*J. Agr. Sci. Tech. (2013) Vol. 15: 627-638*

# Composted Olive Mill By-products: Compost Characterization and Application on Olive Orchards

P. Toscano[1], T. Casacchia[1], M. Diacono[2*], and F. Montemurro[3]

ABSTRACT

**Olive mill by-products could be composted and applied to olive orchard soils. These practices solve the problem of these wastes disposal and reduce the need for chemical fertilizers. Therefore, the aims of this research were: (i) proposing 'on-farm' composting process of different olive mill waste mixtures; (ii) investigating the chemical, physical, and microbiological characteristics of produced composts; (iii) evaluating the agronomical performance of the composts. Two on-farm composting trials were carried out in Southern Italy by using "two-phase" and "three-phase" olive mill wastes. The obtained composts were analyzed for their main characteristics and were spread in two different olive orchards (Nocellara and Leccino). At the end of field trial, soil properties, olive tree yield, and oil production were determined. The results highlighted that both composts reached a chemical composition in line with the thresholds established by the Italian fertilizers legislation for "green wastes compost". When the two compost piles became stable and mature, their microbial properties reached similar values. Also, the results suggested the efficiency of the composting process and good hygienic conditions of the matrices. Soil application of composted olive mill by-products increased olive yields on average by 9% compared to the untreated soils. Both olive orchards showed good results in productive parameters. In particular, oil ha$^{-1}$ increased by 166.4 and 179.9 kg in treated olive orchards, compared with untreated soils. However, more experimental data might be needed to confirm the effects of compost application in the long time and on different olive orchard soils.**

**Keywords:** Microbial cultures, Olive-oil industrial sector, Olive trees yield, Olive waste composting, Soil fertility.



## INTRODUCTION

Soil is a non-renewable resource and it is an essential component of the biosphere. It is characterized by potentially rapid degradation rates, but, slow formation and regeneration processes (Van-Camp *et al*., 2004). In the Euro-Mediterranean region, the main ecological conditions, such as aridity, have generated sensitivity to land erosion and deterioration of soil structure. In addition, according to Lal (2008), the transition from traditional methods to intensive-mechanized agriculture systems, indiscriminate use of agro-chemicals and, also, reducing soil organic matter content have contributed to soil losses.

Organic matter supports soil fertility, which is the capacity of soil to provide physical, chemical, and biological needs for plants growth (Abbott and Murphy, 2007). Therefore, there is a need to encourage practices that return organic materials to the

[1] Consiglio per la ricerca e la sperimentazione in agricoltura – (Research Centre for Olive Growing and Olive Product Industry), Rende, Cosenza, Italy.
[2] Consiglio per la ricerca e la sperimentazione in agricoltura – (Research Unit for Cropping Systems in Dry Environments), Bari, Italy.
[*] Corresponding author; e-mail: mariangela.diacono@inwind.it
[3] Consiglio per la ricerca e la sperimentazione in agricoltura – (Research Unit for the Study of Cropping Systems), Metaponto (MT), Italy.

soil, for maintaining or improving soil fertility as well as crop yields and quality (Lal, 2006; Komatsuzaki and Ohta, 2007).

Land spreading of a wide range of organic-rich agro-industrial effluents can be a sustainable and cost-effective recycling of nutrients and organic matter to soil, and could contribute to close the natural ecological cycles (Montemurro and Maiorana, 2008; Maftoun and Moshiri, 2008). In particular, in many Mediterranean countries the olive oil industrial sector generates each year a great amount of organic by-products during a short period (November–February) (Roig *et al*., 2006; Montemurro *et al*., 2011a; Tortosa *et al*., 2012).

The three-phase continuous centrifugation is the most common olive oil extraction process in all Mediterranean countries (Roig *et al*., 2006). It produces three "phases", i.e. olive oil, pulp (about 50% moisture), and olive mill wastewater (Saadi *et al*., 2007). Moreover, a two-phase system has been introduced in modern mills, which produces olive oil and a semi-solid pomace with about 60–70% of moisture (Saviozzi *et al*., 2001). Different researches (Montemurro *et al*., 2004; Montemurro *et al*. 2011b) indicated that these organic materials, obtained by olive oil mills, could be spread on land, thus solving the problem of disposal and reducing the need for chemical fertilizers. However, the use of organic wastes for fertilizing soils requires technologies for processing the raw materials, in order to prevent soil contamination by some toxic substances, such as phenolic compounds and lipid fraction (Van-Camp *et al*., 2004; Diacono *et al*., 2012). On this matter, several studies have demonstrated that composting the olive mill by-products with complementary residues (e.g. pruning wastes and olive leaves) allows to produce a low-cost humified and sanitized organic amendment or fertilizer for agricultural systems (Paredes *et al*., 2002; Baeta-Hall *et al*., 2005; Alfano *et al*., 2008; Alburquerque *et al*., 2009; García-Ruiz *et al*., 2012). The obtained compost is a product of aerobic exothermic biodegradation carried out by a microbial community, generally on a mixture of different organic substrates (Insam and de Bertoldi, 2007).

Despite a wide interest on recycling olive oil mill wastes (i.e. raw materials), characterization and application of their composting products to olive orchard soils in Mediterranean area has been generally neglected. Therefore, we tried to broaden current knowledge on recycling by-products of different olive oil extraction techniques.

The aims of this research were: (i) to propose "on-farm" composting process of different olive mill waste mixtures; (ii) to investigate the chemical, physical and microbiological differences of composts produced; (iii) to evaluate the agronomical efficiency of the composts both on soil characteristics and olive trees production potential.

