



Intraguild interactions of a generalist predator, *Orius albidipennis*, with two *Bemisia tabaci* parasitoids

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Abstract

The influence of intraguild predation between *Orius albidipennis* Reuter and two parasitoids, *Eretmocerus mundus* Mercet or *Eretmocerus eremicus* Rose and Zolnerowich, on the suppression of *Bemisia tabaci* Gennadius was investigated under laboratory conditions. Through a non-choice test, the 2nd and 3rd instar nymphs of *B. tabaci* and larval and pupal stages of both parasitoids were offered separately to both 5th instar nymphs and adults of *O. albidipennis*. In the choice test, various combinations of parasitized and unparasitized preys were provided for two stages of *O. albidipennis*, and their preference was recorded. Both predator stages readily preyed upon unparasitized and parasitized nymphs of *B. tabaci*. The most predation of *O. albidipennis* adults occurred on *E. eremicus* larvae, while for the 5th instar nymphs, it was recorded on *E. eremicus* larvae and pupae. The least predation of both stages was recorded on unparasitized nymphs of *B. tabaci* and *E. mundus* pupae. None of the prey combinations showed any obvious preference of adults and the 5th instars of *O. albidipennis* toward parasitized or unparasitized prey.

Keywords Anthocoridae · Aphelinidae · Parasitoid · Predator · Preference

Introduction

Intraguild predation (IGP) is one of the possible interspecific interactions that occur when different natural enemies are released to control the same pest in a system (Polis et al. 1989). IGP commonly occurs in food webs, both in natural and managed systems, where species compete for a common pest prey/host. IGP may occur between predators, parasitoids, and predators and parasitoids (Polis et al. 1989; Rosenheim et al. 1995; Rosenheim 1998). Predator–parasitoid interaction occurs in two different modes. In addition, predators may prey directly on parasitoids or indirectly by consuming the parasitized host and the associated immature parasitoid (Rosenheim et al. 1995).

Insects represent different interactions with IGP. IGP may disrupt biological control and thus lead to an increase in the pest population (Erbilgin et al. 2004; Rosenheim et al. 1993;

Sohrabi et al. 2013). However, the effect of IGP on biological control is not always negative (Herrick et al. 2008). Positive effects have also been shown when an increase occurs in the efficacy of natural enemies (Gardiner and Landis 2007; Schausberger and Walzer 2001; Snyder et al. 2004).

Bemisia tabaci Gennadius is a very harmful pest worldwide for many crops, especially greenhouse crops such as ornamentals, tomato, pepper, bean, eggplant, and cucumber. More than 600 species of different plants are the hosts of *B. tabaci* (Oliveira et al. 2001). Biological control of *B. tabaci* mostly relies on parasitoids from family Aphelinidae such as the genus *Eretmocerus* and *Encarsia* (Hymenoptera: Aphelinidae) (Gerling et al. 2001; Naranjo and Ellsworth 2005; Zandi-Sohani et al. 2009). *Eretmocerus mundus* Mercet is a parasitoid that is able to efficiently control *B. tabaci* (Gabarra et al. 2006; Stansly et al. 2005). *Eretmocerus eremicus* Rose and Zolnerowich are native to the Americas (Rose and Zolnerowich 1997). In Iran, this parasitoid has been reported from Gilan Province (Shahbazvar et al. 2010). In greenhouse crops, polyphagous predatory insects of the genus *Orius* (Heteroptera: Anthocoridae) are also used to control *B. tabaci* (Sohrabi et al. 2013). *Orius albidipennis* Reuter, a common predator in several regions of Iran, has been reported as a promising generalist biocontrol agent in greenhouses and fields (Salehi et al. 2016). Therefore,

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in programs for control of *B. tabaci* in greenhouse crops, the concurrent use of *E. mundus* or *E. eremicus* and *O. albidipennis* is expected to decline the pest population.

