



Effects of long-term olive mill wastewater disposal on the physical properties of an olive orchard soil in an arid Mediterranean region

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Abstract

In Mediterranean areas, high quantities of oil mill wastewater (OMW) are produced annually over a limited period (October to February). Spreading OMW on agricultural fields changes the soil's biological, chemical, and physical properties. In fact, this operation is also intended for soil amendment. The purpose of this research is to assess the long-term effects of recurrent OMW disposal at different doses (50, 100, and 200 m³ ha⁻¹) on the physical properties of different soil layers in order to evaluate the degradation risk after 5 successive years compared to a control soil. Results showed a significant increase of soil organic matter content and potassium concentrations. However, OMW reduced the hydraulic conductivity, the total porosity, and consequently the infiltration rate notably at the highest dose (200 m³ ha⁻¹). An increase of penetration resistance and thus the soil degradation risk was confirmed. As for the productivity of the olive orchard, the average olive production after 5 successive years of OMW discharge into the field showed a high production with 100 m³ ha⁻¹ and a significant production decrease with the highest OMW volume (200 m³ ha⁻¹).

Keywords Olive mill wastewater doses · Hydraulic conductivity · Total porosity · Infiltration rate · Penetration resistance · Olive yield

Introduction

The olive oil extraction industry is a very important economic activity in Mediterranean countries. Spain is the leader country in the world, followed by Italy, Greece, Tunisia, Turkey, and Syria (Magdich et al. 2016). Olive tree groves cover 9.5 M ha in the world, which accounts for more than 900 M olive trees, nearly 95% of which are in the Mediterranean basin (IOC 2015).

Olive mill wastewater (OMW) is the primary waste of olive oil processing. The annual OMW production in Mediterranean olive-growing countries is estimated to more than 3.10⁷ m³ and 700 000 m³ in Tunisia alone (Mekki et al. 2013; Ben Rouina et al. 2014). This industrial wastewater is heavily loaded with chemical oxygen demand (COD) values from 60 to 185 g L⁻¹ (Rinaldi et al. 2003; Rigane et al. 2015). Its high toxicity is mainly attributed to phenolic compounds (Capasso et al. 1992; Perez et al. 1992). OMW is also an acidic effluent (pH between 3.5 and 5.5) with 83 to 95% of water content (Nasini et al. 2013; Magdich et al. 2016). Therefore, the management of this by-product using technological processes is deemed necessary to minimize its environmental damage and ensure a sustainable use of this available bioresource. Different disposal processes based on evaporation ponds (Paredes et al. 2002; Hytiris et al. 2004), physico-chemical treatments (Negro and Solano 1996; García-Gómez et al. 2003), biotechnological transformations by microbiological treatments (López and Ramos-Cormenzana 1996; Ramos-Cormenzana et al. 1995), composting (Vlyssides et al. 1996; Sellami 2008a,b; Hachicha et al. 2009), anaerobic digestion (Marques 2001), recycling

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as a low-cost amendment which is rich in mineral elements (Mohawesh et al. 2014; Chatzistathis and Koutsos 2017; Mekki et al. 2018; Chehaba et al., 2019), and direct application in agricultural soils for organic amendment (Yaakoubi et al. 2010; Mekki et al. 2013; Hassine et al. 2017; Meftah et al. 2019) have been investigated. Spreading OMW on agricultural lands is intended for the recycling of both organic matter and nutritive elements, within the agroecosystem. It was shown that soil OMW application changes the soil's biological, chemical, and physical properties. In fact, Caruso et al. (2018) investigated the effects of raw OMW on forage yield and grain production of broad bean and chickpea in a marginal semi-arid Mediterranean agroecosystem. They reported that OMW is a valuable amendment to maximize legume yield. Moreover, long-term OMW spreading induces the growth of soil fungal and fungus-like communities and aerobic N₂ fix micro-organisms (Lanza et al. 2017). OMW application is also useful for the increase of soil carbon groups which enhance the SOC stabilization for long-term sequestration (Ben Mbarek et al. 2020). Furthermore, it increases SOM, nutrient content (Chatzistathis and Koutsos 2017; Meftah et al. 2019), and the growth of microflora (Hemmat et al. 2010; Barbera et al. 2014; Rusan et al. 2016; El Hassani et al. 2020).

The spraying of OMW at 50, 100, and 200 m³ ha⁻¹ on poor sandy soil for 10 years increased soil aggregates larger than 2 mm for 200 m³ ha⁻¹ and improved aggregate stability and consequently soil structure (Abichou et al. 2009). Mahmoud et al. (2010) reported that the application of OMW for 5 and 15 years enhanced the aggregation and the structure of soil by its adhesive behavior. In fact, it binds micro-aggregates together to macro-aggregates and consequently forms larger pore spaces. Moreover, Mahmoud et al. (2012) reported that a regular application of OMW for 5 and 15 years increased soil aggregate stability compared with the control. However, repeated spreading of OMW for several years decreased aggregate stability due to the replacement of calcium by potassium, sodium, and magnesium from OMW (Mekki et al. 2006). Therefore, a recurrent application of OMW on clayey soils is not recommended for the soil disaggregation. However, Meftah et al. (2019) reported negative effects of OMW on soil properties associated to its high mineral salt content, low pH, and the presence of phytotoxic compounds, especially polyphenols, including the available N immobilization (Saviozzi et al. 1991) and decrease or increase of available elements and salts (Lopez et al. 1996). Mahmoud et al. (2010) also reported the reduction in saturated hydraulic conductivity after OMW application for different periods (5 and 15 years). Steinmetz et al. (2015) found no significant effect on saturated hydraulic conductivity. Contrarily, Albalasmeh et al. (2019) revealed a short-term increase in aggregate stability, hydraulic conductivity, and water repellency after OMW application in selected soils.

