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Landscapes with high intensive fruit cultivation reduce wild pollinator services to sweet cherry

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ABSTRACT

Fruit cultivation highly depends on insect pollination for fruit development. Yet, fruit cultivation as an intensive land use can possibly alter the diversity of pollinator communities and the corresponding pollination service. In this study we investigate how intensive fruit cultivation influences both pollinator diversity and fruit set in sweet cherry orchards in Flanders, Belgium. Negative relations were detected between intensive fruit cultivation within 250 m around the orchards and both pollinator species richness and wild pollinator abundance. Honeybee abundance on cherry blossom was positively related with intensive fruit cultivation within 1000 m. Sweet cherry fruit set decreased with increasing intensive fruit cultivation within 250 m and 1000 m around the orchards. These findings suggest that intensive land use such as intensive fruit cultivation can undermine the pollination service of wild pollinators. In addition, the loss of this pollination service was not compensated by honeybees. In these intensive agricultural landscapes the production of sweet cherry is below the optimum, inducing a clear yield gap. In order to gain the full benefit of intensive agriculture, the pollination service needs to be optimised. Landscape-scale measures need to be taken, such as conservation of semi-natural habitat to improve nesting and flowering resources.

1. Introduction

More than 70% of the leading agricultural crops and more than 85% of all flowering plants depend on insect pollination for the development of seeds, fruits or both (Klein et al., 2007; Ollerton et al., 2011). To date the use of honeybees (*Apis mellifera*) or other managed pollinator species (*Bombus* spp., *Osmia* spp. and *Megachile* spp.) is the most common management practice for pollination in agricultural crops. On the other hand, pollination services provided by wild pollinators have a considerable added value (Gallai et al., 2009; Garratt et al., 2014; Kleijn et al., 2015). Many studies have found that more diverse pollinator communities and flower visitation of wild pollinators enhance and stabilise pollination rates in different crop systems despite application of honeybees (Garibaldi et al., 2013). When present, wild pollinators also interact with honeybees, improving the pollination performance of the honeybee (Greenleaf and Kremen, 2006; Carvalheiro et al., 2013; Brittain et al., 2013).

Land use intensification and habitat loss are among the multiple human-induced pressures that have contributed to recent declines of wild pollinator diversity (Potts et al., 2010; Goulson et al., 2015). Natural and semi-natural habitat such as forest and hedgerow patches in agricultural landscapes can counteract this by supporting communities of wild pollinators (Winfree et al., 2011; Mallinger et al., 2016). Consequently species richness as well as flower visitation of wild pollinators in agricultural fields increase with increasing proximity of natural and semi-natural habitat in the surrounding landscape (Ricketts et al., 2008; Garibaldi et al., 2011). Local scale research suggests that natural and semi-natural habitat enhance pollinator diversity as well as the corresponding pollination service in agricultural fields (Watson et al., 2011; Holzschuh et al., 2012; Klein et al., 2012; Morandin and Kremen, 2013; Hopfenmuller et al., 2014; Martins et al., 2015).

Aside from the presence of such natural and semi-natural habitat in landscapes, intensive agricultural practice itself can alter the diversity and composition of wild pollinator communities (Andersson et al., 2013; Kennedy et al., 2013). In general, increasing agricultural intensification causes landscape simplification or landscape homogenisation with reduced nesting sites and

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impoverished flowering resources for wild pollinators. This entails negative effects on species richness, abundances and community composition of wild pollinator communities (Le Feon et al., 2010; Andersson et al., 2013; Petersen and Nault 2014). Whereas, inclusion of natural and semi-natural elements in landscapes can improve such landscapes through provision of abundant and diverse nesting and flowering resources. As a consequence, wild pollination service to e.g. apple (*Malus sylvestris*), strawberry (*Fragaria ananassa*), spring oilseed rape (*Brassica napus*), buck-wheat (*Fagopyrum esculentum*), field bean (*Phaseolus vulgaris*) and pumpkin (*Cucurbita pepo*) decreases with increasing intensive agriculture in the surrounding landscape (Bartomeus et al., 2014; Peterson and Nault, 2014; Connelly et al., 2015). Likewise, in a countrywide study, Deguines et al. (2014) saw no increase in mean crop yield and yield stability with increasing agricultural intensification for high pollination dependent crops. Decreasing pollinator abundances with increasing agricultural intensity could suggest a landscape-wide dilution of pollinators (Holzschuh et al., 2016). Moreover, certain mass flowering crops in the landscape can attract pollinators during their short time of bloom. When these crops are very abundant and widespread in the landscape the pollinator populations become diluted over the landscape (Holzschuh et al., 2011; Montero-Castaño et al., 2016).

