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Evaluation of two different methods to measure the effects of the management regime on the olive-canopy arthropod community

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ABSTRACT

The effects of the management regime, mostly differentiated for using or not insecticides, on biodiversity have frequently been difficult to analyze and understand because of the rapid re-colonization by good-dispersers, the quick recuperation of generalists and the continuity of insecticide-resistant arthropod species. The presence of these different communities may produce values of abundance, diversity indices and species richness which do not reflect the changes caused by the impact of the insecticides in the sprayed area. In this study we assess the impact of the olive tree management on the arthropod community and the changes in this community according to the blooming season. This study has been developed in olive groves subjected to conventional and organic management regimes by two different approaches: (a) the abundance-diversity approach, measuring and comparing abundance, richness and the Shannon-Weaver diversity index (H') of total arthropods and per guild and (b) the food-web approach, building food-webs and comparing their unweighted quantitative descriptors. We sampled the arthropods in the tree canopy in six conventional and six organic olive groves (12 plots), and in two of the periods of greatest diversity and abundance: pre-blooming and post-blooming seasons. The abundance of total arthropods, but only those within the guild of phytophagous, diminished significantly when insecticides were used. The species richness of total arthropods and specifically predators were also reduced in the conventional plots. These variables were always greater in organic olive groves. Conversely, the total and per guild Shannon-Weaver diversity index (H') did not detect any management effect on the olive-canopy arthropod community. Furthermore, all the food-web unweighted quantitative descriptors such as size, complexity and prey-predator asymmetries showed the significant effect of the management on the olive-canopy arthropod community and also presented greater values in organic olive groves. We also found that the blooming season did not significantly change the food-web structure, contrary to what we predicted. However, predator, parasitoid and phytophagous abundance, total and predator richness were greater in the post-blooming season. This study shows that the abundance-diversity approach, and especially H' diversity index, was not useful for describing the effect of different management systems on the canopy arthropod community. On the contrary, the food-web approach emerges as a useful tool for understanding and evaluating the ecological effect of the application of insecticides (and probably other disturbances during the management) affecting the agro-ecosystems.

1. Introduction

The Mediterranean region is the main producer of olive oil in the world (Civantos, 1997). Specifically, Andalusia (southern Spain) is the region with the highest olive production and surface involved in this activity (1.5 million Ha) (Junta de Andalucía, 2016a).

Since the green revolution, most of the olive groves in Andalusia have been managed under conventional intensive practices, periodically using agrochemicals (including insecticides) to control pests and ploughing to remove the natural vegetation cover and avoid water competition (Cirio, 1997). This kind of management system (named conventional) resulted in a significant environmental (public health) and ecological (decrease of non-target predator, parasitoid and pollinator populations) disturbance, groundwater contamination and a general loss of biodiversity, which has transformed the olive groves into simplified and unstable systems, dependent on external inputs (Beaufoy and Pienkowski, 2000; Metzidakis et al., 2008; Gómez Calero, 2009). Even in 2015, more than 60% of the total olive growing surface in

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Andalusia was dedicated to conventional management, and a part of this surface (14.1%) is located within high ecological value zones (Natura 2000 network, Ministry of Agriculture, Fishery, Food and Environment, 2017). As a consequence of all these facts, the management system of olive groves has important effects on general biodiversity and emblematic and preserved natural ecosystems (Junta de Andalucía, 2016b). This situation could be extrapolated to other olive-oil producing countries in southern Europe (Beaufoy and Pienkowski, 2000).

In contrast, the organic management of olive crops prohibits the application of synthetic insecticides, allowing only those of natural origin and low persistence, although they may have some negative impact on the arthropod community in the olive groves (Ruiz and Montiel, 2007; Scalercio et al., 2009). Nonetheless, the organic management of crops should have important ecological benefits, such as the improvement in the levels of soil organic matter, the reduction of erosion and favouring biological pest control and general biodiversity (Altieri, 1999; Picchi et al., 2017).

The effect of insecticides on olive-canopy arthropod communities has generally been analyzed by comparing parameters such as relative abundance, species richness and diversity indices, especially the Shannon-Weaver index (H' thereafter) which is generally used and permits comparison amongst different studies (Ruano et al., 2004; Santos et al., 2007; Scalercio et al., 2009), but offers an incomplete view, as in some of these studies unexpected results were produced, especially with H' and other diversity indices (Ruano pers. comm.). Thus, the H' diversity index is based on the species richness and evenness (Shannon and Weaver, 1949) and insecticide spraying in conventional groves causes the reduction of the pest abundance which then favours the increase of evenness amongst the other species. This effect results in an increase of diversity indices in conventional crops which did not reflect the effect of insecticides on the diversity of the sprayed area.