The increased amount of OMW production in Mediterranean countries, notably in arid regions characterized by low soil fertility and water scarcity, led researchers to test the direct application of OMW on soil fertility (Chaari et al. 2014; Mohawesh et al. 2014), chemical properties (Ben mbarek et al. 2020; El hassani et al. 2020), and plant performance (Bene et al. 2013, Sahraoui et al. 2015; Meftah et al. 2019). However, up to our knowledge, very few studies investigated the impact of the direct application of OMW for a long term in an olive grove and its effect on olive production. Therefore, the objective of this study was to investigate the effect of five successive yearly applications of OMW soil with different doses (50, 100, and 200 m³ ha⁻¹) on several chemical and physical properties (hydraulic conductivity, total porosity, infiltration rate, and penetration resistance) with soil depths (0–20, 20–40, and 40–60 cm) in order to evaluate soil degradation risk in an olive grove and the effect on olive yield.

Materials and methods

OMW characterization

The wastewater was collected from the OMW disposal site in Agareb, Sfax (Southeastern Tunisia) where the effluents are subjected to natural evaporation (Jarbouli et al. 2008). The collected OMW has a black color, acidic pH (~5), a relatively high electrical conductivity (20 mS cm⁻¹), high organic matter, and high content of total phenols (12.3 g L⁻¹). The main OMW characteristics are presented in Table 1.

Table 1 Main characteristics of OMW

Parameters	OMW
Dry matter (%)	10 ± 0.13
Density (g cm ⁻³)	1.05 ± 0.01
Electrical conductivity (mS cm ⁻¹)	20.1 ± 0.32
pH	4.92 ± 0.05
Organic matter (% dry matter)	78.57 ± 0.43
COD (g l ⁻¹)	110 ± 0.9
BOD (g l ⁻¹)	24.0 ± 0.4
TOC (g l ⁻¹)	27.43 ± 0.47
Total nitrogen (g l ⁻¹)	0.74 ± 0.11
Total PO ₄ (ppm)	259.72 ± 1.278
Na ⁺ (ppm)	280.40 ± 1.496
Ca ⁺⁺ (ppm)	72.40 ± 0.854
Total phenols (g l ⁻¹)	12.3 ± 0.2

Study site and sampling

The study area was an olive tree field located in Sfax region in southeastern Tunisia (Taous area) (Fig. 1). The general characteristics of the soil used in this study are displayed in Table 2. The soil texture is sandy (sand 93.5%, clay 4.7%, silt 1.3%) with a moderately alkaline pH (7.94) and a low content of organic matter (0.17%). Its EC value was recorded at 0.3 mS cm⁻¹.

The studied region is characterized by an arid Mediterranean climate, with a mean annual rainfall of about 200 mm/year and an average annual temperature of 18–20 °C. The experimental station belongs to the upper arid bioclimatic stage. This climate is known by an extreme irregularity of rain and thermal phenomena: a cold and rainy winter and a hot and dry summer.

The field was divided into four plots (24 m × 24 m within a hectare). Three plots T1, T2, and T3 were treated with 50, 100, and 200 m³ ha⁻¹ of OMW, respectively, in one application, and a control plot (TC) was not irrigated and not amended (Fig. 2). OMW was applied once a year for 5 successive years at the specified doses with a pneumatic liquid manure spreader towed by a tractor (Figs. 3 and 4). Plots were tilled with a tractor-driven cultivator five times a year and tillage reached 20 to 25 cm in depth. Planting density is the common density used in the region corresponding to 17 trees/ha with a squared grid of 24 m. There is no irrigation system in the experimental field.

Soil samples (0–20, 20–40, 40–60 cm in depth) were collected from different parts of each plot after 5 years of OMW application. Twelve soil samples were collected from all plots using soil auger. In fact, three soil samples were taken from each plot, and each soil sample was composed of sub-samples from three sampling points mixed together.

Table 2 Main soil chemical and physical characteristics of the study (n=5)

Property	Mean
Sand (%)	93.5 ± 2.1
Silt (%)	1.3 ± 0.4
Clay (%)	4.7 ± 1
pH	7.94 ± 0.25
EC(mS cm ⁻¹)	0.3 ± 0.03
C _{total} (g kg ⁻¹)	1 ± 0.2
N (ppm)	263 ± 3.5
Na (ppm)	28 ± 2.5
K (ppm)	67 ± 2.1
Mg (ppm)	252 ± 3.2

Undisturbed soil samples of 100 cm³ were collected for the determination of porosity and saturated hydraulic conductivity. Disturbed soil samples were collected from a given plot then mixed, air-dried, sieved (< 2 mm), and stored until analysis for chemical characteristics.

