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Utilization of olive mill waste liquids as soil amendment in northwestern coast (matrouh area) – Egypt

M. S. Abd-El aziz, and A. A. Mousa
Soil conservation dept., desert research center, cairo, Egypt
*Corresponding author: azmy15@yahoo.com

Abstract

The reuse of industrial wastes and its by-products such as, olive mill waste (OMW) is beneficial to prevent or at least to reduce the environmental problems, where uncontrolled disposal of OMW is becoming a serious environmental problem. OMW is the main product generated by the olive oil extraction process, especially in the areas where olive cultivation is frequent, such as North Western Coast Zone of Egypt (NWCZ). Therefore, a field study was carried out during two winter seasons of 2015/2016 and 2016/2017 at Matrouh area, NWCZ of Egypt. Two field experiments were conducted for olive trees and corn plants, where each experiment included five treatments with four replication. The treatments were control (without any soil conditioner application, **C**), olive mill wastewater (OMW) at the rate of $20m^3.fed^{-1}$, (**O**), compost farmyard manure FYM with OMW at the rate of $10t.fed^{-1}$, (**FO**), compost FYM at the rate of $10t.fed^{-1}$(**F**) and compost FYM with effective microorganisms (EM) at the rate of $10t.fed^{-1}$(**FEM**). Data illustrate that the soil of the experimental site is approximately shallow, light soil textural class, calcareous, non-saline, and poor in organic matter and CEC and consequently low in fertility. The differences in pH values for the different cultivation types that used the same amendments are very low and it can be avoid them. The percentage decrement is reach to 41, 60, 52 and 67% under olive cultivation and 40, 47, 44 and 53% under corn cultivation, for **O**, **FO**, **F** and **FEM** treatment, respectively. The average percentage increment of available water is 8, 39, 23 and 50% for **O**, **FO**, **F** and **FEM** treatments, respectively. Using **FO** or **FEM** caused decrease bulk density compared to using **O** only by about of 11 and 16%, respectively. Regardless the crop type, the efficiency of the used OMW and compost in increasing organic matter content can be arranged in the following order: **FEM** > **FO** > **F** > **O**, respectively. The levels of total nitrogen, exchangeable potassium and available phosphorus for the soils that treated by OMW amendments is higher than that for the initial soil. Regardless crop type, the average increment percentage for Fe, Mn, Zn and Cu varied from 148 to 250%, from 43 to 90%, from 97 to 142% and from 38 to 118%, for **F** and **FEM** treatments, respectively. The percentage increment of olive fruits yield reached 57, 38, 32 and 19% for **FYM**, **FO**, **F** and **O** treatments, respectively, while, the respective values for corn grains reached 58, 45, 41 and 8%, respectively, as compared to that for traditional cultivation.

The investment ratio for using olive mill wastewater and organic composts with cultivation olive trees and corn crops under rainfed agriculture can be arranged in the following ascending order: **FO** < **FYM** < **F** < **O** treatment, respectively, because of the olive mill wastewater is inexpensive. According to this study, integrated use of olive mill wastewater in organic compost has agricultural, environmental and economically feasibility.

Keywords: olive mill waste (OMW), Effective microorganisms (EM), Olive orchards, Corn plant.

Introduction

Large areas in North Western Coast Zone of Egypt (NWCZ) are subject to degradation processes due to losses of organic matter, which helps maintain aggregate stability, by intensive agricultural. In addition, the farmers under rainfed agriculture did not add any organic farm manure for their farmers. The (NWCZ) is characterizes by cultivation of olive trees depending on the rain that fall in winter season (150 - 200mm). The olive trees cultivation is traditional and expanded rapidly during the last years. Uncontrolled disposal of OMW is becoming a serious environmental problem. Therefore, 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).** Olive mill wastes led to exacerbate the environmental problems in Mediterranean countries. These wastes are highly phytotoxic and contain phenolic compounds, lipids and organic acids. They also contain high percentages of organic matter and a vast range of plant nutrients that could be reused as fertilizers for sustainable agricultural practices, especially potassium, **Roig et al. (2006)** and **Abu Khayer et al., (2013)**. OMW contains organic fraction is composed by sugars, N-compound, organic acids, fats as well as phenols and pectin whish are responsible phototoxic and anti-bacterial effects (**De Ammibale et al; 2006; EL – Hajjouji et al; 2007**). Also never the less, the olive mill wastewater (OMW) contains useful levels of fertilizers such as nitrogen and potassium and can act a source of organic matter (**Cereti et al; 2004; Zenjari et al; 2006**), which could the way for its use in agriculture. OMW application, however, has been to found to significantly affect the soils biological (**Saadi et al., 2007; Mechri et al., 2008**), chemical (**Jarboui et al., 2008; Lopez-Pineio et al., 2008; Kavvadias et al., 2010**) and physical properties. The long-term application of untreated OMW decreases the saturated hydraulic conductivity and increasing the soil disposition to water repellency (**Mahmoud et al., 2010**). The enhanced organic matter content of OMW furthermore increases sorption and degradation processes, and OMW application may therefore retard the mobility of pesticides (**Cox et al., 1997**). The land application of olive oil solid waste has been shown to improve the soil aggregate stability (**Kavdir and Killi, 2008**), because it increases the organic matter content and soil fertility (**Yaakoubi et al., 2010**). **Mahmoud et al., (2012**) reported that the irrigation of OMW for 5 and 15 years has been shown to have distinct effects on the properties of soil aggregates. Both the porosity of the aggregates and the aggregate stability increased with OMW application. This is a consequence of the enhanced organic C content, resulting from residual oil and grease, which binds the soil particles together. By that on the one hand, larger interspaces are created, and on the other hand, stability is increased. These considerations have motivated researches in development of solutions to reduce the polluting effect of OMW. Such as evaporation ponds, physic-chemical, composting process, direct application to agricultural soils as soil amendment and organic fertilizer as solutions for OMW, (**Mekki et al; 2006**).

