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Impact of Blended Treated Wastewater and Irrigation Frequency on Corn Production and Soil Nutrients

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ABSTRACT

This research investigates the impacts of blended treated wastewater (TWW) reuse with freshwater (FW) and irrigation frequency on corn (Zea Maize L.) crop yield and NPK (nitrogen, phosphorus, and potassium) soil content. The experiment comprised of three irrigation frequencies IF1: daily, IF2: every other day, and IF3: every 3 days; and five blended water treatments T100(100%TWW), T75(75%TWW and 25%FW), T50(50%TWW and 50%FW), T25(25%TWW and 75%FW), and T0(100%FW), in four replications. Results indicate that the significant effect of the irrigation frequency was mainly on corn cobs yield and consequently crop yield. Crop yield increases as the ratio of TWW increased in the blended irrigation water, with the highest significant yield (58,036 kg/ha) by using pure TWW(T100) and the lowest yield (37,695 kg/ha) was obtained by using FW (T0). Regardless of the irrigation frequency, the highest soil NPK content was obtained by using pure TWW (T100), while the lowest NPK soil content was obtained by using FW treatment (T0). Available soil N, P, and K contents in T100 treatment were significantly higher than that in T0 treatment by 50.4%, 62%, and 53%, respectively. Thus, the use of TWW in agricultural irrigation could provide a good balance of plant nutrients which can markedly increase crop yield and reduced the need for expensive commercial fertilizers.

Keywords: Treated wastewater, Irrigation, Evapotranspiration, Corn, Irrigation frequency, Blended treated wastewater, Nutrients.

INTRODUCTION

One-third of the world's population lives in countries facing moderate to severe water shortages. By 2025, more than three billion people in 52 countries will suffer from chronic shortages in water for drinking and sanitation (Asano & Levine, 1998). Water deficit causes significant problems in arid and semi-arid countries, especially with the acceleration of population and economic growth (Al-Busaidi& Ahmed, 2014; Ahmed *et al*., 2008). The world population is growing persistently, and people's desire for higher living standards is also increasing (UN DESA, 2015). This situation is putting more stress on water resources all over the world, especially in arid areas (Rosegrant, 2016). Africa, the Middle East, and Central Asia are desperately suffering from water shortage and they are the regions with less water availability per capita/year than other world areas (Noah, 2002).

Jordan is an arid country, with a land area of approximately 89 thousand km2 with more than 78% of the

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land area receiving an annual average rainfall of less than 200 mm(Hadadin *et al*., 2009). Jordan is considered as one of the poorest ten countries in the world in water resources and falls below the water poverty line [1000 m3/capita/year, (Hadadin *et al*., 2009)].

By 2025, Jordan's Ministry of Water and Irrigation (MWI) is expected a reduction in water allocation per capita, where the amount of water per capita will be reduced from 145 m3 in 2008 to 100 m3 in 2025. The last figure is far below the annual benchmark level of 1000 m3 per capita which is often used as an indicator of water scarcity. Freshwater (FW) resources in Jordan are very limited because it depends mainly on rainfall, where the total amount of rainfall is estimated to be 8.5billion m3/year of which about 85% is lost by evaporation and the remainder goes into valleys and partially infiltrates into deep aquifers (MWI, 2005; and Bashar, 2007).

Jordan has experienced an imbalance in the population-water resources equation. Its per capita share of renewable water resources is among the lowest in the world and is declining with time. The greatest environmental challenge that Jordan faces today is considered the scarcity of water. Under the limitation of water resources, the competition on FW resources has increased with increasing population, progressive industrial activities, and expansion of the agriculture sector. The current use of water in Jordan already exceeds the renewable supply [(MWI, 2019); and Al-Kharabsheh&Ta'any (2005)]. The deficit is being covered through the mining of groundwater resources at 130% of their safe yields and exploitation of non-renewable groundwater (Abu-Awwad, 2011).

Approximately, 70% of world water use including all the water diverted from rivers and pumped from underground is used for irrigation, so consequently, the reuse of treated wastewater (TWW) for agricultural and landscape irrigation uses reduces the number of water demands from natural water sources and minimizes the discharge of wastewater to the environment (Pedrero *et al*., 2010). The reuse of TWW is one of the main options being considered as a new source of water in regions suffering from water scarcity (Vojdani, 2006).

