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Scope of Using Treated Olive Mill Wastewater in Tomato Production

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Abstract An experiment was carried out to evaluate the feasibility of using treated olive mill wastewater (OMW) in irrigating tomato crops. The OMW was filtrated using a home-made filter of a matrix that mimics nature. OMW filtration improved physical and chemical properties of the filtrate as it became clear with neutral pH. The results showed that the 10% dilution of the filtrate gave best results compared with those irrigated with tap water. The 20% dilution gave the second best outcome followed by the 50% which gave an intermediate plant growth and production. Irrigation with untreated OMW killed the plants in a couple of days. Treated OMW was found to be useful in irrigating tomato crops at economic level.

Keywords Olive mill wastewaters, Tomato, Irrigation, Agriculture

1. Introduction

Olive mill waste water (OMW) is defined as the liquid waste produced during olive oil production. It consists of water soluble macromolecules such as, tanen, polyphenols, polyalcohols and polymers. OMW also contains an insoluble matter like cellulose, pectin and oil. Especially because of the dangerous effect of phenols in OMW, phenols must be removed to reduce pollution. The quantity of OMW produced in the process ranges from 0.55 to 2 liters perkilogram of olives, depending on the oil extraction process. The manufacturing process of the olive oil usually yields next to olive oil (20%), a semi-solid waste (30%), and aqueous liquor (50%). The aqueous liquor comes from the vegetation water and the soft tissues of the olive fruits. The mixture of this water-based by-product with the water used in the different stages of oil production makes up the so-called ‘‘olive-mill waste water’’ (OMW). Furthermore, olive washing water, waters from filtering disks, and from washing of equipment and rooms are to be included into this wastewater [1].

Because of this, the OMW treatment is very important for Palestine and for the other producer countries that deal with OMW and olive oil extraction. The content and amount of OMW depends on the maturity of the fruit, the trees, the agricultural methods for growing the trees, the quality of the soil, climate and especially to the kind of olive oil process system. Treatment methods of OMW can be classified as physical, chemical, biological and all combination where these techniques are used together. Main examples are aerobic, anaerobic treatments, filtration, flocculation, wet-oxidation, evaporation and adsorption. Phenols in the OMW are resistant to bio degradation, they cause inhibition and toxicity because of this they are tried to be adsorbed on a surface. The bioactivity and analysis of OMW bio phenols has been Reviewed [15].

From an environmental point of view, OMW is the most critical waste emitted by olive-mills in terms of both quantity and quality. In view of this, it is apparent that an olive waste must be treated and preferably utilized. Up to now the emphasis has been on detoxifying OMW prior to disposal. However, the present trend is towards further utilization of OMW by recovering useful by-products. Essentially, the OMW composition is water (80–83%), organic compounds (15–18%), and inorganic compounds (mainly, potassium salts and phosphates) 2%, and it varies broadly depending on many parameters such as olive variety, harvesting time, climatic conditions, and oil extraction process. The presence of large amounts of proteins, polysaccharides, mineralsalts, and other useful substances for agriculture, such as humic acids, OMW hasa high fertilizing power. Therefore, OMW can serve as natural, low-costfertilizer available in large amounts. [2, 3] Unfortunately, besides these useful substances for agriculture, OMW also contains phytotoxic and bio-toxic substances, which prevent it from being disposed off. The phytotoxic and antibacterial effects of OMW have been attributed to its phenolic content. Phenolic compounds are present in OMW at concentrations in the range from0.5 to 24 g/L, and are strictly dependent on the processing system used for olive oil production. A group of phenolic compounds found in OMW are derived from