In recent years, many management options have been proposed for the treatment and valorization of OMW. Most of these methods aim to the reduction of the phytotoxicity in order to reuse it for agricultural purposes, but more recently, other alternative methods have also been proposed. These methods included evaporation in storage ponds in the open, applied directly on soil and composting. The evaporation of OMW produces sludge. **Paredes et al. (2002)** studied the composting process of OMW sludge with maize straw and cotton waste and concluded that this can be an environment friendly alternative to OMW sludge disposal. **Vitolo et al. (1999)** proposed the preparation of a fuel by mixing the solid residue of OMW with olive husk. Another imaginative way of recycling this waste was proposed by **Hytiris et al. (2004);** they investigated the potential of using OMW sludge as an additive for the development of construction materials. **Rinaldi et al. (2003)** applied OMW without pre-treatment on a wheat crop for 3 years and observed some necrotic spots on the leaves and a reduction in secondary stems emergence. However, at harvest no significant differences were observed in grain yield. OMW may reduce the mobility of certain organic compounds in soil. **Kotsou et al. (2004)** verified the OMW suppressiveness against the plant pathogen *Rhizoctoniasolani*, Therefore, its addition prior to planting could be a good prevention method. **Tomati et al. (1995)** found that a fertilizer with a high level of humification and no phytotoxic effects was obtained by composting OMW with wheat straw. **Tomati et al. (1996)** also observed an enhancement of activities in the plant soil system after the addition of OMW compost. The law No. 190/T issued in 2007 by the Ministry of Agriculture in Syria allows the spreading of up to 50 m^3 ha^{-1} OMW from traditional presses and up to 80 m^3 ha^{-1} OMW from modern centrifugal mills; the very same application rates are also permitted, e.g., in Italy (**Giuffrida, 2010**).

The aim of the present work was to study the effect of the addition of EM on the co-composting of OMW determining the dose and the most appropriate moment in order to optimize the performance of the composting process and the quality of the final compost. Finally, the quality of the obtained composts was evaluated through agronomic tests.

Materials and Methods

Olive mill wastewater is obtained from the olive press of the Desert Research Center Station by collecting the liquid and solid wastes together, placing them in half a large barrel, dilution it with water (1:1) and leaving it for two weeks. Then, adding it to the soil at a rate of 20 $m^3.fed^{-1}$. Olive mill wastewater added with the farm residues compost, that collected, cut into small pieces, isolated and covered with a layer of solid waste for the olive presses by (1:1), then wetted with liquid waste for the olive press, well covered by plastic sheet for three months and then added to the soil at a rate of $10t.fed^{-1}$. The compost of the farm residues was done in the same abovementioned way with adding water instead of adding olive mill wastewater, and then it lasts for three months with good coverage by plastic sheet and then added to the soil with rate of $10t.fed^{-1}$. Effective Microorganisms (EM) added with the compost of the farm residues by rate of 4 liters per 2 cubic meters was done by the same abovementioned way.In this method, the diluted EM with water by rate of 1:10 is spray on the farm residues and lasts well covering for three months by plastic sheet. The product compost is called Al-Bokashi compost and then added to the soil at a rate of $10t.fed^{-1}$. Bokashi as a soil conditioner is a Japanese word that means "fermented organic matter". Different samples of the final product of composts were taken before addition on the soil surface for analysis of its characteristics.

The field experiment was conducted during seasons of 2015/2016 and 2016/2017 at the Marsa Matrouh Research Station, Desert Research Center, North Western Coast Zone–Egypt. The two experiments were conducted for olive trees and corn plants in a completely randomized blocks design, where each experiment included 5 treatments with four replicates. The area of experimental plot is 3.5 X 3.5m for the corn experiment. However, for olive experiment, the experimental plot is contained 3 trees with age of 7 years that represented three replicates. The treatments were control (without any soil conditioner application, **C**), olive mill wastewater (OMW) at the rate of $20m^3.fed^{-1}$, (**O**), compost farmyard manure FYM with OMW at the rate of $10t.fed^{-1}$, (**FO**), compost FYM at the rate of $10t.fed^{-1}$(**F**) and compost FYM with effective microorganisms (EM) at the rate of $10t.fed^{-1}$(**FEM**). All amounts of the applied compost were mixed with the upper soil surface depth of 30 cm, especially before three weeks from corn cultivation. At olive experiment, the treatments were added on the soil surface layer in mid-November 2015in the circumference of the olive tree, and then mixed with soil. Olive fruits yield was collected at the end of July 2016 and then weighted. The farm is irrigated by rain and supplementary irrigation through ground tanks and drip irrigation system.

Seeds of corn (*Zea maize L.*,CV. Pioneer 30 K8) at the rate of $10kg\ seeds.fed^{-1}$were planted at April 2016 & April 2017 in rows spaced apart 50cm. At each row, two seeds were placed at 5 cm depth in hills spaced apart 20 cm. Plants were thinned to one plant per hill after 20 days from sowing. Superphosphate at the rate of 200 $kg.fed^{-1}$ (15.5% P_2O_5) was added before sowing. Ammonium nitrate fertilizer was added at the recommended rate of 400 $Kg.fed^{-1}$(33.5% N) through two equal doses. The first one was applied after thinning, while the second one was applied after 15 days later. Potassium sulphate fertilizer was added at rate of 50 $kg.fed^{-1}$(48% K_2O) through two equal doses at the same time of adding nitrogen fertilizer. The other agronomic practices were done as recommended at the appropriate time. Plants were cut at maturity after 120 days from planting. Ears were manually harvested, shelled, and weighed. Biological and grain yields were recorded.