In a context of global climate change leading to severe limitations of FW resources for agriculture, irrigation with unconventional water sources such as TWW represents a key factor for sustainable agricultural production in arid and semi-arid regions (Diaz *et al*., 2013). This water source has considerable potential for irrigation and it has been increasingly applied in many arid and semi-arid regions worldwide, including China, the Middle East, Mediterranean countries, Australia, North and South America, and Africa (Grattan *et al*., 2015).

The reuse of TWW for agricultural irrigation is a valuable strategy to maximize available water resources, but the marginal quality of this water is often considered a challenge for agricultural sectors(Carr, *et al*., 2011). The reuse of TWW for agricultural irrigation, landscape, and surface or groundwater recharge purposes is being widely implemented (Alade&Ojoawo, 2009; Carr *et al*., 2011). Although the reuse practices are followed by several benefits related to the improvement of water balance (reduce the gap between water supply and demand). Furthermore, the input of TWW is reported to be a rich source of useful and important nutrient elements such as N, P, and K in addition to Na, Ca, Mg, Cu, Fe, organic matter and microbes required for plant growth. Irrigation with TWW adds components into the soil which support soil health and plant growth and consequently permits a higher yield in many crops as compared to FW (Singh *et al*., 2012; Chalkoo *et al*., 2014; Iqbal *et al*., 2017).

According to Jordan's water strategy which was formulated in 1998 (Water for Life: Jordan's Water Strategy 2008-2022), TWWis considered as a non-conventional water resource that cannot be treated as "waste" but as an important source for agricultural crop irrigation (MIW, 2001; and Taha &Haddadin, 2005). Moreover, the government of Jordan has regulated and developed standards for TWWreuse. Jordanian standards for reclaimed domestic wastewater (JS893/2006) are based on reuse categories. It determines the standard, regulations and guidelines that are required for water reuse. It is purposely set to specify the conditions that the reclaimed domestic wastewater discharged from wastewater treatment plants should meet to be discharged or used in various fields such as artificial discharge of groundwater aquifers and irrigation purposes.

Jordan has made significant strides towards achieving its goal of TWW reuse to save FW resources. Many crops are grown using blended TWW such as citrus, bananas, vegetables, and cereals such as corn, barley, and wheat (FAO 2003). Using TWW for crops irrigation faces many challenges due to low quality such as salinity, presence of chloride, fecal coliforms, and nematode eggs (Duqqah *et al.,* 2004).

Corn (Zea Maize L.) is a major fodder and forage crop for poultry, livestock feeding, and human diet. Jordan's maize production is negligible, with an annual production of under 10,000 metric tons (10 million kg), and Jordan's maize imports in 2019/2020 increased by slightly over 4% to 835,000 metric tons (Khraishy, 2019). Maize is a very nutrient-demanding crop, requiring intensive application of inorganic or organic fertilizers to produce a high yield (Awotundum, 2005). Thus, it is possible to obtain high corn yields without deterioration of their quality by using TWW for irrigation. Therefore, this study is carried out to (i) investigate the impact of irrigation frequency on corn crop yield, (ii) investigate the short-term influence of TWW on NPK soil content and corn crop yield, and (iii) evaluate the impact of blended TWW on corn crop yield.

Materials and Methods

Experiments site and design:

The experiment was conducted in the open field at Al-Zarqa city (El-Sokhna town). The location has an elevation of 625 m above sea level, 36°05′16″E longitude, and 32°04′21″N latitude. The climate is characterized by an arid climate with warm summer and temperatures ranging from 25°C to 33°C and relatively short and cold winters with an annual average rainfall of about 182 mm. The experiments were conducted in the open field. The experimental design was split-plot a complete randomized design with four replications. In the open field experiment (summer season), the corn seeds (Zea Maize L.) were seeded on the 25th of April 2020 in drain-lysimeter-pots with dimensions of 50 cm soil depth, 70 cm upper diameter, and 36 cm lower diameter. The experiment was comprised of three main plots irrigated with the crop actual evapotranspiration: IF1: daily, IF2: every other day, and IF3: every 3 days; and five irrigation water qualities (blended TWW and FW) as sub-plots: T100(100%TWW), T75(75%TWW and 25%FW), T50(50%TWW and 50%FW), T25(25%TWW and 75%FW), and T0(100%FW).