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cinnamicacid: the parent unsubstituted cinnamic acid, o- and p-coumaric acid (4-hydroxycinnamic acid), caffeic acid (3, 4dihydroxycinnamic acid), and ferulicacid (4-hydroxy-3-methoxycinnamic acid). [14] Another group of phenolic compounds found in OMW are derived from benzoic acid: the parent unsubstituted benzoicacid, protocatechuic acid, and b-3,4-dihydroxyphenyl ethanol derivatives, such astyrosol and hydroxytyrosol. [5] Another group of phenolic compounds found in OMW are derived from benzoic acid: the parent unsubstituted benzoicacid, protocatechuic acid, and b-3,4-dihydroxyphenyl ethanol derivatives, such astyrosol and hydroxytyrosol. [5] Other phenols found in OMW include catechol, 4-methylcatechol, p-cresol, and resorcinol. [6]

Some of the characteristic parameters carried out on fresh OMW samples obtained from olive-mills processing olives by pressure and 3-phase centrifugation systems is shown in Table 1. [4]

Table 1. Typical components of OMW

Parameter	Pressure system	3-Phase centrifugation system
pH	5.27	5.23
Dry meter (g/l)	129.7	61.1
Specific weight	1.049	1.020
Oil (g/l)	2.26	5.78
Reducing sugars (g/l)	35.8	15.9
Total phenols (g/l)	6.2	2.7
o-Diphenols (g/l)	4.8	2.0
Hydroxytyrosol (mg/l)	353	127
Precipitate with alcohol (g/l)	30.4	24.6
Ash (g/l)	20	6.4
COD (g O_2/l)	146.0	85.7
Organic nitrogen (mg/l)	544	404
Total phosphorous (mg/l)	485	185
Sodium (mg/l)	110	36
Potassium (mg/l)	2470	950
Calcium (mg/l)	162	69
Magnesium (mg/l)	194	90
Iron (mg/l)	32.9	14.0
Copper (mg/l)	3.12	1.59
Zinc (mg/l)	3.57	2.06
Manganese (mg/l)	5.32	1.55
Nickel (mg/l)	0.78	0.57
Cobalt (mg/l)	0.43	0.18
Lead (mg/l)	1.05	0.42

In this study a new filtering method was developed and the filtrate was evaluated for agricultural use. This new filer was composed of material easily accessible to farmers, readily available at low cost, and can be recycled. As olive mills generates about 200 thousand m^3/year in West Bank [5], the project aimed to explore the possibility of using OMW as available option for crop irrigation. In addition the project aimed to reduce the impact of OMW on environment as it contributes largely to the core problem of surface and groundwater pollution. Jenin governorate was selected for study as it contributes for 84.2% of total olive oil production in the West Bank [6].

2. Materials and Methods

OMW source

The OMW was collected from different automated olive mill from Jenin governorate and transferred to the chemistry lab of the Arab American University, Jenin (AAUJ). The olive mill waste aqueous solutions were obtained from three –phase centrifugal extraction mills. For sedimentation of solid impurities, the OMW was left for an overnight period at room temperature.

Filter Preparation

The filter was prepared using six layers of different natural materials as shown in Figure 1.

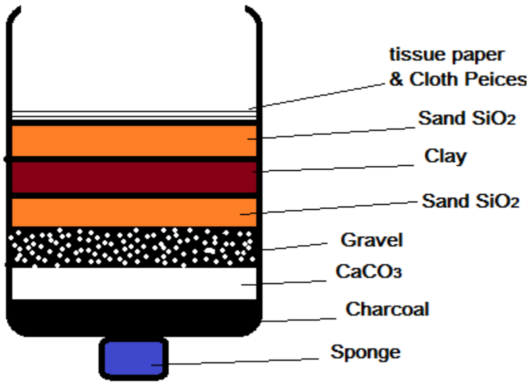

Figure 1. The matrix content of the home-made filter

Filtration Process

The OMW was added to the top of the filter and left overnight to pass through the matrix. The process of filtration is illustrated in Figure 2. The filtrate was evaluated for the turbidity and the pH for treated and untreated OMW was measured.