Soil samples from surface and subsurface layers (0 – 50 cm) represented all the treatments were taken before sowing and after harvesting of corn plant. Concerning, olive experiment, the soil samples at the same depths is taken before carry out and after end the experiment. The soil samples is air dried, sieved through 2 mm mesh and analyzed for the following: Particle size distribution was determined by the pipette method (**Piper, 1950**), soil pH using pH meter model Jenway 3510, soil salinity using EC meter model Orion 150A+, soil organic matter content was determined as described by **Jackson (1967)**, total calcium carbonate using Collins Calcimeter **Richards (1954)**, Total N using Kjeldahl method according to **Page et al. (1982)**, available P by the method of **Olsen et al. (1954)** and exchangeable K by flame photometer model ANA-10B according to **Jackson (1973)**. Analysis of water and the applied conditioners were determined by standard methods according to **Black (1983), Page et al. (1982), Cottenie et al. (1982) and AOAC (1995).** The statistical analysis was carried out according to **Snedecor and Cochran (1982).**

Results and Discussion

The results of the investigated soil analysis for some physical and chemical properties are given in **Table 1**. It is clear that the light soil textural class is the dominant in the studied area, i.e. loamy sand, approximately. Therefore, available water content is low and is not more than 8% for soil surface layers, (**Table 1A)**. Water remains in these soils is little at wilting point (<10%) and can cause drought stress to occur during dry periods, especially between storms events. The permeability class for the investigated soil is rapid (6 - 20 $inch.hr^{-1}$) according to **Brady et al. (2008)**, where its value is $6.25m.day^{-1}$. The average soil bulk density is $1.6g.cm^{-3}$, approximately, for soil surface layer up to 50cm. The soil has low content of calcium carbonates, where its value for the soil surface layer (0 -50cm) is 5.7%, **(Table 1B)**. In addition, the data indicate that the soil is non-saline, where its electrical conductivity value is not more than $4dS.m^{-1}$. Thus, this soil is not suffered from sodicity hazards, where the percentage value of SAR and ESP are 2.2 and 1.9%. The CEC value is low and reached to $7.6cmol.kg^{-1}$ for soil surface layer up to 50cm. The soil is poor in organic matter, where its value is 3.5g/kg. From the abovementioned data, it can be conclude that the soil of the experimental site at Marsa Matrouh area is approximately shallow, light soil textural class, calcareous, non-saline, and poor in organic matter and CEC and consequently low in fertility. Therefore, enhancement soil quality under rainfed conditions through using some soil amendments, especially olive–mill waste (OMW) and farmyard manure is very important to achieve the sustainable agricultural development. Also, avoid the serious environmental problems for the uncontrolled disposal of OMW.

Table 1. Physical and chemical properties of the initial soil at the investigated site.

(A):Physical properties

Soil depth (cm)	Particle size distribution (%)				Texture* class	Field capacity (%)	Wilting point (%)	Av. soil water (%)	Bulk density ($g.cm^{-3}$)	Hydraulic conductivity ($m.day^{-1}$)
	Coarse Sand	Fine sand	Silt	Clay						
0 - 60	53.02	28.66	10.14	8.18	LS	17.27	9.48	7.79	1.58	6.25

(B): Chemical properties

Soil depth (cm)	pH	EC ($dS.m^{-1}$)	Soluble cations ($mmolc.L^{-1}$)		O M (g/kg)	$CaCO_3$ (%)	CEC ($Cmol.kg^{-1}$)	SAR (%)	ESP (%)
			$Ca^{++} + Mg^{++}$	Na^+					
0 - 60	7.58	2.51	17.55	6.63	3.50	5.71	7.63	2.21	1.90

* LS Loamy sand

In Matrouh area, the main source of water for supplementary irrigation is the rainwater stored in reservoirs or ground tanks or cisterns. The analysis of irrigation water is shown in (**Table 2)**. Data show that the water salinity is non-saline (EC = 0.77$dS.m^{-1}$). Sodium is the dominant cation, where its value is 3.42$mmolc.L^{-1}$. Chloride is the dominant anion, where its value is 3.41$mmolc.L^{-1}$. The pH value (7.22) indicated that the water is neutral approximately. Therefore, the majority of salt in this water is still in the free-state (sodium and chloride).

Table 2. Chemical composition of the applied irrigation water.

pH	EC ($dS.m^{-1}$)	Soluble cations ($mmolc.L^{-1}$)				Soluble anions ($memolc.L^{-1}$)				SAR (%)
		Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	
7.22	0.77	1.39	2.79	3.42	0.04	-	1.24	3.41	3.00	2.36

Soil conditioners are products that are added to soil led to improve the soil quality. Major problems encountered in the present day agriculture are low soil fertility and inadequate water retention. **Table 3** depicts the properties of soil conditioners, i.e. olive mill wastewater, farmyard manure and Bokashi, that used in this study. Data in **Table 3** illustrate that olive mill wastewater conditioner is acidity (pH = 5.2) as compared to other conditioners. The pH value for compost farmyard manure with olive mill wastewater, farmyard manure and bokashi is natural (7.6 ± 0.2). The applied conditioners are considered moderate saline, where the value of $EC_{(1:5)}$ is 7.6 ± 0.2$dS.m^{-1}$. The applied conditioners had a low bulk density, where its values is 0.54 ± 0.08, a high total organic matter, where the organic matter content is 96 ± 1, and relatively high element nutrients, especially potassium and iron. **Hanafi et al.** (**2010**) reported that olive mill wastes contain 83-96% water, 3.5-15% organics and 0.52% mineral salts. Sugars (18%), N-compounds (0.5-2.4%), organic acids (0.5-1.5%), fats (0.021%), phenols and pectins (11.5%) are organic fractions of olive mill wastes. **Roig et al. (2006)** stated that negative effects are associated with its high mineral salt content, low pH and the presence of phytotoxic compounds, especially polyphenols. Positive effects are related to its high nutrient concentration, especially K, and its potential for mobilizing soil ions.

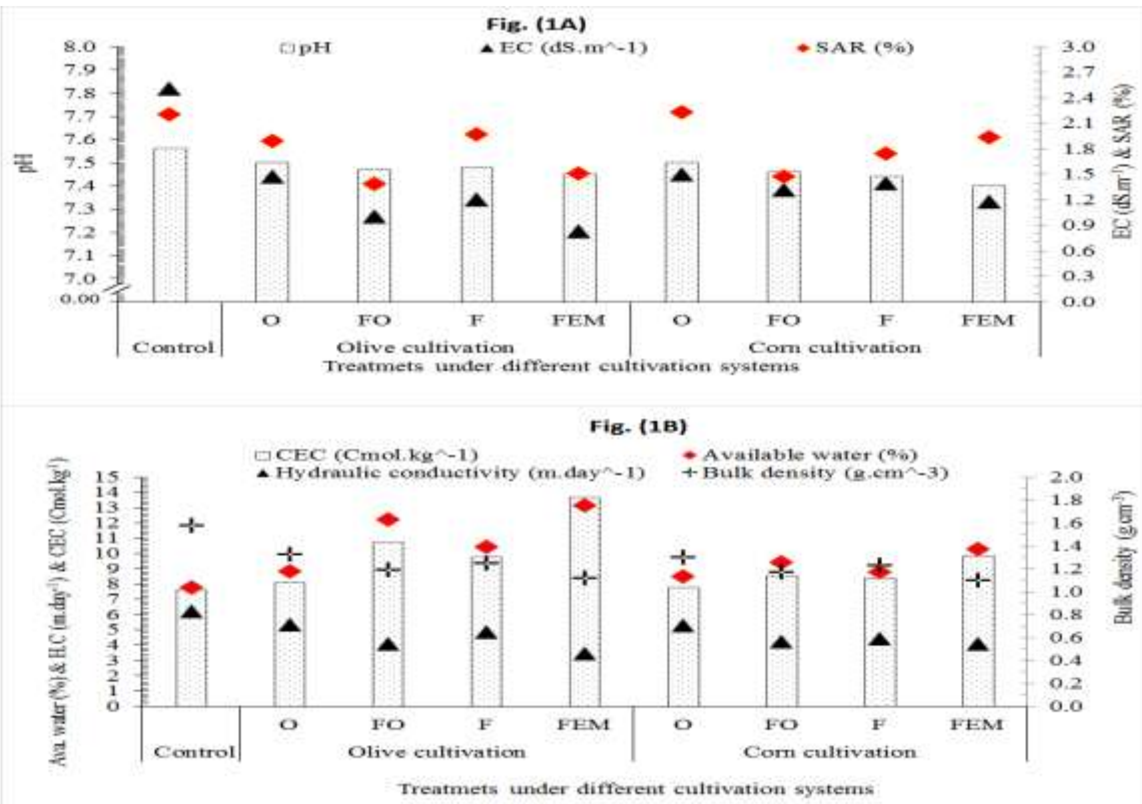
Table 3. Properties of the applied soil conditioners before adding on the soil.

Conditioner	pH (1:5)	EC ($dS.m^{-1}$) (1:5)	O.M (g/kg)	Total macronutrients (%)			Total micronutrients (mg/kg)				Bulk density ($g.cm^{-3}$)	Moisture content (%)
				N	P	K	Fe	Mn	Zn	Cu		
Olive mill wastewater	5.20	7.82	…..	0.38	0.29	15.4	2000	92	36	27.6	…..	…..
Farmyard manure with Olive mill wastewater	7.77	7.75	98.2	0.42	0.61	13.0	686	50	24	15.6	0.62	4.37
Farmyard manure	7.62	7.44	84.5	0.35	0.53	9.5	512	42	22	10.0	0.52	3.24
Bokashi	7.45	7.35	106.4	0.55	0.76	10.2	972	58	44	29.4	0.48	4.96

Effect on Some Soil Properties:

Soil Reaction (pH):

Soil reaction is an indication of the acidity or alkalinity of soil. Data in **Fig. 1A** indicate that the soil pH values for the different applied treatments were relatively lower than that for the initial soil (control treatment). The highest pH value was evident was control treatment (pH = 7.56). The percentage decrement of soil pH values under olive and corn cultivation varied from 0.8 to 2% depending on the type of applied soil amendment. The greatest reduction in soil pH is for the soil treated compost FYM with effective microorganisms (FEM) (pH = 7.40). However, the soil treated with olive mill wastewater (O) has the lower reduction in soil pH value (pH = 7.50). Also, the differences in pH values for the different cultivation types that used the same amendments are very low and it can be avoid them. For example, the soil treated with O amendment and cultivated by olive tree and corn crop had pH value of 7.5. The small reduction in soil pH values is attributed to the high puffer capacity of the soil and the formation of organic and inorganic acids, CO_2 and hydrogen ions (H^+) through the decomposition process of the applied organic amendments in the soil by the soil microbes. In addition, the values associated with compost were low, especially olive mill wastewater and farmyard manure. Also, addition EM solution with farmyard manure led to increase the microbial activity in the soil and consequently accelerate the decomposition the organic materials. A pH between 5.5 and 8.5 is an optimal environment for compost microorganisms (**Mustin, 1987; Das, 2007**). As bacteria and fungi digest OM, they release organic acids. Typically, these organic acids are subjected to further degradation the compost (**Hachicha et al., 2009**). Due to these low pH values reached, the microbial activity was reduced, taking importance the chemical oxidation between the organic substrates contained in the wastes and the organic acids. Because of this, the process shifted from a pure bio-conversion of the wastes to a combination of biological and chemical conversion (**Sanchez-Arias et al., 2008**).



* Treatments, where **C**: Control treatment (without any soil conditioner application),
O: Olive mill wastewater (OMW) at the rate of $20m^3.fed^{-1}$ treatment,
FO:: Compost farmyard manure FYM with OMW at the rate of $10t.fed^{-1}$ treatment,
F: Compost FYM at the rate of $10t.fed^{-1}$ treatment, and
FEM: Compost FYM with effective microorganisms (EM) at the rate of $10t.fed^{-1}$ treatment.

Fig. 1: Effect of the applied conditioners on some physical and chemical properties of the investigated soil.

