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The effect of Wastewater from the Dorah Refinery Treatment Unit on *Lycopersicon esculentum* Mill. Tomato Grown in Three Types of Soil

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Abstract

The main objective of this study is to evaluate the effects of waste water from the Dora refinery's treatment unit on tomato *Lycopersicon esculentum* grown in three types of soil taken from the same area, with consideration to the number of leaves, lycopene, and beta-carotene content in tomato yield, as well as the plant's ability to absorb the toxic compounds furfural and -1, 2 dibromoethane. The experiment was carried out using pots in the glass house belonging to the Department of Biology, College of Education for Pure Sciences/Ibn Al-Haytham, University of Baghdad, for the seasons 20/9/2022–19/3/2023. The experiment included 45 treatments with 3 types of soil (clay, mixed, and sandy), and each type of soil had 5 treatments with 3 replicates. Control plants were left without treatment for each type of soil. The soil was sprayed with different volumes of water discarded from the treatment unit (0.1, 0.2, 0.3, and 0.4 ml/kg) before planting, and adding the same treatments with irrigation water was repeated after 53 days of planting at the stage of 4-6 leaves. The results showed that the treatment exceeded 0.1 ml. kg^{-1} soil in leaf area, number of leaves, lycopene, and beta-carotene content, as it gave the highest mean with an increase of 16.48%, 7.52%, 1.21%, and 0.54%, respectively, compared to untreated plants. As for the ability of the fruits to store furfural and 1,2-dibromoethane, it reached the highest average with a volume of 0.4 ml. kg^{-1} soil. The results also indicated that the mixed soil was superior in all traits except for the fruit content of furfural, which was superior to the clay soil.

Keywords: Dora refinery, wastewater, Soil types, Tomato plant.

1. Introduction

The tomato *Lycopersicon esculentum* Mill was placed under the Solanaceae family and is one of the economically important plants [1]. They are an excellent source of biologically active compounds, especially for carotenoids such as lycopene and beta-carotene, as well as phenolic substances such as ascorbic acid, tocopherols, and flavonoids [2,3]Tomato fruits provide antioxidants and prevent the formation of cancer cells and other health disorders [4]. It is a good source of vitamins A and C and helps to reduce the deficiency of these vitamins in the body [5].

as it determines the physical, chemical, and biological properties of the soil, which include soil structure, soil aggregation, water holding capacity, filtration ability, nutrient absorption, root penetration resistance, microbial activity, soil carbon turnover, erosion susceptibility, compaction and soil suitability for agricultural production [6, 7]. The fraction of sand, silt, and clay present in a soil sample determines the properties of water content in the soil, plant growth, and crop selection. Sandy soils are low in holding capacity for water and organic matter. The ability of alluvial soils to retain water is higher than that of sandy soils. Clay soils show a high capacity to retain water and a high degree of plasticity and thickness, while sandy soils are characterized by the absence of these characteristics. The water-holding capacity of sandy loamy soils is low compared to loamy and silty loamy soils. Soil texture indirectly affects plant growth, plant weight, and chlorophyll percentage [8-10]. Soil is an important part of successful agriculture and is the main source of nutrients used in growing crops. Soils are the basis of all production systems on farms and forests. Soil stores water, nutrients, and proteins in order to make them available for proper crop growth and development [11, 12]. The oil refining industry is one of the most important industries because it contains many production units. The oil refining process consumes large amounts of water, as water is an essential element and raw material for many stages of the oil industry, from extraction to refining and conversion, as it is involved in generating vacuum pressure for isolation towers, generating steam in distillation towers, operating steam-powered engines, and cooling in cooling towers. As polluted water is produced from the crude oil filtration process, it is called waste water containing pollutants that are collected in special basins to remove large pollutants by means of the separation process [13]. Opportunities for using waste water in various refining systems have increased. Refineries produce waste water containing chemicals and solid waste, 80% of which can be considered hazardous due to the presence of toxic organic products and heavy metals, given that the refinery pollutants are complex and diverse. However, some studies showed the possibility of using treated filtered water to stimulate plant growth because it contains compounds and elements that plants can benefit from [14]. The water of oil refineries contains abundant organic matter and a variety of nutrients necessary for plant growth, and this is consistent with [15, 16], as it was shown that the use of furfural can significantly improve soil quality and increase plant growth. [17] showed that the wastewater was successfully used to irrigate the olive plant.

