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Grassland plantings and landscape natural areas both influence insect natural enemies

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ABSTRACT

Local habitat management and landscape composition are main factors in determining the abundance and diversity of conservation biological control agents. In Midwestern U.S.A., the establishment of conservation plantings is encouraged through government programs. These plantings buffer streams from agricultural inputs and increase wildlife habitat. We examined the effects that these plantings and semi-natural areas in the surrounding landscape have upon the abundance and diversity of natural enemies of the soybean aphid. We quantified abundances of soybean aphids and their natural enemies in soybean fields and adjacent plantings in Newton County, Indiana, U.S.A. We found a higher number of natural enemies in conservation plantings than in soybean fields before aphids arrived. When soybean aphid populations were increasing, aphid abundance was a main factor influencing the four major predator groups (*Anthocoridae*,*Nabidae*, and exotic and native *Coccinellidae*). Along with aphid abundance, the presence of adjacent plantings and forest areas within 3 km affected nabid abundance and the presence of adjacent plantings and grassy areas within 5 km influenced the abundance of native coccinellid in soybean fields. Lastly, this study showed that the presence of grassland strips enhances beta diversity of natural enemies in soybean fields. Therefore, natural enemy communities may be more resilient to disturbance in landscapes containing conservation plantings. The increased natural enemy abundance with plantings and semi-natural areas in the surrounding landscape may enhance conservation biological control and benefit farmers.

1. Introduction

Insect natural enemies provide an important pest control service, one example of an ecosystem service that delivers economic benefits to people. The service of biocontrol provided by insects is worth an estimated $4.5 billion annually to U.S. agriculture (Losey and Vaughan, 2006). Pest control provided by native and naturalized species may be especially important in an aggregative sense, for crops such soybeans, the second-most-planted field crop in the U.S.A. (USDA Economic Research Service, 2012). Major outbreaks of soybean aphids (*Aphis glycines* Matsumura) in odd-numbered years between 2001 and 2007 caused significant loss of soybean yields, as high as 40% loss over wide areas (Ragsdale et al., 2004; Ragsdale et al., 2007). A diverse community of soybean aphid natural enemies (Ragsdale et al., 2011) provided an estimated $239 million/yr in biological control services across four states in the north central U.S. (Landis et al., 2008), exemplifying the importance of naturally occurring biological control in this system.

Conservation biological control is defined as, “modification of the environment or existing practices to protect and enhance specific natural enemies or other organisms to reduce the effects of pests” (Hajek, 2004). Local habitat management, usually by establishing planted floral strips adjacent to crop fields, is considered a conservation biological control method that provides natural enemies with alternative food resources, host plants, and shelter (Dennis and Fry, 1992; Landis et al., 2000). Many studies have shown the positive effects of vegetation strips near field edges and of semi-natural areas at landscape scales on the abundance and diversity of natural enemies (Steffan-Dewenter, 2002; Weiser et al., 2003; Koji et al., 2007; Tscharntke et al., 2007; Walton and Isaacs, 2011; Werling et al., 2011). Vegetation strips such as unmanaged roadside grasses and buckwheat floral strips around soybean fields have also led to enhance natural enemy abundance (Kemp and Barrett, 1989; Woltz et al., 2012). The US Department of Agriculture (USDA) Conservation Reserve Program (CRP) plantings (conservation plantings, hereafter) at field margins, which provide small but abundant and widespread habitat vegetation strips

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across U.S.A. The establishment of conservation plantings is a local habitat management method that has converted 36 million acres of cropland in the U.S.A. to grassland, shrub, and forest habitats. In total, 27 million acres of grasslands area are currently enrolled in the CRP (Riffell et al., 2008; USDA Farm Service Agency, 2013). Initially, the CRP was enacted in 1985 for reducing soil loss on agricultural lands; however, there are other significant ecological benefits to the program that merit evaluation (Dunn et al., 1993). For example, the role of the CRP grasslands specifically in conservation of grassland birds has been assessed (Johnson and Schwartz, 1993; Gill et al., 2006; Riffell et al., 2008). There are very few reports, however, on the effects of these conservation plantings on the conservation of natural enemies (Elliott et al., 2002a; Elliott et al., 2002b).

Landscape-scale factors may mediate the ability of local habitat management actions to influence natural enemy abundance (Tscharntke et al., 2005; Bianchi et al., 2006). Landscape composition, such as the amount of semi-natural area in a landscape surrounding soybean fields, is often associated with the abundance of natural enemies (Elliot et al., 2002b, Gardiner et al., 2009b; Gardiner et al., 2010; Werling et al., 2011; Woltz et al., 2012) and greater control of soybean aphids (Gardiner et al., 2009a).