Electrical Conductivity (EC) & Sodium Adsorption Ratio (SAR):

Electrical conductivity (EC) reflects the degree of salinity in soil, indicating its possible phytotoxic/phyto-inhibitory effects on plant. Electrical conductivity of the saturation soil extracts (EC_e) as affected by all treatments applications are shown in **Fig. 1A**. Data show that the application of OMW or compost decreases the ECe comparing to the control treatment. The EC value of the soils treated by different soil amendments was decreased as compared to that for the initial soil (control treatment), that has EC value of 2.51dS.m^{-1}, **(Fig. 1A)**. However, the lowest EC value of 0.83 and 1.18dS.m^{-1} obtained at FEM treatment cultivated by olive tree and corn crop, respectively. The decrement percentage in the EC value for the soil treated by composts varied from 67 to 40% for soil cultivated by olive tree with FEM and soil cultivated by corn crop with O amendments, respectively. The percentage decrement is reach to 41, 60, 52 and 67% under olive cultivation and 40, 47, 44 and 53% under corn cultivation, for W, O, FO, F and FEM treatment, respectively. Consequently, under cultivation of olive tree or corn crop, using FEM conditioner has the greatest effect on reducing EC values (av. EC = 1dS.m^{-1}), followed by FO (av. EC = 1.17dS.m^{-1}), F (av. EC = 1.3dS.m^{-1}) and O conditioner (av. EC = 1.49dS.m^{-1}), respectively. Generally, the favorable effect of compost on reducing EC values may be due to its role in improving physical properties of the soil under investigation. Minerals abundant in OMW increase the EC, but since these are water-soluble, they could be lost by leaching as observed by **Abid and Sayadi (2006)** and **Said-Pullicino et al. (2007)**. In addition, **Beata-Hall et al. (2005)** reported an increase in EC being correlated with water evaporation. OMW is a saline effluent (EC about 20dS.m^{-1}). However, the final composts EC were low (5.4dS.m^{-1}) and the application of the effluent to the compost pile could continue without risk for compost quality deterioration (**Mari et al., 2003**).

Data presented in **Fig. 1A** indicate that the soil SAR values are favorably affected by the application of all amendments as happened with salinity values. It is clear that (FO) was superior to all treatments in reducing such values, where the rate of decrement for soil SAR values as compared to initial soil (control treatment) reached to 37% under olive cultivation, 33% under corn cultivation, respectively. It is worth to mention that the SAR values were below 12 at any amendment application. This means that such soil did not have any serious problems in permeability or tilts and plants did not have any difficult in absorbing water, **Brady (1999)**.

Cation Exchange Capacity (CEC):

With respect to soil cation exchange capacity (CEC), data in **Fig. 1B** indicate that soil CEC values increased by addition of any conditioner to the soil. The soil CEC values under olive treatments were greater than that under corn treatments, this is may be due to the repeated tillage practices for soil cultivated by olive from previous years as compared to the soil that cultivated by corn in this study. Regardless the cultivation type, the greatest percentage increment in soil CEC value was evident with addition of compost farmyard manure with EM solution (FEM). These increases might be due to the presence of ash in Bokashi (FEM), which helps for the immediate release of the occluded mineral nutrients like Ca, K and N for crop use, **Scheuner et al., (2004).** The average percentage increment in CEC value for MEF treatment is reached to 54 %, while it reached to 4, 26 and 19% for O, FO and F treatments, respectively.

Hydraulic Conductivity & Available Water:

Concerning the effect of OMW and other compost on soil hydraulic conductivity, data in **Fig. 1B** show a decrease in soil hydraulic conductivity with the OMW and all compost application under both of olive and corn cultivation. The decreases in hydraulic conductivity relative to that for initial soil (HC = 6.25m.day^{-1}) reached to 14.4, 34.08, 28.32 and 44.8% under olive cultivation, respectively, and to 14.3, 31.67, 28.62 and 33.76% under corn cultivation, respectively, for W, O, FO, F and FEM treatments, respectively.

Data in **Fig. 1B** illustrate that, vice versa as soil hydraulic conductivity decrease the available water is increased. The average percentage increment of available water is 8, 39, 23 and 50% for O, FO, F and FEM treatments, respectively. This indicated that using olive mill wastewater as amendments or other soil amendments will led to increase the available water to the cultivated plants under rainfed conditions, especially during drought periods between storms or at the maturity stage at the winter season end and consequently increasing the yield productivity. Decrease soil hydraulic conductivity and increase available water by addition of composting manure, such as compost olive mill wastewater with farmyard manure or bokashi, attributed to high organic matter content in farmyard manure (OM = 9% approximately) that save water. Consequently, using compost of olive mill wastewater with farmyard manure as soil amendment under rainfed conditions is led to save the water for the cultivated crops. However, **El- Sherbiny (2002)** reported that soil hydraulic conductivity increased in calcareous soil by addition of composting manure. This attributed to that the particles are held together by cementing substances such as hums and $CaCO_3$ subsequently increase macro pores and velocity of water movement within the soil. **Russell (1989)** reported that hydraulic conductivity decreases as the pore sizes decrease.

Bulk Density:

According to data in **Fig. 1B**, the value of bulk density is higher (1.58gm.cm^{-3}) in the initial soil (Control treatment) than in the soil treated by addition of different soil amendments. This is indicated that the soil surface of NWCZ is characterized by relatively surface compaction. Regardless the crop type, the average greatest decrement in bulk density as compared with its value in the initial soil (30%) was observed for FEM treatment, followed by 25, 22 and 16% for FO, F and O treatments, respectively. Consequently, using compost olive mill wastewater with farmyard manure (FO) or compost bokashi (FEM) caused decrease soil bulk density compared to using olive mill wastewater only (O) by about of 11 and 16%, respectively. Therefore, using olive mill wastewater with farmyard manure led to increase the amount of organic matter content that led to enhance soil structure after it is decomposed in the soil. **Soane (1990)** stated that mixing organic residues with the soil matrix led to reduced bulk density **Bauer and Black (1992)** reported that a unit increase in organic matter and clay content caused a relatively larger decrease in soil bulk density. **Arshad et al. (1996)** stated that soil bulk density is a dynamic property that varies the structural conditions. It is influenced by some physical and chemical properties and can be altered by cultivation, trampling by animals, agricultural machinery and weather, i.e. raindrop impact. Knowledge on soil bulk density is essential for soil management, and is important in soil compaction and structure degradation, as well as in the planning of modern farming techniques.

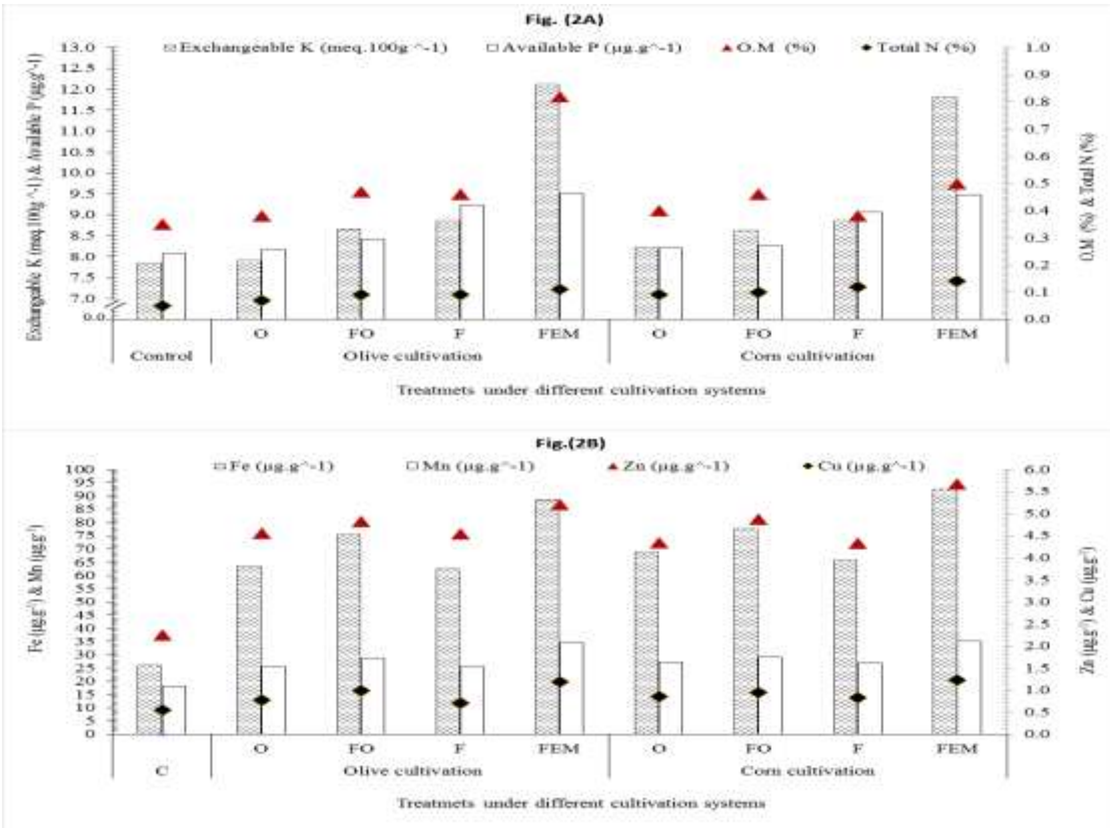
Organic matter (OM):

Data in **Fig. 2A** indicate that the organic matter content in the initial soil (Control treatment) is 0.35%. Soil organic matter is increased by added OMW and compost application under olive or corn cultivation. This may be due to high organic carbon content in the applied compost. Generally, regardless the crop type, the efficiency of the used OMW and compost in increasing soil organic matter content can be arranged in the following order: FEM > FO > F > O, respectively. The average percentage increment of soil organic matter under the recent applied compost reached to 11, 34, 20 and 88% for O, FO, F and FEM treatments, respectively. These results are agreement with that obtained by **Al-Widyan et al. (2005)** and **Paredes et al. (2005)**. OM provided by compost improves soil structure and increases its permeability and stability, **De Viron (2000)** reported that OM degradation released soil-fertilizing elements; this biodegradation of OM is accompanied by production of a plant growth hormone and plant nutrients. Compost improved soil fertility because it modified both physic-chemical and microbiological properties, (**Houot, 2000)**, and this is owed to the improvement of soil aeration and thus to the enhancement of soil microorganism activity to biodegrade soil organic matter. **Sellami et al. (2008)** expected that using compost would enhance plant growth because of its physical and chemical properties. Indeed, The major factor responsible for organic fertility of soil is humified OM, which is the most resistant part of OM to microbial decomposition. A highly humified OM increases the agricultural value of compost (**Bernal et al., 2009**).

Soil Macro- & Micronutrient Elements:

It can be notice that total N values of the investigated soil took the same trends residually mentioned for organic matter content, (**Fig. 2A)**. It can be notice that the rate of increment in total N under the O, FO, F and FEM treatments as compared to that for the initial soil (control treatment) reached 40, 80, 80 and 120%, under olive cultivation and 80, 100, 140 and 180% under corn cultivation, respectively. The positive effect of compost on increasing total N of soil may be due to its decomposition by soil microorganisms (**Paredes et al., 2005**). Total nitrogen increased in the prepared compost and reached to the maximum value (0.55%) for bokashi (FEM) compost, followed by FO compost (0.42%), FM compost (0.4%) and O conditioner (0.38%), respectively, **(Table 3)**. Comparison of the mineral composition of amendments showed that the higher the percentage of P, K, Na in olive mill wastewater amendments and consequently the more concentration of these macronutrients in the product compost, such as FM, FO and FEM compost. Therefore, olive mill wastewater increased the mineral concentration in the final compost. Similar to the total nitrogen, the levels of exchangeable potassium and available phosphorus for the soils that treated by amendments is higher than that for the initial soil. Data in **Fig. 2A** show that the increase in available P as rate of increment over the control (8.08µg.g^{-1}) reached 1, 4, 14 and 18% under olive cultivation and 1, 2, 12 and 16% under corn cultivation, for O, FO, F and FEM treatments, respectively. The exchangeable K values of the investigated soil took the same trends for available P values. It can be notice that the average rate of increment in exchangeable K under the OMW and applied compost compared to control treatment (7.85meq.100g^{-1}) follows the ascending order as follow: O (2%) < FO (10%) < F (12%) < FEM (52%), respectively. These results are agreement with those obtained by **Speir et al. (2004)** who found that total N and available p of soil were increased markedly by increasing the rate of organic amendments.

Concerning micronutrient elements, the addition of the studied amendments to soil increases available Fe, Mn, Zn and Cu elements (**Fig. 2B**) due to the role of such amendments in reducing soil pH values, **(Fig. 1A)**. Regardless, crop type, the average increment percentage for Fe, Mn, Zn and Cu is varied from 148 to 250%, from 43 to 90, from 97 to 142% and from 38 to 118%, for F and FEM treatments, respectively. This indicated that greatest increase is evident with iron, followed by zinc, cupper and manganese element, respectively. Generally, the role of OMW and applied compost in release the micronutrient elements can be arranged in the following ascending order: F < O < FO < FEM treatments, respectively, **(Fig. 2B)**. These results are agreement with that obtained by **Speir et al. (2004).** Consequently, this increase and slow release from soil particles or organic matter to soil solution is contributing thus to the improvement of soil quality and to enhancement crop productivity.