Soil preparation and planting

All drain-lysimeter-pots were filled with soil from the same source and the same texture and distributed randomly in the open field. The soil in the pots was saturated with FW and left to equilibrate for 48 hours to reach field capacity. Ten corn seeds were planted in each potato 3 cm depth. The planting date for the experiment was April 25, 2020, in the summer season. The treatments were commenced at 3-4 leaf stages, the experiment was started with the design treatments. Corncobs were started to emerge 9 weeks from the planting date and harvested after 18 weeks.

Irrigation method

Readily available water was estimated using the following formula:

$$RAW = (FC - PWP) \times Vs \times MAD$$

Where

RAW: Readily available water (cm3)

FC: field capacity on a volume basis.

PWP: permanent wilting point on a volume basis.

Vs: soil volume (cm3)

MAD: management allowable depletion

The estimated RAW was 4.8, 9.5, and 14.3 liters for 25%MAD (25% of the total available water), 50%MAD(50% of the total available water), and 75% MAD(75% of the total available water), respectively. The soil water content was controlled by using an extra drain-lysimeter-pot to control and update actual evapotranspiration. The representative pot was intermittently irrigated with a small-known amount of water until the water drain from the bottom of the pot. The actual crop evapotranspiration was calculated by subtracting the amount of drainage water from the amount of water added.

Irrigation water

TWW was collected from the Abu-Nuseir wastewater treatment plant. Mixing of TWW with FW was practiced manually and the mixture was shaken before each irrigation event. Water samples were analyzed for NPK. Total N was determined by the Spectrophotometric method (Eaton *et al*., 1995). Available P was measured by the ascorbic acid spectrophotometric method (Olsen & Dean, 1965). Available K was measured directly by a flame photometer (Pratt, 1965).

Soil analysis

Soil samples were collected from three soil depths (0-10, 10-30, and30-50 cm) from each pot before planting and at the end of the growing season. Total available N, P, and Ksoil content were determined by the Kjeldahl method [Bremner, (1965)], ascorbic acid [Olsen, *et al* (1965)], and flame photometers [Pratt, (1965)], respectively.

Corn crop yield

Corn crop growth parameters were evaluated. Four random samples were collected from each treatment. The wet and dry weight of corn fodder biomass, wet and dry weight of corn grain, and wet and dry corn plants without corn stover biomass were measured.

Statistical analysis

Statistical analysis was conducted using the SAS (2009) with irrigation frequency (IF1: daily, IF2: every other day, and IF3: every 3 days) as the main plot and water quality T100(100%TWW), T75(75%TWW and25%FW), T50 (50%TWW and 50%FW), T25(25%TWW and 75%FW), and T0(100%FW)) and their interaction. Means of significant effects ($P < 0.05$) were compared using the Duncan Multiple Range Test.

Results

Soil texture (sand, silt, and clay), field capacity, permanent wilting point, soil bulk density, and initial NPK soil content was determined before the experiments started. Table 1presents some soil physical and chemical properties, and TWW and FW nitrogen, potassium, and phosphorous content. The TWW content was 5 times, 27 times, and 5 times higher than FW content for N, P, and K, respectively.

Table 1. Some soil physical and chemical properties and TWW and FW nitrogen, phosphorous, and potassium (mg/L) content.

Soil		TWW (mg/L)	FW (mg/L)
Field capacity (cm3/cm3)	0.2943		
Permanent wilting point (cm3/cm3)	0.983		
Sand (%)	40.03		
Clay (%)	14.77		
Silt (%)	43.57		
Soil texture	Silt Loam		
Bulk density (g/cm3)	1.39		
Initial total nitrogen, N (mg/kg)	1.93	17.5	3.5
Available phosphorus, P (mg/kg)	13.13	134.87	4.98
Available potassium, K (mg/kg)	10.89	45	9

