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Studying the effect of irrigation water quality (fresh water, treated water and wastewater) on some soil physical and chemical properties and the protein content in the paulownia leaves.

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Abstract

Samples of soil irrigated with three types of water: Fresh water (F), wastewater (W), fresh water and wastewater (F1W1, alternative irrigation) were collected at two depths (0-15 cm and 15-30 cm) for two consecutive years. The bulk density, true density, soil total porosity, electrical conductivity, pH, percentage of organic matter, and concentration of phosphorus and potassium were measured. In addition, the length and circumference of paulownia tree trunk were measured, and the protein content of dry and green leaves was estimated. The results showed the differences in the apparent density values, as wastewater irrigation decreases the apparent density and increased the soil total porosity. The results also indicated that there were significant differences in the soil PH between the three treatments, as treated water irrigation decreased the pH and insignificantly increased the soil electrical conductivity. However, there were significant differences when irrigating with wastewater, as the electrical conductivity and organic matter content increased in the soil irrigated with wastewater compared to soil irrigated with fresh water at two depths (0-15cm and 15-30cm). Moreover, the concentrations of phosphorus and potassium increased in the soil irrigated with wastewater and treated water compared to fresh water. Furthermore, there were significant differences in the height of paulownia tree and its trunk circumference when irrigating with treated water compared to wastewater and fresh water. As for the protein content in paulownia leaves, it was observed that there were significant differences when irrigating with wastewater compared to treated water and fresh water. There was high protein content in the dry and green leaves when irrigating with the three types of water, but the highest protein content was for wastewater irrigation.

Key words: Irrigation, treated water, soil, heavy metals

Introduction

The issue of water scarcity and water quality degradation has emerged in many countries of the world due to population growth, as the world population is expected to reach 10 billion people in the next thirty years. Thus, it becomes more challenging to secure basic water supplies. The World Health Organization and UNESCO have stated in their annual report that by the year 2050, the water demand will rise by 20-30% for the daily requirement [1] and that the production (i.e, agricultural, industrial, etc) has to increase for meeting the needs of growing population. The agricultural production is expected to increase by 70%. However, agriculture is the largest fresh-water user, accounting for approximately 75% of total freshwater withdrawals,[2] so it puts further pressure on freshwater resources. Therefore, ensuring water security, which is the basis of sustainable agricultural development, [3] is one of the most important challenges facing many countries in the world. Syria is one of those countries. It has only 10.5 billion cubic meters of renewable water resources, and uses 89% of which in irrigating 1.2 million hectares of agricultural land [4].

Due to limited water resources and resulting cumulative deficit in their use for agricultural purposes, it has been necessary to find alternative water sources that support the current water budget. Thus, the aim is to develop a significant strategy for saving fresh drinking water and improving surface water quality by reusing wastewater or treated water an efficiency, based on modern and non-traditional techniques. Wastewater results from clean water daily use in various areas, such as cleaning and washing, along with its use in industries…etc [5].

Most Arab countries have extensively treated water and used it in agricultural irrigation, despite the effects of irrigation of these alternative sources on the soil and its productivity.

A study conducted by [6] has showed that this type of water constitutes about (2-3%) of the annual groundwater consumption and can rise by (5-7%) in areas with high population density.

Reusing treated or untreated water in irrigation requires studying the water and accurately determining its quality to avoid any potential obstacles by [7].

Many countries have set strict biological standards to reuse treated liquid waste for its impact on plant, human and soil [8].

Many researchers have concluded that using treated water in agriculture is an economical because it is the least expensive and most profitable(9,10). Moreover, it is noted that the use of treated and untreated water in irrigation has an impact on soil physical properties. It increases porosity, field capacity, and plant available water [11], and accordingly, improves soil structure stability [12, 13,14].

Prolonged wastewater irrigation decreases the hydraulic conductivity [15,16,17], which affects the movement of soil water without affecting the movement of elements [18,19, 20].

Wastewater is also characterized by its high organic matter content, and many farmers still depend on this type of water to extract organic fertilizers [9]. Studies by by

[21,22], have showed that the irrigation with wastewater increases the soil organic matter content and maximum holding capacity for longer period.

Irrigation with treated and untreated water also increases the content of nitrogen, phosphorus, potassium, and calcium in soil [23,24]. Many countries in the world have growing attention to the use of this type of water to irrigate agricultural crops during the last hundred years [25] because that is the most economically efficient method [26]. This type of unconventional water was used in Syria as an additional renewable water resource within the national water budget [5].

As for increasing the overall agricultural production , it is possible to introduce new types of agricultural crops and forest trees in Syria. Among these trees are paulownia trees, which are considered beautiful ornamental trees and have many benefits, including supporting the growth of other trees around as they grow quickly to reach a height of more than 3 m in the second year after planting.

Paulownia tree also constitutes an important source of light wood used in the manufacture of furniture and floors. Moreover, its broad leaves improve soil fertility and physical properties after they fall and decompos [27, 28], and its flowers provide subsistence for bees in the spring.

Paulownia can be planted in all coastal areas, in all types of soil even rocky soil, on river banks and near sewer, at an altitude of 2000 m above sea level. It tolerates subzero temperature in winter and 50 degree temperature in summer.Its leaves and flowers are also rich in nitrogen which is useful as a natural fertilizer. Being a good source of protein, it is a good animal fodder, especially in Syria that suffers from shortage of animal feed resources and thus animal products.

