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Research Article

Effect of municipal wastewater irrigation and well water on plant and soil characteristics

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Abstract

In order to investigate the effect of treated wastewater on forage yield, nutrient elements and heavy metals in corn plants (*Zea maize,* 704 single cross), a field experiment was conducted in RCBD with three treatments in four replications in 2017. Irrigation with well water as first treatment, irrigation with wastewater as second treatment and irrigation with well water and wastewater was alternately applied as a third treatment. The results showed that the highest amount of forage corn yield, stalk and ear dry weight, plant height and leaf number and spade index were obtained in irrigation with wastewater. The highest nitrogen content of leaf and stalk and corn grain was obtained in irrigation with wastewater treatment and the least amount in irrigation with well water treatment was obtained. The amount of phosphorus and potassium measured in leaf and stalk of corn in all three treatments were not significantly different. Also, the highest amount of iron and zinc in leaf and stalk of corn was obtained in irrigation with wastewater treatment. The results showed that the amount of heavy metals including lead, cadmium and nickel in soils were not significantly different in all three treatments. According to the results, the use of urban wastewater not only does not cause soil and plant pollution to heavy elements, but also increases plant yield and nutrition.

Keywords: nutritional elements; pollution; yield components

Introduction

Iran is an arid and semi-arid land. The increasing growth of the world population and especially Iran, the improvement of living standards, in line with the development of agriculture and industry, the occurrence of multiple and subsequent droughts, lack of proper management of water resources and environmental degradation in the last three decades, has caused The exploitation of fresh water resources reaches peak in the whole country, especially in the arid regions. Regarding the above, lack of water resources has always been

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considered as a limiting factor for various activities, especially agriculture in Iran (Alizadeh, 2003). Due to the amount of water resources and per capita consumption, Iran is one of the countries in the group of countries faced with a physical shortage of water. In 2022, more than 10 billion cubic meters of water are expected to be used in urban, rural and industrial areas. With a recycling rate of 60% to 70%, there will be about 6 to 7 billion cubic meters of water coming from the wastewater and the wastewater will enter the agricultural land (Harati *et al.*, 2011). Irregular water abstraction from groundwater, which reaches about 60 billion cubic meters per year, is another major problem in the country's water sector and has caused irreparable damage to groundwater resources in many parts of the country (Noor, 2017). The limitation of water resources in countries in arid and semi-arid regions is one of the most important problems in the agricultural sector.

Therefore, the use of unconventional water sources (including wastewater treatment plants) in these countries is becoming more important. Sewage effluent according to its origin, it can contain organic matter and nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium and other elements (Sacks and Bernstein, 2011). Which can play an important role in plant growth and metabolism and soil fertility improvement (Kiziloglu *et al.*, 2007). Clearly, the use of sewage, regardless of its quality, type or classification, is increasingly used throughout the world not only in urban and suburban agriculture, but also in the rural areas of large cities for irrigation (Mateo-Sagasta *et al.*, 2013). The effects of urban wastewater treatment on the growth and photosynthesis and chickpea yield under different nitrogen levels showed that this water source contains many essential food sources that increase the yield of the product and replace the fertilizer or reduce the fertilizer requirement (Tak *et al.*, 2012).

Investigating the effects of urban sewage effluent on wheat traits under different concentrations of NPK showed that the use of sewage alone compared to well water with increasing spike length and number of spike and grain per spike increased yield. Alizadeh *et al.* (2001) reported that irrigation with sewage at all stages of plant growth led to the highest grain yield and biological yield of corn. Sewage effluent can increase plant growth and yield as well as proper plant nutrition by increasing soil organic matter and improving the physical properties of the soil (Castro *et al.*, 2011). Sewage may, depending on its source, contain some potentially harmful substances such as heavy metals and pathogens that accumulate in soil and biological systems and cause toxicity.

