Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 9[7] June 2020 : 46-52
©2020 Academy for Environment and Life Sciences, India
Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.876
Universal Impact Factor 0.9804
NAAS Rating 4.95

ORIGINAL ARTICLE **OPEN ACCESS**

Effect of Addition of Olive Mill Wastewater (OMW) on Wheat and Physical and Chemical Properties of Soil in the Area of Jerash University

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ABSTRACT

This study examined effects of addition of olive mill wastewater (OMW) on wheat and physical and chemical properties of soil in the fields of the Faculty of Agriculture in Jerash University. The study comprised a control site and four treatments, corresponding to addition of OMW at four levels: 5, 10, 15, and 20 L/m^2. Wheat was grown after 42 days from addition of OMW to the soil. Length of wheat plant and some soil properties were assessed six weeks after the addition of OMW to the soil. The results indicated an improvement in some soil properties like decreases in the values of porosity and bulk density with the amount of OMW added, in addition to increase in the soil organic matter content. However, these enhancements did not reflect positively on plant growth as the effect of the high amounts of OMW added to the soil on wheat growth was negative in the first month after the germination stage, where plant became yellowish in color, besides becoming empty, under the high OMW treatments. This may be attributed to the total phenolic compounds in the OMW as well as to deficiency in the available plant nutrients in the soil due to their consumption by the soil microorganisms that decompose the organic matter, which is available in OMW at relatively high levels.

Key words: *Olive Mill Wastewater, Soil, Wheat, Physical Properties, Chemical Properties, Jerash University*

Received 09.02.2020 Revised 12.05.2020 Accepted 20.05.2020

INTRODUCTION

Olive is considered as the main agricultural crop in Jordan. "Olive oil production, an agro-industrial activity of vital economic significance for many Mediterranean countries, is associated with the generation of large quantities of wastes and by products" [1]. The growing demand on olive oil led to a wide increase in the proportion of the land grown with olives, which was estimated at 5.0% annually during the past 10 years. In 2012, the Ministry of Agriculture, Jordan, indicated that there are about 130 olive mills that produce nearly 200,000 m^3 of water as olive mill effluents.

The treated olive mill effluents have been used in agriculture as an alternative source of irrigation water. It is expected that their use will increase in the countries suffering from scarcity in the fresh water sources. The olive extraction industry is an important activity in the Middle East countries. It produces huge quantities of the olive mill wastes during extraction of oil. The olive mill water, as residues, is by-product that results from the olive oil extraction processes by the pressing systems or centrifugation.

The most commonly used extraction methods produce three phases of products: the oily phase, solid residues (pressed oil residue), and aqueous phase. The latter phase, when associated with the washing water, produces the so-called olive mill wastewater (OMW), which is locally named as Zeabar. Volume of this effluent water depends on the extraction method employed and ranges from 0.5-10.5 m3 per ton of the extracted olive [2]. The total; product of this water in the Middle East is estimated at higher than 30 million m3 [3, 4]. This water constitutes a big problem as regards the ideal method how to get rid of it and discharge it. This water is characterized by containing high concentrations of fats, oils, greases, and polyphenolic compounds [5]. It is thought that presence of phenols and both short-chain and long-chain fatty acids is the reason behind toxicity of the OMW to plants, i.e., phtotoxicity [6] and behind its anti-microbial activity [7].

It is prohibited, by force of law, to discharge the excess water resulting from mills into the municipal sanitary water discharge systems. In the time being, most of the mill water in Jordan is without adequate treatment. Therefore, it threatens the quality of the already scarce and valuable water resources. Several physical and chemical methods have been employed for purification of the olive mill water. Cost effectiveness of those methods is under doubt owing to that they are costly and/or producing poor quality liquid wastes. However, many studies indicated that the possibility of spreading the olive mill water wastes on the planted soil as a viable approach to recycling these wastes as amelioratiors and low-cost useful fertilizers [8, 9].

Use of the OMW caused a significant increase in the grain produce of wheat and an increase in absorption of the nitrogen, phosphorous, and potassium elements by plants. In addition to that, significant increases were observed in the percentage organic carbon, soil aggregate stability, total nitrogen content, available potassium, cation exchange capacity, and water-holding capacity in the Middle East soils [10, 11].

Marsilio et al. [12] pointed out that addition of 100-300 m3 of OMW to each hectare reduced use of chemical fertilizers or replaced them. Ben Rouina et al. [13] found that use of treated OMW in an olive field of sand soil at the rate of 100 m3/ha for 10 years improved soil fertility noticeably. That experiment revealed increases in the organic matter content, nitrogen, and potassium, whereas the phosphorous content and pH remained constant, The organic matter percentage increased from 0.3% to 1.3% and, in turn, led to increases in soil permeability and water exchange capacity.

