Utilization of Liquid Olive Mill Waste and Some Natural Conditioners for Improving Sandy Soil Properties

A. Kh. A. Khalil[1,] G. Abdel-Nasser[2,] Wafaa H. M. Ali[2,] A. A. Abou Hasham[1]
[1]Soil Conservation Dept., Water Resources and Desert Soils Division, Desert Research Center, Cairo, Egypt
[2]Soil and Agricultural Chemistry Dept., Faculty of Agriculture Saba Basha – Alexandria University

ABSTRACT: A field experiment conducted at Gilbana village, Southern El-Qantara Shark, North Sinai, Egypt. The aim of the study was to evaluate the role of olive mill wastewater and some natural conditioners (farmyard manure and K-Feldspar) in improving sandy soil properties. All the three used soil conditioners applied individually and in combination. The experimental design was Randomized Complete Block Design and the cultivated plant was sugarbeet. Results of the present study revealed that the application of all the studied treatments decreased pH and EC values, while increased organic matter content, as well as available N, P and K. On the other hand, such treatments increased microelements concentration of the investigated soil. Importantly, the combined treatment (Olive mill wastewater + Potassium feldspar + Farmyard manure) had the most effective treatment in the present study. Therefore, the application of such treatment to sandy soils is necessary to improve its properties.

Keywords: Olive mill wastewater - feldspar - farmyard manure - natural soil conditioner.

INTRODUCTION

Olive mill wastewater (OMWW) is the liquid by-product generated during olive oil production (Mekki *et al*., 2013). This by-product has a critical environmental problem for the most olive oil producing countries. The problem concern to its large volumes, salinity, low pH, high organic load and toxic and phytotoxic compounds, such as polyphenol (Di Bene *et al*., 2013; Chaari *et al*., 2014).

The additions of the olive–mill waste as an organic amendment can improve soil quality and hence mitigate the negative environmental and agronomic limitations of these soils (Lopez-Pineiro *et al.*, 2008). These wastes contain high percentages of organic matter and a vast range of plant nutrients that could reused as fertilizers for sustainable agricultural practices (Roig *et al.*, 2006; Abu Khayer *et al*., 2013). Also, OMWW application has found to have significant effects on the soil's physical, chemical and biological properties (Saadi *et al*., 2007; Mechri *et al*., 2008; Jarboui *et al*., 2008; Lopez-Pineio *et al*., 2008; Kavvadias *et al*., 2010).

Mahmoud *et al.* (2010) found that the saturated hydraulic conductivity decreased by long-term application of untreated olive mill wastewater, while the soil disposition to water repellency increased. Olive mill wastewater enhanced the total organic content in the soil and increased total extracted carbon, humified organic carbon, available phosphorus and potassium (Montemurro *et al.*, 2011).

Compost farmyard manure with Olive mill wastewater caused a decrease in soil bulk density compared to using olive mill wastewater by approximately 11% (Abd- El Aziz and Mousa, 2017). Compost farmyard manure with olive mill wastewater increased organic matter content more than compost farmyard manure only, and compost farmyard manure was more effective than olive mill wastewater (Abd- El Aziz and Mousa, 2017; Al-Widyan *et al*., 2005; Paredes *et al*., 2005).

Feldspar is by far the most abundant range of minerals in the earth's crust, forming about 60% of the earth's rocks. Most deposits provide sodium feldspar as well as potassium feldspar and mixed feldspar. Feldspar primarily used in industrial applications and is used as a soil conditioner. Wahba and Darwish (2008) found that feldspar and compost, individually or mixed, increase the available potassium content in sandy and calcareous soils.

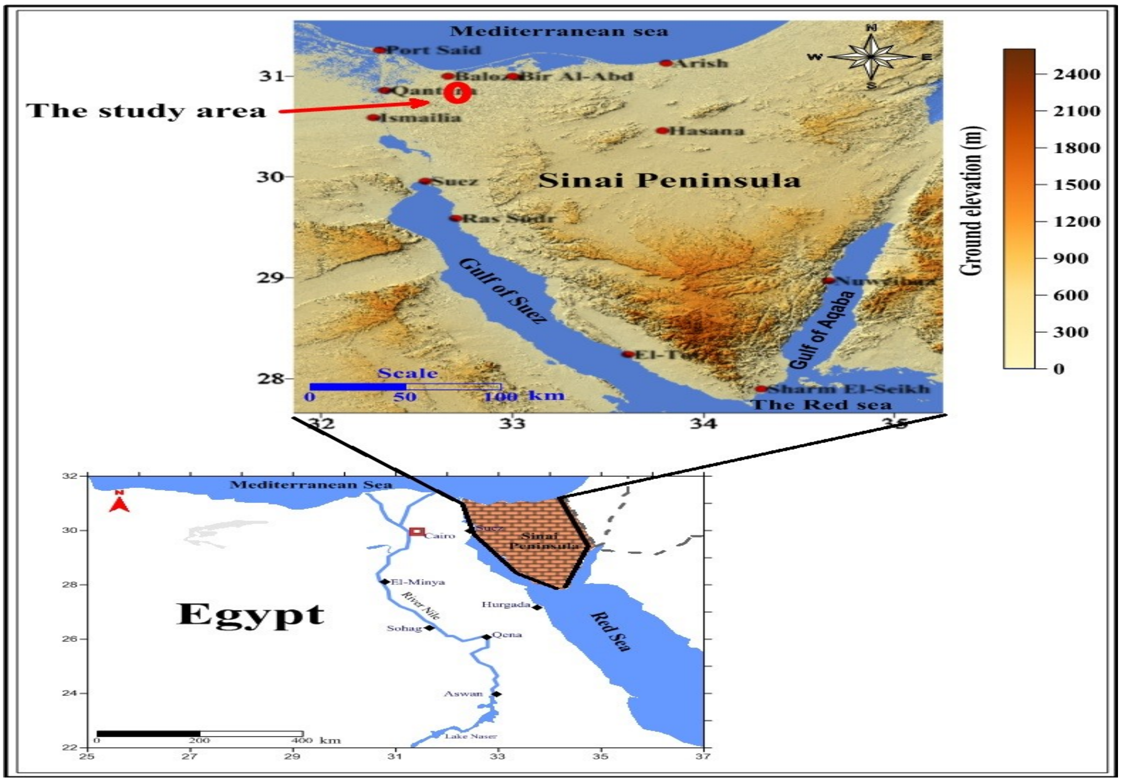
The objective of this present study is to evaluate the role of olive mill wastewater, K-feldspar and farmyard manure as natural soil conditioners in improving sandy soil properties in Gilbana village, southern El-Qantara- shark, North Sinai, Egypt. The effect of the treatments on sugarbeet productivity will illustrated in another paper.

