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Use of Composted Olive Waste as Soil Conditioner and its Effects on the Soil

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ABSTRACT

The protection of agro-ecosystems necessitates the use of soil management techniques targeted to fertility preservation. This study was aimed to assess the cumulative effect of mineral fertilization and of the incorporation of increasing doses of composted olive pomace on the sandy-loam soil. The trial involved a split-plot design with 3 replicates and was aimed at comparing 2 types of compost (in large plots), the untreated control (0), mineral fertilization (Min), the conditioner made from composted olive pomace at the rates of 15-30-45-60 mg ha^{-1} of dry matter and the integration of 30 mg ha^{-1} with ½ of the N rate used for the Min treatment. As compared to the non-conditioned soil, the spreading of 60 mg ha^{-1} leads to increase organic matter by 100%, total nitrogen by 1.29 g kg^{-1}, available phosphorus by 11.5 g kg^{-1}, exchangeable potassium by 251 mg kg^{-1}. Moreover, the land spreading with increasing doses of olive pomace seems to increase the structure stability index (+71% without pre-treatment and+30% with alcohol pre-treatment) favoring particle aggregation. This leads to improve pore distribution, which is extremely important for hot arid environments where soils have depleting organic matter levels so they are more and more de-structured. The application of composted olive pomace as fertilizer has been an effective alternative to mineral fertilization and a valuable tool to achieve a threefold objective: storing carbon in the soil, improving soil quality and reducing the environmental impacts associated with the disposal of organic materials.

Key words: Composted olive pomace, soil conditioner, mineral fertilization, soil fertility

INTRODUCTION

Olive farming plays an important role in the economy of Mediterranean countries and is part of their history and traditions; oil extraction, however, produces-within a short period of time (from October to February)-large amounts of wastes, which may have a strong impact on terrestrial and aquatic environments due to their high phyto-toxicity (Albiach *et al*., 2001; Altieri and Esposito, 2010).

Land spreading of olive pomace is allowed only in areas of low environmental vulnerability. Moreover, the short period of the year in which olive effluents are produced and the difficult access to agricultural land in winter make this practice quite complicated. Low cost and low impact alternative solutions would be required for transforming, possibly in situ, oil mill wastes into simple and effective soil conditioners (Altieri and Esposito, 2010).

Olive pomace composting is an effective option that would enable overcoming some problems related to the land spreading of untreated wastes, while making use of the organic matter contained (Casa *et al.*, 2001). The high purity of oil-mill wastes (free of heavy metals and toxic substances) ensures the quality and competitiveness of the compost made from the biological transformation of these residues (Roig *et al.*, 2006).

The protection of agro-ecosystems necessitates the use of soil management techniques targeted to fertility preservation. (Ventrella *et al.*, 2011). The re-use of agri-food wastes for soil conditioning constitutes an effective tool to combat desertification and improve soil fertility. Moreover, the subsequent fixation of organic carbon in soils contributes to reduce the CO_2 emissions associated with global warming.

In agro-ecosystems land spreading of compost is a strategy that would close the cycle of matter, by returning the organic matter to the soils impoverished by intensive farming. The compost-based conditioning influences the soil physic-chemical properties, by improving the structure, increasing the organic matter content, modifying the exchange complexes and nutrient availability and it has beneficial effects on the microbial load of the soil (Angers and Giroux, 1996; Piccolo, 1996; Spaccini *et al.*, 2001; Cavazza *et al.*, 2002; Saha *et al.*, 2007).

Intensive farming techniques have led, over the last decades, to a significant reduction of the organic matter content that in turn has resulted in loss of fertility and soil degradation processes. A possible solution to this problem would be the use of a carbon-rich conditioner, like the compost. Soil conditioning by compost contributes to environmental sustainability, for it reduces the amount of organic wastes sent to landfills, moderates the use of chemical fertilizers, improves soil quality and fertility and favors C sequestration. Actually, in modern agriculture the use of alternative organic matrices, like quality compost, is finding a growing interest for extensive field applications or to restore soils with poor or no organic matter content. Also, it is necessary to study the impact on soil quality to exploit its potential as soil conditioner and prevent its detrimental effects on the environment (Hachicha *et al.*, 2006; Canet *et al.*, 2008; Alfano *et al.*, 2009; Galvez *et al.*, 2012).