2. Materials and Methods

The experiment was carried out using pots in the glass house belonging to the Department of Biology, College of Education for Pure Sciences/Ibn Al-Haytham, University of Baghdad, for the growing season 20/9/2022–19/3/2023. Tomato seeds were sown in a pot of 15 kg of soil and 20 seeds per pot on 9/20/2022. Three types of soils (clay, mixed, and sandy) were used. **Tables 1, 2,** and **3,** respectively, show the physical and chemical properties of the soil before planting. Soil samples were air-dried, ground, and sieved with a 2 mm-diameter sieve, and the volumetric distribution of soil particles was estimated by the pipette method [18]. As for the pH, it was estimated by the pH Tester, the manufacturer HANNA instruments, model HI98107pHep, EC, and TDS.

It was estimated by the TDS Tester, the manufacturer HANNA instruments, model HI98301DiST1, and organic matter according to the described method [19] and nitrogen according to the described method [20]. The elements (phosphorus and potassium) were analyzed.

Magnesium, Iron, Manganese, Zinc, Copper, Lead, and Cadmium by X-Ray Fluorescence (XRF) Manufacturer Ametek Model Spectro Xepos

Table 1. Some chemical and physical properties of clay soil before planting**.**

Adjective	the value	Unit
mud	51.5	%
silt	35.8	%
the sand	12.7	%
soil texture	mud	---
Soil reaction (pH)	6.2	---
Electrical conductivity (EC)	11.32	Desi Siemens. M^{-1}
The amount of dissolved salts (TDS)	566	mg. lt^{-1}
organic matter	1.67	%
nitrogen	0.5121	%
phosphorous	0.1501	%
potassium	1.0933	%
magnesium	2.7358	%
Iron	3.2977	%
manganese	0.0689	%
zinc	0.0131	%
copper	0.0045	%
Lead	0.0038	%
cadmium	0.0002	%

Table 2. Some chemical and physical properties of mixed soil before planting**.**

Adjective	the value	Unit
mud	24.1	%
silt	35.7	%
the sand	40.2	%
soil texture	mixture	---
Soil reaction (pH)	6.5	---
Electrical conductivity (EC)	6.07	Desi Siemens. M^{-1}
The amount of dissolved salts (TDS)	303	mg. lt^{-1}
organic matter	1.75	%
nitrogen	0.1697	%
phosphorous	0.0353	%
potassium	0.9606	%
magnesium	2.7250	%
Iron	3.5908	%
manganese	0.0711	%
zinc	0.0071	%
copper	0.0035	%
Lead	0.0009	%
cadmium	0.0002	%

Table 3. Some chemical and physical properties of sandy soil before planting.

Adjective	the value	Unit
mud	4.4	%
silt	8.4	%
the sand	87.2	%
soil texture	sandy	---
Soil reaction (pH)	6.0	---
Electrical conductivity (EC)	3.90	Desi Siemens. M^{-1}
The amount of dissolved salts (TDS)	210	mg. lt^{-1}
organic matter	1.56	%
nitrogen	0.0979	%
phosphorous	0.0354	%
potassium	0.7802	%
magnesium	1.5766	%
Iron	2.5030	%
manganese	0.0619	%
zinc	0.0042	%
copper	0.0015	%
Lead	0.0074	%
cadmium	0.0002	%

The samples were taken from the final sedimentation basin after treatment in the Dora Refinery, which is located southeast of the capital, Baghdad, before being thrown into the Tigris River. Some elements were studied, as shown in **Table 4**, and the organic compounds were examined with a gas chromatography device (GC) manufactured by DANI, model 2010, in the Iraqi Ministry of Science and Technology, as shown in **Table 5**.

Table 4. Some elements in the waste water from the treatment unit in the Dora refinery.

Adjective	the value	Unit
nitrogen	0.01	mg. lt^{-1}
phosphorous	0.00	mg. lt^{-1}
potassium	1.00	mg. lt^{-1}
magnesium	0.05	mg. lt^{-1}
Iron	0.01	mg. lt^{-1}
manganese	0.01	mg. lt^{-1}
zinc	0.07	mg. lt^{-1}
copper	0.01	mg. lt^{-1}
Lead	0.00	mg. lt^{-1}
cadmium	0.00	mg. lt^{-1}

Table 5. Organic compounds in the waste water from the treatment unit in the Dora refinery.

Adjective	the value	Unit
furfural	41.42	mg. lt^{-1}
1,2-dibromoethane	4.99	mg. lt^{-1}
O-xylene	3.41	mg. lt^{-1}
bromoform	0.99	mg. lt^{-1}
1,2,3- trichloro Propane	1.11	mg. lt^{-1}

The experiment included 45 treatments, and the parameters were as follows:

1. For each type of soil, there were 5 treatments, with 3 replications.
2. Control plants were left without treatment for each type of soil.

