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Organic *vs.* conventional farming dichotomy: Does it make sense for natural enemies?

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ABSTRACT

As an alternative to conventional farming, organic farming is considered a promising type of production to meet the challenges of modern agriculture. In particular, organic farming is assumed to favour the biological control of pests by their natural enemies and, therefore, is considered a possible way to reduce the use of pesticides. Effects of organic *vs.* conventional farming on insects natural enemies have been compared, but the results remain uncertain, probably because the diversity of crop management strategies is rarely considered. In this study, we assessed whether or not the diversity of farming practices implemented in organic and conventional farming affects natural enemies of aphids (ladybirds, carabid beetles and parasitoids) in winter wheat. Entomological surveys were carried out in 20 pairs of organic and conventional fields. We interviewed the farmers to identify variables that describe farming practices and identified the most important practices using a ranking approach based on random forests. Abundances of aphids' natural enemies were tested in relation to different levels of description of farming practices (from organic *vs.* conventional farming to individual practices). We found a large diversity of farming practices, which were evenly distributed along a gradient from organic to conventional farming. Abundances of aphids' natural enemies were greater in organic fields, but the three species groups had different responses to the diversity of farming practices. Ladybirds were influenced by tillage frequency, number of wheat varieties and pesticides, and carabid beetles by tillage frequency, whereas parasitoids were not affected by any practice. Even though the organic *vs.* conventional farming dichotomy was meaningful to explain aphids' natural enemies abundances, the consideration of more detailed practices improved our understanding of their response to crop management strategies. Our results help identify the level at which agro-ecosystem actors must intervene to promote effective biological control.

1. Introduction

Due to its strong impact on the environment, agriculture is considered a major cause of the global decline in biodiversity. Its intensification during the 20th century has led to the homogenization of agricultural landscapes and to the development of farming practices that are unfavourable to many species (Benton et al., 2003; Leroux et al., 2008). To ensure food supply of an increasingly large human population, it was suggested to link biodiversity with farming practices (Thrupp, 2000; Chappell and LaValle, 2011; Tscharntke et al., 2012). Indeed, the ecosystem services that it provides could increase agroecosystems sustainability. Organic farming is considered a promising solution (Hole et al., 2005) to meet this challenge. Since the 1990s, the number of organic farms has greatly increased and now comprises 0.86% of the farming land worldwide and 2.23% in Europe (Willer et al., 2013). In Europe, organic farming is characterized by the ban of chemical pesticides, chemical fertilizers, growth hormones, antibiotics, and genetically modified organisms (GMOs) (Council of the European Union, 2007; Gomiero et al., 2011). Organic farmers also adopt other practices to compensate the prohibited use of chemical inputs. For example, they often use longer crop rotations and frequent mechanical weeding to control weeds (Zehnder et al., 2007). Biological control of crop pests is considered a promising alternative to pesticide use and could help farmers meet proposed targets for the reduction in pesticide use (*e.g.* in Europe, Council of the European Union, 2007).

The efficiency of the biological control of crop pests can be affected by numerous factors, including farming practices (Altieri,

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1999; Zehnder et al., 2007). Many studies have tested the effects of organic *vs.* conventional farming (*i.e.* non-organic farming) on the abundance or diversity of natural enemies of crop pests (Bengtsson et al., 2005; Hole et al., 2005). Overall, organic farming systems seem to maintain a higher diversity than conventional ones. The explanation presented in the literature is that they combine practices that are more favourable to natural enemies (Gabriel et al., 2006; Rundlöf and Smith, 2006; Winqvist et al., 2011), such as organic fertilization (Garratt et al., 2011) or a lack of pesticides (Theiling and Croft, 1988).

However, there is no real consensus on the mechanisms for a higher diversity in organic farming systems. In a meta-analysis, Bengtsson et al. (2005) showed that 16% of studies found a negative effect of organic farming on species richness. The results were heterogeneous because of different responses from different taxa and the effects of other factors, such as landscape context (Bianchi et al., 2006; Fahrig et al., 2011). Hole et al. (2005) emphasized that contradictions are due to methodological problems. A simple comparison between organic and conventional farming does not consider the diversity of practices that may exist within each farming system (Vasseur et al., 2013). Farmers choose their own combination of practices, depending on numerous economic and agronomic objectives and constraints (Reganold et al., 2011), potentially resulting in a large diversity of crop management strategies. Consequently, some conventional farmers may use techniques similar to organic farming even if they are not certified, whereas some organic farmers may use organic inputs and frequent and deep tillage, which are allowed by the specifications but are potentially lethal for arthropods (Thorbek and Bilde, 2004; Bahlai et al., 2010).