For getting further insight on the subject, a long-term research was undertaken at the Department of Agricultural and Environmental Science, University of Bari, with the aim of assessing the cumulative effects of increasing doses of composted olive pomace, used as conditioner and of mineral fertilization on the soil and on crop rotation. This note deals only with the effects on the soil.

MATERIALS AND METHODS

The study was conducted in the 2008-2010 period in the experimental field close to the Agricultural Faculty of the University of Bari (Italy), within a long-term trial aimed to assess the cumulative effect of mineral fertilization and of the incorporation of increasing doses of composted olive pomace on the soil and on succession cropping (sunflower-wheat-wheat), grown in 240 dm^3 containers, placed outdoor and filled with sandy-loam soil (Table 1). The trial involved a split-plot design with 3 replicates and was aimed at comparing 2 types of compost (in large plots), the untreated control (0), mineral fertilization (Min), the conditioner made from composted olive pomace at the rates of 15-30-45-60 mg ha^{-1} of dry matter (15, 30, 45 and 60, respectively) and the integration of 30 mg ha^{-1} with ½ of the N rate used for the Min treatment, in plots (single containers). Applied mineral fertilizers (N, P_2O_5 and K_2O) were equal to crop requirements, i.e., 150-100-100 kg ha^{-1} for sunflower and 120-100-100 kg ha^{-1} for wheat. The first compost (C), produced by the "Cooperativa Agricola Nuovo Cilento" from S. Mauro Cilento (SA), was obtained from the bio-oxidation and maturation of a mixture made up of virgin pitted pomace (72%), cereal straw (8.5%), sawdust and wood shavings (8.5%) and wool waste (11%). The second compost (R),

Table 1: Main properties of the soils being tested

Properties	Values
Chemical properties	
Total nitrogen (Kjeldahl method) (g kg^{-1})	0.91
Available phosphorus (Olsen method) (mg kg^{-1})	22.50
Exchangeable potassium ($BaCl_2$ method) (mg kg^{-1})	252.00
Organic matter (Walkley black method) (g 100 g^{-1})	1.60
Total limestone (g 100 g^{-1})	2.58
Active limestone (g 100 g^{-1})	1.40
pH	7.30
ECe (dS m^{-1})	0.42
ESP	0.80
CEC ($BaCl_2$ method) (meq 100 g^{-1} of dry soil)	20.16
Particle-size analysis	
Total sand $2>\varnothing>0.02$ mm (g 100 g^{-1})	60.49
Silt (%) $0.02>\varnothing>0.002$ mm (g 100 g^{-1})	20.02
Clay (%) $\varnothing<0.002$ mm (g 100 g^{-1})	19.49
Hydrologic properties	
Field capacity (field determ.) (g 100 g^{-1} of soil dry mass)	23.63
Wilting point (-1.5 Mpa) (g 100 g^{-1} of soil dry mass)	12.51
Bulk density (t m^{-3})	1.38

produced at the Agostinelli Farm, sited in Rutigliano (BA) within the Research Unit for the Cropping Systems of hot arid environments (Bari) of CRA, was obtained from the bio-oxidation and maturation of a mixture made up of pitted pomace (74%), green chopped material resulting from the pruning of ornamental and fruit trees available in the farm (21%), Pedian LRM (2.5%) and urea (2.5%). Pedian is a natural inoculator for compost produced by polysaccharides and other organic raw material to stimulate the activity of microorganisms in compost heaps and accelerate the decay of organic waste.

Once spread, the two composts were immediately ploughed in; two months after their application, soil surface refinement works started for the preparation of the seedbed of the renewal crop. The high-oleic sunflower cv PR64H61 HS was sown on 23 April 2008, whereas the two subsequent crops of durum wheat, cv Claudio in the first year and Simeto in the second year, respectively, were sown on 3 December 2008 and 27 November 2009. From the plantlet emergence to the end of the irrigation season, sunflower and wheat crops were irrigated whenever 30 and 50%, respectively, of the maximum available water were lost by evapotranspiration and the applied volume was calculated to restore field capacity in the whole soil mass contained in each pot. At the end of the cropping cycle of second-year wheat, mean soil samples were taken from each pot, along the 0-0.60 m profile, by 0.20 m steps and tested by the official methodologies (Violante, 2000) for the following parameters: Electrical conductivity (ECe) and pH of the saturation extract, organic matter, total nitrogen (N), available phosphorus (P), exchangeable potassium (K), structure stability and hydrologic constants. In addition, the Total Organic Carbon (Toc), Total Extracted Carbon (TEC) and Humified Carbon C(HA+FA) were also determined (Sequi *et al*., 1986). Based on the experimental data obtained, the following parameters were then calculated:

