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Insect communities in soybeans of eastern South Dakota: The effects of vegetation management and pesticides on soybean aphids, bean leaf beetles, and their natural enemies

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A B S T R A C T

Although most pests of soybeans, *Gycine max* (L.), in the Northern Great Plains are managed using pesticides, farm management practices that encourage biodiversity offer promising long-term, sustainable solutions for controlling insect and weed pests profitably. The recent invasion of the Northern Great Plains by the soybean aphid (*Aphis glycines* Matsumura; Hemiptera: Aphididae) has had potentially important implications for insect communities in soybeans of this region, although recent descriptions of this regional community are scarce. We describe how three pest management systems that vary in the intensity with which they rely on herbicides and insecticides (chemically intensive, reduced chemical, and spring cover crop treatments) affect insect pest populations, arthropod predator communities, weed assemblages, and soybean yield and profitability. Soybean aphids exceeded economic thresholds in all three years, and insecticides successfully suppressed these outbreaks in the two chemical treatments; aphids exceeded the economic injury level in the cover crop treatment in two of three study years. Bean leaf beetle (*Cerotoma trifurcata* Forster; Coleoptera: Chrysomelidae) populations were sub-economic in all treatments; insecticides targeting soybean aphid also reduced bean leaf beetles in the first year of study when beetle populations were at their highest. Foliar-dwelling predator populations were substantially higher in the cover crop treatment than in the chemical treatments in all years of study; population declines in the latter treatments were strongly associated with insecticide applications targeting soybean aphids. Foliar predator populations did not rebound within the growing season after insecticides were applied. Soil predator populations were largely unaffected by treatment (except in 2006, when they were more abundant in the cover crop treatment than in the chemical treatments). Weed communities varied among treatments and study years, with few consistent trends except that the chemically intensive treatment had lower weed densities than the other treatments. Although input costs of the cover crop and reduced chemical treatments were lower than the chemically intensive treatment, the chemically intensive treatment was the most profitable of the three. Nevertheless, we contend that the cover crops can be managed more efficiently in order to increase the profitability and competitiveness of this treatment while gaining the long-term benefits gleaned from conserving biodiversity in our agroecosystems.

1. Introduction

The Northern Great Plains lies on the western edge of soybean (*Gycine max* [L.]) production in North America, and as such harbors a regionally adapted suite of insects and weeds. Soybeans in this and surrounding regions were largely free from insect pests prior to the introduction of the Asian soybean aphid (*Aphis glycines* Matsumura [Hemiptera: Aphididae]) (Ragsdale et al., 2004, 2011). Aphid populations rapidly increase during outbreak years (which do not occur every year), alter the physiology of soybean plants, reduce soybean yields, and potentially transmit soybean viruses (Clark and Perry, 2002; Macedo et al., 2003; Riedell and Catangui, 2006; Beckendorf et al., 2008; Riedell et al., 2009). Bean leaf beetle (*Cerotoma trifurcata* Forster [Coleoptera: Chrysomelidae]) is

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another predominant, but sporadic, pest of soybeans in this region. Adults of this pest defoliate soybean plants and transmit bean pod mottle virus (Mabry et al., 2003; Bradshaw et al., 2008; Byamukama et al., 2011), and larvae consume root nodules of the soybean plant and disrupt its nitrogen dynamics (Lundgren and Riedell, 2008; Riedell et al., 2011). These two pests support a diverse and abundant natural enemy community throughout much of the soybean-producing region of North America (Toepfer et al., 2009; Ragsdale et al., 2011), but this natural enemy community has been poorly described in the Northern Great Plains (but see Seagraves and Lundgren, 2012 for one report). Although soybeans are commonly produced in the Northern Great Plains (Nebraska, South Dakota and North Dakota were ranked 6th, 8th, and 9th in 2011 soybean hectares harvested; National Agricultural Statistics Service, www.nass.usda.gov), there have been no peer-reviewed, comprehensive studies of insect communities in this crop after the invasion of the soybean aphid. This is particularly important in light of the fact that the introduction of soybean aphid has accompanied a dramatic increase in insecticide use (Ragsdale et al., 2004; Fausti et al., in press), and this undoubtedly has changed the dynamics of insect communities in this region substantially.

