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Temporal variability of aphid biological control in contrasting landscape contexts

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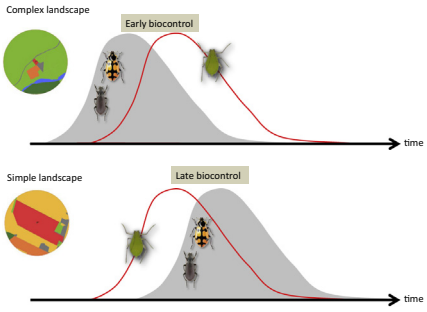
HIGHLIGHTS

- Abundance and temporal dynamics of aphid predators in wheat fields differ between contrasted landscape contexts.
- Coccinellid beetles are present in the crop earlier in the complex than in the simple landscapes.
- Temporal dynamics of aphids similar whatever the landscape context.
- There is a negative correlation between abundance of predators and aphid population growth rate.

GRAPHICAL ABSTRACT



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ABSTRACT

Landscape complexity may provide ecosystem services to agriculture through the provision of natural enemies of agricultural pests. Strong positive effect of adjacent semi-natural habitats on natural enemies in croplands has been evidenced, but the resulting impact on biological control remains unclear. Taking into account the temporal dynamics of pest and natural enemies in agricultural landscapes provides better resolution to the studies and better understanding of the biological control service.

In this study, the population dynamics of aphids and two groups of predators (coccinellid and carabid beetles) were examined. Insects were sampled in 20 wheat fields, surrounded by structurally simple and complex landscapes in Chilean central valley. Considering the whole sampling period, the diversity of aphids and natural enemies were similar in wheat crops surrounded by both types of landscapes, and the abundance of ladybirds was higher in crops in the complex landscapes. The dynamics of predators was more advanced in complex landscapes than in the simple ones, whereas the dynamics of aphids were similar in both types of landscape. Negative correlation between abundance of predators and aphid population growth rate in both landscape contexts were observed suggesting a control of the pest population by the predators. Different temporal patterns were observed in these correlations in the two landscape contexts, which suggests differences in the biological control related to the landscape composition.

The present study shows that colonization of crops by natural enemies occurs sooner in structurally complex landscapes and suggests that this early colonization may facilitate an early and efficient control of aphid populations, nevertheless the biological control efficiency seems to be higher in structurally simple landscapes later in the season.

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1. Introduction

A positive relationship between landscape complexity and diversity/abundance of natural enemies is observed in most of the studies (Chaplin-Kramer et al., 2011; Veres et al., 2013), even if in some cases a higher abundance of natural enemies was observed as arable land increased (Caballero-López et al., 2012). Despite all the above, there is no clear evidence that the a higher abundance and/or diversity of natural enemies supports a more efficient biological control function (Chaplin-Kramer et al., 2011). Several ecological processes may explain why a higher diversity of natural enemies in the complex landscapes does not necessarily increase the efficiency of biological control. Indeed, the diversity of natural enemies supported by the complex landscapes may produce antagonistic effects due to competition and intra-guild predation that may decrease the level of biocontrol (Schellhorn and Andow, 2005; Snyder and Ives, 2003). Moreover, a higher abundance of alternative preys in the complex landscapes may decrease the predation on the pest if these alternative preys are preferred (Roschewitz et al., 2005). Context dependency of the effect of diversity on the biocontrol function has been thoroughly discussed in the literature. It has been suggested that the biodiversity could increase, stabilize and generate more resilient ecosystemic functions, but not ensure the complete success of biological control due to inter-specific interactions in the system (Laliberté and Tylianakis, 2010; Tscharntke et al., 2007; Tylianakis and Romo, 2010). The effect of diversity on biocontrol is conditioned by the life traits of the pest and of the natural enemies, by their distribution, and by the spatial and temporal scale at which studies are conducted. For the control of aphids, the effect of the natural enemies diversity is particularly complicated to assess, as the patchy distribution of the pest and the high temporal fluctuations in its populations, promote a positive effect of natural enemy diversity, whereas the aphids' simple life history is likely to decrease this effect (Tylianakis and Romo, 2010).

