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Organic farming and host density affect parasitism rates of tortricid moths in vineyards

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ABSTRACT

Natural pest control by predators and parasitoids is an important ecosystem service supporting crop production. It is now well known that the proportion of semi-natural habitats as well as organic farming enhance abundance and species richness of natural enemies in agroecosystems. However, few studies have examined how these environmental variables affect natural pest control services. Moreover, most studies have been performed in annual cropping systems and almost nothing is known about the effect of landscape complexity and organic farming in perennial crops, which differ greatly from annual ones in terms of disturbance regimes. In this study, we analyzed how landscape composition and farming systems affect abundance of insect pests of grape and their parasitism rates in 79 vineyards in southwestern France. Our results show that farming systems and host density affect biological control of tortricid moths by their parasitoids. Surprisingly, organic fields had lower parasitism rates compared to conventional ones and this rate was negatively correlated to host density at the field scale. We also found that moth community composition depended on the proportion of grapevine crop in the landscape in a 1 km radius but that pest abundance and parasitism rates did not change with landscape complexity. Our results suggest that some farming practices that are frequent in organic farming, such as organic-certified insecticides, copper or sulfur, can reduce parasitoid populations and thus limit biological control in vineyards. Negative density dependence relationship between parasitism rates and host abundance suggest a dilution effect of the biological control potential at the landscape scale and potential mechanisms such as variable parasitoid population sizes, relatively limited female longevity or fecundity, as well as increase in handling time. Further research on the effect of organic and conventional farming practices are now needed to provide a more mechanistic understanding of how these agricultural practices shape ecological processes such as biological control of pests.

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1. Introduction

Agricultural production systems are facing a challenge. Rising demand for agricultural products in yields and quality will increase pressure to further intensify farming systems while there is a need to minimize negative impacts on the environment (Bommarco et al., 2013; Tilman et al., 2002). Ecological intensification of cropping systems thus appears to be a promising alternative to meet such a challenge, by enhancing the services provided by biodiversity and reducing the negative impacts of agriculture on the environment (Bommarco et al., 2013; Godfray and Garnett, 2014). Achieving food security and environmental well-being therefore require improved understanding of the factors affecting service-providing communities and about how to integrate the management of ecosystem services into our farming systems (Bommarco et al., 2013; Power 2010; Rusch et al., 2010).

Natural pest control by predators and parasitoids is an important ecosystem service supporting crop production (Losey and Vaughan 2006). It is now well known that this process is affected by several variables acting at different spatio-temporal scales, such as crop management at the field scale or landscape context (Rusch et al., 2010; Tscharntke et al., 2007). A growing body of evidence suggests that the proportion of semi-natural habitats in the landscape strongly influences natural enemy communities and trophic interactions in agroecosystems (Bianchi et al., 2006; Tscharntke et al., 2007), and it is now demonstrated that landscape complexity enhances abundance and diversity of natural enemies (Chaplin-Kramer et al., 2011) that can lead to higher parasitism or

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predation rates of phytophagous pests (Letourneau et al., 2009; Rusch et al., 2013; Thies et al., 2003). This positive effect of landscape complexity is due to the fact that semi-natural habitats provide several key resources for natural enemies such as alternative host and prey, nectar, overwintering sites or favorable microclimatic conditions (Landis et al., 2000; Rusch et al., 2010; Sarthou et al., 2014). Thus, it is usually assumed that higher proportion of arable land in the landscape will increase pest pressure due to reduced biological control by natural enemies and higher food resources for pest populations (Meehan et al., 2011). However, very few studies have considered the effect of landscape context on pest populations and pest damage (Chaplin-Kramer et al., 2011; Rusch et al., 2013).

Several studies show that organic farming practices at the field scale enhances the abundance and the diversity of natural enemies compared to conventional farming practices (Bengtsson et al., 2005; Hole et al., 2005; Tuck et al., 2014). This effect is usually attributed to the use of synthetic pesticides and higher levels of disturbance in conventional farming (Bengtsson et al., 2005). However, each type of farming system encompasses a wide range of practices and their relative and combined effects on natural enemy communities and pest control remain largely unexplored (but see Puech et al., 2014). It can be hypothesized that organic fields have higher rates of biological control and higher spatio-temporal stability in the biological control due to higher species richness and functional complementarity between species (Crowder et al., 2010). However, a very limited number of studies have examined the effect of farming systems on the level of natural pest control and these studies have produced contrasting results (Crowder et al., 2010; Lohaus et al., 2013; Macfadyen et al., 2009; Roschewitz et al., 2005; Sandhu et al., 2010). Moreover, it has been recently hypothesized that the effect of organic farming at the local scale on biodiversity is modulated by landscape context ("the intermediate landscape complexity hypothesis"—Tscharntke et al., 2012). According to this hypothesis, the benefits of organic farming at the local scale on biodiversity are smaller in very complex landscapes (that already support high level of biodiversity) or in very simple landscapes (with a poor species pool) compared to landscapes of intermediate complexity. However, this hypothesis remains poorly tested on natural enemy communities and biological control (but see Rusch et al., 2014). There is therefore a need for additional studies in contrasted farming systems to understand the relationships between management and functioning in annual and perennial agroecosystems.