Crop yield analysis

All treatments received almost the same irrigation water quantities. Net seasonal irrigation water was 527.4, 519.3, and 527.4 liters/pot for IF1, IF2, and IF3 irrigation frequency treatments, respectively. Table 2presents corn crop growth parameters as affected by irrigation frequency. Results revealed that the IF1 treatment had significantly ($p<0.05$) highest wet and dry corn grain yields (9,494 and 5,351 kg/ha, respectively) compared to IF2 (6,341 and 4,169 kg/ha, respectively) and IF3 (5,266 and 3,486 kg/ha, respectively). There was no significant ($p<0.05$) difference between wet and dry corn grain yields inIF2 and IF3 treatments and there was no significant difference between IF1 and IF2 treatments in wet (51,105 and 48,286 kg/ha, respectively) and dry (32,860 and 30,694 kg/ha, respectively) corn fodder biomass yields; whereas two treatments gave significantly higher wet (42,734 kg/ha) and dry (27,640 kg/ha) yields IF3 treatment. Noticeably, there were no significant differences between the three irrigation treatments (IF1, IF2, and IF3) in the wet corn stover biomass yields.

Table 2. Corn growth parameters yield as affected by three irrigation frequency(*)

Irrigation treatment	Wet corn fodder biomass yield (kg/ha)	Wet corn grain yield (kg/ha)	Wet corn stover biomass yield (kg/ha)	Dry corn stover biomass yield (kg/ha)	Dry corn grain yield (kg/ha)	Dry Corn fodder biomass yield (kg/ha)
IF1	51,105 a	9,493.6 a	41,945 a	27,509 a	5,350.8 a	32,860 a
IF2	48,286 a	6,341 b	41,611 a	26,525 ab	4,169.3 b	30,694 a
IF3	42,734 b	5,265.6 b	37,469 a	23,978 b	3,482 b	27,460 b

(*) Columns with the same letters are not significantly different ($p<0.05$)

With regards to irrigation water quality, five mixing ratios (T100, T75, T50, T25, and T0) were used under each irrigation frequency treatment. Table 3 presents corn growth parameters yield as affected by water quality.

Over recorded growth parameters (wet and dry weights of fodder biomass yield; and wet and dry yields of corn grain), the highest values (58,036 and37,695 kg/ha; and 10,199kg/ha and 6,602 kg/ha, respectively) were obtained in TWW (T100) treatment and the lowest values (34,113 and 22,828kg/ha; and 3,456and2,146 kg/ha, respectively) were recorded using FW (T0) treatment. The results show that all corn growth parameters significantly increased as the ratio of TWW increased compared to FW. Corn wet and dry fodder biomass yields were significantly higher by 70% and 65%, respectively in T100 treatment as compared to T0 treatment. Wet and dry corn stover biomass yield increased significantly by 56% and 50% for the same treatments, respectively. Whilst, corn grain wet and dry yields were significantly higher by 1.95 and 2.08 times, respectively in T100 as compared to T0 treatment. Even though corn yield is higher in T100treatment than that in T75, they are not significantly different. The wet weight of corn fodder biomass and corn grain yields in T50 treatment was significantly higher than that in T25 and T0treatments by 20% and 46%, respectively. The results show that there was no significant difference in dry corn yield, wet and dry corn grain yield between treatments T25 and T0treatments, and the only significant difference was in wet corn biomass yield. Table 4 represents the mean square and significant level for the different measures.

Table 3. Corn crop growth parameters yield as affected by irrigation water quality(*)

Water quality	Wet corn fodder biomass yield (kg/ha)	Wet corn grain yield (kg/ha)	Wet corn stover biomass yield (kg/ha)	Dry corn stover biomass yield (kg/ha)	Dry corn grain (kg/ha)	Dry Corn fodder biomass yield (kg/ha)
T100	58,036 a	10,199 a	47,837a	31,093 a	6,602 a	37,695 a
T75	53,530 ab	9,032 ab	44,498 a	28,351 ab	5,551 ab	33,901 ab
T50	49,800 b	7,817 b	41,983 ab	25,766 bc	4,686b	30,452 bc
T25	41,396 c	4,664 c	36,732 bc	24,128 cd	2,686 c	26,814 cd
T0	34,113 d	3,456 c	30,657 c	20,682 d	2,146 c	22,828 d

(*) Columns with the same letters are not significantly different ($p<0.05$)

Table 4. Mean square (MS) and significance level for the different measures.

