Disentangling local agronomic practices from agricultural landscape effects on pest biological control

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Abstract: The biological control of crop pests is a valuable service provided by various beneficial organisms that are naturally present in agricultural landscapes. Semi-natural habitats has long been recognized as essential to preserve beneficial insects, but proof of their efficiency to enhance biological control of pests remains non conclusive. Here, we examined the variability of landscape effect on biological pest control and the way local agronomic practices may modulate it. Biological pest control was monitored in 80 commercial fields (arable crops and orchards) during three consecutive years in four contrasting French agricultural landscapes distributed along a double gradient of pesticide use and landscape complexity measured in a 1 km^2 area centred on each field. Biocontrol efficacy in each field was assessed using three types of sentinel preys (weed seeds, moth eggs, and aphids). The effects of landscape simplification, pesticide use intensity and their interaction on the predation of each sentinel prey were analysed using generalised linear mixed models. At local level, the intensity of pesticide use reduced the predation of weed seeds and aphids. At landscape level, the proportion of the monitored crop reduced the predation of weed seeds and moth eggs. Finally, significant interactions between local and landscape factors were detected for each sentinel prey: (i) the predation of moth eggs was negatively influenced by landscape simplification at low pesticide use intensity only, whereas the effect was positive at high pesticide use intensity; (ii) aphid predation significantly decreased with increasing crop-wood interface length and proportion of meadow, but only at high pesticide use intensity; (iii) weed seed predation significantly decreased when land use diversity around the fields increased under high pesticide use intensity and, inversely, increased with land cover diversity around the fields at of low pesticide use intensity. These results suggest that reduction in pesticide use should be associated with the reinforcement of semi-natural habitats in agricultural landscape to enhance natural biocontrol.

Key words conservation biological control, predation, sentinel prey, aphid, seed, moth egg, landscape complexity, agricultural practices, pesticide treatments.

Introduction

Agriculture is one important driver of global change and among the most serious threats to biodiversity (Tylianakis et al. 2008). To support agricultural profitability, large-scale modern farming has increased nutrient and pesticide uses, agrosystem simplification and reduction and fragmentation of semi-natural habitats. This modern agriculture led to conflicts between crop production and other ecosystem service provisions, on which agriculture also depends. One challenge of a post-modern sustainable agriculture is maximising the benefits of ecosystem services designing agricultural landscape for biodiversity-based-ecosystem services (Landis 2017). Agroecological research during the last decades highlighted the primary importance of semi-natural habitats in agricultural landscape to promote farmland biodiversity (Billeter et al. 2008) and mitigate negative impacts of local agronomic practices on within-field biodiversity

(Gabriel et al. 2010). However, the benefit for agriculture of non-crop habitats remain non conclusive, notably in terms of pest biocontrol enhancement (Karp et al. 2018). In order to shed light on integrated pest management strategies at multiple spatial scales (Begg et al. 2017), we examined in this study the effects of landscape simplification, agronomic practice intensity and their interaction on pest biocontrol.

Material and methods

Selection of the monitored fields

The study was conducted into 80 commercial fields distributed in agricultural landscapes from four distinct bioclimatic regions close to Avignon, Toulouse, Rennes and Dijon in France (http://sebiopag.inra.fr/). In each regions, 20 fields were selected along a double gradient of intensity in local agronomic practices and of landscape complexity. In each selected field, intensity of agronomic practices was assessed as the treatment frequency index of the pesticide used (TFI). Six landscape complexity metrics were calculated based on land cover map in 1 km^2 circle centred in each selected field: percentage of wood and meadow semi-natural habitats, lengths of crop-wood and crop-meadow interfaces, Shannon diversity index of the land cover, and percentage of monoculture identical to the monitored crop.

Exposition of sentinel preys

In each selected field, predations of three different types of sentinel prey glued on 5x5 cm paper cards were monitored: ten weed seeds (*Viola arvensis*), a cluster of about 100 moth eggs (*Ephestia kuehniella*) and three aphid adults (*Acyrthosiphon pisum*). Weed seed and moth egg cards were exposed during four days. Aphid cards were exposed during one day. Weed seed cards were studded on the ground. Aphid and moth egg cards were fixed to in the plant canopy. Cards of each sentinel prey were evenly positioned at ten plots along two transects within each selected field (minimum distance of ten meters between two plots). Cards were exposed twice each year (early and late spring sessions) in 2014, 2015 and 2016. Predation rate was estimated as the proportion of consumed prey of each type per field.

Statistical analyses of pest biocontrol potentials

Principal Component Analyses (PCA) were performed (R package ade4) to provide synthetic descriptors of the meteorological conditions (temperature, rain fall, humidity and wind speed) during sentinel prey exposition sessions. The first three PCA axes were used as covariables to account for regional and seasonal meteorological variations in subsequent statistical analyses. Landscape variables and TFI were normalized over the whole dataset according to the monitored crop, the region and the year.