## MATERIALS AND METHODS

### Compost Mixtures and Composting Set-up

Two 'on-farm' composting trials were simultaneously carried out in Southern Italy (Calabria Region, Cosenza, 39°28' N - 16°25' E), starting in 2007, by using "two-phase" (CM2 mixture) and "three-phase" (CM3 mixture) olive mill by-products, respectively. The specified residues proportions (on fresh weight basis) in the composting mixtures are reported in Table 1.

**Table 1.** Organic residues (tons) mixed in the composting piles (on fresh weight basis).

| Matrices | CM2[c] | CM3[d] |
|---|---|---|
| Semi-solid pomace [a] | 25 | -- |
| Pomace[b] | -- | 40 |
| Olive Wastewater | -- | 9 |
| Wheat straw | 5 | -- |
| Pruning wastes | 2.5 | 25 |
| Total biomass | 32.5 | 74 |

[a] Two-phase mill residue; [b] Three-phase mill residue; [c] Two-phase matrices mixture, [d] Three-phase matrices mixture.

The mixtures were composted in trapezoidal piles (1.5 m high with a base of 2–3 m). Both mixtures were placed outdoor on beaten soil and weekly turned by using a tractor with front loader, to ensure biomass oxygenation. The internal temperature of windrows was measured randomly at ten different points and depths, by using a digital thermometer (Delta OHM HD 2101.1). Moisture content in the piles was weekly determined by gravimetrical method and was adjusted by manual irrigations using well water. Both temperature and moisture were monitored throughout the initial composting period, which is generally characterized by heat release.

The C2 compost was obtained from CM2 mixture and the C3 from CM3, by conducting the composting process over about 5 and 8 months, respectively. The bio-oxidative phase was considered finished when the temperature was stable, close to the external value, and reheating did not occur. At the end of composting, the volume of the piles was nearly 50% lower than at the beginning of the process.

## Composts Sampling and Analytical Determinations

At the end of each composting process, five samples were randomly collected in different parts and depths of each pile. Then, the samples were combined and mixed to generate a composite sample of 5 kg for each compost. Each composite sample was hermetically sealed in plastic bag, stored in a cooled box at 4°C for transport, and analyzed within 48 hours for chemical, physical, and microbiological properties.

Chemical and physical characteristics of composts were evaluated by using the official analytical methodologies by Pagliai and Sequi (1997) and Violante and Sequi (2000). The moisture content (% on dry matter) was determined by drying three sub-samples of 0.2 kg per each compost at 105°C until the constant weight was reached. The pH was measured in 1:10 (w/v) water soluble extraction at 24±1°C and the used pH-meter was a HI 9321 (Hanna Instruments). Total Organic Carbon (TOC, g $kg^{-1}$) was measured by Walkley-Black method and total Nitrogen (N, g $kg^{-1}$) was determined by the Kjeldahl method. Organic matter (OM, g $kg^{-1}$) was estimated from TOC value (as average of two replications per sample) by using the conventional "Van Bemmelem factor" of 1.724, which is based on the assumption that the OM contains 58% carbon.

Phosphorus ($P_2O_5$, g $kg^{-1}$) was determined by Olsen method and potassium ($K_2O$, g $kg^{-1}$) by Milestone microwave digestion (on nitric acid), and both were assayed by an atomic absorption spectrophotometer (VARIAN CARY 50 BIO).

## Assessing Compost Microbiological Characteristics

The standard procedures (Picci and Nannipieri, 2002) utilized for assessing compost microbiological characteristics are described as follows: In order to investigate the composts microbiological features, 2 kg of both composts were sieved at 4 mm using metallic sterile sieve, to eliminate the roughest fractions, and then were dissolved in sterile deionized water. Working under hood, microbic cultures were obtained by using sterilized broths from each compost. The broths were produced by putting 1 kg of sieved compost in 3 liters of deionized water, shaking for 12 hours, filtering the solution through cheesecloth, and then sterilizing it at 121°C for 20 minutes. The broths obtained from each compost were utilized as diluents for scalar dilutions and growth substrates preparation.

The microbial community was assessed through plate-counter and expressed as log colony-forming units (CFU) $g^{-1}$ dry weight sample. Serial dilutions were prepared to obtain CFU counts in the range of 30-300 per plate, and 100 µl of the corresponding decimal dilutions were plated in triplicate with the following specific nutritive media:

Plate Count Agar (PCA; Oxoid Lim., Hampshire, UK) for Total Cultural Bacteria; nutritive media for Actinomycetes according to Sofo *et al*. (2010); *Pseudomonas* Agar Base medium (Oxoid) with the addition of *Pseudomonas* C-N supplement (Oxoid) for *Pseudomonas* spp.; Yeast Dextrose Agar (YPD: 1% yeast extract, 2% peptone, 2% glucose) added with 150 mg $kg^{-1}$ Chloramphenicol (Sigma-Aldrich, MO, USA), to inhibit bacteria growth, for Moulds and Yeasts; Violet Red Bile Agar (VRBA, Merck & Co. Inc., NJ, USA), for Total Coliforms and Slanetz - Bartley medium (Merck) for Fecal Coliforms. The isolation of *Bacillus* was carried out in PCA (Plate Count Agar) nutritive medium (Oxoid) supplemented with 0.20 g $K_2HPO_4$ and 0.05 g $KH_2PO_4$, and was performed in diluted suspensions placed in water bath at 80°C for 10 minutes, to kill thermolabile ´non-*Bacillus*´ microorganisms.

All plates were incubated at 25°C, with the exception of fecal coliforms which were incubated at 44°C, and colony counting took place after 36 hours of incubation.

