Agriculture, Ecosystems and Environment 265 (2018) 244–253

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Value of ecological infrastructure diversity in the maintenance of spider assemblages: A case study of Mediterranean vineyard agroecosystems

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ARTICLE INFO

Keywords:
Green infrastructure
Ecosystem services
Spider guilds
Body size
Hedge
Strip

ABSTRACT

Within agricultural landscapes, ecological infrastructures like hedges, grass strips or wildflower strips, can be essential for the provision of ecosystem services, and their role in maintaining and promoting functional biodiversity has been widely demonstrated in temperate zones. However, although the Mediterranean basin is considered to be a biodiversity hotspot, there is a lack of information about the role played there by these elements in biodiversity conservation. Spiders are generalist predators that are considered important components of biodiversity in vineyard ecosystems, where they can play a prominent role in the natural control of pest populations. Nevertheless, the influence that ecological infrastructures have on driving spider assemblages in Mediterranean vineyard agroecosystems is practically unknown. In a study conducted in an area exclusively devoted to traditional vineyard crops (La Rioja, northern Spain), we analyzed spider assemblages across four types of linear ecological infrastructures differing in their structural diversity: woodland hedges, *rosaceous* hedges, grass strips and flower strips. Spider assemblages were examined across three levels of organization (taxon, guild and body-size group). Taxonomic composition was different among infrastructures, as was guild composition and the distribution of body sizes. Abundance and richness of spiders were higher in more structurally diverse infrastructures. The response to habitat type differed among guilds but, overall, higher densities of spiders from different guilds were found in hedges. Body-size groups had a more balanced distribution in strips and hedges with higher levels of structural diversity. Our results suggest that it is crucial to preserve varied typologies of ecological infrastructures, with an optimal level of complexity and heterogeneity, to maintain diversified assemblages of these important biocontrol agents within Mediterranean vineyard agroecosystems.

1. Introduction

Ecological infrastructures include many non-crop areas that are considered key elements in maintaining and enhancing biodiversity (Boller et al., 2004). Different types of ecological infrastructures can be distinguished according to their size and structure, including linear elements like hedges, grass strips or wildflower strips (Boller et al., 2004). In the current context of biodiversity loss, the presence of these elements within agricultural landscapes may be extremely important to the functioning of ecosystems and the provision of ecosystem services (Duffy, 2009; Franin et al., 2016).

Vineyards are one of the main crop systems in the Mediterranean basin (Froidevaux et al., 2017), and in Spain they constitute 5.69% of arable land (Secretaría General Técnica, 2017). Ecological infrastructures could play an important role in maintaining biodiversity within Spanish vineyard agroecosystems since, in most cases, crop management practices include the removal of ground cover vegetation by tillage and herbicide application throughout the year (Bell et al., 2001; Costello and Daane, 1998; Rypstra et al., 1999; Sharley et al., 2008). Vineyard ecological infrastructures are part of Green Infrastructure, and as such contribute to the EU Green Infrastructure Strategy. Ecological infrastructures deliver different Ecosystem Services, in particular natural pest control, and can help achieving sustainability targets like the reduction of pesticide application (Boller et al., 2004; Snäll et al., 2016). The contribution made by ecological infrastructures depends on features such as their structural diversity (i.e. complexity and heterogeneity) or degree of disturbance (Boller et al., 2004). It has been reported that arthropods benefit from structurally diverse habitats because they provide a wide range of resources and protection from predators, buffer environmental extremes, and

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https://doi.org/10.1016/j.agee.2018.06.026
Received 14 March 2018; Received in revised form 20 June 2018; Accepted 22 June 2018

insulate these animals from disturbance (Gunnarsson, 1996; Janssen et al., 2007; Langellotto and Denno, 2004; Loomis et al., 2014; Loomis and Cameron, 2014; Rypstra et al., 1999). Moreover, in agricultural systems ecological infrastructures play an important role in the colonization of crop fields by predators like spiders (Hogg and Daane, 2010; Marc et al., 1999; Thomson and Hoffmann, 2013).

Spiders are generalist predators occurring in high abundance and richness in agricultural ecosystems (Caprio et al., 2015; Sunderland and Samu, 2000; Wise, 1993). These generalist predators are considered important in vineyards, in which they may play a role in the suppression of pest populations (Caprio et al., 2015; Costello and Daane, 1998; Drieu and Rusch, 2017). Previous studies have demonstrated that spiders may benefit from the availability of non-crop habitats within agricultural landscapes (Hogg and Daane, 2010; Öberg et al., 2007; Schmidt et al., 2005; Schmidt and Tscharntke, 2005). The occurrence of these arthropods, at small scale, is determined by local habitat features such as vegetation structure, foliage density, prey availability or habitat disturbance (Battirola et al., 2016; Gomez et al., 2016; Halaj et al., 1998; Heikkinen and MacMahon, 2004; Horváth et al., 2005; Podgaiski et al., 2013; Spears and MacMahon, 2012). Additionally, spider assemblages can be influenced by habitat features not only in terms of taxonomy and guild composition (Cardoso et al., 2011; Dennis et al., 2015), but also in the distribution of body size, which shows considerable variation in this group and is strongly related to many life-history traits that can affect the structure and dynamics of food webs (De Souza and Martins, 2004; Entling et al., 2010; Gunnarsson, 1996; Woodward et al., 2005).