- Degree of humification = DH (%) = C(HA+FA)/TEC+100
- Humification rate = HR (%) = C(HA+FA)/TOC+100
- Extracted and non humified organic carbon = NH = TEC-C(HA+FA)
- Humification index = HI = NH/C(HA+FA)

Table 2: Changes in the pH, electrical conductivity of the saturation extract (ECe), organic matter (OM), total nitrogen, available phosphorus and exchangeable potassium of a soil conditioned with increasing doses of two types of composted olive pomace and supplied by mineral fertilization

Doses of comp. olive	pH	ECe ($dS\ m^{-1}$)	OM ($g\ 100\ g^{-1}$)	N ($g\ kg^{-1}$)	P ($mg\ kg^{-1}$)	K ($mgkg^{-1}$)
Olive pomace ($mg\ ha^{-1}$)						
0	7.30C	0.39E	1.62F	0.94F	17.84F	194.00F
15	7.53B	0.45D	2.30D	1.34D	22.00D	258.25E
30	7.85A	0.56C	2.72C	1.58C	24.09C	322.00D
45	7.89A	0.65B	3.04B	2.01B	26.81B	396.42B
60	7.93A	0.75A	3.24A	2.24A	29.32A	444.25A
30+½ N	7.86A	0.67B	2.67C	1.55C	24.05C	362.16C
Min. treat.	7.44B	0.49D	1.77E	1.09E	19.79E	255.66E
Compost						
R	7.69A	0.52B	2.46A	1.51A	23.39A	318.00A
C	7.67A	0.63A	2.56A	1.56A	23.44A	319.64A
Profile (m)						
0-0.20	7.66A	0.66A	2.78A	1.74A	26.01A	388.43A
0.20-0.40	7.69A	0.57B	2.52B	1.57B	23.76B	349.64B
0.40-0.60	7.70A	0.50C	2.20C	1.30C	20.46C	318.82C
Significantly						
Compost	ns	**	ns	ns	ns	ns
Doses	**	**	**	**	**	**
Profile	ns	**	**	**	**	**
Compost * doses	ns	**	**	**	*	**

For each effect considered, the values followed by the same letter are not significantly different, according to the SNK test at $p \leq 0.01$, NS: Non significant, * and **: Significant at 5 and 1% probability level, respectively

Data were then processed using the GLM procedure of the statistical analysis system (SAS, 2009), the analysis of variance (ANOVA) and the significance of differences between the mean values were assessed using the Student-Newman-Keuls (SNK) test. The most representative results are shown in Table 1 to 2 and represented in Fig. 1 to 3.

RESULTS AND DISCUSSION

Based on the analysis of the soil samples, taken just after the spreading-repeated for three years-of increasing doses of two types of composted olive pomace (R and C), after the harvest of second-year wheat, it results that these conditioners induce significant beneficial effects on the soil physicochemical properties, as compared to mineral-fertilization treatments. Composts showed to be most performing when applied at the highest rates. Significant compost type×rates interactions were often found.

pH and electrical conductivity (ECe) of the saturation extract: It may be asserted that the supply of increasing doses of composted olive pomace, whose pH is definitely sub-alkaline (pH 7.9 and 7.2, respectively for Rutigliano and Cilento composts) seems to induce moderate changes in the soil pH, presumably related to the high buffering capacity of the soil (Table 2).

The electrical conductivity of the saturation extract (ECe) that expresses the soil solution salinity, although remaining at an acceptably low level, increases from the soil amended with compost R (0.52 $dS\ m^{-1}$) to the soil conditioned with compost C (0.63 $dS\ m^{-1}$) and in any case with increasing rates and along the soil profile shifting from deeper to shallow layers (Table 2).