### Site of Field Trial, Experimental Treatments, and Measurements

The field research was carried out in the experimental farms of S. Demetrio Corone at Corigliano (Cosenza, northern Calabria) during 2007-2008 and 2008-2009, hereafter referred to as 2008 and 2009, respectively. The climatic conditions were those of a typical Mediterranean environment, characterized by temperatures that can range from below 0°C in winter and early spring seasons, to above 40°C in summer, with rainfall unevenly distributed during the year, being concentrated mainly in the winter.

The two composts were spread in two olive (*Olea europaea* L.) orchards at mid-October both in 2008 and 2009, on plots of 6×4 m (with 15 trees). The soils were Vertisol classified as sandy clay loam by Soil Taxonomy-USDA (Soil Survey Staff, 1999), with on average 55% sand; 24% silt and 21% clay. The C2 compost was spread over a 15-year-old Nocellara messinese cv, and the C3 over a 20-year-old Leccino cv. Each compost was applied at a rate of 150 kg $tree^{-1}$ (60 t $ha^{-1}$) and buried with disk-harrow tillage.

At the end of experimental trial, three soil sub-samples were taken at 0-20 cm depth from each elementary plot, pooled in one sample for each replication and treatment, air dried, ground to pass a 2 mm sieve and then analyzed according to the methods previously reported for composts characterization.

Soil water-retention was obtained by using a Richards pressure chamber. The relation between soil moisture tension and soil moisture content (expressed as volume percentage) was determined. In order to delineate the moisture retention curve of each soil, the moisture content was measured by putting the moist soil sample at a succession of known pF values (pF range of 2.0 - 4.2; 0.1-15 bar of suction) till attainment of equilibrium, each time determining the amount of moisture that was retained.

The agronomical performance of composts application on soils was evaluated at harvest (in 2008 season for C2, and 2009 for C3), comparing the differences in OM level of treated (TS) and untreated (US) soils. Yield (kg $tree^{-1}$) of 15 treated (TT) vs. 15 untreated (UT) olive trees was measured. Also, drupe weight (g) on 150 fruits, pulp $pit^{-1}$, drupe oil content (%) on fresh dry matter (Infralyser) and total oil produced (kg $tree^{-1}$) were further determined.

### Statistical Analysis

The data obtained in each field experiment were subjected to analysis of variance (ANOVA), using the SAS software package (SAS Institute, 1990). The differences between the experimental treatments were compared using the Least Significant Difference (LSD) test at the $P \leq 0.05$ probability level. The arccosine

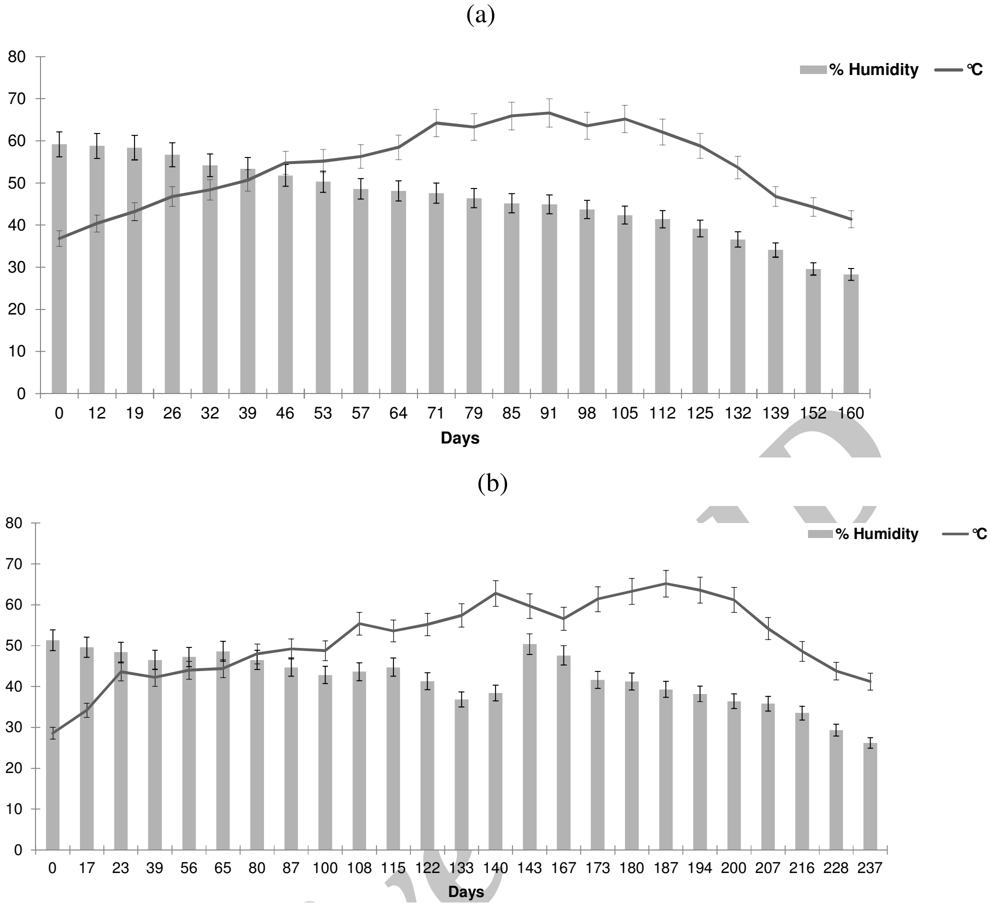


**Figure 1**. Temperature and moisture content of composting mixture (CM2) from two-phase olive mill by- products (a) and of composting mixture (CM3) from three-phase olive mill by products (b).

transformation of data was used to evaluate statistical differences among variables expressed as percentages. To compare the temperature, moisture, and soil water retention, the standard error at each sampling data was determined.