To measure the olive yield, olives were harvested by hand, nets or plastic sheets were placed on the ground under each tree, and the harvesters climbed ladders and combed the fruit from the branches. Long-handled plastic rakes were used to pull the olives from each tree. The weight of yield was determined for each tree. The total yield weight of each studied parcel was calculated, and production per hectare was determined.

Chemical analysis

Particle size distribution was determined by the Robinson pipette’s method (Pauwels et al. 1992). The carbon content was determined by the dichromate oxidation technique as described in the Anne method. The amount of organic matter

Fig. 1 Geographical situation of study area

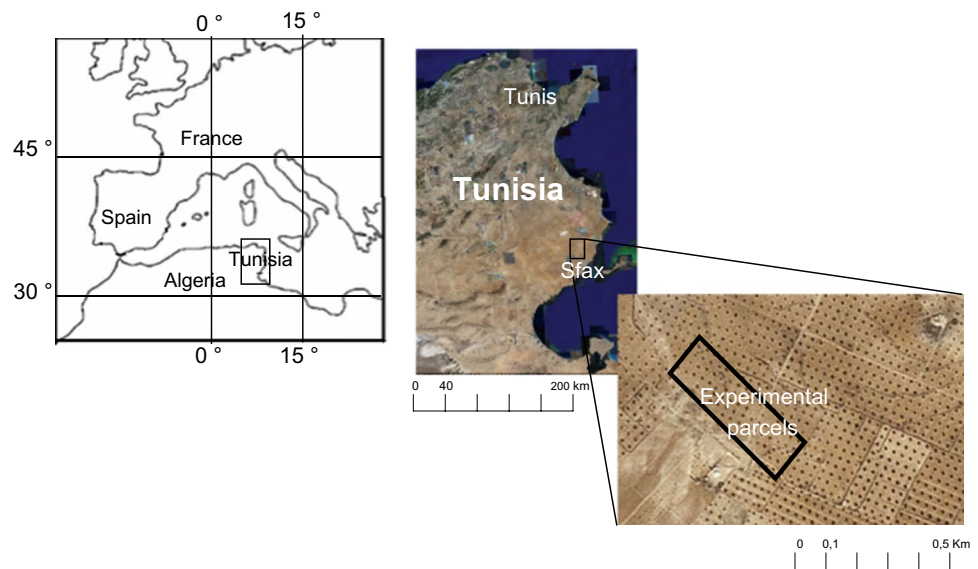


Fig. 2 Soil mapping of experimental plot

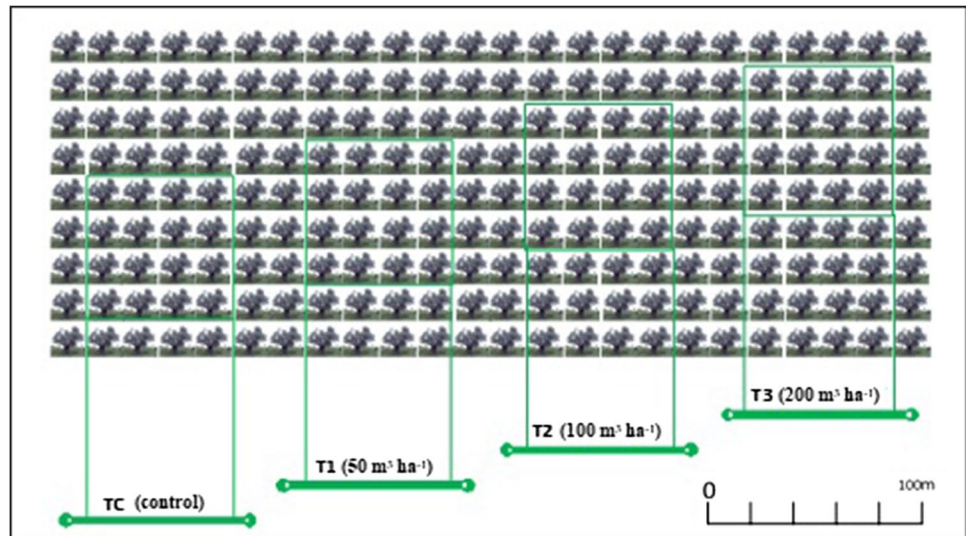


Fig. 3 OMW spreading operation



Fig. 4 Soil surface after OMW spreading

(OM) in the soil was determined through carbon content determination using the Van Bemmelen correction factor (1.724) that assumes that soil organic matter is 58% carbon (Pansu and Gautheyrou 2003). Soil pH was measured in a soil–water mixture (10 g of soil was mixed with 25 mL of water) using a pH meter (type Mettler Toledo MP225). The electrical conductivity (EC) of soil was measured by a conductivity meter to measure the liquid extract of the saturated paste. Available K, N, and Na were extracted by mixing 5 g of soil with 100 mL ammonium acetate (0.1 N); stirring during 60 min was then followed by filtration. The filtrate was assayed by atomic absorption spectrophotometry (Pauwels et al. 1992).