MATERIALS AND METHODS

A field experiment conducted at Gilbana village, Southern El-Qantara Shark, North Sinai. The studied area is located at latitude 30º 52` 16.8” N and longitude 32º 19` 55.2`` E, and altitude 6 m (ASL). Map (1) shows the location of Galbana village, south of Al-Qantara Shark area, Egypt. Some physical and chemical characteristics of the experimental soil samples presented in Table (1).The other agronomic practices for sugarbeet cultivation done as recommended at the appropriate time. The experimental design was the Randomized Complete Block design with three replications and the experimental treatments were as follows:

1 - Control (without any conditioner application).
2 - Olive mill wastewater (12.6 m^3/fed.).
3 - Potassium feldspar (15 ton/fed.).
4 - Farmyard manure (15 ton/fed.).
5 - Olive mill wastewater (12.6 m^3/fed.)+ Potassium feldspar (15 ton/fed.).
6 - Olive mill wastewater (12.6 m^3/fed.)+ Farmyard manure (15 ton/fed.).
7 - Potassium feldspar (15 ton/fed.) + Farmyard manure (15 ton/fed.).
8 - Olive mill wastewater (12.6 m^3/fed.) + Potassium feldspar (15 ton/fed.) + Farmyard manure (15 ton/fed.).

The conditioners in the combined treatments added at the same rates previously mentioned as the individual ones. The data in Table 2 illustrates some chemical characteristics of such conditioners.



Map (1). Location of Gilbana village, southern El-Qantara Shark area.

The sugar beet plant as test crop harvested after 180 days from sowing date (May 20, 2017). Soil samples representing all treatments taken from two depths; i.e., surface layer (0-30 cm) and subsurface layer (30-60 cm) then prepared for analysis.

Table (1). Some chemical and physical characteristics of the experimental soil

Soil depth (cm)	pH	EC	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$+ HCO_3^{-}	Cl^{-}	$SO4^{=}$	SAR	MAR	SSP	ESP	PI	KR
		dSm^{-1}	Soluble Cations (meq/l)				Soluble anions (meq/l)			-	-	%		-	-
(0:30)	7.95	2.98	7.44	3.67	18.20	0.67	10.00	11.00	8.80	7.72	33.0	60.7	9.2	0.73	1.64
(30:60)	7.65	2.84	8.60	4.30	14.90	0.55	8.00	17.60	2.80	5.87	33.3	52.6	6.88	0.64	1.16

Table (1). Cont.…

Soil depth (cm)	N	P	K	Cu	Fe	Mn	Zn	$CaCO_3$	O.M	Ks	MWD	GMD	Texture	Cr
	mg/kg							%	%	cm/day	mm	mm		-
(0:30)	224	11.6	64	0.08	1.34	1.62	0.28	7.43	0.07	100	0.35	0.3	SAND	1.48
(30:60)	196	10.4	60	0.07	1.13	5.95	0.28	6.29	0.03	118	0.34	0.3	SAND	1.40

Table (2). Some chemical characteristics of the tested conditioners

Parameters	OMWW	K-Feldspar	Farmyard manure
pH	3.86	7.58	8.00
EC, dS/m	15.63	2.54	12.82
OC,%	19.7	-	16.5
OM, %	33.96	-	28.45
$CaCO_3$, %	-	14.28	28.57
Total Elements(mg/kg)			
N	560	350	11340
P	179.3	73.5	52.55
K	18300	4675	25500
Ca	4890	9532.5	10230
Mg	679.3	3580	3482
Fe	405.4	14898	1565
Mn	43.25	455.25	195.3
Cu	35.55	42.175	32.31
Zn	25.06	132.6	48.69

Soil analysis
Soil physical characters:

The soil samples taken from each treatment after harvesting and analyzed for the following properties:

- **Soil particle density (Mg/m^3)** using the Pycnometer method (Carter and Gregorich, 2008).
- **Soil bulk density (Mg/m^3)** using the soil core method (Carter and Gregorich, 2008).
- **Mean weight diameter (MWD)** according to Dimoyiannis (2009) method using the following equation:

$$MWD = \sum_{i=1}^{n} f_i \times d_i \quad (1)$$

Where: di is the mean diameter of any particular size range of aggregates separated by sieving (mm), and fi is the weight of aggregates in that size range as a fraction of the total dry weight of soil used (%).

- **Geometric mean diameter (GMD)** according to the method of Shirazi and Boersma (1984)using the following equation:

$$GMD = EXP\left[\sum_{i=1}^{n} f_i \times \log d_i\right] \quad (2)$$

- **Structure coefficient (Cr)** as described by (Pieri, 1992) using the following equation:

$$Cr = \frac{\text{weight of particls} > 0.25\text{mm}}{\text{weight of particles} < 0.25\text{mm}} \quad (3)$$

- **Permeability index (PI)** as calculated by the method suggested by Domenico and Schwartz (1990) as follows:

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{2+} + Mg^{2+} + Na^{+}} \quad (4)$$

Where the ion concentrations are in meq/l

- **Kelley's ratio (KR)** as described by Kelley (1963) as follows:

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} \quad (5)$$

- **Soil water retention** at 0.0, 0.1, 0.33, 1, 5, 10, and 15 bar was measured using pressure cooker device and pressure membrane apparatus and soil water constants (FC, PWP and AW) deduced from the values of soil moisture content percentage at different pressures according to van Genuchten's model (Van Genuchten, 1980):

$$\theta = \theta_r + \frac{(\theta_s - \theta_r)}{\left[1 + (\alpha h)^n\right]^m} \quad (6)$$

Where:
h is the matric suction (cm),
θ is the volumetric water content ($cm^3\ cm^{-3}$),
θ_s is the saturated water content ($cm^3\ cm^{-3}$),
θ_r is the residual water content ($cm^3\ cm^{-3}$),
α is a parameter, the inverse of which, $1/\alpha$, is an indication of the suction at the air-entry point (cm^{-1}), and
n and m are the dimensionless parameters related to the homogeneity of the pore size distribution.

