

## Biological Control of Aphids by the Predatory Midge *Aphidoletes aphidimyza* in the Presence of Intraguild Predatory Bugs and Thrips

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### Abstract

In organically grown sweet peppers, aphids are the most important pest. The wide range of natural enemies of aphids, that are commercially available, is not a guarantee for successful control but rather an indication that this problem is difficult to tackle. Strategies for control vary among organic growers and it is still not known which natural enemy complexes give the best results. When releasing natural enemies for aphid control, it is important to consider the possible interactions with other pest species and natural enemies present. Within man-made natural enemy communities for multiple pest control, direct and indirect interactions occur which can enhance or disrupt biological control, such as predators eating other predators, behavioural changes, plant responses or apparent competition. Here we investigated the effects of the generalist predatory bugs *Orius laevigatus* and *Orius majusculus* on biological control of green peach aphids, *Myzus persicae*, by the predatory midge *Aphidoletes aphidimyza* in the absence or presence of thrips. Our results showed that intraguild predation of aphidophageous midges by generalist predatory bugs is a realistic phenomenon, but the risk of disruption of aphid control seems to be limited. The addition of thrips and *O. majusculus* to predatory midges even enhanced the suppression of aphids. We conclude that a broad system view with predator-prey complexes is required for identifying successful natural enemy complexes for aphid control.

### INTRODUCTION

Aphids are the most destructive pest species in organically grown sweet peppers. The green peach aphid, *Myzus persicae* (Sulzer), especially the red phenotype, is notorious for its fast reproduction and tendency to colonize flowers and young leaves. This behaviour directly results in reduction in growth of the plant and fruit production. Moreover, the honeydew secreted by these aphids pollutes leaves and fruit, which consequently facilitates growth of sooty mould. Another damaging aphid species in sweet pepper is the foxglove aphid, *Aulacorthum solani* (Kaltenbach). This species typically induces strong plant responses such as yellow necrotic spots and leaf deformation, which can occur at low aphid densities. At higher densities, aphid-induced damage can result in leaf drop.

Biological control of these aphids is mainly based on weekly releases of the parasitoids, *Aphidius colemani* Viereck and *Aphidius ervi* Haliday, and the predatory midge, *Aphidoletes aphidimyza* (Rondani). Additionally, growers release the slower reproducing wasps *Aphelinus abdominalis* (Dalman) and chrysopid, syrphid or coccinellid predators. Despite releases of multiple natural enemies, biocontrol programs often do not succeed. One reason could be that these natural enemies interact with biocontrol agents that are released to control other pest species, such as generalist predatory mites and predatory bugs for the control of thrips. We recently showed that predatory mites strongly disrupt the biological control of aphids using the predatory midge, *A. aphidimyza*, because of hyperpredation of the midge eggs (Messelink et al.,

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2011). Another threat for predatory midges could be the predation by generalist Orius bugs, which are mainly used for controlling thrips. These predators are known to feed not only on thrips, but also on aphids and the aphidophagous predator *A. aphidimyza* (Christensen et al., 2002). Such interactions have been referred to as intraguild predation (Fig. 1), which occurs when one predator species (the intraguild predator) kills and eats another predator species (the intraguild prey) with whom it also competes for shared prey (Polis et al., 1989; Holt and Polis, 1997). In theory, intraguild predation can disrupt biological control (Rosenheim et al., 1995), but in practice, results are mixed (Janssen et al., 2006, 2007; Vance-Chalcraft et al., 2007). Here we examine the effects of *Orius laevigatus* (Fieber) and *Orius majusculus* (Reuter) on the biological control of aphids with predatory midges in the presence of thrips as an alternative prey for Orius. Furthermore, we discuss the role of species interactions in developing management strategies for aphid control in sweet pepper.

## MATERIALS AND METHODS

### Rearing

Sweet pepper plants, *Capsicum annuum* L. 'Ferrari' (Enza Zaden), were grown in rockwool blocks in a greenhouse compartment. We used the red phenotype of the green peach aphid, *M. persicae*, which was cultured on sweet pepper plants. Western flower thrips, *Frankliniella occidentalis* (Pergande), were cultured on flowering chrysanthemum plants, 'Mirimar'. The predatory midge, *A. aphidimyza*, and predatory bug, *O. laevigatus* (Fieber), were obtained from Koppert Biological Systems (Berkel en Rodenrijs, The Netherlands), whereas the predatory bug, *O. majusculus*, was obtained from Biobest NV (Westerlo, Belgium).

