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Non-crop vegetation associated with chili pepper agroecosystems promote the abundance and survival of aphid predators

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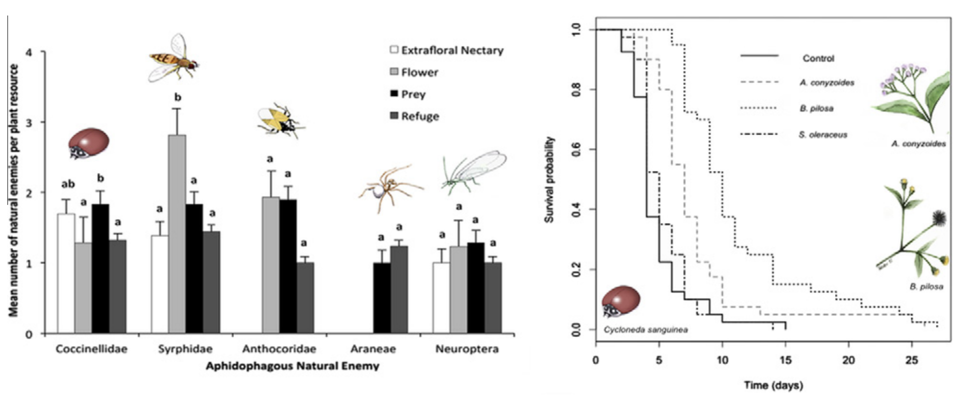
HIGHLIGHTS

- ▶ We assessed the role of non-crop weeds for maintaining aphidophagous predators in tropical agroecosystems.
- ▶ We quantified the survival of two coccinellids feeding on weed floral resources.
- ▶ The interactions between non-crop weeds and natural enemies varied according to plant species and predators group.
- ▶ Native and exotic coccinellids survived differently according to flower resource.
- ▶ Non-crop weeds can affect aphid natural enemy abundance and survival.

GRAPHICAL ABSTRACT



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ABSTRACT

Habitat manipulation has long been used as strategy to enhance beneficial insects in agroecosystems. Non-crop weed strips have the potential of supplying food resources to natural enemies, even when pest densities are low. However, in tropical agroecosystems there is a paucity of information pertaining to the resources provided by non-crop weeds and their interactions with natural enemies. In this study we evaluated (a) whether weeds within chili pepper fields affect the diversity and abundance of aphidophagous species; (b) whether there are direct interactions between weeds and aphidophagous arthropods; and (c) the importance of weed floral resources for survival of a native and exotic coccinellid in chili pepper agroecosystems. In the field, aphidophagous arthropods were dominated by Coccinellidae, Syrphidae, Anthocoridae, Neuroptera and Araneae, and these natural enemies were readily observed preying on aphids, feeding on flowers or extrafloral nectaries, and using plant structures for oviposition and/or protection. Survival of native *Cycloneda sanguinea* (Coleoptera: Coccinellidae) differed between plant species, with significantly greater survival on *Ageratum conyzoides* and *Bidens pilosa*. However, no evidence was gathered to suggest that weed floral resources provided any nutritional benefit to the exotic *Harmonia axyridis* (Coleoptera: Coccinellidae). This research has provided evidence that naturally growing weeds in chili pepper agroecosystems can affect aphid natural enemy abundance and survival, highlighting the need for further research to fully characterize the structure and function of plant resources in these and other tropical agroecosystems.

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1. Introduction

The adoption of ecological practices aimed at strengthening trophic relationships within agroecosystems for regulation of herbivores is gaining prominence, especially in organic production systems (Zehnder et al., 2007). Top-down forces such as predation and parasitism directly influence agricultural communities, and can be managed to reduce pest outbreaks (Stireman et al., 2005; Macfadyen et al., 2009). From this perspective, the enhancement of natural enemies through habitat manipulation and increasing vegetational diversity can improve herbivore control (Landis et al., 2000; Gurr et al., 2003) and is associated with enhanced environmental heterogeneity which itself serves to sustain natural enemies in the environment. Indeed, such plant diversity not only functions as a refuge for many natural enemies, but can provide food such as nectar, pollen and alternative prey (Bugg and Pickett, 1998; Frank et al., 2007; Jonsson et al., 2008), all of which enhance natural enemy populations prior to pest arrival. However, natural enemy – pest interactions are complex and non-crop vegetation does not universally translate into improved levels of biological control (see Landis et al., 2000). Thus, understanding the complex interactions between natural enemies and non-crop resources forms a critical framework for the implementation of sound conservation biological control strategies.