Considering the country's rainfall situation, especially in arid and semi-arid regions of the country, population growth and the need to maintain sustainable production based on sustainable water resources and high water consumption in the agricultural sector and the problem of water supply for this area and the limitation of groundwater resources, And on the other hand, sewage effluent production as a very important potential in arid and semi-arid regions of the country, It was decided to study various aspects of the use of wastewater for irrigation of corn, which is one of the main plants cultivated in dry and semi-arid regions of the country.

Materials and Methods

This research was conducted during 2017 in a plot of 1000 square meters in the Dolatabad area of Isfahan province. It is located at 32° 48' N latitude and 51° 44' E longitude and has an elevation of 1560 m above sea level. In order to determine the chemical and physical properties of the soil, a soil sample was collected and sent to the Laboratory of Soil and Water Research Center of Isfahan Agricultural and Natural Resources Research Center. These samples were also analysed for standard physic-chemical properties.

Table 1. Physical and chemical characteristics of the tested soil

Soil texture	(EC) (dSm^{-1})	pH (1:2)	N-total	OC	P	K	Cu	Zn	Mn	Fe	Ni	Cd	Pb
			(%)		($mg\ Kg^{-1}$)								
Silty clay	4.4	7.52	0.05	0.51	1.45	319	1.12	0.72	4.36	13.8	0.76	0.06	1.8

The soil samples were air-dried and ground to pass a 2 mm sieve size, and then extracted using a solution of DTPA (0.05 mol/l) contains $CaCl_2$ (0.01 mol/l) in pH of 7.3 (Lindsay and Norvell, 1978). The extractable DTPA-Pb, Cu, Fe, Cd, Ni, Cu, and Zn were determined by atomic absorption method. This research was carried out in a Randomized Complete Block Design (RCBD) with three irrigation water treatments on *Zea mays* (704 single cross).

Water treatments at three levels were considered as irrigation with well water (control, T1), irrigation with semi-refined municipal wastewater (T2) and irrigation with well water and semi-refined wastewater, which was alternately considered (T3). The design was carried out with 4 replications and 12 plots (4*5=20 m^2). In order to prevent the transfer and leakage of water in the soil between the plots in each replication 3 meters and between blocks 4 meters distance was considered as the boundary. The wastewater required by the tanker was transferred from the Shahin Shahr sewage plant to the ground and well water was supplied from the well in the same place.

According to the results of soil analysis, 300 kg/ha of superphosphate fertilizer was mixed with secondary soil tillage. Nitrogen fertilizer required by urea fertilizer was fed on two planting and stemming times of 250 kg/ha. The soil texture was of silty clay type (sand 11, silt 48, clay 41%). After finishing the ploughing stage with the worker, the boundaries of each plot were restored and within each plot, rows of 70 cm spacing were created for seeding of maize seed and corn seeds were planted with a spacing of 15 cm in each row in mid-June 2017. Forage corn irrigation was conducted according to the common pattern in the region.

By reaching the soft dough stage, it was taken to sample and sent to the laboratory to measure the traits. Fresh and dry forage weight (yield), ear, stalk and leaf fresh and dry weight, plant height, Number of plant leaves at sampling time, chlorophyll index of ear leaf were measured. In order to determine the fresh forage yield, 2 m^2 plants were collected in the middle of each experiment unit and the organs were weighed separately. Samples were transferred to the oven and dry forage yield was measured. For plant analysis, after harvesting each plant and drying their plant samples (in the oven for 48 hours and 70 °C), the total nitrogen concentration in the seeds, stems and leaves was determined by the Kjeldahl method (Bremner, 1996), To determine phosphorus in plant samples, The colorimetric method was performed at a wavelength of 470 nm using a spectrophotometer.

Potassium of the plant organs was performed using flame photometric method (Waling *et al.*, 1989). For measuring plant micro nutrient content (Fe, Cu and Zn) leaf and stalk and grain samples were collected after harvesting time then washed, oven dried, ground and extracted with wet acid digestion method and analysed for elemental content of Fe, Cu and Zn by Atomic Absorption Spectrophotometer, model 2380 (Jones and Case, 1990). Statistical analysis was performed using SAS statistical software. Means were compared by using the least significant difference of Fisher LSD method at 5% probability level.

