Biological Control 126 (2018) 7–14

Contents lists available at ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

Intraguild predation between two aphidophagous coccinellids, *Hippodamia variegata* (G.) and *Coccinella septempunctata* L. (Coleoptera: Coccinellidae): the role of prey abundance

Muhammad Hamayoon Khan*, Zeynep Yoldaş

Ege University, Department of Plant Protection, Izmir 35100, Turkey

ARTICLE INFO

Keywords:
Coccinella septempunctata
Hippodamia variegata
Intraguild predation
Prey abundance
Preference

ABSTRACT

Intraguild predation (IGP) is a common phenomenon among the predacious coccinellids which involves a combination of predation and competition. The aphidophagous predators, *Coccinella septempunctata* L. and *Hippodamia variegata* (G.) comprise major part of coccinellid predator species in the agroecosystem of Turkey. We investigated the IG interactions between these aphidophagous predators under laboratory conditions. Our results revealed that predation of the eggs of *H. variegata* by the adult male, female and 4th instar larvae of *C. septempunctata* was maximum at 0 prey abundance, however, substantial number of eggs were also consumed at aphid densities of 30 and 80. Consumption of 1st and 2nd instar larvae was also higher in the absence of aphids, intermediate at 80 aphid density and greatly reduced or almost negligible at 350 prey abundance. The same sequence was also true for the predation of the different juvenile stages of *C. septempunctata* by *H. variegata* adult male, female and 4th instar larvae. The adult female and 4th instar larvae of both *C. septempunctata* and *H. variegata* proved to be more voracious towards different heterospecific juvenile stages compared to adult male. Results on the preference of *C. septempunctata* and *H. variegata* towards conspecific or heterospecific eggs revealed that both the aphidophagous coccinellids showed higher degree of preference for egg cannibalism (conspecific egg consumption) over IGP (heterospecific egg consumption).

1. Introduction

Most of the predacious coccinellids share similar food and space at different periods of their life cycles (Hodek and Honek, 1996; Lucas et al., 1998, 2009; Felix and Soares, 2004). The extraguild prey of these predaceous coccinellids have an aggregated distribution in time and space leading to their aggregation at one point and hence the intraguild interactions are likely to happens (Agarwala and Yasuda, 2001; Lucas et al., 2002; Howe et al., 2015; Rocca et al., 2017). Intraguild interaction between two predators may be intraguild predation or parasitism, which involves killing or eating of a potential competitor by one species (Polis et al., 1989; Felix and Soares, 2004; Rondoni et al., 2014; Howe et al., 2015; Rocca et al., 2017), exploitative competition, where competition occurs through the consumption of a declining essential resource (Grover, 1997), interference competition, in which competition takes place when activities of one species limits the access of another species to a diminishing essential resource (Ridenour and Callaway, 2001) and apparent competition, in which competitors share a common natural enemy. Of these interactions, intraguild predation (IGP) is the most common interaction that frequently occurs among coccinellid predators.

IGP is known to be triggered frequently by nutritive needs such as periods of extraguild food shortage or scarcity of alternate prey and lower nutritive value of the natural food (Agarwala and Dixon, 1992; Lucas et al., 2009; Rocca et al., 2017). The intensity of IGP decreases as extraguild prey density increases (Lucas et al. 1998; Hindayana et al., 2001; Yasuda et al. 2004). Furthermore, an increase in extraguild prey density can generate a dilution effect protecting furtive intraguild prey (Lucas and Brodeur 2001). This implies that the frequency and direction of IGP seems to be highly related to the prey abundance (Polis et al., 1989; Evans, 1991; Dong and Polls, 1992; Agarwala and Dixon, 1992). However, it is also important to mention that IGP involving coccinellids is common in the field even at high extraguild prey densities (Gardiner and Landis 2007). This may be due to high probability of encounters between the guild members providing grounds for high IGP intensity (Noia et al. 2008).

The IGP may be asymmetrical where a generalist predator attack intraguild prey of smaller size (Polis et al., 1989; Polis and Holt, 1992;

* Corresponding author.
E-mail address: mhkhan170@gmail.com (M.H. Khan).

https://doi.org/10.1016/j.biocontrol.2018.07.011
Received 15 February 2018; Received in revised form 9 June 2018; Accepted 17 July 2018
Available online 18 July 2018

Lucas et al., 1998) as smaller individuals being more vulnerable to bigger predators (Werner and Gilliam, 1984; Lucas et al., 1998; Obrycki et al., 1998). The adults and older larva (third and fourth) are usually stronger intraguild predators compared to younger stages. An encounter of younger larva or eggs with older larvae or adults often results in antagonistic interactions. However, mobility of the guild members also influences the occurrence of IGP as IG prey with greater mobility power can easily escape IGP (Edmunds, 1974; Lucas et al., 1998).

C. septempunctata and *H. variegata* population comprise major part of coccinellid predator species present in the croplands. Most of the times, they can be seen simultaneously in the fields sharing common prey that leads to frequent IG associations between these two predators (Aleosfoor et al., 2014). The eggs usually appear to be the more vulnerable stage in IG interactions between *C. septempunctata* and *H. variegata* (Agarwala, 1991; Hodek and Honek, 1996). However, it has also been reported that eggs contain toxic alkaloids that have role in defensive mechanism against intraguild predation (Daloze et al., 1995; Hemptinne et al., 2000; Agarwala and Yasuda, 2001). The ability of a predator to detoxify the toxic chemicals and alkaloids present in intraguild prey after ingestion decides its potential for IGP (Kajita et al., 2010).