Filtrate dilution

The Filtrate was divided into 4 parts. Part 1 was left without dilution while, parts 2, 3 and 4 were diluted with tap water into 10%, 20% and 50% respectively (table 1). The process of filtration is illustrated in Figure 2.

Figure 2. The home-made filter showing the process of filtration

Assay plant preparation

Thirty tomato plants were divided into six groups each with five replicates. The plants were grown in a greenhouse at the AAUJ campus. The plants were first irrigated with tap water for one week. Irrigation was done using the OMW dilutions as pointed above as well as a control sample including untreated OMW and tap water.

Plant growth evaluation

Plant growth was evaluated by measuring the vegetative growth including plant height and leaf length. In addition, fruits were collected upon maturation and weighed for fresh and dry weights.

Statistical analysis

Analysis of the data was performed using the Two-Sample Test of Proportion (TSTP). The results were analyzed using a level of significance when α=0.05.

3. Results

Filtrate properties

A clear filtrate was obtained with yellowish color without any apparent impurities. The pH of the filtrate was 7.12 compared with 4.60 for the untreated OMW as shown in **Figure 3**. Furthermore the filtrate was characterized with a pungent odor.

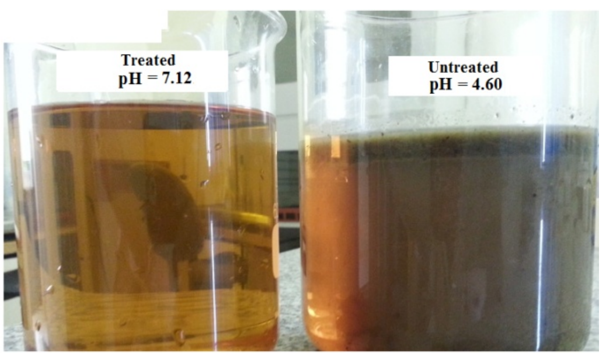

Figure 3. Comparison of clearance of treated and untreated OMW

Plant growth evaluation

Plant height and leaf length obtained from irrigation with different dilutions are shown in table 2. In addition, fruit weight was displayed in Table 3. Fruit size and quality as well as plant growth and development are shown in Figures 4 and 5.

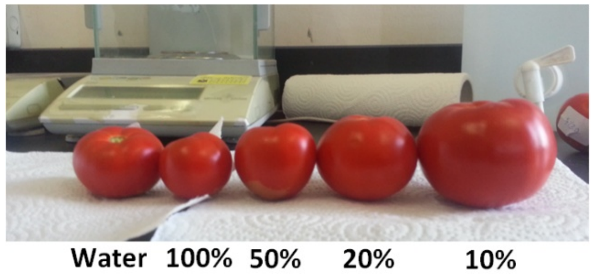

Figure 4. Fruit size and quality irrigated with OMW

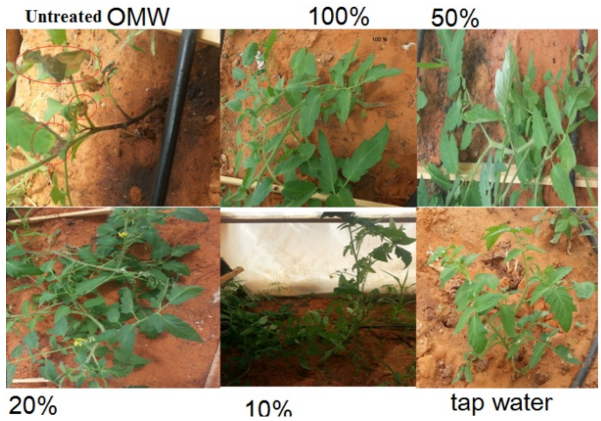

Figure 5. Growth and development of tomato plants irrigated with OMW

Table 2. Plant height and leaf length (in centimeters) of tomato irrigated with OMW. Comparison of data using TSTP when Z-table (critical value) =1.645