* Treatments, where **C**: Control treatment (without any soil conditioner application),
O: Olive mill wastewater (OMW) at the rate of $20m^3.fed^{-1}$ treatment,
FO:: Compost farmyard manure FYM with OMW at the rate of $10t.fed^{-1}$ treatment,
F: Compost FYM at the rate of $10t.fed^{-1}$ treatment, and
FEM: Compost FYM with effective microorganisms (EM) at the rate of $10t.fed^{-1}$ treatment.

Fig. 2: Effect of the applied conditioners on some fertility constituents of the investigated soil.

Effect on Yield:

The olive fruits and corn grains yields grown on the soil under investigation are significantly increased by added OMW or organic compost, **(Table 4)**. The yield of olive fruit and corn grain under traditional cultivation without addition organic compost is 1.84 and 1.48 $t.fed^{-1}$, respectively. The highest yields in olive fruits and corn grains reached to 2.88 and $2.34t.fed^{-1}$, respectively, for FYM treatment. The percentage increment of olive fruits yield reached 57, 38, 32 and 19% when addition compost FYM with EM at the rate of $10t.fed^{-1}$, compost FYM with OMW (FO) at the rate of $10t.fed^{-1}$, compost FYM at the rate of $10t.fed^{-1}$ treatment (F) and olive mill wastewater at the rate of $20m^3.fed^{-1}$ (O) to the soil, while, the respective values for corn grains reached 58, 45, 41 and 8%, respectively, as compared to that for traditional cultivation. In general, the used of OMW or compost treatments on increasing the olive fruits and corn grains yields can be arranged in the following order: FEM >

FO > F > O, respectively, as compared to that for traditional cultivation under control treatment. The positive effect of organic compost on increasing olive fruits and corn grains yields may be due to that organic compost contains essential nutrients for plant growth, which it will abundance in root zone, as well as the role of organic compost in enhancing soil quality, as abovementioned discussed. Consequently, the uptake of nutrients and dry matter formation for the cultivated plants will increased.

Table 4. Yield of olive fruits and corn grains as affected by the applied conditioners.

Yield ($t.fed^{-1}$)	W*	O*	FO*	F*	FEM*	L.S.D at 5%
Olive fruits yield	1.84	2.19	2.53	2.42	2.88	0.048 ***
Corn grain yield	1.48	1.74	2.15	2.09	2.34	0.035 ***

* Treatments, where **W**: Control treatment (without any soil conditioner application),
O: Olive mill wastewater (OMW) at the rate of $20m^3.fed^{-1}$ treatment,
FO:: Compost farmyard manure FYM with OMW at the rate of $10t.fed^{-1}$ treatment,
F: Compost FYM at the rate of $10t.fed^{-1}$ treatment, and
FEM: Compost FYM with effective microorganisms (EM) at the rate of $10t.fed^{-1}$ treatment.
*** Indicate that the differences between treatment is very high significant at significant level of 5%.

Economic feasibility:

Yields of olive and corn under rainfed conditions have been shown to increase with addition of olive mill wastewater and organic compost as abovementioned discussed .Olive mill wastewater and organic compost can act as a replacement for chemical fertilizers and organic materials. In addition to its chemical and biological benefits, the beneficial use of olive mill wastewater and organic compost in agriculture also offers a number of economic and environmental advantages. The total cost for cultivation corn crop and olive trees under rainfed agriculture with traditional agriculture system is approximately similar (2650L.E fed^{-1}), where the olive orchards is already exists and this cost included preparation and cultivation operation only, **(Table 5)**. The mean costs associated with applying olive mill wastewater and organic compost for corn crop or olive trees was higher than that for traditional cultivation by 1, 57, 38 and 68% for O, FO, F and FEM treatments, respectively, **(Table 5)**. Therefore, using OMW as amendments is inexpensive especially in the regions that characterized by large areas cultivated by olive trees. In all cases, the highest total cost for cultivation corn and olive trees was evident with adding of bokashi soil conditioners (4450 L.E fed^{-1}).

Table 5. The economical evaluation of using soil conditioners under agricultural conditions at Matrouh area.

Treatments	Soil conditioners preparation cost ($L.E.fed^{-1}$)	Cultivation preparation and management operation cost** ($L.E.fed^{-1}$)	Total cost ($L.E.fed^{-1}$)	Yield price (Profit) ($L.E.fed^{-1}$)		Ne profit ($L.E.fed^{-1}$)		Investment Ratio (IR)	
				Olive fruits yield	Corn yield	Olive fruits yield	Corn yield	Olive fruits yield	Corn yield
W*	……	2650	2650	14720	3517	12070	867	5.55	1.33
O*	20		2670	17520	4070	14850	1400	6.56	1.52
FO*	1500		4150	20140	4930	15990	780	4.85	1.19
F*	1000		3650	19360	4690	15710	1040	5.30	1.28
FEM*	1800		4450	23040	5420	18590	970	5.18	1.22

* Treatments, where **W**: Control treatment (without any soil conditioner application),
O: Olive mill wastewater (OMW) at the rate of $20m^3.fed^{-1}$ treatment,
FO:: Compost farmyard manure FYM with OMW at the rate of $10t.fed^{-1}$ treatment,
F: Compost FYM at the rate of $10t.fed^{-1}$ treatment, and
FEM: Compost FYM with effective microorganisms (EM) at the rate of $10t.fed^{-1}$ treatment.
** Cultivation preparation and management operation cost is including agriculture machinary cost (500 L.E/ fed), irrigation water energy cost (500L.E /fed), seeds cost (150L.E/fed), manegment operation and manpower cost (1000L.E /fed), and mineral fertilizers cost (500L.E /fed).