Furthermore, it is also possible to use artificial methods in growing Paulownia using artificial methods, as experiments have proven that its seedlings are disease-free and grow naturally when the roots are well cared for. Seedlings can be produced in nurseries under artificial growing conditions, so the artificial method is the best for planting Paulownia [29]. Many studies conducted to estimate the amount of water required for the growth of Paulownia tree in the first year after planting have shown that rain-fed irrigation at a rate of 50 mm per month may be insufficient for its growth. It is also noted that it grows better in areas with a rainfall average between 100 and 150 mm per month [30].

The research aims to study the effect of using different types of water (fresh water, wastewater and treated water) on some physical and chemical soil properties and on the protein content of paulownia leaves.

Materials and Methods

Experiment implementation site: The research experiment was implemented under field conditions in the village of Nasiriyah in Al-Qusayr district, which is 35 km away from Homs in its southwestern side.

Study materials

Water: Three types of irrigation water sources were used in the experiment:

- Fresh water (F) from a 150-meter deep well in the study area.
- Treated water (T) transported from Al-Duwair station in the city of Homs by tankers designed especially for this purpose.
- Wastewater (wastewater, W) was transported from the Al-Duweir station before treatment in Homs using special tanks designed for that purpose.

Three tanks were designed: a fresh water tank connected by the well submersible, a wastewater tank, and a treated water tank. They were also connected to a drip irrigation network. Water samples were collected from fresh water and from the entrance and exit of the station. Scientific methods were applied to collect the samples [31], using one liter plastic bottles after cleaning and sterilizing them with hot water. That process was repeated several times to remove residual sterilant.

They were then filled with water, closed tightly, and transported to the laboratory for analysis. The pH was measured using a pH meter, and the EC was measured using a conductivity electronic meter. The amount of phosphorus, nitrate (N-NO3), ammonium (N-NH4), sulphate (SO4), and carbonate (CO3) were estimated. The total concentration of some heavy metals (lead, cadmium, and nickel) was also estimated using an atomic absorption spectroscopy. The results of analyzing the used water samples showed, as can be seen in the table No. (1), that the pH did not vary significantly between fresh water and wastewater, whereas the lowest pH was recorded for the treated water compared to fresh water and wastewater. Besides, there were significant differences ($P < 0.05$) in the values of water properties (electrical conductivity, salt content in the soil, and total sulfates and carbonates). They were significantly higher for wastewater compared to the fresh water and treated water. The results of analyzing the heavy metal content in the used water samples (table No.2) showed that there were significant differences at ($P < 0.05$) between the types of water. The concentrations of lead, nickel and cadmium in wastewater were higher than those in fresh water. However, they were far less than maximum permissible limits of Syrian standard specifications. Average concentrations of heavy metals were observed in treated water compared to the concentrations in fresh water and wastewater.

Table (1): Results of analyzing the water samples used in the experiment

Co$_3$ mg/l	So$_4$ mg/l	K mg/l	P mg/l	N-NH4 mg/l	N-NO3 mg/l	EC mmhos/cm	pH	Irrigation water
5.38±4.10^{b}	4.90±0.62^{b}	5.88±0.36^{b}	4.92±0.34^{b}	-	-	0.20±0.02^{c}	7.99±0.08^{a}	F
25.93±5.02^{b}	16.12±2.73^{b}	16.43±1.15^{a}	11.53±0.71^{a}	6.70±1.02^{b}	23.57±2.16^{b}	0.39±0.08^{b}	7.36±0.16^{b}	T
46.47±8.43^{a}	28.07±7.41^{a}	17.23±1.12^{a}	12.97±1.56^{a}	11.43±0.86^{a}	33.23±3.23^{a}	0.79±0.05^{a}	8.26±0.17^{a}	W
0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.001	$P^{\#}$

* The irrigation water sources used are F (fresh water), T (treated water) and W (wastewater).

The presence of different letters in the same column indicates significant differences at P < 0.05

Table (2): Results of analyzing the heavy metal content of water used in the experiment

Nickel, mg/L	Cadmium, mg/L	Lead, mg/L	Irrigation water
0.0013±0.001^c	0.0045±0.001^c	0.028±0.004^c	**F**
0.0177±0.002^b	0.012±0.003^b	0.140±0.046^b	**T**
0.033±0.003^a	0.044±0.007^a	0.403±0.015^a	**W**
0.000	0.000	0.000	***P*#**

* The presence of different letters in the same column indicates significant differences at P < 0.05

Soil: Soil samples were collected from two different depths (0-15 cm and 15-30 cm) before the start of irrigation (9/2019), at the end of the first season (10/2021) and at the end of the second season (10/2022). Samples of about 3 kg of soil were obtained and placed in bags. After writing the basic data, they were sent to the laboratory. The samples were dried in air for a sufficient time, crushed, ground, and sieved using a 2 mm sieve. Soil particles that were less than 2mm in diameter were separated and placed in bags to be analyzed. Analysis of samples physical properties [32] included:

- Estimating the apparent density using cylinder method.
- Estimating the total soil porosity using apparent and true densities, then calculating it.

Analysis of soil chemical properties by the following indicators according to [33].

- Measuring the electrical conductivity (EC) of a soil water extract (5:1) using an electrical conductivity meter [34].
- Measuring a pH of 1:2.5 soil/water suspension using a pH meter [35].
- Estimating soil organic matter using wet oxidation method in the presence of potassium dichromate in a highly acidic medium [36].
- Estimating the available phosphorus by Olsen method(37)The available phosphorus was determined by using a 0.2 N sodium bicarbonate solution and adding ammonium molybdate to develop the blue colour. It was then quantified with a spectrophotometer at a wavelength of 660 nm.
- Estimating soil available potassium that was extracted by ammonium acetate and tested using flame spectrometer [38,39].