### Greenhouse Experiment

A cage experiment was carried out to assess the effects of predatory bugs on the suppression of aphids, in the presence of the predatory midge *A. aphidimyza*. Thrips were introduced to a subset of cages to provide an alternative prey for the predatory bugs. Individual flowering sweet pepper plants, ca. height 30 cm with 15–17 leaves, were put into a single cage (diameter 30 cm, height 40 cm, top with side-openings covered with insect gauze). Cages were placed on tables and maintained, at an average of 21°C, in one greenhouse compartment. The lower plant stem and roots in rockwool extended through a sealed hole at the bottom of the cages in order to allow automatic supply of a standard nutrient solution with an ebb-and-flow system. There were 8 treatments, with 4 replicates per treatment: (1) aphids only, (2) aphids + *O. laevigatus* + thrips, (3) aphids + *O. majusculus* + thrips, (4) aphids + *A. aphidimyza*, (5) aphids + *A. aphidimyza* + *O. laevigatus*, (6) aphids + *A. aphidimyza* + *O. majusculus*, (7) aphids + *A. aphidimyza* + *O. laevigatus* + thrips and (8) aphids + *A. aphidimyza* + *O. majusculus* + thrips. Each plant was infected with 20 aphids of mixed age, which were collected with a fine brush from the culture on sweet pepper. Adult thrips were introduced three times in the destined treatments in densities of 20, 20 and 40 females per plant after 1, 11 and 23 days post aphid release, respectively. Repeated releases of thrips were necessary because thrips proved to be controlled effectively. The predatory midge *A. aphidimyza* was introduced 10 days after aphid release by adding 10 pupae per cage in humid vermiculite. The adult midges emerged within 4 to 7 days, and no mortality of pupae was observed. Ten adult female predatory bugs were introduced 17 days after aphid release in each cage. The densities of all insects were assessed once, 28 days after aphid release, by checking all parts of each plant under a stereomicroscope (40x). For statistical analyses, we performed a standard ANOVA on the log transformed densities of insects. Differences among treatments were tested at the 5% level using Fisher's Least Significant Difference (LSD) method.

## RESULTS AND DISCUSSION

Densities of the predatory midge were significantly reduced ( $F_{4,19} = 4.14$ ,  $p = 0.019$ ) in the presence of predatory bugs, suggesting intraguild predation. For *O. majusculus*, this effect was only significant when thrips were also present (Fig. 2). We also observed dead and empty sucked midge larvae in the treatments with predatory bugs. The presence of thrips did not significantly affect the extent of intraguild predation by either *Orius* species (Fig. 2).

Aphid densities were also significantly affected by the treatments ( $F_{7,31} = 1.9593$ ,  $p < 0.001$ ). The addition of predatory bugs and thrips reduced aphid densities slightly, but the trend was not found to be significant. The predatory midge alone or when present with either *Orius* sp. showed a clear control of aphids (Fig. 3). The addition of *Orius* bugs to cages containing predatory midges did not result in significant increases of aphid densities (Fig. 3). The presence of thrips did not affect the combined effect of *O. laevigatus* and predatory midges on aphids. However, the presence of thrips significantly increased the control of aphids by *O. majusculus* and predatory midges compared with the combined treatment of these predators without thrips (Fig. 3). The composition of prey (aphids, thrips, midges) significantly affected the final densities of *O. majusculus* and *O. laevigatus* ( $F_{5,23} = 3.97$ ,  $p = 0.013$ ) (Fig. 4).

## DISCUSSION

In this study, we clearly demonstrate that both *O. majusculus* and *O. laevigatus* can significantly reduce densities of the aphid predator *A. aphidimyza*. The results with *O. majusculus* confirm earlier observations (Christensen et al., 2002). However, the observed intraguild predation in our study did not significantly disrupt the control of aphids by the predatory midge. It could be that reduced densities of midge larvae were not only counterbalanced by aphid predation by the predatory bugs, but also by increased predation rates of the remaining midge larvae because it has been observed that larvae of *A. aphidimyza* increase predation activity at higher prey-predator ratios (Markkula et al., 1979).

