INCREASING SOIL FERTILITY AFTER APPLICATION OF COMPOSTED OLIVE MILL POMACE IN ORGANIC OLIVE OIL GROVES

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1 INTRODUCTION

Between 2 to 3 million tonnes of olive mill pomace are produce annually during the two-phase extraction procedure in the Andalusia olive oil industry, in just 3-4 months. Most (~ 80 %) of the nitrogen (N), phosphorus (P) and potassium (K) harvested with the olives appears in the olive mill pomace during its transformation to olive oil. Olive mill pomace is characterised by its high organic matter (typically > 40%) and carbon (> 20%) content. Until recently, olive mill pomace was considered as an environmentally harmful residue. The valorisation of olive mill pomace fulfils some of the objectives of sustainable agricultural systems. Olive mill pomace can be used as a potential source of nutrients and might provide organic matter and carbon, increasing the soil fertility and thus long term sustainability. However, because of the high polyphenol and biological oxygen demand levels and its very high water content, its composting is highly recommended before any further use in agriculture. However, before recommendations can be made on doses, frequency and timing of application of the composted olive mill pomace (COMP), short, medium and long term changes in soil fertility after soil application of COMP should be assessed.

The objective of this investigation was to evaluate the improvements in soil fertility and soil C sequestration in olive oil farming which apply COMP. In addition, we have also assessed the effects of the number of years since COMP has been applied on soil fertility indicators.

2 MATERIALS AND METHODS

Five organic olive oil groves which had received COMP (+COMP) for different numbers of years and 5 nearby and comparable but without COMP (-COMP) were selected: Olvera (O) during the last 3 years, Reja (R) and Villaviciosa (V) during the last 4 years, Tobazo (T) during the last 9 years and Andujar (A) the last 16 years. 5 soil samples (composed of four subsamples soil) were collected in April (2009).

Soil samples were analysed for pH in soil:water extract (1:10, w:v). Organic matter content was analysed by loss on ignition. The percentage of stable aggregates was determined by the method of Lax et al. (1994). The water holding capacity and particle size distribution were determined by the methods of Klute (1986) and Gee and Bauder (1986), respectively. Exchangeable Ca, Mg, K and Na, following Grant (1982), carbonate and labile phosphorus contents (Olsen and Sommers, 1982) were determined on air-dried samples. Cation exchange capacity was analysed according to Rhoades (1982). Total C and N contents were determined using a Leco CNH-932 analyser. Potential N mineralization (PNM) and the potential rate of soil ammonium oxidation were analysed according to Kandeler (1995). The mineralization and nitrification rate were determined by in situ bag technique during 1-2 months and the subsequent analyses of NO_3^- and NH_4^+ (Keeney & Nelson, 1982). Soil inversate, xilanase and celullase were analysed by Schinner and Von Mersi (1990) and acid phosphatase, dehydrogenase, protease, arilsulfatase and β-glucosidase according Tabatabai (1982). The geometric mean of the assayed enzyme activities (GM, hereafter) was calculated.

Differences between treatments were analysed by ANOVA, and the Fisher post hoc test. Principal Components Analysis (PCA) was applied with all variables analysed to obtain the ordination of cases in the 2 new axes.

3 RESULTS AND DISCUSSION

3.1 Physico-chemical and biological properties

Soil organic matter (SOM) was significantly higher in the +COMP olive farming (Table 1); however this was depended on the number of years that COMP had been applied. SOM was similar after 3 years but was 8.5 times higher after 16 years of COMP application. According to the higher SOM values, water holding capacity (WHC) and the percentage of soil stable aggregates (SA) were significantly improved in 4 out of the 5 olive groves. Therefore, the regular application of COMP might help to mitigate the relative high soil erosion of many olive groves and improve soil water conservation.

Soil organic carbon (SOC) and nitrogen (SN) were also significantly higher in the COMP olive farming (in 3 out of 5), especially in those that applied COMP for more than 7 years (Table 1). SOC and SN in the olive farming that applied COMP for 17 years were 8.5 and 14.8 times higher than the comparable farming without COMP. Theses results indicates that COMP nitrogen retention is high and application of COMP might be an adequate strategy to increase soil carbon sequestration in olive farming. The soil capacity to retain cations (CEC) was also significantly improved after the application of COMP (Table 1).

