



## Local predator composition and landscape affects biological control of aphids in alfalfa fields



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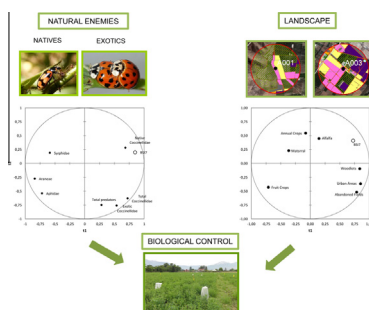
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### HIGHLIGHTS

- We studied landscape and predator effects on biocontrol (BSI) of aphids in alfalfa.
- BSI was positively associated with native coccinellids and syrphids.
- BSI was positively associated with woodlots and urban habitats in the landscape.
- BSI was negatively associated with fruit crops in the landscape.
- Landscape effects on biological control only become important when local predator abundance is low.

### GRAPHICAL ABSTRACT



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### ABSTRACT

The biological control service supplied to croplands is a result of the predator community present within a focal crop, which is likely influenced by surrounding landscape composition and configuration. In this study, using cage experiments in two regions near Santiago, we determined if predator communities supplied a significant biological control service in alfalfa fields, examined how the abundance of exotic and native coccinellids, as well as other key predator groups, influenced biological control of aphids and measured how landscape composition and heterogeneity at three spatial scales influenced this service. We found that predators significantly suppressed aphid populations in both regions, but the relative importance of predators versus landscape variables on biological control differed between regions. In the region where predators were abundant, biological control was higher and related to the abundance of native coccinellids and syrphids, highlighting the importance of native species as providers of crucial ecological services. In the region where predators were not abundant, biological control was lower, and it was related to landscape composition, being positively associated with the abundance of woodlots and urban habitats, and negatively associated with fruit crops in the landscape. Therefore, landscape effects on biological control service may be weaker than local factors, and only become important when local predator abundance is low.

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### 1. Introduction

Arthropods provide multiple ecosystem services within agroecosystems including decomposition, pollination and biological control that influence the sustainability of crop production (Losey

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and Vaughan, 2006; Isaacs et al., 2009). In general, species rich communities are predicted to support the greatest combined capture of resources such as pollen or prey (Cardinale et al., 2006). However, species may vary in their contribution to an ecosystem service and interactions among guild members may affect the combined provision of a beneficial arthropod community. For predators and biological control services, many interactions such as facilitation and intraguild predation occur commonly (Losey and Denno, 1999; Finke and Denno, 2002; Cardinale et al., 2003) and can modify relationships between predator abundance, diversity, and function (Ives et al., 2005; Caballero-López et al., 2012).

Understanding how variation in predator community composition influences biological control is particularly important when exotic generalist predators are introduced into agricultural landscapes (Crowder and Snyder, 2010). Exotic predators can have varying impacts on populations of competitors through both direct mortality and indirect competition for shared resources (Evans, 2004; Crowder and Snyder, 2010; Tapia et al., 2010; Grez et al., 2012; Smith and Gardiner, 2013, in press). Thus, the addition of exotic generalist predators to agroecosystems may or may not enhance resource capture of prey within croplands (Elliott et al., 1996). For example, the introduction of exotic coccinellids has coincided with the rapid decline of several native taxa worldwide (Koch et al., 2006; Brown et al., 2011; Gardiner et al., 2012; Roy et al., 2012). While exotic generalist predators such as coccinellids are effective biological control agents in several cropping systems (Lucas et al., 2007; Soares et al., 2007; Koch and Galvan, 2008) it cannot be assumed that they will provide the same level of biological control services as potentially displaced native competitors.

