (Murdoch, 1969; Chesson, 1984; Van Baalen, 2001). Conversely, in the situation of 'negative/anti-switching', the ratio of the two prey species in the diet of a predator increases commensurately slower than in the environment (Chesson, 1984). In other words, switching is a behavioural phenomenon whereby a predator alters its preference for the prey species as prey relative densities change (Oaten and Murdoch, 1975).

Plants possess a variety of ecologically important traits that affect the outcome of enemy–prey interactions, in some cases enhancing enemy attack and in others interfering with it (Price *et al.*, 2011). Nutritional qualities and structural features of the host plant can influence the prey–predator behaviour, and the host plant can influence the behaviour of the predatory bugs (Eubanks and Denno, 1999; Hossini *et al.*, 2010).

Bemisia tabaci and *T. turkestani* may co-exist on sweet pepper and cucumber crops. In this study, the predation rate, preference and switching behaviour of *O. albidipennis* on *B. tabaci* and *T. turkestani* as food sources were evaluated on sweet pepper and cucumber crops under laboratory conditions to understand the potential of *O. albidipennis* as a control agent for these two pest species.

Material and methods

Predator and prey rearing

Seeds of sweet pepper (*Capsicum annuum* L.) and cucumber (*Cucumeris sativus* L.) were grown in plastic pots (diameter 20 cm). Pots were incubated in a greenhouse until plants were 20–25 cm high with 5–6 leaves. Each plant was then maintained separately in insect cages (0.5 m × 0.5 m × 2 m) inside an air-conditioned room at 25 ± 1 °C, 65 ± 10% RH, and a LD-16:8 h photoperiod.

Whiteflies (*B. tabaci*) and spider mites (*T. turckestani*) were collected from sweet pepper and cucumber fields in greenhouses in Ahvaz District, Iran. Adults of whiteflies and spider mites were released in the cage with their own host plants, in separate cages (0.5 m × 0.5 m × 1 m) at 25 ±1 °C with a photoperiod of LD-16:8 h.

Orius albidipennis bugs were obtained from unsprayed open maize fields. A single female from the collected bugs was put into a Plexiglas cylinder (18 cm length, 7.5 cm diameter) covered with a fine gauze lid. At least one male was selected from the offspring of each female, and was identified by keys of Pericart (1972). To initiate pilot rearing, 50 newly emerged adults of *O. albidipennis* were put together in the Plexiglas cylinder, and fed on the eggs of Mediterranean flour moth *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae). Leaves of Swedish begonia *Plectranthus verticillatus* Druce and bean pods were supplied as oviposition substrates. Leaf petiole of *P. verticillatus* was maintained in water. The Plexiglas cylinders were lined with crumpled paper tissue to provide a hiding place to rest and reduce cannibalism. Rearing took place in an incubator at 25 ± 1 °C, 60 ± 5% RH, and a photoperiod of LD-16:8 h.

Predation rates

The effect of the host plant on predation rates was investigated using 2-day-old pupae of *B. tabaci* and 2-day-old female adults of *T. turkestani* as prey, and 2-day-old adults of *O. albidipennis* as predator. Only female adults of *B. tabaci* and *T. turkestani* were used in the experiments (Madadi *et al.*, 2009). The developmental stages of *B. tabaci* and *T. turkestani* were obtained by introducing adults (50 adults per plant) on each host plant (cucumber and sweet pepper) in the insect cage. The adults were removed and the eggs on the plants allowed to develop to appropriate stage for the experiments. Pupae (2-day-old) of *B. tabaci* and female adults (2-day-old) of *T. turkestani* were obtained after 16 and 12 days after removal of the *B. tabaci* and *T. turkestani* adults, respectively. The experimental arena consisted of an octagon dish of 10-cm diameter and 3.8-cm height. To facilitate ventilation, a hole was made on top of the dish (2.5 cm) and covered with fine mesh. Each arena contained a cucumber or sweet pepper leaf disk placed upside down on a 20-ml layer of agar (5%) (Montserrat *et al.*, 2000). Based on preliminary tests, densities of 0, 5, 10 and 20 whiteflies and 0, 5, 10 and 20 spider mites per arena per one *O. albidipennis* female were used in the experiments. Each density of prey was replicated four times. After 24 hrs, the predatory bug was removed and the numbers of killed prey recorded. The mortality data were corrected using Abbott's formula (Abbot, 1925). All predator–prey experiments were performed at 25 ± 2 °C, 60 ± 5%, and a photoperiod of LD-16:8 h.