Physical analysis

The structure stability was determined by an aggregate analysis, submitted to three pretreatments (water, alcohol, benzene); stable and dispersed fractions were determined. Henin et al. (1958) proposed an instability index (I_s) by measuring the weight of soil fragments retained on 0.2-mm sieves after pre-treatments with alcohol, benzene, and water. It was calculated according to the following formula:

$$I_s = \frac{\text{Clay} + \text{silt}}{((\text{ASA} + \text{BSA} + \text{WSA})/3) - 0.9 \text{ sand}} \quad (1)$$

where clay, silt, and sand are the percentages of clay, silt, and sand in the suspension treated with benzene or water. ASA, BSA, and WSA are the percentages of stable aggregates after treatment with alcohol, benzene, and water, respectively.

Undisturbed soil samples were taken by using a steel core sampler of a 100 cm³ volume (5 cm in diameter and 5 cm in height). Total porosity and saturated hydraulic

conductivity were determined with the 12 undisturbed soil samples. Saturated hydraulic conductivity was measured according to Klute and Dirksen (1986) by the falling-head method. The samples were used for saturation to determine the total porosity which was calculated in undisturbed water-saturated samples of 100 cm³ assuming no air trapped in the pores using a particle density of 2.65 g cm⁻³ (Danielson and Sutherland 1986).

Mechanical resistance was measured using a proving-ring penetrometer (Bradford 1986) at 5 cm increments from the soil surface to the 35 cm depth, in the row and between rows. The cone used had a 308 angle, 40 mm length, and a diameter of 21.5 mm (CN-970, SOILTEST, Lake Bluff, Illinois).

In order to measure the infiltration rate, a double ring infiltrometer was used. The inner and outer rings were 30 and 50 cm in diameter, respectively, and the height was 35 cm. The infiltration test data were analyzed and followed through time.

The resistance to penetration was carried out using a penetrometer that is a device for assessing the resistance of a given section in the ground to the sinking of a metal rod. This measurement consists of recording, by means of a dynamometer, the force necessary for the progressive sinking of the rod into the ground.

Statistical analysis

Analysis of variance was calculated to determine changes in the studied parameters using the statistical software SPSS 13.0. The mean values of the treatments were compared using the Tukey's range tests at a 5% level of significance ($p < 0.05$). In the same soil, we used a, b, c, and d letters for parameter classification in each depth. Analyses were performed in triplicate.

Results and discussion

Impact of spreading OMW on soil chemical properties

OMW addition in soil for 5 successive years had different effects on some chemical properties. Soil pH was significantly reduced in the top layer (0–20 cm) for all treatments: T1 (50 m³ ha⁻¹), T2 (100 m³ ha⁻¹), and T3 (200 m³ ha⁻¹) (Fig. 5). In the 20–40 cm layer, the pH decreased mainly in T2 (100 m³ ha⁻¹). This confirmed the concentration of acids in this layer. In the 40–60 cm layer, no significant changes occurred in T1 and T2, whereas a significant soil pH decrease was noticed in T3.

OMW addition for five successive years changed the soil pH essentially in surface layers. The acidity of the OMW (~5) was neutralized in all treated soil layers (pH > 7). This is due to the soil carbonate alkalinity as reported by Yaakoubi et al. (2010).

The organic matter content increased significantly after OMW addition for all treatments and in all soil layers (Fig. 6). In the surface soil, the organic matter concentration was about 0.2% in the control soil (TC) followed by 0.28, 0.49, and 0.62% in T1 (50 m³ ha⁻¹), T2 (100 m³ ha⁻¹), and T3 (200 m³ ha⁻¹), respectively. The most important organic matter contents were recorded in 20–40 cm where OM progressed from 0.38 in TC and T1 to 0.46 and 0.95% in T2 and T3, respectively. In the third layer (40–60 cm), the OM content evolved from 0.28% in TC to 0.45% and 0.51% in T2 and T3. The application of OMW for 5 successive years induced a significant increase of soil organic matter content. This result has a great importance in arid conditions where agricultural soils, poor in organic matter, are dominant and are subjected to intense degradation. These results are in agreement with those obtained by Dakhli et al. (2021) who reported that OMW application increased the rate of organic matter in a sandy soil under arid conditions. Gargouri et al. (2014) also reported the same result indicating that OMW

Fig. 5 pH in the treated plots after 5 years. TC (control), T1 (50 m³ ha⁻¹), T2 (100 m³ ha⁻¹), and T3 (200 m³ ha⁻¹). Lower-case letters indicate significance within treatment at each depth. Means with different letters indicate a significant difference at $p < 0.05$