A practice that has been widely adopted for habitat management in agroecosystems is the conservation of weed strips, which can enhance beneficial arthropod populations (Altieri and Whitcomb, 1978; Wyss, 1995; Nentwig, 1998; Liljesthröm et al., 2002; Gurr et al., 2003; Norris and Kogan, 2000, 2005). Although less predictable than managed wildflower plantings that promote populations of beneficial arthropods (Fielder et al., 2008) through the provisioning of food resources (Wäckers et al., 2005), natural weed strips provide the farmer with a low-investment option to enhance biological control. These weed strips are typically integrated into, and/or surrounding, crop fields, depending on habitat characteristics and the movement patterns of arthropod natural enemies (Corbett, 1998; Gurr et al., 2003; Skirvin et al., 2011). It is this interaction between weed strips and arthropods that can influence predator–prey interactions (Norris and Kogan, 2000, 2005), broaden the food resource base and increase the number of sites available for oviposition and shelter, thereby enhancing the pest suppression potential of natural enemies (Nentwig, 1998; Thies and Tscharntke, 1999; Landis et al., 2000). Specifically, flowers of weeds provide pollen and nectar that attracts and maintains a diverse community of arthropod predators such as syrphids (Tooker et al., 2006; Haenke et al., 2009), ladybirds (Cottrell and Yeargan, 1999; Burgio et al., 2006), lacewings (Nentwig, 1998) and predatory bugs (Atakan, 2010). Nutrients present in floral resources also improve natural enemy survival during their non-carnivorous life stage and are utilized as complementary food resource when prey are limiting.

An important component of successfully integrating weeds into pest management decision making processes is quantification of the mechanisms and resources that influence the response of natural enemies to such plants (Andow, 1988; Snyder et al., 2005). Here, we sought to examine such interactions in a tropical agroecosystem to clarify the role of weed strips in an important crop of South America, chili pepper. This cropping system is important in several regions of Brazil and is typically cultivated on small diverse farms (Ohara and Pinto, 2012). Crucially, there are currently no pesticides registered by the Brazilian government for use on pests attacking chili peppers, thus finding alternative management solutions to control pest species is critical. Given the lack of access to pest control technology, farmers rarely achieve efficient management of arthropod pests and can, during outbreak years, incur significant economic losses. Two aphids, *Myzus persicae* (Sulzer) and *Aphis gossypii* Glover (Hemiptera: Aphididae), are particularly important pests of chili pepper and cause both direct and indirect damage to the crop (Venzon et al., 2006, 2011). Within these agroecosystems, coccinellids are highlighted as particularly important natural enemies (Venzon et al., 2006, 2007) and both *Cycloneda sanguinea* (L.) and *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) have a particularly close association with these aphids (Venzon et al., 2011). However, while the former has native range from the southern United States to Argentina (Gordon, 1985), thus encompassing the field sites in which this research was undertaken, the latter has an original distribution of Japan, Ryukyus [Ryukui Islands], Formosa [Taiwan], China, Saghalien [an island in the Russian Far East] and Siberia (after Sasaji, 1971) and is an exotic species in South America. In a multi-faceted approach, this study focused on the use of weed resources in chili pepper agroecosystems and clarified their role in influencing the abundance and diversity of aphid predators in the field. Additionally, the interactions between two coccinellids and weeds were quantified in laboratory feeding trials to quantify the effect of these non-prey resources on survival parameters of *C. sanguinea* and *H. axyridis*. Enhancing our understanding of such interactions could therefore establish an important framework for future conservation management in chili pepper (and other tropical) agroecosystems.

2. Material and methods

2.1. Field sampling of weeds

Field research was undertaken in five chili pepper fields located in the county of Piranga (Minas Gerais, Brazil, GPS coordinates 20° 45′45″ S, 43° 18′10″W) during the main growing season (March–August). Chili pepper fields were selected based on their similarity in size (~1 ha) and small farmer agricultural practices. No insecticides were applied throughout the experiment and all fields were separated by at least 2 km. Sampling was conducted every 2-weeks from 29 March to 23 August 2011 (10 sampling dates) and the commencement of field collections corresponded to a reduction in weed control by farmers.

Total abundance of weed species was characterized using 0.25 m^2 quadrats (0.5 m × 0.5 m) (adapted from Smith et al., 2011) from 20 randomly selected sites within and surrounding all chili pepper fields. Predators present on weeds were sampled using three 100 m transects per field. This sampling approach incorporated a weed strip along a field border and transected the chili pepper field to the weed strip border on the opposite side of the field. To quantify arthropod abundance, each transect was meticulously inspected, all plant species recorded and all arthropods on the plant were collected (approximately 10 min collection/plant) and their location recorded based on the following parameters: (i) prey, when arthropods were feeding upon aphids or another prey; (ii) on/in plant flower parts, (iii) extrafloral nectaries, when arthropods were feeding on an extrafloral structure; and (iv) refuge, to categorize arthropods that were found on plants but were not feeding or associated with any plant food resource. After visual observation for arthropods, plants were also sampled by beating foliage over a collection tray to ensure comprehensive sampling of the fauna. All arthropods were transferred into 70% ethanol and returned to the laboratory for identification. Sampling was undertaken between 09:00 and 16:00 h.

2.1.1. Statistical analysis

The abundance of predators was analyzed using a generalized linear model (GLM), assuming a Poisson distribution and a log link