

Research Article

Interactions between *Orius albidipennis* and *Aphidius colemani* (Hymenoptera: Braconidae) for the control of *Aphis gossypii* on greenhouse cucumber

Mehran Attarzadeh¹, Ali Rajabpour^{1*}, Mohammad Farkhari² and Arash Rasekh³

1. Department of Plant Protection, Faculty of Agriculture, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, Ahvaz, Iran.

2. Department of Genetics and Plant Productions, Faculty of Agriculture, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, Ahvaz, Iran.

3. Department of Plant Protection, College of Agriculture, Shahid Chamran University of Ahvaz, Ahvaz, Iran.

Abstract: Aphis gossypii Glover (Hemiptera: Aphididae) is an important cucumber pest especially in greenhouse. The efficacy of simultaneous release of generalist predator, Orius albidipennis Reuter (Hemiptera: Anthocoridae) and a specialist parasitic wasp, Aphidius colemani Viereck (Hymenoptera: Braconidae), was evaluated in laboratory conditions against the pest. For this purpose, investigations were carried out on preference of the predator between parasitized and non-parasitized aphids. In addition, production of volatile infochemicals between the natural enemies (NEs) was studied by olfactometry trials. In another part of this research, systemic production of volatile synomone by the infested cucumber plants for attraction of each NE was examined by the olfactometry tests. Results revealed that O. albidipennis had no obvious preference to either the parasitized or non-parasitized aphids, while both NEs were significantly attracted to volatiles emitted from infested host plants. Our findings revealed that each of the NEs avoided odors which indicated the presence of another intraguild competitor. The documented facts from the entire study reveal that the NEs are good biocontrol agents against A. gossypii on cucumber, but their avoidance from each other makes simultaneous release of the predator and parasitic wasps unsuitable for biological control of this aphid.

Keywords: predatory bug, parasitoid wasp, simultaneous release, infochemicals, aphid biocontrol

Introduction

Problems associated with chemical pesticides, such as pest resistance, side effect on non- target organisms, secondary pest outbreaks, environmental contaminations etc. (Pedigo, 2002) resulted in the development of integrated pest management (IPM) theory in 1970 (Knipling, 1972). Biological control has been a valuable method in IPM programs around the world for many years (Orr, 2009). Two natural enemy species are frequently released simultaneously to control one pest species in greenhouse biological control programs (Orr, 2009). In some cases, releasing of two or more biocontrol agents increased mortality by 12.97% and reduced pest abundance by 27.17% compared to single release

Handling Editor: Yaghoub Fathipour

^{*} **Corresponding author**, e-mail: rajabpour@ramin.ac.ir Received: 26 September 2018, Accepted: 19 December 2018 Published online: 9 January 2019

against aphid pests (Stiling and Cornelissen, 2005). In simultaneous release of two natural enemies against a pest, intraguild predation (IGP) and interspecific competition (IC) between the natural enemies might affect the biological control and these phenomena can directly or indirectly disrupt biological control programs (Orr, 2009). The effect of IGP and IC on biocontrol efficacy of some anthocorid bugs and some parasitoid wasps were investigated by some authors. For example, occurrence of IGP between Anthocoris nemurum L. and Aphidius colemani Viereck on Myzus persicae Sulzer (Hom., Anthocoridae) (Meyling et al., 2004), Orius majusculus Reuter and Encarsia formosa Gahan (Hym., Aphelinidae) on Bemisia tabaci Gennadius (Hom., Aleurodidae) pupa (Sohrabi et al., 2012) were studied in laboratory conditions. Moreover, IGP between other generalist predators like Hippodamia convergens GuérinMéneville (Col., Coccinellidae) and Lysiphlebus testaceipes Cresson (Hym., Braconidae) on Aphis gossypii Glover (Colfer and Rosenheim, 2001), Harmonia axyridis Pallas (Col., Coccenillade) and Aphelinus Aphelinidae) on asvchis Walker (Hym., euphorbiae Thomas Macrosiphum (Hom. Aphididae) (Synder et al., 2004), Macrolopus Wagner Miridae) pygmeus (Het., and Trichogramma macro Nagaraja and Nagarkatti (Hym., Trichogrammatidae) on Tuta absoluta Meyreck eggs (Chailleux et al., 2013), Coccinella septempunctate L. (Col. Coccinellidae) and Lysiphlebus fabarum Marshall (Hym., Braconiidae) on Aphis fabae Scopoli (Meyhofer and Klug, 2002), H. axvridis and A. asvchis on Myzus pesicae Sulzer (Fu et al., 2017) were previously evaluated.

