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Synergistic effects of ground cover and adjacent vegetation on natural enemies of olive insect pests

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ABSTRACT

The use of pesticides in conventional agriculture poses several risks to humans and to the environment, and may turn out to be inefficient in the long-term as pests can develop resistance to pesticides. Non-chemical control methods can be preferable to prevent pest damage. One way to achieve this involves the establishment of ground cover or the restoration of vegetation adjacent to the crop. Either of these methods can effectively increase the abundance of natural enemies, particularly in perennial crops, but their interaction has been typically neglected. In this study we used maximum likelihood methods to analyse the synergistic effects of ground cover and different types of adjacent vegetation (herbaceous, woody) on the abundance of the main natural enemy groups of insect pests in olive groves. A Gaussian function was used to predict their abundance as a response of time, ground cover, different types of adjacent vegetation and year (2010, 2011). We examined 40 different alternative models for each group of natural enemies: spiders, ants, predatory Heteroptera, and parasitoids. Spiders, parasitoids, and one species of predatory Heteroptera (*Deraeocoris punctum*), showed a greater abundance in ground cover plots. Overall, herbaceous and large woody vegetation adjacent to the crop influenced the abundance of natural enemies more than small woody vegetation. However, this effect was modulated by ground cover. When both structures were present in the crop, the abundance of some groups of natural enemies (spider and parasitoids) was positively influenced by adjacent vegetation, whereas this effect was lower or even reversed in bare soil crops. We thus encourage olive farmers to use both habitat management approaches simultaneously, since the interaction of these ecological infrastructures produce an effect that maximises the abundance of natural enemies.

1. Introduction

Olive culture is of great importance in the circum-Mediterranean region. Olive crops occupy ca. 7.6 million hectares, of which 2.5 million hectares are in Spain, the main olive oil producer and exporter. In 2012 alone, this crop yielded approximately 1.5 million tonnes of olive oil in Spain. Conventional production practices are based on the use of fertilizers, herbicides and pesticides. This has led to important environmental problems, such as the loss of natural vegetation and bare soil due to herbicide use, which can cause erosion and loss of natural soil fertility (Metzidakis et al., 2008). To avoid some of these problems, new policies are currently being implemented in the European Union, aiming at the restoration of adjacent natural vegetation and the establishment and maintenance of ground cover (IOBC, 2012).

Vegetation adjacent to the crop (henceforth natural vegetation) has been shown to be an efficient tool to enhance the abundance and diversity of natural enemies (Altieri and Letourneau, 1982; Bianchi et al., 2006; Griffiths et al., 2008; Thomson and Hoffmann, 2009). This in turn can translate into decreased crop damage in adjacent crops and could provide direct benefits by reducing the use of costly pesticides (Tscharntke et al., 2002; Tsitsilas et al., 2006) and associated environmental and human health concerns (Meehan et al., 2011). Herbaceous and woody vegetation patches interspersed within the crop, or located at the crop margins mainly form this natural vegetation (Bianchi et al., 2006). Overall, these structures are very important for the establishment and survival of arthropods (Thies and Tscharntke, 1999), since they can provide food resources such as nectar, pollen or alternative prey, and shelter when the crop is disturbed (Landis et al., 2000). Therefore, they have been used to increase natural enemy efficiency in order to reduce the incidence of crop pests (Scheid et al., 2011; Simpson et al., 2011).

In perennial crops, the use of natural or planted ground cover vegetation can also contribute to an increase in the abundance of

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natural enemies, in addition to reduced soil erosion. Ground cover has been reported to increase the abundance of different groups of natural enemies (Smith et al., 1996; Rieux et al., 1999; Danne et al., 2010; Silva et al., 2010) but in some studies this increase has not been reported (Costello and Daane, 1998; Bone et al., 2009). Most of these studies, however, have systematically neglected the role of natural vegetation interspersed within or near the crop, thus ignoring the possibility of synergistic effects between ground cover and natural vegetation (but see Woltz et al., 2012 for a case study in soybean fields).

We hypothesised that populations of natural enemies within the olive grove may be affected by adjacent natural vegetation, and their response might differ depending on the presence of ground cover within the crop. We therefore aimed to: (i) establish the effect that ground cover, as compared to bare soil areas, has on the abundance of natural enemies in olive groves; (ii) determine the influence of different types of adjacent natural vegetation on their abundance; and (iii) identify potential synergistic effects between ground cover and different types of adjacent natural vegetation.

The results of this study will contribute to a deeper understanding of the interactions between arthropods, ground cover and adjacent vegetation, and will provide mechanisms to improve the biological control of pest outbreaks in so widespread and socially important crop such as olive orchards, while reducing environmental and production costs by avoiding (or minimising) the use of chemical products.