Plant material (Paulownia)

The Paulownia tree is one of the plants that does not require many agricultural practices throughout its life, as it does not need pruning, spraying, or any other agricultural practice. Paulownia one-month old seedlings planted in pots filled with 200 cm^3 of peat moss were brought from Lebanon. They were then moved to 2 liter pots after preparing a mix at a ratio of one third peat moss to two-thirds soil (in volume) in the studied area. They were irrigated with fresh water for approximately 3 months, and transplanted to the previously prepared holes which were 50-60 cm at a spacing (5*5.5). Space from seedling to another on the same row was 5m, and the space between rows was 5.5m with an average of three seedlings on the same row. Thus, the total number of seedlings was 27; 3(treatments) *3(plants in the row)*3 (replicates) =27 (seedlings).

Irrigation with fresh water continued for about a year (from 10/15/2019 until 10/10/2020). Afterthat, the shrubs were cut at a height of 10 cm from the ground above two buds. Shrubs ranged in height from 100 cm-110 cm and the stem circumference was about 8 cm in the cut area. Then, the seedlings were irrigated using the drip irrigation method.

The process was repeated in the second season for a full year. A drip irrigation network was designed in a way that the irrigation lines extended parallel to the planting lines, with one 4 L/hr dripper adjacent to each seedling using different sources of water (F fresh water of well, T treated water, W wastewater), from 15 October2020 to 15 October 2022. The productivity of Paulownia trees was evaluated by measuring both the length of the stem and the periphery of the tree trunk. Moreover, the green and dry plant leaves were analyzed to determine their protein content using Kjeldahl method.

Statistical analysis

The experiment was designed according to completely randomized blocks (RCBD, Randomized Complete Blocks Design).Three treatments were applied in the experiment, and three replications were included for a total of 9 experimental units. The data was analyzed by a one-way ANOVA using Minitab 16 to determine the physical and chemical properties of the soil as well as the characteristics of the studied plant. Tukey's test was used to decide the least significant difference at the significance level $P<0.05$.

Results and Discussion

Properties and heavy metal content of soil before irrigation

Table (3) showed the properties of soil at two different depths (0.15 cm-15-30 cm) before irrigation. The results showed that the soil was moderately alkaline according to PH value which did not change with the depth of soil samples. With respect to other studied properties (electrical conductivity and active lime and total carbonates content of soil), the results were close at the two different depths. It was also noted that the topsoil contains more organic matter and higher concentrations of phosphorus, potassium, lead, cadmium and nickel, compared to subsoil. Thus, the amount of essential nutrients for large and small plants was greater in topsoil than subsoil.

Table (3): Results of chemical analysis of soil and its heavy metal content before planting

nickel ppm	cadmium ppm	lead ppm	Potassium ppm	Available phosphorus ppm	Organic matter%	Active lime %	Total carbonate%	Electrical conductivity mmhos/cm	PH	Depth cm
0.53	0.028	0.025	116.3	29.5	1.56	4.6	9.8	0.39	8.04	**0-15**
0.3	0.01	0.013	105.5	24.4	1.45	5.02	10.2	0.38	8.02	**15-30**

Table (4): The effect of using different sources of irrigation water on some physical properties of the soil ((X̄±Sd)

Rate of disintegration	Degree of granulation	Hygroscopic moisture	Total porosity	True density	Apparent density	Treatments *	Season
25.79.±0.10^{b}	42.98±0.23^{b}	4.43±0,02^{b}	44.35±.012^{c}	2.45±0.01^{b}	1.36±0.0065	**F**	**First season**
23.27±0,09^{c}	44.85±0.39^{a}	4.47±0,06^{b}	45.74±0.34^{b}	2.48±0,005^{a}	1.32±0,006^{b}	**T**	
28.44±.012a^{a}	40.93±.024^{c}	4.80±.01^{a}	47.79±0,01^{a}	2.49±0,006^{a}	1.29±0,01^{c}	**W**	
0.000	**0.000**	**0.001**	**0.000**	**0.001**	**0.000**	***$P^{\#}$***	
25.93±0,21^{b}	42.68±0,47^{b}	4.43±0,02^{b}	43.40±0,24^{c}	2.43±0.03^{b}	1.36±0,02^{a}	**F**	**Second season**
24.73±0,07^{c}	45.48±0,18^{a}	3.98±0,18^{c}	48.60±0.20^{b}	2.50±0,01^{a}	1.29±0,01^{b}	**T**	
28.95±0,09^{a}	39.96±0,18^{c}	5.00±0,17^{a}	50.26±.041^{a}	2.52±0,01^{a}	1.25±0,01^{c}	**W**	
0.000	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	***P***	
25.86.±0.17^{b}	42.83±0.37^{b}	4.43±0,02b^{b}	43.88±0.55^{b}	2.44±0.02^{b}	1.36±.0.01^{a}	**F**	**Average of the**
24.00±0,81^{c}	45.16±0.44^{a}	4.23±0,29^{b}	47.17±1.59^{a}	2.49±0,02^{a}	1.32±0,02^{b}	**T**	
28.69±0.30^{a}	40.44±.0.56^{c}	4.90±.017^{a}	49.02±1.38^{a}	2.51±0,02^{a}	.127±0,02^{c}	**W**	

0.000	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	***P***	

Irrigation water sources are F (fresh water), T (treated water), W (wastewater)

The presence of different letters in the same column for the same season or for the mean values indicates the significant differences at $P < 0.05$.

