

The impact of ant attendance on protecting *Aphis gossypii* against two aphidophagous predators and its role on the Intraguild Predation between them

Tahereh Karami-jamour¹ · Alinaghi Mirmoayed¹  · Abbasali Zamani¹ · Yadolah Khajehzadeh²

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Abstract In this study the changes in *Aphis gossypii* Glover populations tended by the homopteran- tending ant, *Tapinoma simrothi* Krausse when exposed to the natural enemies *Chrysoperla carnea* Stephens and *Coccinellia septempunctata* Mulsant was studied. We also studied the effect of ant's attendance on the consequence of intraguild predation (IGP) between these two predators. The presence of ants *T. simrothi* had deterrent impact on natural enemies of *A. gossypii* compared to control aphid populations in absence of ants. Equally we observed that IGP between two aphid predators decreased when *T. simrothi* was present. The lowest IGP level was observed when both aphids and ants were present in the microcosm arena. In the microcosm arena the presence of ants had an indirect effect on the occurrence of IGP. Our results suggest that although the mutualistic ants have an indirect impact on the IGP by aphidophages predators, but their roles should not be ignored.

Keywords Hemipteran · aphidophages · intraguild predation · mutualism · *Aphis gossypii* · *Tapinoma simrothi*

✉ Alinaghi Mirmoayed
alimirmoayed@gmail.com

Tahereh Karami-jamour
karami.tahereh65@yahoo.com

Abbasali Zamani
zamany_a55@yahoo.com

Yadolah Khajehzadeh
khajehzadeh1339@yahoo.com

¹ Department of Plant Protection, Faculty of Agriculture, Razi University of Kermanshah, P.O. Box 6715685414, Kermanshah, Iran

² Plant Protection Research Institute, Agricultural Research Center, P.O. Box 6134814534, Ahwaz, Khuzestan, Iran

Introduction

The cotton or melon aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae), is a highly polyphagous aphid species and is broadly distributed from tropical to temperate zones. Aphids of this species have been reported from 90 plant families, including important agricultural crops such as cotton, cucumber, melon, avocado, tomato, papaya, eggplant (Charaabi et al. 2008; Carletto et al. 2009; Ebert and Cartwright 1997). In temperate regions, they principally attack vegetables both in the fields and in greenhouses (Charaabi et al. 2008; Carletto et al. 2009; Satar et al. 1999). Damages caused by them include the curling up of leaves of host plants plus growth of black sooty mould fungus resulted from the production of honeydew by aphids. In addition, these aphids are efficient vectors of plant pathogenic viruses such as Cucumber Mosaic Virus (Ebert and Cartwright 1997). Several strategies of control were applied to reduce aphid outbreaks and economic damages caused by them, including the use of beneficial arthropods (Ebert and Cartwright 1997; Zarpas et al. 2007). One of the most famously used predator of aphids, coccids and mealy bugs was *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae). It was reported to be an efficient generalist predator in the past (Mirmoayedi 2001; Singh and Manoj 2000; Zaki and Gesraha 2001) and was widely used for aphid biocontrol (Venkatesan et al. 2000a, b) as well as other insect pests (Obrycki et al. 1989). Its success is due to its cosmopolitan and polyphagous nature, adaptability with selective insecticides and accountability for mass production (Ridgway et al. 1970; Ridgway and Murphy 1984; Uddin et al. 2005). Additionally, seven spotted ladybird beetle, *Coccinella septempunctata* Linnaeus (Coleoptera: Coccinellidae) is a well-known predator of aphid pests of cotton as well as other crops (Debaraj and Singh 1990; Nakamuta and Saito 1985; Nunez-Perez et al. 1992).

Although these beneficial insects have been successfully used as agents of biological control to reduce aphid populations in the past, but several new studies revealed that the activities of natural enemies should be hindered by other factors such as intraguild predation (IGP), cannibalism and hyperparasitism. The quality of a habitat or a patch generally should be diminished when other natural enemies use it simultaneously. For instance, ladybirds and green lacewings frequently co-occur both in space and time. Most studies have been reported that mutual IGP between natural enemies under laboratory and field conditions (Sengonca and Frings 1985; Lucas et al. 1998; Phoofole and Obrycki 1998). For example, Nedved et al. (2013) reported that the lacewing, *C. carnea* was a superior intraguild predator in larval stage despite its smaller body size, relative to an aggressive coccinellid, *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae). *C. carnea* larvae were also the most successful intraguild predator against larvae of the ladybird *Coleomegilla maculata* De Geer (Coleoptera: Coccinellidae), winning 89% and 63% of contests in petri dishes and microcosm with plant material, respectively (Noppe et al. 2012). Likewise, Rondoni et al. (2014) showed that *C. septempunctata* hunted *Hippodamia variegata* Goeze (Coleoptera: Coccinellidae) at a higher rate (70%) than the opposite (43%). *C. septempunctata* larvae equally displayed asymmetrical IGP upon *Adalia bipunctata* L. (Coleoptera: Coccinellidae), both in petri arenas as well as in semi-field experiments.

The term ‘intraguild’ was used in the past to describe the interspecific interaction between species that exploit shared limiting resources and are thus potential competitors. The incidence of this phenomenon among aphidophagous communities can

reduce the efficiency of biological control (Lucas 2005; Okuyama 2009). Moreover the presence of ants in greenhouses is generally considered as pest infestation because they tend honeydew-producing hemipterans like aphids, mealy bugs or soft scales and can increase hemipteran populations by intervening with the role of natural enemies (Beattie 1985; Ness and Bronstein 2004; Way 1963). Thus, biological control of hemipteran pest could be at risk due to the presence of ants which may prevent the role of natural enemies to control aphids and may cause direct mortality to them (James et al. 1999; Kaneko 2003; Katayama and Suzuki 2003; Mgocheki and Addison 2009).

The interaction between ants and hemipterans is a common and important ecological interaction (Stadler and Dixon 2005; Styrsky and Eubauks 2010). Ants and hemipterans are two highly *successful group* of organisms, which often live in the same place (Stadler and Dixon 2005); and interact frequently (Powell and Silverman 2010). In antagonistic interactions between ants and homopterans, ants get food from them, honeydews excreted by aphids, for example, are rich in carbohydrates and contain also amino acids, amides, proteins, minerals and B-vitamins (Way 1963; Carroll and Janzen 1973; Hölldobler and Wilson 1990).