Chemical information plays a critical role in foraging behavior of natural enemies. The chemical information can originate from herbivore, its food, or other natural enemies (Takabayashi *et al.*, 1994). The importance of infochemicals, in foraging behavior of parasitoids and predators has been previously documented. For instance, olfactory tests revealed that *Anthocoris* spp. respond to pear trees infested by *Psylla pyrii* L. (Hem., *Psyllidae*) (Drukker *et al.*, 1995). In addition, positive behavioral response of O. tristicolor (White) to bean plants damaged bv Frankliniella occidentalis Pergande (Thy., Thripidae) Tetranychus urticae Koch (Acari, Teranychidae), O. sauteri Poppius to eggplant and infestation by Thrips palmi Karny (Thys., Thripidae) (Mochizuki and Yano, 2007) were reported. Effect of plant infochemicals on behavior and preference of some parasitoid wasps like Cotesia glomerata L. (a parasitoid of Pieris rapae L. on cabbage) (Steinberg et al., 1992), C. sesamiae Cameron (a parasitoid of Chilo spp. on maize and sorghum) (Ngi-Song et al., 1996), Trichogramma chilonis Ishii (a parasitoid of Helicoverpa armigera Hubner in sorghum) (Romeis et al., 1997) and Microctonus hyperodae Loan (Hymenoptera: Braconidae) (a parasitoid of Listronotus oregonensis LeConte on graminae) (Cournover and Boivin, 2004) were studied in a tritrophic system.

Our ability to develop successful biocontrol programs will be enhanced by experimental or field studies which address the probable trophic interactions occurring in an agricultural system (Rosenheim *et al.*, 1995).

Predatory bugs which belong to the genus Orius are generalist predators of various soft bodied arthropods like aphids (Reitz et al., 2006). O. albidipennis Reuter is a common predator in several regions of Iran and its ability as a potential biocontrol agent has been reported especially in greenhouse conditions (Rajabpour et al., 2011, Salehi et al., 2016, Banihashemi et al., 2017). Another important biological control agent of aphids is A. colemani which is released commercially against the pest in greenhouses (Enkegaard, 2005). The wasp larvae develop entirely inside aphid body and do not kill their host until the larvae are ready to pupate (Enkegaard, 2005). Among the many species of greenhouse aphids, A. gossypii is an economically important aphid which attack many greenhouse plants including cucumber (Blackman and Eastop 2000).

Generalist predators, including *Orius* spp., and parasitoids are considered as important natural enemies of aphids. The generalist predators not

only feed on the aphids, but might also consume aphidophagous parasitoids at all stages of development (Traugott *et al.*, 2012). The aim of the present study is to investigate interactions between two important biocontrol agents (*O. albidipennis* and *A. colemani*) for simultaneous release against *A. gossypii* in greenhouse cucumber. In addition, production of volatile infochemicals by the infested host plants or interspecific competitors in response to each natural enemy will beevaluated in laboratory conditions.

Materials and Methods

Host plant

Cucumber (*Cucumis sativus* cv. superdaminos) seeds were sown in pots filled with a perlitecocopeat mix (1: 1, v: v) moistened regularly with half-strength Hoagland nutrient solution. The plants were grown in cages, $0.6 \times 0.6 \times 2m$, in growth chamber with photoperiod of 14:10h (light: dark), at 20 ± 5 °C, and maximum photon flux density of 1000µmolm⁻²s⁻¹.

Insect cultures

Wingless females of *A. gossypii* were provided from an experimental colony at Insect Ecological Laboratory of Shahid Chamran University of Ahwaz, Khuzestan province, south west Iran. The aphids were released in the rearing cages, $1 \times 1 \times 0.6$ m, with the cucumber plants. The cages were kept inside an air conditioned room at a temperature of 25 ± 3 °C, relative humidity of $65 \pm 5\%$, with a photoperiod of 14: 10h (light: dark). After the colony establishment, the wingless female adults or 2^{nd} instar nymphs from the colony were used in the trials or for *A. colemani* rearing, respectively.

Mummies of *M. persicae* Sulzer and *A. gossypii* (parasitized by *A. colemani*) were provided from Koppert BV, Netherlands. After emergence of the parasitoid adults, 100 adults were introduced to the insect rearing cages with cucumber plants infested by *A. gossypii* at ambient conditions earlier mentioned for aphids rearing.

Adults of the predatory bugs, O. albidipennis, were collected from unsprayed

sunflower fields in Mollasani region, Khuzestan province, south west Iran. Female bugs were isolated in a Plexiglas cylinder (18cm high, 7.5cm diameter) covered with a fine gauze lid on the top and margin for ventilation. At least one male was selected from the offspring of each female bug and was identified using keys of Pericart (1972). The bugs were reared on Ephestia kuehniella eggs of Zeller (Lepidoptera: Pyralidae) while date palm pollen was used as daily diet and bean pod as oviposition substrate at 25 ± 1 °C, $60 \pm 5\%$ RH, and 16: 8h (light: dark) in an incubator. The Plexiglas cylinders were lined with crumpled wipe papers to provide a hiding place to rest and reduce cannibalism.

