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Using olive pruning residues to cover soil and improve fertility

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ABSTRACT

The application of organic materials to land is a common practice in sustainable agriculture. The current availability of several types of pruners and choppers on the market has boosted the use of these types of residues as plant cover. Applying these types of residues increases the content of organic matter in the soil, which is very positive for the fertility of the soil and agricultural biodiversity. The latter should be taken into account in ecological olive groves where fertilisation programmes are highly limited. However, no quantitative information is available to provide farmers with a precise assessment.

Experiments were conducted over a period of two agricultural years (2009/10 and 2010/11). Treatments consisted of pruning applications to fine (<8 cm in diameter) and thick (>8 cm in diameter) in the amounts indicated, I = 2.65 kg m^{-2} fine; II = 2.65 kg m^{-2} fine + 1.12 kg m^{-2} thick; III = 5.30 kg m^{-2} fine; IV = 5.30 kg m^{-2} fine + 2.24 kg m^{-2} thick; and a control of spontaneous weeds.

The greatest loss of residue mass was recorded at the beginning of the sampling period. The estimated biomass loss in the first six months represented 37–50% of the total. After 704 days of decomposition, the soil maintained cover percentages of 62, 76, 74 and 88% for treatments I, II, III and IV, respectively.

The various treatments applied to pruning residues have been more effective at increasing the levels of soil organic matter (SOM) than spontaneous cover. SOM values on the surface (0–5 cm) rose by 0.86, 1.04, 1.28 and 1.52% for treatments I, II, III and IV in regard to the control treatment, maintaining this improvement in fertility at a depth of 0–20 cm, where SOM increased by 0.43, 0.46, 0.84 and 0.47% for treatments I, II, III and IV, respectively, in regard to the control.

Considering all the soil sampled, the largest increase in SOM in regard to the initial content of the soil was achieved by treatment III, which contained the largest amount of fine residues, with 0.63%, compared to increases of 0.33, 0.29, 0.36 and 0.10% for treatments I, II, IV and spontaneous weeds, respectively.

1. Introduction

Andalusia (Spain) is a leader in world olive oil production. This industry is an essential part of the economic activity in over 300 towns and villages in the region. The Andalusia olive industry accounts for 80% of Spanish production, a third of the olive groves in Europe and produces 40% of the olive oil in the world (MARM, 2010).

Olive oil production in Andalusia (Spain) faces two serious problems that have not yet been solved, namely the loss of soil productivity and increasing diffuse pollution due to soil erosion (Rodríguez-Lizana et al., 2007).

The benefits of establishing plant covers for soil protection against erosion and for improving their water balance are associated with the presence of plant remains which maintain a dense cover on the soil for the longest possible time. However, the cover percentage and its permanence over time depend on the type of residue and on the area's climatology (Thorbum et al., 2001).

Some experiments have been carried out on the use of plant covers in woody crops, where the conservation benefits have been shown. Francia et al. (2000), in olive tree plots with a 30% slope, indicate a reduction of 83% in the loss of soil with the use of plant covers. Gómez et al. (2009) indicate that plant cover reduces 93% of soil loss due to runoff with respect to an olive grove on bare soil. Ordóñez et al. (2007a) found that covered soils reduce the effects of erosion in ecological olive orchards by 56% and 80% as compared to conventionally tilled soils. Monteiro and Lopes (2007) and Francia et al. (2006) recommend extending the use of cover crops to olive groves and vineyards in Mediterranean areas to improve soil and water conservation.

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Apart from the benefits described above, one of the factors that contribute to the increased use of plant covers in olive groves in Mediterranean areas is that more environmental criteria are being incorporated into agricultural policy and Community rural development through The Code of Good Agricultural Practice and, more recently, the single payment system (Calatrava and Franco, 2011).

Practically all the studies have been performed on live plant covers. However, in rain-fed plantations, these types of cover can compete for water and nutrients with trees. As a result, the modification of other cultural practices is necessary, such as the dose and application time of fertilisers. Although this type of cover improves infiltration (Pastor, 1989), better water balances are obtained by using inert plant covers that do not compete with trees (Márquez et al., 2007a,b). Alcántara et al. (2011) indicate the importance of when live cruciferous plant covers are mowed so they do not compete with olive trees for water and nutrients. Moreover, the trees make better use of such plant covers (Welker and Glenn, 1991).

Inert covers include pruning remains, of which the rain-fed Andalusian olive orchards supply similar annual amounts to the harvest of olives (between 1.3 and 3.0 mg ha^{-1}) (Ordóñez et al., 2007b). Pursuant to current legislation, farmers must take into account Decree 247/2001 (amended by Decree 371/2010), which approves the Regulations to Prevent and Combat Forest Fires, when removing pruning residues.

The decomposition rate of organic residues varies significantly depending on whether they are located on the surface or within the soil (Alvararado, 2006), on their spatial distribution (Khalid and Anderson, 2000; Lim and Zahara, 2000) and on the size of the residues (Khalid et al., 2000). The size of the residues affects the specific surface in contact with the ground and therefore microbial colonisation and the exchange of water and nutrients with the surrounding soil. In this study, Fruit et al. (1999) cited by Guérif et al. (2001), indicate that the ideal average for such pruning remains should be between 5 and 15 cm.

