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The effect of semi-natural habitats on aphids and their natural enemies across spatial and temporal scales

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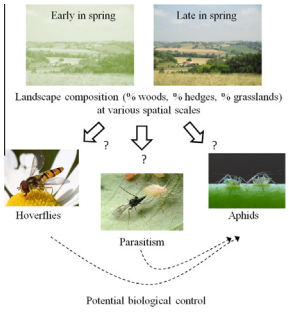
HIGHLIGHTS

- Aphids and hoverflies abundances were positively related.
- Aphid abundance decreased with grasslands and hedges density.
- Woods enhanced abundance of hoverflies in early spring.
- Hedges enhanced aphid parasitism in late spring.

GRAPHICAL ABSTRACT



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ABSTRACT

Semi-natural habitats in agricultural landscapes are generally assumed to enhance the biological control of insect pests based on native beneficial insects, by providing alternative prey and hosts, resources and refuges for overwintering. We hypothesized that natural enemies of winter wheat aphids should arrive sooner in fields near semi-natural habitats. We compared aphid, hoverfly (larvae and eggs) and parasitized aphid (mummies) abundances in 54 winter wheat fields located in southern France from 2003 to 2007. Six surveys were recorded each spring and were split into the early period (defined as the period before the peak of aphid growth) and the late period (after the peak). The wheat fields differed by their surrounding landscape composition measured as the proportion of semi-natural habitats (woods, hedges and grasslands), at three different spatial scales: 200 m, 500 m, and 1200 m. Despite great variability in abundance data between years, the abundance of hoverflies appeared more sensitive to landscape composition than aphid abundance was. Early abundance for both aphids and hoverflies was positively related to wood cover, but not late abundance in spring. The abundance of hoverflies was positively related to hedge and grassland cover at all spatial scales and both periods considered. Aphid parasitism was higher near hedges at the small spatial scale late in the spring. Our results confirmed that higher proportions of semi-natural habitats in agricultural landscapes enhance the biological control of pests, but this effect depends on the spatial scale, the time period in the spring and the natural enemies considered.

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1. Introduction

The structural heterogeneity of agricultural landscapes influences biodiversity, and notably many groups of arthropods providing services to crop production e.g. pest control, pollination (Burel et al., 1998; Weibull et al., 2003; Schmidt et al., 2004; Tscharntke et al., 2005a). Some of these organisms are mobile and their presence depends on resource availability that is segregated from the location or time where ecosystem services are provided (Kremen et al., 2007). Many authors argue that habitat management at a landscape-scale is needed to enhance ecosystem services such as pollination or pest biological control by effective habitat management (Tscharntke et al., 2007). To disentangle the effects of landscape complexity on pests as well as on their natural enemies, it is necessary to identify the appropriate landscape elements, spatial scales and time periods to be considered (Kremen et al., 2007; Chaplin-Kramer et al., 2013).

The landscape elements involved in the life cycle of many beneficial arthropods are quite well documented. It is now known that most of the natural enemies of crop pests do not complete their life cycles in cultivated fields (Hani and Boller, 1998), but use semi-natural habitats (such as hedges, field margins, beetle banks, meadows and fallows) in the agricultural landscape (Landis et al., 2000; Gurr et al., 2004). Semi-natural habitats favour populations of natural enemies and improve their efficiency as control agents by providing alternative prey and hosts, nectar and pollen resources (Marino and Landis, 1996; Thies and Tscharntke, 1999), and refuges against unfavourable weather conditions(i.e. "winter refuge", Corbett and Rosenheim, 1996; Sarthou et al., 2005). Thus, semi-natural habitats can represent important sources of natural enemies colonizing crop fields, and proximity to such habitats may result in increased control of agricultural pests (i.e. "spill over hypothesis", Rand et al. 2006). Spatial scales at which species respond to landscape heterogeneity revealed different responses according to species or groups (Purtauf et al., 2004; Schmidt et al., 2008).

In addition to spatial scales, there is a growing interest in considering the temporal scale in order to identify the relationships between pest densities, natural enemies dynamics and pest control services (Chaplin-Kramer et al., 2013). Past empirical studies generally consider short-term data sets (i.e. a few weeks), making it difficult to understand the mechanisms behind the response patterns and the long-term dynamics of species. Although one of the laws to prevent pest infestations is "the earlier the natural enemies, the better the control" (Altieri and Nicholls, 2004), the time periods during which beneficial arthropods exploit particular landscape elements remain unclear (but see Bianchi and van der Werf, 2004; Sarthou et al., 2005). This is a crucial aspect of any recommendations for the enhancement of ecosystem services by landscape management, as for example in planning the mowing or reaping of grassland or the pruning of hedges.