As they are generalist predators with diverse hunting strategies, spiders can act against a broad range of prey types in different ways (Marc and Canard, 1997; Wise, 1993). Different spider guilds, defined as a group of species that exploit the same resource in a similar way, can be distinguished in agricultural systems: sheet, orb and space web-building spiders, stalking and ambushing spiders and foliage and ground running spiders (Uetz et al., 1999). Complementarity between different hunting strategies and prey preferences among spider families, genera, or species positively contributes to the potential of spiders in terms of biological control, and the effect of spiders on a prey population is related to the ratio of spiders to prey (Betz and Tscharntke, 2017; Marc and Canard, 1997; Markó et al., 2009; Riechert and Bishop, 1990; Sunderland and Samu, 2000). Moreover, there are special features of the predatory behavior of spiders that contribute to their potential as biocontrol agents, such as the fact that both web weavers and hunting spiders capture prey that can be partially consumed or even not consumed (Sunderland and Samu, 2000). Thus, conservation of spiders within agricultural systems may contribute to more sustainable farming management by enhancing biological pest control (Betz and Tscharntke, 2017; Nyffeler and Sunderland, 2003). The sensitivity of spiders to the environment, combined with their abundance, make them appropriate indicators of ecological change (Gerlach et al., 2013). Besides, the strong relationship between spider assemblages and habitat structure has led to the proposal that this group be used as an indicator to detect human disturbance (Marc et al., 1999).

A number of studies have been conducted on spiders within agroecosystems in general, and vineyards in particular (e.g., Betz and Tscharntke, 2017; Caprio et al., 2015; Froidevaux et al., 2017; Hogg and Daane, 2010; Markó et al., 2009; Nyffeler and Sunderland, 2003; Öberg et al., 2007; Schmidt and Tscharntke, 2005; Sunderland and Samu, 2000; Uetz et al., 1999), but much less is known about the role of linear non-crop elements in maintaining spider communities (but see Fischer et al., 2013; Ysnel and Canard, 2000). Furthermore, although the effects of ecological infrastructures on improving biodiversity have been reasonably well investigated in temperate areas (Boller et al., 2004), these effects are poorly documented in Mediterranean agroecosystems (e.g., Burgio et al., 2006; Franin et al., 2016). Thus, there is a need to better assess the role of these elements in Mediterranean climate areas, such as the Iberian Peninsula, which have been identified as biodiversity hotspots for conservation priorities (Hewitt, 2011; Myers et al., 2000). We believe that there is a lack of information about the contribution that linear ecological infrastructures have on driving spider assemblages in Mediterranean vineyard agroecosystems, this information being crucial to develop strategies for the conservation of these important biocontrol agents.

The aim of this study was to examine how spider assemblages are related to ecological infrastructures in vineyard agroecosystems in northern Spain, across three different levels: taxon, guild and body-size group. We hypothesized that spider family composition and guild composition will differ between different types of ecological infrastructures, and that abundance and richness of spider families will increase with increasing structural diversity (complexity and heterogeneity) in these elements. Moreover, and due to their variability in habitat requirements, we also hypothesized that infrastructures with a more diverse structure will support a wider diversity of spider guilds and a broader size diversity.

2. Methods

2.1. Study area

Fieldwork was carried out in the municipality of Cenicero (La Rioja, northern Spain) (42°, 27′ N, 2° 38′ W). The climate of the region is Mediterranean with a continental influence. The average annual temperature varies from 12 to 13 °C, with January being the coldest month (mean: 5.2 °C) and July the hottest (mean: 20.9 °C). The mean annual precipitation is 400 mm. Summers are dry, with August being the driest month (15.2 mm). The study area comprises 604 ha belonging to the same landscape subunit, and exclusively devoted to traditional vineyard crops. Vineyards are located on hillsides between 432 and 746 m, with small and medium-sized fields (overall less than 1 ha) between which interspersed natural ecological infrastructures are remaining (Fig. 1). Different types of infrastructures can be distinguished in the area (i.e. woodland patches, hedges, and strips) (according to Boller et al., 2004), most of which are linear elements (86% of the total number of infrastructures) (Fig. 1). Production is regulated by the Rioja Qualified Designation of Origin (Rioja D. O. Ca). The soil is artificially maintained bare by plowing and applying herbicides. Vegetation in non-cropped areas includes evergreen sclerophyllous woods, where the dominant species is *Quercus ilex* L., and sclerophyllous Mediterranean thicket formations, composed of species like *Quercus coccifera* L., *Dorycnium pentaphyllum* Scop., *Cistus albidus* L., *Daphne gnidium* L., *Lavandula pedunculata* (Mill.) Cav. or *Thymus vulgaris* L.

2.2. Sampling design

Four types of linear ecological infrastructures (mean length 140.608 ± 35.461 m), representative of those found in the region, were selected maintaining the highest possible degree of uniformity in terms of shape and aspect (Fig. 1). They were characterised by different levels of structural diversity (i.e., complexity and heterogeneity) and different degrees of disturbance, being (i) *woodland hedges*: infrastructures with very low levels of disturbance and high structural diversity (many tall and medium-sized trees and shrubs) and consisting of local plant species typically associated with Mediterranean forests, such as *Q. coccifera* L. or *Q. ilex* L.; (ii) r*osaceous hedges*: infrastructures with low levels of disturbance and intermediate structural diversity (few trees), dominated by *Rubus ulmifolius* Schott and *Rosa canina* L. shrub species; (iii) *grass strips*: infrastructures with intermediate levels of disturbance, dominated mainly by grass species and with very few shrubs and fruit trees (low structural diversity); and (iv) *flower strips*: highly-disturbed infrastructures consisting of flowering plants that are mainly ruderals and with few isolated fruit trees (very low structural diversity).

The spider community was sampled monthly from May to