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Management matters: A comparison of ant assemblages in organic and conventional vineyards

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ABSTRACT

Agriculture is one of the dominant types of soil use throughout the world, and understanding patterns of species distributions across agroecosystems is a significant challenge for the future. The intensive use of agrochemicals affects the presence and distribution of several taxa, and organic agricultural methods are believed to be more environmentally sound than conventional ones. In general, organically grown crops host higher species richness for many different taxa, although this evidence is not always unequivocal. The aim of this study was to contribute to understanding whether different management options (organic vs. conventional) affect ant assemblages in vineyards, one of the most important permanent crops in Mediterranean-type environments. To this purpose, we analyzed ant assemblages from organic and conventional vineyards in the Chianti area, Italy. To reduce confounding effects, we chose vineyards with similar soil management (frequency of tillage) and placed within a comparable habitat matrix. The results of this study showed that organic and conventional vineyards hosted a similar species pool, but the structure of their assemblages differed and the effect of insecticides particularly appears to be relevant. Both ant abundance and the number of species per unit area were significantly greater in organic than conventional vineyards. The use of insecticides appeared to be particularly relevant given that vineyards that did not use insecticides also had greater alpha and beta diversity than vineyards where these chemicals were used.

1. Introduction

Agriculture is one of the dominant types of soil use throughout the world, and the expansion of cultivated areas over the last 50 years poses a severe threat to the maintenance of worldwide biodiversity on an unprecedented scale (Tilman et al., 2001; Green et al., 2005; Tscharntke et al., 2005; Firbank et al., 2008). Understanding patterns of species distributions across agroecosystems therefore, represents an important challenge for the future (Benton et al., 2003; Vandermeer and Perfecto, 2007; Whittingham, 2007). In many areas, the intensification of agricultural practices has led to the reduction and simplification of original landscapes, and this in turn, has caused the decline of many species of invertebrates and vertebrates with noticeable biodiversity losses occurring (Chamberlain et al., 2000; Vickery et al., 2001; Carvell et al., 2007; Firbank et al., 2008; Benton et al., 2003; Ottonetti et al., 2010). Additionally, the intensive use of agrochemicals affects the presence and distribution of several taxa (e.g. Benton et al., 2002; Thomson and Hoffmann, 2006; Nash et al., 2008; Rundlöf et al., 2015). The negative effects of agrochemicals on biodiversity may be both direct, i.e. killing of target and non-target species, and indirect, when mediated by the reduction of resources and/or alteration of competition and prey-predator relationships (e.g. MacFadyen et al., 2009).

Organic agricultural methods are believed to be more environmentally sound than conventional systems. Available reports show that in the majority of cases, organically grown crops host a higher species richness for birds, arthropods, and plants (Bengtsson et al., 2005; Hole et al., 2005; Fuller et al., 2005; McFadyen et al., 2009; Jerez-Valle et al., 2014; Inclán et al., 2015). This effect is mostly attributed to the lack of agrochemicals, since pest control primarily relies on cultural practices, natural predators, and selective parasitoids to control insect pest outbreaks (Lampkin, 1999; McGourty et al., 2011). Furthermore, organic farming is often, although not always, associated with less impactful landscape management techniques, such as less frequent tillage, the maintenance of hedgerows, or larger amounts of

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natural or semi-natural vegetation (see e.g. Gibson et al., 2007), which in turn contribute to maintaining higher biodiversity levels.

The common vine (*Vitis vinifera*) is a highly valuable crop which represents a significant source of income for many Mediterranean-type countries, and its importance is predicted to increase even in more northerly countries (e.g. Hannah et al., 2013; Moriondo et al., 2013). From an ecological point of view, vine cultivation is often considered to have significant environmental effects. This, in fact, imposes extreme environmental simplification, needs the application of herbicides, fungicides, and insecticides throughout the growing season, and relies on the massive use of inorganic nutrients (Aranda et al., 2005; Ardente et al., 2006; Hildebrandt et al., 2008; Rosado et al., 2013). In recent years, however, organic vine cultivation has experienced a steady increase in many areas, and for example, at the end of 2011 more than 200,000 ha were grown in the European Union, which corresponds to about 15% of total grapevine cultivation (Willer et al., 2014).

Among the taxa adversely affected by agricultural practices, soil invertebrates are among the most vulnerable (Stork and Eggleton, 1992; Badji et al., 2004). Among these, ants deserve special mention, since they play an important role in the dynamics of many terrestrial ecosystems where they affect the structure and dynamics of all arthropod assemblages (Philpott and Armbrecht, 2006; Sanders and Platner, 2007; Ottonetti et al., 2010). Due to their ecological relevance, ants are also used as indicators of ecosystem functioning, although their importance is often overlooked when assessing the sustainability of agroecosystems (De Bruyn, 1999; Chong et al., 2010).

