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Effects of oil mill wastes on surface soil properties, runoff and soil losses in traditional olive groves in southern Spain

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ABSTRACT

In Spain, agriculture triggers soil degradation and erosion processes. New strategies have to be developed to reduce soil losses and recover or maintain soil functionality in order to achieve a sustainable agriculture. This experiment was designed to evaluate the effect of two olive mill wastes (olive leaves and "alperujo") on soil properties and soil erosion in a rain fed olive grove in SE Spain. After three years experiment, oil mill wastes application significantly improved physical and chemical properties of the studied soil with respect to control. The organic matter content, bulk density and porosity were increased, which confirmed the interactions of these properties. Available water capacity increased with olive leaves but decreased when applied "alperujo". With respect to erosion, after simulated rainfall experiments it was found that the oil mill wastes contributed to increase the roughness and the interception of raindrops, delaying runoff generation and enhancing the infiltration of rainwater. Treatment with oil mill wastes contributed to a reduction in runoff generation and soil losses compared to bare soil, especially when applied olive leaves.

1. Introduction

Olive oil production worldwide estimated to be about 2.8 10^6 Mg per year (IOOC, 2009). Within the EU, the main producer is Spain with an average production of 0.9 10^6 Mg per year, reaching 1.4 10^6 Mg in the 2003–2004 campaign (AAO, 2010). There are approximately 750 10^6 productive olive trees in the world (IOOC, 2004), of which 215 10^6 are in Spain (De Hidalgo, 2008).

Proper management and utilization of olive mill wastes is becoming more urgent due to the expansion of this industry and an increasing awareness of environmental protection (Pfeffer, 1992). Spain, Italy and Greece, three Mediterranean countries, involved in solving the olive mill wastes problem, have made many studies regarding the possible ways of cleaning and recycling olive mill wastes (Tomati and Galli, 1992; Cardelli and Benítez, 1998; Colodrero et al., 1998 and Benítez et al., 2000). Annually, Spain generates 5.89 10^6 Mg "alperujo" (waste from the current procedure for olive oil extraction in two stages) and 0.367 10^6 Mg olive leaves (olive leaves dragged along with the olives at harvest and separated in the initial cleaning process at the mill) (Moreno, 2009).

Several advantages were reported for proper uses of olive mill wastes, using them as a source for plant nutrients and a supply of organic matter to improve soil fertility (Melgar et al., 2000; Sainz et al., 2000; Alburquerque et al., 2006 and Altieri and Esposito, 2008). On the other hand, the disadvantages may be represented by the polluting load and accumulation of high mineral elements and organic phytotoxic compounds (Aqeel and Hameed, 2007).

Soil erosion is a major problem in the Mediterranean region due to its arid conditions, storm intensity and rainfall concentration, which are factors that contribute largely to agricultural land degradation (López-Bermúdez and Albadalejo, 1990 and Lal, 1999). On average, in Spain, it lost 23 Mg ha^{-1} of soil per year, contributing to desertification and loss of agricultural production (Fernández, 2008). López (1990) estimated an annual average of soil erosion in olive groves in 80 Mg ha^{-1}. Therefore it is necessary to replace the annually lost of organic matter to support agriculture in areas that already are low in organic matter (Fernández, 2008).

This is why soil erosion control strategies are largely being applied to agricultural land. Catch crops, no-tillage or reduced tillage, chipped pruned branches, straw mulch, geotextiles and weed control by herbicides (or no-tillage techniques) are some of the land management currently being applied on experimental farms to reduce the usually high erosion rates on rain fed agricultural land in eastern Spain (García-Orenes et al., 2009).

New soil management practices will not only affect the erosion processes, but also the soil properties. Several studies show that agricultural management has an important influence on chemical, physical and biological parameters (García et al., 1997; Caravaca et al., 2002 and Marinari et al., 2006), as microbial populations and activities are fundamental for maintaining soil quality by mediating the processes of organic matter turnover and nutrient cycling (Doran and Parkin, 1994).

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Fig. 1. Images of the three plots, from left to right: control plot, "alperujo" plot, olive leaves plot.

Differently from other land uses, cultivated soils show low organic matter contents (Masciandaro et al., 1998). Intensive soil use throughout history has led to the depletion in soil quality, leading in turn to low yields because of the consequent reduced organic matter (Reicosky et al., 1995). Celiki (1987) observed that Mediterranean cultivated soils present lower saturated hydraulic conductivities than forest soils. He found that cultivation degrades soil physical properties, and makes soils more susceptible to erosion processes.

Furthermore, olive trees are usually grown in areas where water is scarce. The trees explore substantial soil volumes during their long lifetime, and depend on the soil water storage capacity to avoid water stress. The timing of water deficits has important effects on productivity. Although several soil management strategies may be applied to olive tree cultivation, the most widely used method is mechanical tillage. Recent findings, however, suggest that only an enhanced rate of water filtration would technically warrant interest in mechanical tillage (Hernández et al., 2005).

There is strong evidence, especially for soils of low soil water storage capacity such as the present study, that water-saving production techniques are important requirements under drought conditions for the crop to reach its yield potential, particularly if the frequency and duration of droughts increase or soil and groundwater reserves decrease. Within this approach and in line with resource-soil and water conservation concepts, the use of crop residues is quickly gaining popularity.

Mulching protects soil from rainfall-induced erosion by reducing the raindrop impact. A partial covering of mulch residue on the soil can strongly affect runoff dynamics, and reduce the runoff amount (Rees et al., 2002 and Findeling et al., 2003). Blavet et al. (2009) have reported a significant reduction of soil loss when plant residues were left on the soil. They found that vineyards mulched with straw or with rock fragment cover were protected against runoff, and soil erosion.

The addition of organic plant residues to crop soils also helps to improve soil water storage capacity because it improves soil structure. The addition of crop residues to cultivated soils helps to improve soil quality and productivity through its favorable effects on soil properties (Lal and Stewart, 1995 and Mulumba and Lal, 2008). The application of crop residue mulches to cultivated soils increases the organic matter content (Havlin et al., 1990; Duiker and Lal, 1999 and Saroa and Lal, 2003). Mulumba and Lal (2008) reported positive effects on soil porosity, available water content, soil aggregation, and bulk density after the application of wheat straw mulch.

The objectives of this work are [1] to compare the effects of two oil mill wastes ("alperujo" and olive leaves) on the decrease of soil erosion and improving the physical and chemical properties of soil; [2] to recycle oil mill wastes apply them to the soil and convert them