A limited number of studies have investigated IGP by generalist predators on specialist parasitoids against whiteflies. For instance, Sohrabi et al. (2013) reported IGP by adults and the 5th instar nymphs of *Orius majusculus* (Reuter) (Heteroptera: Anthocoridae) on *Encarsia formosa* (Gahan) (Hymenoptera: Aphelinidae), a parasitoid of *B. tabaci* (Sohrabi et al. 2013). The IGP of *Geocoris punctipes* (Say) (Hemiptera: Lygaeidae) on *E. eremicus* was assessed while the parasitoid developed on the nymphs of *Trialeurodes vaporariorum* Westwood (Hemiptera: Aleyrodidae) (Velasco-Hernández et al. 2013). In another study, the interactions of *Macrolophus pygmaeus* (Rambur) with *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) and *E. mundus* and their effects on *B. tabaci* were studied on tomato plants (Moreno-Ripoll et al. 2014). To the best of our knowledge, there is no information regarding IGP by *O. albidipennis* on *E. mundus* and *E. eremicus* or other parasitoid species on *B. tabaci*. The aim of this study is to investigate the ability of *O. albidipennis* to prey on parasitized *B. tabaci*. After proving such an ability, we investigate the predator feeding preference on parasitized and non-parasitized whitefly nymphs.

Materials and methods

Plants

Commercial seeds of cucumber, *Cucumis sativus* L. (C.V. F1), were sown in plastic pots (9 cm high and 8 cm diameter) into compost. The pots were maintained in cages (120 × 120 × 60 cm³) covered with a white nylon mesh of 210 μm aperture. These cages were in a laboratory at 16–25 °C, 40–50% R.H., and a 14:10 (L:D) photoperiod. When the plants reached 4 to 6 leaves of development, they were used for whitefly rearing.

Insects

A cucumber field in the Mollasani region, Ahvaz, Iran, was used for collecting *B. tabaci* individuals to initiate colony in September 2015. The collected whiteflies were released on the leaves of cucumber plants in the cages similar to those described in the above lines. When the plants withered, new ones were added to the cage.

The pupae of *E. mundus* were collected from the same cucumber field to establish a colony in September 2015. *E. eremicus* wasps were purchased as pupae from Gyah Company, Iran, which was originally produced at Koppert Co. Then, the pupae of both wasps were put into separate petri dishes (9 cm diameter) inside different cages containing cucumber plants infested by *B. tabaci*. After emergence, the

adult wasps started parasitizing *B. tabaci* nymphs, and the colonies of *E. mundus* and *E. eremicus* were created.

Orius albidipennis adults were collected from an unsprayed sunflower field in the experimental plots of Agricultural Sciences and Natural Resources University of Khuzestan, Iran. Then, the females were isolated in a plexiglass container (18 cm height and 7.5 cm diameter) covered with a fine gauze on the top for ventilation. Bean pods also were supplied an oviposition substrate. One male was selected among the offspring and identified by the keys of Pericart (Péricart 1972). After identification, the glasses with *O. albidipennis* were maintained for building a colony, and other species were removed. For feeding of *O. albidipennis*, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) eggs and corn pollen were used. To avoid cannibalism, crumpled wipe papers were placed at the bottom of the plexiglass cylinders (Salehi et al. 2016). An incubator was used for rearing insects, which were set at 25 ± 1 °C, 65 ± 5 R.H., and 16:8 h (L: D).

Parasitized whiteflies nymphs for experiments

Cucumber plants with 4–6 leaves were used to obtain parasitized nymphs of whiteflies for experiments. First, groups of 10 adult whiteflies collected from the colony were released into clip cages (2 cm diameter) on the bottom side of the leaves. Afterward, they were left to oviposit for 24 h, followed by deleting their clip cages. The plants with whitefly eggs were transferred to incubators that were set at 25 ± 1 °C, 65 ± 5 RH, and 16:8 h (L: D). After about 2 weeks, the eggs developed to the 3rd instar nymphs, which is the favorite stage for *E. mundus* and *E. eremicus* to parasitize. Subsequently, groups of 5–6 adults of both parasitoids were moved to a larger clip cage (4 cm diameter) on the whitefly nymphs separately and were left to parasitize for 24 h. Then, the plants were maintained in the mentioned conditions until parasitoid was developed to the desired larval or pupal stage for experiments.

No-choice bioassays

In these experiments, IGP of *O. albidipennis* on *E. mundus* and *E. eremicus* was studied separately for the 5th instar and adults of the predator. Observations were performed in the experimental arena consisting of organdy-vented petri dishes (9 cm diameter). Leaf discs containing parasitized nymphs in larval and pupal stages of parasitoids and the 2nd and 3rd instar nymphs of whitefly were offered separately to each predator stage. Leaves with parasitized or unparasitized whitefly nymphs were taken from plants described above. On each leaf, 20 parasitized or unparasitized nymphs were retained, and other whitefly nymphs were removed by a pin. The petioles of the detached leaves containing nymphs were completely covered in moist cotton to keep the leaves fresh during the experiments. The bottom of the arena was also

covered with moistened filter paper completely. One newly molted 5th instar nymph or an adult female of *O. albidipennis* with no feeding during the past 24 h was introduced into leaf disc. After 24 h, predators were eliminated, and the number of attacked prey was counted on each leaf disc. The number of replications was 10 for each treatment. All the tests were carried out in an incubator with the same condition mentioned for predator rearing.

Choice bioassays

In these bioassays, the same procedure described for the no-choice test was used with some difference in the kind of preys offered to predators in the arena. According to the results of no-choice bioassay, *O. albidipennis* was able to consume both parasitized and unparasitized whitefly nymphs. Therefore, the following prey combinations were used in choice bioassays:

- 1) 15 parasitized nymphs with the larval stage of parasitoids and 15 unparasitized 2nd instar whiteflies
- 2) 15 parasitized nymphs with the larval stage of parasitoids and 15 unparasitized 3rd instar whiteflies
- 3) 15 parasitized nymphs with the pupal stage of parasitoids and 15 unparasitized 2nd instar whiteflies
- 4) 15 parasitized nymphs with the pupal stage of parasitoids and 15 unparasitized 3rd instar whiteflies

The experimental conditions were similar to those described for no-choice bioassays. The experimental arena was also the same with some modifications. In this experiment, two different leaf discs were used in each petri dish, which one of them contained parasitized nymph and another one with unparasitized whitefly nymphs of the appropriate stage. All the abovementioned tests were carried out separately for the 5th instar nymphs and adult females of *O. albidipennis*. For each parasitoid, all the experiments were done separately. The predators were released individually into the experimental arena, and the number of prey attacked by the predator was recorded after 24 h. Each combination was replicated 10 times.

Data analysis

No-choice bioassays

To test the differences between predation rates among groups of prey stages and between predator stages, a two-way ANOVA was performed using the procedure GLIMMIX of SAS (SAS Institute 2003). The effect of prey and predator stage together with their interaction was included as fixed effects, and the means were separated using the LSD test at $P = 0.05$, where applicable. It was assumed that the number of individuals was Poisson-distributed with an unknown

overdispersion, which had to be estimated. The natural logarithm was used as a link function. The two-sample t-test was used to compare predation by different predator stages when offered the same prey (SAS Institute 2003).

Choice bioassays

For the choice experiments, the experimental design was a two-way ANOVA including the fixed effects of prey combination and predator stage together with their interaction. It was assumed that the number of individuals chosen was binomially distributed with an unknown overdispersion, which had to be estimated. The logit function was used as a link. A two-sample t-test was used to compare the predation by different predator stages when the same prey combination was offered. The means of whitefly nymphs consumed were separated between prey combinations within each predator stage using the LSD test at $P = 0.05$, where applicable. All analyses were performed using the GLIMMIX procedure of SAS (SAS Institute 2003).

The assessment of prey preference was based on the formula for Manly's preference index (Manly 1974) for each predator stage and each prey combination:

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

where β_1 is the preference for prey type 1, e_1 and e_2 are the numbers of prey 1 and 2 remaining after the experiments, respectively, and A_1 and A_2 are the number of prey types 1 and 2 offered, respectively. The values of preference index (β_1) vary within the range of 0 to 1, where the values higher than 0.5 indicate a preference for prey type 1. Differences between prey preference indices including the fixed effects of prey combination and predator stage together with their interaction were analyzed using two-way ANOVA. The one-sample t-test was applied to represent a significant difference in each preference index from the value of 0.5 using SAS 9.0 (SAS Institute 2003).

Results

No-choice bioassays

According to the results, both 5th instar nymphs and adults of *O. albidipennis* are capable of preying on different stages of unparasitized nymphs of *B. tabaci* and nymphs parasitized by *E. eremicus* and *E. mundus* (Table 1). The predation rate was significantly influenced by prey stage ($F = 36.67$, $df = 5108$; $P < 0.0001$), predator stage ($F = 45.00$, $df = 1108$; $P < 0.0001$), and the interaction between predator and prey stage ($F = 3.07$, $df = 5108$; $P = 0.0125$). Adult *O. albidipennis* had the most