Table 2. Water analysis of the well site and used wastewater

	EC*10^6	pH	TDS	N-NH4	N-NO3	P	K	Mn	Fe	Zn	Pb	Cd	Cr
	µS/cm		(mg L-1)										
Well water	3.36	7.7	2150	0	2.4	0.12	6.7	0.08	0.01	0.01	0.02	0.01	0.01
Waste water	1.70	7.2	1088	46	7.80	5.8	11.9	0.07	0.06	0.05	0.02	0.01	0.01

Results and Discussion

Yield and yield components

The highest yield of corn containing total fresh weight of leaf and stalk and ear was obtained in irrigation with wastewater and irrigation intervals, which did not show statistically significant difference but there was a difference in the treatment of well water (Table 4). It should be noted that in corn fodder, economic yield is the same fresh weight of the shoot that the highest amount of leaf and stalk and ear fresh weight obtained in irrigation with wastewater treatment. Of course, it should be noted that there was no statistically significant difference between the results of irrigation with wastewater and alternative treatments (Table 4). The presence of macro and micro nutrients in the waste water can help to produce photosynthesis and produce more carbohydrates by providing adequate nutrients.

It should be noted that leaf, stalk and ear weight gain as photosynthetic organs can increase the yield by increasing carbohydrate production. In other studies, increase the photosynthesis level of the plant, the durability of the leaves and the content of their chlorophyll as a result of nutrients in the wastewater has been reported (Monte and Esousa, 1992; Badiei *et al.*, 2016). The results of Ozyazici *et al.* (2013) on wheat planting patterns in India showed that the use of wastewater increased the yield and yield components significantly. Nitrogen is one of the main components of the formation of chlorophyll and in general, it will increase photosynthesis and thus increase plant growth. An increase in the shoot dry weight maybe due to the presence of high levels of nitrogen, phosphorus and potassium in the wastewater relative to well water (Kumar *et al.*, 2014). Harati *et al.* (2012) examined the effects of irrigation with urban wastewater in southern Tehran on corn fodder. Their research results showed that increasing sewage increased plant height, plant weight, root weight, stalk weight and total dry weight. Harati *et al.* (2012) stated that irrigation with wastewater provides nutrients and thus improves plant growth characteristics. Increase yields of irrigated corn crops with wastewater due to the higher nitrogen and phosphorus in the wastewater, as well as the improvement of soil physical and chemical conditions for better plant growth.

Table 3. The results of variance analysis of the effect of irrigation treatments on corn traits

		(Mean of square)			
s.v	*df*	Leaf fresh weight	Stem fresh weight	Ear fresh weight	Fresh yield
Block	3	32928.9	89945.2	21246.30	5.65
Treatments	2	78502.08	1213132*	618856.08*	462.49**
Error	6	30185.63	126739.55	102055	38.59
CV (%)		16.085	8.575	16.058	8.603
s.v	*df*	Biologic yield	Plant height	No. leaves per plant	Spad index
Block	3	0.675	36.30	0.371	8.192
Treatments	2	46.011*	1727.58**	6.127**	33.535*
Error	6	4.366	43.13	0.361	5.328
CV (%)		8.959	2.933	4.010	5.471

ns, * and ** are not significant, significant at 5 % and 1 % level of probability, respectively

Height and number of leaves

The highest plant height and number of green leaves per plant were obtained in irrigation treatment with wastewater treatment, irrigation alternate and the least those were obtained in irrigation with well water (Table 4). Gupta *et al.* (2015) examined the effects of irrigation with urban wastewater on the growth and yield of forage sorghum in a field experiment. The results of their research showed that irrigation with wastewater as a water source increased plant height, number of leaves per plant, leaf area index, leaf biomass to stalk (green and dry) and green forage yield. Harati *et al.* (2012) observed that irrigation with urban wastewater on fodder corn in southern Tehran increased plant height than control. They stated that irrigation with sewage provides nutritional elements and therefore the plant growth characteristics Improves. The number of leaves or leafy index is one of the important factors in forage plants that affects palatability and digestibility.