Prey preference

The conditions of prey preference experiments were similar to predation rate experiments. The arena consisted of 10:10 and 20:20 ratio of *B. tabaci* pupae and female adults of *T. turkestani* that were placed on leaf discs of each host plant. Experiments were performed with one female of *O. albidipennis* simultaneously, which were starved for 24 hrs before release.

Experiment containers were placed in the incubator at 25 ± 1 °C, 60 ± 5% RH and a LD-16:8 h photoperiod. Each trial was repeated 14 times and the number of prey eaten by each predator recorded after 24 h. Manlyś α index was applied to measure prey preference (Manly, 1974; Chesson, 1984; Krebs, 1989):

$$\alpha \equiv \frac{\ln((n_{i0} - r_i)/n_{i0})}{\sum_{j=1}^{m} \ln\left((n_{j0} - r_j)/n_{j0}\right)}, i = 1, \ldots, m, \quad (1)$$

where α is Manly's α index for prey type, n_{i0} is initial number of prey items of type i, r_i is the number of prey items of type i consumed by the predator and m is the number of prey types in the experiment. The α index gives values between 0 and 1, and the number of the different prey types always sum up to one. In several experiments, all individuals of both prey species were consumed. To calculate Manly's α index in these cases, the formula was modified by adding one prey individual of the completely depleted prey type to corresponding n_{i0} and n_{j0} in the above equation. This correction is based on the assumption that if another individual of the prey in question were present, it would survive. The corresponding estimate of α_i is slightly conservative (Klečka, 2010).

Switching

Prey switching was evaluated for *O. albidipennis* by providing pupae of *B. tabaci* and female adults of *T. turkestani*. Female adult of *O. albidipennis* was confined in the disposable container (18-cm length, 9-cm width and 5.5-cm high) with different combinations of the two prey species at one of the three ratios of *B. tabaci* to *T. turkestani*: 10:20, 15:15 or 20:10. The experimental container consisted of two Petri dishes, one for each prey on separate leaf discs. Leaf discs were placed on wet filter paper to keep them fresh. A paper tape connected the two Petri dishes to facilitate movement of the bugs. Sweet pepper and cucumber leaf discs were separately used in each experiment. After 12 hr, the predator was removed and the number of prey eaten recorded. Each treatment had 14 replications.

It is a simple predation model that demonstrates results from experiments in which *O. albidipennis* exhibited a preference between two prey species, which are presented to one predator species. The first requirement is a criterion for switching, and this involves establishing a 'null case', that is, the expected results in the absence of switching. Essentially, this null case is a simple model of predation. The model (Oaten and Murdoch, 1975) is

$$P_1/P_2 = CN_1/N_2, \quad (2)$$

where P_1/P_2 is the expected ratio of the two prey species in the diet (the food eaten), N_1/N_2 is the ratio given, and C is normalization constant in equal density of prey type 1 and 2 described as

$$C \equiv \frac{n_1 par}{n_2 par}, \quad (3)$$

where, n_1 par is average number of prey type 1 eaten, n_2 par is average number of prey type 2 eaten. C is the measured preference and can be defined as the ratio of Species 1 to Species 2 that are eaten when the two prey species are equally abundant. When $C = 1$, there is no preference. When $C > 1$, there is a preference for type 1. When $C < 1$, there is a preference for type 2 (Murdoch, 1969).

Finally, to test the occurrence of switching, the observed ratio with the expected ratio based on the ratios given was compared. When the observed ratio E1/E2 is higher than expected ratio at high values of N1/N2, switching occurs (Murdoch and Marks, 1973).

Table 1. Mean ± SE consumption rates of *Tetranychus turkestani* and *Bemisia tabaci* by *Orius albidipennis* on cucumber and sweet pepper leaves ($df = 6$) in non-choice tests

		Predation rate (%±SE)			
Prey	Prey density per leaf disc	Cucumber	Sweet pepper	*T*	*P*-value (independent *t*-test)
T. turkestani	5	60.0 ± 8.2	85.0 ± 5.0	− 2.61	0.4
	10	65.5 ± 4.80	82.5 ± 4.8	− 2.21	0.05
	20	62.5 ± 3.20	81.3 ± 2.4	− 4.66	0.003
B. tabaci	5	50.0 ± 5.80	55.0 ± 5.0	− 0.66	0.537
	10	37.5 ± 2.50	52.5 ± 2.5	4.24	0.005
	20	31.3 ± 2.3	41.3 ± 1.3	3.70	0.01

Table 2. Mean of Manly's α index values ± SE of prey preference of predatory bug *Orius albidipennis* for *Tetranychus turkestani* and *Bemisia tabaci* in equal quantities