Pests are often a symptom of producing crops under monoculture conditions, and efforts to increase the diversity of vegetation within cropland often increase natural enemy populations and reduce pest intensity (Andow, 1991; Tillman et al., 2004; Broad et al., 2009; Lundgren and Fergen, 2010; Letourneau et al., 2011; Lundgren and Fergen, 2011; Koch et al., 2012). Sources of this vegetation diversity may be in the form of low levels of weeds or the use of cover crops or ground covers. In-season ground covers in soybeans can reduce soybean aphid populations, likely through a combination of altered plant quality for pest (soybean aphids and potato leafhopper [*Empoasca fabae* Harris]) development and augmented populations of natural enemies (Miklasiewicz and Hammond, 2001; Schmidt et al., 2007). But these understory ground covers can also reduce soybean yields to such levels that some researchers concluded that their use is unrealistic for producers (Schmidt et al., 2007). Cover crops do not necessarily have these negative effects on soybean yields (Davis, 2010; Smith et al., 2011). Weed populations provide another source of vegetation diversity that is used by natural enemies of soybean aphids (Griffen and Yeargan, 2002; Lundgren et al., 2009b). The effects of weed presence on soybean aphids has not been well studied, but is likely going to be more important as glyphosate-resistant populations of weeds expand their ranges (Lundgren et al., 2009a; Heap, 2012; Mortensen et al., 2012). Because input costs vary substantially depending on pest management approaches, and insect management decisions are linked to other aspects of crop production, the benefits of vegetation diversity on pest management of soybean insects can only be verified using a systems-level approach that incorporates the relative economic costs and benefits of different best-practice management philosophies.

We used a systems-level approach to examine the relative effects of three soybean production systems on insect and weed communities and soybean profitability at one location over three years in the Northern Great Plains. Specifically, we compared the effects of a cover crop-based system designed to minimize chemical inputs and a system intended to reduce herbicide inputs (and harbor low levels of weeds) with a system reliant on high chemical usage typical of our region. These treatments varied across years and even among plots depending on the prevailing conditions observed at the sites, but were unified through the underlying philosophies that defined the treatments. Although systems-level projects such as these lack the ability to identify clear mechanisms for how specific results are produced within a particular system, this approach provides a 'real world' picture of how these systems will affect key crop production characteristics for end-users. In addition to examining the relative costs and benefits of these different systems, this study represents the most comprehensive recent survey of insect communities of soybeans in the Northern Great Plains published in the peer-reviewed literature.

2. Methods

2.1. Experimental field sites

Research was conducted in 2005–2007 on the Eastern South Dakota Soil and Water Research Farm, near Brookings, SD (latitude, longitude: 44.348, −96.811). Experimental plots were 24.4×30.5 m in 2005, 12.1×18.3 m in 2006, 18.3×18.3 m in 2007, and the three treatments were arranged in a RCB design with three replicates in 2005 (nine total plots) and four replicates in 2006 and 2007 (12 total plots). At least 6 m margins separated the plots; these margins were spring-planted to winter wheat (*Triticum aestivum* L.) of mixed varieties at 111 kg/ha. The three treatments examined were 1) chemically intensive management, 2) reduced chemical management, and 3) cover crop-based management (each is described more extensively below). Experiments were embedded in a split, 12.5-ha field; the two halves were rotated between corn and soybeans so that half the field was soybeans each year. Soybeans were planted at approximately 370,000 viable seeds per ha on 6-June 2005, 9-June 2006, and 7-June 2007 (using 0.76 m row spacing). Throughout the experiment, the chemically intensive and reduced chemical systems were planted to soybean variety 91M40 (a glyphosate tolerant variety; Pioneer HiBred, Johnston, IA). The cover crops system was initially planted to 91M40 in 2005, but was switched to 91M10 soybeans in 2006 & 2007; 91M10 is not glyphosate tolerant, and thus fits within the philosophy of this management system better than the 91M40. The field was under conventional tillage (fall and spring chisel plow), and received 224 kg/ha of 14–36–13 (N–P–K; ammonium phosphate) in 2005. In 2006 and 2007, no fertilizer or inoculant was applied. Plots were harvested by combine in mid- to late-October, when grain moisture reached approximately 13% as measured using a grain moisture tester (DICKEY john Corporation, Auburn, IL). Grain yields were calculated, and grain quality was assessed (% dry matter, oil, and protein) using a near infrared spectrometer (Foss North America, Eden Prairie, MN). For these grain metrics, three subsamples were taken per plot. Two of the 2007 plots could not be harvested due to high weed pressure (one in the cover-crop based treatment and one in the reduced chemical treatment); yields were considered as zero for these plots, and the data from these plots were excluded from the nutrient analyses. Average maximum seasonal temperatures were 26.11 (2005), 25.00 (2006) and 26.11 °C (2007), and total precipitation from June 1 to September 30 was 52.37 (2005), 37.13 (2006) and 27.41 (2007) cm.

2.2. Chemical intensive system

This study system is meant to represent conventional production practices of our region. Specifically, pre-emergent herbicide and glyphosate are used to manage weed populations, and insecticides are applied as soybean aphids exceed economic thresholds. At planting in 2005, glyphosate (RoundUp, Monsanto Company, St. Louis, MO) was applied at 4.7 L (1.66 kg ai) per ha tank-mixed with the pre-emergent herbicide S-metolachlor (Dual Magnum®, Syngenta, Greensboro, NC) at 2.3 L (2.1 kg ai) per ha. In 2006, the same rate of glyphosate was applied, but the S-metolachlor (Dual II Magnum, Syngenta) pre-emergent herbicide was applied at 1.2 L (1.1 kg ai) per ha. In 2007, 2.3 L (0.83 kg ai) per ha of glyphosate was applied at planting without a pre-emergent herbicide. An