Table (4) showed that there were very little differences between the values of soil studies properties in the first season and the second season. Thus, the mean values of the two seasons were discussed.

Apparent density

table (4) and Figure (1) showed that the soil irrigation with wastewater led to a significant decrease in the mean apparent density (1.27) in comparison with irrigation with fresh water and treated water (1.36, 1.32, respectively).

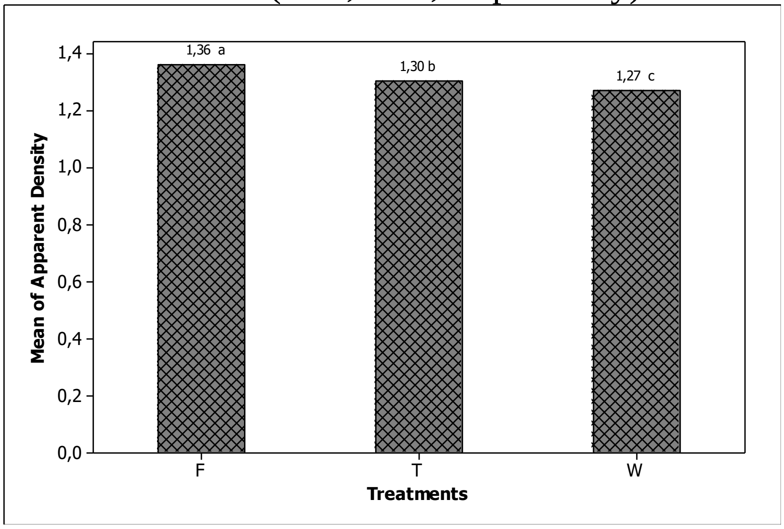


Figure (1): The effect of irrigation water quality on soil apparent density values

The low apparent density and high total porosity could be due to the increase in the soil mean weight diameter and other indicators for soil structure and high organic content and salt level in the irrigation water. These findings were in line with those by [40,41,12] who indicated that the use of wastewater and treated water led to a decrease in apparent density. Apparent density is one of the most important soil physical properties. It is an indicator for the soil quality structure, compaction, aeration condition, available water holding capacity and plant available water.

True density

Table (4) and Figure (2) showed that the mean values of true density of soil irrigated with the different sources of irrigation water were somehow close. There were no significant differences in true density between soil irrigated with wastewater and soil irrigated with treated water (2.51 and 2.49, respectively). The true density was significantly different in soil irrigated with fresh water (2.44), and had the lowest value. However, the insignificant increase in true density was because of the high organic matter content in topsoil when irrigating with wastewater and treated water [11,42].

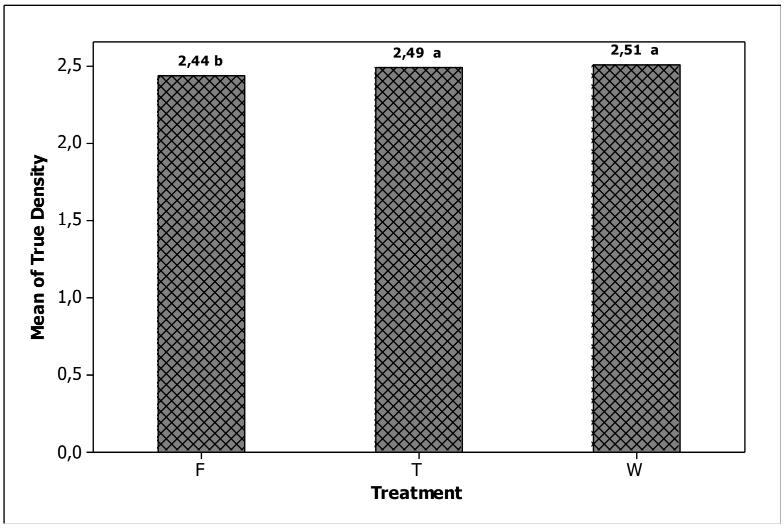


Figure (2): The effect of irrigation water quality on the soil true density values

Total porosity

Table (4) and Figure (3) showed that irrigation with wastewater and treated water (49.02, 47.17) significantly increased the soil porosity, compared to irrigation with fresh water (44.88). That could be attributed to the decrease in the soil apparent density and the improvement in the soil structure, the available water holding capacity, the movement of water and air through soil, and the soil drainage. All these were reflected in the soil fertility and productivity. These findings were in line with those by [41], who indicated that irrigation with wastewater and treated water increased the soil total porosity.

