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Pollen beetle mortality is increased by ground-dwelling generalist predators but not landscape complexity

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ABSTRACT

Biological control of crop pests by naturally occurring arthropods depends on the entire community of natural enemies, but generalist predators and parasitoids are rarely considered in the same study. Also, the level of biological control in the field is affected by both within-field and landscape scale management. A multi-taxa approach that integrates multiple scales of management is needed to understand drivers for pest mortality. We examined local (weed cover and soil characteristics) and landscape (proportions of semi-natural and oilseed rape habitat) effects on natural enemy communities and biological control of pollen beetles in 15 oilseed rape (OSR) fields in Sweden. We found that agricultural intensification at the local (low weed cover) and landscape scale (low proportion of semi-natural area) increased evenness of generalist predators, but had no effect on the densities of pests and their natural enemies. This suggests that the generalist predators in OSR are well adapted to crop lands, at least within the examined gradient. Increasing OSR in the landscape decreased parasitoid densities and increased pest density, indicating a potential loss of pest control services by specialist natural enemies in landscapes with a high proportion of OSR. Finally, pollen beetle mortality increased with ground-dwelling generalist predator abundance and soil clay content. Parasitism rates did not affect pest mortality, which is interesting as parasitoids have been considered major control agents in OSR. The hypothesis that increasing semi-natural habitat in the landscape enhances natural enemy abundances and species richness in agricultural landscapes was not supported. Local measures targeting generalist predators appear as a reasonable strategy to maximize pollen beetle control.

1. Introduction

Biological control of crop pests is an important ecosystem service delivered by a community of generalist and specialist natural enemies. Biological control is affected by a combination of management interventions and habitat qualities within the field and in the landscape in which the field is embedded (Martin et al., 2013; Rusch et al., 2010; Tylianakis and Romo, 2010). While much research has been performed on single taxon and landscape impacts, few assessments have been made that encompass the impact of both field and landscape scale management on a wider community of generalist and specialist natural enemies, and their actual impact on pest population suppression.

Increasing within-crop plant diversity generally enhances abundance and diversity of natural enemy assemblages (Langellotto and Denno, 2004; Letourneau et al., 2011). It has been hypothesized that within-crop diversification of plants will enhance biodiversity and ecosystem services more in structurally simple, rather than in cleared (i.e. extremely simplified) or in complex landscapes (Tscharntke et al., 2012). This "intermediate landscape-complexity" hypothesis has been both supported (Concepción et al., 2012, 2007; Jonsson et al., 2015; Midega et al., 2014) and refuted (Phillips and Gardiner, 2016; Rusch et al., 2015b, 2016a; Woltz et al., 2012), but lacks general empirical support in major crops such as oilseed rape.

Interactions among predator functional guilds can increase or decrease the pest predation level through facilitation, intraguild predation or behavioral interference (Letourneau et al., 2009; Martin et al., 2013; Straub et al., 2008). There is increasing evidence that abundance, species richness and community evenness of different taxa of biological control agents respond differently to landscape complexity with implications for pest control services (Gardiner et al., 2010; Rusch et al., 2014; Woodcock et al., 2010). However different natural enemy groups are rarely examined simultaneously. In a meta-analysis on natural

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enemy response to landscape complexity only two out of 46 studies simultaneously examined parasitoid and generalist natural enemies and only one estimated actual impact of multiple natural enemies on pest mortality (Chaplin-Kramer et al., 2011). These two studies confirm that the relationship between landscape context and arthropod abundances in crops are taxon specific with generalist predators responding more to woody habitats than specialists (Bianchi et al., 2005; Perović et al., 2010).

In addition, body size is a critical life-history trait determining the type and the strength of interactions among species (Schneider et al., 2012; Woodward et al., 2005; Rusch et al., 2015a). It is hypothesized that species with larger body sizes would be more vulnerable to landscape simplification because of higher disturbance (ie. short crop rotations) (Blake et al., 1994; Ewers and Didham, 2006). However, investigation across predator taxa has found increased mean body size with landscape complexity for rove beetles but not for carabids and spiders in barley fields (Rusch et al., 2014). It is expected that landscape simplification will reduce natural pest control (Rusch et al., 2016b). However, studies to ascertain which components of the natural enemy community (abundance, species richness, evenness, mean body size) respond to landscape complexity and affect pest mortality are lacking.

The pollen beetle (*Meligethes aeneus* Fabricius 1775; Coleoptera, Nitidulidae) is among the major insect pests in OSR (*Brassica napus* L.) in Europe (Ekbom, 2010). Landscape composition, influences pollen beetle abundance directly by affecting its dispersal and mortality (Rusch et al., 2013; Schneider et al., 2015; Zaller et al., 2008a) and indirectly by affecting parasitism rates (Beduschi et al., 2015; Rusch et al., 2011; Schneider et al., 2015; Thies et al., 2008, 2003; Thies and Tscharntke, 1999; Zaller et al., 2009). Generally, increasing cover of semi-natural habitat in the landscape has a positive effect on both pollen beetle abundances and parasitism rates in OSR crops. Generalist natural enemies have been suggested to be important pollen beetle predators (Büchi, 2002; Haschek et al., 2012; Öberg et al., 2011), but little is known about their actual impact on pollen beetle population dynamics or how they respond in OSR to within field and landscape complexity. In addition, mortality of different life stages of the pollen beetle has rarely been considered. Abiotic factors such as increasing percent of clay in soil (Marrone and Stinner, 1984; Simelane, 2007; Turpin and Peters, 1971) and decreasing pH (Johnen et al., 2010; Li et al., 2007) are known to increase other coleopteran larval survival in the laboratory. Despite the fact that pollen beetles spend larval and pupal stages in the soil (Osborne, 1960) the effect of soil texture and pH on net pollen beetle mortality in the field remains unknown.

