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Non-crop plant communities conserve spider populations in chili pepper agroecosystems

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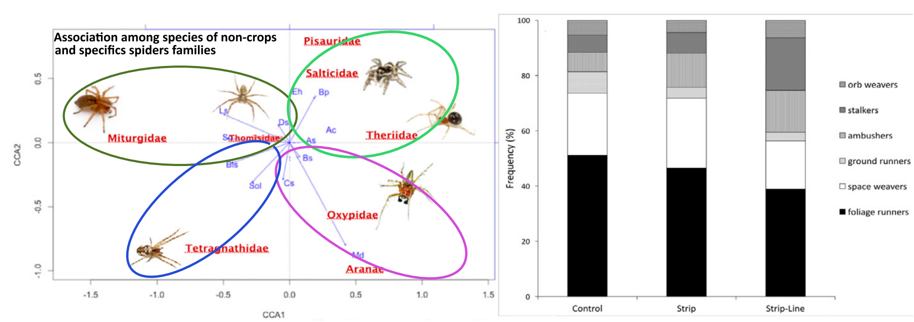
HIGHLIGHTS

- We found association between spider families and non-crop plant species in a chili pepper agroecosystem.
- Non-crop habitat increased spider abundance and altered guild composition.
- The spatial analyses showed that non-crop plant strips influence the aggregation tendencies of spiders.
- The intrinsic correlation between spider families and non-crop plants is promising for selecting non-crop plants.
- Non-crop plants enhance recruitment of spiders to improve biological control potential.

GRAPHICAL ABSTRACT



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ABSTRACT

Habitat management enhances heterogeneity in agroecosystems and also has the potential to increase recruitment of spiders, which can improve the biological control services afforded by these important predators. A paucity of studies has documented the associations of spiders with plant communities or the efficacy of non-crop plants for increasing the density and diversity of spider populations. Here we examined natural associations of spiders with native non-crop plants within Brazilian chili pepper agroecosystems. Following this characterization, a manipulative experiment was undertaken at two locations to identify the effects of non-crop plant strips and borders on spider community structure. The composition of native plants altered the community of spiders. The abundance of these predatory spiders was highest on Asteraceae. Spatial Analyses by Distance Indices (SADIE) determined that there was significant aggregation of spiders in chili pepper fields under these plant management strategies. Although incorporating this habitat management approach reduced the overall cropping area, the corresponding increase in generalist predator abundance could offset costs by improving the natural control of pests. This study revealed associations between native plants and spider communities, and how these help to conserve predator biodiversity. Targeted management of native non-crop plants promote the abundance of natural enemies and enhances biological control in chili pepper agroecosystems.

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1. Introduction

Integrating multiple strategies for sustainable crop production while simultaneously promoting the provisioning of ecological services on farms and within rural landscapes is a challenge for modern agriculture (Tilman et al., 2002; Bommarco et al., 2013). Enhancing agricultural systems to be rich in ecosystem services requires management that conserves and promotes biodiversity of flora and fauna within and around crop fields (Gurr et al., 2003). Typically, management strategies to enhance vegetational diversity that subsequently increases the biodiversity of beneficial arthropods vary with crop type (perennial or annual) and region (temperate or tropical), at both local and landscape scales (Thies and Tscharntke, 1999). Importantly, efforts to conserve biodiversity may positively affect arthropod natural enemies that provide biological control of insect crop pests (Altieri and Whitcomb, 1978; Wyss, 1995; Landis et al., 2000; Norris and Kogan, 2000, 2005; Letourneau et al., 2011).

Generalist natural enemies play a fundamental role in biological control of pest species and are impacted differentially by the vegetational diversity of non-crop plants due to variation in their behavioral and physiological characteristics (Symondson et al., 2002; Stiling and Cornelissen, 2005). Importantly, their feeding habits allow them to shift between different food resources when target prey (i.e., pests) are low in abundance (Eubanks and Denno, 2000). Thus, the presence of non-crop plants in agroecosystems provides resources to allow natural enemy survival, growth and reproduction, even when pest species are absent. Additionally, the presence of diverse non-crop plant communities, may aggregate generalist arthropods with complementary foraging strategies, promoting functional diversity of natural enemies, which can translate to additive levels of biological control services. However, despite the recognition that non-crop habitats improve the abundance and diversity of natural enemies, little is known about the specific generalist-predator associations with non-crop plants, and a scarcity of information is available to guide related conservation biological control efforts.

