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Application of compost of two-phase olive mill waste on olive grove: Effects on soil, olive fruit and olive oil quality

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ABSTRACT

Composting is a method for preparing organic fertilizers that represents a suitable management option for the recycling of two-phase olive mill waste (TPOMW) in agriculture. Four different composts were prepared by mixing TPOMW with different agro-industrial by-products (olive pruning, sheep manure and horse manure), which were used either as bulking agents or as N sources. The mature composts were added during six consecutive years to a typical "Picual" olive tree grove in the Jaén province (Spain). The effects of compost addition on soil characteristics, crop yield and nutritional status and also the quality of the olive oil were evaluated at the end of the experiment and compared to a control treated only with mineral fertilization. The most important effects on soil characteristics included a significant increase in the availability of N, P, K and an increase of soil organic matter content. The application of TPOMW compost produced a significant increase in olive oil content in the fruit. The compost amended plots had a 15% higher olive oil content than those treatment with inorganic fertilization. These organics amendments maintained the composition and quality of the olive oil.

1. Introduction

The olive oil industry is very important not only in Mediterranean countries, where most of the olive oil is produced, but also in other regions around the world sharing similar climatic conditions. About 3 million tonnes of olive oil are produced annually in the world (FAOSTAT, 2012) leading to the generation of large amounts of wastes. In Spain, the main world producer, the new two-phase centrifugation system for olive oil extraction quickly replaced the three-phase system in the early 1990s. The new olive oil extraction system has produced a new solid waste called two-phase olive mill waste (TPOMW), "alperujo" which is generated in large quantities during a short period of time. Approximately 4 million tonnes of TPOMW are generated annually in Spain (FAOSTAT, 2012), which has caused serious management problems due to its phytotoxicity and semisolid texture (Roig et al., 2006; López-Piñeiro et al., 2011). Usually, the olive husk obtained from the three-phase system underwent a second oil extraction with organic solvents after its drying. However, when TPOMW was attempted to be treated similarly, great difficulties appeared owing to its high moisture and low fat. The new waste requires a drying process before the second oil extraction that significantly increases production cost due to the large demand of energy (Roig et al., 2006). Moreover, the higher temperatures necessary for drying the TPOMW may also alter its composition reducing the oil quality.

Different technologies have been proposed for TPOMW treatment based on evaporation ponds, thermal concentration, phenolic components extraction (Fernández-Bolaños et al., 2002; Boucid et al., 2005) and its application to agricultural soils to enhance the absorption of herbicides and insecticides (Albarrán et al., 2004; Cox et al., 2004; Cabrera et al., 2009). Composting as a method for preparing organic fertilizers and amendments is economically and ecologically sound and may well represent an acceptable solution for the disposal of TPOMW (Alburquerque et al., 2007). The physicochemical characteristics of TPOMW are adequate to be used in agriculture as organic amendment, such as a slightly acidic pH (4.8–5.6), an intermediate level of N, mainly organic, and also a significant quantity of other plant nutrients such as K, P, Ca, Mg and Fe (Alburquerque et al., 2004). An important feature of olive mill wastes is the high K concentration, since

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this element is absorbed in large amounts by olive trees and is the most abundant nutrient in olive fruits (Fernández-Hernández et al., 2010a). Another important advantage of this waste is the high organic matter concentration which is mainly composed by lignin, hemicellulose and cellulose and that it is free of heavy metals and other potential pollutants.

The agronomic value of TPOMW has been evaluated either as an organic fertilizer or an organic amendment in many crops: ryegrass (Alburquerque et al., 2007), tomatoes (Walker and Bernal, 2008; Killi and Kavdir, 2013), Swiss chard (Paredes et al., 2005) and olive grove (Altieri and Esposito, 2008; López-Piñeiro et al., 2011; Garcia-Ruiz et al., 2013; Nasini et al., 2013; Toscano et al., 2013). Most of these studies have been performed on short cycle crops since they are easy to grow and provide a quick response to different treatments. The mineral concentration of plant parts, in particular leaves, is used to identify nutrient deficiencies, excesses, or imbalances in a crop. The nutritional status of fruit trees affects fruit quality as well as crop yield (Caser et al., 2004). In the case of olive trees, many factors may affect the quality of the fruit and the olive oil, including cultural practices such as fertilization (Fernández-Escobar et al., 2006), the irrigation management and agronomic practices adopted in the field (Patumi et al., 1999). For instance, Jordaó et al. (1990) observed that the fat content is correlated to the concentration of nitrogen, phosphorus and potassium in fruits. Finally, the concentration of linoleic acid in olive oil is correlated to the levels of magnesium, manganese, zinc, phosphorus, boron, copper in the leaves (Jordaó et al., 1990). These results reinforce the need for the adequate nutrition of olive trees. Leaf-nutrient analysis is the most common evaluation technique used for diagnosing tree nutritional status, and it represents an important tool for determining future fertilization requirements (Fernández-Escobar, 2004).

The aim of this paper is to study the effect of the application of TPOMW composts, prepared with different agro-industrial wastes, on an olive grove of Jaén (Spain) by monitoring the changes in soil properties, crop yield and nutritional status and also on the quality of the fruit and olive oil after 6 years of agronomic application of compost.

