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Management diversity within organic production influences epigeal spider communities in apple orchards

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ABSTRACT

When compared to conventional production, organic production often has positive effects on the biodiversity of non-pest arthropods. However, organic production is only defined by the ban of synthetic pesticides and fertilizers and each farmer can still apply a wide variety of management practices that may also directly and indirectly influence arthropod biodiversity. Taking epigeal spiders inhabiting apple orchards as a case study, we first characterised the main agricultural practices applied in 20 selected organic orchards around Avignon in the South-East of France. Using ordination (PCA) and classification (HAC) methods, we identify three groups within these organic apple orchards: (i) the Biodynamy group, (ii) the Net group and (iii) the Classic group. The growers from the Biodynamy group used significantly less insecticides (40% less than those from the Classic group) and had more favourable habitat management practices (hedge and ground cover). We then sampled spider communities in each orchard in spring (April) and summer (June) using pitfall traps and showed that the spider communities in the Biodynamy and Net groups were significantly more abundant (+4% on average), species rich (+60% on average) and diverse (+70% on average) than those in the Classic group. GLM analysis showed that these differences were mainly due to reduced insecticide use but also the hedge quality of these orchards. A trait-based approach was further used to differentiate the spiders found in the three groups of orchards. The most striking finding was that spiders that use webs to forage (Linyphiidae, Agenilidae and Titanoecidae) were favoured in the Net group. This is probably because these nets protect the orchards from the major pest, allowing reduced pesticide use but also because the nets protect orchards from the windy conditions frequently observed around Avignon.

1. Introduction

In theory, organic production follows four principles: health, care, fairness and ecology (IFOAM, 2006). The principle of ecology is the basis for plant protection and states that “organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them”. In practice, organic production is defined mainly based on the ban of chemical pesticides, chemical fertilizers, growth hormones, antibiotics, and genetically modified organisms. Besides this, other practices are recommended or encouraged such as habitat management to increase biodiversity and especially the abundance and diversity of natural enemies. Thus, farmers who adopt organic production can still use a large set of different practices (Wyss et al., 2005; Zehnder et al., 2007). In addition, in the last two decades and with regulatory harmonisation at the European scale in 1991, the proportion of organic farms has increased in Europe to reach 2.23% (Willer et al., 2013). This increase has resulted in an additional diversity of practices due to either new alternatives or recent conversion to organic production for economical rather than ecological/ethical reasons (Lamine and Bellon, 2008). It is thus difficult to consider organic production as a homogeneous system, completely distinct from conventional production (Vasseur et al., 2013; Puech et al., 2014). Several authors suggested that diversity within the system could explain why meta-analyses comparing

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biodiversity in organic and conventional production did not detect significant differences for some taxa (Hole et al., 2005; Bengtsson et al., 2005). However this diversity of practices was rarely described in such studies. Furthermore, to our knowledge, its potential consequences on natural enemy communities have not yet been investigated.

To test this idea, we chose apple orchards in Provence (South-East of France) as an agronomic case study and the epigeal spiders inhabiting these orchards as a target community. Commercial organic apple orchards in the South-East of France are a highly sprayed crop with, on average, 25 pesticides applied each year (Sauphanor et al., 2009; Marliac et al., 2015). An additional advantage of orchards is their perennial and multi-strata status (soil surface, grass and trees) in which habitat management is thought to have greater effects (Landis et al., 2000; Simon et al., 2010). This means that the effects observed on natural enemies may be increased and/or stabilised by the repeated application of the same agricultural practices over years. In orchards, communities of epigeal spiders are mainly influenced by pesticide applications (Pekar, 2012; Mazzia et al., 2015) and by habitat management within (ground cover) or around (hedges) orchards (Horton et al., 2002; Minarro et al., 2009; Marko and Keresztes, 2014). In this study we also benefited from the recent introduction of exclusion netting, also called Alt'carpo, a new alternative for controlling codling moth (*Cydia pomonella*), the main apple pest (Dib et al., 2010; Sauphanor et al., 2012). When these nets cover every single row in the orchards, the number of insecticides applied is significantly reduced and the micro-climate is slightly modified (Capowiez et al., 2014).

The aim of this study was to define groups of practices in organic apple orchards based on differences in pesticide use and habitat management. We then used taxonomic and functional approaches to examine how these groups of practices influence spider community characteristics. In particular, we wanted to determine whether any effects on spider communities were due to differences in pesticide use.