Although to date most studies on intraguild predation have not accounted for the effects of alternative prey, recent theoretical models have shown that the presence of alternative prey influence the effects of intraguild predation in various ways (Holt and Huxel, 2007). Thrips are a suitable prey for *Orius* bugs, but in the case of *O. laevigatus*, we could not detect any influence of thrips on intraguild predation. Surprisingly, we found improved control of aphids when thrips were added to the combined treatment of *O. majusculus* and predatory midges. Several underlying interactions might explain the results.

One explanation for a better control of aphids with predatory midges and *O. majusculus* in the presence of thrips could be that thrips increase *Orius* densities, which consequently can increase the predator's effects on aphids. Such a predator-mediated pest interaction has been referred to as apparent competition (Holt, 1977) and was shown to enhance pest control (Messelink et al., 2008). We did not find evidence for this effect in our study because we did not include control treatments with only predatory bugs and aphids. However, we observed increased densities of *O. laevigatus* with increased prey diversity, suggesting a positive effect of increased prey numbers on the reproduction of *Orius* bugs (ca. 90% of the final populations were juveniles). However, in the case of *O. laevigatus*, aphids were present in sufficient numbers (at least >50 aphids/predator) in all treatments. This suggests that increased reproduction might not only be caused by the presence of more food, but also by a better performance of the predators on a mixed diet. The lower final densities of *O. majusculus* in the treatment with predatory midges + aphids + thrips might be explained by food depletion because in this treatment aphids were suppressed to low numbers (Fig. 4).

In the treatments with thrips, another possible mechanism may have involved behavioural changes of the predatory bugs in presence of multiple prey; so-called trait-mediated effects (Prasad and Snyder, 2006). For example, it could be that the presence of

*A. aphidimyza* larvae increased the predation of predatory bugs on aphids by changing foraging activity. Other studies showed that the aphid predators *Harmonia axyridis* Pallas and *Coccinella septempunctata* L. ate more apple aphids when leafroller larvae were present (Lucas et al., 2004). Likewise, when provided with fruit flies, the carabid, *Bembidion lampros* (Herbst), ate more cereal aphids (Madsen et al., 2004). The generalist predators *Nabis* spp. ate significantly more aphids when eggs of the Colorado potato beetle were available, compared with an environment where there were no alternative prey present (Koss et al., 2004). We suggest that such mixed prey effects on predator behaviour and predator development deserve more attention in future research with generalist predators in greenhouses.

## CONCLUSIONS

Intraguild predation of aphidophagous midges by generalist predatory bugs is a realistic phenomenon, but the risk of disruption of aphid control seems to be limited. The addition of thrips and *O. majusculus* to predatory midges even enhanced the suppression of aphids. Thus, this predator seems to be a promising natural enemy for multiple pest control. For further development of biocontrol programs, we suggest the importance of evaluating natural enemies within a context of realistic communities of pests and predators. This broader view of a system will contribute in identifying natural enemy complexes that will control both aphids and thrips in crops.

## ACKNOWLEDGEMENTS

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## **Figures**

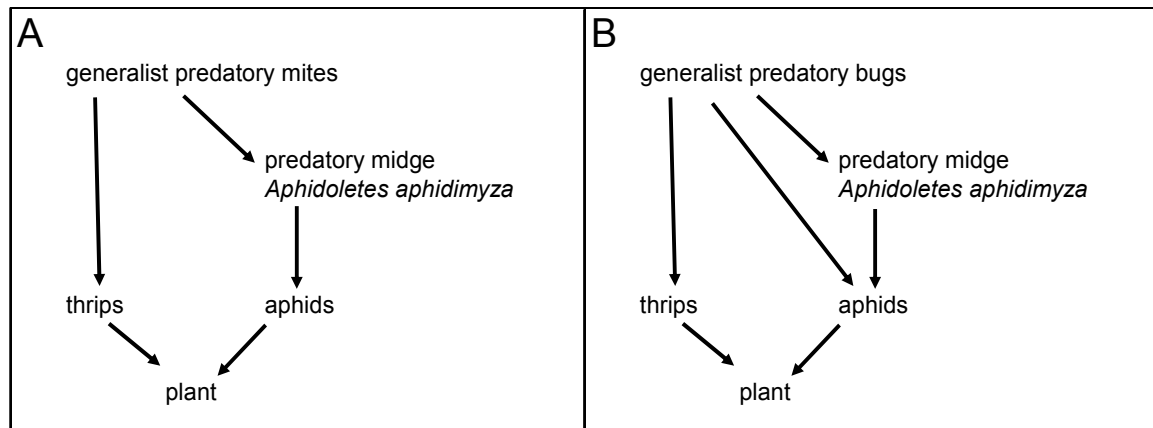


Fig. 1. Food webs showing the difference between hyperpredation (A) and intraguild predation (B).

