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Patterns of flower visitor abundance and fruit set in a highly intensified cereal cropping system in a Mediterranean landscape

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ABSTRACT

In intensive agricultural landscapes, decreased pollinator numbers have often been attributed to the loss of natural habitats. However, several studies show that certain mass flowering crops, such as oilseed rape (OSR), can alter the pattern of pollinator abundance at a field and landscape level. These studies have focused mainly on bees; information about the effect of OSR crops on other taxa is missing. We evaluated the abundance of bees and other (non-bee) flower visitors, and the fruit set of insect-pollinated target plants (*Raphanus sativus* and *Onobrychis viciifolia*) on the margins of OSR and cereal fields in landscapes with varying densities of non-cropped habitats (landscape structure). The presence of OSR crops and wildflower resources in field margins had varying effects on the abundance of bees and non-bee flower visitors. Bee abundance was enhanced by OSR crops, but decreased in complex landscapes. On the other hand, the abundance of non-bee flower visitors depended on the landscape structure, particularly on the location of cereal fields. Despite the numerous and diverse communities of pollinators attracted by OSR crops and wildflower resources, fruit set was enhanced only for generalist insect-pollinated plant species, because competition processes for pollinators affect specialist plant species. We conclude that the incorporation of OSR crops and maintenance of wildflower resources in agri-environmental schemes should be considered to improve the pollination services in agricultural landscapes highly dominated by cereal fields.

1. Introduction

Agricultural intensification is one of the main causes of biodiversity decline (Matson et al., 1997; Tilman et al., 2001) and disruption of associated ecosystem services (Kleijn et al., 2009). Agricultural intensification from within field to landscape levels is generally correlated with the decline of wild pollinators and the services they provide to crops and wild plants (Steffan-Dewenter et al., 2005; Biesmeijer et al., 2006; Potts et al., 2010). Changes in land-use and landscape structure affect the composition of nearby habitats and pollinators, in turn affecting their interactions at individual, population and community levels (Kremen et al., 2007).

In agricultural landscapes that are devoted to the production of crops that do not require insect pollination, such as cereal plantations, the provision of pollination services to insect-pollinated plants can be compromised. For example, insect pollinators may depend on the presence of natural and semi-natural vegetation that provides shelter, nesting sites and food. Pollinators can be displaced from natural and semi-natural vegetation to cropland if pollinators benefit from mass flowering crops or wildflower resources thriving in the field margins (Tscharntke et al., 2012).

For diverse agronomic and economic benefits, mass flowering crops have been incorporated into crop rotations to break-up the continuous cultivation of cereals (Pimentel et al., 1997; Klein et al., 2007; Kennedy et al., 2013). Moreover, these crops can reduce the food resource limitations for pollinators, thereby supporting pollination services (Westphal et al., 2003; Diekötter et al., 2010). Oilseed rape (*Brassica napus* L., OSR) is one of the most commonly used mass flowering crops because of the demand for its oil and increasing biofuel demand (FAO, 2015). OSR crops offer a highly rewarding resource of pollen and nectar that enhance pollinator abundance (Morandin and Winston, 2005). Most studies have evaluated the effect of OSR crops on bees, particularly honeybees, which are considered the most economically valuable pollinator (McGregor, 1976). Although other pollinators could also be enhanced by OSR crops in intensive agricultural landscapes, information about this relationship and about the abundance and diversity of other taxa remains scarce.

In highly intensified arable landscapes, the presence of patches of

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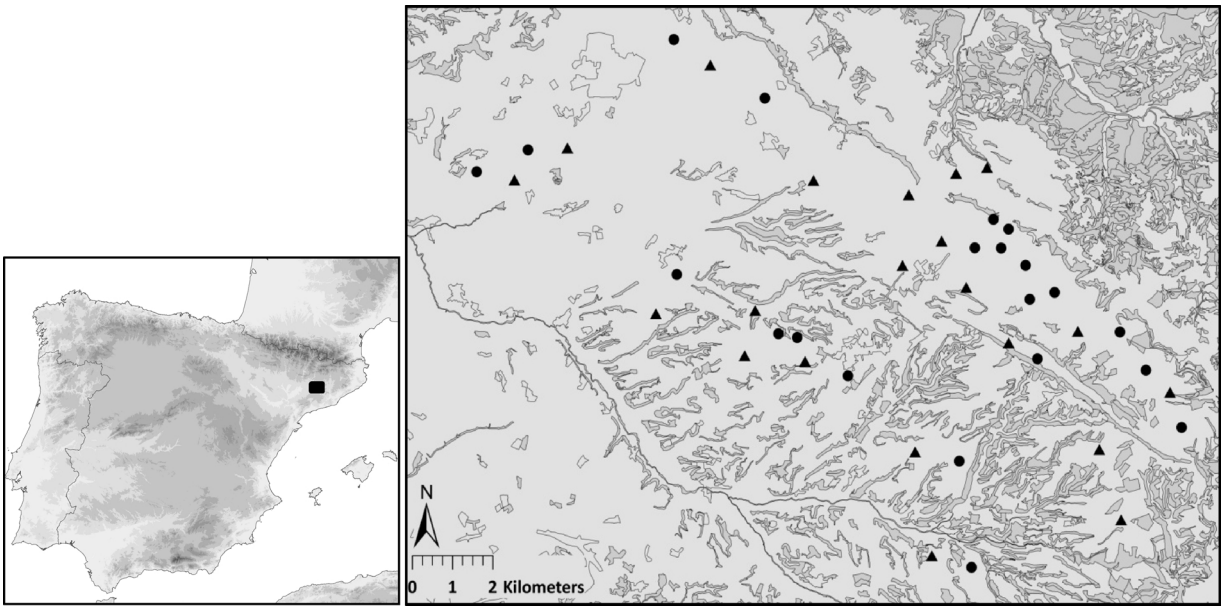