2. Materials and methods

2.1. Characterisation of the orchards and crop management practices used therein

The study was carried out in the South-East of France, where 24% of French apple orchards are concentrated (Agreste, 2007), with 4% under organic farming (Agence Bio, 2012). We surveyed 24 organic apple farmers identified by the technical advisors of the region to represent the widest diversity of crop protection strategies in organic apple orchards in the South-East of France. Based on the results of these interviews, a set of 20 orchards (belonging to 12 farmers) was chosen in a 20 km circular region around Avignon (43°57′00″N and 4° 49′01″E, Appendix A).

A set of characteristics was selected to describe the diversity of practices within these orchards. Due to the limited number of orchards studied, this number of characteristics was kept as low as possible and care was taken to ensure that these were not well correlated with each other (all correlation coefficients were <0.7). Some basic orchard characteristics (area and shape) were assessed but not included in the analysis of the farmer practices since, at least in the short-term, farmers cannot easily modify these characteristics. The shape of each orchard was computed by dividing its perimeter by the square root of its surface (this value increases as the orchard becomes more rectangular). The six selected characteristics focused on orchard vicinity (proportion of orchards: OP), habitat management (grass cover height and hedge quality: HQ) and pesticide use (TFI for fungicides, microbial and classical insecticides).

The linear proportion of orchards (OP) in close proximity to other orchards was computed as follows:

$$OP = \frac{\sum_{i-l}^{4} b_i \times L_i}{\sum_{i-1}^{4} L_i}$$

with i as the indice for each orchard border, L_i the length of each orchard border and b_i equal to 1 when this border separated two orchards (otherwise $b_i = 0$). We only considered a 4-connectivity, i.e. the four edges of each orchard (corners were neglected). As no crops or woods were found around the 20 selected orchards, the proportion of orchards was also the inverse proportion of natural habitats (gardens, fallows or meadow) around each orchard.

The landscape around Avignon is characterised by the presence of a dense network of windbreak hedgerows protecting orchards against the prevailing northern winds. We thus computed an index (HQ) that merged hedgerow quantity and quality (in terms of floral diversity):

$$\text{HQ} = \frac{\sum_{i-}^{4} a_i \times L_i}{\sum_{i-1}^{4} L_i}$$

with i as the indice for each orchard border, L_i the length of each orchard border and $a_i = 0$ when no hedgerow was present, $a_i = 1$ for the presence of a hedgerow with a very low plant diversity (typically pure *Cypressus* hedgerow) and $a_i = 2$ for the presence of a hedgerow with higher plant diversity (i.e. the dominant species represents less than 80% of the trees). Some farmers under organic management chose to decrease the frequency of mowing to promote the abundance and diversity of natural enemies within orchards (Marliac et al., 2015). Since the ground cover density did not vary (natural grass species) and was very dense in all the orchards, we only characterised its mean height based on the measurements made at the two spider sampling dates. For this, ten measurements were carried out at randomly chosen locations in the rows of each orchard.

Only natural pesticides are authorised in organic orchards. The main pesticides used in apple production are: copper and sulphur (fungicides), mineral oils, *Pyrethrum* and spinosad (insecticides), which target aphids and codling moth and some microbial insecticides targeting codling moth (granulovirus and *Bacillus thuringiensis*). In each orchard, treatment calendars were recorded and analysed to compute the overall treatment frequency index (TFI) as the total number of treatments per hectare with commercial products, weighted by the ratio of the dose used to the recommended dose (Jørgensen, 1999). The TFI was determined for three classes of pesticides: fungicides, microbiological insecticides, and other insecticides and computed following the formula:

$$\text{TFI} = \sum_{i=1}^{n} \frac{\text{AD}_i}{\text{HD}}$$

where n is the total number of pesticides applied in one year in an orchard, AD_i is the amount of each pesticide applied and HD is the recommended amount per hectare.

To study the variability within these 20 organic orchards, a PCA was applied to the six orchard characteristics (OP, ground cover height, HQ and TFI for the three classes of pesticides) and followed by a Hierarchical Ascending Classification (HAC) using Ward's algorithm of aggregation by variance applied on Euclidean distances. After visual inspection of this classification, three well-separated groups of orchards were defined (Appendix B).