The rate of net nitrogen supply via mineralization and nitrification under field conditions were significantly higher in the +COMP-plots (Table 1). Moreover, differences between +COMP and –COMP farming were greater in relation to the number of years of COMP application. So, the regular application of COMP provides available nitrogen during COMP decomposition, at least at the long term.

Soil enzyme activity has been described as soil health/quality indicators (Pascual et al., 2000). Soil alkaline phosphatase, β-glucosidase, protease, invertase and dehydrogenase (date not shown) and a combine index, such as geometric mean (GM), were all significantly higher (in some cases even an order of magnitude higher) in olive farming which received COMP (Table 1), except at V. Thus, soil functional quality was greatly improved after COMP application.

TABLE 1 **Some properties of soil from olive oil farming with COMP (+COMP) and without COMP (-COMP). Data are the mean ± standard deviation (n=3). Different letter denote significant differences (*P*<0.05) between one plot and its comparable conventional.**

Site	**WHC** (%)	**SA** (%)	**SOM** (%)	**SN** (%)	**SOC** (%)	**CEC** meq $100g^{-1}$	**Soil net N mineralisation** (μg N $g^{-1}d^{-1}$)	**GM** (Relative values)
O (+COMP)	0.26±0.01[a]	51.9±2.0[a]	3.94±0.9 [a]	0.25±0.03[a]	2.3±0.55[a]	22.2±1.5[a]	0.39±0.11[a]	39.3±3.2[a]
O (-COMP)	0.22±0.01[b]	34.1±1.6[b]	3.45±0.8 [a]	0.28±0.02[a]	2.0±0.49 [a]	20.8±0.2[a]	0.31±0.19[a]	4.13±4.0[b]
R (+COMP)	0.22±0.01[a]	58.0±1.8[a]	8.34±3.6 [a]	0.29±0.03[a]	4.8±2.12[a]	25.3±4.7[a]	0.33±0.19 [a]	30.4±2.9[a]
R (-COMP)	0.21±0.02[a]	37.2±1.0[b]	3.96±1.1 [b]	0.23±0.01[b]	2.3±0.63[b]	18.6±0.3[b]	0.16±0.07[b]	2.35±2.3[b]
V (+COMP)	0.21±0.01[a]	38.4±1.4[a]	4.97±0.6[a]	0.12±0.01[a]	2.8 ±0.36[a]	12.8±1.9[a]	0.86±0..13[a]	13.4±3.6[a]
V (-COMP)	0.16±0.01[b]	32.1±3.1[b]	5.48±1.2[a]	0.13±0.01[a]	3.1±0.71[a]	11.7±0.4[a]	0.90±0.11[a]	14.9±2.0[a]
T (+COMP)	0.24±0.01[a]	56.8±0.2[a]	6.31±2.2[a]	0.25±0.08[a]	3.6±1.28[a]	21.1±4.2[a]	0.39±0.37[a]	22.6±7.2[a]
T (-COMP)	0.21±0.01[b]	22.7±0.7[b]	2.39±0.2 [b]	0.15±0.02[b]	1.3±0.35[b]	15.4±2.5[b]	0.02±0.12 [b]	15.2±0.6[b]
A (+COMP)	0.30±0.01[a]	24.0±1.1[a]	16.1±3.4[a]	0.74±0.32[a]	9.3 ±2.02[a]	23.3±8.5[a]	0.29±0.19[a]	22.9±6.9[a]
A (-COMP)	0.29±0.01[a]	23.7±1.6[a]	1.88±0.4 [b]	0.05±0.01[b]	1.1±0.24[b]	10.6±1.5[b]	-0.44±1.29[b]	16.4±3.1[b]

3.2 Principal components analyses

To summarize the information a principal component analysis was performed. The first axis (PC1) showed significant negative correlation with soil enzymes activities and long and medium terms stock of nutrient as total SN, SOM, PNM or CEC. Therefore, PC1 separates olive farming according to a soil fertility gradient. Figure 1 shows the scores of the each plot (+COMP and -COMP) along PC1 and PC2. Olive oil farms which applied COMP were situated in the negative range of the PC1 values (high fertility) whereas the –COMP plots in the positive range (low fertility plots). Figure 2 shows the difference in PC1 of each pair of olive oil farms, which differ in COMP. Clearly the application of COMP improved soil fertility, except for the V site. Moreover, these differences increased along the number of years since COMP has been added, except to V (Figure 2). The reasons of lack of differences at

V are unknown, and highlight the fact that the effect of COMP application on soil fertility depend on site (i.e. soil properties).

