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A functional approach to assessing plant–arthropod interaction in winter wheat

B. Caballero-López[a,*], J.M. Blanco-Moreno[b], N. Pérez[c], J. Pujade-Villar[a], D. Ventura[d], F. Oliva[e], F.X. Sans[b]

[a] Department of Animal Biology, Faculty of Biology, University of Barcelona, Diagonal Av., 645 08028 Barcelona, Spain
[b] Department of Plant Biology, Faculty of Biology, University of Barcelona, Diagonal Av., 645 08028 Barcelona, Spain
[c] Department of Biodiversity and Environmental Management, León University, E-24071 León, Spain
[d] Functional Ecology and Climate Change Group, Laboratory of Plant Ecology and Forest Botany, Forest Technology Centre of Catalonia (CTFC), Road of Sant Llorenç de Morunys, km 2, 25280 Solsona, Spain
[e] Department of Statistics, Faculty of Biology, University of Barcelona, Diagonal Av., 645 08028 Barcelona, Spain

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ABSTRACT

This paper deals with the effect of the farming system on the arthropod community through its effects on plant community characteristics by comparing organic and conventional winter wheat fields in the Mediterranean region. Arthropods and plants were surveyed sequentially in each plot within each field. Most arthropods were identified to family and each taxon was classified into one of the following feeding groups: chewing-herbivores, flower-consumers, omnivores, saprophages, sucking-herbivores, parasitoids, and predators. Plant species were classified into three functional groups (grasses, forbs and legumes) which represent highly distinct resources for the arthropods.

The farming system had a significant impact on the abundance and richness of grasses, forbs and legumes. In turn, the plant community, mainly conditioned by the farming system, affected the entire community of arthropods, indicating that small-scale plant community characteristics must be taken into account in order to achieve a better comprehension of the arthropod's response to the farming system.

There is still no clear perception of the importance of weeds in arable ecosystems, but the role of legumes in enhancing the richness of saprophages, parasitoids and predators underlines the importance of investigating further cropping systems that combine crop production with the maintenance of essential ecosystem services.

1. Introduction

A considerable amount of research has shown that organic farming in arable land systems tends to increase weed species richness, due to the lack of herbicides and of mineral fertilisers, and often more diverse crop rotational schemes (Bengtsson et al., 2005; Hole et al., 2005). Nonetheless, the relationship between weed community and arthropod populations has still been scarcely addressed in the arable land context (Gabriel and Tscharntke, 2007; Gibson et al., 2006), even though it is known that weeds are of central importance to arable system food-webs (Hyvönen and Huusela-Veistola, 2008).

The study of organic and conventional cereal fields that share the same vegetation along boundaries but differ in weed communities, appears to be a suitable model to further explore the relationship between arthropod and plant communities. Furthermore, the comparison of organic and conventional insecticide free managed fields in a Mediterranean context allows the indirect effects of insecticide applications on the plant–arthropod interaction (Hole et al., 2005) to be avoided.

We hypothesize that farming systems would present a significant effect of plant community characteristics and that, in turn, we might detect individual patterns of abundance and richness of the different feeding groups (F.G.s) of arthropods in relation to plant community characteristics, because each F.G. has specific foraging, reproduction and overwintering requirements. Our research goals were to assess (1) the effect of farming type (organic vs. conventional) on the plant community, and (2) the effect of the cover of grasses, forbs and legumes, and weed species richness, on the abundance and family richness of each F.G. of arthropods.

2. Materials and methods

The study was carried out in Montblanquet (NE of Spain), a small village located about 150 km south of Barcelona (41°29′0.9″N, 1°7′16.4″E; 627 m.a.s.l.). The agricultural landscape is dominated by woodlands, mainly pines (*Pinus nigra* subsp. *salzmannii*) and evergreen and deciduous oaks (*Quercus ilex* and *Quercus faginea*),

* Corresponding author. Tel.: +34 93 402 14 44; fax: +34 93 403 57 40.
E-mail address: bertacaballero@ub.edu (B. Caballero-López).

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Table 1
Agronomic characteristics of the organic and conventional winter wheat fields included in the study.

Farming system	Organic	Conventional
Crop rotation	Legume/winter wheat/polyculture	Winter wheat/winter barley
Tillage	2–3 times, 20 cm of depth	3 times, 15 cm of depth
Cereal	Winter wheat cv. *Bonpain*	Winter wheat cv. *Etecho* (2 fields), *Soissons* (2 fields)
Sowing density (kg ha^{-1})	180–200	170–200
Nitrogen inputs (kg N ha^{-1})	Green manure and occasionally hen droppings (<160)	~180 of pig slurry/year <100 of mineral N at times
Weed control	Mechanical*	Chemical**
Pests and diseases control	None	None

* Once after seedling growth stage of wheat.
** All conventional farmers applied Glyphosate (N-(phosphonomethyl) glycine at 2.5 L ha^{-1}) and 2-4-D (2,4-dichlorophenoxyacetic at 1.3 L ha^{-1}) as pre-emergence non-specific herbicides, Splendor 25 SC (Tralkoxidin at 1.6 L ha^{-1}) as a post-emergence grass herbicide and Oxytril (ioxinil, bromoxinil, plus mecoprop at 2 L ha^{-1}) as a broad-leaved herbicide.

scrublands and perennial dominated grasslands. The arable fields, mainly cereals, represented a small percentage of the agricultural landscape (40%) and were intermingled with patches of natural vegetation. Field boundaries were mainly colonised by perennial grasslands dominated by *Brachypodium phoenicoides* and by a mixture of blackthorn-bramble hedgerows and thickets of *Rosmarinus officinalis*. The climate is Mediterranean, with a mean annual precipitation of 450 mm and mean annual temperature of 13 °C.

