



Does local habitat management or large-scale landscape composition alter the biocontrol services provided to pumpkin agroecosystems?



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HIGHLIGHTS

- Predators reduced spotted cucumber beetle but not squash bug eggs in pumpkin fields.
- Formicidae, Opiliones, Gryllidae and Araneae are among the key predators of pest eggs.
- Addition of insectary habitats did not enhance biocontrol services in pumpkin crops.

GRAPHICAL ABSTRACT

Prediction: Floral insectaries and diverse landscapes enhance egg predation in pumpkin crops



Results: No effect of floral insectaries on egg predation; landscape effects varied by year

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ABSTRACT

Cucurbit crops are attacked by a pest complex that threatens production via direct feeding and disease transmission. The goals of this study were to quantify the amount of biocontrol service supplied to pumpkin fields and determine if this was affected by local habitat management or the surrounding landscape. Using sentinel eggs, we measured predation of squash bug, *Anasa tristis*, and spotted cucumber beetle, *Diabrotica undecimpunctata howardi*, by generalist predators. We found that predators significantly removed *D. undecimpunctata howardi* but not *A. tristis* eggs. The guild of predators found to attack *D. undecimpunctata howardi* included Araneae, Carabidae, Cricetidae, Entomobryidae, Formicidae, Gryllidae and Opiliones. A smaller, but overlapping guild of predators was found to attack *A. tristis*, which included Araneae, Cricetidae, Formicidae and Gryllidae. Formicidae was consistently the dominant predator of both pest species. We examined how the addition of either a non-native annual plant insectary of sweet alyssum, *Lobularia maritima*, or a diverse insectary planted with native perennial forbs and grasses influenced predator abundance, composition, or biocontrol services relative to a grass control. We found no difference in either the predator community feeding on pest eggs or the proportion of eggs that they removed from adjacent pumpkin fields. Larger-scale landscape composition did influence the amount of egg predation occurring in pumpkin agroecosystems, however, these relationships varied among pests and across years of the study. Biological control is commonly predicted to increase with landscape diversity and the amount of non-crop habitat present surrounding focal fields, yet we found that when landscape did influence egg predation it was agricultural landscapes supporting the highest egg removal. This study illustrates that patterns relating landscape and localized habitat management to crop pest predation are not constants, they can vary among years within a crop as well as among agricultural cropping systems.

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1. Introduction

Agricultural landscapes are subject to frequent disturbances, some of which may be mitigated through the addition of floral insectaries (Landis et al., 2000; Zehnder et al., 2007). Floral insectaries provide food and shelter resources for natural enemies and can increase their abundance and the biocontrol service provided within adjacent cropland (Shahjahan, 1968; Baggen and Gurr, 1998; Platt et al., 1999; Johanowicz and Mitchell, 2000; Lee and Heimpel, 2005; Pease and Zalom, 2010; Gillespie et al., 2011). However, large-scale landscape composition and heterogeneity may influence the species pool of organisms supplied to insectary, and the resultant arthropod mediated ecosystem services that are provided (Isaacs et al., 2009; Batáry et al., 2011; Concepción et al., 2012; Rodríguez-Saona et al., 2012). Thus, an understanding of how landscape composition and heterogeneity may influence the value of habitat management plantings for sustainable crop production is necessary. The goal of this study was to evaluate the utility of habitat management in achieving sustainable cucurbit production by testing three hypotheses: (1) Predator guilds significantly reduce the abundance pest eggs within pumpkin crops, (2) When floral insectaries are planted adjacent to pumpkin, populations of natural enemies enter from the established plantings and enhance the provision of egg predation, and (3) Landscape composition mediates the effects of a floral insectary addition on egg predation, with natural landscapes enhancing the pest suppression benefits gained from their addition.

Annual plants are commonly used in habitat management because they are inexpensive to establish, moveable from year-to-year, fast-growing, and some make effective cover crops or are economically important themselves (Bugg and Waddington, 1994; Prasifka et al., 1999; Dufour, 2000; Landis et al., 2000). Native perennials have also been explored (Fiedler and Landis, 2007a, 2007b; Frank et al., 2008; Tuell et al., 2008; Gill et al., 2014), and species mixes can be designed to bloom continuously throughout the growing season, thereby providing a highly attractive habitat for beneficial insects.

