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Seasonal, spatial and diel partitioning of *Acyrthosiphon pisum* (Hemiptera: Aphididae) predators and predation in alfalfa fields

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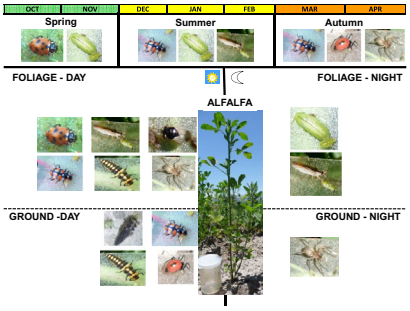
HIGHLIGHTS

- *Acyrthosiphon pisum* was used as sentinel prey in alfalfa to study predators segregation.
- A seasonal, day–night and foliage–ground segregation of predators was observed.
- Coccinellids were the main predators, with daytime activity mainly in spring and summer.
- Syphids were the main nighttime predators in spring and summer.
- More predatory activity was observed on the foliage than on the ground.

GRAPHICAL ABSTRACT



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ABSTRACT

Predators are important natural enemies, often responsible for preventing pest population outbreaks of in many crops. Complementarity in resource use involves spatial or temporal segregation of predators, which can result in better biological control when several species of natural enemies share a prey. In this study, we investigated the seasonal, spatial and diel segregation of *Acyrthosiphon pisum* predators and its predation in alfalfa fields, by setting out cards with sentinel aphids, and making observations every 3 h for a 24 h period. A temporal and spatial segregation of predators was observed. Coccinellids were the most abundant predators, representing 51% of the total observations, followed by syrphid larvae. Coccinellids were also responsible for high levels of predation throughout the year, although the species responsible varied from spring to summer and autumn. On the other hand, syrphids were only found in spring and summer, while spiders only in autumn. Predator species also differed on their preferred sites for predation, with Heteropterans and syrphids found on the foliage, the spider *Neomaso articeps* only on the ground, and coccinellid and Anyphaenidae species on both sites. The two main predator groups also showed distinct diel patterns, with coccinellids observed only during day and syrphids only during night. This predatory activity corresponded with aphid predation, observing more predation in spring, on the foliage and during the day time. The proportion of predators observed preying on cards in the different seasons did not corresponded tightly with their field abundance, particularly in the case of coccinellids, which maintained high levels of predation in spite of great variations in its field abundance. Our results support the hypothesis of a spatio-temporal segregation of the predators associated with *A. pisum* in alfalfa, which might be beneficial for the outcome of biological control of this pest.

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1. Introduction

Predators are important natural enemies of pests in many crops and are often responsible for preventing outbreaks of pest populations. The relationship between the diversity of natural enemies' assemblages and the efficiency of biological control has been largely discussed (Snyder et al., 2005, 2006; Casula et al., 2006; Letourneau et al., 2009; Straub et al., 2008; Snyder, 2009). Although neutral or negative effects might occur if mechanisms like functional redundancy or intraguild predation occur (Casula et al., 2006; Straub et al., 2008), frequently a higher diversity of consumer communities may lead to greater total prey consumption via a sampling effect (i.e., more species are more likely to include particularly efficient predators) or species complementarity in resource use (i.e., natural enemies with different feeding niches) (Loreau and Hector, 2001; Casula et al., 2006; Snyder et al., 2006; Straub et al., 2008; Letourneau et al., 2009; Northfield et al., 2010).

