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Influence of soil management on soil physical characteristics and water storage in a mature rainfed olive orchard

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ABSTRACT

Mechanical tillage represents the most common technique of soil management in olive orchards within the Mediterranean Basin. Such practice may result in soil structure degradation which can significantly reduce water infiltration causing runoff and erosion processes. An alternative opportunity is given by the use of cover crops which eliminates most of the disadvantages of conventional tillage. An experiment was carried out from 2007 to 2009 in a mature and rainfed olive grove located in Southern Italy with the aim to evaluate the effect of different soil management techniques on soil structure and soil water content and storage along the profile. The experimental site was characterised by a slope gradient ranging from 0 to 16%. Since 2000, the olive grove was subjected to two different management systems: sustainable system, SS (no-tillage, spontaneous vegetation cover, annual recycling of pruning material) and conventional system, CS (tillage, no recycling of pruning material). Modifications of soil structure induced by the two different management systems were quantified by micromorphometric analysis of macroporosity. Soil hydrological behavior was determined by field saturated hydraulic conductivity (K_{sat}) measurements. Soil water content was measured at 10/15-day intervals by gypsum resistivity blocks placed in flat and steep areas (summit, backslope, and footslope) of both systems at different soil depths (25, 50, 75, 100, 150 and 200 cm).

In the SS soil macroporosity was not very high (about 10%) but homogeneously distributed along the profile which favored the vertical water movement down to deeper horizons. In the CS the occurrence of soil crusting and of compacted layers along the profile hindered infiltration and percolation of rainfall water influencing the soil water content below the 100 cm layer. The SS was able to better store water from rainfall, received during the autumn–winter period, especially in the deepest soil layer (from 100 to 200 cm). This was evident especially in the steep area at the summit position, where the water amounts stored by SS were 45 and 17% higher than those retained by the CS in 2007 and 2009, respectively. During summer such reserves were available for the olive root systems which usually, under the driest conditions, explore the deep soil zone in search of water. Under our experimental conditions, no yield reduction was observed due to the prompt mowing of the spontaneous cover crops. Therefore, the suitable use of cover crops should be communicated to the olive farmers and strongly recommended within agricultural policy strategies for its evident agronomical and environmental benefits (increase of soil organic carbon, soil structure improvement, reduction of soil and water losses, carbon sequestration).

1. Introduction

The olive tree (*Olea europaea* L.) is one of the most widespread crops of the Mediterranean Basin, where it covers a surface area of about 9.5 Mha (FAOSTAT, 2012). It grows in semi-arid environments characterized by wet winters and dry summers. Since ancient times the olive tree is grown under rainfed conditions on marginal lands, due to its ability to adapt to limiting environmental conditions such as drought and infertile, shallow, stony and steep soils. However, soil water availability is the major constraint to olive productivity.

In the Mediterranean olive orchards, mechanical tillage still represents the most common technique of soil management (Beaufoy, 2002; Xiloyannis et al., 2008). It is performed as both ordinary horticultural practice – to destroy weeds and thereby

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reducing competition for water and mineral nutrients and fire danger during the dry season, to incorporate fertilizers, residues, and manure into the soil, to facilitate harvest operations such as nets placing and operators access – and dry farming technique. In the latter case, such practice is aimed to reduce soil evaporation by interrupting water capillary rise and augmenting soil surface roughness (Ozpinar and Cay, 2006). Moreover, tillage should improve infiltration of rainfall water into soil and water distribution in the profile. The effect of tillage on infiltration varies according to soil type and location, and methods used for tillage (Gómez et al., 1999). In many cases, the increased water infiltration only occurs for a short period of time immediately after the machine passage (Pastor et al., 2000). As a matter of fact, tillage may result in soil structure degradation which can significantly reduce water infiltration rate causing runoff and erosion processes (Abid and Lal, 2009). Such detrimental effects are evident especially in olive groves placed on steep slopes (Kosmas et al., 1997; Raglione et al., 1999; Francia Martínez et al., 2006; Fleskens and Stroosnijder, 2007; Romero et al., 2007; Gómez et al., 2009a). Hence, environmental, hydrogeological, and socio-economic consequences can be serious at both farm and watershed level (Xiloyannis et al., 2008). In addition, the combination of intensive tillage and high air temperatures, typical of Mediterranean climate, induces oxidative soil metabolism determining high rate of organic matter mineralization. A significant loss of soil organic carbon (SOC) leads to a further deterioration of soil and its hydraulic properties, precisely those which allow a better recharge and storage of rainfall water into the soil (Lipecki and Berbeć, 1997; Strudley et al., 2008).