The experimental data for soil water retention fitted to van Genuchten's model with optimization software RETC (Van Genuchten *et al*., 1991).

- **Soil saturated hydraulic conductivity (Ks)** was determined using undisturbed soil cores under constant water head in the laboratory following the method recommended by Klute (1986). Darcy's equation used to calculate the (Ks) value (Richard, 1954).

Soil chemical characters:

- **Soil pH, Electrical Conductivity (dS/m), soluble cations (meq/l), soluble anions (meq/l), total calcium carbonates (%), and organic matter (%)** were determined according to the methods outlined in Carter and Gregorich (2008).

- **Magnesium Adsorption Ratio (MAR)** was calculated by the following formula (Richards, 1954; Eaton, 1950):

$$MAR = \frac{Mg^{2+}}{Ca^{2+}+Mg^{2+}} \times 100 \quad (7)$$

Where: Na^+, Ca^{2+} and Mg^{2+} contents of soil solution expressed in meq/l.

- **Sodium Adsorption Ratio (SAR)** as calculated by the following formula (Richards, 1954):

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \quad (8)$$

- **Soluble Sodium Percentage (SSP)** was calculated by the following formula (Richards, 1954):

$$SSP = \frac{Na^+ \times 100}{Na^+ + Ca^{2+} + Mg^{2+}} \quad (9)$$

- **Exchangeable Sodium Percentage (ESP)** was calculated by the following formula (Richards, 1954):

$$EESP = \frac{(-0.0126+0.01475 \times SAR)*100}{1+(-0.0126+0.01475 \times SAR)} \quad (10)$$

- **Soil available nutrients:** Soil available macronutrients (N, P and K) and soil available micronutrients (Fe, Mn, Cu and Zn) were determined as follows.
- **Available nitrogen content (mg/kg):** The soil sample was extracted by 2M KCl (1:20), available N was determined in soil extract by using micro-Kjeldahl method described by Paech and Tracey (1956).
- **Available phosphorus content (mg/kg)**: Available phosphorus extracted with 0.5 M $NaHCO_3$ solution and adjusted to pH 8.5 according to Olsen *et al*. (1954) and determined by ascorbic acid molybdenum blue method according to Jackson (1973).
- **Available potassium content (mg/kg):** available K extracted by ammonium acetate (1N of pH 7.0) and determined by flame photometry according to Jackson (1973).
- **DTPA-extractable micronutrients:** Ten grams of air-dried soil sample shaken with 20 ml of extracting solution (0.005 M DTPA + 0.01 M calcium chloride + 0.1 M TEA, pH 7.3) for two hours. The soil suspension filtered using Watman No. 42 filter paper and the contents of Fe, Mn, Cu and Zn measured by atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

El-Salam Canal irrigation water

Chemical analysis data of the applied irrigation water presented in Table (3). It is clear that such water having pH value of 7.23, which mean that it enriched with soluble alkaline ions. It is also having EC value of 2.60 dS/m and SAR value of 5.75, which mean that, it is in the safe side (less than 10) according to Ayres and Westcot (1985).

Table (3). Chemical analysis data of the applied irrigation water

Parameters	values
pH	7.23
EC (dS/m)	2.60
Soluble cations(me/l)	
Na^{+}	8.20
K^{+}	3.50
Ca^{++}	13.90
Mg^{++}	0.43
Soluble anions(me/l)	
CO_3^{--}	0.00
HCO_3^{-}	6.00
Cl^{-}	15.20
SO_4^{--}	4.80
SAR	5.75
MAR	29.91
SSP (%)	53.40
ESP (%)	6.73
PI	0.64
KR	1.19

RESULTS and DISCUSSION

1. Effect of olive mill wastewater and natural conditioners on the tested soil physical properties:

Data in Table (4) illustrated the effect of the applied soil amendments on some physical properties of the soil surface layer. There are no significant differences between treatments on soil bulk density (BD). It can notice significant differences in soil saturated hydraulic conductivity (Ks) and Mean weight diameter (MWD) with LSD equal to 16.82 and 0.0368, respectively. The combined treatment (Olive mill wastewater + Potassium feldspar + Farmyard manure) was the best in this concern, where it showed the lowest Ks value (12.8 cm/day) and the highest MWD value (0.42 mm). Geometric mean diameter (GMD) and Rate of disintegration conducted slight significant differences with LSD 0.0301 and 0.0228, respectively. In addition, the combined treatment (Olive mill wastewater + Potassium feldspar + Farmyard manure) showed the highest GMD value (0.33 mm). The structure coefficient (Cr), Permeability Index (PI) and Kelley’s ratio (Kr) showed a non-significant difference with LSD equal to 0.40, 0.16 and 0.67, respectively. The combined treatment (Olive mill wastewater + Potassium feldspar + Farmyard manure) showed the highest Cr value (1.90), while it showed the lowest values in PI and Kr equal (0.51 and 0.55), respectively. Hunt and Gilkes (1992) reported that, for optimum movement of air and water through the soil, it is generally desirable to have soil with a low bulk density (<1.5 g/cm^3).

With respect to the physical properties of soil subsurface layer (Table 5), it can be notice that all the studied parameters took the same trends previously mentioned for soil surface layer, except that Ks showed slight significant differences and Rate of disintegration showed non-significant.