Theoretical and empirical evidence suggest that natural enemy species with similar traits, such as microhabitat use and phenology, may result in strong competition for resources (Straub et al., 2008). On the other hand variation in how, where and when enemies attack prey, may yield complementary prey suppression (Snyder et al., 2006). Therefore studying if predators in a given system have different traits regarding spatial (microhabitat) and temporal (season, time of day) predatory activity, is the first step to identify the natural enemies functional groups present and how they might be potentially partitioning a resource (Straub et al., 2008; Snyder, 2009). Spatial prey partitioning can occur when a single pest species have more than one feeding place, and different predators can specialize on these different places, without directly interfering with each other, thereby complementing prey predation (Losey and Denno, 1998a, 1998b; Grez et al., 2007; Straub and Snyder, 2008; Northfield et al., 2010). Seasonal prey partitioning occurs when different species of natural enemies colonize the crop and reach their highest abundance in different times of the year, either as a response of predators to prey density or by complementary phenology, with some species appearing only early or late in the season, preying when other predator species are not present (Roy et al., 2005). Diel partitioning takes place when predators forage at different times of the day, resulting in ensembles that differ greatly between day and night. This segregation makes less likely that predators encounter each other, and thus, may lower direct antagonistic interactions, like intraguild predation. This segregation mechanism has been poorly explored in resource partitioning studies (Pfannenstiel and Yeargan, 2002; Nakashima and Akashi, 2005; Lucas, 2005, 2012). The spatiotemporal activity observed for predators might be an active choice or the result of biological constraints, which in turn could be modulated by biotic and/or abiotic factors (e.g. Gable et al., 2012). Therefore the patterns observed may change under varying conditions but limited by the extent of the species plastic behaviour.

Alfalfa (*Medicago sativa* L.) is a widely distributed crop around the world that harbours a high diversity of insects, including herbivores and their natural enemies (Flint and Dreistadt, 1998; Gerding and Devotto, 2000; Pons et al., 2005; Rakhshani et al., 2009). Among them, the pea aphid, *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae) is one of its most important pests all over the world (Summers, 1976; Nakashima and Akashi, 2005; Rakhshani et al., 2009). This aphid, and others present in alfalfa, is preyed upon by a variety of aphidofagous predators like carabids, coccinellids, syrphids, nabids, anthocorids, geocorids, chrysopids and spiders (Wheeler, 1977; Gerding and Devotto, 2000; Lucas, 2005; Grez et al., 2007, 2010). In alfalfa fields many of these predators coexist, but it is not known if they, and their predation activity, partition either in space or time. In this study, we aimed to determine the seasonal, spatial and diel activity of *A. pisum* predators and aphid predation patterns in alfalfa fields in central Chile. We hypothesized that the predatory activity of the aphidophagous species found in alfalfa differs in space, season and time, and consequently the spatiotemporal pattern of aphid predation.

2. Materials and methods

2.1. Field sites

The experiments were carried out in alfalfa fields (cultivar WL903 WL-Agvance S.A.) at the Agricultural Experimental Research Station, of the Pontificia Universidad Católica de Chile, located in Pirque – Chile (33°40′09S, 70°36′31W), from October 2009 to April 2010. No pesticides were used, and observations were made when alfalfa was between 50 and 70 cm height. Temperature was measured during the experiments with Hobo® Weather Station data logger (Pro series Onset Computer Corporation, USA).

2.2. Aphid predation and predator activity

To determine aphid predation and the predators responsible for it, six live *A. pisum* (4th instar nymphs and adults) were mounted in transparent plastic cards (5.5 × 1.5 cm) using a glue spray (Spray-Mount, 3M, USA). Aphids were obtained from a laboratory colony on broad bean (*Vicia faba* L.). Cards were randomly placed near the centre of the fields, separated at least by 4 m, in 42–63 sampling points. In each sampling point, two cards were set, one fixed at the ground level with a cocktail stick, and the other on the foliage, 20–30 cm above the ground, attached to the plant with a wire (Fig. 1). Cards were placed in the field at mid morning, and then monitored at 3 h intervals for the next 24 h. Therefore, there were four observations during the day (10:00, 13:00, 16:00 and 19:00 h), and four during the night (22:00, 1:00, 4:00, and 7:00 h). The 7:00 am time was considered part of the night time observations because it represented predation that occurred between 4:00 and 7:00 am, although in summer at this time it was already clear. In each observation time, the number of aphid preyed upon on each card was noted, and cards were replaced when 50% or more aphids were consumed. Additionally, when

Fig. 1. Sentinel aphids on cards positioned at (A) foliage and (B) ground level.