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Soil arthropod community in the olive agroecosystem: Determined by environment and farming practices in different management systems and agroecological zones

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ABSTRACT

Research on the relationship of the olive agroecosystem biodiversity with farm management and environment is limited, despite the importance of olive production for Mediterranean countries. In this study, we assumed less intensified olive orchard management to enhance soil arthropod community, and farm management and environmental factors to be important drivers shaping it. Soil arthropods were monitored seasonally for two years in organic, conventional and integrated olive orchards, located in hilly and plain agroecological zones of Crete, Greece. Farming practices, climate and landscape complexity were recorded. Two subgroups of functional taxa were defined, with respect to the prioritized agroecosystem services of biological pest control and nutrient cycling. Significant differences in arthropod community were found between agroecological zones for specific taxa, seasonal diversity indexes and functional subgroups. The group of climate, farming practices and landscape factors explained always a larger portion of arthropod variability, than management systems and agroecological zones together. Temperature, soil tillage, as well as relative humidity, appeared as the most important explanatory variables. Agroecological zones explained a biggest fraction of arthropod variability than management systems. Agricultural management and environment should be considered in the biodiversity assessment of the olive orchard agroecosystem.

1. Introduction

Olive production is a major agricultural, environmental and economic driving force for Mediterranean countries. Olive trees are cultivated within a variety of landscapes and agroecological zones, where management systems of different intensity are applied. Olive cultivation frequently follows a conventional agricultural protocol, especially in industrialised, modern olive orchards, which face ecological problems (Kabourakis, 1999; Volakakis et al., 2012). The biodiversity of agroecosystems where intensification takes place is led to impoverishment (Biaggini et al., 2007), while soil arthropod fauna is especially affected (Cotes et al., 2010; Ruano et al., 2004; Santos et al., 2007).

A major, related to above, concern is that enhanced agro-ecosystem biodiversity, when correctly assembled, provides several services, supporting soil fertility, crop protection and productivity (Altieri, 1999). The part of agro-biodiversity delivering such desired services, depending always on the stakeholder's objectives and priorities, is regarded as "functional" (Bàrberi, 2013; Moonen and Bàrberi, 2008). Soil arthropod community may well deliver substantial services in the olive agroecosystem, in terms of biological control of the olive fly (*Bactrocera oleae* (Rossi), Diptera: Tephritidae), the main olive pest worldwide (Daane and Johnson, 2010). In fact, several studies have shown that the predatory soil

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arthropod community can increase mortality on the Tephritidae pupae (Orsini et al., 2007). Another major service is nutrient cycling and decomposition, by litter fragmentation, grazing on microflora and improvement of soil structure (Reichle, 1977).

As a consequence of the decline of biodiversity, growing concerns arise for the sustainability of farming practices (Hole et al., 2005). Agri-environmental schemes, including less intensive farming systems, like organic, are considered important tools to combat the negative effects of intensive agricultural production (European Environment Agency, 2004). However, the assessment of the environmental effectiveness of such systems, often encounters methodological problems (Bengtsson et al., 2005; Ponce et al., 2011). Hole et al. (2005) pointed out several issues related to the problematic nature of different management systems comparison, with regards to their impact on biodiversity. They identified several universal problems, including the incorrect conclusions drawn due to lack of control for extraneous variation, such as the influence of landscape characteristics to community structure, identified as well by Bengtsson et al. (2005) and Gomiero et al. (2011). The short time-scale of studies, often limited to a single season/year, was also regarded as representing stochastic variability in community structure, rather than the differences resulting from farming regimes. On the other hand, factors such as location, climate, crop-type and species are listed as those influencing the effect of management system on biodiversity (Hole et al., 2005).

Another issue is the limited number of studies having focused up to date on the response of fauna or flora communities in perennial crops, under different management systems (Bruggisser et al., 2010). Most of these were carried out in middle or high latitudes, but scarcely in the Mediterranean region, where climatic conditions are quite different (Ponce et al., 2011). Even further, only few studies have evaluated the effects of farming practices applied in olive production systems biodiversity (Cotes et al., 2009; Gonçalves and Pereira, 2012), while research focusing on functional subgroups of soil arthropods is scarce.