An alternative opportunity to manage soil in olive orchards is given by the use of cover crops which eliminates most of the disadvantages of conventional tillage. Such environment-friendly practice reduces runoff and soil erosion by intercepting raindrops, thus reducing their erosive impact on the soil, and by speeding infiltration of excess surface water. Furthermore, soil cover, assured by the resulting mulch (cover crop residues mowed and left on the ground), allows to conserve soil moisture and reduce water evaporation from soil surface. Some reports indicated an increase of soil moisture in cover cropped olive groves as a consequence of an augment in the infiltration rate and in SOC content (Gómez et al., 1999; Pastor et al., 2000; Hernández et al., 2005; Durán-Zuazo et al., 2009; Gómez et al., 2009a,b). Nevertheless, the use of cover crops is not common in semi-arid areas where soil water availability represents the limiting factor for crop production (Gómez et al., 2009b). At present, contradictory results exist on the effect of soil management on productive performances of olive trees. Gómez et al. (1999), in a 15-year trial, did not find any difference between yields coming from mature plants conducted according to conventional (CT – weed control and harvest preparation by discing to about 20 cm several times in the spring and autumn) and no tillage (NT – weed control by spraying with the herbicide simazine) soil management systems. Differences were recorded just in one very dry experimental year when NT produced about twice as much as CT. The authors suggested that the presence of roots in the surface layers of NT favored tree water uptake rather than water evaporation from soil, while in the CT, such roots are eliminated periodically by tillage and a higher proportion of surface water content was lost to direct soil evaporation over the season. According to the authors, these differences could be significant in very dry years: in their study case rainfall of that experimental year was 67% of average rainfall (Gómez et al., 1999).

Diverse findings were reported by Gucci et al. (2012) who found higher fruit and oil yields in young olive orchards managed by tillage with respect to orchards grown under a permanent natural cover. However, the same authors suggested that the negative effect on yields could be attributed to the early establishment of permanent cover and recommended to delay its adoption to the third or fourth year after olive grove planting depending on tree growth. Ferreira et al. (2013) by comparing three different soil management systems applied to mature olive groves – glyphosate, tillage and sheep-walk – found the higher accumulated olive yields (from 2002 to 2011) in the glyphosate treatment applied once a year in April.

A comparative experiment was performed in a mature rainfed olive grove grown under semi-arid conditions to evaluate the effect of two different soil management systems, sustainable (cover cropped with spontaneous species – SS) and conventional (continuously tilled – CS), on certain soil parameters affecting soil structure and, consequently, rain infiltration. Soil water content was measured at different soil depths (up to 2 m) during 2007 and 2009 in order to evaluate the soil capacity to store rainwater fallen in the autumn–winter period. In SS cover cropping lasted since 2000 and was combined with the recycling of olive pruning material, an important source of organic matter internal to the olive grove.

2. Materials and methods

2.1. Site description and climatic parameters

The experiment was carried out from 2007 to 2009 in a rainfed olive grove located in Southern Italy (Ferrandina–Basilicata region, 40°29′ N, 16°28′ E), characterised by a slope gradient ranging from 0 to 16%. Olive trees (*Olea europaea* L. – cv Maiatica, a double aptitude variety) had more than 50 years and were in the productive stage. Trees were vase trained and planted at a distance of about 8 × 8 m. The average volume of the tree canopy, calculated according to Ĉermák et al. (2007), was equal to 87.7 ± 11.0 m^3 (mean ± standard deviation).

The soil of the experimental grove is a sandy loam classified as a Haplic Calcisol (FAO, IUSS, ISRIC, 2006) (Table 1).

The climate of the area is classified as semi-arid. The mean annual rainfall is 574.1 mm (mean of 1976–2009), and the mean annual temperature ranges from 15 to 17 °C.

The key meteorological parameters (air temperature, rainfall, humidity, etc.) were measured daily in 2006, 2007, 2008, and 2009 by a standard weather station placed close to the trial area. The reference evapotranspiration (ETo), provided by the Servizio Agrometeorologico Lucano service of the Extension Regional Service (www.alsia.it), was the mean value coming from the application of Blaney–Criddle, radiation and Hargreaves methods for ETo estimation (Allen et al., 1998).

2.2. Experimental treatments and yield measurements

Since 2000, the olive orchard was split into two parts subjected to different soil management systems: sustainable system (SS) and conventional system (CS).

In SS, the entire soil surface was homogeneously covered by spontaneous grasses providing a maximum ground cover close to 100%. Spontaneous herbs were mowed at least twice a year (at the end of March, before bloom and, if necessary, during the pit

Table 1
Main physical and chemical characteristics of the soil at the beginning of the experiment.

Horizon		Sand	Silt	Clay	Organic C
				g kg^{-1}	
Ap1	0–30 cm	657	196	147	8.6
Ap2	30–50 cm	651	192	152	6.3