Some authors have suggested that the lack of consideration of temporal dynamics in studies could explain the lack of evidences for a landscape effect on biocontrol (Chaplin-Kramer et al., 2013; Schellhorn et al., 2014). Many differences between studies could be due to temporal misrepresentation. To this regard, it is particularly interesting to consider the population dynamic in the early growing season. In several systems, it has been evidenced that the presence of natural enemies and more specifically predators during the beginning of the growing season provide a more efficient control of pest populations (Landis and Van der Werf, 1997; Settle et al., 1996; Tenhumberg and Poehling, 1995). This is particularly important in aphids, which tend to increase their populations and produce the most significant damage early in the season due to the sap sucking and viral transmission. It has been well established that many predator species use the non-cultivated areas to hibernate and posteriorly colonize the crops from these areas (Bianchi and Van der Werf, 2003; Corbett and Rosenheim, 1996; Renckenm, 2006). Structurally complex landscapes in which non-cultivated habitats are abundant and homogeneously distributed in the landscape mosaic are thus likely to allow an early colonization of crop fields from semi-natural habitats by the beneficial organisms that exploit these habitats during the winter period. Due to this early colonization, biological control is expected to be more efficient in structurally complex landscapes. However, it is not possible to detect a potential effect of landscape structure on the colonization time and on the biological control in the early spring if taking only a snapshot of pest and enemy densities at one time during the season, or by using cumulative measures (Chaplin-Kramer et al., 2013). It is then paramount to include temporal information in future studies in order to understand the pest/natural enemy complex throughout the season.

Aphids (Hemiptera: Aphididae) are important pests in cereal crops as they cause direct and indirect damages by sap sucking, viral transmission and production of honeydew. Although classical biological control of cereal aphids in Chile has been carried out through the action of parasitoid wasps (Hymenoptera: mainly Aphidiidae) (Gerding et al., 1989; Starý et al., 1994; Zepeda-Paulo et al., 2013), the role of the predators may also be important, particularly in the early spring before the build-up of parasitoid populations. Coccinellid beetles are known to be important aphid predators in various agricultural systems (Frazier, 1988; Hodek and Honek, 1996; Obrycki et al., 2009), and native and introduced species are present in Chile, providing a substantial biological control service (Grez et al., 2004; Zaviezo et al., 2006). Carabid beetles have been suggested as another important group of beneficial insects in agricultural fields with some carnivorous and granivorous species that are known to provide ecosystem services, such as biological control of pest insects and weed regulation (Bohan et al., 2011; Lang et al., 1999). This group has been extensively studied in European agrosystems and its distribution has been evidenced to be strongly influenced by the landscape structure (Aviron et al., 2005; Jonason et al., 2013; Östman et al., 2001). In Chile, the knowledge on carabid beetles is scarce (but see Grez et al., 2004; Carrillo et al., 2007), and despite that they are present in Chilean agricultural systems it seems that they have a limited role as biological control agents of aphids (Carrillo et al., 2007; Ximenez-Embun et al., 2014).

The central valley of Chile represents a system of Mediterranean climate, characterized by the co-existence of various agricultural landscapes structures both in terms of composition and configuration. The central depression is characterized by a homogeneous landscape with a low diversity of native plant species and large croplands, whereas the pre-cordillera hills, where the slopes are more pronounced, are characterized by small patches of cultivated areas. In these pre-mountainous sites, around the crops patches, remnant native plant community generates a complex landscape (Ovalle et al., 1990, 2006). In an area of a few tens of kilometers wide and under similar climatic conditions (Santibañez and Uribe, 1993), it is thus possible to find great contrasts in landscape structure (composition and configuration).

The present study focuses on the ecology of cereal aphids and their predators (coccinellid and carabid beetles) in contrasting agricultural landscapes. The main objectives are: (1) to analyze the assemblages of cereal aphids and their putative predators, and their temporal population dynamics; (2) to analyze the correlations between the density of natural enemies and the pest population growth in order to approximate and compare the level of biological control in crops surrounded by contrasted agricultural landscapes.

2. Material and methods

2.1. Study region

The study was carried out in the Maule region in central Chile. Within this region, two sets of 10 winter wheat fields were selected in two contrasting landscape contexts. The landscape context was determined according to the proportion of arable land (including both annual and perennial crops) within a 500 m circular buffer around the center of the selected fields. Landscape characteristics were determined using spatially explicit information on agricultural land-use analyzed in QGIS v2.2 (QGIS Development Team, 2014) and the relative proportion of cultivated and