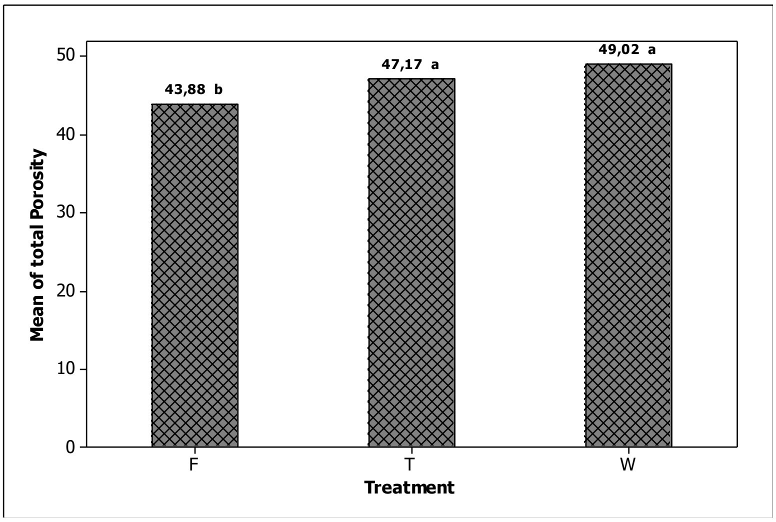


Figure (3): The effect of irrigation water quality on the soil total porosity

Water Hygroscopic water

Results listed in table No. 4 and Figure.4 showed that using wastewater irrigation significantly increased the soil hygroscopic moisture [4,9] , while there were no significant differences in hygroscopic moisture between soil irrigated with fresh water and soil irrigated with treated water (4.43, 4.23 respectively). That increase was perhaps because the wastewater irrigation increased the organic matter which improved the available water holding capacity.

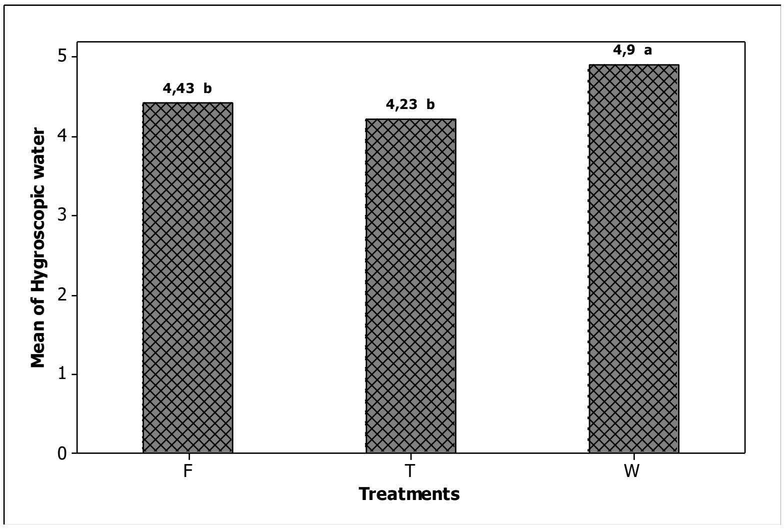


Figure (4): The effect of irrigation water quality on the soil hygroscopic moisture

Dissociation degree

Table 4 and Figure. 5 indicated that there were significant differences in the dissociation degree, as its mean value was the highest (45.16) in soil irrigated with treated water, the lowest (40.44) in soil irrigated with wastewater, and the average between the two previous values (42.83) in soil irrigated with fresh water. The increase in the dissociation degree as a result of irrigation with treated water in comparison with the control was due to the effective role of organic materials in gluing soil particles, and thus decreasing the percentage of soil particles smaller than 0.05 mm in diameter. This meant that the soil organic matter bound small particles together into larger-sized particles. Consequently, the percentage of <0.05 soil aggregates increased and disintegration rate decreased, in line with the findings of [42].

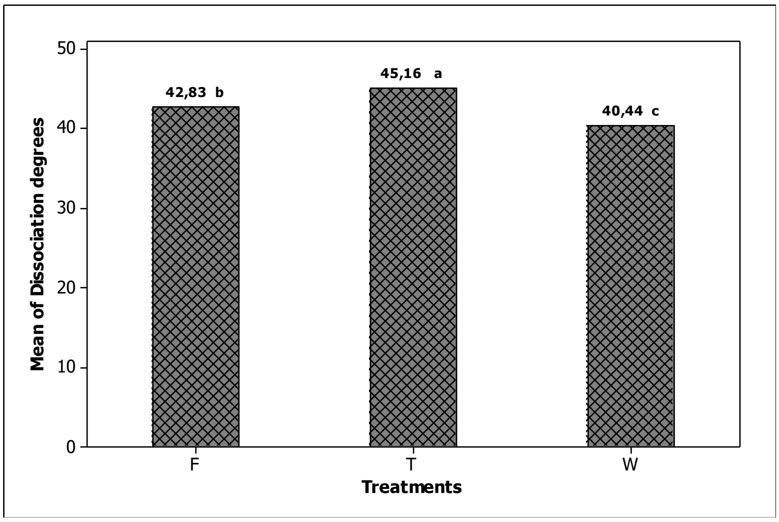


Figure (5): The effect of irrigation water quality on the soil dissociation degree

Disintegration rate: Significant differences were observed in the disintegration rate (Table 4 and Figure 6). It decreased in soil irrigated with treated water (24.00), while it increased in soil irrigated with wastewater (28.69). This increase was due to the high levels of salt and high concentrations of Sodium and potassium, which disintegrated soil aggregates and thus increased the soil disintegration rate, in line with the findings of [43].