		Wet corn fodder biomass yield		Wet corn grain yield		Wet corn stover biomass yield		Dry corn stover biomass yield		Dry corn grain yield		Dry Corn fodder biomass yield	
Source	df	MS	P-value	MS	P-value	MS	P-value	MS	P-value	MS	P-value	MS	P-value
Irrigation	2	362789521	0.0104	96569506	0.0003	124361323	0.1	66413848	0.0467	17868983	0.001	147700709	0.0084
Error 1 Replicates (Irrigation)	9	45872554		4095643		41366342		15121277		1088843		17331059	
Water Quality	4	1107149689	<.0001	99129894	<.0001	548893139	<.0001	189896101	<.0001	42758047	<.0001	406944494	<.0001
Irrigation × Water Quality	8	20613321	0.9485	1918128	0.9023	21985809	0.9161	8137374	0.8831	1572069	0.7455	9238225	0.8976
Residual Error	36	62317270		4584139		55679996		18126459		2487569		21680397	

Nitrogen, phosphorus, and potassium soil content

The results revealed that there were significant differences in the NP K soil content as affected by irrigation frequency and water quality. Table 5presents NPK soil content, at the end of the growing season, as affected by the irrigation frequency treatments. The highest available N (1.8 mg/kg) and K (12.26 mg/kg) soil content was in the IF3treatment and the lowest N (1.56 mg/kg) and K (11.57 mg/kg) soil content was in the IF1treatment (Table 5). Nitrogen and potassium soil content in the IF3 treatment was significantly higher (by 15% and 6%, respectively) than that in the IF1 treatment. However, there was no significant difference for both N and K soil content between IF1 and IF2 treatments; and between IF3and IF2 treatments. Also, there were no significant differences between all irrigation frequency treatments (IF1, IF2, and IF3) in soil available P (14.44, 14.75, and 14.75mg/kg, respectively). The decrease in soil available N and K in IF1could be attributed to corn crop production. Table 6 represents the mean square and significant level for the different measures.

Table 5. Available NPK soil content as affected by irrigation frequency treatments (*)

Irrigation frequency treatment	N (mg/kg)	P (mg/kg)	K (mg/kg)
IF1	1.56 b	14.44 a	11.57 b
IF2	1.66 ab	14.75 a	11.69ab
IF3	1.80 a	14.75 a	12.26 a

(*) Columns with the same letters are not significantly different ($p<0.05$).

Table 6. Mean square (MS) and significance level for the different measures.

		N		P		K	
Source	df	MS	P-value	MS	P-value	MS	P-value
Irrigation	2	0.823	0.054	1.960	0.5718	6.629	0.5157
Error 1 Replicates (Irrigation)	9	0.200		3.293		9.293	
Water Quality	4	2.803	<.0001	309.500	<.0001	175.190	<.0001
Irrigation × Water Quality	8	0.054	0.9513	5.648	0.6353	5.596	0.3783
Residual Error	36	0.166	0.4436	7.384	0.5325	5.032	0.7418

Table 7 presents NPK soil content, at the end of the growing season, as affected by the interaction between irrigation frequency and water quality. Results indicate that there were significant variations in NPKsoil content among the different combinations of irrigation frequency and water quality. The highest N, P, and K soil content was inT75, T50, and T25 treatments, ranges from 1.93 mg/kg to 2.25 mg/kg, from 19.01 mg/kg to 17.91 mg/kg, and from 15.06 mg/kg to 13.45 mg/kg, respectively; and the lowest N, P, and K soil content was in IF1/T0, IF2/T0, and IF3/T0treatments, ranges from 1.25 mg/kg to 1.46 mg/kg, from 10.88 mg/kg, to 12.44 mg/kg, and from 10.16 mg/kg to 9.50, respectively.

Regardless of irrigation frequency, Table 8shows that soil available NPK content at the end of the growing season in treatment irrigated with TWW is significantly higher than that in treatment irrigated with FW by 50.4%, 62% and 53%, respectively. In general, NPK soil content at the end of the growing season significantly increased as the ratio of TWW in irrigation water increased. These results could be attributed to the TWW nutrients content. TWW treatment added 9.23 gN/pot, 71.13 g P/pot, and 23.73gK/pot, while FW added just 1.85 gN/pot, 2.63 gP/pot, and 4.75 g K/pot (Table 9).

