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Interactions between conservation agricultural practice and landscape composition promote weed seed predation by invertebrates

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ABSTRACT

Assuring future crop yields whilst minimising impacts of agriculture on the environment requires that we adopt managements that replace pesticides by fostering pest regulation. However, large-scale empirical evidence for in-field and landscape properties supporting natural enemy abundance and their regulation of pests, as an ecosystem service in agriculture, is scarce. Using data from 67 arable fields, we examined whether the duration of adoption of in-field conservation agricultural practices (CA) and the landscape context of those arable fields explains the levels of in-field weed seed predation. Our results indicate that landscape and CA, in interaction, do indeed explain a large proportion of the observed variation in weed seed predation in-field. CA practice maintains high in-field abundances of carabids, but only after a period of four years of adoption. Prior to this, carabid abundance was only high for fields in landscapes with high percentage cover of arable crops and/or permanent grassland. Our work shows that the effect of landscape composition is conditional on local in-field management and that both local and landscape scales can be used to enhance the abundance of carabid beetles and the amount of seed predation in arable fields.

1. Introduction

The challenge of sustainable agriculture is how to maintain high crop yields whilst reducing pesticide inputs which can have negative impacts on human health and the environment (Bommarco et al., 2013; Godfray and Garnett, 2013). The global, economic cost of crop yield loss due to weeds is as important as that due to animal pests and pathogens combined (Oerke, 2006). To achieve substantial reductions in herbicide use whilst meeting global food demands, we need to identify agro-ecological alternatives for weed control (Petit et al., 2015). In temperate arable agroecosystems, carabid beetles are important, naturally-present weed seed predators (Westerman et al., 2003; Honek et al., 2003) that significantly affect both weed seed bank turnover (Bohan et al., 2011) and population growth (Crawley, 2000) and thus have the potential to reduce weed related crop yield losses (Bohan et al., 2011; Kulkarni et al., 2015).

Understanding the in-field and landscape factors that support or limit weed seed predation by carabids is a prerequisite for predicting and managing the efficacy of weed biological control (Swope and Satterthwaite, 2012; Kulkarni et al., 2015). Previous studies have shown that weed seed predation tends to increase as the intensity of in-field crop management is reduced (O'Rourke et al., 2006; Menalled et al., 2007; Meiss et al., 2010; Trichard et al., 2014). At landscape scales, weed seed predation has been found to both increase and/or decrease with changes in landscape composition (Menalled et al., 2000; Diekötter et al., 2010; Trichard et al., 2013a; Jonason et al., 2013). The complexity of this picture can be further exacerbated by the effect of interaction between in-field management and the landscape context of arable fields where landscape effects vary according to in-field management (Fischer et al., 2011). These partial results call for additional studies that consider simultaneously local and landscape scale factors as drivers of weed seed predation.

Gaining a better understanding of the mechanisms that explain the impact of in-field and landscape factors on weed seed predation will require that we consider how these factors affect carabids. Our assumption is that the effects of local and landscape scale factors on seed predation reflect the impact of these multiple-scale drivers on the richness, diversity and abundance

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of carabids in-field (Kulkarni et al., 2015). This view is supported by previous studies, for example Trichard et al. (2013a) demonstrated that the identity and the respective weights of in-field and landscape factors affecting seed-eating carabids and weed seed predation were identical. Several studies have detected robust and generic positive links between weed seed predation and seed-eating carabid abundance (Gallandt et al., 2005; Westerman et al., 2005; Bohan et al., 2011; Kulkarni et al., 2015). Documenting the impact of in-field and landscape factors on carabid abundance thus appears critical, especially as studies on carabid response to landscape drivers has mostly focussed on carabid richness and diversity rather than on carabid in-field abundance (but see Purtauf et al., 2005; Woodcock et al., 2010; Labruyere et al., 2016a).

In addition to accounting for the impact of in-field management on the abundance of seed-eating carabids and in turn on in-field predation rates, it is acknowledged that in- field management affect carabid species composition (Kromp, 1999). Moreover, in-field habitat conditions affect the activity and mobility of carabids as well as the availability of alternative prey (Haschek et al., 2012; Labruyere et al., 2016b). As seed predation levels can potentially be affected by carabid species richness, diversity or the identity of individual carabid species and the patterns of seed consumption by carabids (Gaines and Claudio Gratton, 2010; Jonason et al., 2013), it is plausible that in-field management play a role in seed predation levels, independently of its effect on the abundance of seed-eating carabids.