Treatment	Plantheight	leaf length
10%	110 **a**	12**(a)**
20%	104 **b**	12 **(a)**
50%	60 **c**	9 **(b)**
100%	53 **d**	6 **(c)**
Untreated OMW	36 **e**	5 **(c)**
Tap water	44**f**	5 **(c)**

**Similar letters indicate no significant difference. [17, 18]

Table 3. Fresh and dry weights (in grams) of tomato irrigated with OMW. Comparison of data using TSTP when Z-table (critical value) = 1.645

Treatment	Fresh weight	Dryweight
10%	130.12**a**	28 **(a)**
20%	71.90 **b**	20**(b)**
50%	42.60**c**	13.3**(c)**
100%	30.47**d**	6.3 **(d)**
Untreated OMW	0 **e**	0 **(e)**
Tap water	50.62 **f**	14 **(c)**

**Similar letters indicate no significant difference. [17, 18]

4. Discussion

Water resources in Palestine are under tremendous stress due to several reasons including increasing demand on fresh water, political situation and population growth. In addition, natural and man-made issues may increase the seriousness of water scarcity in the country. Because of its geographical location (semi-arid), Palestine receives an average of 300 - 400 mm of water yearly. Misuse is also another problem. The country is urgently in need of alternative options toward water management and wastewater treatment. This requires shifting from the use and disposing approach to the use, treat, and reuse approach. The current experiment proposes a set of alternatives for sustainable water management in the agricultural sectors in the West Bank that alleviate the stress on water resources. Implementing a combination of water management alternatives that will put water management in the West Bank in Palestine on a sustainable track. [7-9]

In this research, OMW was filtered through a specially designed apparatus and the collected filtered water was made into various dilutions. Each dilution was dosed to tomato plants and the influence and progress on these plants were monitored. It was noticed that plants irrigated with 10% and 20% dilutions were the best as they had strong structure, greenest leaves, longest stem and the longest leaves. Plants irrigated with 50% dilution were less tall. Irrigation with 100% filtrate produced plants shorter than the plants irrigated with lower dilutions but stronger than the once that irrigated with tap water. This is mainly that the filtrate may contain elements that promoted growth of the plants. Another reason is that the filtrate may contain some polyphenols that have antiseptic activities and anti-oxidant properties.

The polyphenols, specifically hydroxytyrosol and catechol are responsible for many biological effects, including antibiosis, ovipositional deterrence and phytotoxicity. Of all the polyphenols considered, hydroxytyrosol, is worth noting as the main natural polyphenolic compound in OMW. Possibly it arises from the hydrolysis of oleuropein by an esterase during the milling process (**see Figure 6**). Hydroxytyrosol is characterized by major bio-antioxidant activity. Hydroxytyrosol is one of major phenolic compounds present in olive fruit and it has been revealed to be the most interesting, because of its remarkable pharmacological and antioxidant activity. hydroxytyrosol has variety of applications: as natural food antioxidant, preparation of functional foods, pharmaceutical solutions or cosmetics. Oleuropein has been considered a valuable component with certain antiviral, antibacterial, antifungal, antioxidant and anti-inflammatory properties (Fig.1) [10, 11].

Previous research has analyzed the content, composition, and physicochemical status of metal cations and inorganic anions in raw OMW and treated OMW. **Table 4** shows the concentration values of the metal cations and inorganic anions OMW. The OMW contain an enormous supply of organic matter very rich in phenolic compounds, which are toxic. Untreated olive mill wastewater (OMW) is an acidic effluent with a high nutrient content that can be used to fertilize the soil. However, treated olive mill wastewater (OMW) is a slightly alkaline effluent, rich in inorganic loads such as potassium, calcium, magnesium and iron. Its phenolic compounds content was lower than 1 g L^{-1}, reflecting a significant reduction of its toxicity from 13 BOD in untreated OMW to only 1.8% BI. Such high content of non-toxic organic compounds, macro-elements and micro-elements indicated a significant fertilizing potential of the treated OMW that could be used advantageously in agronomy (Table 4) [12]. In addition to its high organic load, substantial amounts of plant nutrients the, OMW may represent a low cost source of water [13]. Other researchers indicated that the compost of the OMW can be used as biobased pesticides against weeds, fungi, and nematodes [16].

