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Higher efficiency in organic than in conventional management of biological control in horticultural crops in north-eastern Italy

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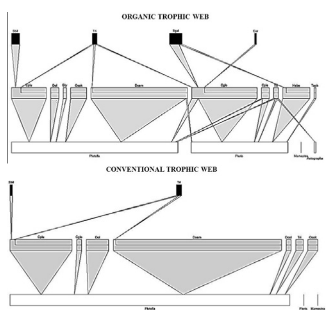
HIGHLIGHTS

- The efficiency of pest control in organic and conventional agroecosystems with horticultural crops was analysed.
- In particular, natural control agents (parasitoids and predators) of *Plutella xylostella* were considered.
- Phytophagous communities were more diverse in organic than in conventional fields.
- The parasitization of *P. xylostella* was significantly higher in organic than in conventional fields.
- Food-web structure was more complex in organic than in conventional fields.

GRAPHICAL ABSTRACT



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ABSTRACT

This research analyzes the efficiency of natural pest control in horticultural crops (Red chicory and White cabbage) within different regimes (organic and conventional). Agroecosystem food-web structure was examined in conventional and organic fields, in north-eastern Italy, considering phytophagous, parasitoid and hyperparasitoid guilds. Natural control agents were analysed, especially parasitoids of *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), one of the most problematic pests on cabbage crops. Phytophagous communities were more diverse and more predators and parasitoids were present in organic than in conventional farms. The parasitization of *P. xylostella* was significantly higher and the food-web structure was also more complex in organic than in conventional fields. Even with lower spray inputs, organic fields often supported a less abundant phytophagous community than conventional fields, even though the crop damage was similar in both management systems. The present data seem to indicate that the higher presence of biological control agents (predators and parasitoids) in organic fields is effective in moderating crop pest populations.

1. Introduction

Many authors emphasize the positive relationship between biodiversity and provided ecosystem services, such as soil nutrient cycles, organic matter degradation, pollination, pest control (de Vries et al., 2013; Gagic et al., 2011; Letourneau and Bothwell, 2008; Macfadyen et al., 2009a; Paoletti and Pimentel, 1992; Schmidt et al., 2003) but despite the large amount of available information some knowledge gaps remain, as highlighted for example by Geijzendorffer and Roche (2013). In agroecosystems, natural pest control has been considered a key ecosystem service

Abbreviation: DBM, Diamondback Moth (*P. xylostella*).

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because it can eliminate or moderate pest outbreaks that can seriously reduce crop production (Altieri, 1994; Sandhu et al., 2010a). According to the "insurance hypothesis", higher biodiversity of natural enemies (mainly predators and parasitoids) can ensure more efficient pest control, thanks to the presence of multiple species that can support the functioning of control even if some species fail (Yachi and Loreau, 1999). In conventional farms pest control is primarily achieved by the use of synthetic insecticides. In fact although natural enemies can contribute to pest control, their function may be reduced by the use of broad-spectrum substances. On the other hand, organic farms rely largely on cultural practices and naturally occurring predators and parasitoids, possibly drawing upon natural substances, such as pyrethrum, only when necessary (Zehnder et al., 2007). Under these conditions, the role of biodiversity can be particularly important (Altieri, 1999; Sandhu et al., 2010b). Well-structured hedgerows, natural vegetation and appropriate agricultural practices, which can promote biodiversity and predation efficiency (Gurr et al., 2004; Paoletti et al., 1997), are widely adopted by organic farmers. If organic farms support higher levels of biodiversity (Hole et al., 2005) and biodiversity improves pest control (e.g. insurance hypothesis), the efficiency of predators and parasitoids should be higher in organic than in conventional farms (Macfadyen et al., 2009a). Several researchers have tried to compare the effect of different agricultural management systems on pest control (Altieri et al., 1983; Altieri, 1999), considering also the landscape structure (Bianchi et al., 2013). In many cases the research has focused on just one species of crop pests (e.g. Alalouni et al., 2013; Alizadeh et al., 2011) and/or just one species or group of its natural control agents (e.g. Alizadeh et al., 2011; Arvanitakis, 2013; Bertolaccini et al., 2011; Wagener et al., 2004). Only in few cases the complex of pests and natural enemies has been considered (e.g. Bone et al., 2009; Gagic et al., 2011). In many cases the supposed positive effect of organic management on pest control was not detected. For example, Lohaus et al. (2013) and Macfadyen et al. (2009a,b) did not find higher parasitoid pressure on aphids in organic versus conventional cereal farms.