## RESULTS AND DISCUSSION

### Composting Results

Depending on the feedstock and its physical state, the composting temperature usually rises to 60–70°C during the so-called active composting time (ACT), which is the initial phase of degradation of labile organic components (Paredes *et al*., 2002). Temperature remains at this level with minor fluctuations for several days, and then gradually decreases to a constant state near the environmental level (Epstein, 1997).

The temperature profiles of each studied composting windrow are shown in Figure 1 (a-b). Although the behavior was variable according to the different composting mixtures, the results confirmed the phases described above, in agreement with the findings of other authors (Hachicha *et al*., 2008; Montemurro *et al*., 2009). Temperature fluctuations during composting processes may be due to both windrows moistening and turning. The comparison of the temperature profiles suggested that the composition and proportion of matrices in CM3 probably slowed up the compost maturation, as compared to CM2.

On the other hand, the moisture content gradually decreased throughout the composting processes (Figure 1, (a-b)), and reached values of about 30% at the end of the processes.

Table 2 shows the chemical and physical characteristics (on dry weight basis) of the obtained composts. The results highlighted how both C2 and C3 composts reached a composition in line with the thresholds established by the Italian fertilizers legislation for a "green wastes compost" (Decree n.75/2010). In particular, the TOC contents of the final composts were higher on average by 57% than the minimum value of 200 g $kg^{-1}$ established by the Italian legislation. This finding is particularly important for compost utilization as organic fertilizer in semiarid conditions, where the high mineralization rate could rapidly decrease the soil organic matter content. Moreover, these composts could constitute a valuable slow release nitrogen source (Diacono and Montemurro, 2011).

Compost maturity generally refers to the degree of decomposition of phytotoxic organic substances produced during the active composting stage (Wu *et al*., 2000). The commonly used C:N ratio cannot be considered as an absolute indicator of the degree of compost maturity, because of the large variation of the raw materials. However, the C:N values found in this research could be considered satisfying for ready-to-use composts, thus confirming previous researches (Montemurro *et al*., 2009; Montemurro *et al*., 2011b). In any case, the C:N ratio should be associated with some other chemical and microbiological parameters to establish compost maturity.

**Table 2.** Chemical and physical characteristics of the two composts at the end of biodegradation process (on dry weight basis).

| Parameters | C2 [a] | C3 [b] | Italian Law threshold values [c] |
|---|---|---|---|
| Moisture content (%) | 28.3 | 26.2 | < 50% |
| pH | 6.8 | 7.3 | 6-8.5 |
| C/N | 23.4 | 24.9 | < 50 |
| TOC[d] (g $kg^{-1}$) | 321 | 307 | > 20% |
| OM [e] (g $kg^{-1}$) | 552 | 528 | - |
| N (g $kg^{-1}$) | 13.7 | 12.3 | - |
| $P_2O_5$ (g $kg^{-1}$) | 7.2 | 6.8 | - |
| $K_2O$ (g $kg^{-1}$) | 12.2 | 10.8 | - |

[a] Compost obtained from two-phase matrices; [b]Compost obtained from three phase matrices; [c] Decree n.75/2010; [d] Total organic carbon, [e] Organic matter.

## Microbiological Characteristics of Obtained Composts

Compost stability may be correlated with compost maturity and it refers to the level of microbial activity, which can be determined by $O_2$ uptake rate, $CO_2$ production rate, or by the heat released (Benito *et al*., 2003). Also, Morel *et al.* (1985) suggested that compost maturity and stability may be assessed by total microorganisms count, monitoring biochemical parameters of microbial activity and analysis of biodegradable constituents.

Similar total cultural bacteria values (Figure 2) were achieved in the two compost cultures. This result demonstrated that, although the composition of the composting mixtures was different, when the two compost piles became stable and mature their microbial properties reached similar values, as observed by Tiquia (2005). This might be due to composts production at similar physical location, so that composting mixtures were exposed to similar microbial populations after peak heating (Alfano *et al*., 2008). The results also suggested that the bacterial growth was not inhibited by poliphenols, which are generally contained in the olive mill wastes as reported by Niaounakis and Halvadakis (2006).

*Pseudomonas* spp. and moulds and yeasts showed comparable values between composts, therefore, warranting the correct OM degradation (Zaitlin *et al*., 2004).

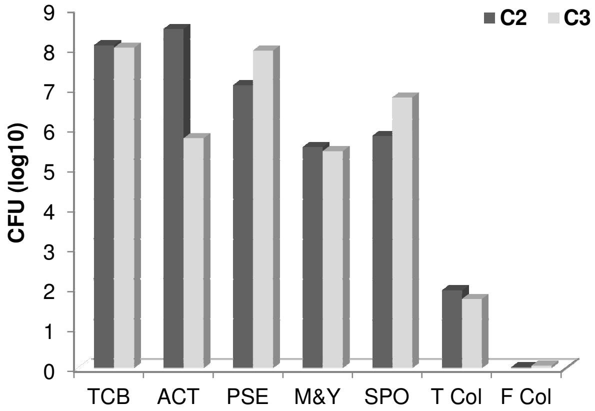


**Figure 2.** Colony forming units (CFU) counts (in two-phase (C2) and three-phase (C3) olive mill by-product composts) for: Total Cultural Bacteria (TCB); Actinomycetes (Act); *Pseudomonas* spp (Pse); Moulds and Yeasts (M and Y); Sporigen Bacteria (Spo); Total Coliforms (T Col) and, Fecal Coliforms (F Col).

