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Short communication

Pest regulation and support of natural enemies in agriculture: Experimental evidence of within field wildflower strips

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ABSTRACT

Restoring ecosystem services in agriculture is vital to reach a sustainable food production. More specifically, developing farming practices which enhance biological pest control is a main issue for today's agriculture. The aim of this study was to assess whether the two strategies of complicating the search of host plants by pests by increasing plant diversity, and of supporting their natural enemies by managing habitats, could be combined simultaneously at the field scale to restore biological pest control and reduce chemical insecticide use. In Gembloux (Belgium), wildflower strips (WFS) were sown within wheat crops in which pests (i.e., aphids), their predators (i.e. aphidophagous hoverflies, lacewings and ladybeetles) and parasitoid wasps were monitored for 10 weeks in the period of May through July 2015 as indicators of the ES of pest control. Aphids were significantly reduced and adult hoverflies favoured in wheat in between WFS, compared to monoculture wheat plots. No significant differences were observed for adult lacewings, ladybeetles and parasitoids. In all treatments, very few lacewing and ladybeetle larvae were observed on wheat tillers. The abundance of hoverfly larvae was positively correlated with the aphid density on tillers in between WFS, showing that increasing food provisions by multiplying habitats within fields, and not only along margins, can help supporting aphidophagous hoverflies in crops. By enhancing the ecosystem services of biological pest control, this study shows that increasing both plant diversity and managing habitats for natural enemies may reduce aphid populations, hence insecticide use. Future research should continue this vein of work by quantifying the link between agricultural practices and the delivery of ecosystem services in order to guide future measures of agricultural policies.

1. Introduction

The intensification of agriculture in Europe, which was characterised by an increased use of external inputs (i.e., improved seeds, chemical fertilisers and pesticides), has led to a simplification of agricultural ecosystems, environmental damages and health issues (Robinson and Sutherland, 2002). This acknowledgement goes beyond scientific concerns, as attested by, among other, the European Biodiversity Strategy which clearly states the need to "increase the contribution of agriculture to maintaining and enhancing biodiversity" (Target 3). More specifically, the spread of large monoculture fields and the loss of natural habitats have increased the risk of pest outbreaks (Altieri and Nicholls, 2004) and led to a reduction of biodiversity imperilling the provision of ecosystem services (ES) (Flynn et al., 2009). Moreover, the harmful effects on human health and the environment of chemical insecticides used to control agricultural insect pests have been largely proved (Baldi et al., 2013; Devine and Furlong, 2007). The ever-tighter regulation on pesticides (Skevas et al., 2013) and the call from consumers for healthier food (Howard and Allen, 2010) encourage the development of innovative agroecological practices that would restore ES, which may allow farmers to reduce their reliance on these inputs. Among other strategies (Zehnder et al., 2007), two may be of particular interest: (i) complicate the search

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of host plants by pests, and (ii) provide habitats supporting pest natural enemies that may exercise predation and parasitism.

According to the 'resource concentration' hypothesis of Root (1973), it is more difficult for specialist herbivores to find their host plant in diversified fields than in monoculture. In practice, intercropping and agroforestry systems (i.e., cultivating simultaneously several crops or crop and trees, respectively) are known to increase plant diversity at the field scale (Malézieux et al., 2009). Previous studies showed that, when applied in wheat fields, aphids (*Hemiptera*: *Aphididae*) were systematically less abundant in these systems compared to pure stands (Lopes et al., 2016; Muhammad et al., 2005). However, these studies reported inconsistent results regarding natural enemy support. One reason can be that through these systems, adult natural enemies – which exclusively (e.g., hoverflies [*Diptera*: *Syrphidae*]) or partly (e.g., ladybeetles [*Coleoptera*: *Coccinellidae*], lacewings [*Neuroptera*: *Chrysopidae*], parasitoid wasps [*Hymenoptera*]) depend on non-prey food (Wäckers and Van Rijn, 2012) – do not find the resources they need, such as proteins, various sugars, amino-acids, mineral ions, alkaloids (Lundgren, 2009). These resources can be made available through managing appropriate infrastructures in agricultural landscapes. For instance, wildflower strips (WFS) are known to be habitats for pest natural enemies (Haaland et al., 2011) as they potentially provide them the needed resources through nectar and pollen (Lu et al., 2014). Moreover, they may support additional prey for predators and hosts for parasitoids and be a shelter from adverse conditions (Landis et al., 2000). Several studies assessed the potential of sowing WFS along field margins to favour natural enemies and enhance pest control in the adjacent fields. Some recently showed a positive effect on pest reduction (Balzan and Moonen, 2014; Tschumi et al., 2016a, 2016b) but previous ones recall that it may not be systematic (Hickman and Wratten, 1996; Pfiffner et al., 2009).