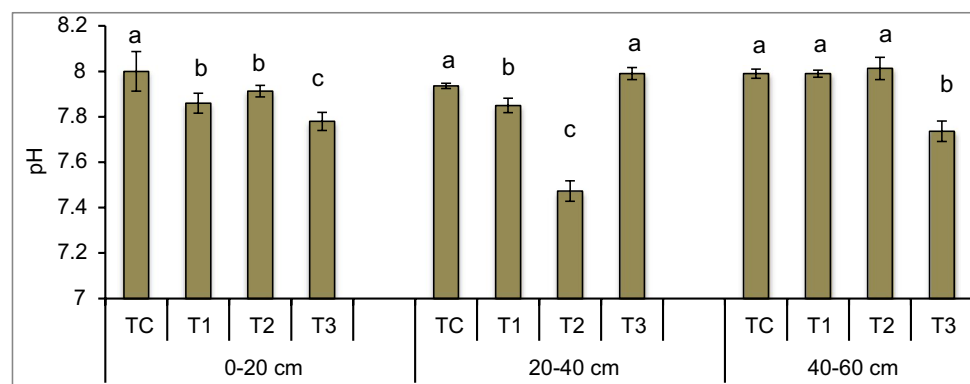
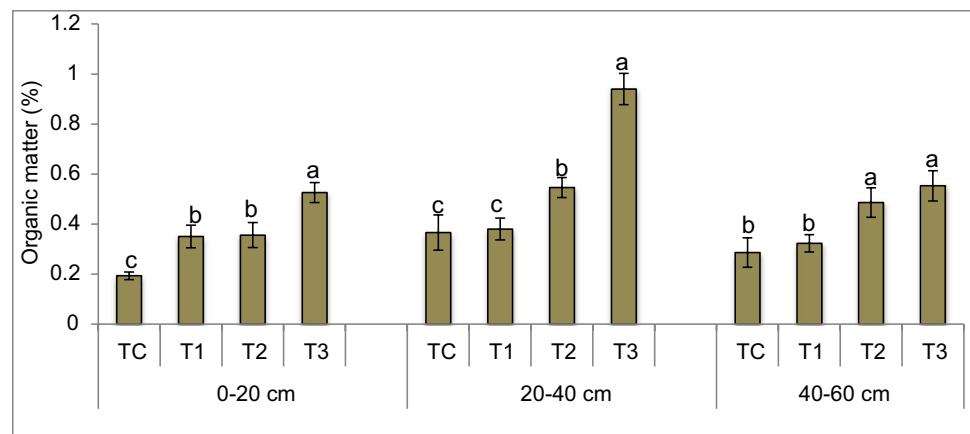


Fig. 6 Organic matter in OMW-treated plots. TC (control), T1 ($50 \text{ m}^3 \text{ ha}^{-1}$), T2 ($100 \text{ m}^3 \text{ ha}^{-1}$), and T3 ($200 \text{ m}^3 \text{ ha}^{-1}$). Lowercase letters indicate significance within treatment at each depth. Means with different letters indicate a significant difference at $p < 0.05$



application increases soil organic carbon content under arid conditions.

A considerable significant enrichment in available K was noticed after OMW addition proportionally with OMW doses (Fig. 7). This enrichment in available K is attributed to the added OMW quantities. A similar result was obtained by Dakhli et al. (2021) who revealed a significant increase in soil exchangeable K after OMW spreading for 3 successive years. Demetrio et al. (2019) also revealed a significant increase in exchangeable K after gradual OMW quantity application. We conclude that OMW constitutes a potential source of K that can have a beneficial effect on soil fertility.

Soil physical properties

Instability index

The soil instability index can be applied to test soil aggregation stability and thus indicate the influence of OMW on soil stability and then the resistance to wind-caused erosion (Abichou et al., 2009). Results showed a significant increase of the instability index after 5 years of OMW application for all treated soils compared to control soil essentially in the topsoil (0–20 cm) as shown in Fig. 8. However, no significant differences were noticed in deeper layers (20–40

and 40–60 cm). This result confirms that long-term OMW application contributes to a decrease of soil stability in the top soil. This result is congruent with Mahmoud et al. (2012) who reported that OMW is characterized by its adhesive behavior that affects the aggregation and structure of the top soil by binding micro-aggregates together to macro-aggregates and then forming further pore spaces. Consequently, the use of OMW for irrigation for a long period alters the surface layer of soils. Soils treated with $200 \text{ m}^3 \text{ ha}^{-1}$ of OMW registered the highest instability index values for all soil layers as shown in Fig. 8 improving soil degradation risk and then increasing wind erosion risk. Abichou et al. (2009) also reported that a successive OMW spreading on a sandy soil with doses below $200 \text{ m}^3 \text{ ha}^{-1}$ improved soil agglomeration, increased structural stability, and decreased wind erosion. Five years of spreading OMW at high doses decreased the structural stability of soil and increased the wind erosion risk.