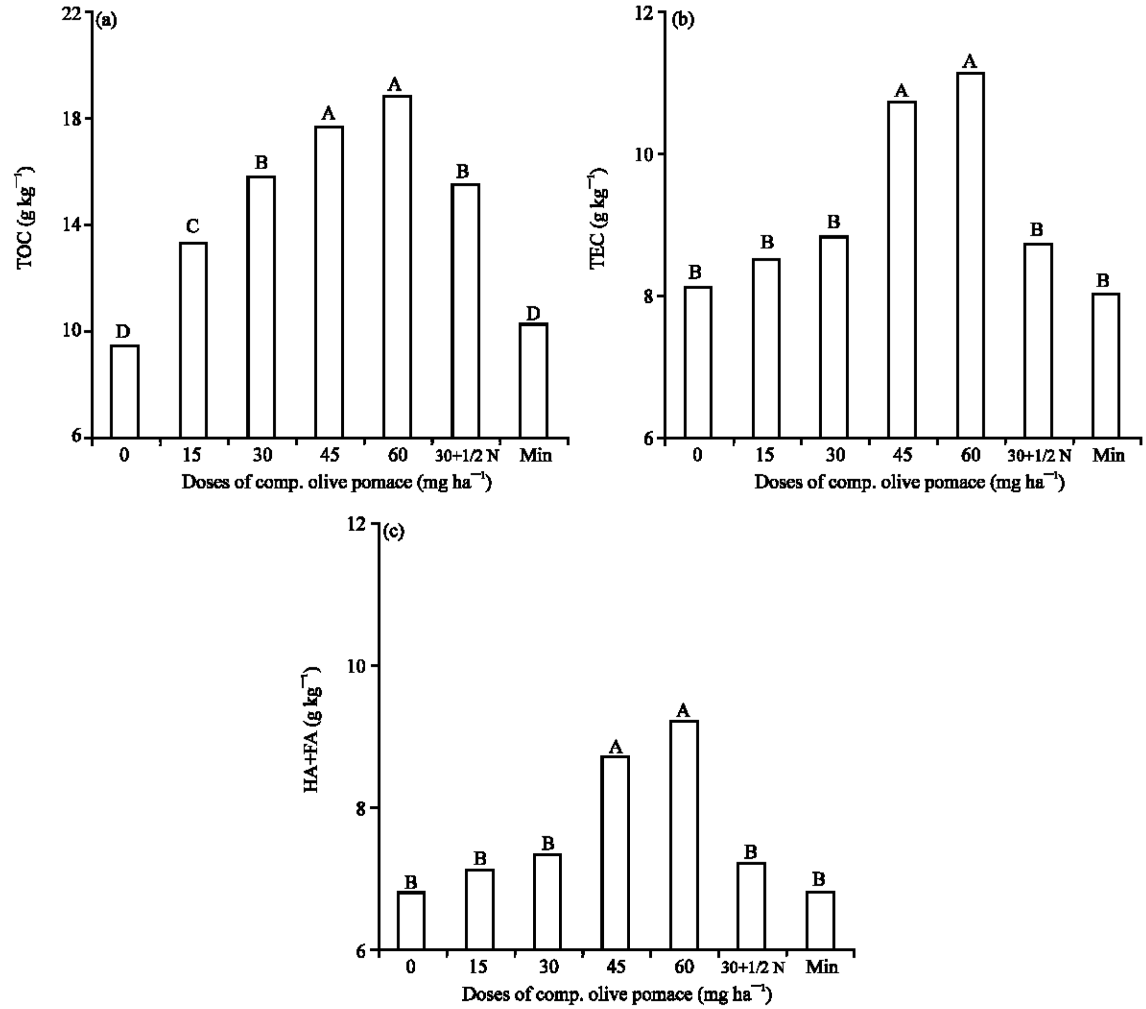

Fig. 1(a-c): Change in the Total Organic Carbon (TOC), Total Extractable Carbon (TEC) and Humified Carbon (HA+FA) of a soil conditioned with increasing doses of two types of composted olive pomace and supplied with mineral fertilization, For each effect considered, the values followed by the same letter are not significantly different, according to the SNK test at $p \leq 0.01$

Organic matter and total nitrogen: After land spreading of composted olive pomace, applied for three years, a positive significant difference was observed, both in terms of Organic Matter (OM) storage and total nitrogen content, which has basically reflected the organic matter dynamics. The higher value of both parameters is correlated to the rate of ploughed in composted olive pomace. Shifting from the control (0 mg ha^{-1} of compost) to the soil spread with 60 mg ha^{-1} of compost, the OM increased on average from 1.62 to 3.24 g 100 g^{-1} and total nitrogen raised from 0.94 to 2.24 g kg^{-1}, in agreement with Bonari *et al.* (2001) (Table 2).