Table 7. NPK soil content as affected by irrigation frequency and water quality(*)

Treatment	N (mg/kg)		Treatment	P (mg/kg)		Treatment	K (mg/kg)	
IF3/T_{100}	2.25	A	**IF3/TWW**	19.01	a	**IF2/ TWW**	15.06	a
IF1/T_{100}	2.01	Ab	**IF2/TWW**	18.90	a	**IF1/T3F1**	14.98	a
IF3/T_{75}	1.95	Ab	**IF1/TWW**	17.91	ab	**IF1/ TWW**	14.19	ab
ISC	1.93	Ab	**IF3/T3F1**	16.65	bc	**IF2/T3F1**	13.90	ab
IF1/T_{100}	1.93	Ab	**IF1/T3F1**	16.40	bc	**IF2/T2F2**	13.71	abc
IF1/T_{75}	1.84	Bc	**IF2/T3F1**	16.23	bcd	**IF3/TWW**	13.45	abcd
IF2/T_{75}	1.75	Bcd	**IF2/T2F2**	15.29	cde	**IF3/T2F2**	12.08	abcde
IF3/T_{50}	1.69	Bcde	**IF1/T2F2**	14.06	def	**IF1/T1F3**	11.05	bcde
IF2/T_{50}	1.63	Bcdef	**IF3/T2F2**	13.85	ef	**ISC**	10.89	bcde
IF3/T_{25}	1.63	Bcdef	**ISC**	13.13	efg	**IF1/T2F2**	10.26	cde
IF2/T_{25}	1.52	Cdef	**IF1/T1F3**	12.92	fg	**IF3/FW**	10.16	de
IF1/T_{50}	1.49	Cdef	**IF3/FW**	12.44	fg	**IF2/FW**	9.93	e
IF3/T_0	1.46	Cdef	**IF2/T1F3**	12.24	fg	**IF2/T1F3**	9.57	e
IF2/ T_0	1.40	Cef	**IF3/T1F3**	11.79	fg	**IF1/FW**	9.50	e
IF1/T_{25}	1.31	Ef	**IF2/FW**	11.11	g	**IF3/T1F3**	9.39	e
IF1/ T_0	1.25	F	**IF1/FW**	10.88	g	**IF3/T3F1**	8.80	e

(*) Columns with the same letters are not significantly different ($p<0.05$)
ISC represents initial soil nutrient content.

Table 8. Available NPK soil content at the end of the growing season as affected by water quality treatments (*)

Water quality treatment	N (mg/kg)	P (mg/kg)	K(mg/kg)
T100	2.06 a	18.61 a	14.50 a
T75	1.85 b	16.43 b	13.93 a
T50	1.60 c	14.40 c	10.83 b
T25	1.49 cd	12.32 d	10.63 b
T0	1.37 d	11.48 d	9.48 c

(*) Columns with the same letters are not significantly different ($p<0.05$)

Table 9. NPK water quality treatments nutrient content

Water quality treatment	N (g/pot)	P (g/pot)	K(g/pot)
T100	9.23	71.13	23.73
T75	7.38	54.00	18.99
T50	5.54	36.88	14.24
T25	3.69	19.75	9.49
T0	1.85	2.63	4.75

Discussion

Results revealed that the significant effect of irrigation frequency was mainly on corn grain yield and consequently fodder biomass yield. Whilst, all corn growth parameters yield significantly increased as the ratio of TWW increased compared to FW. In general, wet and dry corn fodder biomass and/or stover biomass yields in T100 and T75 treatments were significantly higher than that in T25 and T0 and there were no significant differences between T75 and T50 treatments.

Awotundum, (2005) reported that maize is a very nutrient-demanding crop, requiring intensive application of inorganic or organic fertilizers to produce a high yield. In this experiment and since no fertilizer was added for all treatments and the only source for nutrients was irrigation water, it could be concluded that the significant increase in corn yield was attributed to TWW nutrients content which provided the plant with the essential nutrients for plant growth and production.

These results agree with the results obtained by Mohammad &Ayadi (2004) and Khattari&Jamjoom (1988). They found that corn crop yield increased by using TWW as compared with the FW treatment. Mohsen (2003) indicated that total dry matter and ears yield of sweet corn irrigated by TWW were higher than that irrigated with FW. Tavassoli *et al.* (2010) reported a major increase in fresh and dry forage yield of corn irrigated with TWW with a significant influence on crude protein content, ash percentage, and macro elements (N, P, and K). Also, several studies have been found that TWW irrigation increases and improves the productivity for soil with poor fertility (Kiziloglu *et al.*, 2007) as well as the concentration of different nutrients involved in plant growth (Rezapour&Samadi, 2011; Sacks &Bemstein, 2011).