Table (4). Some physical properties for surface layer of the studied soil as affected by the applied soil conditioners

Treatments	BD (g/cm^3)	K_s (cm/day)	MWD (mm)	GMD (mm)	Cr	Rate of disintegration	Pi	Kr
Control (T1)	1.56	78.17	0.34	0.29	1.42	0.023	0.70	1.28
OMWW (T2)	1.56	30.87	0.33	0.29	1.43	0.058	0.69	0.98
K- Feldspar (T3)	1.58	54.23	0.41	0.32	1.76	0.044	0.73	1.29
FYM (T4)	1.45	22.67	0.36	0.30	1.70	0.047	0.59	1.10
OMWW+K- Feldspar(T5)	1.56	45.37	0.41	0.33	1.85	0.069	0.59	0.60
OMWW + FYM (T6)	1.55	34.33	0.37	0.31	1.77	0.033	0.63	0.89
K-Feldspar + FYM (T7)	1.55	30.60	0.39	0.32	1.71	0.039	0.64	1.04
OMWW+ K-Feldspar+ FYM (T8)	1.53	12.80	0.42	0.33	1.90	0.044	0.51	0.55
LSD(0.05)	0.12^{ns}	16.82**	0.04**	0.03*	0.40^{ns}	0.023*	0.16^{s}	0.67^{ns}

**: significant difference at 0.01 *: significant difference at 0.05 ns: non-significant

Table (5). Some physical properties for subsurface layer of the studied soil as affected by the applied soil conditioners

Treatments	BD (g/cm3)	Ks (cm/day)	MWD (mm)	GMD (mm)	Cr	Rate of disintegration	Pi	Kr
Control	1.57	110.93	0.32	0.27	1.18	0.071	0.70	1.43
OMWW	1.56	36.47	0.33	0.28	1.31	0.039	0.70	0.97
K- Feldspar	1.58	79.00	0.37	0.30	1.49	0.039	0.75	1.19
FYM	1.44	45.80	0.35	0.29	1.51	0.047	0.66	1.11
OMWW+K- Feldspar	1.56	69.83	0.38	0.31	1.56	0.065	0.71	1.05
OMWW+ FYM	1.55	34.93	0.35	0.29	1.52	0.034	0.72	1.32
K-Feldspar + FYM	1.55	45.17	0.38	0.31	1.54	0.029	0.70	1.26
OMWW+K-Feldspar+ FYM	1.53	27.10	0.40	0.32	1.69	0.030	0.65	0.95
LSD(0.05)	0.12ns	0.40*	0.03**	0.02*	0.31ns	0.03ns	0.14ns	0.63ns

The OMWW significantly increased the water retention capacity of the soils in all treatments (Table 6). This effect can be notes from the shape of the WRC, primarily in the low suction range. The high organic matter content in OMWW significantly improved the soil water-holding capacity, despite significantly reducing the large macro pore percentage. Table (6) shows the soil moisture constants for all treatments. The significant reduction of large soil pores found with OMWW amendment because of the higher organic matter and salt content of these liquid wastes, which blocked large-sized pores (Mahmoud *et al*., 2010). It is also apparent that fluctuation in soil-water retention capacity among different treatments resulted from the aggregation effects of OMWW application on pore size rather than from other factors; hence, this fluctuation mainly affected by soil structure (Gharaibeh *et al*., 2007).

Table (6). The soil moisture constants as affected by treatments

Treatments	Surface layer 0 – 30 cm			Subsurface layer 30 – 60 cm		
	θ_r cm^3/cm^3	θ_{fc} cm^3/cm^3	θ_s cm^3/cm^3	θ_r cm^3/cm^3	θ_{fc} cm^3/cm^3	θ_s cm^3/cm^3
Control	0.018	0.107	0.339	0.017	0.104	0.339
OMWW	0.022	0.131	0.352	0.020	0.103	0.352
K- Feldspar	0.025	0.168	0.404	0.021	0.155	0.404
FYM	0.038	0.183	0.419	0.035	0.127	0.419
OMWW+K- Feldspar	0.030	0.159	0.355	0.021	0.118	0.355
OMWW+ FYM	0.041	0.205	0.469	0.032	0.146	0.469
K-Feldspar + FYM	0.042	0.198	0.456	0.035	0.127	0.456
OMWW+ K-Feldspar+ FYM	0.043	0.210	0.540	0.052	0.174	0.540
LSD (0.05)	0.011**	0.037**	0.076**	0.011**	0.042*	0.076ns

Table (7) show the available water for all treatments in surface and subsurface layers. The treatment T8 (OMWW+ K-Feldspar+ FYM) illustrated the highest available water content in the surface and subsurface layers, which equal to 17.03% and 13.16 cm/100 cm, respectively. Avoiding environmental seriousness and producing good quality crops requires utilizing natural byproducts, which became necessity. One way of improving the quality of applied wastes is composting, which yields an excellent product due to the accumulation of humus as substances produced from the biochemical process that takes place during composting (Rivero *et al*., 2004).

Table (7). Available water as affected by treatments in surface and subsurface layers

Treatment	Available water (cm/100 cm depth)	
	Surface layer	Subsurface layer
Control	8.85	8.77
OMWW	10.88	8.30
K- Feldspar	14.30	12.00
FYM	12.84	9.80
OMWW + K- Feldspar	12.90	9.27
OMWW + FYM	16.45	10.38
K-Feldspar + FYM	15.51	7.56
OMWW+ K-Feldspar + FYM	17.03	13.16
LSD(0.05)	3.29**	4.01*

2. Effect of olive mill wastewater and natural conditioners on the tested soil chemical properties:

2.1. Soil pH, EC and soluble ions

Data presented in Tables (8 and 9) showed that the soil pH values ranged between 7.14 to 7.92 and 7.0 to 7.8 in surface and subsurface layers of the investigated soil respectively. It is clear that the application of all treatments reduced the soil pH values where the lowest value was associated with farmyard manure and OMWW treatments. This reduction may be due to the various acids or acid-forming compounds released from the added organic material.