In contrast, the homopteran receives a number of benefits due to the mutualistic relationship with ants. The ants protect their partners from predators and parasitoids (Cushman and Whitham 1989; Daane et al. 2007; Muller and Godfray 1999; Morales 2000; Powell and Silverman 2010) and in return, the homopteran will acquire increased development rate, production of honeydew, adult body size, fecundity and reproductive rate (Bach 1991; Bishop and Bristow 2003; Bristow 1984; Katayama and Suzuki 2002; Stechmann et al. 1996; Yao et al. 2000; Way 1963). The degree of protection myrmecophilous aphids against aphidophages differs and depends on the potential level of aggressiveness of ants, their colony size and organization of honeydew collection (Novgorodova and Gavrilyuk 2012; Novgorodova 2015). For instance, Novgorodova and Gavrilyuk (2012) studied the potential level of aggressiveness of six ant species towards larvae of ladybirds, lacewings and hoverflies in the laboratory. They pointed out that the degree of protection of myrmecophilous aphids from natural enemies depends both on the potential level of aggressiveness of ants and their foraging strategy when collecting honeydew. Moreover, they explained that *Formica* s. str. were the most aggressive and provided aphids with the highest degree of protection. Furthermore, Novgorodova and Gavrilyuk (2012) showed that ants usually drive away the quickly moving aphidophages or kill them (adult parasitic wasps and other insects) but do not pay attention to the slowly moving aphidophages (larvae of hoverflies and lacewings).

The homopteran gets direct benefits from the presence of ants, sometimes it may also negatively affect homopterans through predation and parasitism. Although ants protect homopteran population against their enemies, there are specialist predators or parasitoids that use the symbiotic relationship between aphids and ants, e.g. the specialist aphid parasitoid, *Lysiphlebus hirticornis* Mackauer (Hymenoptera: Braconidae: Aphidiidae) are often attacked by ants but successfully parasitize aphids by evading ants (Fischer et al. 2001). Moreover, the parasitoid females (*Lysiphlebus cardui* Marshall (Hymenoptera: Aphidiidae)) have developed the ability for searching within ant-tended aphid colonies for oviposition and ant guards did not attack them. Likewise, the incidences of hyperparasitism reduced about 30% in the presence of ants

(Völkl 1992). Liere and Perfecto (2008) also explained that because of the waxy filaments of *Azya orbiger*a Mulsant (Coleoptera: Coccinellidae) larvae, the ant species *Azteca instabilis* F. Smith (Hymenoptera: Formicidae) were unable to effectively attack them, therefore the predation rate of *A. orbiger*a on the green coffee scale, *Coccus viridis* Green (Hemiptera: Coccidae), did not reduce in the presence of ants. Nevertheless, *A. instabilis* protected *A. orbiger*a from *A. orbiger*a's parasitoids (*Homalotylus shuvakhinae* Mayr (Hymenoptera: Encyrtidae)) by aggressive behaviour. In fact, the indirect positive effect for a mutualistic ant and a coccidophagous coccinellid was often observed. In this research we tried to distinguish whether the homopteran-tending ant, *Tapinoma simrothi* Krausse (Formicidae: Dolichoderinae), could have a greater positive impact on mutualistic homopteran via the impact of the ant species on homopteran natural enemies. This ant species is endemic in many countries across the world, spanning Africa, Asia and Europe. Besides, *T. simrothi* is also the most widespread species in different regions of Iran. They may also nest in the soil and seams of rocks at a distance of 20 m from the aphid's colony. *T. simrothi* use a relatively stable food source such as honeydew in nature. The workers collect honeydew from honeydew-producing insects (e.g., aphids, scale insects and mealybugs). The foraging behaviour of this species is known to depend on using chemical trails. They use predominately chemical trails to locate food resources. The pygidial (anal) gland serves as the source of the trail pheromones in the ant *T. simrothi*. When receiving high emission rates from a source, the ants respond by the use of their alarm. Actually they attack the source with raising abdomen and opening their mandibles. Several different factors limit the foraging activity of genus *Tapinoma* spp. These factors may include the species of ant, their colony size, available food resources, temperature ranges, humidity, time of the day and seasonality (Simon and Hefetz 1999; Barbani 2003; Novgorodova 2015).

Although we did not find records of mutualism of *T. simrothi* with homopteran and its impact on natural enemies of the latter in the literature, but we did find some reports about the mutualistic behaviour of other species of the genus *Tapinoma*. For example, Addicott (1979) explained that ant-aphid mutualism between *Tapinoma sessile* Say (Hymenoptera: Formicidae) and *Aphis varians* Patch (Hemiptera: Aphididae) had no clear positive impacts on aphid populations, therefore it may have a little effect on biocontrol agents of this aphid. Moreover, Powell and Silverman (2010) studied changes in populations of *A. gossypii*, tended by the North American native *T. sessile*, when exposed to natural enemies such as *C. carnea*, *Hippodamia convergens* Guer. (Coleoptera: Coccinellidae) and *Aphidius colemani* Viereck (Hymenoptera: Aphidiidae). In a field experiment, the number of *A. gossypii* on plants with *T. sessile* were greater than on plants without ants. Mansour et al. (2012) studied the interactions among the ant, *Tapinoma nigerrimum* Nylander (Hymenoptera: Formicidae) and the significant natural enemies of both the citrus mealybug, *Planococcus citri* Risso (Hemiptera: Pseudococcidae) and the vine mealybug, *Planococcus ficus* Signoret (Hemiptera: Pseudococcidae) in laboratory conditions. They pointed out that while the adults of *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) fought against *T. nigerrimum*, the predatory potential of *C. montrouzieri* larvae was significantly reduced as an impact of the presence of the mutualistic ants. The first objective of our study was to investigate IGP interactions in the laboratory between immature stages of *C. carnea* and *C. septempunctata* and to verify the findings of previous studies about beneficial effects of symbiotic