We investigated how pest mortality in OSR was affected by natural enemy communities, and how characteristics at the local and landscape scale in combination influence the pest and its natural enemies (Fig. 1). Firstly, we hypothesized that generalist predator (spiders, carabids, and rove beetles) abundance, species richness, and community evenness and mean body size, as well as abundance of parasitoids and parasitism rates would increase with increasing coverage of semi-natural habitat in the landscape. Second, we expected within-field weed cover to have a positive effect on predator abundance, richness, mean body size, and evenness; and that this effect would be stronger in landscapes with low cover of semi-natural habitat (Tscharntke et al., 2012). Third, we examined the effect of natural enemy community and soil characteristics on pollen beetle mortality to investigate the biological control potential at the field scale. We expected specialist and generalist natural enemy abundances to additively enhance pollen beetle mortality, and pest mortality to increase with generalist predator community richness, evenness, and mean body size. Finally, because part of the pollen beetle life cycle is spent in the soil we expected mortality to be affected by soil properties.

2. Material and methods

2.1. Experimental design

The study was carried out in 2013 in 15 conventionally managed winter OSR fields in the Swedish province of Västra Götaland (Figure A and Table A, Supplementary material). Average temperature and precipitation for the months of May and June were 13 °C (min = −1.5, max = 24) and 77 mm (min = 32, max = 100). The landscape of this region is dominated by arable land (46%) comprising mostly cereals (47%), pastures (6%) and woodlands (48%) (Statistics Sweden 2013: http://www.scb.se/sv). To ensure variation in landscape composition among fields, they were chosen along a gradient of agricultural intensity measured as percentage arable land in a circular landscape sector of 1.5 km diameter encompassing the field (Zaller et al., 2008b). Percentage arable land in the landscape varied between 38% and 93.62%. Within each field, we selected a plot, 40 × 70 m, of unsprayed (insecticides, herbicides and fungicides) area located at the edge of the field. The field edge was adjacent to a grassy strip in all fields. Observations of invertebrates and weed coverage were made along two transects parallel to the field edge 3 and 30 m within the field. Each transect included five sampling points 5 m apart (Figure A, Supplementary material). In each point we sampled densities of the pest, the natural enemies, and the weed coverage in a similar spatial arrangement among sites.

The landscape characterization was obtained from the Integrated Administrative and Control System (IACS) database and interpreted with MATLAB R2012b. The land use was measured in a circular sector around each field of 500 m and 1000 m radius. Pollen beetle abundance and parasitism are found to be affected by landscape components at scales ranging from 750 m (Thies et al., 2003) to 1250 m or larger (Zaller et al., 2008a, 2008b). Here, we defined a radius of 1000 m, as the mean between the distances reported in the literature. We also tested 500 m radius as non-crop features at this scale can have an effect on generalist predators (Maisonhaute and Lucas, 2011). The landscape variables investigated at each scale were: proportion of winter OSR in 2013 (OSR_{t0}), proportion of past year winter and spring OSR (OSR_{t-1}) and proportion of semi-natural habitat (including pasture, ley, grasslands and forest) (SN). These variables have been found to affect pollen beetles dynamics and parasitism rates (Rusch et al., 2011; Schneider et al., 2015; Thies et al., 2008).

2.2. Study organisms

Pollen beetles produce one generation per year and adults usually overwinter outside the field in semi-natural habitats (Rusch et al., 2011). In the spring, the beetles migrate to OSR fields where they feed on and oviposit in the buds. The larvae feed on pollen and when fully grown drop to the soil for pupation. The next generation of adult beetles emerges in the middle of the summer and these will overwinter. *Meligethes aeneus* is the dominant species in Sweden. Pollen beetle damage and effects on yield in the studied system are published (Gagic et al., 2016).

2.3. Sampling

2.3.1. Weed and soil sampling

Weed cover in the OSR crop was used as a measure for within-field complexity. Weed cover was visually estimated using quadrats (1 × 1 m), measurements were replicated four times at each sampling point. Each quadrat was given a rank from 1 to 6 corresponding to a percent weed coverage category (1: < 1%; 2: 1–5%; 3: 5–12.5%; 4: 12.5–25%; 5: 25–50%; 6: > 50%) (Winqvist et al., 2011). To measure soil properties, we collected five random soil cores of 15 cm depth and 6 cm diameter at each site. Cores were mixed and transported at 5 °C and protected from sunlight. We determined pH (SS-ISO 10390) and