Regarding EC values, it is clear that remarkable changes were obtained due to the applied treatments, where the variations not more than a unit of dS/m. In addition, the values of soil salinity lie in slightly to moderately salinity classes according to Richards (1954). The lowest EC value obtained with Potassium feldspar treatment as it reached 1.05 and 0.94 dS/m for surface and subsurface layers of the investigated soil, respectively. The positive effect of Potassium feldspar on EC values reflects its role in improving physical properties of the investigated soil as found in this study (Tables 8 & 9), therefore salts of soil would easily leached out. Rinaldi *et al.* (2003) reported that soil application of OMW could increase soil electrical conductivity. Therefore, periodically monitoring of soil salinity (EC) and developing a proper irrigation management strategies are required to minimizes the adverse effects of salt accumulation on soil quality and plant growth (Azam *et al*., 2002). Data in the same tables also indicate that the soluble soil cations and anions favorably affected by all the applied treatments. The application of the potassium feldspar treatment showed the highest reduction in both soluble Na+ and soluble Cl- values compared with the other treatments. As the decrement rate of such values under the control reached (19.57, 15.28 %) and (39.01, 13.72 %) for surface and subsurface layers of the investigated soil respectively.

2.2. Total calcium carbonate and organic matter content

Data in Tables (8 and 9) indicated that soil total calcium carbonate content favorably affected by all the applied treatments and the combined treatment (Olive mill wastewater + Potassium feldspar + Farmyard manure) was the best treatment. The rate of decrement under the control due such treatment reached 52.81 and 15.18% for surface and subsurface layers of the investigated soil, respectively. The amendments application remarkably increased soil organic matter content as compared to the control treatment. The highest organic matter values obtained with the combined treatment of (Olive mill wastewater + Farmyard manure) as the rate of increment over the control reached 2700 and 2675 % for soil surface and subsurface layers respectively. The positive effect of such treatment on increasing soil organic matter content may be due to the higher organic carbon content in these materials, Table (2). These results are in a good agreement with those obtained by Speir et al. (2004) who found that the application of organic amendments led to increase in the total organic carbon of soil.

Table (8). Some chemical properties for surface layer of soil as affected by the applied conditioners

Treatments	pH	EC dS/m	Soluble Cations (me/l)				Soluble anions (me/l)			CaCO3 (%)	OM (%)
			Ca	Mg	Na	K	HCO3	CL	SO4		
Control	7.71	1.28	2.14	3.12	7.05	0.49	2.85	7.26	2.70	12.19	0.11
OMWW	7.41	1.16	3.60	1.94	5.35	0.72	4.85	5.55	1.21	12.19	0.7967
K- Feldspar	7.94	1.05	3.37	1.14	5.67	0.32	2.96	6.18	1.37	9.527	0.12
FYM	7.14	2.38	6.14	2.87	9.92	4.92	2.19	10.06	11.59	8.193	2.4533
OMWW+K- Feldspar	7.75	1.39	4.77	1.73	3.90	3.50	4.98	7.58	1.35	9.903	0.3133
OMWW+ FYM	7.43	2.47	4.86	5.72	9.32	4.76	10.50	9.78	4.39	6.663	3.0867
K-Feldspar+ FYM	7.33	2.24	6.35	1.75	8.37	5.98	8.11	9.95	4.39	7.05	2.5333
OMWW+K-Feldspar + FYM	7.20	2.39	7.39	4.08	5.93	6.50	11.13	9.06	3.72	5.713	2.77
LSD(0.05)	0.22**	0.68**	2.27*	1.88*	5.89ns	2.44**	2.43**	3.99ns	2.28**	3.21*	0.65**

Table (9). Some chemical properties for subsurface layer of soil as affected by the applied conditioners

Treatments	pH	EC dS/m	Soluble Cations (me/l)				Soluble anions (me/l)			CaCO3 (%)	OM (%)
			Ca	Mg	Na	K	HCO3	CL	SO4		
Control	7.62	1.42	2.63	3.15	8.05	0.37	4.64	5.76	3.79	8.76	0.08
OMWW	7.29	1.03	2.95	1.91	4.68	0.70	4.07	5.20	0.98	12.38	0.42
K- Feldspar	7.87	0.94	2.82	1.38	4.91	0.28	3.47	4.97	0.96	10.29	0.10
FYM	7.04	1.94	5.22	3.05	9.06	2.06	5.98	7.17	6.25	7.05	1.74
OMWW+K- Feldspar	7.59	1.21	3.97	1.41	5.70	1.02	4.65	6.18	1.27	8.00	0.16
OMWW + FYM	7.34	2.50	5.43	3.71	11.78	4.08	11.27	10.31	3.42	8.76	2.22
K-Feldspar + FYM	7.22	1.88	4.31	3.24	9.41	1.87	6.52	8.95	3.36	10.67	2.06
OMWW+K-Feldspar +FYM	7.12	2.19	5.42	4.80	9.68	2.00	9.96	8.49	3.46	7.43	1.82
LSD(0.05)	0.20**	0.53**	1.79*	2.22*	3.64*	1.91*	2.27**	3.27*	3.05*	7.52ns	0.37**

Magnesium Adsorption Ratio (MAR) and Soluble Sodium Percentage (SSP) showed slight significant differences with LSD 21.851 and 17.951 for the surface layer, while they showed non-significant differences for the subsurface layer with LSD 26.511 and 12.991, respectively. The control treatment showed the highest percentages for both layers for MAR and SSP. Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP) showed non-significant differences for the surface layer with LSD 2.80 and 4.17, respectively, and the same for a subsurface layer but different LSD values (2.0722 and 3.0859), respectively. For the surface layer, the highest percentages occurred with T4 for SAR and ESP (4.68% and 5.7%), while the lowest percentages occurred with T5 (2.17% and 1.96%), respectively. For subsurface layer, T2 showed the lowest percentages for SAR and ESP 3.01% and 3.21%, and T6 showed the highest percentages (5.57% and 7.02%), respectively. Table (10) represent SAR, MAR, SSP and ESP analysis for surface and subsurface layers, respectively. Lopez-Pineiro *et al*. (2008) reported that using olive mill wastewater as an organic amendment decrease the negative environmental; enhance soil quality and agronomic limitations of these soils.

Table (10). Influence of olive mill wastewater and the natural conditioners on some chemical properties of the studied soil for surface and subsurface layers

Treatments	Surface layer				Su-surface layer			
	SAR	MAR (%)	SSP (%)	ESP (%)	SAR	MAR (%)	SSP (%)	ESP (%)
Control	4.22	59.97	53.35	5.01	4.79	54.44	53.43	5.87
OMWW	3.23	36.11	46.32	3.53	3.01	38.61	45.43	3.21
K- Feldspar	3.81	26.39	54.09	4.41	3.40	31.67	52.44	3.79
FYM	4.68	32.07	41.16	5.70	4.46	35.81	47.55	5.37
OMWW + K- Feldspar	2.17	27.14	27.90	1.96	3.46	26.55	46.90	3.89
OMWW + FYM	4.09	52.99	38.11	4.82	5.57	39.02	46.64	7.02
K-Feldspar + FYM	4.18	21.20	34.67	4.96	4.86	42.99	50.14	5.96
OMWW+ K-Feldspar + FYM	2.54	36.15	24.25	2.52	4.29	47.08	44.24	5.12
LSD(0.05)	2.80ns	21.85*	17.95*	4.17ns	2.07ns	26.51ns	12.99ns	3.08ns

2.3. Available nutrient contents

Data in Tables (11 and 12) indicate the effect of the applied amendments on available nutrients of soil surface and subsurface layers. The results showed significant differences for all the rated nutrients. With respect to increasing the availability of N, P and K, it is clear that the combined treatment (Potassium feldspar + Farmyard manure) was the best in this concern. As the values of such elements reached (420 and 294 mg/kg), (188 and 139 mg/kg), (558 and 424 mg/kg) for N, P, K in the surface and subsurface layers, respectively. Farm manure increased P and K content in soil significantly while it had not effect on N content (Iqbal *et al*., 2005). Data in the same tables indicated that the available Fe, Mn, Zn and Cu in soil increased by the application of all the studied experimental treatments to the soil. The highest rate of increment in such elements was associated with the combined treatment (Olive mill wastewater + Potassium feldspar + Farmyard manure) as the rate of increment over the control reached (617.96 and 579.84 %), (884 and 735.33 %), (661.22 and 272.5 %), (520 and 600 %) for Fe, Mn, Zn, Cu in soil surface and subsurface layers respectively. The positive effect of the applied amendments on increasing the availability of all these nutrients may be due to the higher initial content of these nutrients in the applied amendments or due to its role in decreasing soil pH values Table (4). This reduction in soil pH increased the availability of soil nutrients, especially the micronutrients for the cultivated plant. OMWW and FYM contain nutrients and other compounds that might be beneficial to the soil fertility and productivity (Belaqziz *et al*., 2008; L´opez-Pi˜neiro *et al*., 2011). This is particularly important for the soil of the arid and semi-arid regions where low fertility, low nutrient availability, and productivity as well as low microbial activity and microbial biomass levels characterize the soil. This is due to low content of organic matter and low level of essential nutrients for the plant growth. Furthermore, soils of the semi-arid region are vulnerable to erosion and degradation due to poor soil structure because of lower organic matter content (Zhang *et al*., 2014).

Table (11). Available nutrients content in surface layer of the studied soil as affected by the applied conditioners

Treatments	Available macro-nutrients (mg/kg)			Available micro-nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
Control	252.00	14.90	68.00	1.67	1.75	0.49	0.055
OMWW	317.30	23.60	106.00	1.67	6.87	0.55	0.095
K- Feldspar	308.00	13.70	69.33	1.72	3.03	0.54	0.059
FYM	392.00	180.67	499.33	6.35	14.69	2.40	0.428
OMWW + K- Feldspar	317.30	28.27	179.33	4.22	9.17	0.75	0.136
OMWW + FYM	420.00	188.00	558.00	10.08	13.06	2.40	0.400
K-Feldspar + FYM	382.70	177.03	616.67	5.86	13.93	1.71	0.246
OMWW+ K-Feldspar + FYM	420.00	175.47	615.33	11.99	17.22	3.73	0.341
LSD(0.05)	36.43**	28.32**	208.56**	0.81**	2.61**	0.34**	0.10**

Table (12). Available nutrients content in subsurface layer of the studied soil as affected by the applied conditioners

Treatments	Available macro-nutrients (mg/kg)			Available micro-nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
Control	238.00	13.83	64.67	1.29	1.67	0.40	0.06
OMWW	280.00	18.40	88.00	1.49	5.49	0.58	0.09
K- Feldspar	280.00	10.53	63.33	1.68	2.33	0.48	0.08
FYM	317.33	136.27	256.00	4.14	11.19	1.41	0.25
OMWW + K- Feldspar	275.33	21.53	102.67	3.78	7.76	0.70	0.17
OMWW + FYM	294.00	139.30	424.00	8.01	10.52	1.65	0.38
K-Feldspar + FYM	303.33	121.57	258.00	4.08	11.46	1.54	0.32
OMWW+ K-Feldspar + FYM	298.67	132.30	304.00	8.77	13.95	1.49	0.42
LSD(0.05)	31.48*	31.99*	125.12**	2.23**	3.80**	0.34**	0.18*

CONCLUSION

Olive mill wastewater (OMWW) contains many nutritive elements, which could improve the agricultural production. The OMWW considered as a fertilizer material for crop cultivation. Furthermore, OMWW does not present any risks for the soil salinity; in addition, it generates an improvement of some physical and chemical soil properties.

The results of this study confirmed the ability of olive mill wastewater when used alone to improve the properties of sandy soil and compensate the deficiency of its nutrients. Moreover, when the soil treated with mixtures of olive mill wastewater and potassium feldspar or farmyard manure gave the highest reduction in salinity. It indicated that the application of the combined treatment (Olive mill wastewater + Potassium feldspar + Farmyard manure) resulted in the best treatment. Therefore, the application of such treatment to sandy soils is necessary to improve its physical and chemical properties. The application of olive mill wastewater to a sandy soil can used as an economic and simple alternative for disposal methods of such material. The use of each material in the present study is easily producible, biodegradable, and less expensive and cause no environmental hazards to human health. These products will be ecologically safe and culturally more acceptable among farmers.

REFERENCES

Abd-El aziz, M.S. and A.A. Mousa (2017). Utilization of olive mill waste liquids as soil amendment in northwestern coast (Matrouh area)-Egypt. Annals of Agric. Sci., Moshtohor, 55(4): 989-1001.

Abu Khayer, M.D., M. B. Chowdhury, C.S. Akratos, D.V. Vayenas and S. Pavlou (2013). Olive mill waste composting: A Review. International Biodeterioration& Biodegradation 85,108-119.

Al-Widyan, M. I., N. Al-Abed and H. Al-Jalil (2005). Effect of composted olive cake in soil physical properties. Commun. Soil Sci. Plant Anal. 36 (9-10), 1199-12120

Ayers, R.S. and O. W. Westcot (1985). Water quality for agriculture irrigation and drainage. Paper No 29, FAO, Rome.

Azam, F., M¨uller, C., Weiske, A., Benckiser, G., and Ottow, J. (2002). Nitrification and denitrification as sources of atmospheric nitrous oxide – role of oxidizable carbon and applied nitrogen. Biology and Fertility of Soils, 35(1), 54–61.

Belaqziz, M., Lakhal, E.K., Mbouobda, H., & El-Hadrami, I. (2008). Land spreading of olive mill wastewater: effect on maize (zea maize). Journal of Agronomy and Crop Science, 7: 297–305.

Carter, M. R. and E. G. Gregorich (2008). Soil sampling and methods of Analysis. Second Edition. Canadian Soc. Soil Sci., Boca Raton, FL: CRC Press, 1264 pages.

Chaari, L ,N. Elloumi ,and K. Gargouri (2014). Evolution of several soil properties following amendment with olive mill wastewater .Desalin . Water Treat. 52(10-12): 2180-2186.

Di Bene, C., E. Pellegrino, and M. Debolini (2013). Short- and long-term effects of olive mill wastewater land spreading on soil chemical and biological properties. Soil Biol. Biochem., 56: 21-33.

Dimoyiannis, D. (2009). Seasonal soil aggregate stability variation in relation to rainfall and temperature under Mediterranean conditions. Earth Surfaces, Processes and Landforms, 34: 860-866.

Domenico, P.A.and F.W. Schwartz (1990). Physical and Chemical Hydrogeology. John Wiley & Sons, Inc., New York, NY.

Eaton, F.M. (1950). Significance of carbonates in irrigation water. Soil Sci., 69: 123-133.

Gharaibeh, M. A., N. I. Eltaif, and B. Al-Abdullah (2007). Impact of field application of treated wastewater on hydraulic properties of vertisols. Water Air Soil Pollut 184:347–353

Hunt, N., and R. Gilkes (1992). Farm Monitoring Handbook. The University of Western Australia, Nedlands, WA.

Iqbal, M., Ul-Hassan, A., Rizwanullah, M., Ali, A., (2005). Nutrient (N, P and K) Content in Soil and Plant as Affected by the Residual Effect of Tillage and Farm Manure. Int. J. Agri. Biol. 7 (1), 50-53.

Jackson, M.L. (1973). Soil chemical analysis, Prentice Hall of India Private Limited, New Diehl.

Jarboui, R., F. Sellami, A. Kharroubi, N. Gharsallah and E. Ammar (2008). Olive-mill wastewater stabilization in open-air ponds: impact on clay-sandy soil. Bioresiurce Tchnology 99, 7699-7708.

Kavvadias, V., M.K. Doula, K. Komnitsas and N. Liakopoulou (2010). Disposal of olive oil mill waste in evaporation ponds: effects on soil properties. Journal of Hazardous Materials 182, 144-155.

Kelly, G. A. (1963). A theory of personality, Norton, Nueva York,

Klute, A. (ed), (1986). Methods of Soil Analysis. Part 1. Agronomy Monograph. 9. American Society of Agronomy and Soil Science Society of America, Madison, WI.

Lindsay, W.L. and W.A. Norvell (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J., 42: 421-428.

Lopez-Pineiro, A., J. Fernandez.; A. Albarran., J.M. Rato Nines and C. Barreto (2008). Effects of de-olied tow-phase olive mill waste on Mediterranean soils and the wheat crop. Soil Science Society of America Journal 72, 424-430.

Lopez-Pineiro, A., Albarr´an, A., Nunes, J.M.R., Pe˜na, D., and Cabrera, D. (2011). Cumulative and residual effects of two-phase olive mill waste on olive grove production and soil properties. Soil Science Society of America Journal, 75(3): 1061–1069.

Mahmoud, M., M. Janssen, N. Haboub; A. Nassour and B. Lennartz (2010). The impact of olive-mill wastewater application on flow and transport properties in soils. Soil & Tillage Research 107, 36-41.

Mechri, B., F. Ben Mariem, M.Baham, S. Ben Elhadj and M. Hammami (2008). Change in soil properties and the soil microbiological community following land spreading of olive mill wastewater effects olive trees key physiological parameters and the abundance of arbuscular mycorrhizal fungi. Soil Biochemistry 40, 152-161.

Mekki, A., Dhouib, A., & Sayadi, S. (2013). Effects of olive mill wastewater application on soil properties and plants growth. International Journal of Recycling of Organic Waste in Agriculture, 2(1), 15.

Montemurro, F., Diacono, M., Vitti, C., Ferri, D., (2011). Potential Use of Olive Mill Wastewater as Amendment: Crops Yield and Soil Properties Assessment. Communications in Soil Science and Plant Analysis 42, 2594–2603

Olsen S.R., C.V. Cole., F.S. Watanabe and L.A. Dean (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Washington, USDA Circular 939, U.S. Government Printing Office, 1–19.

Paredes C.; J. Cegarra; M. P. Bernal and A. Roig (2005). Influence of olive mill waste waterin composting and impact of the compost on a Swiss chard crop and soil properties. Environ Int 31:305 – 312.

Peach, K. and Tracey, M. (1956). Modern methods of plant analysis. Springer-Verlag, berlin.

Pieri, C. (1992). Fertility of soils. A Future for Farming in the West African Savannah. Springer, Berlin, 348 pp.

Richards, L.A. (1954). Diagnosis and improvement of saline and alkali soils, U.S.Dept., Agric., Handbook 60.

Rinaldi, M., G. Rana, and M. Introna (2003). Olive-mill wastewater spreading in southern Italy: effects on a durum wheat crop. Field Crops Research, 84(3): 319–326.

Rivero, C.; T. Chirenje; Q. L. Ma and G. Martinez (2004). Influence of compost on soil organic matter quality under tropical conditions. Geoderma, 123: 355–361.

Roig, A.; M.L. Cayuela and M.A. Sanchez-Monedero (2006). An overview on olive mill wastes and their volorisation methods. Waste management 26, 960-969.

Saadi, I.; Y. Laor.; M. Raviv and S. Medina (2007). Land spreading of olive mill wastewater; effects on soil microbial activity and potential phytotoxicity. Chemosphere 66, 75-83.

Shirazi, M.A. and L. Boersma (1984). A unifying quantitative analysis of soil texture. Soil Sci. Soc. Am. J., 48:142–147.

Speir, T., J. Horswell, A. Schaik, R. Mclaren and G. Fietje (2004). Composted biosolids enhance fertility of sandy loam soil under dairy pasture. Biology and Fertility of Soil, 40 (5): 349-358.

van Genuchten, M.Th. (1980). A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J., 4:892-898.

van Genuchten, M.Th., F.J. Leij, and S.R. Yates (1991). The RETC Code for Quantifying the Hydraulic Functions of Unsaturated Soils, Version 1.0.

EPA Report 600/2-91/065, U.S. Salinity Laboratory, USDA, ARS, Riverside, California.

Wahba, M.M. and Kh. M. Darwish (2008). Improving the availability of potassium from feldspar in sandy and calcareous soils, Egypt. Egypt. J. Soil Sci. 48(3), 393-398.

Zhang, P., Wei, T., Jia, Z., Han, Q., Ren, X., and Li, Y. (2014). Effects of straw incorporation on soil organic matter and soil water-stable aggregates content in semiarid regions of northwest china. PLoS ONE, 9(3), e92839.

الملخص العربي

الاستفادة من المخلفات السائلة لمعاصر الزيتون وبعض المحسنات الطبيعية لتحسين خواص التربة الرملية

على خليل عبد الحميد خليل[١] جمال عبد الناصر خليل[٢] وفاء حسن محمد على[٢]
عبد الله أبو هاشم عبد الله علي[١]

[١] قسم صيانة الأراضي شعبة مصادر المياه والأراضي الصحراوية – مركز بحوث الصحراء بالمطرية – القاهرة

[٢] قسم الأراضي والكيمياء الزراعية – كلية الزراعة سابا باشا – جامعة الاسكندرية

أجريت تجربة ميدانية في قرية جلبانة، جنوب القنطرة شرق، شمال سيناء، مصر خلال موسم ٢٠١٦/٢٠١٧. الهدف من هذه الدراسة هو تقييم دور المخلفات السائلة لمعاصر الزيتون وبعض محسنات التربة الطبيعية في تحسين خصائص التربة الرملية. وقد اخذ في الاعتبار دور محسنات التربة الطبيعية مثل الفلسبار وسماد المزرعة. وكان النبات المزروع بنجر السكر وقد اضيفت محسنات التربة الثلاثة المستخدمة بشكل فردى ومجتمعة وكان التصميم الإحصائي للتجربة قطاعات كاملة العشوائية حيث شملت التجربة ثمانية معاملات مع ثلاث مكررات وكانت المعاملات كالتالي الكنترول بدون أي اضافات والمعاملة الثانية اضافة مخلفات معاصر الزيتون السائلة بمعدل (١٢.٦م٣/فدان) والمعاملة الثالثة اضافة فلسبار البوتاسيوم بمعدل(١٥ طن/فدان) والمعاملة الرابعة اضافة سماد المزرعة بمعدل(١٥ طن /فدان) والمعاملة الخامسة خلط مخلفات معاصر الزيتون السائلة مع فلسبار البوتاسيوم واضافتها والمعاملة السادسة خلط مخلفات معاصر الزيتون السائلة مع سماد المزرعة والمعاملة السابعة خلط فلسبار البوتاسيوم مع سماد المزرعة واضافتهم والمعاملة الثامنة خلط مخلفات معاصر الزيتون السائلة مع فلسبار البوتاسيوم مع سماد المزرعة بنفس النسب السابقة. وقد اظهرت نتائج هذه الدراسة أن تطبيق جميع المعاملات التي تمت دراستها أدى إلى انخفاض قيم الاس الهيدروجيني وقيم معامل التوصيل الكهربي ، في حين زاد محتوى المادة العضوية وزادت محتوى العناصر من النيتروجين والفوسفور والبوتاسيوم ،وكانت المعاملة الأكثر

فاعلية في هذه الدراسة هي المعاملة الثامنة (مخلفات معاصر الزيتون السائلة + البوتاسيوم الفلسبار + سماد المزرعة)، لذلك فإن اضافة مثل هذه المعاملة على التربة الرملية ضروري لتحسين خصائصه ورفع إنتاجيته، كذلك يمكن استخدام مخلفات معاصر الزيتون السائلة كمحسن للتربة الرملية كبديل اقتصادي وبسيط لطرق التخلص من هذه المواد. استخدام كل مادة في هذه الدراسة سهل الإنتاج وقابل للتحلل البيولوجي وأقل تكلفة ولا يسبب أي مخاطر بيئية على صحة الإنسان.