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Effect of tertiary treated wastewater on some soil properties and wheat yield

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A B S T R A C T

Water shortages in arid and semi-arid zones like Palestine, as anticipated, led to the search for new sources for agricultural use such as tertiary treated wastewater (TWW). The experiment was carried out during the seasons (2018–2019) at the Faculty of Agriculture and Veterinary Medicine, An-Najah National University, Palestine, to test the effect of tertiary treated urban wastewater effluent irrigation on the soil, wheat growth and yield. Three local wheat landraces were used in the study. A split plot design with three replicates was used. After wheat harvest, soil chemical properties, crop yield and growth were studied. No significant interaction was observed between the treatments and the varieties for the effect of TWW on growth and yield variables of the three wheat varieties. The concentration of all tested parameters on the soil was increased significantly by irrigation with TWW. Significant reduction of total nitrogen was observed in the plant under TWW treatment, whereas no significant effect of TWW was reported on plant phosphorus (P), potassium (K), sodium (Na), calcium (Ca) and ash content. In order to avoid eventual risks, the use of TWW requires regular monitoring and the reuse standards must be respected

Keywords: Conventional water; Municipal wastewater; Sewage water; Trace elements; *Triticum aestivum*; Wheat

1. Introduction

Water resources in arid and semi-arid zones like the Palestinian Territories are irregular and unequally distributed. These resources are concentrated in superficial and underground water. Under these circumstances, water management can be considered as one of the key challenges of agriculture development and utilization of unconventional water resources such as brackish water, desalinated water and treated wastewater [1]. Industrial and municipally treated wastewaters may be considered as a potential economic power that will contribute to saving water resources, irrigating agricultural land and even reducing fertilizer inputs [2,3].

In fact, the reuse of municipal tertiary treated wastewater (TWW) in the irrigation of agricultural crops, is classified as an unconventional intervention to water scarcity and a means of environmental protection by reducing the

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discharge of water into rivers and oceans [4–6]. The moderate to high content of organic matter in TWW leads to high yields of crops without causing any reduction of their quality [7,8]. However, the application of TWW generally leads to increased concentrations of heavy elements in the soil and plants [9]. The suitability of irrigating with TWW depends mainly on the choice of crops that will be irrigated with such water [10].

Wheat (*Triticum aestivum* L.) is classified as the third most important food crop in the world after rice and corn. It provides millions of people with a stable food source and major supplements in the human diet. Approximately 66% of wheat production in the world is used for human food [11]. However, the average wheat productivity in the Palestinian Territories is below the international average and the wheat cultivated area was not increased in the same proportion to the population growth [12]. This low productivity is caused by several factors including low soil fertility and the reliance on rain-fed agriculture due to lack of irrigation water [13].

To improve wheat productivity, chemical fertilizers are applied which in addition to increasing the production cost, is harmful to the environment as these chemicals get leached through the soil beyond the root zone and may reach the groundwater. The use of TWW in agriculture may be an applicable way to improve agricultural production in areas suffering from a shortage of conventional water resources. However, using TWW is not free of threat for both crop production and soil physical and chemical properties [6]. In the West Bank (Palestinian Territories), about 31 million cubic meters (MCM) of wastewater are produced per year. More than 75% of this wastewater is discharged into the environment without any treatment due to a lack of functioning treatment plants [14]. Currently, there are three treatment plants in the Palestinian Territories in addition to another plant that is about to become operational and another two that are planned to be constructed. As a result, the West Bank could produce over 50,000 m^3/d of treated wastewater, which can be reused to irrigate over 2,000 ha (20 km^2) [14]. To date, the reuse of treated wastewater has been limited to irrigate about 300 ha. This shows the lack of interest given to this unconventional and valuable water resource. The objective of this study was to evaluate the influence of municipal TWW on the soil and the yield of three local wheat landraces.