relationships with homopteran enemies (Liere and Perfecto 2008; Volkl 1995). We investigated whether the mutualism between *T. simrothi* and *A. gossypii* have any positive or negative effects on IGP consequences between these two natural enemies. In addition we examined whether *T. simrothi* is capable of reducing aphid mortality due to predation. In invaded urban areas, *T. sessile* exhibits extreme polygyny and polydomy and becomes a dominant invasive pest, its colony have an annual fission-fusion cycle, and occupies one or a few nests during the winter. In a study on its nest forming, 119 ant nests were discovered in a 3.15 ha plot, 90 (76%) of which belonged to *T. sessile*. *Tapinoma sessile* exhibited strong colony connectivity as 78/90 (87%) of nests were connected to at least one other nest by a trail. Mean persistence time for *T. sessile* nests was 133 ± 5 days (Buczowski and Bennet 2008). Results obtained in another study on food collecting strategies of two species of ants, *Linepithema humile* and *Tapinoma sessile*, showed that in collecting honeydew from honeydew-producing hemipterans domination of local native ant species may reduce or eliminate competition for resources (Powell and Silverman 2010). Barbani indicated that odorous house ants (*Tapinoma sessile* (Say)) do not strongly discriminate between time of day or night when foraging (Barbani 2003).

Materials and Methods

Insect colonies

The cucumber plants (*Cucumis sativus* L. cv. ‘Superdominus’) used for this study were planted in plastic containers (10 cm diameter) under greenhouse conditions (25 ± 5 °C, 40–50% relative humidity and 14 L: 10D h). The plants were used in this study when they were 4–5 weeks old and have 3–4 true leaves. An aphid colony was collected from a cucumber field in the campus of Ahvaz Agricultural Research Centre, Ahvaz ($48^{\circ} 40'$ E, $31^{\circ} 19'$ N), Khuzestan province, south-western Iran. The colony was mass-reared on cucumber plants in wooden-framed cages ($120 \times 50 \times 50$ cm), conditions of rearing was similar to those described above. Aphids were transferred every four days to fresh cucumber plants. *T. simrothi*, was observed when the colony of aphid was kept on cucumber for 5–6 generation before we start the experiment. Each plant on which aphids were attended by the ants was kept in wooden-framed rearing cages ($50 \times 50 \times 80$ cm). The colony of aphids was attended by ants almost all the time.

Mass rearing of *C. septempunctata* was established for approximately 100 adults collected in spring in a cucumber field located in Ahvaz Agricultural Research Center. They have been maintained on cucumber plants infested with *A. gossypii*. The plants were kept in a similar wooden-framed cage as described above. Approximately ten plants were maintained in each cage and about five plants were replaced with fresh plants every week to maintain the culture. The wooden-framed cages were kept in the greenhouse in similar conditions as described above. Adults of *C. carnea* were collected from the wheat fields of Agricultural Research Center of Ahvaz and mixed sex (approximately 1:1) were placed in glass test tubes (18×2.5 cm). Mouths of test tubes were covered by the wet cotton for a good ventilation. These adults were fed on semisolid artificial diet comprising yeast, honey, sugar and water (1: 1: 1: 4). The diet was stuck on a

sheet of white paper horizontally in the adult rearing tube. Freshly laid eggs of *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) were placed into each vial as larval diet. These eggs were placed in a freezer to delay their hatching. *E. kuehniella* eggs were provided three times during the larval period before the cocoon formation. The stock culture of *C. carnea* was maintained in a climatic chamber at 25 ± 2 °C, $60 \pm 10\%$ RH and a 14 L: 10D h photoperiod.

The young instars of *C. septempunctata* and *C. carnea* have four and three larval stages respectively. The older life-stages (the fourth and third instar larvae of *C. septempunctata* and *C. carnea*, respectively) were chosen in case of both predators since they were more effective on aphids than younger ones (Table 1). The larvae of the two predators were tested within 24–36 h after moulting to obtain individuals of similar ages. The larvae were starved for 12 h before they were introduced into the feeding arena. For all experiments, each predator larva was used only once.

Study conditions

All experiments were conducted in a climatic chamber at 25 ± 2 °C, $60 \pm 10\%$ RH and with a 14 L: 10D h photoperiod (approximately 5000 lx).

Experimental set up

C. carnea vs. *T. simrothi*

The cucumber plants infested with 250 aphids of the 2nd instar nymphs of the melon aphid were introduced into a plexiglass cylinder (9 cm in diameter, 20 cm high), covered with mesh screen cloth. The cylinder was placed over a cucumber plant approximately 15 cm tall, with four to five fully developed leaves, then five ants were allowed to forage on cucumber plant to adjust with experiment arena 24 h before the experiment. After this period, two treatments of introduction of lacewing larvae were considered. In the first treatment 1 L3CC and in the second treatment 3 L3CC were introduced into the plastic container. The predators, ants, and aphids were allowed to interact with each other for the next 24, 48 and 72 h. After 24, 48 and 72 h, the number of live aphids and the presence or absence of predators and ants were recorded for each container. Five control treatments were chosen: (1) one and three *C. carnea* larvae in the presence of melon aphids and absence of mutualistic ants; (2) one and three *C. carnea* larvae in the presence of ants and absence of melon aphids and (3) three *C. carnea* larvae in absence of mutualistic ants and melon aphids. All treatments were replicated 10 times.

Table 1 Abbreviated names for instars of predators larvae used in our study

Abbreviated names	What does it stands for
L4CS	4th instar larvae of the seven spotted ladybird
L3CC	3rd instar larvae of green lacewing
L4CS + L3CC	4th instar larvae of ladybird +3rd instar larvae of lacewing

C. septempunctata vs. *T. simrothi*

This treatment was conducted following the same pattern and protocol as the previous bioassay, but using *C. septempunctata* as a predator agent. In addition we have used L4CS in this experiment. Ladybeetle and lacewing larvae were chosen because they were common and abundant predators that consume large numbers of aphids in the fields infested with aphids.