Table 4. The concentration of cations & anions of OMW [12]

Item	Raw	Treated
pH (25ºC)	5±0.2	8.1±0.2
Electrical conductivity (25ºC) (dS m^{-1})	8.1±0.1	14.2±0.1
Chemical oxygen demand (g/l)	53.3±1.8	4.5±0.41
Biological oxygen demand (g/l)	13.42±0.8	1.8±0.16
COD/BOD_s	4±0.72	2.5±0.45
Water content (g/l)	960.6±19	984±19
Total solids (g/l)	39.4±1.8	16±0.8
Mineral matter (g/l)	6.5±0.3	10.15±0.5
Volatilesolids (g/l)	33±1.5	48±0.2
Total organic carbon (g/l)	17.6±0.88	3.2±0.16
Phenolic compound (g/l)	8.6±0.5	0.77±0.08
Total nitrogen (g/l)	0.5±0.05	0.25±0.03
Carbon/nitrogen	35.2±7.04	128±2.56
Toxicity by LUMIStox (B_I (%))	99±2	30±0.7
Phosphor (P) (mg/l)	36±3.6	15±1.5
Sodium (Na) (g/l)	0.8±0.08	0.86±0.09
Chlorures (Cl) (g/l)	1.45±0.15	1.3±0.13
Potassium (K) (g/l)	8.6±0.8	5.34±0.5
Calcium (g/l)	0.9±0.09	3.2±0.3
Iron (Fe) (g/l)	23.4±2.3	38.3±3.8
Magnesium(Mg) (mg/l)	186.9±18.7	281±28.1

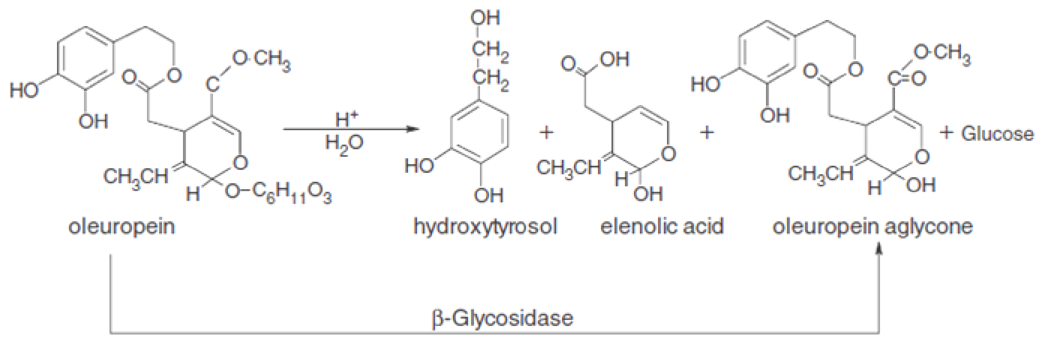

Figure 6. The structure of oleuropein and its hydrolysis products

5. Conclusions

Olive mill wastewater constitutes a hazardous environmental problem. A simple treatment filter proposed to treat their contaminant impacts. Soils in semi-arid and arid areas are known to have low organic matter levels, a low fertility and a high exposure to degradation, desertification and pollution. Treated olive mill wastewater may contain relatively good nutrients for plants as well as an important volume of water and a potential use as a fertilizer, especially for soils and crops.

Finally, the physical method that was used in this experiment is cheap and easy to use everywhere. The plants that were irrigated with high concentrations of filtrate were weaker than those were irrigated with low concentrations; because that high concentration has some toxic materials in low concentrations.

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