2. Materials and methods

2.1. Experimental design and plant material

The experiment was handled under-protected net house at the Faculty of Agriculture and Veterinary Medicine, An-Najah National University, Palestine (32.31519° N, 35.02033° E, 75 m altitude) during growing seasons (2018/2019). The experiment was arranged as a split-plot based on the completely randomized design with three replicates. Treatments were two irrigation water types: treated municipal wastewater (TWW) and freshwater (control). Subplots consisted of three local wheat landraces: Kahatat, Anbar and Dubbie. Wheat cultivars were sown on the 1st of November in plastic pots (35 cm × 25 × 45 cm) filled with agricultural sand. Ammonium sulfate (21% N) was added to the irrigation water used in the control according to the recommended amount for wheat (500 kg/ha) [11] while no chemical fertilizers were added to the TWW. Irrigation water was applied at 2 to 3 d intervals. Irrigation rate was adjusted according to the average annual rainfall in the study area (630 mm. Because irrigation water was controlled, deep filtration and runoff were assumed to be insignificant.

2.2. Growth, yield and yield components

During the growing season the following parameters were evaluated:

- *Days to the heading*: was calculated from sowing until 90% of the plants reached heading.
- *Chlorophyll content at heading and filling were recorded*: was measured by Chlorophyll Meter (SPAD 502 m, Konica Minolta Optics, INC, Osaka, Japan).

At maturity the following parameters were evaluated:

- *Days to maturity*: was calculated from sowing plants reached maturity.
- *Plant height (cm)*: was measured from ground level to the plant tip.
- *Flag leaf area (mm)*: was measured using the AM350 Portable Leaf Area Meter (ADC BioScientific Ltd., UK).
- *Average tiller number*: was measured as the average of five plants.
- *Spike number*: was measured as the average of five plants.
- *Spike length (cm)*: was measured without awns as the average of five plants.
- *1,000 seed weight (g)*: was measured using a three digits balance.
- *Total grain yield per plant (g)*: was measured using a three digits balance as the average of five plants.
- *Total grain yield per ha (kg)*: was estimated based on the total yield of the experimental units.
- *Total vegetative biomass per ha (kg)*: was estimated based on the total yield of the experimental units.

2.3. Water, plant and soil analysis

Treated wastewater from Nablus western station was used in the experiment. The analysis of the used TWW is presented in Table 1. From each treatment, soil samples were composed randomly before sowing from different pots and analyzed for various characteristics as follows:

- Magnesium (Mg) and calcium (Ca) content were analyzed using the titration method.
- Potash (K) and sodium (Na) were analyzed using a flame photometer.
- Phosphorus (P) was analyzed using a spectrophotometer.
- Total nitrogen (TN) was analyzed using the Kjeldahl method.
- Ash was analyzed by burning.

2.4. Statistical analysis

Data were analyzed using Minitab 18. ANOVA was conducted followed by mean separation using Duncan test at 0.05 probability level, numbers were presented as averages.

Table 1
Chemical analysis of treated wastewater and soil used across the experiment

Parameter	Concentration	Parameter	Unit	Concentration
pH	7.65	Al	ppm	0.051
Total nitrogen, ppm	31.06	Cu	ppm	N.D
Na, ppm	132.3	Fe	ppm	N.D
Mg, ppm	16.54	Mn	ppm	0.012
Ca, ppm	90	Ni	ppm	N.D
P, ppm	9.32	Pb	ppm	N.D
BOD_5, mg/L	<5	Cd	ppm	N.D
SS, mg/L	<2	Zn	ppm	0.028
COD, mg/L	14	Cr	ppm	N.D
Dissolved solids, mg/L	725	Co	ppm	N.D
Cl, ppm	156.16	B	ppm	N.D
SO_4, ppm	56.94			

Table 2
Effect of TWW on days to heading, days to maturity, plant height (cm), flag leaf area (mm), Chlorophyll content (SPAD) at heading and at filling stage of three wheat landraces

Treatment	Days to heading	Days to maturity	Plant height	Flag leaf area	SPAD (Heading)	SPAD (Filling)
Control	76.44^a	90.33^a	54.94^a	3,898.7^a	53.16^a	49.89^a
TWW	75.67^a	89.00^a	55.67^a	3,383.7^a	51.60^a	47.98^a
Varieties						
Kahatat	85.67^a	98.00^a	66.67^a	3,457.0^a	54.52^a	41.45^b
Anbar	74.00^b	86.17^b	54.00^{ab}	3,684.0^a	48.35^b	51.13^a
Dubbie	68.50^c	84.83^b	45.25^b	3,782.5^a	54.27^a	54.22^a

Means per columns that share a letter are not significantly different ($P \leq 0.05$).