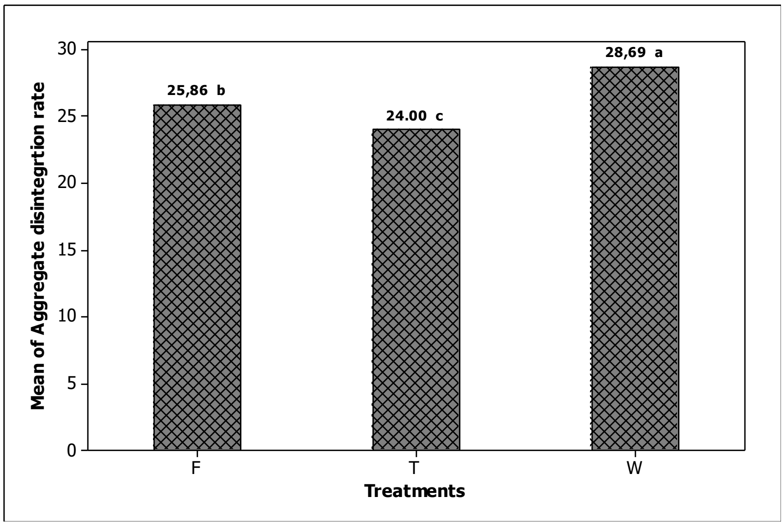


Figure (6): The effect of irrigation water quality on the soil disintegration rate

The effect of the quality of irrigation water on soil pH and electrical conductivity

Table (5) showed the effect of the quality of irrigation water (fresh water, treated water and wastewater) on the pH and the electrical conductivity of the soil at different depths (0-15 cm) and (15-30 cm).

Table (5): The effect of using different sources of irrigation water on the pH and the electrical conductivity of the soil at different depths (X̄±Sd)

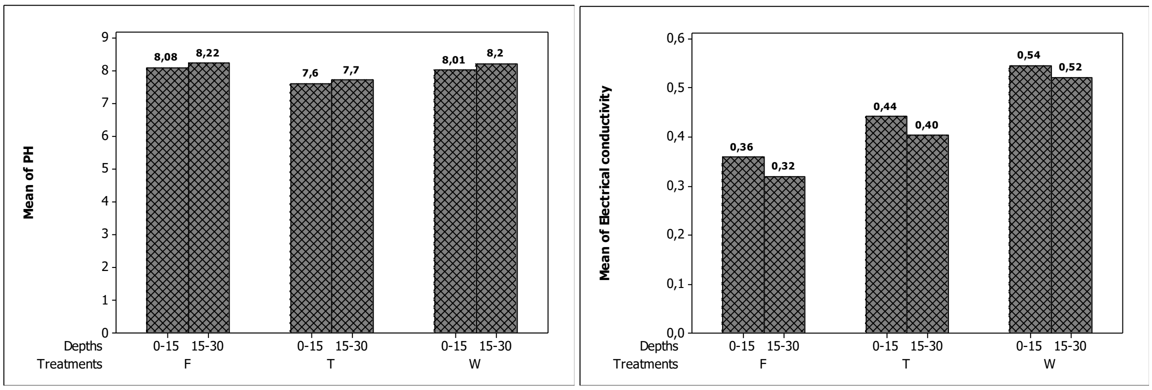
Electrical conductivity	PH	Treat	D

Mean	Second season	First season	Mean	Second season	First season	ments*	
0.36±0,01^{c}	.037±0,02^{c}	0.35±0,01^{c}	8.08±0.07^{a}	8.06±0.05^{a}	8,1±0,1	**F**	**0-15cm**
0.44±0,02^{b}	0,46±0,003^{b}	0,42±0,005^{b}	.760±0,35^{b}	7.3±0,17^{b}	7.9±0,1	**T**	
0,54±0.03^{a}	0,57±0.001^{a}	0,52±0.01^{a}	8.01±0,06^{a}	8.00±0,1^{a}	8.02±0,01	**W**	
0.000	**0.000**	**0.000**	**0.003**	**0.000**	**0.063**	***P#***	
0,32±0,04^{c}	0,35±0,03^{c}	0,29±0,005^{c}	8.22±0,17^{a}	8.23±0,21^{a}	8.2±0,17^{ab}	**F**	**15-30**
0.40±0,02^{b}	0.43±0,003^{b}	0,38±0,005^{b}	7.70±0,24^{b}	7.50±0.1^{b}	7.9±0,1^{b}	**T**	
0.52±0,03^{a}	0.55±0,003^{a}	0,49±0,002^{a}	8.21±0.22^{a}	8.01±0,01^{a}	8.4±0,1^{a}	**W**	
0.000	**0.000**	**0.000**	**0.001**	**0.001**	**0.009**	***P***	

The irrigation water sources used are F (fresh water), W (wastewater), F1W1 (alternative irrigation with fresh water and wastewater).

The presence of different letters in the same column for each different depth indicates the significant differences at P<0.05.

Table (6) and Figure (7). showed that there was a significant difference in the pH values of soil samples irrigated with fresh water and waste water. Irrigation with wastewater increased pH values, while irrigation with treated water significantly decreased pH values. That difference was due to various factors: water filtration, the nature of the soil, and the mechanical composition from one point in the ground to another. The decrease in pH value was due to the decomposition of organic materials and the production of acids. Higher pH values could be attributed to the large amount of salts in the water , PH values decreased when soil was irrigated with treated water because that water contained high concentration of NH4-N which was biologically oxidized and generated H ions that yielded a low pH (44) in comparison with the control.



A B

Figure (7): The effect of irrigation water quality on the soil pH and electrical conductivity

Table (6) and Chart Noshowed that the values of electrical conductivity were significantly different when different types of irrigation water were used. However, their values did not vary by different season and soil depth. The highest values were for soil samples irrigated with wastewater, while the lowest values were for soil irrigated with fresh water. The high electrical conductivity of soil was due to the high electrical conductivity of wastewater compared to fresh water. The high ratio of total dissolved solids in wastewater increased the salt content of salts, so the soil electrical conductivity increased during irrigation with wastewater for two consecutive as shown in table No.1 and in line with the findings (45,24).