C. carnea vs. *C. septempunctata* and *T. simrothi*

To study the differential effect of ant mutualism on interactions between the two predators, a second bioassay with new protocol was performed. In this treatment the cucumber plants infested with 250, 2nd instar nymph of the melon aphid. Five ants were allowed to forage on cucumber plant to adjust with experiment arena 24 h before the start of the experiment. After this period, a single L3CC was released onto one of the oldest leaves on the plant, while one L4CS was already placed on the stem of the same plant. These two life-stages were selected because they were the most likely to occur simultaneously in the aphid colonies during their developmental period in spring (personal observation), besides in *C. septempunctata*, fourth instar larvae and in *C. carnea*, third instar larvae are the most voracious larval instars. The predators, homopteran-tending ants and aphids were allowed to interact with each other for the next 24, 48 and 72 h. After each 24-h period, predators were recovered, observed under the stereo microscope and the occurrence of IGP was determined. It is possible to distinguish natural mortality from intraguild predation and cannibalism by observing the evidence of consumption of the IG prey. Moreover, the numbers of alive aphids and the presence or absence of ants were recorded. Five control treatments were used: (1) aphid mortalities in the absence of predators and ants; (2) aphid mortalities in presence of mutualistic ants and absence of predators; (3) consumption of aphids in the presence of two predators, but in absence of ants; (4) predators mortalities in presence of ants and absence of aphids and (5) predators' mortalities (IGP) in absence of ants and melon aphids. All treatments were replicated 10 times.

Statistical analysis

A generalized linear model (GLM) was run to test the effects of the different combinations of aphids and predators, various exposure times (24, 48 and 72 h) and the presence or absence of ants on the mean numbers of live aphids per treatments. Dependent variables required to perform a one-way ANOVA, if treatment interactions were not significant and means were compared by the Tukey's honest significant difference (HSD) test. In addition, the method described by Lucas et al. (1998) was used to calculate symmetry levels of IGP and levels of cannibalism (CANN). In present study, we considered levels as the results of dividing the replicates with IGP and CANN by the total number of replicates and symmetry was calculated as the results of counting the number of eaten predators in a specific treatment and dividing it by all the treatments in which there was an IGP. A symmetry of more than 0.5 was indicative that *C. carnea* was the most successful predator, while a symmetry of less than 0.5

pointed out that *C. septempunctata* was the most efficient predator. To test whether the symmetry differed significantly from 50%, a chi-square test (χ^2) was performed. SPSS (2007) was used also for necessary calculations.

Results

Aphid survival experiment

The mean numbers of live aphids varied with both different combinations of predators-aphids and presence or absence of ants (Fig. 1). GLM results showed that the interaction of ‘time \times different combinations of predators and aphids \times ant’ ($F = 0.230$; $df = 10, 330$; $P = 0.993$), ‘ant \times time’ ($F = 0.533$; $df = 2, 330$; $P = 0.587$) and different combinations of predators and aphids \times time’ ($F = 1.842$; $df = 10, 330$; $P = 0.056$) on the number of surviving aphids were not significant. However the interactions of different combinations of predators and aphids \times ants were significant ($F = 3.041$; $df = 5, 330$; $P = 0.011$). Moreover the results indicated that the effect of different times ($F = 13.208$; $df = 2, 330$; $P = 0.001$), the presence or absence of ants ($F = 18.196$; $df = 1, 330$; $P = 0.001$) and different combinations of predators and aphids ($F = 281.557$; $df = 5, 330$; $P = 0.001$) on the number of surviving aphids were significant.

After 24, 48 and 72 h in ants excluded treatments, the highest aphid survival rate was obtained in treatment with 1 L3CC and combination treatment (L3CC + L4CS) and the lowest aphid survival rate was seen in treatments with 3 L4CS, 3 L3CC, and 1 L3CS.

Moreover when symbiotic ants were added to these treatments the aphid survival rates were increased compared to the same treatments in absence of ant for the same time durations (24, 48 and 72 h). According to (Fig. 1) in the experiment with symbiotic ants the maximum of survived aphids was observed in 1 L3CC and 1 L3CC + 1 L4CS treatments and the lowest aphid survival rate was seen in treatments with 3 L4CS, 3 L3CC, and 1 L3CS after 24, 48 and 72 h. In addition, the maximum effect of ant-aphid interaction was found in the treatment which included two predators in combination (L3CC + L4CS) (3.19% aphid survival rate in the treatment without ants vs. 24.4% in treatment with ants after 72 h).

Besides, the results showed us that the treatments in which one and three individuals of fourth instar larvae of *C. septempunctata* were present, the predators did consume more nymphal stages of *A. gossypii* than in any other treatments. Furthermore in the experiment with coccinellid larvae more aphids were found alive when *C. septempunctata* larvae were placed in treatment with ant presence and combination treatment (L3CC + L4CS) (with or without ants) compared to the treatment in which the aphids were present together with coccinellids in absence of ants for 24 h (Fig. 1). Actually, the presence of lacewings and ants have reduced the coccinellid predation rates by diminishing the searching ability of coccinellid larvae.

The impacts of mutualistic ants on cannibalism

These experiments were done to evaluate the effect of ants’ presence on the probability of incidence of cannibalism. According to Fig. 2, symbiotic ants could have a role on the survival rate of *C. carnea* in treatment with 3 L3CC. During the first day in this