The true spiders, Araneae, are a diverse group of generalist predators and are frequently the first natural enemies to colonize new crop areas (Riechert and Lockley, 1984; Öberg and Ekbom, 2006; Royaute and Buddle, 2012). Spiders exhibit a diversity of foraging characteristics and behavior (Rypstra, 1983; Uetz et al., 1999; Hofer and Brescovit, 2001) that promote biological control (Marc et al., 1999; Hibbert and Buddle, 2008). For instance, ambush predators, such as those in the family Salticidae, have acute vision, to track down and attack resting prey (Jackson and Pollard, 1996). Conversely, web spiders, such as Linyphiidae, that build webs near the base of plants for intercepting prey, may provide complementary pest control (Sunderland et al., 1986; Welch et al., 2013), often catching very high numbers of pests within these microsites (Harwood et al., 2001, 2003). The potential benefit of diverse predator communities is that the behavior of one species (e.g. actively pursuing prey) may facilitate prey capture by another species by changing the behavior of the prey (Sih et al., 1998; Ives et al., 2005). Thus, promoting spider diversity likely enhances biological control in agricultural systems (Schmidt-Entling and Doebeli, 2009). A fundamental understanding of specific spider associations with non-crop plants is required to improve biological control by designing management plans that promote diverse assemblages of natural enemies such as spiders.

Here we examined spiders collected in chili pepper (Solanaceae; *Capsicum frutescens*) agroecosystems to determine specific associations between spider feeding guilds with native non-crop plants. In Brazil, chili pepper production is challenged by because a complex of multiple pest species, including mites (*Polyphagotarsonemus latus*), aphids (*Myzus persicae*, *Aphis gossypii*), whiteflies (*Bemisia tabaci*) and fruit borers (*Symmetrischema* sp., *Neosilba* sp.), which attack the plants during different crop stages. Being a minor crop, it lacks efficient tools for pest management (Venzon et al., 2011). Chili pepper production, therefore, is reliant on the design and implementation of successful conservation biological control programs that promote pest management throughout the season. Amaral et al. (2013) provided evidence that native non-crop plant communities on the borders of chili pepper fields have positive effects on natural enemy abundance and survival. In the current study, we analyzed the spider communities associated with non-crop plant species. Our experiments and analyses were designed to: (1) characterize spider associations with non-crop plant species in Brazilian chili pepper agroecosystems, and (2) evaluate the effects of non-crop plant management on spider abundance and community structure in Brazilian chili pepper agroecosystems.

2. Materials and methods

2.1. Characterization of spider communities associated with non-crop plants in chili pepper agroecosystems

Spiders were collected from non-crop plants at adjacent borders of five chili pepper fields (*C. frutescens*) located in the county of Piranga (state of Minas Gerais, Brazil, GPS coordinates 20° 45′45″ S, 43° 18′10″ W). All fields were separated by at least 2 km and were selected based on their similarity in size (~1 ha, which is the typical size for chili pepper fields in Brazil). Chili pepper plants were spaced 1 m apart within a row and between rows. Standard agricultural practices were used including organic and mineral fertilization (Pinto et al., 2012). A compound fertilizer NPK (20:5:20) was applied at the rate of 50 g per plant at monthly intervals. The plants were managed using common practice with manual tools (e.g. hoe, sickle and rake). Minimal tillage was used in the plots, as is typical in the region because mechanized tools and tractor cultivation are not effective at managing non-crop plants in chili pepper crops. No pesticides were applied throughout the experiment.

After 90 days from planting, non-crop plant management by farmers was reduced as the presence of such plants do not interfere more on crop production (Reifschneider, 2000). Sampling started from this date (29 March) and took place every two weeks until 23 August 2011.

The assessment of most abundant non-crop plant species identity was done 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 each chili pepper field (see Amaral et al., 2013). In each quadrat, all non-crop plants at least 10 cm tall were separated according to species and counted. Sampling was done in March, before the spider field collection.

The spiders present on non-crop plants were sampled by selecting three 100 m transects per field on each sampling date. Transects started within the non-crop border that ran perpendicular to the chili pepper rows, and ended outside of the opposite non-crop border. We walked through the transect and stopped every 10 m to sample spiders on non-crop plants (10 plants/transect). In each field five chili pepper plants were randomly selected and the spiders found on foliage were collected. Each plant (non-crop or chili pepper) was first meticulously visually surveyed. To dislodge any remaining spiders, we followed visual sampling with beating foliage over a collection tray. All collections were done between 9:00 and 16:00 h.