Table (6): The effect of using different sources of irrigation water on the phosphorus and potassium content of soil at different depths (± X̄Sd)

Potassium ppm			**Phosphorus ppm**			**Organic matter**			**Treat ments**	**Depth**
Mean	**Second season**	**First season**	**Mean**	**Second season**	**First season**	**Mean**	**Second season**	**First season**		
112.33± 6.6^{c}	106.7 ±3.1^{c}	118.0±2 .0^{c}	17.5±1 .06^{c}	16.5± 0,2^{c}	18.4± 0,2^{c}	1.30±0 .03c	1.28± 0,03^{c}	1.32±0 ,03^{c}	**F**	**0-15 cm**
140.50± 6.4b	146±1,7 ^{a}	135±3a	26.15± 1.83^{a}	27.8± 0.3^{a}	24.5± 0,3b^{a}	1.55±0 .08^{b}	1.62± 0.04^{b}	1.49±0 ,01b	**T**	
133.33± 6,1^{aa}	138.7±1 ,2^{b}	128.0±2 .7^{b}	22.83± 2.21^{b}	24.8± 0,2^{b}	20.9± 0,8^{b}	1.69±0 .07^{a}	1.75± 0,03^{a}	1.63±0 ,02^{a}	**W**	
0.000	**0.000**	**0.002**	**0.000**	**0.000**	**0.002**	**0.000**	**0.000**	**0.000**	***P*$^{\#}$**	
97.95±1, 29^{b}	98.0±2. 0^{b}	97.9±0. 36^{c}	10.18± 0.4^{b}	9.87± 0.3^{c}	10.50 ±0,2^{c}	1.21±0 .08^{C}	1.14± 0.02^{c}	1.28±0 ,006^{c}	**F**	**15-30 cm**
117.92± 9.27a	126.33± 1.53a	109.50± 0.10^{a}	21.32± 4.5a	25.43 ±0,4^{a}	17.20 ±a0,2	1.36±0 .07b	1.30± 0,02^{b}	1.42±0 ,02^{b}	**T**	
113.73± 10.35^{a}	123.17± 1,02^{a}	104.30. ±0.2^{b}	18.48± 6.4^{a}	24.3± 0,4^{b}	12.7± 0,2^{b}	1.51±0 .07a	1.45± 0,03^{a}	1.57±0 ,02^{a}	**W**	
0.002	**0.000**	**0.000**	**0.002**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	***P***	

The sources of irrigation water used are F (fresh water), W (wastewater), F1W1 (alternative irrigation, fresh water and waste water).

The presence of different letters in the same column indicates the significant differences at $P < 0.05$

Table No. (7) and Figure (3) showed that the soil organic matter increased when irrigating with wastewater compared to fresh water in the first season and second season. Moreover, it increased in the second season compared to the first season during irrigation with wastewater and treated water. However, soil organic matter did not differ between the first season and second season during irrigation with fresh water, perhaps because the wastewater contained organic wastes and fertilizers that could increase the organic matter in soil, especially in the surface layers, in line with the findings of those by researchers (46); (24). As for the soil depth, there were no significant differences in the organic matter during irrigation with all types of water at the two studied depths. The reason could be that the organic matter decreased with increasing depth.

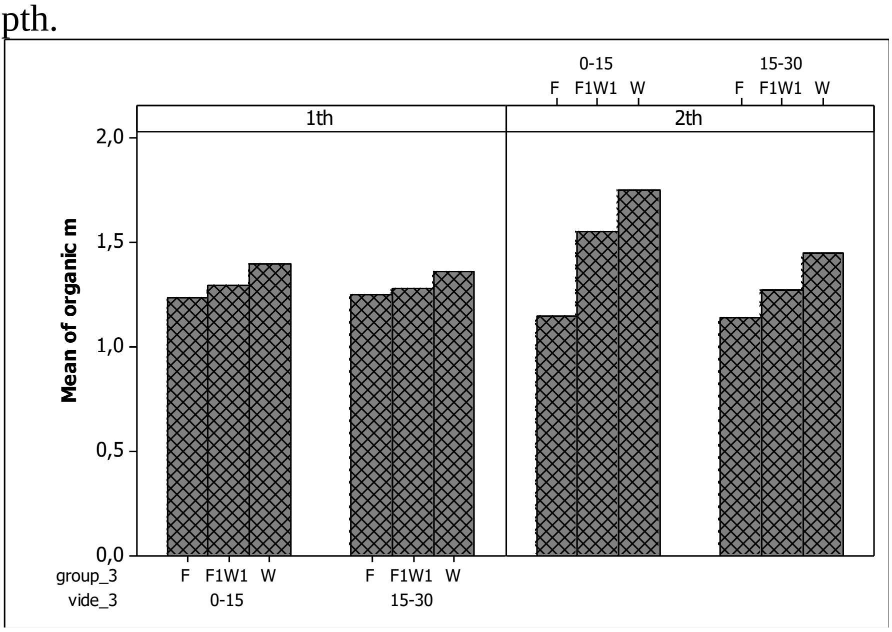


Figure (3): Percentage of organic matter in soil irrigated with different types of water: fresh water (F), waste water (W) and alternative irrigation of fresh water and wastewater (F1W1) during two consecutive seasons (1th, 2th) and at two different soil depths (0 -15, 15-30 cm)

The effect of the quality of irrigation water on the phosphorus and potassium content in soil. Table No. (7) showed the effect of the quality of irrigation water (fresh water, wastewater, and alternative irrigation with fresh water and wastewater) on the phosphorus and potassium content of soil at depths of 0-15 cm and 15-30 cm. It could be seen from the table that the soil phosphorus and potassium available for plants increased as a result of irrigation with treated water and wastewater compared to fresh water. The reason could be that the wastewater contained a good percentage of substances rich in phosphorus and potassium from the waste of laboratories and factories, which increased the content of these two elements in soil, in line with the findings of many previous studies [46, 24].