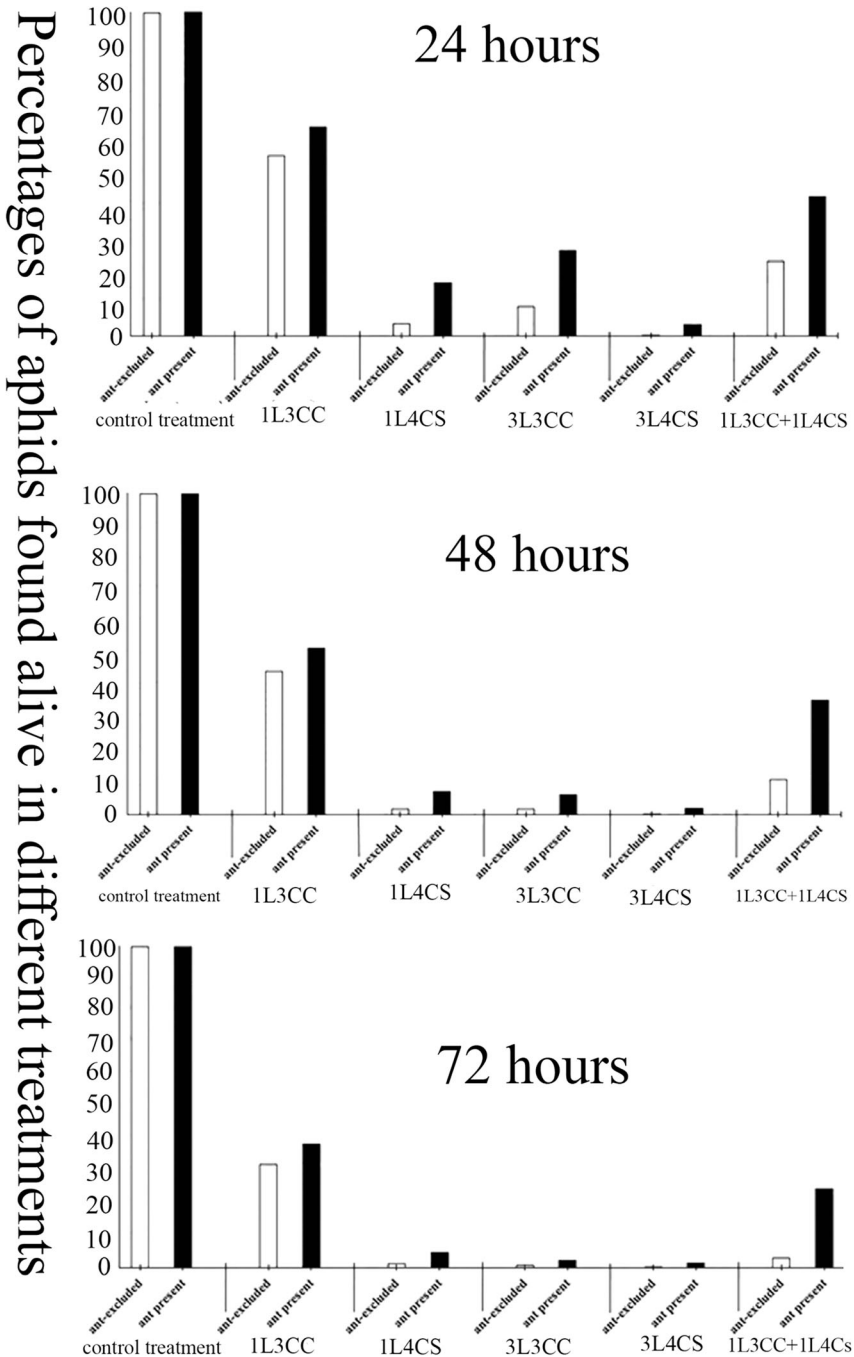


Fig. 1 The effect of ants presence on percentage of aphids found alive in different treatments after 24, 48 and 72 h. More aphids were found alive, when symbiotic ants were added to these treatments compared to the treatments in which the ants were absent. In this figure the effect of presence and absence of mutualistic ant on percentage of aphids found alive in six different treatments is indicated by black and white bars, respectively

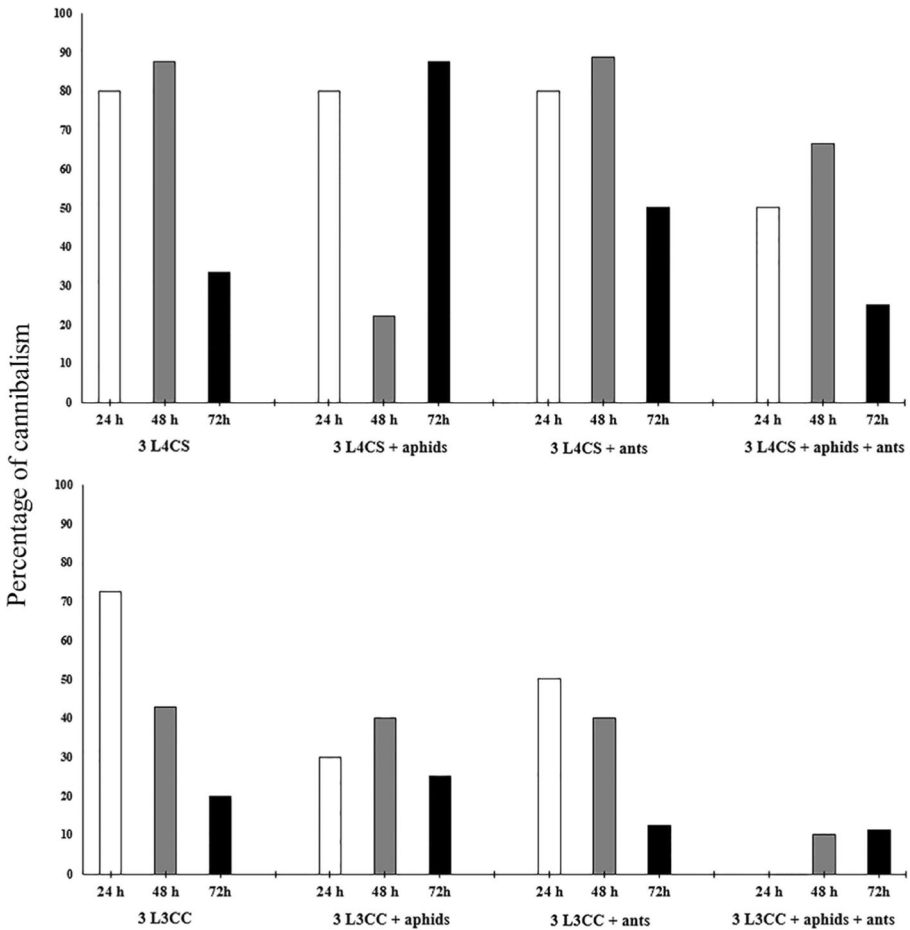


Fig. 2 The impact of the presence of ants and aphids on level of cannibalism (%) in different treatments after 24, 48 and 72 h. More cannibalism rate was found when 3 L3CC and 3 L4CS were placed in the treatment without extraguild prey (aphids) and symbiotic ants

treatment the highest cannibalism levels was observed in treatment without extraguild prey (aphids) and symbiotic ants. When aphid was added to these treatments, the cannibalism level decreased. In contrast when symbiotic ants were added to the experiment without aphids the cannibalism level decreased but the decrease was less than in treatments with aphids present. Moreover, when both symbiotic ants and extraguild prey was added to 3 L3CC treatments, cannibalism did not occur and the level of cannibalism was 0%, 24 h after the offering (Fig. 2). After 48 h, the level of cannibalism in treatments with 3 L3CC, 3 L3CC + aphids, and 3 L3CC + ants were 40%, but in treatment with 3 L3CC + aphids + ants, cannibalism level was 10% (Fig. 2). During the third day, the minimum cannibalism levels was observed in treatment with both extraguild prey and symbiotic ants (11.11%).