Table 1 Mean number \pm SE of consumed preys by adults and 5th instar nymphs of *O. albidipennis* including *Bemisia tabaci* nymphs parasitized by *Eretmocerus eremicus*, *Eretmocerus mundus*, and unparasitized nymphs

| Prey stage | Adult | 5th instar nymph |
|-----------------------------------|------------------|-------------------|
| 2nd instar <i>B. tabaci</i> nymph | 2.0 \pm 0.25Ad | 1.0 \pm 0.25 Bd |
| 3rd instar <i>B. tabaci</i> nymph | 3.0 \pm 0.25Ac | 1.9 \pm 0.27Bc |
| <i>E. eremicus</i> larvae | 6.5 \pm 0.5Aa | 4.0 \pm 0.25Ba |
| <i>E. eremicus</i> pupae | 4.3 \pm 0.36Ab | 3.2 \pm 0.32Bab |
| <i>E. mundus</i> larvae | 4.4 \pm 0.40Ab | 2.7 \pm 0.36Bbc |
| <i>E. mundus</i> pupae | 2.0 \pm 0.25Ad | 1.9 \pm 0.23Ac |

Means in a column followed by different lower case letters are significantly different (LSD test; $p < 0.05$). Upper case letters are used to compare predation by different predator stages when offered the same prey (two sample t-test; $P < 0.05$)

predation on the parasitized nymphs containing larval stage of *E. eremicus*. The 5th instars had the highest predation on parasitized nymphs of *B. tabaci* containing larval or pupal stages of *E. eremicus* with no significant difference between these two prey types. Predation by adults was significantly higher than predation of 5th instar nymphs on all offered preys, except on the pupae of *E. eremicus* such that both adults and the 5th instar nymphs showed the same predation rate (Table 1).

Choice bioassays

The results of choice tests of *O. albidipennis* adults and the 5th instar nymphs between unparasitized nymphs of *B. tabaci* and parasitized nymphs by *E. eremicus* are shown in Table 2. Predation rate varied significantly by predator developmental stages ($F = 19.23$; $df = 1, 72$; $P = 0.0001$), while the effects of prey combination ($P = 0.09$) and the interactions between predator stage and prey combination ($P = 0.61$) on predation rate were not significant. Adults of *O. albidipennis* consumed

more than the 5th instar nymphs in the combination of unparasitized 2nd instar *B. tabaci* nymphs and pupae of *E. eremicus* and unparasitized 3rd instar nymphs of *B. tabaci* and larvae of *E. eremicus* (Table 2). The results also showed that the predator stage ($P = 0.69$), prey combinations ($P = 0.96$), and the interactions between predator stage and prey combinations ($P = 0.97$) had no significant effects on preference indices. Both adults and the 5th instar nymphs of *O. albidipennis* showed no positive preference for parasitized over unparasitized whitefly nymphs (Table 2), and all calculated preference indices were not significantly different from 0.5 ($P > 0.05$).

In choice experiments with unparasitized nymphs of *B. tabaci* and nymphs parasitized by *E. mundus*, predation rates were significantly affected by prey combination ($F = 2.86$; $df = 3, 72$; $P = 0.042$) and predator stage ($F = 4.29$; $df = 1, 72$; $P = 0.042$) but not by the interaction between prey combination and predator stage ($P = 0.62$). Adults of *O. albidipennis* showed significantly more predation than the 5th instar nymphs in prey combination of the 3rd instar nymphs of *B. tabaci* and pupae of *E. mundus* (Table 3). The results also showed that the predator stage ($P = 0.65$), prey combinations ($P = 0.31$), and the interactions between predator stage and prey combinations ($P = 0.48$) had no significant effects on preference indices. None of the adults and the 5th instar nymphs of *O. albidipennis* had a recognizable preference for parasitized over unparasitized whitefly nymphs (Table 3), and none of the preference indices was significantly different from 0.5 ($P > 0.05$).

Discussion

The compatibility between whitefly parasitoids and predators has a significant impact on the effectiveness of biological