The ecology of ants in vineyards is still poorly studied, and much of what is known is limited to the effects of invasive ants, such as *Linepithema humile,* on plant pests (Klotz et al., 2003; Tollerup et al., 2004; Daane et al., 2007). The composition of ant assemblages in South African and Australian vineyards has been described by Addison and Samways (2000) and Chong et al. (2011), respectively, but to our knowledge, no reports are available for European vineyards. Concerning the effects of different management options, information is even more scarce. Rosado et al. (2013) demonstrated that, similarly to other agricultural systems, vine cultivation was associated with a change in ant assemblages, with respect to unimpacted grassland areas nearby, but they did not provide any information on the effect of different management protocols within vineyards. Finally, Chong et al. (2007) investigated the impact of agrochemicals on vineyard ant communities and found no effect of pesticides, whereas Sharley et al. (2008) demonstrated that ant assemblages were negatively affected by soil tillage.

The aim of this study was to contribute to understanding whether different management options alter ant assemblages in vineyards. In particular, we compared ant assemblages from conventionally and organically managed vineyards in an important wine production area in Italy, the Chianti area near Florence, Italy. Vineyards were chosen to reduce confounding effects due to soil management (e.g. frequency of tillage) and associated landscape features (composition of habitat matrix) and reduce many of the differences between the usage, or not, of agrochemicals as much as possible.

2. Materials and methods

2.1. Study area

The study was carried out in the Chianti area near Florence (Northern Tuscany, Italy), Fig. 1. We chose ten wineries: five adopting conventional farming practices and five following organic protocols, as certified by an accredited third party. Despite the winery premises having variable sizes, they were all partitioned into several smaller plots (average size 2 ha), which minimize the effect of vineyard size. Furthermore, all plots were interspersed in a high-quality habitat matrix composed of small wood fragments, pastures, and olive orchards (Falqui and Paolinelli, 2015). All the wineries shared the same climatic and pedological conditions and were chosen to minimize differences not strictly due to management type. A questionnaire about management practices was distributed to winery owners to obtain information about the treatments applied to cultivations in the previous three years. The main types of management activities performed in each winery are summarized in Table 1. All the conventionally-run farms used herbicides, fungicides, and insecticides with repeated treatments during the year. The only exception was Co5, which did not make use of insecticides.

2.2. Ant sampling

In each winery, we randomly placed four square grids of nine pitfall traps, spaced at 3-m intervals. Grids were at least 25 m apart, to ensure the independence of capture events and at least 25 m from field edge, to avoid collecting foraging ants from surrounding habitats (Majer, 1980). The traps consisted of Falcon test tubes (diameter 30 mm) filled with 30 mL of 75%-alcoholic solution added with 2% of glycerol and buried at the soil level. Each trap was left in place for two days before being opened to reduce digging-in effects (Greenslade, 1973). In total, 360 traps were placed in the field during summer 2014, and each trap remained open for 5 consecutive days. Ant trapping was carried out between June and September 2015, and the four trap grids within each vineyard were placed at different times to avoid confounding effects due to local weather conditions. Pitfall trap sampling was chosen because it provides a good estimate of the relative abundance of ground-dwelling ants (e.g. Andersen and Sparling, 1997; Retana and Cerdá, 2000; Santos et al., 2007) and allows for a standardized sampling effort. All specimens were identified at the species level according to Emery (1916), Seifert (1988, 1992) and the online keys provided at http://cle.fourmis.free.fr

2.3. Data analysis

Captures in pitfall traps of the same grid were pooled, and the number of species and their occurrences were calculated for each grid. For each species, the occurrence ranged from 0 (never detected in a grid) to 9 (detected in all the traps of a grid). Comparison among wineries was carried out in two different ways. First we compared organic vs. conventional wineries; secondly, we compared the wineries where insecticides were not used (organic + Co5, hereafter referred to as NoINS) to those where these chemicals were used (INS).

The diversity of ant species in different vineyards were estimated using the method described by Chao et al. (2014). This method, based on the estimation of Hill's numbers, ${}^{q}D$, yields estimates of total (rarefied and extrapolated) species richness ($q = 0$), the exponential of Shannon diversity index ($q = 1$) and Simpson diversity index ($q = 2$), together with an estimate of sample coverage. The 95% confidence intervals were obtained from a bootstrap method based on 4999 replications of the reference sample set.

Differences in observed species density (defined as the number of species captured in each sampling grid) among management types were assessed by mixed-effect modelling with Poisson error distribution and the log link function (Zuur et al., 2009). To account for repeated observations (sampling grids) within each winery, winery identity was considered in the analysis as a random factor, nested within management type.

The value of each species as an “indicator” of habitat type was calculated using the IndVal index (Dufrene and Legendre, 1997). This method combines measurements of the degree of specificity of a species to a habitat type and its fidelity within that habitat. Species with high specificity and fidelity within a habitat will have a high indicator value. In particular, indicator values were computed using the group-equalized index, described by De Cáceres et al. (2010) and their significance was tested using a random reallocation procedure with 4999 iterations.

Compositional differences among habitat types were investigated