In other experiments with three L4CS, During the first day the level of cannibalism in treatments with 3 L4CS, 3 L4CS + aphids and 3 L4CS + ants were 80% but in treatment with 3 L4CS + aphids + ants, cannibalism was reduced to 50% (Fig. 2). After

48 h and 72 h, the minimum cannibalism levels were observed in treatments with 3 L4CS + aphids (22.2%) and 3 L4CS + aphids + ants (25.0%), respectively. Our results showed that, the presence of ants had a hindering impact on cannibalism, as it caused a reduction of the level of cannibalism in treatments with 3 L3CC + aphid and 3 L4CS + aphid after 24, 48 and 72 h, but in presence of ants, reduction in cannibalism was more in treatments with chrysopid larvae than treatments with coccinellid larvae.

Impact of mutualistic ants on intraguild predation

The levels of IGP between L3CC and L4CS are shown in Fig. 3. The presence of *T. simrothi* has negatively affected IGP incidence in treatments in which lacewing and ladybird beetle larvae were put on the cucumber plant. The results showed that significantly higher levels of IGP occurred in the ant-excluded treatments without extraguild prey after 24, 48 and 72 h, respectively. Concerning IGP interactions in microcosms in absence of extraguild prey and ants, the larvae of *C. carnea* were superior to *C. septempunctata* larvae. Adding aphids modified the IGP levels and asymmetry were reduced in presence of aphids. Over the first 24 h when the aphid densities were high, IGP occurred in four cases out of eleven replications (36.3%), and the ladybird larvae were more victorious than lacewing larvae. After 48 h, IGP level decreased and it has occurred only in one case of remaining seven pairs (14.3%). During the third day five pairs of predators were alive without any IGP (Fig. 3). It seems that decrease in hunger levels of larvae due to presence of extraguild prey (aphid) should decrease the larval forage for food, so led to decline of IGP levels.

Moreover, when ants added to the L3CC + L4CS treatment (without extraguild prey (aphid)), IGP has occurred in three cases out of ten replications after 24 h (30.0%) and within the second 24 h, it has occurred in two cases of remaining seven pairs (28.5%) and within the third 24 h, it has occurred in one case of the remaining five pairs (20.0%). It seems that the presence of ants have reduced the IGP levels by reducing the searching ability of lacewings and lady beetles larvae thus reducing their encounter rate on the leaf surface.

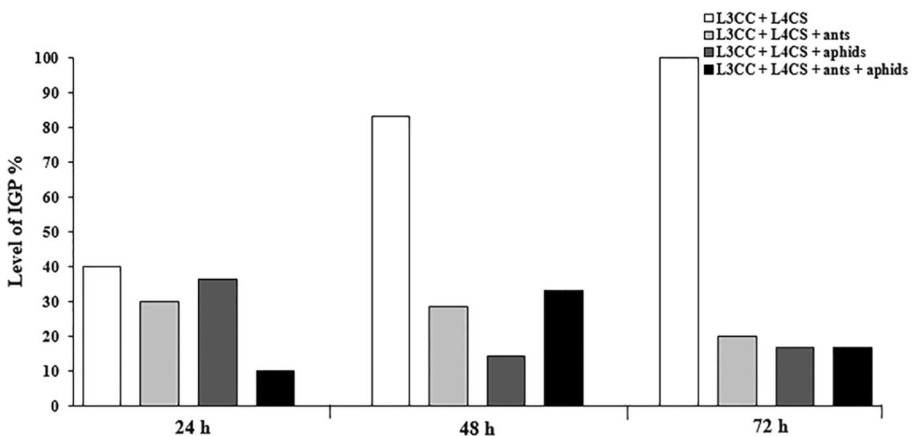


Fig. 3 The impact of the presence of ants on level of IGP (%) in microcosms, both in absence and presence of *T. simrothi* and *A. gossypii* after 24, 48 and 72 h. More IGP rate was found when combination treatment (L3CC + L4CS) was used in treatment without symbiotic ants and extraguild prey (aphids)

In addition the minimum IGP levels was observed in the treatment with both extraguild prey and symbiotic ants, 24 h after offering. In this treatment IGP occurred in one case out of ten pairs (10.0%). After 48 h, it occurred in three cases of the remaining nine pairs (33.3%), although during the third day, it decreased again and occurred only in one case of the remaining six pairs (10.0%) (Fig. 3).

The symmetry index of IGP between L3CC and L4CS is shown in Fig. 4. In the L3CC + L4CS treatment (without extraguild prey (aphid) and symbiotic ants), IGP was significantly asymmetrical ($\chi^2 = 4.0$; $P = 0.04$) during the first day, but afterward IGP was symmetrical in this treatment after 48 h ($\chi^2 = 0.2$; $P = 0.71$) and 72 h ($\chi^2 = 0.8$; $P = 0.38$). In interactions between L3CC and L4CS in presence of aphids, IGP was symmetrical after the first 24 h ($\chi^2 = 0.9$; $P = 0.35$), second 24 h ($\chi^2 = 0.9$; $P = 0.33$), and third 24 h ($\chi^2 = 0.9$; $P = 0.34$). In treatments with L3CC + L4CS + ants, IGP was symmetrical after 24 h ($\chi^2 = 0.3$; $P = 0.59$), 48 h ($\chi^2 = 1.8$; $P = 0.18$) and 72 h ($\chi^2 = 0.9$; $P = 0.34$). Moreover, IGP was symmetrical in the L3CC + L4CS treatment with extraguild prey (aphid) and symbiotic ants after 24 h ($\chi^2 = 1.0$; $P = 0.32$), 48 h ($\chi^2 = 2.7$; $P = 0.11$) and 72 h ($\chi^2 = 0.9$; $P = 0.34$).