On the other hand, values of Actinomycetes were higher by 47.6% in C2 than in C3, probably due to the wheat straw used in the CM2 mixture. Actinomycetes (e.g. *Streptomyces* spp) produce enzymes that help to degrade organic plant materials such as lignin (Ball *et al*., 1989).

Sporogenic bacteria in C3 were higher by 16.5% than in C2, probably because the mechanical aeration did not allow preventing anaerobic degradation processes in the highest total biomass of C3.

The high temperatures during the active phase of composting allowed the composts stabilization leading to very low values of total and fecal coliforms. As a consequence, through the presence of high temperature during biodegradation, the composts obtained showed good hygienic conditions, suggesting the efficiency of the composting process.

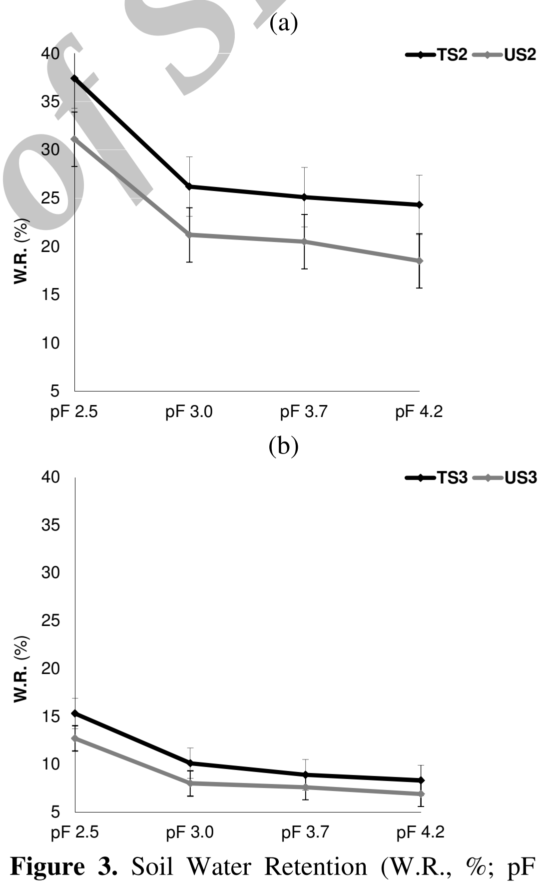


**Figure 3.** Soil Water Retention (W.R., %; pF 0.1-15 bar of suction) in soil untreated (US2) and amended (TS2) with compost from two-phase olive mill by-products **(a)**, and in soil untreated (US3) and amended (TS3) with compost from three-phase olive mill by-products **(b)**.

## Effects of Different Composts Application on Soil Properties and on Olive Tree Yield and Oil Production

In the first field trial, soil organic matter increased by up to 38.6% (from 8.8 to 12.2 g $kg^{-1}$ of content) in 0-20 cm soil depth after C2 application. Also, soil water retention (Figure 3a) enhanced on average by up to

24.4%. In the second trial, soil organic matter increased by up to 40.6% (from 10.1 to 14.2 g $kg^{-1}$ of content) in C3 amended soil. Similarly, positive results on organic matter content were found in Spain after repeated applications of composted olive pomace (García-Ruiz *et al*., 2012). These findings confirm the importance of olive pomace composts application as soil amendments in Mediterranean environment, which is characterized by high temperatures in the summer and, consequently, soil water deficit. This latter problem reduces the transport of nutrients from soil to plants. In these conditions, the functions of amender of a fertilizer could be more important, than the presence of nutrients, due to the high mineralization rate and the consequent depletion of organic matter in the soil. Therefore, the addition of composted agricultural or agro-industrial organic materials to soil is becoming a common agricultural practice, as indicated by several researches (Montemurro *et al*., 2005; Montemurro *et al*., 2007).

The soil water retention (Figure 3-b) increased on average by 21% in C3 treated soil. At larger water suctions (pF> 2.5), the water retention capacity may be related to interaction of aggregate soil fractions and TOC, improved by compost application, although sandy soil (as that of the study site) has many wide pores and loses much of its moisture. In any case, the results of this research are based on a short-time period, thus more experimental data might be needed to confirm effects of compost application on soil properties in the long time (Mohammadi *et al*., 2009; Diacono and Montemurro, 2011). However, our findings seem to show that an appropriate use of organic amendments can maintain a suitable soil structure, improving pore space suitable for water retention.

Even with no statistical difference, the application of C2 and C3 to soil contributed to an increase in olive yields of about 5.5 and 13%, respectively, compared with untreated soils (Table 3). This result confirms that the distribution of organic materials to soil shows its positive effect only after repeated applications (Montemurro *et al*., 2005; Montemurro and Maiorana, 2007), while in the first years only a low contribution on yielding performance can be recorded. Also, this finding was in accordance with the results of López-Piñeiro *et al*. (2011), even though these authors found an increase in olive yields only in the residual year of an eight-year application of de-oiled two-phase waste. Moreover, in this recent study, the greatest source of concern regarding such long-term use of raw material was the risk of soil salinization, which could be supposed almost non-existent after using composted wastes.