Experimental design

Prey preference trials

Experiments were performed at 25 ± 1 °C, $60 \pm 5\%$ RH within a photoperiod of 16: 8h (light: dark) in an incubator. Parasitized and nonparasitized female adults of *A. gossypii* were used as prey of *O. albidipennis*. For this purpose, five females of *A. colemani* (3-4 days-old) were introduced into a standard 10cm plastic Perti dish that contained 20 wingless aphids which located upside a wet filter paper. To facilitate ventilation, a hole was made on top of the dishes (2.5cm diameter) and covered with fine net. After 8h, the parasitic wasps were removed from the Petri dishes. The parasitized aphids were used in the prey preference experiments 3 days post removal of parasitic wasp.

The experimental arena included the Petri dishes (with characteristics mentioned above) that comprised a cucumber leaf disk placed upside down on a 20ml layer of agar (5%) (Montserrat *et al.*, 2000). Based on preliminary tests, densities of 5 or 10 parasitized aphids and 5 or 10 non-parasitized aphids per arena were used in the trials. To identify parasitized from non-parasitized aphids, one antenna of parasitized aphid was separated by fine pincet. Adult of the predatory bug (2-4 days old) was introduced to the experimental arena. Experiments were performed in a completely randomized design with 10 replications. After 2h, the predator was removed

Olfactory trials

A Y-shaped olfactometer device was applied in the trials. Various parts of the device are shown in Figure 1. A leaf of cucumber plants was infested by adults of *A. gossypii* in a clips cage (5cm diameter). After 24h, another leaf from the plant was picked and placed in chamber 2. The leaf was washed by distillated water before use. Another cucumber leaf from plant without previous infestation was placed in chamber 3. Air flow (3.5lit/sec.) was passed across chambers 2 and 3 and reached location 1. A female wasp (2-4 days old and starved for 8h) was introduced to location 1. In another trial, a female predatory bug (3-4 days old and starved for 8h) was released in location 1.

After 10 min, location of the parasitic wasp or predatory bug in chamber 2 was recorded. If

the wasp or bug did not move, and location 2 or 3 were not selected by the natural enemies, the trial was canceled and repeated again.

To investigate the production of volatile infochemicals by the intraguild competitors, a cucumber leaf with five wingless female aphids + one female predatory bug were placed in chamber 1 and five wingless female aphids were placed alone in chamber 2. Then a female parasitic wasp (2-4 days old) was introduced to location 1. In another scenario, five female aphids + a female parasitoid and five female aphids were placed alone in chambers 2 and 3, respectively. The location of the wasp or bug was determined after 10min.

All olfactory experiments were conducted in an incubator at 25 ± 2 °C, $60 \pm 5\%$ RH and a photoperiod of 16:8h (light: dark). Each trial was repeated for 20 times based on a completely randomized design.



Figure 1 Schematic figure of Y-shaped olfactometry device (1. Common entrance tube, 2 and 3. Sample chamber, 4. Connective tube, 5. Electric engine to create airflow).

Data analyses

Manly's α index was used to evaluate prey preference (Manly, 1974; Chesson, 1984):

$$\alpha = \frac{ln\left(\frac{n_{io} - r_i}{n_{i0}}\right)}{\sum_{j=1}^{m} ln \frac{n_{jo} - r_j}{n_{j0}}}, i = 1, \dots m$$

Where α = 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, n_{j0} is initial number of prey items of type *j*, r_j is the number of prey items of type *j* consumed by the predator and *m* is the number of prey types in the experiment. The α index give values between zero and one, and the number of the different prey types is always summed to be one and 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 the addition of one individual prey 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 is present, it would survive. The corresponding estimate of α_i is slightly conservative (Klecka, 2010).

One sample t-test was used to compare Manly's α index mean of each sample with 0.5 in prey preference trials. In addition, chi-square test was used to analyze olfactory trials. All statistical analyses were performed using SPSS statistical analysis package (SPSS, 1993).

Results

Prey preference experiments

Manly's aindex of *O. albidipennis* preference was calculated between parasitized and nonparasitized aphids at 5 and 10 densities for each prey (Table 1). Results show that Manly's α index of the predatory bug was not significantly different when fed on parasitized and non-parasitized aphids at different densities. Therefore, *O. albidipennis* has no obvious preference for either of the two preys.

Olfactory experiments Synomone production studies

Responses of *O. albidipennis* and *A. colemani* female adults to volatile cues which originated from leaves of plants previously infested (IP) and not infested (NIP) by *A. gossypii* are presented in Table 2.

Results indicated that adults of *O*. *albidipennis* were significantly attracted to leaf of IP in comparison with NIP. Same behavior was observed for female adults of *A*. *colemani* in the olfactometry tests.

Inter-specific competition

Results of olfactometry trials for indicating IC between *O. albidipennis* and *A. colemani* are shown in Table 3.

Table 1 Manly's a indices of Orius albidipennis for the parasitized and unparasitized Aphis gossypii.