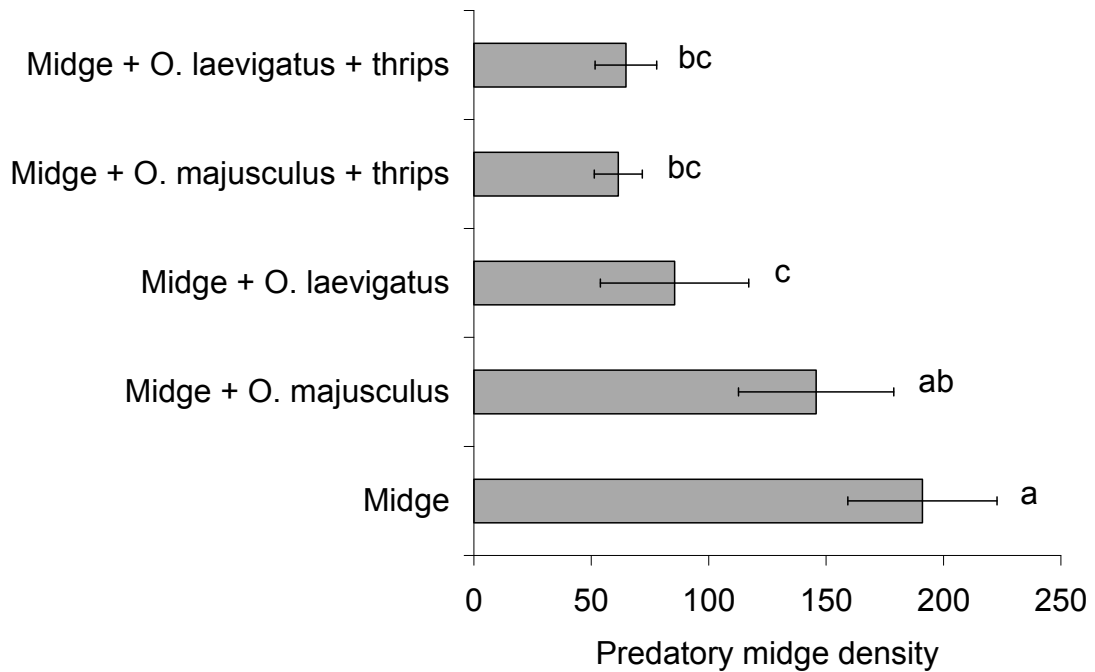


Fig. 2. Effects of predatory bugs on densities of the predatory midge *A. aphidimyza* in the presence or absence of thrips. Shown are average ( $\pm$ SE) densities of larvae per plant. Different letters indicate significant differences among treatments (Fisher's LSD test,  $p < 0.05$ ).