In the light of these results, the aim of this study was to assess whether the two strategies of complicating the search of host plant by pests and of supporting natural enemies could be combined simultaneously to restore biological pest control and reduce chemical insecticide use. To our knowledge, flowering habitats are almost always sown in strips at field margins. Only Sutherland et al. (2001) investigated whether WFS sown as one large patch or several smaller ones within fields better support hoverflies. However, the effect was assessed in the patches only, and not in the adjacent crops. In the present study, we tested whether sowing multiple WFS within fields could allow reducing pests by an increase of plant diversity and the support of natural enemies.

2. Material and methods

2.1. Field set up

This study was conducted at the experimental farm of Gembloux Agro-Bio Tech (University of Liège), Namur Province of Belgium (50°34′03′′N; 4°42′27′′E). In this region, a deep and loamy soil allows high crop productivity and the landscape is characterised by large crop fields and few non-crop habitats (in this region, 50–70% of the surface is dedicated to agriculture while 9% are wooded areas, respectively the highest and the lowest level in Wallonia, Service Public de Wallonie, 2014). On a surface of 9 ha, five replicated WFS (125 m × 8 m) were sown at a distance of 27 m from each other (the field was surrounded by roads, a two-year old agroforestry system and a woodlot which edge was perpendicular to the WFS and the control plots, Fig. 1). Each WFS was composed of 17 perennial wildflower species and three grass species commonly found in Belgian grasslands (see Uyttenbroeck et al., 2015 for the list of the flower species and details on the sowing protocol) and available on the market (seeds were obtained from ECOSEM, Belgium). Based on this design, four treatments were considered related to the location of wheat plots: (i) plots surrounding the WFS were considered as the treatment 'control'; (ii) the plots between the two first WFS were termed 'lateral' treatment and from west to east, the plots with two and three WFS on each side were termed (iii) 'central 1' and (iv) 'central 2' treatment, respectively. WFS were sown the 6th June 2013 and mown twice each year. The winter wheat (variety 'Edgar') was sown the 23rd October 2014. No insecticides and no herbicides were used in the whole experimental area.

2.2. Insect monitoring

As indicators of the ES of pest control, winged wheat aphids and their adult natural enemies were trapped for 10 weeks from 12 May to 29 July 2015 in wheat plots (excepting one week between the 30th June and 7th July which corresponded to the WFS mowing). Five yellow pan traps (Flora®, 27 cm diameter and 10 cm depth) were installed on a fibreglass stick in each treatment (Fig. 1). Traps were placed at a distance of 12–15 m from WFS and separated from one to another by 25 m. They were positioned at vegetation height, and filled with water containing a few drops of detergent (dish-washing liquid) to reduce the surface tension of water. Their position was adjusted during the growing season to follow wheat growth. Traps were emptied and refilled every seven days, and the trapped insects conserved in 70% ethanol. Wheat aphids, adult hoverflies, lacewings and ladybeetles, whose larvae are aphidophagous, were identified to the species level following Taylor (1981), van Veen (2010), San Martin (2004) and Roy et al. (2013) respectively. Keys from Tomanović et al. (2003) and Rakhshani et al. (2008) were used to identify parasitoid wasps of wheat aphids to the species level. Moreover, aphids and larvae of hoverflies, lacewings and ladybeetles were counted on wheat tillers during the same period. Around each traps, 20 tillers were randomly chosen every week. Rainy days were avoided and no distinction between larval stages was made.

2.3. Statistical analysis

Generalised linear mixed effect models (package 'lme4', function 'glmer', Bates et al., 2014) with Poisson error distribution (log-link function) were fitted to test whether the location of wheat plots with respect to WFS (i.e., treatments) affected the density of aphids and their natural enemies, both trapped and observed. The four treatments were analysed as fixed effects and trapping or observation dates (10 dates) were included as random effects as measurements were repeated each time in the same plot. Replications (five replications per treatment) were also included as random effects, nested into the effect of dates, in order to integrate their dependent relationship (i.e., pseudo-replications). The effect of the wheat plot location on insect abundance was tested using a likelihood-ratio test ($p < 0.05$) and means were compared between the different treatments using a post-hoc test of Tukey ($p < 0.05$, package 'multcomp', function 'glht', Hothorn et al., 2008). After a $\log(x + 1)$ transformation, the linear relation between observed aphids and both adult predators and larvae (i.e., abundance of each predators at each observation point, polled from all observation dates) was tested through a linear regression ($p < 0.05$). The statistical analyses were performed using R Core Team (2013).

3. Results

The presence of WFS significantly affected the aphids observed ($df = 3$; $\chi^2 = 93.1$; p-value < 0.001) and trapped ($df = 3$; $\chi^2 = 13.9$; p-value = 0.003) as well as hoverfly larvae observed ($df = 3$; $\chi^2 = 16.1$; p-value = 0.001) and adults trapped ($df = 3$; $\chi^2 = 16.3$;