Number of Demoiting de Llumono siting d	Unparasitized aphid			Parasitized aphid			
Number of Parasitized. Onparasitized	Maly's α index	t (df=8)	P-value	Maly's α index	t (df = 8)	P-value	
5:5	0.533 ± 0.088	0.379	0.715	0.466 ± 0.088	-0.379	0.715	
10:10	0.504 ± 0.054	0.075	0.942	0.490 ± 0.054	-0.075	0.942	

Table 2 Responding of *Aphidius colemani* and *Orius albidipennis* adults to cucumber plant with previous infestation (IP) and no infestation (NIP) by *Aphis gossypii*.

Species	Volatile cue sources	Total no.	Number of response		Number of no response		P-value
			IP	NIP	-		
A. colemani	IP/NIP	100	63	31	6	10.8	0.001
O. albidipennis	IP/NIP	100	67	29	4	15.0	< 0.001

Table 3 Response and non-response of *Aphidius colemani* and *Orius albidipennis* adults to volatile cues from the aphid + intraguild competitor (IC) and the *Aphis gossypii* only.

Species	Volatile cue sources	Total no.	Number of response		Number of no	χ^2	P-value
			Aphid + IC	Aphid	response		
A. colemani	Aphids + IC/aphids	100	38	58	4	4.16	0.041
O. albidipennis	Aphids + IC/aphids	100	37	60	3	5.45	0.020

Results indicated that both the wasps and bugs significantly avoided the chamber where the competitors were present which is associated with aphid patch. It seems that the *O. albidipennis* and *A. colemani* can recognize volatile odor of their intraguild competitors and avoid the IC when they had another choice.

Discussion

The predatory bug, O. albidipennis, did not exhibit any preference between parasitized and unparasitized adults of A. gossypii. Insect pest predators may prey unparasitized pests or pests which are parasitized and contain the immature stage of endoparasitoids, a form of IGP. Therefore, the biological control of the pest can either be enhanced or disrupted by introducing a predator species to an existing host-parasitoid system. When the predator exhibits a relative preference to unparasitized pest, it can be expected to improve control of the pest even if it produces high levels of IGP. In contrast, if the predator shows significant preference for parasitized pest, the biological control by the parasitoid can be disrupted (Colfer and Rosenheim 2001). Therefore, predator hosts (unparasitized preference for VS parasitized) may be a key factor in determining the net effect of predation in simultaneous release of a generalist predator and a specialist parasitoid to control a pest (Erbilgin et al., 2004). Various findings were obtained by researchers when the preference of a generalist predator was investigated between parasitized unparasitized and preys by specialist parasitoids. For instance, three predators of B. tabaci nymphs, Geocoris punctipes Say, Orius insidiosus Say, and Hippodamia convergens significant Gue'rin-Me'nevil, exhibited а nymphs preference for parasitized by Eretmocerus emiratus nr. (Hym., sp. Ahphelinidae) compared with unparasitized nymphs (Naranjo, 2007). Moreover, adults and 5th instar nymphs of O. majusculus exhibited significant preference for parasitized over unparasitized nymphs of B. tabaci by E. formosa (Sohrabi et al., 2012).

In contrast, adults of C. septempunctat and larvae of Episyrphys balteatus De Geer (Dip., Syrphidae) showed significant preference to unparasitized nymphs of A. fabae in comparison to parasitized nymphs by L. fabarum (Meyhofer and Klug 2002). Also, Takizawa et al. (2000) demonstrated that the larvae of aphidphagous ladybirds (*C*. septempunctat, Harmonia axyridis Pallas and Propylea japonica Thunberg) had significant tendency to feed on unparasitized aphids compared with mummies of Aphis craccivora Koch which contained larvae of A. colemani. H. axyiridis showed significant preference for unparasitized nymphs of *B*. tabaci in comparison with whitefly nymphs parasitized by E. formusa and E. sophia Girault and Dodd (Tan et al., 2016). The tendency of generalist predator to feed on the pest's mummies or unparasitized preys may be attributed to the effect of the preys on performance of the predators. For instance, Takizawa et al., (2000) documented that the coccinellid larvae exhibits different survival, developmental time and body weight when reared with parasitized or unparasitized aphids by A. colemani. In addition, the aphids paralyzed by the parasitic wasp result in decrease of its defensive behavior, therefore, it can be a crucial reason of more attack preference of the predators.

Similar to our findings, no significant preference was observed between parasitized and unparasitized eggs of *T. absoluta* (parasitized by *T. achaeae*) by *M. pygmeus* (Chailleux *et al.*, 2013).

Ikegawa *et al.* (2015) stated that types and combinations of behaviour of prey and predators may greatly affect qualitative outcomes of biological control by multiple natural enemies. Therefore, it is expected that different results were observed for different pest-parasitoid-predator complexes.