In addition to a direct effect of landscape structure on parasitoid populations, parasitism is also likely to be influenced by host abundance (Doak, 2000). The distribution of parasitism rates in relation to host density varies between species (Hassell and Waage, 1984). Some cases reported positive density dependence, in which parasitism rates increased with host density whereas other reported negative density dependence or density independence (Costamagna et al., 2004; Latto and Hassell, 1988; Ray and Hastings, 1996). It has been demonstrated that the relationships between parasitism rates and host density may vary with parasitoid life-history traits and behavior as well as with the spatial or temporal scales (Doak, 2000; Klemola et al., 2014; Roland and Taylor 1997; Teder et al., 2000). Several traits of the parasitoid, such as searching behavior or dispersal abilities, could lead to density dependent parasitism rates. Parasitoids use two main categories of information to localize and parasitize their host: those related to the resource of their host (plant kairomones or plant habitats characteristics such as plant abundance or shape), and those related to the host itself, such as host kairomones (Esch et al., 2005; Finch and Collier, 2000). Host density is probably the most documented driving factor of parasitoid attraction (Walde and Murdoch, 1988). However, most studies document density dependence mechanisms at the plant scale and almost nothing is known about density dependence at larger scales (field or landscape scales for instance). Studying host density at these scales could lead to different patterns. Examining it at the field scale could lead to negative density dependence due to dilution of parasitism capacity because of increase in total handling time or egg depletion, while studying host density effects at smaller scales (e.g., plant) could lead to positive density dependence due to reduced search rate between hosts or natural-enemy aggregation (Rothman and Darling, 1991; Walde and Murdoch, 1988). Moreover, because landscape structure is known to directly affect pest populations as well as their natural enemies, it is of major importance to disentangle the relative effect of host density and landscape context on the level of natural pest control. However, this remains largely unknown as very few studies have examined their relative and interactive effects (but see Costamagna et al., 2004).

Four tortricid moths species are usually found in European vineyards and are distributed mainly according to their climatic requirements: the European grapevine moth *Lobesia botrana* (Denis and Schiffermüller) (Lepidoptera: Tortricidae), the grape berry moth *Eupoecilia ambiguella* (Hübner) and the grape tortix *Argyrotaenia ljungiana* (Thunberg) are polyvoltine, while the leaf-rolling tortrix *Sparganothis pilleriana* (Denis & Schiffermüller) is univoltine. These species are the major grapevine pests in Europe, and larvae naturally develop on most grapevine cultivars (Thiéry and Moreau, 2005; Thiéry et al., 2014). Larvae are polyphagous and can feed on berries (*L. botrana* and *E. ambiguella*) or on leaves and berries (*A. ljungiana* and *S. pilleriana*). Several alternative host plants such as *Clematis*,*Lonicera, Ampelopsis* or *Cormus* species are known to occur in semi-natural habitats such as woodlot or hedgerows located in the surroundings but their occurrence is unknown (Thiéry, 2008). Even if the larvae are polyphagous, *Vitis vinifera* L. is their main host in vineyard-dominated areas (Maher and Thiéry, 2006). A wide range of species are known to be natural enemies of tortricid moths on grape (Sentenac, 2011; Thiéry et al., 2001). Insect parasitoids classically found in Europe are egg parasitoids (mainly Trichogrammatidae) and larval/pupal parasitoids (Ichneumonidae, Braconidae, Chalcididae, Pteromalidae, Eulophidae, Elasmidae, Tachinidae). The most frequent and efficient species in European vineyards is the solitary larval endoparasitoid *Campoplex capitator* (Aubert) (Xuéreb and Thiéry, 2006). This species is known to diapause in its host, is specialized on tortricids and has a rather large dispersal range (Thiéry, 2008). Therefore, parasitoid populations may disperse from other vineyards as well as from semi-natural habitats in the surrounding environment. However, the different factors affecting the distribution of tortricid moths and their natural enemies have mainly been studied at the field scale and nothing is known about the effect of farming systems and landscape context on these communities (Thiéry and Moreau, 2005; Thiéry et al., 2014).

We studied tortricid moths and their parasitoids as a model system to examine the effect of organic and conventional farming systems on pest community composition and parasitism rates along a landscape complexity gradient in a vineyard region. We first hypothesized that moth community composition depends on landscape context and particularly that pest abundance would increase with the proportion of grapevine crop in the landscape due to higher resources availability. Based on the literature, we also hypothesized that parasitism rates of tortricid moths would be higher in organic fields and that this positive effect of organic farming is modulated by the landscape context. We expected a larger effect of organic farming on natural pest control in landscapes of intermediate complexity compared to complex landscapes, in which biodiversity and ecosystem services are already maximized, or to very simple landscapes, in which

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