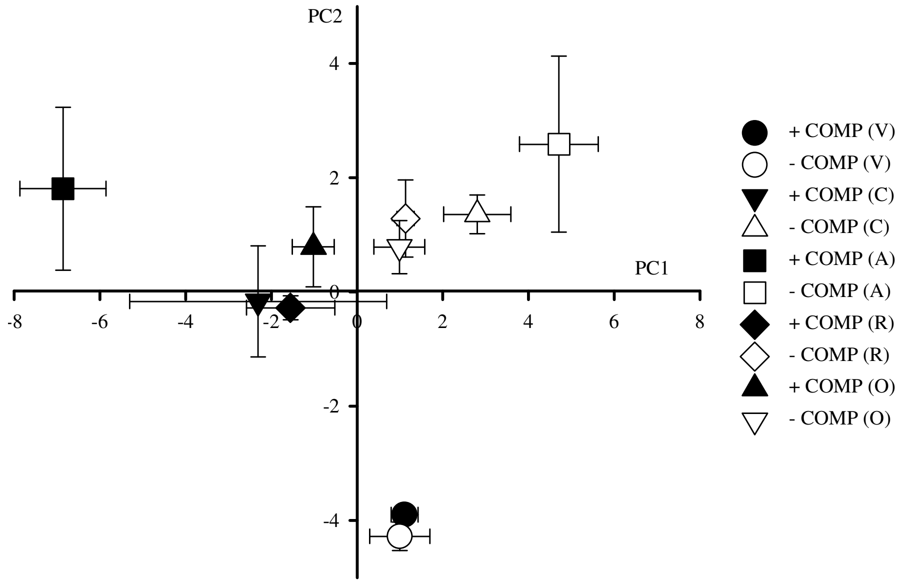

FIGURE 1 **Scores of the olive oil farming (+COMP and –COMP) samples on the PC1 and PC2.**

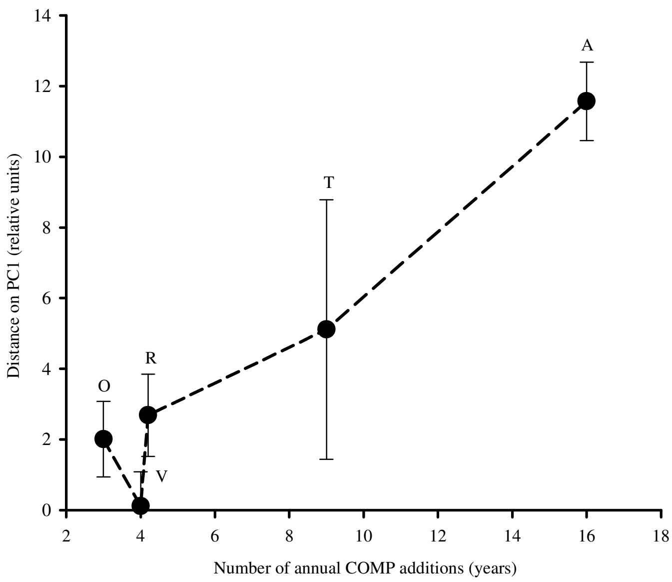

FIGURE 2 **Distance between each olive oil farm with COMP, and the comparable olive oil farm without COMP.**

4 CONCLUSIONS

The revalorization of olive mill pomace as an organic fertilizer after composting reduces the economic and environmental problems associated with the disposal of this byproduct of olive oil industry, which is annually produced in large amounts in Andalusia. The application of COMP as a fertilizer in olive groves improves the physical, chemical and biological soil properties, and provides organic matter and sequesters organic carbon into the soil. In addition, it provides available nitrogen (and phosphorus and potassium) reducing the requirement for chemical fertilisers. There was a clear tendency of soil fertility to increase after three years of regular COMP application, and therefore the benefits are achieved at the short term.

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