In addition, the soil contained a larger amount of phosphorus when irrigating with treated water compared to wastewater and fresh water, because treated water had different levels of phosphorus. In addition, the available phosphorus significantly increased because of its organic and inorganic forms in the wastewater. The mineral phosphorus released as a result of organic waste decomposition and production of organic acids, which solubilized the organic phosphorus compounds [47,44].

Table (8): showed some morphological characteristics of paulownia by a statistical study.

Protein content in dry leaves	Protein content in green leaves	Trunk periphery cm	Trunk length cm	Treatment	
16,13±0,12^{c}	11,17±0,153^{b}	12,33±0,58^{b}	111,67±2,89^{b}	**F**	**First season**
16,77±0,058^{b}	11,7±0,17^{a}	9,33±1,16^{c}	151,67±2,89^{a}	**T**	
17,27±0,058^{a}	12,07±0,12^{a}	16,67±1,16^{a}	86,67±2,89^{c}	**W**	
0.000	**0.001**	**0.000**	**0.000**	**P**	
16,53±0,05^{c}	11,47±0,06^{c}	15,33±0,58^{b}	123,33±2,89^{b}	**F**	**Second season**
17,6±0,17^{b}	12,5±0.01^{b}	20,67±1,16^{c}	168,33±2,89^{a}	**T**	
18,5±0,10^{a}	13,17±0,29^{a}	12,67±0,58^{a}	99,33±1,15^{c}	**W**	
0.000	**0.000**	**0.000**	**0.000**	**P**	
16,33±0,23^{b}	11,32±0,19^{b}	13,83±1,72	117,5±6,89^{b}	**F**	**Average of the two seasons**
17,18±0,47^{a}	12,10±0,45^{a}	15.00±6,3	160±9,49^{a}	**T**	
17,88±0,68^{a}	12,62±0,63^{a}	14,667±2,3	93±7,21^{c}	**W**	
0.000	**0.001**	**0.874**	**0.000**	**P**	

There were clear significant differences in the length of the trunk and its circumference. The highest values were for irrigation with treated water, and the lowest values were for irrigation with wastewater. The growth of the tree was good during irrigation with fresh water. That can be attributed to the important role of nitrogen in the physiological processes of trees, as It is essential for the synthesis of basic compounds (proteins and amino acids), photosynthesis, levels of chlorophyll , plant growth, and increased length of trunk and branches. In addition, it increases the tree ability to absorb other mineral elements [48] Regarding phosphorus, it has been shown that it is essential for the regulation of the tree growth, tissue development and cell division. These findings were in line with those by the researchers [49], who indicated the improvement in the parameters of plant growth in spite of using treated water.

It was also observed that the wastewater irrigation significantly increased the length of paulownia trunk (93 cm) compared to (117 cm) when irrigating with fresh water; and (163 cm) when irrigating with treated water. That was perhaps because the wastewater contained high levels of heavy metals which accumulated in soil, increased the plant ability of absorption and the potential toxicity, in line with [21 , 24,50]. The decrease could be attributed to the fact that the wastewater contained high levels of salts which negatively affect the plant growth by their osmotic and competitive effects. These findings were in line with the findings of, regarding the wastewater.

The differences when irrigating with treated water were due to the role of organic matter in providing the important nutrients for plant growth, such as phosphorus, through the formation of organic complexes, in line with [51,52]. That differences were also due to the adsorption and removal of many pollutants, especially heavy metals [53].

It was also noted that adding organic matter enhanced the plant growth by significantly increasing the values of studied parameters. It provided nutrients and improved their absorption by plant, and improved soil properties and its ability to retain water and nutrients. In addition, it supported the growth of microorganisms that decomposed organic materials and promoted better root growth, in line with [53] The statistical studies also showed that the mean protein content in the dry leaves of trees was 17.88 when irrigating with wastewater, and 17.18 when irrigating with treated water in comparison with the control 16.33 This could be attributed to the high total nitrogen content in the soil irrigated with wastewater compared to soil irrigated with treated water, which consequently led to a high nitrogen content in the green and dry leaves of trees, in line with[54].

The research results indicate that the use of wastewater and treated water has a positive effect on the soil by increasing its content of potassium, phosphorus, and organic matter. However, the way of use has to be considered, because indiscriminate use causes soil pollution. Thus, it must be within acceptable limits and within soil standard specifications. It can be said that the wastewater and treated water can be used to irrigate agricultural lands and forest trees including paulownia, with no adverse effects on the soil and its properties.

The results also show that there is a high protein content in the leaves of paulownia trees which are irrigated with wastewater and treated water. Thus, that leaves are very importance for animals as they can be used in the animal fodder.

Most important recommendations:

As the water specifications we were within the permissible limits, it can be used as an alternative to fresh water especially during the irrigation of forest and economic tree such as Paulownia trees. In addition, using this water in irrigation reduces the groundwater pollution.

Due to the high protein content in the paulownia leaves, it is advised to use them as an animal fodder that means they can be used in feed mixtures and relevant researches can be conducted at the department of animal production in the faculty of Agriculture.

The results also show that the paulownia tree grows when irrigating with waste water and treated water. Thus, it is advised to plant it around pools and drainage for it aesthetic and economic importance

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