Table 2 Mean \pm SE number of prey eaten as well as mean preference indices \pm SE of *O. albidipennis* for *E. eremicus* (β_2) when offered various prey combinations

| Predator stage | Prey combination Bt Ee | | Ee eaten | Bt eaten | Comparison Bt eaten* | Preference index(β_2) |
|----------------|---------------------------|--------------|----------------|----------------|-------------------------|-------------------------------|
| Adult | 2nd instar nymph | larval stage | 4.5 \pm 0.42 | 4.0 \pm 0.29 | Aa | 0.529 \pm 0.04Aa |
| | 2nd instar nymph | Pupal stage | 3.4 \pm 0.26 | 3.5 \pm 0.4 | Aa | 0.498 \pm 0.035Aa |
| | 3rd instar nymph | Larval stage | 5.8 \pm 0.59 | 5.0 \pm 0.44 | Aa | 0.540 \pm 0.054Aa |
| | 3rd instar nymph | Pupal stage | 4.1 \pm 0.37 | 3.9 \pm 0.37 | Aa | 0.516 \pm 0.033Aa |
| 5th instar | 2nd instar nymph | Larval stage | 3 \pm 0.51 | 3 \pm 0.57 | Aa | 0.510 \pm 0.096Aa |
| | 2nd instar nymph | Pupal stage | 2.2 \pm 0.51 | 2.1 \pm 0.37 | Ba | 0.474 \pm 0.105Aa |
| | 3rd instar nymph | Larval stage | 3.0 \pm 0.61 | 2.9 \pm 0.52 | Ba | 0.488 \pm 0.103Aa |
| | 3rd instar nymph | Pupal stage | 2.9 \pm 0.34 | 2.8 \pm 0.53 | Aa | 0.528 \pm 0.084Aa |

Means in a column followed by different lower case letters are significantly different between prey combinations within each predator stage (LSD test; $P < 0.05$). Upper case letters are used to compare predation by different predator stages when offered the same prey combination (two sample t-test; $P < 0.05$). Bt *Bemisia tabaci*; Ee *Eretmocerus eremicus*; * the statistics for comparison of number of *E. eremicus* eaten is the same as for the comparison of number of *B. tabaci* eaten

Table 3 Mean \pm SE number of prey eaten as well as mean preference indices \pm SE of *O. albidipennis* for *E. mundus* (β_2) when offered various prey combinations

| Predator stage | Prey combination Bt Em | | Em eaten | Bt eaten | Comparison Bt eaten* | Preference index (β_2) |
|----------------|------------------------|--------------|----------------|----------------|----------------------|--------------------------------|
| Adult | 2nd instar nymph | Larval stage | 2.1 \pm 0.45 | 3.3 \pm 0.61 | Aab | 0.398 \pm 0.092 Aa |
| | 2nd instar nymph | Pupal stage | 1.7 \pm 0.49 | 2.2 \pm 0.29 | Ab | 0.373 \pm 0.102 Aa |
| | 3rd instar nymph | Larval stage | 3.2 \pm 0.71 | 3.9 \pm 0.8 | Aa | 0.464 \pm 0.106 Aa |
| | 3rd instar nymph | Pupal stage | 3.9 \pm 0.34 | 3.9 \pm 0.37 | Aa | 0.5 \pm 0.047 Aa |
| 5th instar | 2nd instar nymph | Larval stage | 2.5 \pm 0.45 | 2.8 \pm 0.48 | Aa | 0.467 \pm 0.095 Aa |
| | 2nd instar nymph | Pupal stage | 1.5 \pm 0.4 | 1.9 \pm 0.31 | Aa | 0.411 \pm 0.112 Aa |
| | 3rd instar nymph | Larval stage | 2.9 \pm 0.6 | 3.2 \pm 0.62 | Aa | 0.460 \pm 0.107 Aa |
| | 3rd instar nymph | Pupal stage | 2.4 \pm 0.49 | 2.3 \pm 0.49 | Ba | 0.514 \pm 0.118 Aa |

Means in a column followed by different lower case letters are significantly different between prey combinations within each predator stage (LSD test; $P < 0.05$). Upper case letters are used to compare predation by different predator stages when offered the same prey combination (two sample t-test; $P < 0.05$). Bt *Bemisia tabaci*; Em *Eretmocerus mundus*; * the statistics for comparison of number of *E. mundus* eaten is the same as for the comparison of number of *B. tabaci* eaten

control programs against *B. tabaci*. Biological control can be more efficient when useful agents have synergistic or additive effects. In some studies, an increase in the diversity of natural enemies on crops has caused a growing decline in population density of herbivores (Snyder and Ives 2003). However, in some other cases, intraguild predation may result in less successful biological control programs (Rosenheim 1998; Rosenheim et al. 1995; Rosenheim 2005).