In this study, the soil arthropod community of olive orchards, located in southern Crete, Greece, was seasonally investigated over a period of two years, covering the full, biannual circle of olive production. The investigation included the monitoring of soil arthropod fauna in different management systems and agroecological zones. Furthermore, two “functional” sub-groups were defined, related to the prioritized agroecosystem services of biological pest control and nutrient cycling. Following an agroecological approach, climate conditions, farming practices and landscape factors were extensively monitored and correlated with the soil arthropod community in the olive agroecosystem.

The hypothesis of the study was that less intensified agricultural management generally supports greater taxa abundance and diversity. However, farming practices applied under commercial olive production and environmental factors are well expected to be important drivers shaping the soil arthropod community.

A general-to-specific approach was followed in order to:

(a) Compare soil arthropod community structure and diversity under different management systems (organic, conventional and integrated) and under different agroecological zones (hilly and plain).
(b) Investigate the correspondent response of the “functional” arthropods counterpart.
(c) Investigate the importance of factors related to environmental conditions, farming practices and landscape, with regards to their effect on soil arthropod community.

2. Materials and methods

2.1. Study sites and sampling periods

The survey took place in twenty four pilot orchards located in eight different locations in western Messara valley (35°01′N, 24°49′E), 40 km south of Heraklion, a representative olive production region in southern Crete, Greece. Each study location included three neighbouring orchards, one complying with organic standards according to European Union (EU) legislation (Council Regulation (EC) 834/2007), the second following an industry standard for integrated farming, according to the agri-environmental and sustainable development requirements of the EC 2078/92 and 1257/99, and the third complying with EU Common Agricultural Policy (CAP) framework describing conventional farming.

Orchards were managed commercially and had an average size of 0.53 ha, ranging from 0.17 to 1 ha, considered typical for the area (National Statistical Service of Greece, 2009) (Table 1). Orchards were selected following discussions with local stakeholders, and on the basis of previous research carried out in the area (Gkisakis et al., 2015; Kabourakis, 1999; Volakakis et al., 2012). The average distance between neighbouring orchards in each location was 150 m, and the minimum distance between locations was 1 km.

The study area’s landscape consists mostly of olive orchards, covering both hilly and plain agroecological zones of olive production. These zones are differentiated upon elevation, terrain, abiotic (soil type and fertility, rainfall, temperature, humidity), and biotic environment (fauna and flora), and the intensity of management applied in the olive orchards; Cultivation in the hilly zone is considered less suitable for intensive farming practices and inputs, due the limitations posed by the terrain and the pedoclimatic conditions (Kabourakis, 1996; Metzidakis et al., 2008).

Information on the variety of practices applied in the different management systems was collected by means of standardized questionnaires, answered by the farmers participating to the survey. Weekly on-site observations were conducted during the two-year period of the study in order to monitor and quantify variables related to (i) soil management (proportion of orchard soil surface tilled), (ii) soil cover (proportion of orchard soil surface covered with vegetation), (iii) fertiliser applications (manure) and (iv) insecticide applications in the olive canopy, combating olive fly population (Table 1), as well as to validate the information provided by the farmers.

Climate data, including temperature and relative humidity were monitored and recorded hourly for each location, using HOBO data loggers (Onset Computer Corp., Bourne, MA) during the whole survey period. The data loggers were suspended in Stevenson screens as a standard weather shelter, following World Meteorological Organisation methodology (WMO, 1983).

Landscape complexity, defined as the proportion (%) of semi-natural habitats (SNH) surrounding the olive orchards, was measured in a radius of 200 m from the orchard centre, using official topographical maps and Quantum GIS 2.0.1 (QGIS) software (Quantum GIS Development Team, 2010). SNH included non-crop habitats like ditches, field margins, hedgerows, meadows and uncultivated grasslands. These elements are regarded as important for farmland biodiversity enhancement (Vollhardt et al., 2008). In our study area, the proportion of SNH among orchards ranged from 2.9 to 35.8% (Table 1).

The survey covered two standard production years (2011–2013), in terms of climatic conditions and considering the year-to-year deviation in olive tree yield (alternate bearing). The sampling period included five weeklong measurements for each season, from autumn 2011 to summer 2013 (winter: weeks 2–6; spring: