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Research Paper

Effects of organic and conventional crop management on vineyard biodiversity

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ABSTRACT

Although organic farming is rapidly expanding in the vineyards of southern Europe, conventional crop management, using treatments that require a number of chemical inputs to guarantee yields is still the most common approach to crop management. To gauge the effects of these management systems on biodiversity, communities of vascular plants, butterflies, moths and birds were studied in vineyards in the Priorat Appellation of Origin (Catalonia, NE Spain). Measurements inside plots (all four taxonomic groups) and in grass strips between crop lines (only butterflies and vascular plants) were taken in organically and non-organically treated vineyards. Crop treatment was found to have an important effect, stronger on the most sessile organisms. Organic farms hosted consistently richer communities of both vascular plants and butterflies, a trend that was also observed − albeit less significantly − in moths. The weaker response in this group was probably due to insufficient sampling. Birds, the most vagile of the surveyed taxa, showed no significant response to treatments. Grass strips acted in all cases as reservoirs of biodiversity and hosted richer assemblages. The current trend of placing vineyards on slopes without terracing should ensure the existence of uncultivated strips within the vineyards to enhance the biodiversity of these agroecosystems. As well, parameters such as altitude and urban surface area are important drivers of biodiversity in this region. Our results suggest that organic farming may contribute to halting the widespread decrease that is occurring in communities of butterflies and other insects in this region.

1. Introduction

Globally, both social pressure and legislation are encouraging the implementation of crop production systems that are more environmentally sustainable and respectful. The focus is no longer only on yields but also on the quality, health and environmental security of products and procedures. Implementation of the European Union's agri-environment programs has been compulsory for member states since 1992, although they are still voluntary for individual farmers (CEU, 1992). The agri-environmental measures these programs imply are aimed at enhancing environmental biodiversity in and around farmlands, and reward the farmers who put them into practice for the ecological services their lands provide (Bradley et al., 2002). Organic farming (OF) is based mainly on the premise of enhancing biodiversity and using only natural products, that is, no synthetic fertilizers, herbicides or pesticides, or genetically modified varieties are employed during the cultivation process. It also advocates that agroecosystems should have the potential to regulate basic services such as pollination and pest control if they are properly managed and biodiversity is preserved (Altieri and Farrell, 1995). The use of pesticides and herbicides, along with certain aggressive mechanical practices, can seriously harm the biodiversity of agroecosystems, a key component of their capacities to self-regulate and be self-sustainable. Moreover, the ecosystem services provided by healthy agroecosystems transcend the boundaries of farms and stimulate a number of off-farm benefits ranging from protection from erosion and water flow regulation and purification, to pest control and carbon sequestration (Garbach et al., 2014). Nevertheless, to our knowledge no estimates of their global impact exist.

Over the last two decades, OF practices have greatly expanded in Catalonia (NE Spain) and in the period 1995–2015 the amount of OF cultivation rose from just 4936 to 142,024 ha (CCPAE, 2016). Of the crops responsible for this dramatic increase, vineyards are by far the

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most significant: in 2015, organic vineyards occupied 11,706 ha, 36% of all the organic crop surface area in Catalonia (excluding organic pastures, which are widespread in the Pyrenees). Despite the obvious economic importance of organic vineyards (their production in 2014 was estimated in Catalonia at €43.1 million − CCPAE, 2016 −), debate still continues in the farming local community as to whether or not it is worthwhile following the strict criteria imposed by OF. One of the arguments put forward by the Catalan government to promote this type of farming is that it benefits biodiversity; yet to date no studies have ever been carried out to test this assumption in this region.

It could be argued that the lack of consensus about the benefits of OF in vineyards is also reflected in the contrasting conclusions reached by a limited number of studies. Bruggisser et al. (2010), working on Swiss vineyards and focussing on three trophic levels, did not find an increase of diversity in any of the groups studied (vascular plants, grasshoppers and spiders). In fact, grasshopper diversity was even lower in organic compared to conventional vineyards. This result was explained in the context of the intermediate disturbance hypothesis (Huston, 1979) considering that disturbance in OF vineyards was too low to be beneficial for biodiversity (i.e. only a few highly competitive species prevailed under this kind of management). On the other hand, research carried out in N Italy has demonstrated a positive effect of OF in vineyards both in vascular plants (Nascimbene et al., 2012) and in some guilds of arthropod predators (Caprio et al., 2015), Moreover, Kehinde and Samways (2012) found an increase of monkey beetles (an important pollinator guild) but not of bees in OF compared to conventional South African vineyards. Likewise, Thomson and Hoffmann (2009) reported an increase in the abundance of natural enemies (including egg parasitoids) of an important local pest in Australian vineyards that included adjacent natural vegetation.

Therefore, although responses have proven to be idiosyncratic among taxonomic groups, results mostly suggest that OF in vineyards indeed contributes to promoting ecosystem services such as pollination and pest control.