Italy is the leading country for the production of vegetables in Europe, representing 22% of the total production (FAOSTAT, 2012). Horticultural fields are generally less extensive than cereal, with an area seven times less (ISTAT, 2011). Horticulture usually requires more manpower and therefore greater investment of people and resources to obtain higher-valued quality products (Cisilino and Madau, 2008; FAOSTAT, 2014). The use of landrace crop varieties is more common in horticulture than in the cereal industry (Elia and Santamaria, 2013). Pest outbreaks can represent a serious danger with substantial yield loss; for example, *Plutella xylostella* (DBM), one of the main pest in *Brassica* crops, is estimated to produce worldwide yield losses of US$ 1.4 billion annually (Zalucki et al., 2012). With such a scenario, better knowledge of the interactions between crop pests and natural enemies can be particularly valuable in order to enhance the productivity of high-quality crops.

In the present research we have considered two Italian crops, Treviso red chicory (*Cichorium intybus* group *rubifolium*) and White cabbage (*Brassica oleracea* var. *botrytis*), grown up in agroecosystems under different management regimes. In Red chicory the key insect pests are *Agriotes* spp. larvae, aphids (e.g. *Myzus persicae*, *Nasonovia ribisnigri*), Noctuidae (e.g. *Agrotis ipsilon*, *A. segetum*) (Lazzarin et al., 2004). On cabbage several species of Lepidoptera (e.g. *Pieris* spp., *Mamestra* spp., *P. xylostella*), whitefly (*Aleyrodes* sp.), aphids (in particular *Brevicoryne brassicae* and *M. persicae*), *Phyllotreta* spp. are dangerous pests (Kirk and Gray, 1992). Among them *P. xylostella* can be a particularly serious pest: the economic damage caused by this insect can be remarkable and therefore several pesticide applications are direct against this pest (Furlong et al., 2013; Zalucki et al., 2012).

We hypothesized that (1) organic farms, based on more conservative management than conventional ones, support higher biodiversity; and (2) the natural pest control in organic fields is higher in comparison to conventional ones.

2. Materials and methods

2.1. Study sites and sampling devices

The study was carried out in north-eastern Italy, in the provinces of Venice and Treviso (Veneto region, Fig. 1). The area is widely modified by human activities: within a 1-km radius from the centre of each field, arable land-use covers approximately 51% of the surface, with 25% characterized by semi-natural habitats (woodlands, grasslands, hedgerows) and about 20% by urban habitats (towns, houses, streets, industrial areas).

Two crops were studied, Treviso Red chicory in 2012 and White cabbage in 2013. In the study area, ten farms were selected, five organically (certified at least since 2007) and five conventionally managed. To minimize climate, soil texture and landscape structure variability, the farms were considered in pairs (organic and conventional) by geographic proximity, with the minimum distance between the members of each pair ranging from 200 m to 6900 m. The two management regimes were different particularly in the supply of chemicals, as summarized in Table 1. Each farmer, both organic and conventional, practised rotation among different horticultural crops, including Red chicory and White cabbage.

Five pairs of fields were considered for Red chicory and three pairs for White cabbage. The data concerning the two crops were considered separately.

Meteorological conditions during the sampling years were marked by a significant difference in rainfall. 2012 was characterized by drought conditions, with an annual mean precipitation of 771 mm, more than 100 mm lower than the previous eighteen years (1994–2011). The following year (2013) was characterized by wetter conditions, with an annual mean precipitation of 1119 mm, more than 200 mm higher than the same eighteen years (ARPAV data, www.arpa.veneto.it).

In each field, six sampling points were chosen within a distance of two meters from the field edges in order to reduce margin effects; furthermore a distance of at least fifteen meters was maintained among the sampling points, paying attention to distribute them in the whole field surface and possibly not choosing two sampling points in the same crop line. In each sampling period all the sampling points were different from the previous ones. At each sampling point, four plants were visually checked thoroughly, from the ground up to the top of the plant, searching for phytophagous and predator invertebrates. Each specimen found on the sampled plants was identified to a taxonomic level that allowed to attribute it to a specific trophic level. Each field was sampled three times per year (Table 2).

In the cabbage crop, Lepidoptera are considered one of the most problematic phytophagous pests (Furlong et al., 2013; Sarfraz et al., 2005; Zalucki et al., 2012). Larvae and pupae collected from the fields were reared until emergence. After collection, larvae and pupae were isolated in small plastic boxes (diameter 4 cm; height 5 cm) kept in the laboratory at room temperature until the emergence of either adult or parasitoids. Larvae were fed with crop-plant leaves collected from the original sites.

Larvae and pupae that died before completing their development were not included in the analysis. Parasitoid specimens were identified to species or genus level, in order to separate primary parasitoids from facultative and obligate hyperparasitoids.

Crop damage to leaf surfaces was evaluated at each sampling point on a three-point scale, established previously and based on