Discussion

The results of this experiment showed that the presence of symbiotic ant had a significant impact on reducing the mortality rate of aphid in microcosms. In this regard many previous studies have shown that honeydew-producing homopteran receive reciprocal benefits through symbiotic relationships with ants. For instance, Kaplan and Eubanks (2002) reported that *S. invicta* inhibited *C. carnea*, *C. septempunctata* and *H. convergens* larval predation on *A. gossypii* in greenhouse condition. Moreover imported red ants has reduced the survival of lady beetles (*C. septempunctata* and *H. convergens*) and green lacewing larvae (*C. carnea*) by 92.9% and 83.3% respectively in greenhouse experiments. These

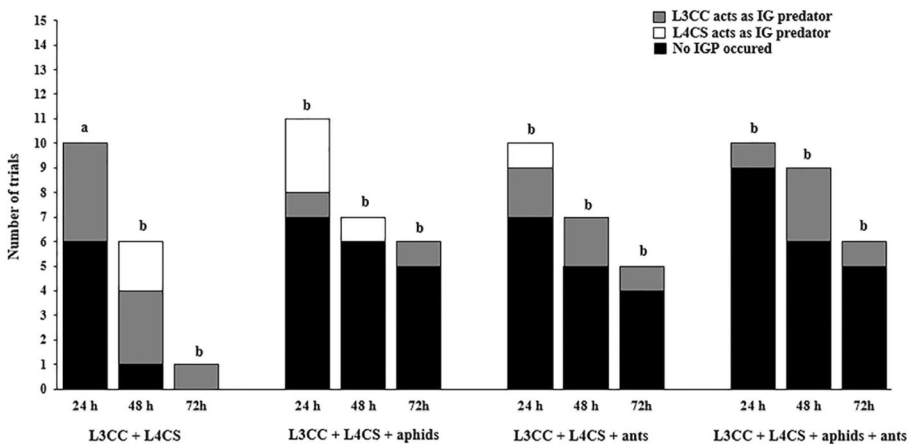


Fig. 4 The impact of the presence of ants on symmetry of IGP (%) in microcosms both in absence and presence of *T. simrothi* and *A. gossypii* after 24, 48 and 72 h. The following figures show that treatments marked as (a), IGP was asymmetric and treatments marked as (b), IGP was symmetric

results were similar to other studies in which the authors indicated that the imported fire ant *S. invicta* could reduce significantly the predation of natural enemies (Bugg and Dutcher 1989; Tedders et al. 1990; Hu and Frank 1996; Dutcher 1998).

Moreover, Harmon and Andow (2007) reported that when the relative density of *Lasius neoniger* Emery was high, it could have positive effect on aphid density and negative effect on the predation potential of the ladybirds (*C. septempunctata* and *H. axyridis* larvae). However when relative ant density was low ladybird's larvae foraged more effectively on *Aphis fabae* Scop (Hemiptera: Aphididae). Finlayson et al. (2009) studied the interactions between the species of lady beetles and the European fire ant (*Myrmica rubra* L.) tending potato aphids (*Macrosiphum euphorbiae* Thomas) in laboratory condition. According to the results of their study ants had a significant impact on reduction of the predation rates of *C. septempunctata*, *H. variegata*, *H. axyridis* and *C. maculata* on potato aphids. In addition, Feng et al. (2015) explained that the ant species *Tapinoma melanocephalum* Fabricius, improved the survival of an invasive mealybug, *Phenacoccus solenopsis* Tinsley, by defending it against parasitoids, *Aenasius bambawalei* Hayat.

Mansour et al. (2012) have expressed that they have observed antagonistic interactions between the ant *T. nigerrimum*, native to the Mediterranean basin and the main natural enemies of both the vine mealybug, *P. ficus*, and the citrus mealybug, *P. citri*, in laboratory conditions. They have pointed out that *T. nigerrimum* could significantly disrupt the predatory potential of the ladybird, *C. montrouzieri* larvae and the parasitism rates of the parasitic wasps *Anagyrus* sp. nr. *Pseudococci*(Girault) and *Leptomastix dactylopii* when attacking the citrus mealybug host. According to the results of our present study the most important impact of the presence of the ant species, *T. simrothi* on aphid populations was seen on the first day, although the predators have taken the presence of ants for granted and both predators have eaten higher percentages of aphids, the days afterwards. One of the possible reasons for reducing protection from the aphids probably is because of an increase in the hunger level of the predators and their aggressive behaviors to gain more aphids. Also some of *Tapinoma* species have lower aggressive behavior compared to many other ant species and thus they are less efficient to deter predators attack on homopteran aggregations. For instance Addicott (1979) explained that ant-aphid mutualism between *T. sessile* and *A. varians* had no clear positive effect on aphid populations and probably have little impact on the natural enemies of this aphid. Likewise, *T. sessile* were less aggressive than *Myrmica lobicornis* Emery (Hymenoptera: Formicidae) and *Myrmica americana* Weber (Hymenoptera: Formicidae) and thus *Myrmica* species were more efficient to deter predators from homopteran aggregations on New York ironweed, *Vernonia noveboracensis* L. (Family: Asteraceae) (Bristow 1984). Kaneko (2007) stated that the presence of two different symbiotic ants (*Lasius japonicus* Santschi (Hymenoptera: Formicidae) and *Pristomyrmex pungens* Mayr (Hymenoptera: Formicidae) together with lady bird *Scymnus posticalis* Sicard (Coleoptera: Coccinellidae) could rapidly reduce the number of aphids while in absence of those ants such reductions were not observed.