2. Material and methods

2.1. Compost production

Four different composting mixtures were prepared by mixing either dried two-phase olive mill waste (D-TPOMW), stored in an evaporation pond for one year, or fresh TPOMW with different organic materials used as bulking agents and N-sources, such as olive tree pruning, sheep manure, horse manure and urea. All these agro-industrial by-products are produced locally either in the olive farm or in the surrounding area. The efficient recycling of these wastes contributes to a sustainable agricultural production system in the olive farm. These composts were prepared during six consecutive years using the same dry weight proportions of the following starting mixtures (to achieve an initial *C*/*N* of 25):

– TS: TPOMW (33%) + Sheep manure (67%).
– DTS: D-TPOMW (50%) + Sheep manure (50%).
– THU: TPOMW (33%) + Horse manure (67%) + Urea (1.4 kg tonne^{-1}).
– TOS: TPOMW (20%) + Olive tree pruning (20%) + Sheep manure (60%).

A full description of the raw materials and the composting process was reported in Serramiá et al. (2010). Briefly, composts were prepared in a pilot-plant using the turning-pile system in trapezoidal piles (5 m length, 2 m width on the base and 1 m height) containing approximately 6000 kg each pile. The piles were turned every two weeks during the bio-oxidative phase (approximately 16–20 weeks, from June to October) and the mixtures were then allowed to mature over a period of two months. Temperature and moisture were used as monitoring parameters to follow the composting progress. Water was added during turning to keep the moisture levels in the range between 40% and 60%. The main characteristics of the different composts are given in Table 1, which summarizes the average nutritional composition of the four compost formulations over the 6 years.

2.2. Experimental design

A six-year field experiment was conducted on a representative olive grove (*Olea europaea* L.) of the 'Picual' cultivar in the experimental farm of IFAPA Centro 'Venta del Llano' at Mengíbar, Spain, North latitude 37°56′32″, West longitude, 03°47′10″, at a mean altitude of 292 m above sea level. The region has a Mediterranean climate with an average rainfall of 445 mm year^{-1} and average annual temperature of 17.7 °C, during the years of the research work. The olive grove has a planting density of 70 trees ha^{-1} (12 × 12 m). Each treatment comprised three replicates, completely randomized, with two 'Picual' olive trees per plot. Each treatment is separated by a buffer lane. The main characteristics of the olive grove soil (0–20 cm depth) at the beginning of the experiment were as follows: sand: 17.2%; clay: 35.0%; silt: 45.8%; carbonates: 39.5%; active lime: 13.3%; pH: 8.4; salinity: 0.3 dS m^{-1}; organic matter: 11 g kg^{-1}; Total N: 1.0 g kg^{-1}; Available-P: 8.9 mg kg^{-1}; Available-K: 528 mg kg^{-1}. This is a representative calcareous soil from typical olive grove in Southern Spain characterized by a balanced nutritional composition and adequate conditions for olive growth (Aguilar et al., 1987).

A comparison of olive oil production and nutritional status was made among treatments amended with compost mixtures (TS, DTS, THU and TOS) and compared to the control (Inorganic fertilizer, IF) by determining the mineral macro- and micronutrients

Table 1
Composition of the composts used in the farm experiment. Results are expressed on dry matter as mean ± standard error of 6 years (*n* = 3).

Composts				
Parameter (unit)	TS[a]	DTS[b]	THU[c]	TOS[d]
Moisture (%)	12.6 ± 1.6	10.8 ± 1.4	12.4 ± 0.8	13.7 ± 2.1
pH	8.7 ± 0.2	9.1 ± 0.1	8.3 ± 0.4	8.9 ± 0.4
EC[e] (ds m^{-1})	5.3 ± 0.3	4.1 ± 0.4	4.6 ± 0.3	5.7 ± 0.8
OM[f] (g kg^{-1})	427 ± 61	403 ± 80	396 ± 58	521 ± 51
TOC[g] (g kg^{-1})	244 ± 27	223 ± 22	233 ± 36	279 ± 18
Polyphenols (%)	0.19 ± 0.03	0.13 ± 0.01	0.05 ± 0.01	0.16 ± 0.03
IG[h] (%)	82 ± 3	82 ± 4	84 ± 3	92 ± 1
C/N	15.6 ± 1.4	16.1 ± 3.3	17.8 ± 0.8	19.2 ± 3.5
Total N (%)	1.73 ± 0.15	1.63 ± 0.14	1.47 ± 0.14	1.60 ± 0.21
P (%)	0.40 ± 0.02	0.30 ± 0.07	0.33 ± 0.06	0.40 ± 0.06
K (%)	2.70 ± 0.57	2.43 ± 0.14	1.83 ± 0.07	3.37 ± 0.07
Ca (%)	14.1 ± 1.4	14.2 ± 2.8	13.2 ± 2.4	12.0 ± 1.4
Mg (%)	1.20 ± 0.21	1.00 ± 0.21	1.07 ± 0.12	1.37 ± 0.19
Na (%)	1.00 ± 0.14	0.90 ± 0.07	1.03 ± 0.18	1.03 ± 0.14
Fe (g kg^{-1})	3.13 ± 0.64	3.87 ± 0.92	2.87 ± 0.07	2.90 ± 0.35
Cu (mg kg^{-1})	120 ± 7	104 ± 10	37 ± 2	88 ± 4
Zn (mg kg^{-1})	57 ± 2	53 ± 3	44 ± 9	58 ± 6
Mn (mg kg^{-1})	158 ± 30	143 ± 27	146 ± 27	141 ± 21

[a] TS (Fresh TPOMW + Sheep manure).
[b] DTS (Dry TPOMW + Sheep manure).
[c] THU (Fresh TPOMW + Horse manure + urea).
[d] TOS (Fresh TPOMW + Sheep manure + Olive tree pruning).
[e] EC (Electric Conductivity).
[f] OM (organic matter).
[g] TOC (Total organic Carbon).
[h] IG (Index Germination).