Natural enemies may respond to different aspects of landscape structure depending on their trophic traits, body size, and dispersal ability. For example, five coccinellid species captured in alfalfa each responded to different types of vegetation cover in the surrounding landscape (Elliot et al., 2002b). Furthermore, natural enemies and biological control may respond to different aspects of landscape structure depending on the spatial scale is being considered. For example, predation of *Mamestra brassicae* eggs in Brussels sprouts was related to the length of forest edge and the percentage of forest and horticultural crops within a 0.15 km radius, but only to the percentage of horticultural crops at a 5 km radius (Bianchi et al., 2005). These studies emphasized that landscape factors and scales are important in determining natural enemy abundance. Consequently, the effects of local habitat management on natural enemy abundance may be more apparent in structurally simple landscapes than in structurally complex landscapes in which natural enemy abundances are already expected to be high (Tscharntke et al., 2005; Tscharntke et al., 2012). Therefore, it should be informative to examine the effects of interactions between habitat management practices and larger-scale landscape compositions on natural enemy abundance through different landscape scales. For example, the richness and diversity of hover fly species, natural enemies of cereal aphids, in sown flower strips adjacent winter wheat fields increased in simple landscape more effectively than in complex landscape (Haenke et al., 2009). Predation of Colorado potato beetle eggs was increased with the amount of field margin in local landscapes, while predation of aphids was increased with the amount of non-crop habitats at a broad scale (Werling and Gratton, 2010). However, to our knowledge there is no research on the combined effects of conservation plantings at a field scale and semi-natural areas at landscape scales on natural enemies in soybean.

Local habitat management practices and landscape-scale factors also influence natural enemy diversity. For example, management practices or a high amount of semi-natural areas can increase landscape complexity, which may enhance beta diversity (i.e., variability in species composition among sites) more than alpha diversity (i.e., the number of species in a site) (Tscharntke et al., 2007; Tscharntke et al., 2012). According to the insurance hypothesis, complex landscapes with high regional diversity, mainly resulting from high beta diversity, may support high resilience after spatiotemporal disturbances (Loreau et al., 2003; Tscharntke et al., 2012). That is, although disturbances may reduce natural enemy density and diversity in limited areas, a heterogeneous landscape can minimize the negative effects by enhancing natural enemy recolonization in the disturbed area. Similarly, conservation plantings within a landscape may play a role in sustaining pest control by supporting natural enemies that can recolonize crop fields after disturbance.

Our objectives were to examine: (1) whether conservation plantings adjacent to soybean fields act as refuges for natural enemies before soybean aphid arrival, (2) how landscape-scale factors and the local-scale presence of a conservation planting adjacent to soybean fields influence different natural enemy groups in soybean fields in a Midwestern agroecosystem, and (3) whether the presence of conservation plantings influences natural enemy beta diversity among adjacent soybean fields. Based on these objectives, we hypothesized that: (1) natural enemy abundance in soybean fields is supported by adjacent conservation plantings, (2) that the abundance of different natural enemies in soybean fields would respond to differently the amount of different types of semi-natural areas in landscapes, and that this would interact with the presence of local plantings, and (3) that the presence of conservation plantings would enhance beta diversity of natural enemies.

2. Methods

2.1. Study sites and insect sampling

A total of 28 soybean field sites were selected as study sites in Newton County, Indiana (Fig. 1A). Among these study sites, we selected ten soybean fields with adjacent conservation plantings known as filter strips (labelled CP21 by the CRP). These plantings are targeted at protecting streams from agricultural contaminants and limiting soil erosion. In Indiana, they are planted in grasses such as big bluestem, switchgrass, Virginia wild rye, timothy, redtop, and orchard grass, and some legumes such as clover and alfalfa (NRCS, 2009). They may be between 20 ft (6.1 m) and 120 ft (36.6 m) wide, but in our study were fairly consistent in width with an average of 24.5 ± 7.0 m (mean $\pm$ sd) wide. We used five soybean fields with adjacent conservation plantings known as wildlife buffers for upland birds (labelled CP33 by the CRP). These plantings are established to provide habitat and dispersal routes to upland birds such as quail and pheasant. In Indiana, the plants used vary with the target bird species, but commonly include little bluestem, big bluestem, partridge pea, and a mix of forbs (NRCS, 2011). They may be between 30 ft (9.1 m) and 120 ft (36.6 m) wide, but in our study had an average width of 30.6 ± 7.6 m (mean $\pm$ sd). Hereafter, we refer to the filter strip plantings as CP_{grass} and the wildlife buffer plantings as CP_{floral}. We had difficulty locating soybean fields adjacent to CP_{floral} (here after, $SoyCP_{floral}$) compared to soybean fields adjacent to CP_{grass} (here after, $SoyCP_{grass}$) because corn was heavily planted at the expense of soybean fields during our study and the CP_{floral} plantings are less common. Thirteen soybean fields with no adjacent conservation planting were selected as control sites (hereafter, SoyCont).

To test the first hypothesis regarding the influence of conservation plantings on natural enemy abundance, we used data on the natural enemy abundance in five different habitat types: SoyCont, $SoyCP_{grass}$, $SoyCP_{floral}$, CP_{grass}, and CP_{floral}. To address the second and third hypotheses regarding the influence of these plantings and different semi-natural areas in the surrounding landscape on abundance and beta diversity in the soybean fields, we focused on the abundance within soybean fields with ($SoyCP_{grass}$ and $SoyCP_{floral}$; hereafter, $SoyCP_{grass\ or\ floral}$) and without adjacent conservation plantings (SoyCont).

In June 2011, two transects 150 m in length were established in each soybean field and each adjacent conservation planting