C. septempunctata is a highly voracious predator and is bigger than *H. variegata*, it was assumed that the former species will be a powerful IG predator of different stages of *H. variegata* and that the latter being smaller may not be able to predate effectively on different developmental stages of *C. septempunctata*. For conclusive results, we investigated the intensity of IGP between these coccinellids predators at different aphid densities and also their preference for IGP or cannibalism.

2. Materials and methods

2.1. Rearing of pea Aphid, Acyrthosiphon pisum (Harris)

The pea aphids were collected from alfalfa and clover and brought to the laboratory. Rearing was maintained on broad bean plants, *Vicia faba* L. planted in sterile soils in 500 ml pots under laboratory conditions (22 ± 1 and 65 ± 5% RH).

2.2. Rearing of Coccinella septempunctata L. and Hippodamia variegata (G).

Adults of *C. septempunctata* and *H. variegata* were collected from different plants in the experimental farm of Ege, University Izmir, Turkey and brought to the laboratory. Adults of both the predator species were transferred separately to plastic jars (height 20 cm, diameter 15 cm) with ventilation holes, two on the sides and one in the lid screened with fine mesh. These jars were kept in wooden framed cages (100 × 70 × 75 cm) having controlled light system for provision of 16 h L: 8 h D photoperiod. The natural hosts (*A. pisum*) were provided regularly on respective host leaves. The eggs laid by females of *C. septempunctata* and *H. variegata* in the respective jars were collected and transferred to other jars for hatching. Similarly, the larvae emerged from eggs were then transferred to plastic jars (separate for each species) with abundant supply of aphids on host leaves. The rearing was maintained at 24 ± 1 °C,65 ± 5% RH and 16 h L: 8 h D photoperiod.

2.3. Intraguild predation (IGP) responses between C. septempunctata and H. variegata

To find out the IGP between *H. variegata* and *C. septempunctata*, 12–15 days old adults (male and female) and fresh fourth-instar larvae of either *C. septempunctata* or *H. variegata* were collected from stock culture and kept individually in clean dry Petri dishes (12 cm diameter) in order to starve them for 12 h to induce a constant level of hunger (Yasuda et al., 2001).

Each 4th instar larvae and adult male and female of *C. septempunctata* was offered with 160 heterospecific eggs (*H. variegata* eggs) alone, 160 heterospecific eggs in combination with 30 aphids, 160 heterospecific eggs in combination with 80 aphids (*A. pisum*), 80 heterospecific first instar larvae alone, 80 heterospecific 1st instar larvae together with 80 aphids, 80 heterospecific 1st instar larvae together with 350 aphids, 50 heterospecific 2nd instar larvae alone, 50 heterospecific 2nd instar larvae along with 80 aphids, 50 heterospecific 2nd instar larvae along with 350 aphids. These treatments were replicated 8 times.

The IGP responses of *H. variegata* towards *C. septempunctata* was investigated by offering each adult male, female and 4th instar larvae of *H. variegata* with 60 heterospecific eggs (*C. septempunctata* eggs) alone, 60 heterospecific eggs in combination with 20 aphids, 60 heterospecific eggs in combination with 50 aphids (*A. pisum*), 35 heterospecific first instar larvae alone, 35 heterospecific 1st instar larvae together with 80 aphids, 35 heterospecific 1st instar larvae together with 350 aphids, 20 heterospecific 2nd instar larvae alone, 20 heterospecific 2nd instar larvae along with 80 aphids, 20 heterospecific 2nd instar larvae along with 350 aphids. These treatments were replicated 10 times. The Petri dishes were inspected after 24 h and observations on the intraguild predation and aphid consumption were recorded. The experiments were performed in a controlled environmental chamber (24 ± 1 °C, 65% ± 5% RH, and 16 h L: 8 h D photoperiod).

In order to investigate the preference of *C. septempunctata* and *H. variegata* for conspecific (cannibalism) or heterospecific (IGP) eggs, the adult male and female (12–15 days old) of *C. septempunctata* or *H. variegata* were collected from stock culture in clean petri dishes (12 cm) and kept starved for 24 h to induce same level of hunger. Known number of conspecific (cannibalism) and heterospecific (IGP) eggs were transferred to each of these petri dishes containing starved predators (n = 10). Data on the consumption of conspecific and heterospecific eggs were recorded after 6 and 24 h interval in order to find out the preference of predators for cannibalism or IGP.

2.4. Statistical analysis

Data recorded on various experiments regarding IGP between the two coccinellid predators were subjected to analysis of variance (one-way ANOVA). Multiple comparison among the means was made using post hoc Duncan's Multiple Range test or Tukey's HSD test ($P < 0.05$).

Feeding preference of ladybird beetles between heterospecific and conspecific eggs was evaluated using Manly's preference index (Manly et al., 1972; Chesson, 1984).

$$\alpha = \frac{\ln[(n_1 - r_1)/n_1}{(\ln(n_1 - r_1)/n_1) + \ln(n_2 - r_2)/n_2]}$$

where α indicates selectivity for prey (Manly's preference index), n_1 and n_2 = number of prey type 1 and 2 respectively (conspecific or heterospecific eggs) offered to predators and r_1 and r_2 = number of prey type 1 and 2 eaten in 24 h by the predators. This method takes into account the depletion in prey density due to predation during the experiment (Sherratt and Harvey, 1993). Manly's index gives values between 0 and 1, where 1 indicates an absence of prey 2 from the diet, 0.5 indicates no selectivity for either prey (no preference). Whereas a value larger than 0.5 indicates a preference for Type 1 prey and smaller than 0.5 indicates a preference for Type 2 prey. Preference results of each predator were compared using independent sample t-tests.

3. Results

3.1. Predation rate of C. septempunctata on H. variegata at different aphid densities

Results on the predation rate of adult male of *C. septempunctata* on