**Table 3.** Tree response to C2 (a) and C3 (b) composts application (trial years: 2008 and 2009, respectively).

(a)

| Parameters | TT | UT |
|---|---|---|
| Yield (kg $tree^{-1}$) | 24.9a | 23.6a |
| Fruit weight (g) | 6.67a | 5.78b |
| Pulp $pit^{-1}$ | 8.26a | 8.03a |
| % Oil in drupes (f. m.) | 16.8a | 16.1a |
| Oil (kg $tree^{-1}$) | 4.2a | 3.8a |

(b)

| Parameters | TT | UT |
|---|---|---|
| Yield (kg $tree^{-1}$) | 23.9a | 21.2a |
| Fruit weight (g) | 6.7a | 5.8b |
| Pulp $pit^{-1}$ | 7.7a | 7.4a |
| % Oil in drupes (fm) | 19.1a | 18.0a |
| Oil (kg $tree^{-1}$) | 3.69a | 3.26b |

TT= Treated olive trees; UT= Untreated olive trees, fm= Fresh matter.

An increase in productive parameters was obtained in our study on treated Nocellara olive trees vs. untreated trees (Table 3-a). In particular, the fruit weight was significantly higher by 15.4% in treated trees than in the untreated ones, and the drupes oil content showed the highest absolute value: a 10.5% increase of oil produced per tree was obtained, although not significantly different.

Also, treated Leccino olive trees (Table 3-b) showed good results in productive parameters. The fruit weight was significantly higher by 15.5% in treated trees than in untreated ones, and an increase was observed in drupes oil content, significantly improving the production of oil by 13.2%. These results corresponded to an increment of 166.4 and 179.9 kg of oil per ha (obtained as the product of the difference of oil kg per tree of treated trees with oil kg per tree of untreated trees, by the number of trees per ha), for C2 and C3 treated plots, respectively. In any case, further works would confirm the obtained results on different olive orchard soils.

## CONCLUSIONS

The objective of this research was the valorization of organic by-products of olive oil mill by using a low-input composting technique. The results obtained pointed out that this biodegradation process could be a feasible alternative for these olive mill wastes recycling, by solving the disposal problem of this specific agro-industrial sector. Composting could be also a way in co-recycling other agricultural residues produced in Mediterranean areas, such as wheat straw and olive pruning wastes. Furthermore, this kind of by-products treatment presents low cost, being in full accordance with the principles of energetic and economic sustainability in the use of resources.

At the used doses, both composts increased soil fertility, improved soil organic matter and water retention, and enhanced plant productivity from the first year of application.

The overall finding of this research was that the olive mill by-products composts, applied in olive orchards, can increase both the olive yields and the oil produced per ha, as compared with untreated soils. Mediterranean environment is characterized by high temperatures in the summer and, consequently, soil water deficit and high mineralization rate with depletion of soil organic matter. Our results confirmed the importance of olive pomace composts used as soil amendments in this environment.

## ACKNOWLEDGEMENTS

The authors wish to thank the owners of guest firms, Mr. Geraci and Mr. Priori, for availability of materials, machinery and structure in support to experimental activities. The work has been supported by Italian Ministry of Agriculture and Forestry Policies (CRA-OLI, RIOM project).

## REFERENCES


1. Abbott, L. K. and Murphy, D.V. 2007. What Is Soil Biological Fertility? In: "*Soil Biological Fertility: A Key to Sustainable Land Use in Agriculture*", (Eds.): Abbott L. K. and Murphy D. V.. Springer, XII, 268 PP.
2. Alburquerque, J. A., Gonzálvez, J., Tortosa, G., Ait Baddi, G. and Cegarra, J. 2009. Evaluation of "Aalperujo" Composting Based on Organic Matter Degradation, Humification, and Compost Quality. *Biodegradation,* **20**: 257–270.
3. Alfano, G., Belli, C., Lustrato, G. and Ranalli, G. 2008. Pile Composting of Two-phase Centrifuged Olive Husk Residues: Technical Solutions and Quality of Cured Compost. *Bioresour. Technol.,* **99**: 4694-4701.
4. Baeta-Hall, L., Sàagua, M. C., Bartolomeu, M. L., Anselmo, A. M. and Rosa, M. F. 2005. Biodegradation of Olive Husks in Composting Aerated Piles. *Bioresour. Technol.,* **96**: 69-78.
5. Ball, A. S., Betts, W. B. and McCarthy, A. J. 1989. Degradation of Lignin-related Compounds by Actinomycetes. *Appl. Environ. Microb,* **55(6)**: 1642-1644.
6. Benito, M., Masaguer, A., Moliner, A., Arrigo, N. and Palma, R. M. 2003. Chemical and Microbiological Parameters for the Characterization of the Stability and Maturity of Pruning Waste Compost. *Biol. Fert. Soils,* **37**: 184–189.
7. Decree n.75/2010. Riordino e revisione della disciplina in materia di fertilizzanti, a norma

dell'articolo 13 della legge 7 luglio 2009, n. 88. Supplemento ordinario alla "Gazzetta Ufficiale n. 121, 26 Maggio 2010- Serie Generale (In italian).

