



Mechanisms underlying the innate attraction of an aphidophagous coccinellid to coriander plants: Implications for conservation biological control



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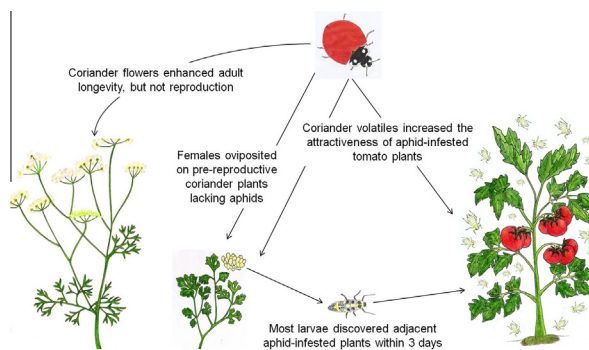
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HIGHLIGHTS

- *Cycloneda sanguinea* exhibits an innate attraction to coriander.
- Coriander volatiles increased the attractiveness of aphid-infested tomato plants.
- Female beetles oviposited on coriander plants lacking aphids.
- Access to coriander flowers increased adult longevity, but not reproduction.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 18 May 2015

Revised 2 October 2015

Accepted 3 October 2015

Available online 9 October 2015

Keywords:

Cycloneda sanguinea

Coccinellidae

Intercropping

Plant volatiles

Tomato

ABSTRACT

Intercropping tomato plants with coriander is known to attract natural enemies of aphids, mostly coccinellids, but the cues involved in such attraction are not yet known. We investigated why coriander plants attract *Cycloneda sanguinea*, a generalist aphid predator. We performed a series of controlled experiments with coriander plants in vegetative and reproductive stages to examine the cues attracting *C. sanguinea* adults and larvae. In a Y-tube olfactometer, *C. sanguinea* adults were attracted by coriander volatiles produced during the vegetative plant stage suggesting an innate attraction to coriander. Attraction increased when aphid-infested tomato plants were offered together with coriander plants. Moreover, *C. sanguinea* females used coriander plants as oviposition sites, regardless of plant stage, which could partially explain the attraction to coriander volatiles during vegetative stage. Larvae hatching on coriander plants without prey were able to find nearby aphid-infested tomato plants within about three days after hatching. Additionally, a diet of coriander flowers increased female survivorship, but oviposition only occurred when females had aphids in their diet. Our results indicate that *C. sanguinea* adults orient to coriander nearing bloom and then use coriander pollen and/or nectar as a supplementary food before aphids become available. The implications of these findings for conservation biological control are discussed.

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<http://dx.doi.org/10.1016/j.biocontrol.2015.10.002>

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1. Introduction

Coccinellids are important biological control agents of aphids and other soft-bodied insect pests (Obrycki et al., 2009; Michaud, 2012). Aphids are ephemeral resources that occur aggregated in patches within a habitat (e.g. a crop) forcing coccinellids to move inside the habitats in order to find suitable patches for feeding and reproducing (Ferran and Dixon, 1993; Evans, 2003; Hodek and Evans, 2012). When searching for habitats, coccinellids can assess a wide array of sensory information. At some distance, adults can use visual cues such as plant architecture and habitat shape (Nakamuta, 1984). Semiochemicals also play an important role in habitat and patch selection by coccinellids and may signal prey quality (Sarmiento et al., 2007; Pettersson et al., 2008; Hodek and Evans, 2012), presence of non-prey food (Schaller and Nentwing, 2000; Ninkovic et al., 2001; Choate and Lundgren, 2013), competitors or intraguild predators (Sarmiento et al., 2007), prey alarm pheromones (Al Abassi et al., 2000; Pettersson et al., 2008; Cui et al., 2012), and mates (Pettersson, 2012). Larvae can also respond to semiochemicals in the tracks of other larvae (Hemptinne et al., 2000). These sensory cues can help coccinellids integrate information about the habitat and make decisions while searching for oviposition sites, shelter or prey in order to maximize their fitness (Evans, 2003).

Generalist aphidophagous coccinellids have broad diets and often utilize plant resources as supplementary foods (Giorgi et al., 2009; Lundgren, 2009; Magro et al., 2010). Polyphagous feeding habits and the use of non-prey foods constitute important adaptations in the evolution of predaceous coccinellids (Giorgi et al., 2009). The provision of prey, plant-derived foods, shelter and oviposition sites via introduced plants can potentially improve the efficacy of coccinellids for biological control of aphids (Evans, 2003; Lundgren, 2009; Obrycki et al., 2009). For example, *Coleomegilla maculata* DeGeer (Coleoptera: Coccinellidae) aggregates in patches within alfalfa fields that contain dandelions, thereby increasing the predation of aphids on the alfalfa (Harmon et al., 2000). Similarly, *Coccinella septempunctata*, *Adalia bipunctata* L., *Propylea quatuordecimpunctata* L. aggregate in lettuce plots containing other spontaneous plants (Segonca et al., 2002). In both studies, the attraction of coccinellids to areas with higher botanical diversity has been attributed to provisioning of additional suitable conditions and supplementary resources such as pollen and nectar. Indeed, pollen and nectar can provide substantial amounts of energy and nutrients for coccinellid survival and reproduction (Lundgren, 2009).