For both parameters a significant type of composted olive pomace×rate interaction was found. In particular, while for the soil amended with compost C, the highest organic matter content (3.22 g 100 g^{-1}) was reached at the highest compost rate (60 mg ha^{-1}), for the soil conditioned with compost R the supply of 45 mg ha^{-1} of composted olive pomace was sufficient to achieve the

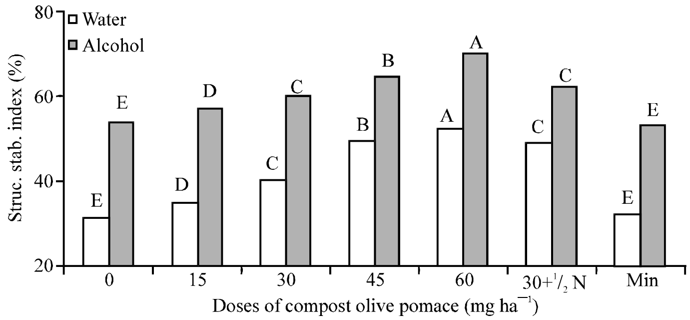

Fig. 2: Variation of the structure stability index in the soil conditioned by increasing amounts of two types of composted olive pomace and supplied with mineral fertilization. For each effect considered, the values followed by the same letter are not significantly different, according to the SNK test at $p \le 0.01$

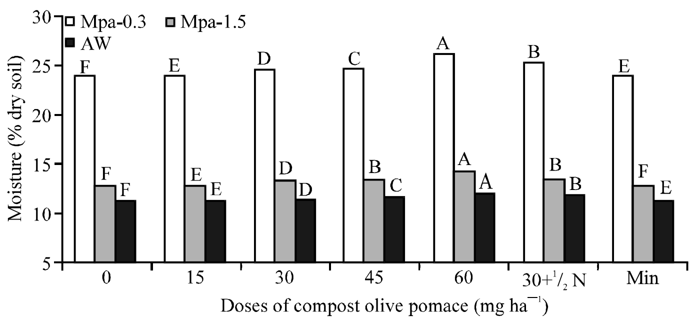

Fig. 3: Variation of percent moisture of dry soil at field capacity and at wilting point, available water in the soil conditioned with increasing doses of two types of composted olive pomace and supplied with mineral fertilization, Mpa: Mega pascal, AW: Available water, For each effect considered, the values followed by the same letter are not significantly different, according to the SNK test at $p \le 0.01$

maximum organic matter and nitrogen content. In the soil conditioned only with mineral fertilization (1.77 g 100 g^{-1}) the organic matter content was very low and did not differ greatly from the control (Table 2).

In any case, along the soil profile the organic matter content decreased from the shallow (0-0.20 m) to the intermediate (0.20-0.40 m) and deeper layers (0.40-0.60 m) (Table 2).

The highest values of the Total Organic Carbon (TOC), extractable carbon (TEC) and humified carbon (HA+FA) equal, respectively to 18.2, 10.9 and 8.9 g kg^{-1}, were observed in the treatments conditioned with the highest compost rates (45 and 60 mg ha^{-1}) (Fig. 1). No significant differences were found between the two types of compost or in the compost type×rate interaction. No notable differences were observed in terms of extractable and humified carbon (Fig. 1) even between the soil added with mineral fertilization, the control and the soil amended with low compost rates. Moreover, in the plots conditioned with the highest compost rates a slight increase of the humified organic component was observed maybe because the soil microbial activity, which accelerated humification processes, was favored by the organic supply, in agreement with Brunetti *et al.* (2005). The calculated parameters of the organic matter humification (degree of humification, humification rate, index of humification), confirm the previous result, pointing out that the soil conditioned only with mineral fertilization showed the lowest values, which did not differ from the control.