Additionally, natural enemies in a given crop can be influenced by the characteristics of the surrounding landscape (Tscharntke et al., 2007; Werling et al., 2011). The heterogeneity of the landscape at different spatial scales, as well as the composition of vegetation have all been shown to influence natural enemy abundance, interactions, and the provision of biological control services (Bianchi et al., 2006; Gardiner et al., 2009a,b, 2011; Grez et al., 2010a; Holzschuh et al., 2010; Gagić et al., 2011; Médiène et al., 2011; O'Rourke et al., 2011; Caballero-López et al., 2012; Amaral et al., 2013). First, not all habitats within a landscape are equally suitable for natural enemies. By comparing coccinellid communities across habitats ranging from natural matorral and riparian habitats to cultivated croplands, Grez et al. (2013) illustrated that habitat disturbance favors exotic coccinellids. The proportion of the coccinellid community composed of exotic species increased with level of habitat disturbance, with the greatest dominance in alfalfa crops compared with the other habitat types mentioned. Second, exotic and native predators can vary in their use of the available resources present within crop patches and edges. For example, Amaral et al. (2013) found that the native coccinellid *Cycloneda sanguinea* (Coleoptera: Coccinellidae) commonly utilized non-crop weed strips as a source of alternative food resources, whereas *Harmonia axyridis* (Coleoptera: Coccinellidae) was rarely found foraging within these strips. Further, variation in landscape composition can influence the abundance of native versus exotic predators present within agroecosystems. For example, Gardiner et al. (2009b) found that native coccinellid abundance in soybean fields was positively related to the abundance of native grassland habitat in surrounding landscapes whereas exotic lady beetle abundance in soybean was greatest in forest-dominated landscapes. In contrast to the many examples showing that landscape composition and heterogeneity affects natural enemy populations, very few report how landscape affect biological control (but see Gardiner et al., 2009a; Woltz et al., 2012). Additionally, the effects of landscape variables related to configuration heterogeneity (the spatial arrangements of habitats, Fahrig et al., 2011), such as mean patch size, shape and edge density, on natural enemies and

biological control services have rarely been studied. Configurational heterogeneity affects the migration of natural enemies to and from crops, their searching efficiency and consequently may affect biological control (Grez and Prado, 2000; With et al., 2002; Bianchi et al., 2006; Zaviezo et al., 2006; Tscharntke et al., 2007; Werling et al., 2011).

In alfalfa fields in regions surrounding Santiago, Chile, there is a diverse community of native and exotic species of coccinellids and other predators that feed on the exotic pea aphid, *Acyrtosiphon pisum* (Harris) (Hemiptera: Aphididae) (Zaviezo et al., 2004, 2006; Grez et al., 2008, 2010a; Ximenez-Embun et al., 2014). Recently, in 2008, the exotic invasive lady beetle, *H. axyridis*, was detected in Chile. Within a few years *H. axyridis* has become common within alfalfa and may alter the outcome of aphid biological control (Grez et al., 2010b, 2013). This system provided an opportunity to test the hypothesis that the predator community within the crop and landscape composition and configuration impact biological control services. Our specific aims were to (1) Determine if predator communities supplied a significant biological control service to alfalfa fields, (2) Examine how the abundance of exotic and native coccinellids and other key predator groups influenced biological control services and (3) Measure how landscape composition and heterogeneity influenced biological control services.

## 2. Materials and methods

### 2.1. Study sites

The study was carried out in two regions near Santiago, Chile, in two consecutive springs (September–October): Pirque (33°38'S; 70°33'W) in 2012, and Calera de Tango (33°37'S; 70°46'W) in 2013. This time of the year is when aphids are most abundant in alfalfa fields (Apablaza and Stevenson, 1995). Both of these regions comprise agricultural landscapes with a diversity of production systems including vineyards, orchards, wheat and alfalfa fields with an average field size of less than 3 ha. Both regions also include remnants of native matorral and other semi-natural habitats such as hedgerows and eucalyptus woodlands (Grez et al., 2013). In each of these regions, we conducted experiments in ten alfalfa fields separated by at least 2 km.

### 2.2. Estimation of biological control services in alfalfa fields

Similar to previous studies (Costamagna and Landis, 2006, 2011; Gardiner et al., 2009a; Caballero-López et al., 2012; Costamagna et al., 2013) biological control was measured by comparing aphid population growth in the presence and absence of predators using exclusion cages. In the center of each alfalfa field, we established four plots which were each separated by 10 m. A plot consisted of three 1 m<sup>2</sup> subplots in a row separated by 1 m. Within each of these subplots, we isolated an alfalfa plant (approximately 15 cm diameter × 20 cm tall) by removing all surrounding stems. Each of these plants was randomly assigned to one of the following three treatments: (1) Exclusion Cage (no access for predators), (2) Sham Cage (allowed predator access, lowered dispersal probability of apteorus aphids and measurement of cage effects such as microclimatic changes and aphid crowding), and (3) Open Plant (un-caged plant allowing predator access). The exclusion cage consisted of a 0.4 m diameter × 0.7 m tall cylindrical framework of wire, covered by a white fine mesh (openings of 1 mm) tied at the top and buried in the soil. Additionally, to prevent access of carabids and other ground-dwelling predators to the excluded plant, we surrounded each cage with a 10 cm high metal ring, buried in the soil. The sham cage was identical to the exclusion cage except that the mesh had six rectangular openings (2 × 20 cm)

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