It has been proved that adults of both natural enemies: *O. albidipennis* and *A. colemani*, could recognize volatile cues of infested cucumber plant by the aphids. The cues are probably produced systemically. Many host plants release volatile compound when infested by herbivorous insects. The compounds are used as cues by predators or parasitoids foraging for their preys or hosts, respectively (Neveu et al., 2002). The attractive volatiles may be emitted only by infested parts of the host plant or systemically released by uninfested parts of the infested host plant, which can probably enhance the detectability of the signal (Dicke et al., 1990; Neveu 2002). The host-derived cues have been shown to guide female parasitoids to locate and evaluate host patches before oviposition. For instance, Neveu et al. (2002) demonstrated that Brassica compestris L. whose roots are attacked by Delia radicum L. larvae, emits volatile cues attracting Trybliographa rapae Westwood (Hymenoptera: Figitidae). In addition, the infochemicals were detected in cereals that were attacked by Sitobion avenae Fabricious. The infochemicals guided Aphidius rhopalosiphi De Stepani-Perez (Hym., Braconidae) to the infested plants in olfactometry tests (Micha et al. 2000). Sasso et al. (2007) showed that Aphid-infested tomatoes (by Macrosiphum euphorbia Thomas) were significantly more attractive towards Aphidius Holiday (Hym., Braconidae) ervi than undamaged plants and aphids themselves. The authors distinguished 8 compounds, a-pinene, (Z)-3-hexen-1-ol, *a*-phellandrene, limonene, (E)-b-ocimene, p-cymene, methyl salicylate, (E)-b-carvophyllene, which were released from the infested plants. The synthetic standard of the compound significantly affected the behavior of the parasitic wasp.

The volatiles released from several aphid and host plant species, alone or in association, were studied for their infochemical role in prey location by the generalist predators. For example, it is documented that *Vicia fabae* L., *Brassica napus* L. and *Sinapis alba* L.are infested by some aphid species, viz *M. persicae*, *Acyrthosiphon pisum* Harris and *Brevicoryne brassicae* L., emit volatile synomone, (*E*) - β -Farnesene, which attract *Adalia bipunctata* L. (Col., Coccinellidae) larvae and adults (Francis *et al.*, 2004). Soybean plants infested by *A. glycines* released volatile cues composed of methyl salicylate, (D)-limonene and (E, E)-a-

farnesene which affected the behavior of C. septempunctat, Chrysopa carnea Stephens Chrysopidae) (Neu., and syrphid flies. However, the behavioral effect was not observed in H. axyridis (Zhu and Park, 2005). Tan and Liu (2014) demonstrated that tomatoes infested by M. persicae distributed attractive volatile cues which stimulate three predator species; C. septempunctata, P. japonica (Col., Coccinellidae), and O. sauteri Poppius (Het., Anthocoridae), two whitefly parasitoid species (E. formosa and E. sophia Girault and Dodd) (Hym., Aphelinidae), and one aphid parasitoid species Aphidius gifuensis Ashmead (Hym., Aphidiidae).

Glinwood *et al.* (2011) demonstrated that predatory coccinellids can learn to associate the odor of aphid-infested plants with the presence of prey, and this olfactory learning ability is sensitive enough to discriminate variability between different genotypes of the same plant.

Our findings showed that both A. colemani and O. albidipennis avoided odors which indicated the presence of another intraguild competitor. It seemed that the natural enemies use the cues for reduction of intraguild competition between each other. Cotes et al. (2015) demonstrated that parasitoids of herbivorous insects utilize volatiles to evaluate predator-derived infochemicals to reduce predation risks. Our findings are in line with the results of Gnanvossou et al. (2003) who demonstrated that phytoseiid mite, Typhlodromalus manihoti Moraes, T. aripo DeLeon and Euseius fustis Pritchard and Baker, avoided patches of Mononychellus tanajoa Bondar inhabited by the other heterospecifics or by conspecifics when tested against a patch without predators. Same results were reported for Neoseiulus californicus McGregor and Phytoseiulus cucumeris Athias-Henriot (Cakmak et al. 2006).

In conclusion, in this study, it was proved that *O. albidipennis* and *A. colemani* have some valuable characteristics for control of *A. gossypii* in greenhouse cucumber e.g.there is no preference of the predatory bugs to the aphid mummies and systemic production of synomone by the host plant for attraction of the natural enemies to infested plants. Although these characteristics make the natural enemies good biocontrol agents against *A. gossypii* on cucumber, especially in greenhouses; avoidance of the natural enemies from each other causes simultaneous release of the predator and parasitic wasp unsuitable for biological control of aphids in greenhouse or field. Results of the study can be applied in biocontrol program of *A. gossypii* on cucumber.

Acknowledgements

The research was supported by Agricultural Sciences and Natural Resources University of Khuzestan [grant number 9328407].