Available phosphorus and exchangeable potassium: It may be stated that as far as the fertilizer is concerned, the land spreading of increasing doses of two types of composted olive pomace induced positive effects on phosphorus and potassium. For both nutrients, an increasing trend was recorded as the application rate of the conditioner increased. In particular, shifting from the control (0 mg $ha^{-1}$of composted olive pomace) to the soil supplied with the highest compost rate (60 mg ha^{-1}) the available phosphorus increased from 17.8 to 29.32 mg kg^{-1}, whereas the exchangeable potassium raised from 194.00 to 444.25 mg kg^{-1} (Table 2). Only for available phosphorus no significant differences were observed between the two highest rates (45 and 60 mg ha^{-1}) of compost C. A significant type of compost×rate interaction was found. Therefore, the modifications induced by composted olive pomace on some soil chemical properties, as compared to the initial conditions, are shown to be generally beneficial and significant, for they increased total N, available P and exchangeable K associated with the compost rate, without jeopardizing the soil original physic-chemical properties.

Structure stability and hydrologic constants: The organic matter stored in the soil as a result of the supply of increasing doses of composted olive pomace has contributed to the formation and subsequent stabilization of aggregates against the weathering action of water. The soil structure stability values measured on 1-2 mm aggregates by water sieving with or without pre-treatment in alcohol Henin and Monnier (1956), have shown on average a progressive increase of the aggregate structure stability index along the mean soil profile, as the application rate of composted olive pomace increased on average no statistically significant differences have been found between the two types of compost. Structure stability indices increased from the non-conditioned soil to the soil spread with the highest compost rate compared (60 mg ha^{-1}), respectively from 31.1 to 52.3% without pre-treatment and from 54.0 to 70.1% with alcohol-pretreatment (Fig. 2). No notable differences were observed in terms of structure stability indices between the non-conditioned soil and the soil supplied with mineral fertilization, although they were kept at very low levels.

For the hydrologic constants as well, no notable differences were found between the two types of compost. Shifting from the soil treatment without any composted olive pomace to the soil incorporated with 60 mg ha^{-1} of compost, the dry soil percent moisture at field capacity (-0.3 Mpa) and at the wilting point (-15 Mpa) varied, respectively from 23.7 to 26.1% and from 12.5 to 14.2%, whereas the available moisture increased from 11.2 to 11.9% (Fig. 3). There is a wide set of experimental cases confirming that the application of organic matter to the soil improves its water retention at field capacity and at the wilting point (Carter and Stewart, 1996; Haynes and Naidu, 1998). The improved water retention capacity might be due to the increase in soil micro-porosity that could have favored a greater water holding capacity and an increase in water conductivity. (Loveland and Webb, 2003).

CONCLUSION

After a three-year research aimed to assess the temporal effects produced on the soil (cultivated with three crops in succession: sunflower in the first year, wheat cv Claudio in the second year and wheat cv Simeto in the third year) by the application of increasing doses of two types of composted olive pomace, mineral fertilization only and compost integrated with nitrogen fertilization, the following conclusions may be drawn.

Both composted olive pomaces, used as conditioners even at high application rates (45-60 mg ha^{-1}) have not produced any negative effect on the soil pH and on the electrical conductivity of the saturation extract.

Soil conditioning using composted olive pomace, a wood cellulose organic material produced from olive oil industry, favors the general increase in fertility through the years, improves the soil structure and hydrologic constants. As compared to the non-conditioned soil (control) the spreading of 60 mg ha^{-1} leads to increase organic matter by 100%, total nitrogen by 1.29 g kg^{-1}, available phosphorus by 11.5 g kg^{-1}, exchangeable potassium by 251 mg kg^{-1}. Moreover, the land spreading with increasing doses of olive pomace seems to increase the structure stability index (+71% without pre-treatment and +30% with alcohol pre-treatment) favoring particle aggregation. This leads to improve pore distribution, which is extremely important for hot arid environments where soils have depleting organic matter levels so they are more and more de-structured. Even the moisture contents at field capacity and at the wilting point increased when applying increasing doses of compost, thus showing a rising trend of the available moisture of the conditioned soil (+6.6%), as compared to the control and to the soil supplied with mineral fertilization. Hence, soil conditioning with the compost derived from olive mill by-products and farm wastes produced and applied in-situ, can be a good agricultural practice to improve soil fertility and quality, by increasing nutrient supply and improving their cycles. At the same time, composting can be a reliable and sustainable means to reuse those by-products that are not easily disposable, thus preventing their dangerous impact on the environment.

In conclusion, the application of composted olive pomace as fertilizer has been an effective alternative to mineral fertilization and a valuable tool to achieve a threefold objective: Storing carbon in the soil, improving soil quality and reducing the environmental impacts associated with the disposal of organic materials.

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