3. Results

3.1. Effect of TWW on growth and yield variables of wheat

No significant effect for the irrigation with treated wastewater on days to heading, days to maturity, plant height, flag leaf area, Chlorophyll content (SPAD) at heading and at filling was observed. A significant effect was observed among varieties for days to heading, days to maturity, plant height and Chlorophyll content (SPDA) at the heading stage (Table 2). The highest plant height (66.67 cm) was obtained in Kahatat. The lowest plant height was also obtained in Dubbie (45.25 cm) (Table 2). Kahatat was the latest cultivar in heading and maturity (85.67 and 98 d respectively) while Dubbie was the earliest cultivar in heading and maturity (68.50 and 84.83 d respectively). Kahatat and Dubbie showed the highest Chlorophyll content at the heading stage (54.52 and 54.27 respectively). No significant interaction was found between the treatments and the varieties.

No significant positive effect of TWW on tiller number, spike length and 1,000-grain seed weight, whereas a significant positive effect of TWW was observed on spike number, grain yield per plant, grain yield per ha and vegetative biomass per ha (Table 3). Anbar and Dubbie showed the highest spike number, 1,000-grain weight, grain yield per plant and total grain per ha, whereas, Kahatat showed the highest total vegetative biomass (Table 3). No significant interaction was observed between treatments and cultivars.

3.2. Effect of TWW irrigation on soil properties

Irrigation with TWW increased soil pH (Table 4). The results showed that soil Na concentration was significantly affected by TWW. Moreover, treated wastewater increased soil salinity level compare with control. Treated wastewater increased soil solution electrical conductivity (EC) from 1.78 to 3.32 (ds/m^{-1}). Soil TN was significantly higher under TWW than the control. Treated wastewater treatments significantly affected the concentration of N, P and K (Table 4).

3.3. Effect of TWW on plant chemical properties

Table 5 shows the effect of TWW on plant total nitrogen (TN) (%), phosphorus (ppm), potash (ppm), sodium (ppm), calcium (ppm) and ash. Heavy metals were not analyzed in soil and plant due to the fact that heavy metals were not detected in the used TWW (Table 1). No significant interaction was observed between treatments and varieties. TWW significantly increased plant TN. No significant effect of TWW was reported on plant P, K, Na, Ca and ash content. Significant differences between varieties were reported in

Table 3
Effect of TWW on average tiller number, spike number, spike length (cm), 1,000 seed weight (g), total grain yield per plant (g), total grain yield per ha (kg) and total vegetative biomass per ha (kg) of three wheat landraces

Treatment	Tiller number	Spike number	Spike length	1,000 seed weight	Total grain yield/plant	Total grain yield/ha	Total vegetative biomass
Control	4.23^a	2.59^b	6.50^a	33.37^a	2.13^b	2,158.1^b	8,298.0^b
TWW	5.18^a	3.47^a	6.66^a	33.49^a	2.93^a	2,854.2^a	7,127.5^a
Varieties							
Kahatat	4.83^a	2.18^b	4.66^c	23.32^b	1.32^b	1,033.0^b	9,974.2^a
Anbar	4.85^a	3.58^a	7.90^a	35.88^a	3.12^a	3,445.8^a	7,677.0^b
Dubbie	4.43^a	3.32^a	7.18^b	41.08^a	3.15^a	3,039.7^a	5,487.1^c

Means per columns that share a letter are not significantly different ($P \leq 0.05$).

Table 4
Effect of TWW on soil total nitrogen (TN) (%), phosphorus (ppm), potash (ppm), sodium (ppm), magnesium (ppm), calcium (ppm), organic matter (OM) (%), electrical conductivity (EC) (ds/m^{-1}) and pH

Treatment	Control	TWW
TN	0.28^b	0.37^a
P	245.89^b	269.22^a
K	57.78^b	162.22^a
Na	9.33^b	19.89^a
Mg	59.22^b	198.78^a
Ca	102.22^b	836.44^a
OM	2.39^b	2.91^a
EC	1.15^b	3.32^a
pH	7.67^b	8.03^a

Means per columns that share a letter are not significantly different ($P \leq 0.05$).

seed TN, P and K content whereas, no significant differences were observed in seed Na, Ca and ash content.