2. Material and methods

2.1. Study area

The study was conducted in an experimental olive grove (235 ha) located in southern Spain, near the city of Granada (37°17′N and 3°46′W). It comprised two adjacent zones separated from each other by a creek occupied by natural vegetation (Fig. 1). The topographical conditions were typical from the olive groves in the region. Climatic conditions were different in both years. Average annual precipitation was higher in 2010 (565.12 mm) than in 2011 (368.82 mm). In 2010 mean average temperature was lower (22.1 °C) than in 2011 (24.5 °C). Average maximum monthly temperature from April to June was 24.7 °C in 2010 and 27.8 °C in 2011. The main insect pests in this area were the olive moth *Prays oleae* Bern. (Lepidoptera: Plutellidae), and the olive psyllid *Euphyllura olivina* Costa (Hemiptera: Psyllidae). Both are widely distributed in the circum-Mediterranean region and often cause costly damage to crops by reducing the number and/or size of the fruits, with a subsequent reduction in the yield and quality of the resulting fruit or oil (Tzanakakis, 2006). Four main natural enemies groups were considered: spiders (Araneae), ants (Hymenoptera: Formicidae), predatory Heteroptera (Hemiptera: Heteroptera) and parasitoids (Hymenoptera: Parasitica). Most of these groups have been reported as natural enemies of *P. oleae* (Morris et al., 1999).

Three different types of adjacent natural vegetation patches were found in and near the crop, namely herbaceous, large and small woody vegetation patches. Herbaceous vegetation was dominated by *Anchusa* sp., *Anacyclus clavatus* Desf. and *Echium plantagineum* L. Woody vegetation patches were divided into two groups namely large woody patches, dominated by trees which occupied the ravines surrounding the grove, and small woody patches, formed by shrubs occupying no more than a few square metres and located inside the grove, usually at hilltops, in areas inaccessible to machinery (Fig. 1). Large woody patches were dominated by *Phyllirea angustifolia* L. and *Quercus rotundifolia* Lam., whereas small woody patches were mainly composed by *Genista*

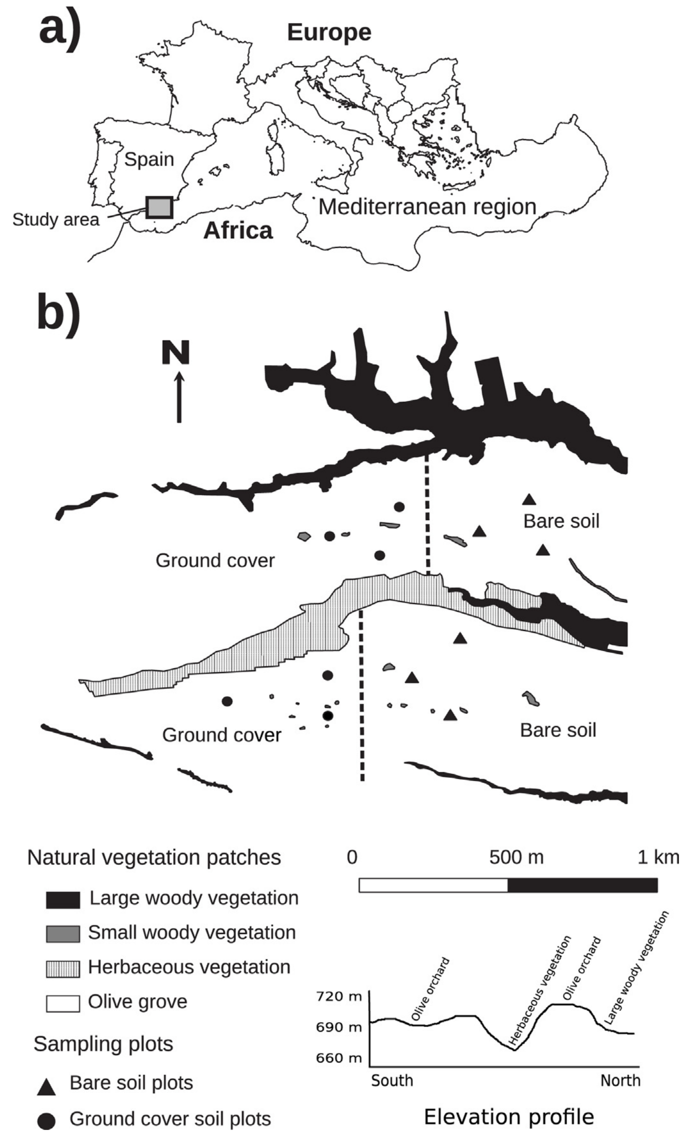

Fig. 1. Location, elevation profile and arrangement of the experimental olive grove. (a) Location of the study area in southern Spain; and (b) distribution of the adjacent natural vegetation and ground cover and bare soil plots within the experimental grove.

hirsuta M. Vahl, *Cistus albidus* L., *Cistus clusii* Dunal, and *Rosmarinus officinalis* L.

2.2. Experimental design and sampling

Each zone within the grove was divided into two subzones, each one occupied by either bare soil or ground cover, respectively. Two broad spectrum herbicides (glyphosate and oxyfluorfen) were sprayed in the bare soil subzones in early spring 2010 and 2011 to remove weeds. In subzones with ground cover, spontaneous herbaceous vegetation was allowed to grow in a 2.5 m wide strip between tree lines. The remaining area between trees was treated with the same herbicides as for bare soil. No insecticides were used in the grove for two years throughout of the experiment. Ground cover was composed of herbaceous plants dominated by *Medicago minima* L., *A. clavatus* Desf., *Hordeum leporinum* L., *Lolium rigidum* Gaudich., and *Bromus madritensis* L.

The basic experimental unit in our study was the plot. There were a total of 12 plots, three in each subzone, which were sampled in different dates (Fig. 1). Plots were located equidistant from