8. Diacono, M. and Montemurro, F. 2011. Long-term Effects of Organic Amendments on Soil Fertility: A Review. In: "*Sustainable Agriculture*", (Eds.): Lichtfouse E., Hamelin M., Navarrete M. and Debaeke P.. Springer Netherlands. Chapter 6, Vol. 2: 761-786.
9. Diacono, M., Ferri, D., Ciaccia, C., Tittarelli, F., Ceglie, F., Verrastro, V., Ventrella, D., Vitti, C. and Montemurro, F. 2012. Bioassays and Application of Olive Pomace Compost on Emmer: Effects on Yield and Soil Properties in Organic Farming. *Acta Agr. Scand B-S P*, **62:** 510-518.
10. Epstein, E. 1997. *The Science of Composting*. CRC Press, LLC, 487PP.
11. García-Ruiz, R., Ochoa, M. V., Hinojosa, M. B. and Gómez-Muñoz, B. 2012. Improved Soil Quality After 16 Years of Olive Mill Pomace Application in Olive Oil Groves. *Agron. Sustain. Dev.,* **32:** 803-810.
12. Hachicha, S., Sellami, F., Medhioub, K., Hachicha, R. and Ammar, E. 2008. Quality Assessment of Composts Prepared with Olive Mill Wastewater and Agricultural Wastes. *Waste Manage.,* **28**: 2593–2603.
13. Insam, H. and de Bertoldi, M. 2007. Microbiology of the Composting Process. In: "*Compost Science and Technology*". Waste Management Series 8, Elsevier Ltd.
14. Komatsuzaki, M. and Ohta, H. 2007. Soil Management Practices for Sustainable Agro-Ecosystems. *Sustain. Sci.,* **2**: 103-120.
15. Lal, R. 2006. Enhancing Crop Yields in the Developing Countries Through Restoration of the Soil Organic Carbon Pool in Agricultural Lands. *Land Degrad. Dev.,* **17**: 197-209.
16. Lal, R. 2008. Soils and Sustainable Agriculture: A Review. *Agron. Sustain. Dev.,* **28**: 57–64.
17. López-Piñeiro, A., Albarrán, A., Rato Nunes, J. M., Peña, D. and Cabrera, D. 2011. Long-term Impacts of De-oiled Two-phase Olive Mill Waste On Soil Chemical Properties, Enzyme Activities and Productivity in an Olive Grove. *Soil Till. Res.,* **114(2)**: 175-182.
18. Maftoun, M. and Moshiri, F. 2008. Growth, Mineral Nutrition and Selected Soil Properties of lowland Rice, as Affected by Soil Application of Organic Wastes And Phosphorus. *J. Agric. Sci. Technol.,* **10:** 481-492.
19. Mohammadi, S., Kalbasi, M. and Shariatmadari, H. 2009. Cumulative and Residual Effects of Organic Fertilizer Application on Selected Soil Properties, Water Soluble P, Olsen-P and P Sorption Index. *J. Agric. Sci. Technol*., **11:** 487-497.
20. Montemurro, F., Ferri, D. and Convertini, G. 2004. Mill Wastewater and Olive Pomace Compost as Amendments for Rye-grass. *Agronomie*, **24:** 481-486.
21. Montemurro, F., Maiorana, M., Convertini, G. and Ferri, D. 2007. Alternative Sugar Beet Production Using Shallow Tillage and Municipal Solid Waste Fertiliser. *Agron. Sustain. Dev*., **27:** 129-137.
22. Montemurro, F. and Maiorana, M. 2007. Nitrogen Utilization, Yield, Quality and Soil Properties in a Sugarbeet Crop Amended with Municipal Solid Waste Compost. *Compost Sci. Util*., **15:** 84-92.
23. Montemurro, F., Maiorana, M., Convertini, G. and Fornaro, F. 2005. Improvement of Soil Properties and Nitrogen Utilisation of Sunflower by Amending Municipal Solid Waste Compost. *Agron. Sustain. Dev*., **25:** 369-375.
24. Montemurro, F. and Maiorana, M. 2008. Organic Fertilization as Resource for a Sustainable Agriculture. In: "*Fertilizers: Properties, Applications and Effects*", (Eds.): Elsworth L.R. *et al*. Paley W.O. p. 123-146.
25. Montemurro, F., Diacono, M., Vitti, C. and Debiase, G. 2009. Biodegradation of Olive Husk Mixed with Other Agricultural Wastes. *Bioresour. Technol.,* **100**: 2969–2974.
26. Montemurro, F., Diacono, M., Vitti, C. and Ferri, D. 2011a. Potential Use of Olive Mill Wastewater as Amendment: Crops Yield and Soil Properties Assessment. *Commun. Soil Sci. Plan.,* **42**: 2594–2603.
27. Montemurro, F., Diacono, M., Vitti, C. and Ferri, D. 2011b. Short-term Agronomical Effects of Olive Oil Pomace Composts on *Pisum arvense* L. and *Trifolium subterraneum* L. and Impacts on Soil Properties. *Comm. Soil Sci. Plan*., **42:** 2256-2264.
28. Morel, J. L., Colin, F., Germon, J. C., Godin, P. and Juste, C. 1985. Methods for the Evaluation of the Maturity of Municipal

Refuse Compost. In: "*Composting of Agricultural and Other Wastes*", (Ed.): Gasser J. K. R.. Elsevier Applied Science, Barking, UK, P.56-72.