Fig. 1. The studied oilseed rape-cereal and cereal-cereal field margins, represented by circles and triangles, respectively, were located in Catalonia, Spain in highly intensified cereal cropping landscapes (light grey – arable fields, dark grey – other habitats).

non-cropped habitats, remnants of natural and semi-natural habitats, and the presence of wildflower resources in the field margins is extremely important for maintaining pollination services (Banaszak, 1992; Walther-Hellwig and Frankl, 2000; Garibaldi et al., 2011; Winfree et al., 2011). Several studies have demonstrated that recurrent resource pulses of mass flowering crops, such as OSR crops, can be beneficial to pollinators only when natural and semi-natural habitats are present in agroecosystems (Westphal et al., 2009; Holzschuh et al., 2013; Diekötter et al., 2014; Riedinger et al., 2015). For instance, Holzschuh et al. (2013) showed that the abundance of a wild bee species was enhanced when nesting habitats were present, particularly depending on the amount of OSR crops. Similarly, some studies proposed that the establishment of various mass flowering crops together with the maintenance of semi-natural habitats are effective conservation measures for maintaining bumblebee populations (e.g. Westphal et al., 2003, 2009). However, most researchers have studied landscapes where mass flowering crops are dominant. It is still unknown how discrete areas of mass flowering crops and wildflower resources at field margins, together with non-cropped habitats, can affect pollinators in cereal-dominated landscapes.

Plant communities can affect the interactions between any given plant species and its ensemble of pollinators by reducing the frequency of pollinators' visits through competition (Pleasants, 1981) or increasing this frequency via facilitation (Waser and Real, 1979; Moeller, 2004). As a consequence, changes in plant communities may strongly affect pollination processes by negatively or positively altering the pollinator's availability and effectiveness in delivering conspecific pollen.

The vulnerability of plant reproduction to land-use change depends on such factors as a species reliance on pollinators and the effect of changes in the surrounding landscape on pollination processes. Species-specific plant traits, including breeding system, specialization of plant-pollinator interaction, and floral traits, strongly influence the likelihood that plant-pollination interactions are disrupted (Bond, 1995; Aizen et al., 2002; Vázquez and Simberloff, 2002; Potts et al., 2010), therefore affecting their sensitivity to land-use changes. Declines in pollination services negatively affect obligate outcrossing plants, especially insect-pollinated plants (Aguilar et al., 2006). Specialist insect-pollinated species are more vulnerable to changes than generalist species (Biesmeijer et al., 2006), but the magnitude of the effects can depend on landscape structure. For instance, some wild plants can compete with the crop for attention from a limited number of pollinators in the vicinity of mass flowering crops (Holzschuh et al., 2011). On the other hand, wild plants can benefit from mass flowering crops if pollinators do not limit their visits to the most attractive flowers, such as from crops, but also visit surrounding areas (Rathcke, 1983). For instance, Hanley et al. (2011) showed an increase of pollination success of wild margin plants owing to the presence of mass flowering crops. However, to our knowledge there are few studies that evaluate the impact of mass flowering crops on generalist and specialist plants species in intensive agricultural landscapes.

The purpose of this study was to evaluate the effect of the presence of a neighbouring mass flowering crop (oilseed rape), landscape structure (represented by the density of non-cropped habitats) and wildflower resources on the abundance of bees (Hymenoptera: Apoidea) and other flower visitors (non-bees) and on the fruit set of two target species with different pollination syndromes. We also compared the abundance of bees, non-bee flower visitors and target species (generalist *vs*. specialist) to landscape structure. We tested the following hypotheses: (i) availability of resources provided by OSR crops increases the abundance of both bee and non-bee flower visitors and the fruit set of target species, (ii) increasing density of non-crop habitats in the landscape enhances the abundance of bees and non-bee flower visitors and improves the fruit set of target plants in field margins near OSR crops, and (iii) the abundance of bees and non-bee flower visitors increases with wildflower resources, but this effect is negligible in field margins near OSR crops; therefore, if wildflower resources benefit the pollination process, this effect is more noticeable in field margins nearby cereal crops. However, competition and facilitation interactions for resources coupled with specific pollinator requirements can affect fruit set patterns.

2. Materials and methods

2.1. Study region

The experiment was conducted between April and June of 2014 in Catalonia, Spain (41° 48′–41° 40′ N; 1° 14′–1° 28′ E) (Fig. 1). The study area is primarily devoted to the production of cereals, but it also includes some mass flowering crops. The natural and semi-natural