Most of the soils in Jordan are poor in organic matter, which passively impacts their fertilities. Therefore, addition of the OMW that is rich in organic materials and nutrients to soils in a controlled way is expected to positively influence their fertilities and improve their chemical and physical properties, which is the aim of this study, that is, to give initial idea about effect of addition of OMW on soil fertility and some chemical and physical properties of soil.

MATERIAL AND METHODS

An area has been selected in the fields of the Faculty of Agriculture in Jerash University that has been ploughed with the disc plough and a field experiment was conducted in this area using five levels of untreated OMW: 0, 5, 10, 15, and 20 L/m3, which are equivalent to 0, 5000, 10000, 15000, and 20000 L/donum. Three replicates of each treatment were made, thus making the overall number of plots 15. Then, the treatment plots of 1 m2, each, were randomly planted with wheat.

The OMW produced by one of the oil mills in the Governorate of Jerash was added to soil surface on 10 November 2015. Then, the wheat seeds were planted in all treatments in four lines for the one treatment separated from each other by a distance of 20 cm. The treatments were irrigated regularly twice weekly.

Samples of the soils used in this experiment, in addition to OMW sample, were sent to the National Center for Agricultural Research and Extension (NCARE) in Bajaah area for analysis. The OMW sample was analyzed for nitrogen, phosphorous, potassium, and organic matter content. Meantime, the soil was analyzed for pH, electric conductivity (EC), organic matter content, nitrogen, phosphorous, and potassium.

Six weeks later to wheat planting, the plant lengths were measured for the different treatments at three replicates for the one treatment. On 13 January 2016, about two months later to application of OMW to the soil, surface soil samples (0-15 cm) were taken from each treatment plot for analysis. The samples were air dried in the laboratory, crushed using wood hammer, passed through a 2-mm sieve, kept in special bottles, and sent to NCARE for analysis. Moreover, undisturbed samples were obtained from each treatment for the purpose of assessing the bulk density of soil following the clod method as illustrated by Black (1965).

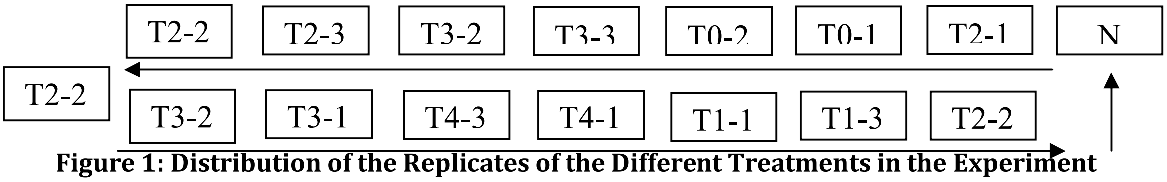

Figure 1: Distribution of the Replicates of the Different Treatments in the Experiment

Treatments

T0: Control

T1: 5 L OMW/m^2

T2: 10 L OMW /m^2

T3: 15 L OMW /m^2
T4: 20 L OMW /m^2

RESULTS AND DISCUSSION

Chemical analyses of OMW (Table 1) indicate that it has high nitrogen, phosphorous, and potassium content whose concentrations of were 1051, 290, and 3327 ppm, respectively. These figures indicate that the OMW has effect in increasing soil fertility, which reduces the need for using the main chemical fertilizers such as the nitrogenous fertilizers (e.g., urea), phosphoric fertilizers (e.g., diammonium phosphate (DAP)), and potassium fertilizers.

Table 1: Some Physical and Chemical properties of the OMW Used in the Experiment

EC (dS/m)	pH	K_2O	P_2O	N	Organic Matter
			(ppm)		(%)
6.6	4.35	3,327	290	1,051	14.5

Table 1 also reveals a low pH of the OMW, which may positively affect in reducing the soil reaction relatively and temporally because of the high buffering capacity of this soil, being calcareous soil. Despite this, it is expected that this temporary soil reaction reduction effect may contribute to increase in availability of some nutritional elements at the early stages of OMW addition to the soil. The physical and chemical properties of the soil prior to addition of OMW (Table 2) indicate that the soil is of clay loam texture, alkaline pH (8.10), and low sand content (EC = 0.72 dS/m). It also had low organic matter content (0.57%). Moreover, its phosphorous and potassium contents were average (Table 2).