Decreasing pollination services are a matter of concern for future food security for our ever-growing human population. In order to anticipate limitations of crop production by a pollination shortage we must gain understanding how different factors might limit the pollination service of wild pollinators. Knowledge about how wild pollinator communities and their services respond to landscape composition and landscape intensification is important to design management strategies to sustain and promote wild pollination services. Moreover, in landscapes where pollination services are crucial, this knowledge is vital to ensure successful cultivation in the long term. Fruit cultivation highly depends on these services, but can be a form of intensive agriculture itself. Therefore, it potentially has its own impact on the suitability of the landscape to support healthy populations of pollinators.

In this study we investigate the effects of intensive fruit cultivation in a landscape in Flanders (Belgium) on the diversity of the pollinator community and on the fruit set in orchards of sweet cherry (*Prunus avium*). More specifically we tested the following hypotheses;

1. High proportions of intensive fruit cultivation in the surrounding landscape of the orchard will have a negative relation with both species richness and abundance of wild pollinators in sweet cherry orchards.
2. Fruit set of sweet cherry will decrease with increasing proportion of intensive fruit cultivation in the surrounding landscape of the orchard.

2. Material and methods

2.1. Study sites

The study area is situated in the provinces Flemish Brabant and Limburg in Flanders, Belgium. In the study area intensive fruit cultivation is widespread and a very important economic activity. Management in these commercial fruit orchards is very intensive and aims at maximizing fruit production. Inputs of insecticides, fungicides, herbicides and mineral fertilizers are high and there is very little herbaceous vegetation or hedgerows. Such management implies that flowering resources before and after the orchard bloom are scarce.

Seven commercial sweet cherry orchards were selected in this area based on a gradient of intensive commercial fruit orchards in the surrounding landscape in a radius of 1 km. The surface area of the selected orchards was between 0.5 ha and 2.4 ha (1.33 ± 0.30 ha, mean ± se). The distance between the studied orchards ranged from 2.7 km to 98 km. Selected study orchards had to meet with certain criteria. All orchards had to be under conventional management (mowing management, application integrated schemes of pesticides, herbicides and fertilizers). In addition, the orchards had to be composed of sweet cherry trees that are at an age of commercial production. The orchards also had to contain one of the sweet cherry cultivars “Kordia” or “Regina” or both. These cultivars are most common in the area and are the ones that are of the most commercial interest. These cultivars are self-incompatible and require pollen from a compatible cultivar for fertilization and consequently fruit set (Lech et al., 2008). Every orchard contains compatible cultivars and all the farmers placed honeybee hives in the orchard during sweet cherry bloom, because of the high pollination dependency of the cultivars.

2.2. Landscape metrics

In order to test our hypotheses we selected orchards in a gradient from 0% to 50% of intensive fruit cultivation in the surrounding landscape within a radius of 1000 m of the orchards. A GIS program (QGIS Development Team, 2012) was used to map the intensive fruit cultivation in the surrounding landscape of each study orchard; based on aerial photographs and topographic maps we allocated the land use class in the 1000 m buffer zone around the orchards. For each site the percentage of intensive fruit cultivation was calculated within a buffer around the orchard with a radius of 250 m and 1000 m using QGIS. In addition to intensive fruit cultivation, the percentage of semi-natural habitat was mapped and taken as extra explanatory variable. The land use types that were considered as semi-natural habitat were; forests, woodlands, brushwood, heathlands, tree lines and hedgerows. Again for each site the percentage of semi-natural habitat was calculated within a buffer around the orchard with a radius of 250 m and 1000 m. Percentage area covered with semi-natural habitat was not correlated with the percentage area of intensive fruit cultivation (Spearman rank correlation: $\rho = -0.07$, $p = 0.88$ and $\rho = 0.43$, $p = 0.35$ for 250 m and for 1000 m, respectively). Other land use classes in the area were mainly urban area and agricultural fields.

2.3. Pollinator sampling

The field work was conducted during spring of 2015. Species richness and abundance of insect pollinators (managed bees, wild bees, hoverflies) was determined during the peak bloom of sweet cherry. Within each site we constructed one observation plot of 5×5 m in the centre of the orchard between two rows of a sweet cherry cultivar that was in full bloom that day. Pollinators were sampled in each orchard for one day; during three times of the day all sweet cherry flower-visiting insects within this observation plot were caught in this plot with an insect net during one hour. We sampled pollinators at 10 h, 13 h and 16 h (3×1 h = 3 h per orchard). Pollinators that could be identified in the field were kept in a conical tube and released after the sampling hour. In this way counting a certain individual multiple times was avoided. Pollinators that could not be identified in the field were preserved for subsequent identification in the laboratory. Because of the difficulty of distinguishing queens of the species *B. terrestris*,*B. lucorum*, *B. magnus* and *B. cryptarum* we pooled these and noted them as *B. terrestris* agg. Pollinator sampling was carried out in no or calm wind (maximum 2 Beaufort), no rain and temperatures