4. Discussion

TWW can be used in agriculture and is considered a useful unconventional water source. TWW is useful in terms of yield stability, increase in total yield, and soil fertility amongst others. The effects of TWW treatments on some yield and yield components traits of wheat were investigated under the semiarid conditions of Tulkarm, Palestine. The experiment was designed based on using TWW for wheat irrigation. Reducing the amount of chemical fertilizers used for wheat production. In the present study, it was found that application of TWW appeared to be as beneficial for the crop as mineral nitrogen fertilization and even more beneficial. The effect of the applied TWW was significant and more apparent on spike number, total grain yield per plant, total grain yield per ha and total vegetative biomass per ha. These results are in agreement with the results reported in millet by Aghtape et al. [15], in barley by Munir et al. [16] and in olives by Petousi et al. [5]. Alizadeh et al. [17] reported that the most biological yield of corn was achieved under-treated wastewater.

Table 5
Effect of TWW on plant total nitrogen (TN) (%), phosphorus (ppm), potash (ppm), sodium (ppm), calcium (ppm) and ash (%)

Treatment	TN (%)	P (mg/g)	K (mg/g)	Na (mg/g)	Ca (mg/g)	Ash (%)
Control	1.26^b	2.16^a	57.22^a	4.61^a	10.11^a	17.71^a
TWW	1.80^a	3.23^a	65.56^a	4.33^a	7.33^a	11.06^a
Accessions						
Kahatat	1.75^a	4.21^a	78.33^a	4.50^a	7.00^a	18.56^a
Anbar	1.36^b	1.82^b	51.67^b	4.67^a	11.25^a	11.98^a
Dubbie	1.49^{ab}	2.07^b	54.17^{ab}	4.25^a	7.92^a	12.62^a

Means per columns that share a letter are not significantly different ($P \leq 0.05$).

Leaf SPAD, (Table. 2) recorded in this work, indicated the absence of Chlorophyll loss in plants irrigated with treated wastewater in comparison with tap waters. This is in agreement with the results reported in strawberry by Djillali et al. [8], rice by Duy Pham et al. [2] and olives by Petousi et al. [5]. Significant variation in plant height was reported which is in agreement with the results reported by Alimiri et al. [18].

The irrigation with TWW increased soil pH which is in agreement with the results reported by several researchers [19, 20, 21]. This minor pH shift can be linked to the release of exchangeable cations during the mineralization of organic materials dissolved in the TWW. The results showed that soil Na concentration was significantly affected by TWW. The minerals in the wastewater are considered as a possible source of increasing soil Na [22]. Moreover, treated wastewater increased soil salinity levels. This is in agreement with the results of Mojiri and Hamidi [23] and Kaboosi [24]. The soluble salt, Na, Mg and Ca presence in the TWW can raise soil EC [25]. Petousi et al. [5] reported that Mg and Ca concentrations in the soil irrigated with treated wastewaters were higher than soils irrigated with tap water. TWW increased soil and plant total nitrogen and the percentage of organic matter which can be due to the considerable urea and N in urban in both ionic forms in wastewater [23, 26, 27, 28, 29]. At the same time, TWW positively affects the total K and P [5, 24, 30, 31]. This increase may be due to the fact that applied wastewater may contain N, P and K more than what wheat plants need [24].

5. Conclusion

Treated urban wastewaters reuse for agricultural irrigation may reduce the demand for conventional water sources. Upscaling treated wastewater use in the irrigation of agricultural lands can be considered an important management practice. Irrigation with urban treated wastewater increased the percentage of organic matter, total N, K, P, Ca, Mg and Na in the soil. On the other hand, urban TWW caused an increase of EC in soil solution than control unit. Increasing soil salinity can be classified as one of the most significant negative effects of urban treated wastewater reuse on the environment, which if not controlled, can decrease productivity in long term. The use of TWW in agriculture is an attractive option because it represents a renewable and additional water resource. However, in order to avoid any risks, the reuse of the TWW has to be regularly monitored and the reuse standards should be respected. Moreover, the Palestinian laws and regulations related to the use of TWW in agriculture should be revised and at the same time, the long-term effect of TWW on soil chemical and physical properties should be studied.

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