The benefits from traditional cultivation was lower than that for other treatments, when the total costs and profits from the agriculture systems are compared, **(Table 5)**, where its value is 867 and 12070L.E fed^{-1} for corn and olive trees, respectively. Therefore, the average benefit from traditional cultivation was less than that for the other studied treatments by 11 and 26% for corn crop and olive trees, respectively. The net profit for olive mill wastewater and organic compost ranged from 780 to 1400L.E fed^{-1} and from 14850 to 18590L.E fed^{-1} for cultivation corn crop and olive trees, respectively. As shown in **(Table 5),** the highest net profit for using olive mill wastewater conditioner is evident with cultivation corn crop (1400L.E fed^{-1}) relative to other treatments. However, the highest net profit for cultivation olive trees (18590L.E fed^{-1}) is observed when applied bokashi conditioner to the soil (FYM treatment). From another point of view, the investment ratio for using olive mill wastewater and organic composts with cultivation olive trees and corn crops under rainfed agriculture can be arranged in the following ascending order: cultivation with FO treatment < cultivation with FYM treatment < cultivation with F treatment < traditional cultivation treatment and cultivation with O treatment, respectively, **(Table 5),** because of the olive mill wastewater is inexpensive. According to this study, integrated use of olive mill wastewater in organic compost has agricultural, environmental and economically feasibility.

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الاستفادة من المخلفات السائلة لمعاصر الزيتون كمصلح للتربة بمنطقة مطروح بالساحل الشمالي الغربي – مصر.

محمد صالح عبدالعزيز – عزمى عبدالله موسى
قسم صيانة الأراضى – مركز بحوث الصحراء– المطرية – القاهرة.

إعادة استخدام النفايات الصناعية ومنتجاتها الثانوية مثل المخلفات السائلة لمعاصر الزيتون (OMW) هي مفيدة للحد او على الاقل لتقليل المشاكل البيئية، حيث التخلص غير المنضبط من OMW أصبح مشكلة بيئية خطيرة. ويعتبر OMW المنتج الرئيسي الذي ينتج عن عملية استخراج زيت الزيتون، خاصة في المناطق التي تنتشر فيها زراعة الزيتون، مثل منطقة الساحل الشمالي الغربي لمصر (NWCZ). لذلك تم إجراء دراسة حقلية خلال موسمين شتويين 2016/2015 و 2017/2016 في منطقة مطروح، الساحل الشمالي الغربي لمصر. تم إجراء تجربتين حقلتين لأشجار الزيتون ونباتات الذرة، حيث شملت كل تجربة خمسة معاملات مع أربع مكررات متماثلة. كانت المعاملات هي الزراعة التقليدية بدون استخدام محسن التربة (**C**)، الزراعة باستخدام المخلفات السائلة لمعاصر الزيتون بمعدل 20م3/ فدان (**O**)، الزراعة باستخدام كومبوست مخلفات المزرعة المعامل بالمخلفات السائلة لمعاصر الزيتون بمعدل 10 طن/فدان (**FO**). الزراعة باستخدام كومبوست مخلفات المزرعة بمعدل 10 طن/فدان (**F**). الزراعة باستخدام كومبوست مخلفات المزرعة المضاف اليه الكائنات الدقيقة الفعالة (**EM**) بمعدل 10 طن/فدان (**FEM**). اظهرت النتائج ان التربة فى الموقع التجريبي هي تقريبا ضحلة، و خفيفة القوام، و جيرية، و غير مالحة، و فقيرة في المواد العضوية و السعة التبادلية الكاتيونية وبالتالي منخفضة في الخصوبة. الاختلافات في قيم الرقم الهيدروجيني لمختلف أنواع الزراعة التي استخدمت نفس المحسنات منخفضة جدا ويمكن تجنبها. وتصل النسبة المئوية للإنخفاض إلى 41 و 60 و 52 و 67% في زراعة الزيتون و 40 و 47 و 44 و 53% في زراعة الذرة لمعاملات **O**، **FO**، **F** و **FEM** على التوالي. متوسط نسبة الزيادة في المياه الميسر هي 8، 39، 23 و 50٪ لمعاملات **O**، **FO**، **F** و **FEM** على التوالي. استخدام معاملات **FO** او **FEM**ادت لانخفاض الكثافة الظاهرية مقارنة باستخدام معاملة **O** فقط بنحو 11 و 16٪ على التوالي. وبغض النظر عن نوع المحصول، يمكن ترتيب كفاءة المخلفات السائلة لمعاصر الزيتون و الكمبوست المستخدم في زيادة محتوى المادة العضوية بالترتيب التالي: **O < F < FO < FEM** ، على التوالي. إن مستويات النيتروجين الكلي والبوتاسيوم المتبادل والفوسفور الميسر للتربة التي تعاملت بمحسنات المخلفات السائلة لمعاصر الزيتون أعلى من تلك الموجودة في التربة الأولية. وبغض النظر عن نوع المحصول، يتراوح متوسط الزيادة المئوية في الحديد والمنجنيز والزنك والنحاس من 148 إلى 250٪، من 43 إلى90٪، من 97 إلى 142٪ ومن 38 إلى 118٪ للمعاملات **F** و **FEM** على التوالي. وبلغت نسبة الزيادة في انتاجية ثمار الزيتون 57 و 38 و 32 و 19٪ للمعاملات **FYM**، **FO**، **F** و **O** على التوالي، بينما بلغت قيم انتاجية حبوب الذرة لنفس المعاملات المقابلة 58 و 45 و 41 و 8٪ على التوالي، بالمقارنة إلى الزراعة التقليدية. ويمكن ترتيب نسبة الاستثمار في استخدام المخلفات السائلة لمعاصر الزيتون والسماد العضوي مع زراعة أشجار الزيتون ومحاصيل الذرة تحت ظروف الزراعة المطرية بالترتيب التصاعدي التالي: معاملة **O < F < FYM < FO**، على التوالي، بسبب رخص سعر المخلفات السائلة لمعاصر الزيتون و الغير مكلفة. ووفقا لهذه الدراسة، فإن الاستخدام المتكامل للمخلفات السائلة لمعاصر الزيتون في الكمبوست العضوى له جدوى زراعية وبيئية واقتصادية.