29. Niaounakis, M. and Halvadakis, C.P. 2006. *Olive Processing Waste Management: Literature Review and Patent Survey*. 2nd Edition, Waste Management Series 5, Elsevier, Amsterdam.
30. Pagliai, M. and Sequi, P. 1997. *Metodi di Analisi Fisica del Suolo.* (Ed.): Angeli, F., MIPA, Osservatorio Nazionale Pedologico e per la Qualità del Suolo, Milano, 400 PP.
31. Paredes, C., Bernal, M.P., Cegarra, J. and Roig, A. 2002. Biodegradation of Olive Mill Wastewater Sludge by its Co-composting with Agricultural Wastes. *Bioresour. Technol*., **85(1):** 1-8.
32. Picci, G. and Nannipieri, P. 2002. *Metodi di Analisi Microbiologica del Suolo*. (Ed.): Angeli, F.. Ministero delle Politiche Agricole e Forestali, Milano, 224 PP.
33. Roig, A., Cayuela, M. A., and Sànchez-Monedero, M. A. 2006. An Overview on Olive Mill Wastes and Their Valorization Methods. *Waste Manage.,* **26**: 960-969.
34. Saadi, I., Laor, Y., Raviv, M. and Medina, S. 2007. Land Spreading of Olive Mill Wastewater: Effects on Soil Microbial Activity and Potential Phytotoxicity. *Chemosphere,* **66:** 75–83.
35. SAS Institute. 1990. SAS/STAT Software. SAS Institute Inc. Cary, N.C., USA.
36. Saviozzi, A., Levi-Minzi, R., Cardelli, R., Biasci, A. and Riffaldi, R. 2001. Suitability of Moist Olive Pomace as Soil Amendment. *Water Air Soil Poll.,* **128**:13–22.
37. Sofo, A., Palese, A. M., Casacchia, T., Celano, G., Ricciuti, P., Curci, M., Crecchio, C. and Xiloyannis, C. 2010. Genetic, Functional, and Metabolic Responses of Soil Microbiota in a Sustainable Olive Orchard. *Soil Sci.,* **175(2)**: 81-88.
38. Soil Survey Staff. 1999. *Soil Taxonomy*. Agriculture Handbook 436, USDA.-NRCS. Washington DC.
39. Tiquia, S. M. 2005. Microbiological Parameters as Indicators of Compost Maturity. *J. Appl. Microbiol.,* **99**: 816–828.
40. Tortosa, G., Alburquerque, J. A., Ait-Baddi, G. and Cegarra, J. 2012. The Production of Commercial Organic Amendments and Fertilisers by Composting of Two-Phase Olive Mill Waste ("Alperujo"). *J. Clean Prod*., **26:** 48-55.
41. Van-Camp, L., Bujarrabal, B., Gentile, A.-R., Jones, R.J.A., Montanarella, L., Olazabal, C. and Selvaradjou, S. -K. 2004. *Reports of the Technical Working Groups Established under the Thematic Strategy for Soil Protection*. EUR 21319 EN/3, Office for Official Publications of the European Communities, Luxembourg, 872 PP.
42. Violante, P. and Sequi, P. 2000. *Metodi di Analisi Chimica del Suolo*. (Ed.): Angeli, F., MIPA, Osservatorio Nazionale Pedologico e per la Qualità del Suolo, Milano, 536 PP.
43. Wu, L., Ma, L. Q. and Martínez, G.A. 2000. Comparison of Methods for Evaluating Stability and Maturity of Biosolids compost. *J. Environ. Qual.,* **29**: 424–429.
44. Zaitlin, B., Turkington, K., Parkinson, D. and Clayton, C. 2004. Effects of Tillage and Inorganic Fertilizers on Culturable Soil Actinomycete Communities and inhibition of Fungi by Specific Actinomycetes. *Appl. Soil Ecol.,* **26(1)**: 53-62.

# کمپوست محصولات جانبی(ضایعات) کارخانه روغن گیری زیتون: ویژگیها و کار برد آن در باغهای زیتون

پ. توسکانو، ت. کاساسچیا، م. دیاکونو، و ف. مونتمورو

## چکیده

ازمحصولات جانبی کارخانه روغن گیری زیتون می توان کمپوست تهیه کرد و در باغ های زیتون به کار برد. این کار مشکل دفع ضایعات این کارخانه هارا حل میکند و نیز در کاهش نیاز به کود شیمیایی موثر است. براین اساس، هدف تحقیق حاضر عبارت بود از (۱) ارایه روش تهیه کمپوست از ضایعات روغن گیری زیتون در سطح مزرعه، (۲) بررسی ویژگی های شیمیایی، فیزیکی، و ریز زیست شناسی کمپوست تهیه شده، (۳) ارزیابی عملکرد زراعی این کمپوست. با این هدف ها، دو آزمون مزرعه ای در جنوب ایتالیا و با استفاده از ضایعات "دو فازی" و "سه فازی" ضایعات مزبور اجرا شد. بعد از تجزیه کمپوست های به دست آمده و تعیین ویژگی های آنها ، کمپوست ها در سطح دو باغ زیتون مختلف (شامل ارقام NocellaraوLeccino ) پخش شدند. در پایان آزمون مزرعه ای، ویژگیهای خاک، عملکرد درختان زیتون، و عملکرد روغن تعیین شد. نتایج نشان داد که ترکیب شیمیایی هر دو کمپوست با مقادیر مجاز قوانین کود برای "کمپوست ضایعات سبز" در ایتالیا همخوان بود.هنگامی که هر دو توده کمپوست به صورتی پایدار و "رسیده" در آمدند ویژگی های میکربی آنها مقادیر مشابهی داشتند. همچنین، نتایج حاکی از کارآیی فرایند کمپوست سازی و شرایط بهداشتی بود. افزودن کمپوست ضایعات روغن گیری زیتون به خاک ، میانگین عملکرد زیتون را در مقایسه با عدم مصرف کمپوست به مقدار ۹٪ افزایش داد. هر دو باغ زیتون نتایج خوبی را از لحاظ عوامل تولید نشان دادند، به ویژه ، عملکرد روغن در هکتار در جایی که کمپوست مصرف شده بود به مقدار۱۶۶/۴ و ۱۷۹/۹ کیلوگرم در هکتار بیشتر از محلی شد که کمپوست مصرف نشده بود. با این وجود، برای تایید این نتایج، میبایست که اثرمصرف کمپوست در خاک باغ های زیتون در دراز مدت بررسی شود.