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Wooded field margins increase potential for cultural and biological control of soybean pests

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ABSTRACT

Crop field margins provide benefits to growers by inhibiting pest dispersal through cultural control and provisioning resources for predators through conservation biological control. The purpose of this study was to elucidate potential soybean insect pest control measures by determining the relationships between pests and spiders, common generalist predators in agroecosystems, and field margin type and distance from the field (0–3 and 3–6 m). Both margin type and distance were significantly correlated with in-field pest abundance (both pooled and taxa-specific). Generally, pest abundance was negatively correlated with the presence of wooded field margins at both distances and could be due to cultural control as hedgerows provide similar ecosystem services in other cropping systems. Spider abundance and spider-pest spatial associations (an indication of potential predation events) within fields were positively correlated with wooded margins from 3 to 6 m, indicating that conservation biological control in addition to cultural control might be contributing to diminished pest abundance in fields with these margins. The lack of wooded margin influence from 0 to 3 m might indicate a need for a minimum wooded area before margins can become a source for within-field spider populations. Furthermore, the number of spider-pest spatial associations was greatest early in the season when pest abundance was lowest and pests were more likely to be spatially aggregated. These data indicate that growers might be able to maintain their field margins, particularly wooded areas, to maximize both potential cultural control and conservation biological control resources, particularly early in the growing season.

1. Introduction

Landscape simplification leads to loss of ecosystem services such as pest control in agricultural systems (Altieri, 1999) but can be remediated by the addition of high-quality habitat for the perseveration of natural enemies (Batary et al., 2011; Chisholm et al., 2011; Cusser et al., 2016; Gardiner et al., 2010). Within agroecosystems, such habitats often involve unmanaged field margins as these areas incur little cost to growers compared to intentionally preserved natural areas (Brodt et al., 2008; Nelson et al., 1998; Potts et al., 2016). Margin composition is especially influential as field margins are the gateway for insects into agricultural fields after disturbance events such as planting, chemical application, and harvest (Altieri and Schmidt, 1986; Buddle et al., 2004). Field margins, therefore, exert pressure on species in multiple ways – by altering movements, inducing species-specific mortality via unfavorable abiotic conditions, changing interspecific interactions between margin and field matrices, and by providing novel spaces for interactions (Fagan et al., 1999). By harnessing margins as sources or sinks for insect populations, cultural and conservation biological control of pests in agricultural fields can be potentially manipulated by changing the composition of margins adjacent to crop fields (Chaplin-Kramer et al., 2011; Dauber and Wolters, 2005; González et al., 2017; Thomas et al., 1991).

Unmanaged field margins provide cultural control by posing a barrier (sink) for pest dispersal between crop fields (Bhar and Fahrig, 1998). Such margins can block the path into a field with an inhospitable environment where the arthropod is without high-quality food, reproductive opportunity, or necessary abiotic conditions. For example, Hawkes reported that the height and permeability of crop borders and the extent to which they acted as windbreaks influenced adult cabbage root fly within-field abundance and aggregation (Hawkes, 1973). Alternatively, margins can act as a trap by luring pests away from crops with preferred host plants or mate access (Stinner et al., 1983). The specific margin-pest interactions and accompanying mechanisms vary by crop type and location, meaning that studies into varying combinations are required to efficiently use field margins for cultural control measures.

Field margins, in addition to posing as a barrier to pest species, also

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Fig. 1. Examples of margin classifications observed around two focal soybean fields. Grass, soybean, and tree were observed 0–3 m from the field while two additional classifications – other crop (typically corn) and roadway – were added from 3 to 6 m.

have the ability to supplement natural enemies (conservation biological control or source population) (Bianchi et al., 2005; Kremen et al., 2011). Not only do margins provide refuge from disturbance and spaces for overwintering (Holland et al., 2008; Landis et al., 2000; Lee et al., 2001), they also host alternative food resources such as non-pest prey items and plant-based foods such as pollen and extra-floral nectar (Amaral et al., 2013; Dyer and Landis, 1997; Landis et al., 2005). For example, natural enemy abundance can increase up to 80% and 71% when given access to herbaceous habitats and woody habitats, respectively, in addition to cropland (Bedford and Usher, 1994; Bianchi et al., 2006). The resulting increase in natural enemy abundance potentially increases within field control of pest arthropods and weeds (Birthisel et al., 2015, 2014; Booman et al., 2009; Brewer and Elliott, 2004).

