Biological Control 79 (2014) 1–7

Contents lists available at ScienceDirect

Biological Control

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

Increased control of thrips and aphids in greenhouses with two species of generalist predatory bugs involved in intraguild predation

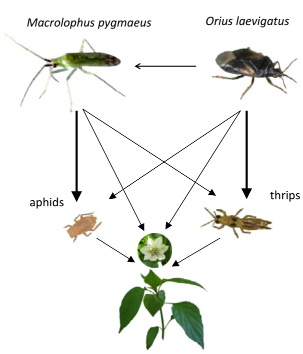
Gerben J. Messelink [a,*], Arne Janssen [b]

[a] Wageningen UR Greenhouse Horticulture, PO Box 20, 2265 ZG Bleiswijk, The Netherlands
[b] IBED, Section Population Biology, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands

HIGHLIGHTS

- We evaluated the co-occurrence of two generalist predators in a sweet pepper crop.
- The predators coexisted in a crop with low densities of pests for 8 months.
- The predators complemented each other in the control of thrips and aphids.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 13 January 2014
Accepted 21 July 2014
Available online 30 July 2014

Keywords:
Orius laevigatus
Macrolophus pygmaeus
Biological control
Coexistence
Intraguild predation
Frankliniella occidentalis
Myzus persicae

ABSTRACT

The combined release of species of generalist predators can enhance multiple pest control when the predators feed on different prey, but, in theory, predators may be excluded through predation on each other. This study evaluated the co-occurrence of the generalist predators *Macrolophus pygmaeus* Rambur and *Orius laevigatus* (Fieber) and their control of two pests in a sweet pepper crop. Both predators consume pollen and nectar in sweet pepper flowers, prey on thrips and aphids, and *O. laevigatus* is an intraguild predator of *M. pygmaeus*. Observations in a commercial sweet pepper crop in a greenhouse with low densities of pests showed that the two predator species coexisted for 8 months. Moreover, their distributions in flowers suggested that they were neither attracted to each other, nor avoided or excluded each other. A greenhouse experiment showed that the predators together clearly controlled thrips and aphids better than each of them separately. Thrips control was significantly better in the presence of *O. laevigatus* and aphid control was significantly better in the presence of *M. pygmaeus*. Hence, combined inoculative releases of *M. pygmaeus* and *O. laevigatus* seem to be a good solution for controlling both thrips and aphids in greenhouse-grown sweet pepper. The predators are able to persist in one crop for a sufficiently long period and they complement each other in the control of both pests. This study also provides further evidence that intraguild predation does not necessarily have negative effects on biological control.

1. Introduction

Generalist predators that feed on more than one species of prey have proven to be efficient biological control agents (Chang and Kareiva, 1999; Symondson et al., 2002; Messelink et al., 2008,

* Corresponding author. Fax: +31 10 52 251 93.
E-mail address: gerben.messelink@wur.nl (G.J. Messelink).

http://dx.doi.org/10.1016/j.biocontrol.2014.07.009
1049-9644/

2012). Because most crops are attacked by more than one species of pest, biological control programs, especially in greenhouse crops, are increasingly based on releases of generalist predators against common greenhouse pests such as thrips, whiteflies, spider mites, aphids and leaf miner moths (Gerson and Weintraub, 2007; Messelink et al., 2008; Urbaneja et al., 2009; van Lenteren, 2012). Moreover, the ability of generalist predators to survive and reproduce on non-pest food sources, such as pollen, nectar or plant sap, allows the release of these predators into the greenhouse system at the start of a cropping cycle when prey are scarce or absent (Ramakers and Rabasse, 1995; van Rijn et al., 2002). This can prevent population build-up and reinvasion of pests (Nomikou et al., 2010; Calvo et al., 2012).

Despite their broad diet spectrum, generalist predators do not always control all pests (Symondson et al., 2002) and other natural enemies are needed in such situations. One approach is to release several species of generalist predators for multiple pest control. However, generalist predators are often involved in competition for shared prey and predation upon each other (intraguild predation, IGP, Polis et al., 1989), which can affect both their coexistence and the results of biological control (Rosenheim et al., 1995; Rosenheim and Harmon, 2006; Janssen et al., 2006). Theoretical models of IGP with one predator (the intraguild predator) feeding on the other predator (the intraguild prey) with whom it competes for a shared prey, predict that stable coexistence of intraguild predator and intraguild prey is only possible when the intraguild prey is the superior competitor for the shared prey, and then only for intermediate levels of productivity (Holt and Polis, 1997). Hence, releasing pairs of generalist predators that are engaged in intraguild predation may result in the exclusion of one of the species, so there seems no reason to release both species (Janssen et al., 2006). However, the negative effects of IGP on species coexistence can be mitigated when the intraguild prey has a temporal refuge (Amarasekare, 2007), through spatial niche partitioning and habitat structure (Finke and Denno, 2006; Janssen et al., 2007) or through the presence of alternative prey (Daugherty et al., 2007; Holt and Huxel, 2007).