Saturated hydraulic conductivity

The analysis of saturated hydraulic conductivity in soil receiving the different OMW treatments at layers (0–20, 20–40, and 40–60 cm) (Fig. 9) showed that the highest mean values were found in the topsoil (0–20 cm) of TC

Fig. 7 Available K in the treated plots after 5 years. TC (control), T1 ($50 \text{ m}^3 \text{ ha}^{-1}$), T2 ($100 \text{ m}^3 \text{ ha}^{-1}$), and T3 ($200 \text{ m}^3 \text{ ha}^{-1}$). Lowercase letters indicate significance within treatment at each depth. Means with different letters indicate a significant difference at $p < 0.05$

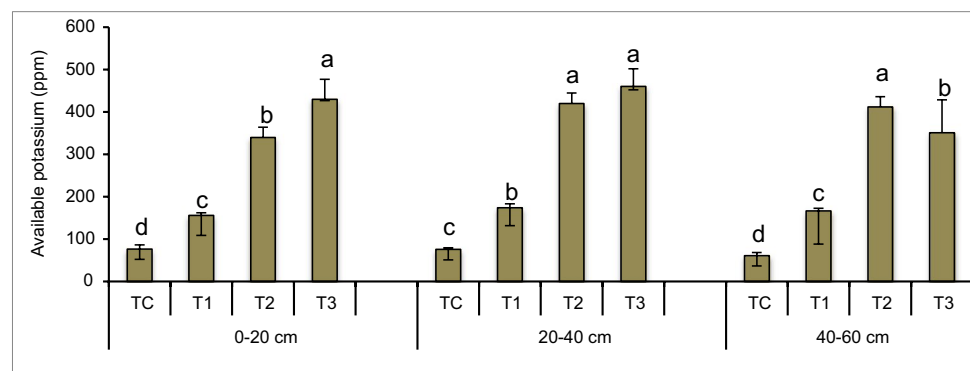


Fig. 8 Instability index in soils affected by application of organic wastes. TC (control), T1 ($50 \text{ m}^3 \text{ ha}^{-1}$), T2 ($100 \text{ m}^3 \text{ ha}^{-1}$), and T3 ($200 \text{ m}^3 \text{ ha}^{-1}$). Lowercase letters indicate significance within treatment at each depth. Means with different letters indicate a significant difference at $p < 0.05$

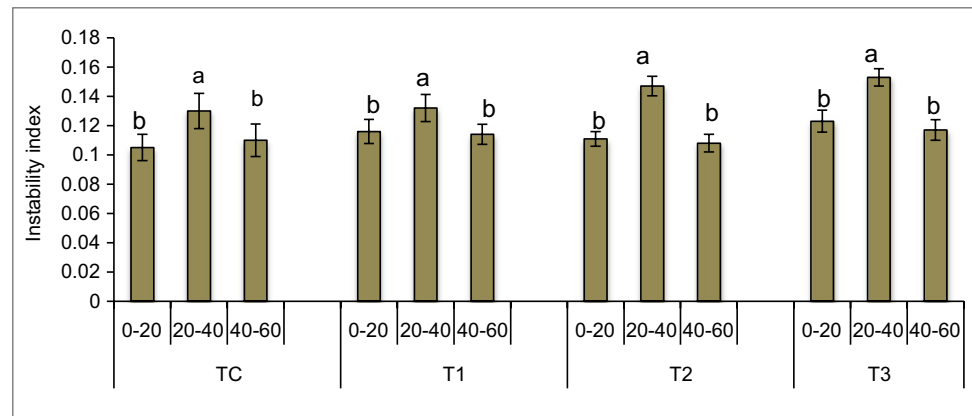
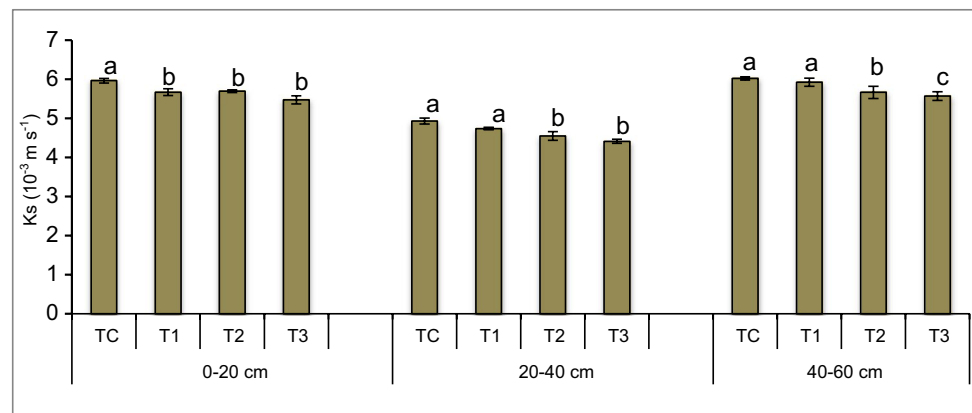


Fig. 9 Saturated hydraulic conductivity in treated plots. TC (control), T1 ($50 \text{ m}^3 \text{ ha}^{-1}$), T2 ($100 \text{ m}^3 \text{ ha}^{-1}$), and T3 ($200 \text{ m}^3 \text{ ha}^{-1}$). Lowercase letters indicate significance within treatment at each depth. Means with different letters indicate a significant difference at $p < 0.05$