In previous studies, we have explored the variations in weed seed predation rates in response to Conservation Agriculture (CA) and the landscape context of CA fields. We established that the effect of CA was not apparent in early years of CA adoption (Trichard et al., 2013a) but was significant in later years (Trichard et al., 2014). The aim of the present paper was to analyse the complex relationships between in-field and landscape scale factors, carabids and weed seed predation. This analysis builds on data collected in 67 winter-cereal fields spread over a gradient of time since conversion to CA and a gradient of landscape composition. Our expectation was that seed predation will be related to combinations of in-field management and landscape properties because in-field management and landscape context directly affect the number of carabids found in-field. We also hypothesise that it is these in-field carabids, and the conditions of management that pertain in-field, which explain the number of weed seeds eaten. Three sequential analyses were thus performed that (i) assessed the relative role of in-field condition, landscape composition and of potential interactive effects between in-field and landscape factors on weed seed predation levels (ii) tested the effect of these same in-field and landscape factors on the abundance of the three trophic guilds of in-field carabids and (iii) analysed the relationships between the abundance of the three trophic guilds and weed seed predation.

2. Materials and methods

2.1. Study area and site selection

The study was carried out within a 50 km radius of Dijon, Burgundy, France (47°19′18″N, 5°02′29″E), an area that is dominated by arable farming with substantial cover of grasslands and deciduous forest stands. The predominant soil types are clay-, shallow calcareous- and silky clay-loams. In this area, some farmers have converted to CA to reduce the environmental impacts of farming practice through the use of direct-drilling methods of tillage and a community of up to five cover plant species to cover the soil during what would be a fallow period between crops. Among the CA farms, we selected 67 fields of winter-sown cereals, namely barley and wheat. The mean distance between two nearest sampled fields was 848 m.

The 67 fields were direct-drilled with the winter cereal in October 2011, following a 2.5-month period of cover planting. The crops grown in the year prior to the experiment were mostly winter oilseed rape (55.2% of fields), winter wheat (11.9%), and spring peas (9.0%), the remaining crops being flax, mustard, spring barley, sunflower, winter barley and winter flax. All fields were managed with no systematic but reasoned use of herbicides and pesticides. Due to the uneven rate of adoption of CA across the region in the six years prior to sampling, field replication numbered 8, 3, 20, 12, 17, and 7 fields, for each of the durations from 1 to 6 years, respectively.

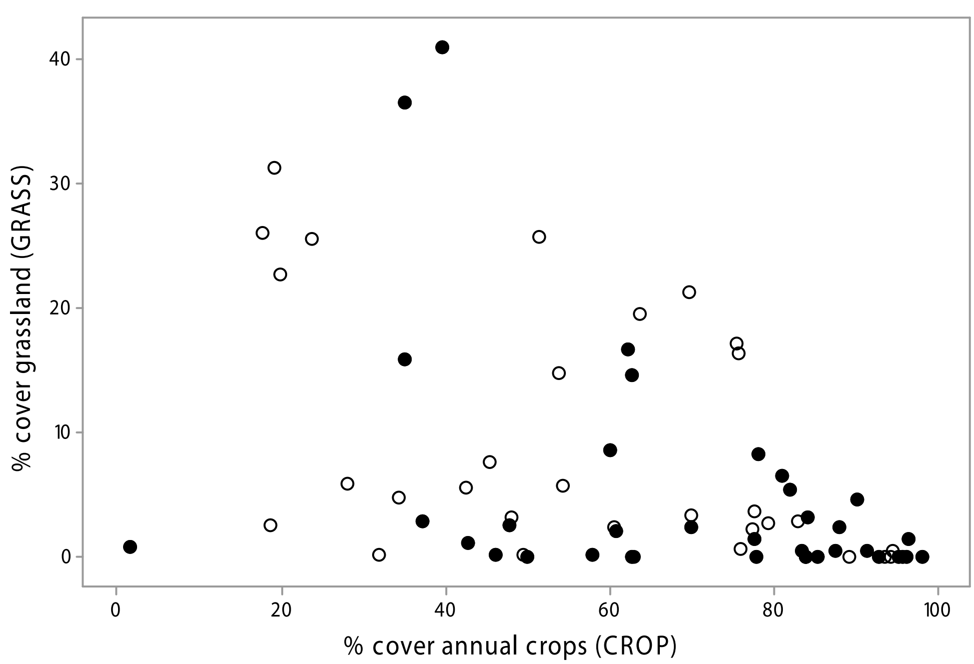

Fig. 1. Location of the 67 sampled fields along the landscape gradient. Fields are represented as a function of% cover area of annual crops within 1 km^2 along axis x and% cover area of grassland within 1 km^2 along axis y. Clear circles represent CA_1 fields (1–3 year under CA) and closed circles represent CA_2fields (4–6 years under CA).