Spiders, generalist predators common in agroecosystems, readily disperse from field margin habitats into crop fields where they can mitigate pest damage (Kuusk and Ekbom, 2012; Maloney et al., 2003; Nyffeler et al., 1987; Young, 1990) by consuming crop pests in agroecosystems such as cucurbits, winter wheat, and soybean (Chapman et al., 2013; Culin and Yeargan, 1983; Schmidt et al., 2014). The resources provided by non-crop habitats enable spiders to move into agricultural fields early in the season for pest suppression (Buddle et al., 2004; Gavish-Regev et al., 2008; Nyffeler et al., 2016; Taylor and Pfannenstiel, 2008). For instance, margins surrounding orchards have increased spider abundance and subsequent suppression of codling moth (Lefebvre et al., 2016). Supplementation of natural enemies such as spiders in crop fields when pest populations are low benefits growers since predation capacity in agroecosystems can be quite high (Harwood et al., 2007).

The purpose of this study was to determine which types and relative distance of margin habitats are useful for altering within-field pest abundances (cultural control) and for encouraging natural enemy colonization of crops (conservation biological control). Additionally, this study aimed to assess the likelihood of within-field spatial associations of spiders to pests, a potential representation of predation events, in relation to field margin characteristics (Bell et al., 2010; Winder et al., 2001; Zhao et al., 2013). We hypothesized that margins closest to the field would have the greatest impacts on both pest and spider abundances but that these communities would respond differently to margin types, specifically that pests would increase and spiders would decrease in abundance near soybean margins. Additionally, within-field spatial associations of spiders to pests were expected to increase with greater pest abundance. The results of this study will provide data on how pest and spider communities interact spatially with potential source and sink habitats, resulting in more informed predictions on how to manage field margins for both cultural control and conservation biological control simultaneously.

2. Materials and methods

2.1. Study sites, sample collection, and field margin composition

Grower managed soybean fields (n = 23; 0.5-22.0 ha) located > 5 km apart throughout central and western Kentucky were sampled from 2012 to 2014 (ten in 2012, seven in 2013, and six in 2014). All fields were planted in late May through early June, with minimum to no-till soil management, no irrigation, and were part of a three crop rotation with field corn and winter wheat. Each field site was sampled once per month from June to August in each respective year to estimate insect pest and spider abundances (number of individuals per group at a specific within field trap location at a given time). Non-baited pitfall traps (dia. 9.5 cm, depth 12 cm) containing ethylene glycol for specimen preservation and covered with a Styrofoam rain guard were deployed for 24 h between crop rows in a grid pattern throughout the field (9–24 locations based on field dimensions) beginning approximately 3 m into each field. At each pitfall location, both sweep-net (10 figure-eights) and hand samples (1 m^2 quadrats over two minutes) were conducted (Doxon et al., 2011). Pitfall traps, sweep samples, and hand samples (n = 1282) were pooled for each grid location within a field as each collection method captures particular specimens more effectively (Lang, 2000). Abundance data as stated throughout the remainder of the paper will be the pooled abundance of these sampling methods per sampling location per time within any given field. Pests from all collection methods were identified to species or family when applicable (referred to taxa-specific hereafter) and spiders were identified to family (AAS, 2005; Johnson et al., 2015). Field margins were observed in person and categorized by general habitat type from 0 to 3 m and 3–6 m from the outermost row of soybeans in the focal field based on commonly observed margin widths. All fields were observed to have grassy areas, soybean, or wooded areas (trees and dense shrub) from 0 to 3 m and grassy areas, soybean, wooded areas, other crops (typically corn or tobacco), or roadways from 3 to 6 m (Fig. 1). The margins were classified based on the predominant type (i.e. > 80% of the area), with all margins meeting this threshold. Measured marginal areas might have been a part of a larger habitat type but are referred to as margins here since they are in relation to the focal fields as such. Each sampling location along field edges was paired with the corresponding adjacent margin types while samples well within the field were considered to be completely surrounded by soybeans for statistical analyses. Samples adjacent to two margin types (i.e. corner locations) were assigned multiple types for analyses.