3. The soil was sprayed with treatments (0.1, 0.2, 0.3, and 0.4 ml/kg) before planting with the water that was discarded from the treatment unit.
4. Adding the same treatments with irrigation water after 53 days of planting at the stage of 4-6 leaves.

The following traits were studied after the plants were harvested on March 19, 2023.

1. Leaf area: The leaf area is measured by using a cylinder of known diameter and taking a specific group of discs from different places of the leaf, along with the weight of these discs. The area is calculated by knowing the total weight of the leaves, the area, and the weight of the discs [21].
2. Number of leaves: The number of leaves per plant was calculated.
3. Lycopene and beta-carotene were calculated according to the method described in [22].
4. Furfural and 1,2-dipomoethane were calculated by the GC apparatus.

Statistical analysis

The data were collected and analyzed statistically according to the arrangement and design used in the experiment using the GENSTAT program, and the significant differences between the means were compared using the least significant difference (LSD) at a significant level of 0.05.

3. Results and discussion

The effect of waste water was discarded from the treatment unit in the Dora refinery and soil type and their interaction on some phenotypical characteristics of tomato plants.

3.1. Leaf area (cm^2)

The results of **Table 6** showed that there were significant differences in the average leaf area due to the effect of soil type. The mixed soil gave the highest mean for this characteristic, amounting to 98.05 cm^2. With an increase rate of 20.34% compared to the clay soil, which amounted to 81.48 cm^2. With an increase of 70.76% compared to sandy soil, which amounted to 57.42 cm^2. The reason is due to the soil texture that affects plant growth, as many processes such as evaporation, sedimentation, water drainage, heat conduction, gas diffusion, and the movement of salts and nutrients depend on soil properties [23], and this is consistent with [12].As for the effect of treatment with waste water, the results indicate that there are significant differences in the average leaf area, as the volume exceeded 0.1 (ml. kg^{-1} soil), giving the highest average leaf area of 87.94 cm^2, an increase of 16.48% compared to the control treatment, which amounted to 75.50 cm^2, and this is consistent with what was obtained [14, 17] that the use of treated filtered water can stimulate the growth and germination of plants. As for the binary interaction between the type of soil and the volume of waste water, it was significant in the characteristic of leaf area, as the mixed soil and a volume of 0.1 (ml. kg^{-1} soil) of waste water gave the highest value of 118.65 cm^2, with an increase of 17.92% compared to the control treatment.

Table 6. The effect of treatment with effluents discarded from the treatment unit and soil type and their interaction on the average leaf area (cm^2) of tomato plants.

Soil type	The volume of water discarded from the treatment unit (ml. kg^{-1} soil)					Average
	0.0	0.1	0.2	0.3	0.4	
Mud	77.42	79.91	82.46	90.94	76.65	81.48
Mixture	100.62	118.65	107.20	93.94	69.83	98.05
Sandy	48.45	65.26	69.88	58.61	44.92	57.42
Lsd 0.05			**10.22**			**4.57**
Average	75.50	87.94	86.51	81.16	63.80	
Lsd 0.05			**5.90**			

3.2. Number of leaves (leaves $Plant^{-1}$)

The results of **Table 7** showed that there were significant differences in the average number of leaves due to the effect of soil type. The mixed soil gave the highest mean for this trait, which was 26.5 (leaf. $plant^{-1}$) with an increase of 0.76% compared to the average clay soil, which amounted to 26.3 (leaf. $plant^{-1}$) with an increase rate of 4.74% compared to the average of sandy soil, which amounted to 25.3 (leaf. $Plant^{-1}$). The reason for this diversity is due to the soil texture that affects plant growth, as many processes such as evaporation, sedimentation, water drainage, heat conduction, gas diffusion, and movement of salts and nutrients depend on soil properties [23], and this is consistent with [24].As for the effect of the treatment with wasted water, the results indicate that there are significant differences in the average number of leaves. The volume exceeded 0.1 ml/kg of soil, giving the highest average number of leaves at 28.6 leaves per plant, an increase of 7.52% compared to the control treatment. Which reached 26.6 (leaf. $plant^{-1}$), and this is consistent with what was obtained [25]: the use of these residues led to an increase in the number of leaves, the size of trees, and the rate of plant growth.As for the binary interaction between the type of soil and the volume of waste water, it was significant in the number of leaves, as the mixed soil and the volume of 0.1, 0.2 (ml. kg^{-1} soil) of waste water gave the highest value of 29.0 (leaf. $plant^{-1}$), with an increase rate of 4.69% compared to the control treatment.

Table 7. Effect of treatment with effluents discarded from the treatment unit and soil type and their interaction on the average number of leaves (leaf. $plant^{-1}$) of tomato plant.