2.1. Experimental design

Four organically and four conventionally managed winter wheat fields were selected in a homogeneous area of 2 km × 2 km. The organic fields were randomly selected from the 12 available in the area, and the conventional fields were then selected, no more than 1 km apart, but detached from the organic fields. Although we tried to select fields that matched in size and shape, we considered the homogeneity of boundary vegetation more important than homogeneity of field size and shape, as the fields were relatively small in any case. For this reason, field size was significantly greater in conventional (mean ± S.E.; 4.08 ± 0.8 ha) than in organic fields (2.19 ± 0.3 ha, χ^2_1 df = 5.78, *P* value = 0.016). In contrast, perimeter-to-area ratio was significantly greater in organic (mean ± S.E.; 0.09 ± 0.01) than in conventional fields (0.06 ± 0.01; χ^2_1 df = 4.85, *P* value = 0.028). All selected fields were flat in order to avoid any bias in slope and aspect. While weeds were controlled mechanically and fertilisation was made up of green manure and occasionally hen manure in organic fields, the conventional ones were regularly sprayed with herbicides and fertilised with a combination of pig slurry and mineral fertilisers (Table 1). Pesticides other than herbicides were not applied under conventional farming. The selected organic fields had been managed for more than one decade following organic guidelines and were certified by the Catalan Council for Organic Farming (CCPAE). All selected fields were sown with winter wheat (*Triticum aestivum*) between 27 October and 7 November 2003, after seedbed preparation with harrowing at 15–20 cm depth (for further details see Table 1).

In each field we established a 80 m transect diagonally across the centre of the field, starting at 55 m from the edge. Within each transect, five 1 m × 1 m plots at 20 m intervals were surveyed. Arthropod sampling and plant surveys were carried out one after the other within each plot. The arthropods were sampled using a petrol-driven, Blow&Vac leaf-blower apparatus (McCullogh BVM250, Italy; sampling cylinder 60 cm high and 12 cm diameter) converted to a suction sampler according to Stewart and Wright (1995). The suction sampler was operated on full power, which produced an estimated constant air flow of 0.142 m^3 s^{-1} (manufacturer's data). The pipe was held vertically, carefully moved over the wheat plants contained in the 1 m^2 quadrate and exhaustion was performed for 60 s. For each plot, the sampling bag was removed from the machine, enclosed in a labelled plastic bag, and stored in a portable fridge in order to prevent the activity of predators in the bag. All samples were taken by the same two people to reduce the variability of sampling. This method has been shown to provide a sound representation of all trophic levels interacting with vegetation (Letourneau and Goldstein, 2001), and is used extensively to study arthropods in crops (Elliott et al., 2006; Stewart and Wright, 1995).

Arthropod sampling was carried out between 10:00 and 19:00 in sunny weather conditions (temperature > 20 °C), and was performed twice, at different stages of the wheat's development (Zadoks et al., 1974), at the beginning of the wheat's anthesis stage between 25 and 27 May and the mid-milk-ripe stage between 24 and 26 June 2004. As one sampling campaign lasted 2 days, the eight fields were sampled in random order to prevent a systematic bias due to daytime.

2.2. Arthropod processing

Arthropod samples were frozen in order to be sorted and identified at a later date. Catches were quantified as the total numbers of individuals, considering adults and immature stages, and were identified to family (most arthropods) or to order level (Lepidoptera and Thysanoptera). The use of higher taxonomic levels has been successfully tested as a surrogate for inventories at species level (Balmford et al., 1996; Biaggini et al., 2007; Wickramasinghe et al., 2004), and it is particularly useful when an F.G. perspective is required, as the majority of family members belong to the same F.G. (see some considerations below). For this reason, most arthropods were identified to family level, although there were a few exceptions to the sorting pattern. When taxa of the same family showed different feeding preferences (e.g. Drosophilidae, Opomyzidae) their individuals were determined to genus or species level, and the predominant feeding habit of the most abundant genus or species was therefore used to classify the entire family in a F.G. In other cases such as Thysanoptera, specimens were identified at order level because of taxonomic difficulties.

All identified taxa were classified into one of the seven F.G.s: chewing-herbivores (C), flower-consumers (F), omnivores (O), parasitoids (Pa), predators (Pr), saprophages (S), and sucking-herbivores (SP). Each F.G. comprised different feeding strategies and was based on field observations, literature review and specialist's advice (see Acknowledgements). Granivores, plant-chewers and miners were included in the chewing-herbivore category, while plant-sap suckers belong to the sucking-herbivore category. Flower-consumers comprised flower predators, pollen consumers and nectarivores. Saprophages included: mycetophages, plant saprophages, animal saprophages and scavengers. When arthropods showed different feeding preferences in larvae and adult stages, they were assigned to both F.G.s in order to consider their whole lifetime impact. A small number of larvae difficult to classify were investigated in terms of total abundance, but were excluded