References

- Banihashemi, A. S., Seraj, A. A., Yarahmadi, F., and Rajabpour, A. 2017. Effect of host plants on predation, prey preference and switching behaviour of *Orius albidipennis* on *Bemisia tabaci* and *Tetranychus turkestani*. International Journal of Tropical Insect Science, 37 (3): 176-182.
- Blackman, R. L. and Eastop, V. F. 2000. Aphids on the World's Crops: An Identification and Information Guide.2nd Edition. John Wiely and Sons, UK.
- Cakmak I., Janssen A. and Sabelis M. W. 2006. Intraguild interactions between the predatory mites *Neoseiulus californicus* and *Phytoseiulus persimilis*. Experimental and Applied Acarology, 38 (1): 33-46.
- Chailleux A., Bearz P., Pizzol J., Amiens-Desneux E., Ramirez-Romero R. and Desneux N. 2013. Potential for combined use of parasitoids and generalist predators for biological control of the key invasive tomato pest *Tuta absoluta*. Journal of Pest Science, 86: 533-541.
- Chesson P. L. 1984. Variable predators and switching behavior. Theoretical Population Biology, 26: 1-26.
- Colfer R. G. and Rosenheim J. A. 2001. Predation on immature parasitoids and its

impact on aphid suppression. Oecologia, 126 (2): 292-304.

- Cotes, B., Rannback, L. M., Norli, H. R., Mayling, N. V., Ramert, B. and Anderson, P. 2015. Habitat selection of a parasitoid mediated by volatiles informing on host and intraguild predator densities. Oecolgia, 179 (1): 151-162.
- Cournoyer, M. and Boivin, G. 2004. Infochemical-mediated preference behavior of the parasitoid *Microctonus hyperodae* when searching for its adult weevil hosts. Entomologia Experimentalis *et* Applicata, 112 (2): 117-124.
- Dicke, M., Sabellis, M. W., Takabayashi, J., Bruin, J. and Posthumus, M. A.1990. Plant strategies of manipulating predator-prey interactions through allelochemicals: prospects for application in pest control. Journal of Chemical Ecology, 16: 3091-3118.
- Drukker, B., Scutareanu, P. and Sabelis, M. W. 1995. Do anthocorid predators respond to synomones from Psylla-infested pear trees in field conditions?. Entomologia Experimentalis *et* Applicata, 77: 193-203.
- Enkegaard, A. 2005. Biological control of arthropod pests in protected crops-recent developments. Proceedings of the International Workshop at Research Centre Flakkebjerg; Denmark. November 1-3, 2005.
- Erbilgin, N., Dahlesten, D. L. and Chen, P. 2004. Intraguild interactions between generalist predators and an introduced parasitoid of *Glycaspis brimblecombei* (Homoptera: Psylloidea). Biological Control, 31: 329-337.
- Francis, F., Lognay, G. and Haubruge, E. 2004. Olfactomrty response of aphid and host plant volatile releases: (*E*)-β-Farnesene and effective kairomone for the predator *Adalia bipunctata*. Journal of Chemical Ecology, 30 (4): 741-755.
- Fu, W., Yu, X., Ahmed, N. and Liu, T. X. 2017. Intraguild predation on the aphid parasitoid *Aphelinus asychis* by the ladybird *Harmonia axyridis*. BioControl, 62 (1): 61-70.
- Glinwood, R., Ahmed, E., Qvarfodt, E. and Ninkovic, V. 2011. Olfactory learning of

plant genotypes by a polyphagous insect predator. Oecologia, 166: 637-647.

- Gnanvossou, D., Hanna R. and Dicke M. 2003. Infochemical-mediated intraguild interactions among three predatory mites on cassava plants. Oecologia, 135 (1): 84-90.
- Ikegawa, Y., Ezoe, H. and Namba, T. 2015. Adaptive defense of pests and switching predation can improve biological control by multiple natural enemies. *Population Ecology* 57 (2), 381-395.
- Klecka, K. 2010. Predation by aquatic insects: species traits and habitat structure mediate predator-prey interactions. MSc thesis, in English. University of South Bohemia, 'Ceské Bud'ejovice, Czech Republic.
- Knipling, E. F. 1972. Entomology and the Management of Man's Environment. Australian Journal of Entomology, 11: 153-167.
- Manly, B. 1974. A model for certain types of selection experiments. Biometrics, 30: 281-294.
- Meyhofer, R. and Klug, T. 2002. Intraguild predation on the aphid parasitoid *Lysiphlebus fabarum* (Marshall) (Hymenoptera: Aphidiidae): mortality risks and behavioral decisions made under the threats of predation. Biological Control, 25 (3): 239-248.
- Meyling, N.V., Enkegaard, A. and Brodesgaard, H. 2004. Intraguild Predation by Anthocoris nemorum (Heteroptera: Anthocoridae) on the Aphid Parasitoid *Aphidius colemani* (Hymenoptera: Braconidae). Biocontrol Science and Technology, 14 (6): 627-630.
- Micha, S. G., Kistenmacher, S., Molck, G. and Wyss, U. 2000. Tritrophic interactions between cereals, aphids and parasitoid: Discrimination of different plant-host complexes by *Aphidius rhopalosiphi* (Hymenoptera: Aphidiidae). European Journal of Entomology, 97: 539-543.
- Mochizuki, M. and Yano, E. 2007. Olfactory response of the anthocorid predatory bug *Orius sauteri* to thrips-infested eggplants. Entomologia Experimentalis *et* Appicata 123 (1): 57-62.