Table 2: Some Physical and Chemical properties of Soil Used in the Experiment

Bulk Density (kg/m^3)	**N (%)**	**K**	**P**	**EC (dS/m)**	**pH**	**Texture**		
		ppm				**Clay (%)**	**Silt (%)**	**Sand (%)**
1,058		340	3.90	0.72	8.10	35	23	42

The results listed in Table 3 show lack of clear differences in values of some chemical properties of the soil after addition of OMW to it. The value of pH showed relative stability before and after addition of OMW; 8.2 and 8.2-8.7, respectively. This suggests that the soil has high buffering capacity because of its high carbonate content. Electric conductivity (EC) was 0.50 dS/m before addition of OMW and became 0.57 dS/m after its addition, even though EC of OMW was 6.66 dS/m. The reason behind the no increase in soil salinity with the added amount of OMW may be the continuous irrigation of the soil after wheat planting (irrigation two times a week) for six weeks. Soil nitrogen, phosphorous, and potassium contents showed slight increase after OMW addition. The results (Table 3) point out a noticeable increase in the organic matter content of the soil with the amount of OMW applied; organic matter content grew from 0.57% in the control plot to 1.07% in the fourth treatment (T4) due to the high organic matter content of the OMW (Table 1).

Table 3: Some Physical and Chemical Properties of Soil under the Different Treatments Six Weeks after Addition of OMW

Parameter	**Treatment**				
	T0	T1	T2	T3	T4
Porosity	39.2	40.7	44.6	46.5	50.4
Bulk Density (kg/m^3)	1.58	1.54	1.44	1.39	1.29
Organic Matter	0.57	0.79	1.06	1.04	1.07
N (%)					
K (%)	526	508	564	536	573
P (%)					
EC (dS/m)					
pH	8.2	8.2	8.7	8.2	8.5

The bulk density of the soil decreased with the amount of OFW added. Its value dropped from 1.58 kg/m3 in the control plot to 1.29 kg/m3 in T4. The reason behind this drop can be the increase in the organic

matter content of the soil with the amount of OMW added to it. The drop in the bulk density values with OMW addition affected soil porosity, which increased from 39.2% in the control soil to 50.4% in T4.
The improvement in the physical properties of the soil in this experiment did not reflect on growth of the wheat planted in this soil. The results, in addition to observations, highlight that growth of wheat was much better in the control plots than its growth levels in the treatment plots. Color of the wheat was pale and its density was low under the OMW treatments of the soil, especially the high treatments, in comparison with the wheat planted in the control plot, which had normal color and high density. As well, lengths of the wheat plants after six weeks of OMW addition (Table 4) reveal noticeable differences between the treatments; lengths of the wheat plants were 18.2, 14.4, 12.6, 12.4, and 11.2, respectively, in T1, T2, T3, T4, and the control plot (T0). The reason for this is effect of the phenolic materials which the OMW contains as it increases with level of OMW addition. The high amounts of organic materials contained in the OMW may simulate the soil microorganisms to work on decomposing these materials after it is added to soil, which makes them consume the nutritional elements, particularly nitrogen, to obtain the necessary energy for that, which reflects passively on the growing plants, especially during the first month after addition.

Table 4: Wheat Plant Height

Treatment	**Replicate**	**Plant Height (cm)**
T0	1	17.5
	2	18.6
	3	18.5
	Average	18.2
T1	1	11.8
	2	15.9
	3	15.6
	Average	14.4
T2	1	13.9
	2	10.6
	3	13.2
	Average	12.6
T3	1	12.4
	2	12.1
	3	12.6
	Average	12.4
T4	1	11.6
	2	11.2
	3	10.8
	Average	11.2

In general, the results of this experiment indicate that while OMW addition to soil resulted in improvements in some of its physical and chemical properties like the increase in its organic matter content and porosity, this addition led to negative impacts on plant growth. This may be ascribed to OMW containing toxic phenolic compounds [5, 6]. Thereupon, it is recommended to treat the OMW before its use in irrigation. This is a necessity that must be abided by. Additionally, the researcher recommends use of this water long before planting date (1 month to two months) to avoid the drop in the levels of the nutrient elements in the soil because of decomposition of the organic matter contained in this material (OMW) by the soil microorganisms and consumption of the available nutrient elements in the soil.

Performed Steps

The followed steps were the following:

1- Observation in general.
2- Relevant irrigation in the periods of no rain.
3- Removal of weeds from the treatment plots and their peripheries.
4- Taking distance measurements using metallic meter.
5- Taking samples of total vegetation after maturity,

6- Taking soil samples for the purpose of phyisico-chemical analysis.