These facts raise the question of whether the usual dichotomy of organic *vs.* conventional farming is relevant for biodiversity, as the wide range of farming practices implemented by farmers can affect natural enemies through modifications of their habitat quality or due to direct lethal effects (Landis et al., 2000). Considering diverse crop management strategies or individual farming practices could provide a better understanding of the ecology of enemies of crop pests. Recently, Gosme et al. (2012) addressed this question for pest populations of winter wheat in intensive cereal cropping systems. They found a clear distinction between organic and conventional farming, which had varying effects on pests. Specifically, leaf blotch incidence and aphid abundance were higher in conventional crops, whereas weed abundance and diversity were higher in organic fields. However, only three organic farmers were involved in this study, resulting in a low diversity of organic practices, which may have biased their results. Furthermore, this approach has still not been investigated for arthropods as natural enemies of crop pests.

The aim of this study was to assess whether the diversity of farming practices implemented in organic and conventional farming affects natural enemies of aphids (ladybirds, carabid beetles and parasitoids) in winter cereals in mixed cash crops-livestock production systems. Specifically the goals were (i) to describe the diversity of crop management strategies or of specific practices implemented in organic and conventional wheat crops, and (ii) to analyze the relationship between this diversity and the abundance of natural enemies in crops.

2. Materials and methods

2.1. Study site

Our study took place in Brittany, western France, in the southern part of Ille-et-Vilaine county. This region is characterized by landscapes of hedgerow networks and mixed crop-livestock farming systems. Forty winter wheat fields were selected, twenty under organic farming and twenty under conventional farming, distributed in an area of about 200,000 ha. Within a radius of 250 m, field contexts were characterized by a high proportion of farmland (86.5 ± 9.7% (SD); min = 62.5%, max = 98.3%) and a low proportion of built areas (10.0 ± 8.5% (SD); min = 0.6%, max = 33.4%) and wood (3.4 ± 5.4% (SD); min = 0.0%, max = 22.8%). In order to minimize the effects of crops landscape context on insects, organic and conventional fields were spatially paired (Kleijn et al., 2006). The mean distance between two paired fields was 279 ± 171 m (SD) (min = 0 m, max = 518 m), and the mean distance between two sites (1 site = the surrounding environment in a 250 m radius of 1 pair of organic and conventional fields) was 25,019 m ± 15,612 m (SD) (min = 130 m, max = 54,755 m). A Moran's *I* test (Dormann et al., 2007) showed that sites (pairs of organic and conventional fields) were not spatially autocorrelated.

2.2. Sampling of natural enemies

Sampling was conducted in each wheat field from April to July 2012 (Table 1), at least 10 m away from field edges to avoid any edge effect.

Adult carabid beetles were caught with pitfall traps filled with monopropylene glycol solution. In each field, two sampling stations with two pitfall traps each were set up 10 m apart. Traps were left open continuously and collected every two weeks, for a total of six sampling periods.

Adult ladybirds were caught with sweep nets and collected with mouth aspirators equipped with recipients. Ten sets of fifty sweeps, each along two transects perpendicular to field edges, were done in each field (total of 500 sweeps per field), which were repeated four times during the study period. The beginning of transects was situated at the pitfall traps locations.

The abundance of parasitoids was estimated by collecting aphid mummies. In each field, 10 sampling points 5 m apart were distributed along two transects (the same as for ladybirds). At each point, mummies were collected on 10 tillers, five times during the study period. Mummies were brought back to the lab to wait for the emergence of adults. All collected natural enemies were identified to species.

2.3. Characterization of habitat quality

Aphids were sampled to determine the availability of food for their natural enemies. In each field, 10 sampling points 5 m apart were distributed along two transects (the same as for ladybirds and parasitoids). At each sampling point, all aphids were counted and identified on 10 tillers, three times during the study period (Table 1).

Habitat conditions in crops were characterized by vegetation structure and density. In each field, wheat height and percentage of ground covered by weeds (Braun-Blanquet index (Braun-Blanquet, 1964)) were measured in four 50 × 50 cm quadrats, seven times during the study period.

2.4. Characterization of cropping systems

A survey of farming practices implemented on the sampled fields was conducted by interviewing 39 farmers (one farmer owned two fields). Data were collected on rotation, previous crop, wheat sowing, tillage, and inputs (organic and mineral fertilization, herbicides, fungicides, insecticides and growth regulators). Fifteen variables were extracted from these interviews (Table 2): the type of previous crop, number of soil interventions (tillage and mechanical weeding), tillage use (no tillage/conventional tillage), number of varieties of wheat sown, wheat density, number of crops in the crop sequence, amount of organic fertilizer, amount and frequency