- Montserrat, M., Albajes, R. and Castañé, C. 2000. Functional response of four heteropteran predators preving on greenhouse Aleyrodidae) and whitefly (Homoptera: flower thrips (Thysanoptera: western Entomology: Thripidae). Environmental 29:1075-1082.
- Naranjo, S. E. 2007. Intraguild predation on *Eretmocerus* sp. nr. *emiratus*, a parasitoid of *Bemisia tabaci*, by three generalist predators with implications for estimating the level and impact of parasitism. Biocontrol Science and Technology, 17 (5/6), 605-622.
- Neveu, N., Grandgirard, J., Nenon, J. P. and Cortesero, A. M. 2002. Systemic release of herbivore-induced plant volatiles by turnips infested by concealed root-feeding larvae *Delia radicum*. Journal of Chemical Ecology 28 (9): 1717-1732.
- Ngi-Song, A. J., Overholt, W. A., Njagi, P. G.
 N., Dicke, M., Ayertey J. N. and Lwande W.
 1996. Volatile infochemicals used in host and host habitat location by *Cotesia flavipes* Cameron and *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae), larval parasitoids of stem borers on graminae. Journal of Chemical Ecology 22 (2): 307.
- Orr, D. 2009. Biological Control and Integrated Pest Management. In: Peshin, R and Dhawan, A. K. (Eds). Integrated Pest Management: Innovation-Development Process. Springer, Netherland.
- Pedigo, L. P. 2002. Entomology and pest management. Iowa University press, USA.
- Péricart, J. 1972. Hémiptères Anthocoridae, Cimicidae et Microphysidae de l'ouestpaléarctique. Fauna de l'Europe et du Bassin Mediterraneen, 7: 1-404.
- Rajabpour, A., Seraj, A. A., Allahyari, H. and Shishehbor, P. 2011. Evaluation of Orius laevigatus Fiber (Heteroptera: Anthocoridae) for biological control of Thrips tabaci Lindeman (Thysanoptera: Thripidae) on greenhouse cucumber in South of Iran. Asia Journal of Biological Sciences, 4: 457-467.
- Reitz, S. R., Funderburk, J. E. and Waring, S. M. 2006. Differential predation by the generalist predator *Orius insidiosus* on

Downloaded from jcp.modares.ac.ir on 2025-05-22

congeneric species of thrips that vary in size and behaviour. Entomologia Experimentalis *et* Applicata, 119: 179-188.

- Romeis, J., Shanower, T. G. and Zebitz, C. P. W. 1997. Volatile plant infochemicals mediate plant preference of *Trichogramma chilonis*. Journal of Chemical Ecology, 23 (11): 2455-2465.
- 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. Biological Control, 5: 303-335.
- SPSS. 1993. SPSS Base System. Release 6.0. SPSS Inc.
- Salehi, Z. Yarahmadi F., Rasekh A. and Zandi Sohani N. 2016. Functional responses of Orius albidipennis Reuter (Hemiptera, Anthocoridae) to Tuta absoluta Meyrick (Lepidoptera, Gelechiidae) on two tomato cultivars with different leaf morphological characteristics. Entomologia Genenelis, 36 (2): 127-136.
- Sasso, R., Iodice, L., Digilio, M. C., Carreta, A., Ariati, L. and Guerrieri, E. 2007. Hostlocating response by the aphid parasitoid *Aphidius ervi* to tomato plant volatiles. Journal of Plant Interaction 2 (3): 175-183.
- Sohrabi, F., Enkegaard, A., Shishehbor, P., Saber, M. and Mossadegh, M. S. 2012. Intraguild predation by the generalist predator *Orius majusculus* on the parasitoid *Encarsia formosa*. BioControl 58 (1): 65-72.
- Steinberg, S., Dicke, M., Vet, L. E. M. and Wageningen, R. 1992. Response of the braconid parasitoid *Cotesia* (=*Apanteles*) glomerata to volatile infochemicals: effects of bioassay set-up, parasitoid age and experience and barometric flux. Entomologia Experimentalis et Applicata, 63 (2): 163-175.
- Stiling, P. and Cornelissen, T. 2005. What makes a successful biocontrol agent? A meta-analysis of biological control agent performance. Biological Control, 34: 236-246.
- Synder, W. E., Ballard, S. N., Yang, S., Clevenger, G. M., Miller, T. D., Ahn, J. J.,

Hatten, T. D. and Berryman, A. A. 2004. Complementary biocontrol of aphis by ladybird beetle *Harmonia axyridis* and the parasitoid *Aphelinus aschis* on greenhouse roses. Biological Control, 30: 229-235.