The current study confirms that both predator stages, adults, and the 5th instar nymphs of *O. albidipennis* are able to prey upon parasitized nymphs of *B. tabaci* in both choice and no-choice tests. Similar results were reported in several studies. *O. majusculus* adults and late instars nymphs had the ability to prey on *B. tabaci* parasitized by *E. formosa* (Sohrabi et al. 2013), *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae) preyed on *B. tabaci* parasitized by *E. mundus* (Kutuk et al. 2011), and *Delphastus catalinae* (Horn) (Coleoptera: Coccinellidae) readily feed on whitefly nymphs parasitized by *Encarsia sophia* (Girault & Dodd) (Hymenoptera: Aphelinidae) (Zang and Liu 2007).

In no-choice tests, adults of predator consumed more on the larval stage of both parasitoids than their pupae. Similar results have been reported in the no-choice test by *O. majusculus* on different developmental stages of *E. formosa* (Sohrabi et al. 2013). In these experiments, adults of *O. albidipennis* showed the least predation on the 2nd and 3rd instar nymphs of *B. tabaci* and *E. mundus* pupae, compared with larval and pupal stages of *E. eremicus* and larval stage of *E. mundus*. In the case of the 5th instar nymphs, the least predation was recorded on the 2nd and 3rd instar nymphs of *B. tabaci* and larval and pupal stages of *E. mundus*. Previous studies have shown that some predators only consume unparasitized hosts while others may prefer parasitized hosts (Brodeur and Rosenheim 2000; Colfer and Rosenheim 2001). The reason why *O. albidipennis* in the current study

consumed fewer unparasitized *B. tabaci* nymphs is the fact that unparasitized nymphs might use defense mechanisms against predators to avoid predation (Meisner et al. 2011). Moreover, a lower rate of predation on the pupal stage of *E. mundus* compared to the larval stage was also seen in the adult predator stage. Some other reports are in parallel with our results. For example, *D. catalinae* consumed fewer whitefly nymphs with *E. sophia* pupae (Zang and Liu 2007), or the parasitoid pupae of *Psyllaepagus bliteus* Riek (Hymenoptera: Encyrtidae) were largely free from the attack of *Anthocoris nemoralis* (Fabricius) (Heteroptera: Anthocoridae) (Erbilgin et al. 2004). Furthermore, both adults and the 4th instar *S. parcesetosum* strongly avoided *B. tabaci* nymphs containing pupae of *E. mundus* (Kutuk et al. 2011). Several reasons could be presumed for this phenomenon including hardening of whitefly cuticle induced by parasitism (Hoelmer et al. 1994; Kutuk et al. 2011), introducing air around the developing parasitoid, physical and chemical alterations in cuticle during the pupal development (Hoelmer et al. 1994), and morphological changes in parasitized prey (Kutuk et al. 2011).

In the choice tests of the present study, *O. albidipennis* did not exhibit a clear preference for *B. tabaci* nymphs or parasitized nymphs by *E. mundus* and *E. eremicus*. The same trend was reported for *D. catalinae* (Zang and Liu 2007), which did not avoid parasitized or unparasitized whitefly nymphs significantly. *Anthocoris nemorum* L. also are involved in IGP with *Aphidius colemani* Viereck and did not discriminate between unparasitized and parasitized aphids and mummies (Meyling et al. 2004). According to Brodeur and Rosenheim (2000), for unparasitized aphids with active behavioral defense mechanisms, there is a higher chance of predation on mummified prey. Since unparasitized nymphs of *B. tabaci* are almost as sedentary as parasitized nymphs, the lack of prey preference can be explained by the above argument. Nevertheless, in a

previous study on *O. majusculus*, Sohrabi et al. (2013) showed that the IG-predator prefer preying upon *B. tabaci* nymphs parasitized by *E. formosa*. In these cases, differentiated size and color of the parasitized nymphs were considered as a reason for the IG-predator preference (Naranjo 2007). In another study, however, *Geocoris punctipes* showed preference to non-parasitized nymphs of the whitefly *Trialeurodes vaporariorum* rather than nymphs parasitized by *E. eremicus* during the choice test (Velasco-Hernández et al. 2013). In such cases, some factors like mechanical aspects (Hoelmer et al. 1994), physiological or chemical changes (Chen 1966; Gelman et al. 2002), and prey species (Roger et al. 2000; Williamson 1980) potentially affect IG-predator responses.

In conclusion, as the parasitized hosts are not avoided by a predator, the presence of *O. albidipennis* could have an undesirable effect on the fitness of both parasitoids. However, to obtain more reliable results, future efforts should be directed toward greenhouse experiments.

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Conflict of interest The authors declare that they have no conflict of interest.

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