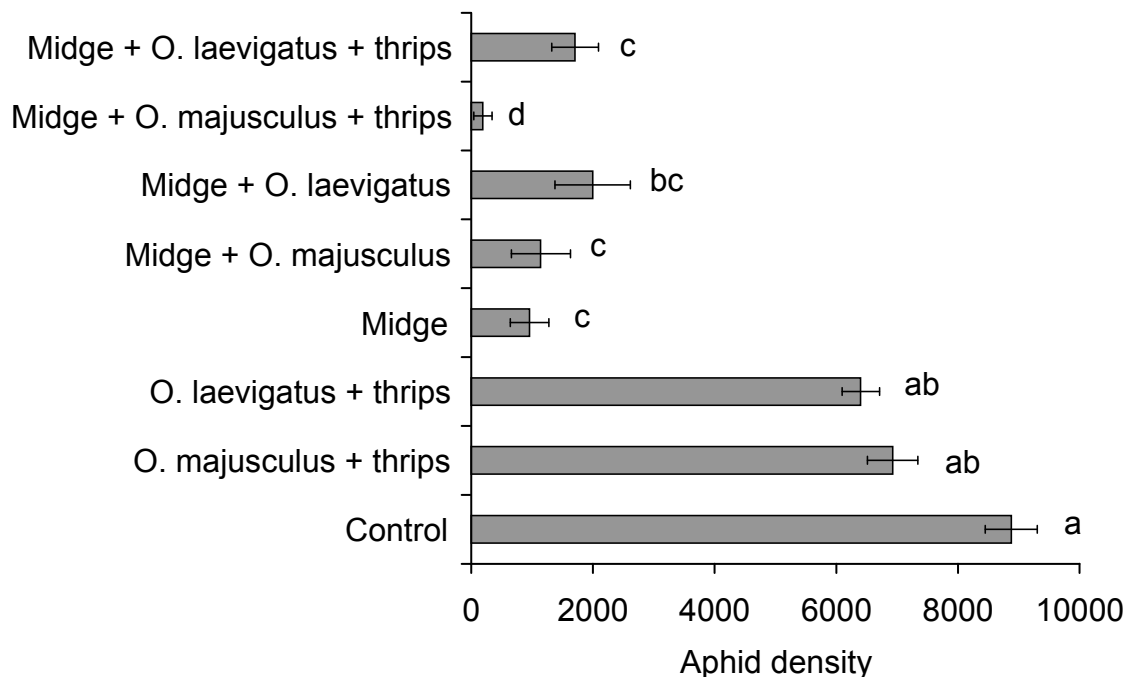


Fig. 3. Effects of predatory bugs on the suppression of aphids by the predatory midge *A. aphidimyza* in the presence or absence of thrips. Shown are average ( $\pm$ SE) densities of the aphid *M. persicae* per plant. Different letters indicate significant differences among treatments (Fisher's LSD test,  $p < 0.05$ ).

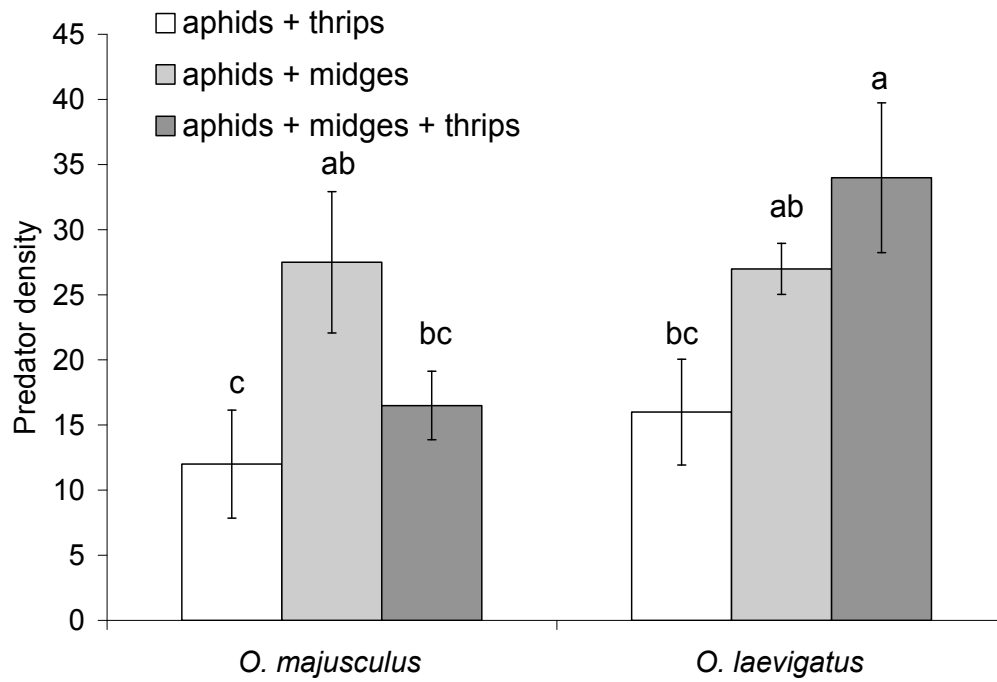


Fig. 4. Performance of predatory bugs on sweet pepper plants with different mixtures of the prey species. Shown are the average densities ( $\pm$ SE) of adults + nymphs per plant. Different letters indicate significant differences among treatments (Fisher's LSD test,  $p < 0.05$ ).