- Takabayashi, J., Dicke, M., Takabayashi, S., Posthumus, M. A. and van Beek, T. A. 1994. Leaf age affects composition of herbivore – induced synomones and attraction of predatory mites. Journal of Chemical Ecology, 20: 373-384.
- Takizawa, T., Yasuda, H. and Agarwala, B. K.
 2000. Effects of parasitized aphids (Homoptera: Aphididae) as food on larval performance of three predatory ladybirds (Coleoptera: Coccinellidae). Applied Entomology and Zoology, 35 (4): 467-472.
- Tan, X., Hu, N., Zhang, F., Ramirez-Romeo, R., Desneux, N., Wang, S. and Ge, F. 2016. Mixed release of two parasitoids and a polyphagous ladybird as a potential strategy to control the tobacco whitefly *Bemisia tabaci*. Scientific Reports, 6: 28245. PMID 27312174 DOI: 10.1038/srep28245.
- Traugott, M., Bell, J. R., Raso, L., Sint, D. and Symondson, W. O. C. 2012. Generalist predators disrupt parasitoid aphid control by direct and coincidental intraguild predation. Bulletin of Entomological Research, 102: 239-247.
- Vet, L. E. M. and Dicke, M. 1992. Ecology of infochemical use by natural enemies in a tritrophic context. Annual Review of Entomology, 37: 141-172.
- Yano, E. 2005. Effect of intrguild predation and intraspecific completion among biological control agents in augmentative biological control in greenhouses. Second International Symposium on Biological Control of Arthropods; Riverside, USA, September 12-16, 2005.
- Zhu, J. and Park, K. C. 2005. Methyl salicylate, a soybean aphid-induced plant volatile attractive to the predator, *Coccinella septempunctata*. Journal of Chemical Ecology, 31 (8): 1733-1746.

برهم کنش بین گونهای (Orius albidipennis (Hymenoptera: Braconidae و Orius albidipennis (برهم کنش بین گونهای برای کنترل Aphidius colemani روی خیار گلخانهای

مهران عطارزاده'، على رجب پور'*، محمد فرخارى ً و آرش راسخ ً

۱- گروه گیاهپزشکی، دانشگاه علوم کشاورزی و منابع طبیعی خوزستان، ملاثانی، ایران. ۲- گروه زراعت و اصلاح نباتات، دانشگاه علوم کشاورزی و منابع طبیعی خوزستان، ملاثانی، ایران. ۳- گروه گیاهپزشکی، دانشکده کشاورزی، دانشگاه شهید چمران اهواز، اهواز، ایران. پست الکترونیکی نویسنده مسئول مکاتبه: rajabpour@ramin.ac.ir دریافت: ۴ مهر ۱۳۹۷؛ پذیرش: ۲۸ آذر ۱۳۹۷

چکیده: شته جالیز (Aphis gossypii Glover (Hemiptera: Aphidida) یک آفت مهم خیار به خصوص در شرایط گلخانهای به حساب می آید. کارایی رهاسازی هم زمان شکار گر عمومی خوار Aphidius یه حساب می آید. کارایی رهاسازی هم زمان شکار گر عمومی خوار (Hemiptera: Anthocoridae) و زنبور پارازیتویید تخصصی Orius albidipennis Reuter (Hemiptera: Anthocoridae) بررسی روی ترجیح این شکار گر بین شتههای پارازیته شده و پارازیته نشده انجام شد. علاوه براین، تولید پیام رسانهای شیمیایی بین این دشمنان طبیعی توسط آزمایشات بویایی سنجی صورت گرفت. در پیام رسانهای شیمیایی بین این دشمنان طبیعی توسط آزمایشات بویایی سنجی صورت گرفت. در این دشمنان طبیعی توسط آزمایشات بویایی سنجی صورت گرفت. در این دشمنان طبیعی توسط آزمایشهای بویایی سنجی مطالعه شد. نتایج نشان داد که شکار گر و دشمن طبیعی به صورت معنی داری به بوهای متصاعد شده توسط گیاهان خیار برای جلب می شدند. یافتههای ما نشان داد که هر دشمن طبیعی از بویی که بیانگر حضور دشمن رقیب درون رسته ای دیگرش است، اجتناب می کند. در کل این آزمایش ها نشان داد که این طبیعی عوامل می شدند. یافتههای ما نشان داد که هر دشمن طبیعی از بویی که بیانگر حضور دشمن رقیب درون کنترل بیولوژیکی خوبی علیه ایمانی در کل این آزمایش ها نشان داد که این دشمنان طبیعی از یک دیگر موجب می شود که رهاسازی هم زمان این شکار گر و زنبور پارازیتویید گزینه مناسبی برای کنترل موجب می شود که رهاسازی هم زمان این شکارگر و زنبور پارازیتویید گزینه مناسبی برای کنترل بیولوژیکاین شته نباشد.

واژگان کلیدی: سنهای شکارگر، زنبورهای پارازیتویید، رهاسازی همزمان، پیامرسانهای شیمیایی، بیوکنترل شتهها