Potential predation was modelled for each sentinel prey using generalized mixed models fitting a beta-binomial distribution (R package glmmADMB). Each model was fitted with seven predictors: crop in the selected field, each PCA axe, TFI, one of each landscape complexity variable and interaction between TFI and the landscape variable. A field identifier was added as a random effect to account for temporal replication in each selected field. Model averaging was performed (R package MuMIn) to estimate the relative effects of each landscape complexity factor and of interaction with TFI.

Results and discussion

Perennial and annual crops in the 80 selected fields were unequally distributed among regions. Predation was measured in rotations of mainly cereal, oleaginous and summer crops in Dijon, Rennes and Toulouse regions and in apple orchards in Avignon region. Predation rates were not correlated between the types of sentinel prey. The mean predation rates were 0.43 (±SD 0.31), 0.56 (± 0.25), and 0.25 (± 0.21) for weed seed, moth egg, and aphid cards, respectively. Weed seed predation was higher in cereal crops than in apple, oleaginous, and summer crops. Moth egg predation was higher in apple, cereal and summer crops than in oleaginous crops. Aphid predation was slightly higher in cereal than oleaginous crops. Meteorological conditions only impacted weed seed and moth egg predations, which were overall higher at low wind speed, high humidity (P<0.001) and low temperature (P<0.05). Rainfall affected positively weed seed predation (P<0.05) and negatively moth egg predation (P<0.01). These results highlight meteorological constraints in pest biocontrol, which likely are different between pests and their natural enemies, but also between seasons and regions.
The intensity of pesticide use (TFI) at the field level (weed seeds and aphids: P<0.05) and the percentage of monoculture identical to this of the monitored field at the landscape level (weed seeds: P<0.01; moth eggs: P<0.05) had overall a negative impact on the predation of each sentinel prey. These results were in total agreement with previous syntheses that point the negative impact of pesticide and landscape simplification on farmland biodiversity and on pest biocontrol potential (Geiger et al. 2010; Muneret et al. 2018). All the other landscape metrics did not affect the predation of each sentinel prey, which is in agreement with the non-conclusive effect of semi-natural habitat on pest biocontrol (Karp et al. 2018). More interestingly, landscape effects on the predation of each sentinel prey mainly depended on the intensity of local pesticide practices (i.e. significant interactions between TFI and the landscape variables, Figure 1)

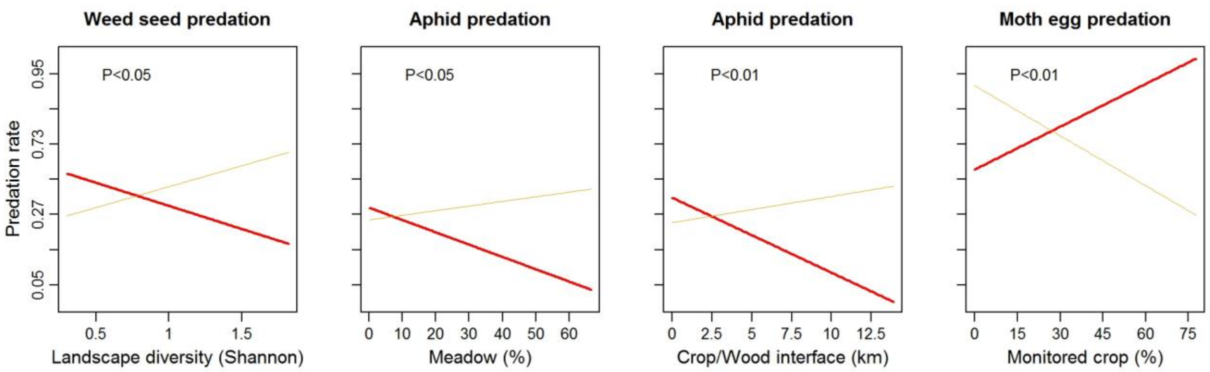

Figure 1. Graphs of significant interaction effects between landscape metrics and pesticide use intensity (TFI). Wide red lines represent predation rate variations for the maximal TFI values in our dataset (maximum = 3.9) and thin orange lines represent predation rate variations for the minimal TFI values in our dataset (minimum=-2.4)

It shows that overall predation did not depend on pesticide use at simple landscape but decreased in cases of high local pesticide use at the more complex landscape (including more semi-natural habitats). These results suggest that pest biocontrol potentials depend on the dynamics of pest and beneficial populations between crops and semi-natural habitats and that pest management strategies, including reduction of pesticide use should be adapted according to the levels of landscape simplification and crop susceptibility to pests.

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