In this study, we evaluated the coexistence of two generalist predatory bugs *Macrolophus pygmaeus* Rambur (Hemiptera: Miridae) and *Orius laevigatus* (Fieber) (Hemiptera: Anthocoridae) in a sweet pepper crop with either plant-derived food (pollen and nectar) as a shared resource, or with both the plant-provided food and two prey species as shared resources. Anthocorid and mirid predatory bugs are important generalist predators used in greenhouse crops for conservation and augmentation biological control (Perdikis et al., 2011; van Lenteren, 2012). These predators are true omnivores, feeding on several trophic levels such as plant materials (pollen, nectar, plant sap), herbivores and other natural enemies (Coll and Ruberson, 1998). Sweet pepper pollen is a suitable alternative food source for both predator species (Cocuzza et al., 1997; Vandekerkhove and De Clercq, 2010) and both predators are commonly found in sweet pepper flowers (Messelink et al., 2011). Laboratory observations showed that *O. laevigatus* adults prey upon nymphs of *M. pygmaeus,* but not vice versa (Messelink, unpublished results), hence, *O. laevigatus* is the intraguild predator and *M. pygmaeus* the intraguild prey. This unidirectional intraguild predation was also found for the related *Orius majusculus* (Reuter) preying on *M. pygmaeus* (previously identified as *Macrolophus caliginosus*) (Jakobsen et al., 2004). The two prey used in the present study were the peach aphid *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) and the western flower thrips *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae), both important pests in sweet pepper (Ramakers, 2004). *O. laevigatus* is commonly used in sweet pepper, mainly for the control of thrips, but can also feed on aphids (Alvarado et al., 1997). *M. pygmaeus* is not commonly used in sweet pepper, but a promising natural enemy of aphids (Alvarado et al., 1997; Perdikis and Lykouressis, 2004; Messelink et al., 2011) and can also prey on thrips (Riudavets and Castañé, 1998). Differences in predation efficiency and prey preference of the two predators for the two different pest species may favour their coexistence (Daugherty et al., 2007; Holt and Huxel, 2007). Hence, the question is whether these two predators can coexist within the time-scale of one cropping cycle in a sweet pepper crop, and whether the control of the two pest species is affected by each other's presence. Persistence of the two predators was studied in a commercial sweet pepper crop in a greenhouse for a time period of 22 weeks at low pest densities. The control of aphids and thrips by both predator species together or by each predator species alone was studied in a separate greenhouse trial. The results of this study may help in developing strategies for multiple pest control in sweet pepper and may increase our understanding of interactions in food webs consisting of several generalist predators and multiple prey.

2. Materials and methods

2.1. Co-occurrence at low pest densities

Densities of the predators *O. laevigatus* and *M. pygmaeus* were followed in a commercial organic sweet pepper crop in a greenhouse of 3 ha in Tinte, The Netherlands. Sweet pepper plants cv. Spider were planted in the first week of January 2011. *O. laevigatus* was released shortly after planting at densities of 0.5 adult/m^2, whereas *M. pygmaeus* was not released deliberately, but came from a remaining population from a previous cultivation of a tomato crop in the same greenhouse. Densities of the predators were monitored at 16, 19 and 22 weeks after planting by counting adults and nymphs of the predators in 80 sweet pepper flowers in 4 randomly chosen rows of plants (20 flowers/row). These observations were carried out between 10:00 and 15:00 h. Pest densities remained low during this period. Thrips were not observed and emerging colonies of aphids (*M. persicae*) were controlled by the predators and through weekly releases of the parasitoid *Aphidius matricariae* Haliday (Hymenoptera: Braconidae) and the predatory midge *Aphidoletes aphidimyza* (Rondani) (Diptera: Cecidomyiidae), a common practice in organic sweet pepper crops. These specialised natural enemies of aphids did not establish because aphid colonies remained small and were quickly controlled. So we can ignore the possible interaction with the predators under study. Hence, the main food source for the predators during these observations was probably the pollen and nectar from the flowers. Co-occurrence of the two predator species under study was analysed using EcoSym (Gotelli, 2000; Gotelli and Entsminger, 2004). This software generates random co-occurrence matrices (5000 in our case) based on the existing co-occurrence matrix, to which they are subsequently compared. We randomized the occurrence of each species among the flowers, while keeping the total numbers of occurrences per species equal to those observed, and assuming that the occurrence of individuals in each flower as equally likely. This corresponds to a simple community assembly rule, with the two species colonising flowers independently (Gotelli, 2000; Gotelli and Entsminger, 2004). We evaluated the *C*-score (the so-called average number of "checkerboard units"), which, for 2 species *i* and *j*, is given by:

$$C = (r_i - S)(r_j - S)$$

(Gotelli, 2000), with *S* being the number of flowers containing both species, and r_i and r_j the total number of flowers with species *i* and *j*. When species exclude each other, the observed *C*-score will be significantly higher than the average *C*-score of the random co-occurrence matrices.