The periodic, continuous monitoring of the experiment was as follows:

1- Visiting the project by the students and their supervisor, Dr. Ashraf Khashroom, twice a week to determine the conditions of the grown plants, the diseases that may affect them, and the insects that may attack them.

2- In view of the no rain periods and irregularity in rainfall, we resorted to complementary irrigation of the grown wheat plant to achieve the desired results.

3- We removed the harmful grasses from inside the treatment plots so that these weeds will not compete with the grown plants. In addition, we removed the weeds from the shoulders of the treatment plots so that they will not be source of attraction of harmful insects.

4- Taking measurements of plant heights continuously to identify the differences in growth rates between the treatments and compare them with the rates of OMW addition.

5- Measurements were taken accurately using iron meter. Three measurements were taken for the two internal lines of the treatment as each treatment was divided into four lines. The measurements encircled the long, medium, and short plants so that they will be truly representative samples.

6- After maturity of the wheat plant, samples were taken diagonally in one direction and on one line, where one plant was cut successively.

7- Afterwards, soil samples were taken for physical and chemical analyses and numbered. Treatment number was fixed on each of these samples.

The results of the taken measurements of plant heights were unexpected. This is ascribed to some errors in the experiment that mainly included:

1- Large quantities of rain entered the plots and not all treatments received the same volume of rainwater. Certain treatments were fully soaked with water.

2- Water was added to the plots until filling them. The different plots varied in their abilities to absorb the water, depending on the amount of OMW designed for each plot.

Plant Height Measurements

Table 5: Wheat Plant Height Measurements on 27 March 2016

Treatment	**Replicate**	**Plant Height (cm)**
T0	1	1.10; 0.96; 1.17
	2	1.20; 0.95; 1.05
	3	1.10; 1.31; 1.07
	Average	1.22
T1	1	0.90; 0.80; 1.0
	2	0.80; 0.95; 1.10
	3	0.76; 0.90; 1.0
	Average	0.91
T2	1	0.60; 0.79; 0.89
	2	0.61; 0.90; 0.80
	3	0.75; 1.0; 0.75
	Average	0.79
T3	1	0.84; 1.0; 0.70
	2	0.99; 0.75; 0.90
	3	1.07; 1.0; 1.10
	Average	1.0
T4	1	0.78; 0.88; 0.95
	2	0.70; 0.85; 0.65
	3	0.80; 0.70; 0.58
	Average	0.76

Table 6: Wheat Plant Height Measurements on 5 April 2016

Treatment	Replicate	Plant Height (cm)
T0	1	1.15; 1.10; 1.10
	2	1.40; 1.10; 1.07
	3	1.20; 1.15; 1.10
	Average	1.13
T1	1	1.20; 1.00; 1.10
	2	1.20; 1.20; 1.05
	3	1.20; 1.07; 1.04
	Average	1.23
T2	1	1.0; 0.90; 1.00
	2	1.10; 0.90; 0.97
	3	1.5; 0.89; 1.00
	Average	1.13
T3	1	1.10; 0.97; 0.84
	2	1.00; 0.90; 1.10
	3	1.30; 1.10; 1.20
	Average	1.05
T4	1	1.05; 1.10; 1.16
	2	1.00; 0.74; 0.84
	3	0.90; 0.97; 0.95
	Average	1.02

Table 7: Wheat Plant Height Measurements on 16 march 2016

Treatment	Replicate	Plant Height (cm)
T0	1	0.87; 1.12; 1.02
	2	1.09; 1.03; 1.10
	3	1.03; 0.86; 0.80
	Average	0.99
T1	1	0.92; 0.93; 1.06
	2	0.95; 0.86; 1.03
	3	1.04; 0.94; 1.12
	Average	1.04
T2	1	0.90; 0.98; 0.78
	2	0.90; 0.80; 1.00
	3	0.80; 0.90; 0.95
	Average	0.89
T3	1	0.70; 0.64; 0.83
	2	0.95; 0.87; 0.93
	3	1.16; 0.99; 1.00
	Average	0.90
T4	1	1.05; 0.95; 1.00
	2	0.72; 0.80; 0.86
	3	0.76; 0.72; 0.73
	Average	0.89

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CITATION OF THIS ARTICLE

Ashraf Omar Khashroom. Effect of Addition of Olive Mill Wastewater (OMW) on Wheat and Physical and Chemical Properties of Soil in the Area of Jerash University. Bull. Env. Pharmacol. Life Sci., Vol 9[7] June 2020 : 46-52