At the end of the growing season, the lowest N and K soil content coincides with the highest corn yield in IF1 treatment and the highest N and K soil content coincides with the lowest corn yield in the IF3 treatment. Regardless of the irrigation frequency, the highest NPK soil content was in treatments irrigated with pure TWW (T100) and the lowest soil content was in treatments irrigated with FW (T0). These results agree with Galavi *et al.,* (2010) who reported that irrigation with TWW leads to a significant increase in NPK than the control treatment. Also, Simmons *et al.,* (2010) reported that soil N and P content increased when irrigation with TWW. Udluft and El-Naser (1991) reported that the use of TWW in irrigated agriculture provides a good balance of plant nutrients (N, P, and K) which can markedly increase crop production and reduced the need for expensive commercial fertilizers.

Conclusion

Results revealed that using TWW for agricultural irrigation could deliver corn plants essential mineral nutrients (NPK) to ensure optimal growth, without using commercial fertilizers. Corn yield and soil nutrients content, at the end of the growing season, increased significantly as the ratio of TWW increased in the blended irrigation water. The significantly highest yield and soil nutrients content were in treatments irrigated with TWW and the significantly lowest values were in treatments irrigated with FW. Also, irrigation frequency has significant effects on corn crop yield, with the highest yield was in IF1 treatments and the lowest being in IF3 treatments. Thus, using light frequent irrigation with TWW effluent will maximize corn crop yield, minimize the use of commercial chemical fertilizer and save the environment.

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تأثير المياه العادمة المعالجة المخلوطة وتكرار الرّي على إنتاج الذرة ومغذيات التربة

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الملخص

يتناول هذا البحث تأثير استخدام المياه العادمة المعالجة بعد خلطها مع مياه عذبة وتكرار الرّي على محصول الذرة (الذرة الرفيعة) ومحتوى التربة من النيتروجين والفسفور والبوتاسيوم، وتضمنت التجربة ثلاثة مكرارات ري: (1) يومياً، (2) كل يومين، و(3) كل ثلاثة أيام؛ وخمسة مياه ري مخلوطة: (1) مياه عادمة معالجة، (2) 75% مياه عادمة معالجة و25% مياه عذبة، (3) 50% مياه عادمة معالجة و50% مياه عذبة، (4) 25% مياه عادمة معالجة و75% مياه عذبة، و (5) مياه عذبة، بأربعة مكررات. أشارت النتائج الى أنّ التأثير المعنوي لتكرار الرّي كان بشكل رئيسي على محصول كيزان الذرة وبالتالي على محصول الذرة. ويزداد محصول الذرة مع زيادة نسبة المياه العادمة المعالجة في مياه الري المخلوطة، مع أعلى محصول معنوي (58,036 كغم/هيكتار) باستخدام المياه العادمة المعالجة، وأقل محصول (37,695 كغم/هيكتار) باستخدام المياه العذبة. وبغض النظر عن تكرار الرّي، كان أعلى محتوى للتربة من النيتروجين والفسفور والبوتاسيوم في المعاملات المرويّه باستخدام المياه العادمة المعالجة، بينما أقل محتوى للتربة في المعاملات المرويّة باستخدام المياه العذبة. وكان محتوى التربة المتاح من النيتروجين والفسفور والبوتاسيوم أعلى بكثير في المياه العادمة المعالجة مقارنةً بالمياه العذبة وبنسب 50.4 % و62% و53%, على التوالي. وبالتالي، فإن استخدام المياه العادمة المعالجة في الرّي الزراعي يمكن أنْ يوفر توازنًا جيدًا للمغذيات النباتية التي يمكن أنْ تزيد بشكل ملحوظ من إنتاج محصول الذرة وتقليل الحاجة إلى الأسمدة التجارية باهظة الثمن.

الكلمات الدالة: المياه العادمة المعالجة، الرّي، التبخر، الذرة، تكرار الري، المياه العادمة المعالجة المخلوطة، المغذيات.