Soil type	The volume of water discarded from the treatment unit (ml. kg^{-1} soil)					Average
	0.0	0.1	0.2	0.3	0.4	
Mud	28.7	28.3	27.0	24.7	23.0	26.3
Mixture	27.7	29.0	29.0	24.3	22.3	26.5
Sandy	23.3	28.3	28.3	23.7	22.7	25.3
Lsd 0.05			**1.7**			**0.8**
Average	26.6	28.6	28.1	24.2	22.7	
Lsd 0.05			**1.0**			

3.3. Fruit content of lycopene (µg.gm^{-1}).

The results of **Table 8** showed that there were significant differences in the average contents of lycopene in the fruits due to the effect of soil type. The mixed soil gave the highest mean for this trait, amounting to 108.84 (µg.gm^{-1}). With an increase rate of 5.46% compared to the average clay soil, which amounted to 103.21 g/m3, with an increase rate of 14.53% compared to the average sandy soil, which amounted to 95.03 g/m2. The reason is due to the soil tissue that affects the growth of the root system of the plant, which affects the absorption of water, salts, and minerals, which increases the processes of building secondary compounds, including carotenoids, as lycopene represents the main carotene in tomato fruits [11], and this is consistent with [26].

As for the effect of treatment with waste water, the results indicate that there are significant differences in the average content of lycopene in fruits. The volume exceeded 0.1 ml/kg of soil, giving the highest average content of lycopene in fruits, which reached 104.19 g/g, with an increase of 1.21. % compared to the control treatment, which amounted to 102.94 g/g. The reason is that the water in oil refineries contains abundant organic matter and a variety of nutrients necessary for plant growth [15, 16].As for the bilateral interaction between one type of soil and the volume of waste water, it was significant in the characteristic of the fruit content of lycopene, as the control treatment in the mixed soil gave the highest value of 112.72 (µg.gm^{-1}), an increase of 2.28% compared to the highest value of the other treatments, which amounted to 110.21. (µg.gm^{-1}) at a volume of 0.3 (ml.kg^{-1}).

Table 8. The effect of treatment with effluents discarded from the treatment unit and soil type and their interaction on the average fruit content of lycopene (µg.gm^{-1}).

Soil type	**The volume of water discarded from the treatment unit (ml. kg^{-1} soil)**					**Average**
	0.0	0.1	0.2	0.3	0.4	
Mud	102.67	103.97	103.66	101.80	103.96	103.21
Mixture	112.72	107.94	107.70	110.21	105.64	108.84
Sandy	93.42	100.65	97.25	91.29	92.53	95.03
Lsd 0.05			**3.71**			**1.66**
Average	102.94	104.19	102.87	101.10	100.71	
Lsd 0.05			**2.14**			

3.4. Fruit content of beta-carotene (µg.gm^{-1}).

Table 9 shows the significant differences in the average beta-carotene content of the fruits that are affected by soil type. The mixed soil gave the highest mean for this trait, amounting to 62.19 (µg.gm^{-1}) with an increase rate of 6.22% compared to the average clay soil, which amounted to 58.55 (µg.gm^{-1}) and an increase rate of 7.24% compared to the average sandy soil, which amounted to 57.99 (µg.gm^{-1}). The reason is due to the soil tissue that affects the growth of the root system of the plant, which affects the absorption of water, salts, and minerals, which increases the process of building secondary compounds, including carotenoids [27], and this is consistent with [11]. As for the effect of treatment with waste water, the results indicate that there are significant differences in the average content of beta-carotene in fruits, as the volume exceeded 0.1 (ml. kg^{-1} soil), giving the highest average content of beta-carotene in fruits, which amounted to 61.88 (µg.gm^{-1}). With an increase rate of 0.54% compared to the control treatment, which amounted to 61.55 (µg.gm^{-1}), and this is consistent with what was obtained [28].As for the bilateral interaction between the type of soil and the volume of waste water, it was significant in the characteristic of the fruit content of beta-carotene, as the control treatment in the mixed soil gave the highest value of 65.38 (µg.gm^{-1}), an increase of 2.54% compared to the highest value of the other treatments, which was 63.76 (µg.gm^{-1}) at a volume of 0.2 (ml.kg^{-1}).

Table 9. The effect of treatment with effluents discarded from the treatment unit and soil type and their interaction on the average percentage of beta-carotene content of fruits (µg.gm^{-1})

Soil type	**The volume of water discarded from the treatment unit (ml. kg^{-1} soil)**					**Average**
	0.0	0.1	0.2	0.3	0.4	
Mud	58.79	59.81	58.33	57.35	58.47	58.55
Mixture	65.38	63.46	63.76	62.94	55.39	62.19
Sandy	60.49	62.38	54.32	53.93	58.81	57.99
Lsd 0.05			**2.25**			**1.01**

Average	61.55	61.88	58.80	58.07	57.56	
Lsd 0.05			**1.30**			

3. 5. Fruit content of furfural (mg. L^{-1}).