	Cucumber				Sweet pepper			
Ratio	*T. turkestani*	*B. tabaci*	$t_{(df=6)}$	*P*-value	*T. turkestani*	*B. tabaci*	$t_{(df)}$	*P*-value
10:10	0.79 ± 0.04	0.21 ± 0.04	−13.2	<0.001	0.77 ± 0.03	0.23 ± 0.03	−8.5	<0.001
20:20	0.78 ± 0.03	0.22 ± 0.06	−12.7	<0.001	0.72 ± 0.03	0.28 ± 0.04	−6.3	<0.001

Data analysis

Comparisons of predation rates between the cultivars and Manly's α index between two prey were done by independent *t*-test. Data were normalized using arcsine transformation. All analyses were done with SPSS software version 16 (SPSS Inc., Chicago, USA) (SPSS, 2007).

Results

Predation rates

The number of mites and whiteflies that *O. albidipennis* consumed at different prey densities on cucumber and sweet pepper leaves is shown in Table 1. For all prey densities, consumption rates of *O. albidipennis* on *T. turkestani* and *B. tabaci* on sweet pepper leaf were significantly higher than on cucumber leaf. Also, predation rates of the predator on *T. turkestani* were higher compared with *B. tabaci*.

Prey preference and switching behaviour

On cucumber at 10:10 and 20:20 ratios, Manley's α index was 0.79 and 0.78 for *T. turkestani*, and 0.21 and 0.22 for *B. tabaci*. Also on sweet pepper at 10:10 and 20:20 ratio, Manly's α index was 0.77 and 0.72 for *T. turkestani* and 0.23, and 0.28 for *B. tabaci* (Table 2). Therefore, the predator preferred *T. turkestani* for feeding when these pests simultaneously existed in the leaves of both host plants at all prey density ratios.

By using Murdoch's index, the preference values (C) were 1.53 and 1.57 on cucumber and sweet pepper, respectively (in comparison with the values 0.66 and 0.63 for *B. tabaci*) (Figs. 1 and 2). The higher C value shows that the predatory bugs prefer *T. turkestani* to *B. tabaci*. The switching behaviour experiment of *O. albidipennis* on *T. turkestani* and *B. tabaci* also shows that the predator prefers *T. turkestani* to *B. tabaci*. As shown in Figs. 1 and 2, prey mortality increased with prey density; thus, prey positive switching was observed in the predator when exposed to various ratios of *T. turkestani* and *B. tabaci* on cucumber and sweet pepper.

Discussion

Predation rates of *O. albidipennis* were greater on sweet pepper than on cucumber. The properties or morphology of the host plants of their prey can influence the foraging success and predation of natural enemies. It has been shown that plant morphological and chemical characteristics can affect different predator traits, including survival, fecundity, and foraging success (Price *et al.*, 1980). Host plant features (such as leaf trichomes), slow predator movement, thereby decreasing prey encounters or decreasing manoeuvrability (Reynolds, 2011; Reynolds and Cuddington, 2012). The high predation rate on sweet pepper suggests that *O. albidipennis* searches for prey more effectively on sweet pepper than cucumber. It could be due to the hairy surface of cucumber leaf that limits the predator foraging or its prey refuging. According to Krips *et al.* (1999), leaf hairs may hamper biological control of *T. urticae* by *Phytoseiulus persimilis*. Host plant

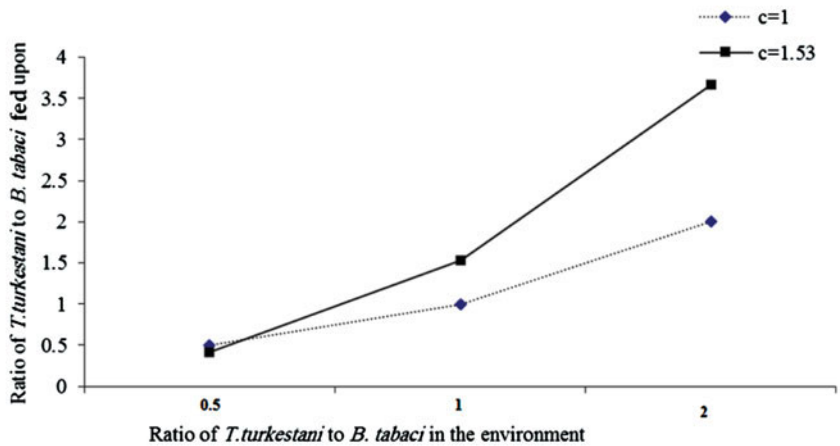

Fig. 1. Predation of *Orius albidipennis* females on *Tetranychus turkestani* and *Bemisia tabaci* when offered together in different ratios on cucumber.