Moreover, Powell and Silverman (2010) studied the impact of presence of the Argentine ant, *Linepithema humile* Mayr (Hymenoptera: Formicidae) and the odorous house ant, *T. sessile* on *A. gossypii* accumulation exposed to three natural enemies, *H. convergens*, *C. carnea* and *A. colemani*. They explained that when plants had higher initial numbers of *A. gossypii*, the predator, *C. carnea* has reduced *A. gossypii* numbers in the absence or presence of ants *T. sessile* and *L. humile*. However, the decline in the population of *A. gossypii* were less in the presence of *L. humile* than when *T. sessile* were present, besides they have revealed that *H. convergens* could reduce aphid numbers both in absence of ants and or in presence of the ant species *T. sessile* but not in presence of *L. humile*. Therefore, the impact of the deterrence of *L. humile* on *H. convergens* predation was more than *T. sessile*. As various Coccinellid and Chrysopid species feed on common prey such as aphids, they should be found together in the same habitats (Hagen 1986; Majerus 1994) and because of their polyphagous behaviour these predators not only feed on prey but may feed on each other as well (i.e., IGP) to varying degrees depending on the predator and prey population densities (Fox 1975; Wilbur 1998). The results obtained in our study showed that IGP between two common predators was reduced when aphid populations were present in microcosm arenas. In this regard, several studies have investigated the effects of extraguild prey on an interaction between the natural enemies. In most cases, the presence of extraguild prey (depending on its density) has reduced the level of IGP and cannibalism. For example, Sengonca and Frings (1985) said that a great reduction in IGP between larvae of *C. carnea* and *C. septempunctata* was seen in presence of extraguild prey (*Acyrtosiphon pisum* Harris) (28 out of 144 mortality) compared to when aphids were not present (78 out of 144 mortality). Lucas et al. (1998) studied the impact of increasing aphid density on IGP among *C. rufilabris* and *C. maculata* larvae and concluded that the encounter rate between ladybirds and lacewings larvae reduced during the 24-h period in the presence of extraguild prey.

Moreover, Hindayana et al. (2001) investigated the interspecific interactions of the larvae of *Episyrrhus balteatus* de Geer with three other aphid predators, *C. septempunctata* L., *C. carnea* and *Aphidoletes aphidimyza* Rondani. The presence of extraguild prey has resulted in a three-fold reduction in the frequency of IGP. In our present study in the presence of aphids, predators spent more time for consuming aphids instead of moving around and as a result their encounter rate with each other and IGP has decreased.

The results obtained in our study showed that IGP between two common predators was reduced when aphid populations were associated together with the presence of symbiotic ants, *T. simrothi* and the lowest IGP levels were observed when aphids were simultaneously present in microcosm arenas together with ants, so the presence of ants should have an indirect effect on the occurrence of IGP. It seems that ants reduced the presence of predator's larvae at leaf area and their encounter rate with each other and consequently reduced the incidence of intraguild predation. On the other hand, predator searching efficiency has decreased in the presence of symbiotic ants in the microcosms.

There are several studies about the impact of presence of ants on directions of interaction between the natural enemies, e.g. IGP, cannibalism, hyperparasitism. In addition, myrmecophilous predators and parasitoids can potentially give ants an

additional benefit, namely enemy-free space by living near the ants (Majerus 1989; Völkl 1992; 1995). Völkl (1992) explained that when mutualistic ants (*Lasius niger* L. (Hymenoptera: Formicidae)) were present the aphid parasitoid, *L. cardui*, were less susceptible to hyperparasitism and Völkl (1995) also has found that the trophic mutualism between ants (*L. niger*) and aphids (*A. fabae*) could reduce the parasitism tolerated by *Platynaspis luteorubra* Goeze (Coleoptera: Coccinellidae). Similarly, Majerus (1989) found that *Coccinella magnifica* Redtenbacher (Coleoptera: Coccinellidae) were released from high predation pressures when spider populations were smaller in near vicinities of *Formica rufa* L. (Hymenoptera: Formicidae) nests. Kaneko (2002) also showed that ants attending the cotton aphid *A. gossypii* have protected the larvae of ant-adapted parasitoid *Lysiphlebus japonicus* Ashmead (Hymenoptera: Aphidiidae) within mummies of aphids in which hyperparasitoids and intraguild predators such as the Asian ladybeetle, *H. axyridis* were present simultaneously. Takizawa and Yasuda (2005) revealed that mutualistic ants *L. japonicas* had a positive indirect interaction on the survivorship of *S. posticalis* by reducing the opportunity of IGP of *C. septempunctata* larvae. Liere and Perfecto (2008) explained that ladybird *A. orbigera* larvae gained protection toward the mutualistic ant *A. instabilis* due to the presence of sticky waxy filaments, therefore the predation rate of *A. orbigera* on the green coffee scale *C. viridis* did not diminish in presence of ants. Nevertheless *A. instabilis* showed violent behavior towards parasitoids of *A. orbigera* (*H. shuvakhinae*) and the presence of ants reduced the parasitism suffered by *A. orbigera*. In fact there was an indirect positive impact for a mutualistic ant and a coccidophagous coccinellid. In contrast, Frazer and van den Bosch (1973); Van den Bosch et al. (1979) studied the impact of the presence of *Trioxys pallidus* Holiday (Hymenoptera: Aphidiidae) on the walnut aphid *Chromaphis juglandicola* Kaltentbach (Hemiptera: Aphididae) and found no significant impact of the presence of ant *Iridomyrmex humilis* Mayr (Hymenoptera: Formicidae) on parasitism and hyperparasitism rates of parasites on aphids. Our study suggests that the presence of mutualistic ants together with two important predators had an influential role in leading the interactions between these predators and their prey. According to the results of our study the symbiotic ants has protected the melon aphids and on the other hand it has protected predators by reducing cannibalism and IGP. In fact the main role of ants was to protect the aphids which as a result of this protection indirectly reduced IGP and cannibalism among predators. On the other hand the presence of the ant-tended aphid cannot be useful in the case of the combined use of predators for the biological control. The reason is clear, although the intensity of cannibalism and IGP decreased in the presence of symbiotic ants, at the same time, the effectiveness of predators in controlling the population of the aphids has decreased as well. We believe that our experiments opened a way for more studies to reveal unknown mechanisms pertaining potentially existing IGP between ants, predators and their prey.

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