Several laboratory and field studies have measured the attractiveness of planted or naturally-growing annuals or perennials, which provide pollen and nectar as well as alternative prey for natural enemies (Wäckers, 2004; Lavandero et al., 2005, 2006; Fiedler and Landis, 2007a, 2007b; Amaral et al., 2012). A common response variable in these studies is the relative attractiveness of the local habitat additions to predators, parasitoids and pests as measured by abundance, richness, or diversity (Cowgill et al., 1993; Bigger and Chaney, 1998; Platt et al., 1999; Thomas and Marshall, 1999; Sutherland et al., 2001; Collins et al., 2003; MacLeod, 1999; Wäckers, 2004; Pontin et al., 2005; Rebek et al., 2005; Burgio et al., 2006; Pascual-Villalobos et al., 2006; Cole et al., 2007; Fiedler and Landis, 2007a; Koji et al., 2007; Haenke et al., 2009; Atakan, 2010; Gillespie et al., 2011; Walton and Isaacs, 2011). Some have also measured how the function of natural enemies is influenced by the addition of habitat management. Several studies indicate a positive impact, with pest suppression enhanced with the addition of flowering plant resources (Hickman and Wratten, 1996; Baggen and Gurr, 1998; Collins et al., 2002; Frank and Shrewsbury, 2004; Lee and Heimpel, 2005; Pease and Zalom, 2010; Bickerton and Hamilton, 2012; Blaauw and Isaacs, 2012; Balmer et al., 2013; Balzan and Moonen, 2012; Gontijo et al., 2013), yet some have documented a neutral impact from this management effort (Berndt et al., 2006; Lee et al., 2006; Olson and Wäckers, 2007; Woltz et al., 2012). Therefore before grower adoption, the utility of these habitat manipulations on biocontrol services should be evaluated for a

focal crop within a range of landscapes that represent localized or, where possible, regional variation.

Evaluation of how landscape composition influences the success of habitat management is important, as the natural enemy response to local habitat plantings is a function of the landscape-scale species pool. A meta-analysis by Chaplin-Kramer et al. (2011) found a more natural landscape dominated by non-crop habitats was positively associated with natural enemy abundance and diversity. Several studies have also examined the influence of landscape on biological control (e.g. Thies and Tschamtkke, 1999; Roschewitz et al., 2005; Gardiner et al., 2009; Thies et al., 2003, 2005, 2008, 2011; Gagic et al., 2011; Jonsson et al., 2012; Grez et al., 2014; Plecas et al., 2014). In general, these studies have demonstrated that overall diversity and/or representation of non-crop habitats enhance pest suppression. For example, Gardiner et al. (2009) found that predation of the soybean aphid, *Aphis glycines* (Hemiptera: Aphididae), across the north central U.S. increased with landscape diversity. Importantly, increased natural enemy activity does not always result in more effective biological control. For example, Roschewitz et al. (2005) found parasitism and cereal aphid populations both increased with a reduction in arable land, resulting in no net benefit.

Further, studies are beginning to elucidate how habitat management practices and landscape complexity interact to influence biocontrol services (Woltz et al., 2012; Haenke et al., 2014; Midega et al., 2014). In theory, landscape composition and heterogeneity affect the species pool of predators and parasitoids able to colonize a planting and spillover into surrounding cropland (Tschamtkke et al., 2012). In practice, interactive effects of landscape and habitat management vary. For example, Midega et al. (2014) compared pest abundance in corn produced in a monoculture versus a push-pull system. Stem borer abundance was reduced within push-pull plots, but in both treatments pest abundance increased with the proportion of grassland habitat in the surrounding landscape (Midega et al., 2014). In contrast, Woltz et al. (2012) found that coccinellid abundance in soybean increased with the amount of semi-natural vegetation in the surrounding landscape, but no interaction between landscape and habitat management was found (Woltz et al., 2012).

In the north central United States, pumpkin, *Cucurbita pepo* L. (Cucurbitales: Cucurbitaceae) is damaged primarily by the striped cucumber beetle, *Acalymma vittatum* (Fabricius) (Coleoptera: Chrysomelidae), spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber (Coleoptera: Chrysomelidae), and squash bugs, *Anasa tristis* DeGeer and *A. armigera* Say (Hemiptera: Coreidae). In addition to feeding damage, these pests also vector pathogens (Ellers-Kirk and Fleischer, 2006).

Cucurbit herbivores are known to be fed upon by a diversity of natural enemies. Cucumber beetle larvae are susceptible to infection by entomopathogenic nematodes (Ellers-Kirk et al., 2000) and a diversity of predators are known to attack eggs, larvae and adults (Whitaker, 1995; Platt et al., 1999; Snyder and Wise, 2000; Williams and Wise, 2003). The eggs, nymphs, and adults of *A. tristis* were consumed by Carabidae, Geocoridae, and Nabidae in the laboratory (Snyder and Wise, 1999; Rondon et al., 2003; Decker and Yeagan, 2008). Under field conditions, Araneae, Geocoridae, Nabidae, and Coccinellidae are known to consume *A. tristis* (Rondon et al., 2003; Decker and Yeagan, 2008; Schmidt et al., 2014).

Given the potential impact of generalist predators on these herbivores, our objectives were to: (1) Quantify the level of *D. undecimpunctata howardi* and *A. tristis* egg predation supplied to pumpkin fields, (2) Identify key predators consuming pest eggs, (3) Determine if habitat management influences predator abundance, composition, or egg predation in pumpkin fields, and (4)

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