Ratio 0.5: 10 spider mites/20 white flies; ratio 1: 15 spider mites/15 white flies; ratio 2: 20 spider mites/10 white flies. C:

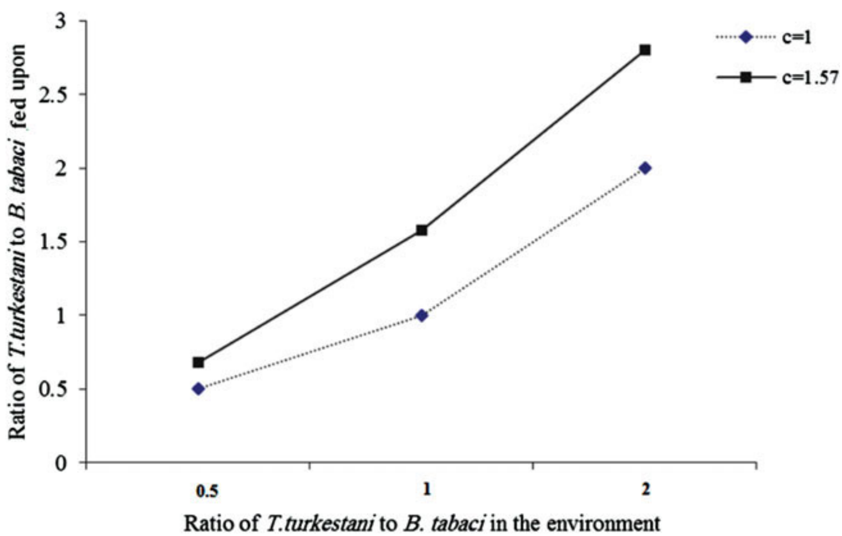

Fig. 2. Predation of *Orius albidipennis* females on *Tetranychus turkestani* and *Bemisia tabaci* when offered together in different ratios on pepper.

Ratio 0.5: 10 spider mites/20 white flies; ratio 1: 15 spider mites/15 white flies; ratio 2: 20 spider mites/10 white flies. C:.

trichomes affect predation rate in the predatory bug *Anthocoris confusus* Reuter (Evans, 2008).

The presence and abundance of alternative prey species that share the same enemy indirectly affect predation of a prey species by a generalist predator (such as *O. albidipennis)* (Tschanz *et al.*, 2007; Jaworski *et al.*, 2013). Our results show that *O. albidipennis* prefers *T. turkestani* to *B. tabaci* on leaves of both cucumber and sweet pepper. The capacity of the predator to detect prey, accessibility of prey for the predator, prey defences against the predator and capacity to effectively feed on prey are four main factors that determine ease of attacking a given prey by a generalist predator (Jaworski *et al.*, 2013). Influence of the host plant leaf trichomes can be one of the main factors. Hassell (1978) reported that polyphagous predators exhibit a preference for one or more prey types when exposed to a variety of prey species. Kousari and Kharazi-Pakdel (2006) examined prey preference of the predatory bug *O. albidipennis* on onion thrips and two-spotted spider mite on cucumber leaf under laboratory conditions. Their experiments demonstrated that the predatory bug preferred the second instar larvae of *T. tabaci* Lindeman to *T. urticae* Koch.

Results of the switching experiment indicate that the predators switch their prey preference from *B. tabaci* to *T. turkestani* on cucumber when *T. turkestani/B. tabaci* ratios are 2 and 3. Chow *et al.* (2008) showed that total and relative predation of *O. insidiosus* on thrips and/or mites depends on the types of available prey. The predator tended to switch to the most abundant type of prey. The switching behaviour of their generalist predator can stabilize the prey populations. The stabilizing effect of the predator on prey population may have useful applications for simultaneously managing multiple pest species in agroecosystems (Jaworski *et al.*, 2013).

Conclusion

Our results show that *O. albidipennis* prefers *T. turkestani* to *B. tabaci* on both host plants but its preference for *T. turkestani* on sweet pepper is significantly greater than on cucumber. The findings suggest that morphological defence traits of plants (such as hairy leaves of cucumber), may effectively change prey preference and reduce predation success of *O. albidipennis*. Our laboratory studies, albeit on a small scale, show that the type of host plant should be considered in release of *O. albidipennis* for biocontrol of insect pests. Further studies are necessary to confirm if this behaviour also occurs on a large scale in the field.

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