Recent studies indicate that predatory coccinellids are attracted to tomato plants intercropped with coriander (Togni et al. 2009, 2010). A similar effect was noted by Resende et al. (2010) when kale was intercropped with coriander. In these studies, coccinellids were most attracted to flowering coriander plants, but even when coriander plants were in vegetative stages, both abundance and diversity of coccinellids were higher in intercropped than in monocultured plots (Resende et al., 2010; Togni et al., 2010). Furthermore, there is some evidence that coccinellids can feed on pollen and nectar from coriander plants (Medeiros et al., 2010) and use these plants for oviposition and shelter (Lixa et al., 2010).

Cycloneda sanguinea L. is one of the most abundant coccinellid species in Brazil (e.g. Sujii et al., 2007; Martins et al., 2009; Harterreiten-Souza et al., 2012) and is often found in plots of tomato plants intercropped with coriander (Togni et al., 2010). It has generalist feeding habits, preys on many aphid species and feeds on plant-derived foods (Amaral et al., 2013). It is able to recognize odors from aphid-infested tomato plants and to discriminate between plants with a superior prey (an aphid) versus an inferior prey (a mite) (Sarmiento et al., 2007). Due to these

characteristics, *C. sanguinea* is considered a promising biological control agent of aphids on tomato plants (Oliveira et al., 2005; Sarmiento et al., 2007).

In the field, *C. sanguinea* is attracted by non-infested coriander plants in both vegetative and flowering stages (Togni et al., 2009, 2010). The reason of such attraction is still not known. To investigate this, we first carried out a series of olfactometer experiments to test the role of odors from vegetative coriander plants on predator foraging behavior. Subsequently, we performed a cage experiment to test whether vegetative stages of the plant affect female oviposition site selection. Because we observed eggs on coriander plants without aphids in the cage experiment (only on plants in the vegetative stage), we also investigated whether larvae hatched on these plants were able to find nearby aphid-infested tomato plants. Finally, we assessed the suitability of coriander flowers as supplementary food for the predator. Our study thus focused on how coriander plants intercropped with commercial tomato plants can contribute to attraction and retention of predatory coccinellids when no obvious resources are available before flowering. Thus, we used only uninfested coriander plants in our experiments. We also evaluated how an association between suitable prey (aphids) and supplementary food resources (coriander pollen/nectar) might benefit the predator. An improved understanding of the attraction of *C. sanguinea* to coriander plants in different stages could contribute to more effective habitat management for conservation biological control of aphids when this plant is intercropped with tomato.

2. Materials and methods

2.1. Plants and insects

Tomato plants, *Solanum lycopersicon* cv. “Santa Clara” (Solanaceae), and coriander plants, *Coriandrum sativum* cv. “Verdão” (Apiaceae), were sown in plastic pots (5 L) containing soil and a commercial plant substrate (Bioplant[®]) (proportion 3:1) in a greenhouse. Tomato plants (one per pot) and coriander plants (10 seeds per pot) were kept inside a wooden-framed cage (0.7 × 0.7 × 0.68 m) covered with a fine-mesh (90 μm) to avoid herbivore contamination.

The aphid *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) and the predator *C. sanguinea* were both collected on non-crop plants and on horticultural crops in the municipality of Piranga, state of Minas Gerais, Brazil (20°45'4" S and 43°18'10" W) and in a field and an orchard at the Federal University of Viçosa, state of Minas Gerais, Brazil (20°45'14" S and 42°52'54" W). Insects were collected twice weekly from September 2011 until February 2012. Aphids were transferred to cabbage plants (50 days old) kept in plastic pots (5 L). Aphid-infested cabbage plants were maintained inside wooden framed cages (0.7 × 0.7 × 0.68 m) covered with a fine mesh (90 μm). Adults of *C. sanguinea* were sexed based on sex-specific patterns on the pronotum and on the prosternum. Couples were maintained inside transparent plastic pots (500 mL) covered with a fine mesh in a climate chamber (25 ± 2 °C, 70 ± 10% r.h. and 13 h of light). Each couple was fed with aphids, *Anagasta kuehniella* (Zeller) (Lepidoptera: Pyralidae) eggs, water and honey. These resources were offered together *ad libitum* to provide a complete adult diet. When eggs were observed inside the pots, adults were removed and transferred to other pots. After egg hatching, larvae were separated and fed the same diet offered to adults. Offspring from field-collected individuals were used only in the survivorship experiment and to evaluate *C. sanguinea* oviposition patterns; field-collected individuals were used in all other experiments.

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