($6 \cdot 10^{-3} \text{ m s}^{-1}$), whereas the lowest mean values were observed in the deeper layer (40–60 cm) of T3 ($4.4 \cdot 10^{-3} \text{ m s}^{-1}$). According to the Tukey test, saturated conductivity values differed significantly ($p < 0.05$) between the control (TC) and all treated plots at 0–20 and 40–60 cm depths, whereas no difference was recorded between TC and T1 at 20–40 cm depth and between T2 and T3 at the same depth. Then, OMW application for long periods reduced significantly soil hydraulic conductivity. This was explained by blocking soil pores by organic suspended matters in OMW that cause a decrease in soil hydraulic conductivity (Bhardwaj et al. 2008; Mahmoud et al. 2010) or the redistribution of soil porosity by a decrease of large pores and an increase of fine pores (Cox et al. 1997). Besides, as indicated by Mahmoud et al. (2010), high concentrations of K and Na in the applied OMW caused an increase in exchangeable sodium percentage (ESP), a decrease in hydraulic conductivity, and a degradation of soil structure (Mekki et al. 2006; Jalali et al. 2008). Gharaibeh et al. (2007) also reported that irrigation using wastewater for long periods reduced soil hydraulic conductivity as compared with non-irrigated area.

Infiltration rate and total porosity

Figure 10 illustrates a significant decrease of final infiltration rate at the experimental plots compared with the control.

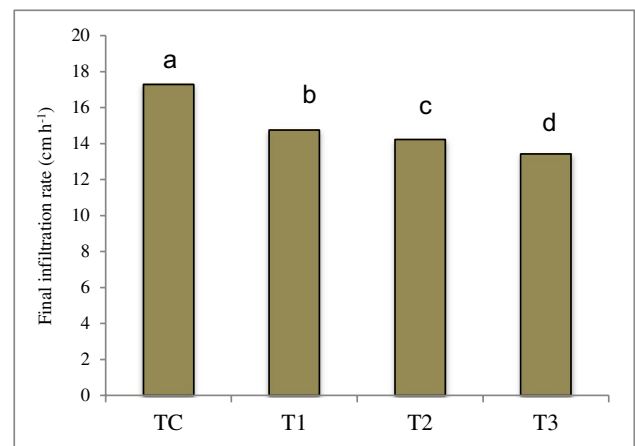


Fig. 10 Final infiltration rate at the experimental plots. TC (control), T1 ($50 \text{ m}^3 \text{ ha}^{-1}$), T2 ($100 \text{ m}^3 \text{ ha}^{-1}$), and T3 ($200 \text{ m}^3 \text{ ha}^{-1}$). Lowercase letters indicate significance within treatment at each depth. Means with different letters indicate a significant difference at $p < 0.05$

This result can be explained by the reduction of the drainable porosity (Mahmoud et al. 2010). The high concentration of suspended solids and organic matter in the OMW may have sealed the surface soil pores and caused a reduction in the infiltration rate as indicated by Abo-Ghobar (1993) and Viviani and Iovino (2004). This result is confirmed by the significant decrease in the total porosity mainly in plots treated with 200 m³ ha⁻¹ of OMW as shown in Fig. 11.

A similar result was noticed by Gharaibeh et al. (2007) who reported that the infiltration rate is altered after long-term OMW application due to the presence of large and deep cracks that predominated and controlled infiltration irrespective of pore size distribution in the soil matrices.

Penetration resistance

The penetration resistance was measured in the top 35 cm soil depth. As shown in Fig. 12, the penetration resistance increased for all treatments. We also noticed that the highest penetration resistance is in soil treated with 200 m³ ha⁻¹ of OMW. Penetration resistance increases with

increasing OMW doses. This result can be attributed to the blocking of pores and sealing of the soil surface that reduce infiltration as reported by Mahmoud et al. (2010). The decrease of infiltration rate and porosity confirmed the penetration resistance increase.

Average production in olive fields

The average olive productions after 5 successive years of OMW discharge into the field showed that, for all treatments, the average production was significantly higher than the control (TC) (Table 3). We also noticed a high production (1134 kg ha⁻¹) with 100 m³ ha⁻¹ OMW treatment and a significant production decrease (965 kg ha⁻¹) with the highest OMW volume (200 m³ ha⁻¹). This result is related to the infiltration rate and porosity decrease that hinders root penetration in soil as confirmed by the increase of penetration resistance. These results confirm the beneficial effect of OMW application in olive tree orchards mainly with doses lower than 100 m³ ha⁻¹.

Fig. 11 Total porosity in treated plots. TC (control), T1 (50 m³ ha⁻¹), T2 (100 m³ ha⁻¹), and T3 (200 m³ ha⁻¹). Lowercase letters indicate significance within treatment at each depth. Means with different letters indicate a significant difference at *p* < 0.05