Aphids (Hemiptera: Aphididae) are major invertebrate pests in agriculture and especially in cereal crops. In winter wheat fields, in south western France as well as in western Europe as a whole, the herbivore community is dominated for a short period by three species of generalist cereal aphids: *Sitobion avenae* (F.), *Metopolophium dirhodum* (W.) and *Rhopalosiphum padi* (L.)., Hoverflies (Diptera: Syrphidae), mainly represented by *Episyrphus balteatus* (De Geer), *Sphaerophoria scripta* (L.) and *Melanostoma mellinum* (L.) are important natural enemies of cereal aphids in Western Europe. Parasitoid wasps (Hymenoptera: mainly Aphidiidae) occupy the same trophic level and specialize in one or more aphid host species. The most abundant aphid parasitoids on the three species of cereal aphids are *Aphidius ervi* (H.), *Aphidius rhopalosiphi* (De Stefani-Perez) and *Praon volucre* (H.) (Sigsgaard, 1997). All three parasitoids overwinter in mummies of aphids that served as host (Langer, 2001). All these taxa (aphids, hoverflies, parasitoid wasps) are assumed to be enhanced by semi-natural habitats providing resources and overwintering sites (Thies et al., 2005) but not necessarily at the same time period (Bianchi et al., 2006).

Here, we investigated how semi-natural habitats in the agricultural landscape affect both aphid and their natural enemies abundance, at three different spatial scales (200 m, 500 m, 1200 m) representative of the range of dispersal of studied species. We surveyed the spring abundance of aphids, hoverflies and mummies (parasitized aphids) in 54 winter wheat fields in south-western France. Our study aimed at testing the following hypothesis for both scales:

(1) Semi-natural habitats such as woods, hedges and grasslands support biological control by favouring hoverflies and parasitoids abundance much more than aphids and thus decreasing aphid abundance in winter wheat-field.
(2) According to the "winter refuge" (Corbett and Rosenheim, 1996; Sarthou et al., 2005) and the "spill over" hypotheses (Rand et al., 2006), natural enemies abundance should be greater in the early spring near semi-natural habitats than in the late spring.

2. Methods

2.1. Study area

The study region lies between the Garonne and Gers rivers, in south-western France (approximately 43°N 1°E). This region is hilly (alt. 200–400 m), composed of south-north valleys, within a sub-Atlantic climate zone subject to both Mediterranean and mountain influences. The hillsides are sculpted in molasse, an argilo-calcareous detrital formation. Forest covers 15–30% of the area and is composed of multiple small, private forest fragments (Balent and Courtiade, 1992). The southern part of the study region (*Wooded zone*), near the Pyrenees, is slightly hillier and more wooded, with 27% of forest cover, than the northern part (*Less Wooded zone*) with 15% of forest cover. Landscapes include a mix of crops (winter cereals, oilseed rape and sunflower, with maize in irrigated lowland), pastures, and small coppice woods. Semi-natural habitats are woodlots, woodlot edges, hedges, field margins, grasslands (wet in the valleys and dry on the hill tops) and fields lying fallow.

2.2. Spring recording of hoverflies, aphids and mummies

Hoverfly, aphid and mummy abundances were studied in winter wheat fields with the same argilo-calcareous soil characteristics and arable management practices (i.e. ploughing, pesticides uses; farmers were questioned before and after the experiment). Each of the fields was larger than 1 ha (6 ha ± 4) and had a similar slope. Due to crop rotation, the fields differed from year to year. Twelve winter wheat fields were studied in spring 2003 and fourteen from spring 2004 to spring 2007.

Aphids, mummies (parasitized aphids) and hoverflies (eggs, larvae and pupae) were counted in a 20 m × 20 m square plot (400 m^2), every 2 weeks (i.e. 6 records each year), from the end of March (to detect early colonization process) to the beginning of June (corresponding to the wheat stem elongation, heading, grain-filling). The 400 m^2 square plot was placed at a distance of 20 m from the field borders in the south western corner of the field. All farmers undertook to avoid biocide (herbicide, fungicide) spraying in the square plot itself. In each plot, ten neighbouring wheat-stalks were cut at 10 different subplots in the square. Each subplot was chosen after an active search for aphid colonies lasting 3 min (if no aphid colony was found, the observer cut ten stalks