Pruning residues decompose and humificate slowly due to their high content of cellulose and lignin, medium to low content of moisture and a high C/N ratio, which makes it possible to ensure long-lasting soil protection (Ramos, 1999).

Most of these residues are usually burnt on the farm requiring a large amount of the labour force. This practice, which is being increasingly controlled by authorities, has several drawbacks, such as the risk of burning olive trees near the bonfire, especially in intensive plantations, and CO_2 emissions into the atmosphere. One additional problem of residue burning is the reduction in C sequestration (Qingren et al., 2010).

Furthermore, in ecological farming systems, fertility management is one of the most important aspects in terms of limiting output (Ostergard, 2002). Ecological agriculture bases the management of soil fertility on organic matter and biological soil processes. As soil organisms are generally heterotrophs, their activity will be particularly relevant when organic matter is readily available.

Olive grove soils generally have a low content of organic matter, a situation which is further aggravated by erosion, mainly due to certain farming practices that have exerted a decisive influence on accelerating this process (Soria et al., 2003). In the Mediterranean region, Álvarez et al. (2007) observed that the carbon in the soil could decrease by up to 50% in olive grove soils, compared to natural areas of vegetation nearby.

As regards plant remains, many authors have indicated the benefits of returning the remains of the crops to the soil and their possible utilisation as an organic rectifier, as they enhance soil quality (Franzluebbers, 2002; Sofo et al., 2005), the most direct effect being an increase in the organic carbon content of the soil (Chivenge et al., 2007; Mondini et al., 2007).

The objective of this research is to assess the capacity of different pruning residue treatments carried out in olive orchard lanes to increase carbon, in addition to estimating the decomposition dynamics of these plant remains and how their evolution over time affects the cover surface, the biomass of the remains and their capacity as a source of carbon for the soil.

2. Material and methods

2.1. Field trials and experiment design

Experiments were conducted over a period of two agricultural years (2009/10 and 2010/11) in Alameda del Obispo (Córdoba, Spain) organic olive orchard farm, with picual olive trees that are 40 years old and a plantation frame of 8 × 8 m. The olive trees had a height average of 4.1 m and a canopy diameter of 5.3 m which represents a volume of 9407 m^3 ha^{-1}. The UTM coordinates in the central point of the trial plot are X = 341 642 m, Y = 4 192 085 m, zone = 30 North, with an elevation of 117 m above sea level. The soil is a calcixerept Inceptisol, according to Soil Survey Staff (1999), with some physicochemical characteristics shown in Table 1.

The experimental unit was a subplot of 28 m^2 and consisted of the distance between 3 olive trees with a cover strip width of 2 m (Fig. 1). A randomised complete block design with six replications was adopted. The experimental plots were sited perpendicularly to the slope (1.7%).

In order to perform the trial, different olive trees on the farm were pruned and the residues obtained per tree were weighed, differentiating the fine wood (light pruning from the cleaning of the orchard, with a diameter equal to or below 8 cm) from the thick wood (renewal pruning greater than 8 cm in diameter). The average pruning of 10 olive trees was measured, obtaining 42.3 (4.4) kg of fine pruning residues and 17.9 (2.4) kg of thick pruning residues per tree. Standard error is indicated in brackets. The olive trees had not been pruned for three years.

In order to include the various chopping options currently available to farmers, two types were distinguished, depending on the size of the residues, namely field treatments with self-fed and hand fed chopping machines. Therefore, two treatments were

Table 1
Physicochemical characteristics of olive grove soil used in the trial.

Depth (cm)	pH H_2O	pH Cl_2Ca	EC (dS m^{-1})	CEC (mol kg^{-1})	Sand (%)	Silt (%)	Clay (%)	Textural class	OM (%)
0–20	8.6	7.8	0.1	0.20	41.6	40.6	17.8	Loam	1.9
20–40	8.6	7.8	0.1	0.19	44.5	37.6	17.9	Loam	1.3
40–60	8.8	7.9	0.1	0.17	44.8	37.5	17.7	Loam	1.0

Depth (cm)	CO_3^{-2} (%)	NO_3^- (mg kg^{-1})	NO_2^- (mg kg^{-1})	NH_4^+ (mg kg^{-1})	P (mg kg^{-1})	K^+ (mg kg^{-1})	Na^+ (mg kg^{-1})	Ca^{2+} (mg kg^{-1})	Mg^{2+} (mg kg^{-1})
0–20	16.4	8.0	0.5	1.1	18.4	402.6	36.9	5482.7	125.3
20–40	20.4	5.8	0.6	1.4	14.1	303.6	38.8	5452.0	122.7
40–60	20.9	8.3	0.3	1.6	12.8	205.0	41.7	5337.3	140.0

EC, electric conductivity; CEC, cation exchange capacity; OM, organic matter.