The results of **Table 10** showed that there were significant differences in the average furfural content of fruits, due to soil type. The clay soil gave the highest mean for this characteristic, which amounted to 113.12 (mg. L^{-1}), with an increase rate of 8.76% compared to the mixed soil, which amounted to 104.01 (mg. L^{-1}). With an increase rate of 65.72% compared to the sandy soil, which amounted to 68.26 (mg. L^{-1}), the reason is due to the ability of each type of soil to retain compounds for a longer period, which gives the plant a longer time to absorb the compounds [29]. As for the effect of treatment with waste water, the results indicate that there are significant differences in the furfural content of the fruits, as the volume exceeded 0.4 (ml. kg^{-1} soil), giving the highest average furfural content of the fruits, which amounted to 167.27 (mg. L^{-1}) compared to the control treatment. The reason for this is that the higher the volume of the treatment, the greater the absorption of the compound by the plant [30].As for the binary interaction between one type of soil and the volume of waste water, it was significant in the characteristic of the fruit content of furfural, as the mixed soil and a volume of 0.4 (ml. kg^{-1}) soil of waste water gave the highest value of 206.91 (mg. L^{-1}).

Table 10. The effect of treatment with effluents discarded from the treatment unit and soil type and their interaction on the average concentration of furfural content of fruits (mg. L^{-1}).

Soil type	The volume of water discarded from the treatment unit (ml. kg^{-1} soil)					Average
	0.0	0.1	0.2	0.3	0.4	
Mud	0.00	104.15	134.47	130.76	196.24	113.12
Mixture	0.00	105.93	71.36	135.83	206.91	104.01
Sandy	0.00	38.55	86.24	117.83	98.67	68.26
Lsd 0.05			**7.11**			**3.18**
Average	0.00	82.88	97.36	128.14	167.27	
Lsd 0.05			**4.11**			

3.6. Fruit content of 1, 2-dibromoethane

The results of **Table 11** showed that there were significant differences in the average fruit content of 1, 2-dibromoethane that are affected by soil type. The mixed soil gave the highest mean for this trait, which reached 1.4020 (mg. L^{-1}), with an increase rate of 11.19 % compared to clay soil, which amounted to 1.2609 (mg. L^{-1}) and an increase rate of 221.49 % compared to the sandy soil, which amounted to 0.4361 (mg. L^{-1}), the reason is due to the ability of each type of soil to retain compounds for a longer period, which gives the plant a longer time to absorb the compounds [29], and this is consistent with [24].As for the effect of treatment with waste water, the results indicate that there are significant differences in the fruit content of 1, 2-dibromoethane, as the volume of 0.4 (ml. kg^{-1} soil) exceeded, giving the highest average fruit content of 1, 2-dibromoethane, which reached 2.1257. (mg. L^{-1}) compared to the control treatment. This is due to the plant's ability to absorb organic compounds and store them in its fruits [31].As for the binary interaction between the type of soil and the volume of waste water, it was significant in terms of the fruit content of 1, 2-dibromoethane, as the mixed soil and a volume of 0.4 (ml. kg^{-1} soil) of the liquid waste gave the highest value of 2.8823 (mg. L^{-1}).

Table 11. The effect of treatment with effluents discarded from the treatment unit and soil type and their interaction on the average fruit content concentration of 1,2-dibromoethane (mg. L^{-1}).

Soil type	The volume of water discarded from the treatment unit (ml. kg^{-1} soil)					Average
	0.0	0.1	0.2	0.3	0.4	
Mud	0.0000	0.5251	2.3958	1.7254	1.6583	1.2609
Mixture	0.0000	0.8252	1.4341	1.8682	2.8823	1.4020
Sandy	0.0000	0.0018	0.0039	0.3159	1.8366	0.4361
Lsd 0.05			**0.0167**			**0.0075**
Average	0.0000	0.4507	1.2779	1.3032	2.1257	
Lsd 0.05			**0.0097**			

4. Conclusion

1. The results showed that the water discarded from the treatment unit in the Dora refinery stimulated plants to grow.
2. There are significant differences in the studied traits.
3. The ability of the plant to absorb furfural and 1,2-dibromoethane and store them in the fruits.
4. More detailed studies in this regard may lead to the possibility of using filtered water to fertilize the soil and stimulate plants to grow.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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