On the other hand, the food-web theory (Strogatz, 2001) has been considered the best way for studying the ecological processes involving the role of species and the influence of biodiversity on ecosystem function (Thompson et al., 2012). We thought that it could be a promising tool for understanding the effects of management regime in the arthropod community of the agro-ecosystems. In this scenario, quantitative descriptors of food-web complexity provide a sensible and accurate approach to define food-web structures (Bersier et al., 2002), to explore the structure of ecological communities and their response to environmental factors (i. e. habitat modification) (Tylianakis et al., 2007), landscape complexity (Gagic et al., 2011) or ecosystem services such as biological pest control (Van Veen et al., 2008; Macfadyen et al., 2009). The five unweighted quantitative descriptors of food-web complexity most commonly used are: 1) number of trophic species (S); 2) link density (LDq') or the ratio of links per node; 3) connectance (Cq') which refers to the number of realized links related to the number of potentially possible links; 4) vulnerability (Vq') which is the mean number of predators per prey; and 5) generality (Gq') or the mean number of prey per predator. The last two refer to the description of the asymmetries in the food web (Bersier et al., 2002; Tylianakis et al., 2007)

Moreover, the structure of ecosystems may experience seasonal changes over time. Thus, Ruano et al. (2004) found that olive groves showed the greatest arthropod abundance during May and June and that abundance differences between managements were more pronounced during these periods. These two months coincide with the pre-blooming and post-blooming season in the olive canopy in the studied region and are close to the two insecticide sprays in the grove (April and July). Nevertheless, it still remains unknown how the presence of flowers and pollen in olive canopies may affect the ecosystem structure. This presence may increase the presence of phytophagous and therefore, the number of predators attracted by them, such as coccinellids or syrphid flies in vegetable crops (Harmon et al., 2000; Bugg et al., 2008). This fact might also be supported by the syrphid fly movement among different heterogeneous patches surrounding olive crops in autumn (Villa et al., 2016). Thus, the blooming season in the olive tree may attract these types of natural enemies to the canopy and contribute to the natural pest control.

The main aim of this study is to better understand the impact of the type of management used in olive groves on arthropods in the olive-canopy community, comparing two different management regimes (i.e. conventional and organic) studied in two different seasons (pre-blooming and post-blooming) and two different approaches: (a) measuring and comparing abundance, species richness and H' diversity index, for the total arthropod community and per guild (i.e. predators, parasitoids and phytophagous); and (b) building food webs for each plot, and comparing their unweighted quantitative descriptors for each management regime.

Our predictions are that a) abundance, species richness and H' diversity index, and b) link density, trophic species richness, vulnerability and generality would be higher in the organic and in post-blooming season than in conventional groves and the pre-blooming season. However, regarding the fact that an increase in species richness seems to be related to a decrease in connectance (Schoenly et al., 1991; Banašek-Richter et al., 2009), we predict that this parameter will be lower in organic olive groves than in conventional ones and in the post-blooming rather than in the pre-blooming season.

2. Material and methods

2.1. Study site and management regime

We conducted our study in the province of Granada (Andalusia, south-eastern Spain) in 12 plots pertaining to six different commercial olive groves (2 plots per grove), with similar environmental characteristics and with a distance of more than 4 km among groves. Three of them (surfaces ranging from 2 to 11.4 ha) were managed under conventional practices in which dimethoate and α- cypermetrin were sprayed in March-April and the beginning of July respectively. The other three (surfaces ranging from 1 to 2.5 ha) have been submitted to an organic management regime since 1999 and neither *Bacillus thuringiensis* (Berliner) nor permitted insecticides were applied during our study. All the groves were irrigated bi-weekly and ploughed from April to July. See Cotes et al. (2011) for a detailed description of each grove and management. Our sampled farms corresponded to the 3 organic and 3 conventional olive groves from Granada Province studied in Cotes et al. (2011).

2.2. Collection of arthropods and taxonomic identification

Samples were collected in 2003 in two of the periods of the greatest diversity and abundance of arthropods in the olive groves: pre- and post-blooming seasons (i.e. during May and June, respectively). In each grove two plots were randomly selected, as separate as possible, with a minimum of 50 m between them. We randomly sampled ten trees in each plot, with each tree being separated by at least 20 m from the nearest sampled tree.

The sampling was conducted in the canopy, where the main effect of the insecticides can be detected, by beating four branches per tree (one by cardinal point in one sample), following Ruano et al. (2004). For preservation, samples were refrigerated in the field and then immediately frozen at −21 °C in the laboratory. After that, the arthropods were separated from the vegetal and inorganic remains, and finally they were taxonomically classified and preserved in alcohol 70% (see Appendix A in Supporting information). A large number of taxonomists collaborated with us in the identification of many individuals to genus or species (see Appendix B in Supporting information). Due to the large number of individuals and taxa collected in the samplings, the identification of each at species level was impossible. Thus, identification at