Within this context, we undertook a study aimed at testing for the first time the biodiversity effects of OF in vineyards in N Spain. We designed a multi-taxon approach, carried out in 2014–2015, for one of the main areas devoted to viticulture in Catalonia as a way of critically exploring and understanding how crop management (OF vs. conventional farming − CF-) affects biodiversity across a range of taxa.

Our study focused on four different taxonomic groups (namely, plants, butterflies, moths and birds) with contrasting ecological attributes (e.g. mobility) that would enable us to gain some understanding of the effects of different types of farming systems at ecosystem level. We hypothesized that, firstly, differences in management practices would result in richer assemblages wherever no synthetic pesticides or herbicides are applied (OF) and secondly, that the magnitude of the response of a set of taxa would be linked to their mobility. We expected sessile organisms (i.e. plants) to be more affected than vagile ones (i.e. butterflies, moths and birds). However, birds and butterflies differ in terms of the spatial scale at which their biological processes occur (Seto et al., 2004). Therefore, given that (i) most butterflies and moths have life cycles that are closely linked to local conditions and to specific host plants, and that (ii) birds, with greater mobility, are more generally affected by vegetation structure at larger spatial scales, we predicted a stronger response to different management treatments in Lepidoptera than in birds.

2. Material and methods

2.1. Study area

The study area consisted of the Priorat Appellation of Origin (DOQP in its original acronym), a wine-producing area located in the county of the same name in Catalonia (41° 8′ N, 0° 49′ E, see Fig. 1). It has a Mediterranean climate influenced by the proximity of the sea (mean annual precipitation around 600 mm). Topographically complex, the Priorat lies between two mountainous ranges and has an average altitude of 472 ± 250 m a.s.l. It has a surface area of roughly 18,000 ha, of which 1887 ha are covered by vineyards, the main economic activity in the area. Most of the vineyards are managed following CF procedures, although the presence of OF is increasing.

2.2. Plot selection and characterization

A total of 10 OF and 10 CF crop plots were selected for the study. Given that the region's vineyards vary greatly in size and are subject to a wide range of environmental conditions (e.g. exposure and altitude), a pre-selection of plots was made to minimize the effect of confounding factors.

To exclude the possible effect of agricultural parcel size, an up-to-date cadastral map of holdings was simplified by merging all neighbouring parcels (i.e. plots) into a number of production blocks. Of these, only blocks with surface areas within the 25th–75th percentile were selected (ranging between 0.6 and 2 ha). A digital elevation map of the region (ICGC, 2013) was used to estimate the altitude and exposure of each block. Since both insolation and altitude are factors that heavily influence community assemblages and are therefore prone to bias the results of surveys, only blocks between 150 and 550 m a.s.l. oriented predominantly southwards (between 135° and 230°) were selected. To prevent the influence of riparian habitats and neighbouring forests on biodiversity, buffers of 300 and 50 m were drawn around streams and forest patches, respectively, on the 0.25 m resolution land cover map (DMAH, 2005) and blocks falling within these buffers were excluded. From the remaining blocks, we also removed those containing a mixture of OF and other management practices. Finally, we selected 10 plots to represent OF management systems and 10 to represent CF management systems out of 20 blocks that shared uniform environmental and physical conditions. Information on the management practices of both OF and CF plots was provided by the DOQP bureau (Table 1). All geographic computations were conducted using QGIS (QGIS Development Team, 2013).

To characterize each plot, a set of nine geographical variables was generated by taking into account the influence of physical conditions (altitude, roughness calculated as the standard deviation of elevation and slope) and habitat features (land covered by vineyards, shrub, forest, herbaceous vegetation and other habitat types, and the Shannon index of landscape diversity) around the vineyards. These variables were computed for three incremental buffer distances around the plots (500, 2000 and 4000 m). Physical variables were estimated from a digital elevation model with a resolution of 15 × 15 m (ICGC, 2013), while habitat features were taken from a land cover map of Catalonia (DMAH, 2005).

To check whether there were differences between treatments (OF and CF) in the nine variables in each buffer, Monte-Carlo tests were run using 1000 permutations of the t-student test. This test is more robust than conventional non-parametric tests and no particular distribution of the data needs to be assumed (Gotelli and Ellison, 2004). No significant differences were found between groups (OF vs. CF) when running the Monte-Carlo test for each independent variable ($/t/ \leq 0.03$; $p > 0.21$; 27 tests in total, corresponding to the nine geographical variables calculated at each of the three buffer distances; see results in Appendix A in Supplementary material). All variables were therefore found to be suitable for use in the model building process (see 'Species richness modelling').

All geo-processing and computation was performed with R (R Core Team, 2015). The Shannon index of landscape diversity was estimated with the package "vegan" for R (Oksanen et al., 2015).

2.3. Sampling

The study was conducted in 2013 and 2014. Plants, butterflies and