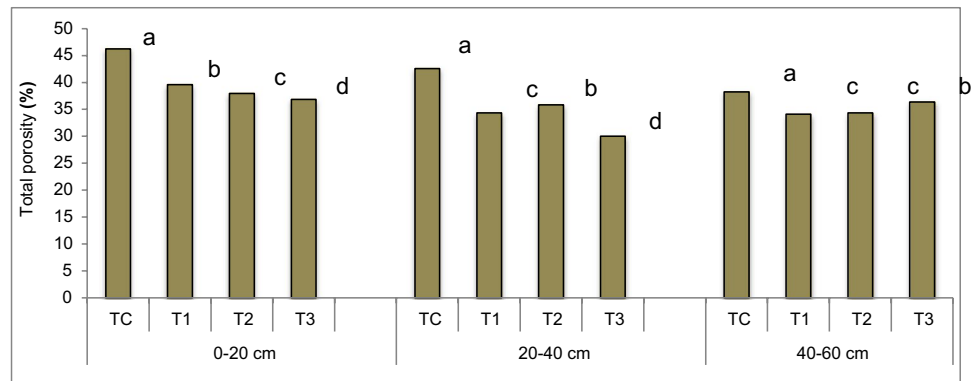


Fig. 12 Progress of penetration resistance in treated plots. TC (control), T1 (50 m³ ha⁻¹), T2 (100 m³ ha⁻¹), and T3 (200 m³ ha⁻¹)

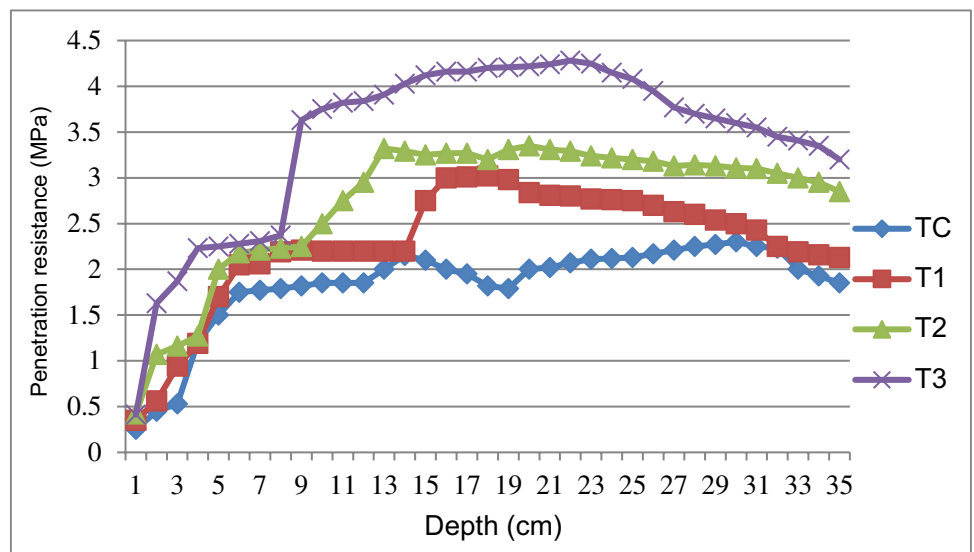


Table 3 Average productions in olive fields in the 3, 4, and 5 years of OMW addition

OMW dose	Production after 3 years (kg ha ⁻¹)	Production after 4 years (kg ha ⁻¹)	Production after 5 years (kg ha ⁻¹)	Average production (kg ha ⁻¹)	Elevation (%)
TC (0 m ³ ha ⁻¹)	539 ^c	75 ^a	1804 ^b	806 ^a	0 ^a
T1(50 m ³ ha ⁻¹)	561 ^b	563 ^c	1860 ^c	995 ^c	+ 23.4 ^c
T2 (100 m ³ ha ⁻¹)	695 ^d	360 ^b	2346 ^d	1134 ^d	+ 40.7 ^d
T3 (200 m ³ ha ⁻¹)	280 ^a	823 ^d	1792 ^a	965 ^b	+ 19.7 ^b

Lowercase letters indicate significance within treatment at each year. Means with different letters indicate a significant difference at $p < 0.05$

Conclusion

The irrigation of olive fields with OMW for 5 successive years showed an increase of organic matter content in all treated soils with all the OMW volumes applied, a decrease in hydraulic conductivity, and an increase of penetration resistance confirmed by the decrease of infiltration rate and porosity. For all treatments, soil treated with OMW had significantly more organic matter and potassium contents than control soil. Higher contents of organic matter and potassium were recorded in T2 and T3 in the surface layer. The statistical analysis indicated that the soil treated with 200 m³ ha⁻¹ of OMW incurs the highest structural instability value. Furthermore, the spreading of OMW for 5 years mainly at 200 m³ ha⁻¹ reduced soil hydraulic conductivity and increased penetration resistance and soil compaction. As for the productivity of the olive orchard, the average olive production after 5 successive years of OMW discharge into the field showed that, for all treatments, the average production was significantly higher than the control TC. We also noticed a high production with 100 m³ ha⁻¹ and a significant production decrease at the highest tested OMW volume (200 m³ ha⁻¹). This result is due to the infiltration rate and porosity decrease that made difficult root penetration in soil as confirmed by the increase of penetration resistance. As a conclusion, soil physical studies showed that long term and high doses (200 m³ ha⁻¹) of OMW application in soils should be avoided. Long-term and intensive application of OMW should be avoided on soil surfaces and in areas with a shallow groundwater table and sandy soils.

The practice of spreading OMW on agricultural lands for long term can deteriorate soil physical properties and then soil stability and fertility.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s12517-022-09644-9>.

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Declarations

Conflict of interest The authors declare no competing interests.

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