Table 4. Mean comparison of irrigation treatments on corn traits

Treatments	Fresh yield (ton ha^{-1})	Ear fresh weight (g m^{-2})	Stem fresh weight (g m^{-2})	Leaf fresh weight (g m^{-2})
Well water	60.06 B	1544.3 B	3542.5 B	919.3 A
Wastewater	80.50 A	2290.0 A	4614.5 A	1145.5 A
Alternate	76.07 A	2134.0 A	4297.5 A	1135.5 A
Treatments	Biologic yield (ton ha^{-1})	Plant height (cm)	No. leaves per plant	Spad index
Well water	19.44 B	202.50 C	13.6 B	38.85 B
Wastewater	25.74 A	244.00 A	16.0 A	44.07 A
Alternate	24.77 A	225.25 B	15.3 A	43.62 A

Means with different letters on the same column are significantly different ($P<0.05$) based on LSD test.

Spad index (SPAD)

The highest SPAD values in wastewater treatment and alternate were 44.07 and 43.62, respectively (Table 4). Moradi *et al.* (2016) investigated the effects of different combinations of water and wastewater on grain yield, aggregate of heavy metals and other traits in oat plants. The results of the research showed that the sewage application had a positive effect on leaf chlorophyll content so that the chlorophyll content of the leaf increased with increasing sewage concentration. Under proper nutritional conditions, the concentration of chlorophyll in the plant increases because the nutrients play an important role in the formation of chlorophyll. Irrigation treatment with wastewater instead of well water can help to provide the nutrients needed as well as help the process to produce chlorophyll to increase the SPAD index.

Macro nutritional elements in leaves and stalks

The highest nitrogen content in leaves and stalks in irrigation with wastewater treatment and irrigation alternate were 1.555 and 1.510%, respectively and the lowest amount in irrigation treatment with well water was obtained at 1.222%. The amount of phosphorus and potassium measured in leaf and stalk of corn in all three treatments were not significantly different (Table 6). In other words, the results of this experiment showed that irrigation water treatment only affected the amount of nitrogen in leaves and stalks and did not affect the amount of phosphorus, and potassium in leaves and stalks. It should be noted that providing sufficient number of elements such as potassium and phosphorus in the soil at the Cultivation stage can reduce the effect of wastewater use and the concentration of the elements in the stem and leaf and cause no significant difference in the results of the experiment. It is clear that sewage alone cannot provide the nutritional requirements of plants for high-consumption elements such as nitrogen.

Therefore, in these cases, their application to proportional amounts of chemical fertilizers must be considered in order to the nutritional requirements of the plant (Sommers *et al.*, 1976). Of course, in other studies, increasing the amount of these elements was observed in irrigation treatment with wastewater to well water. Among them, in a research at Bajaga Research Station, Shiraz University, It was concluded that in irrigation treatments with wastewater, plant yield and concentration of potassium, calcium, phosphorus, chlorine, iron, copper, manganese and zinc, and in comparison with well water, there was a significant difference in the level of 5% (Rajabisorkhani and Ghaemi, 2012).

Micro nutritional elements in leaves and stalks

The highest iron and zinc elements leaf and stalk were obtained in irrigation treatment with wastewater treatment, alternate and the least those were obtained in irrigation with well water (Table 6). Both iron and zinc elements in the leaf and stalk of corn showed a similar trend and both elements in wastewater treatment was significantly different with well water. The most important application of iron in plants is its key role in chlorophyll molecule. This element also regulates the activity of enzymes responsible for the energy transfer cycle, respiration and nitrogen fixation.

Table 5. The results of variance analysis of the effect of irrigation treatments on corn traits

(Mean of square)						
s.v	*df*	Plant remains nitrogen	Plant remains phosphorus	Plant remains potassium	Stems and leaves iron	Stems and leaves zinc
Block	3	0.0128	0.0030	0.0392	2138.1	30.55
Treatments	2	0.1252*	0.0010	0.1507	2865.3	197.33*
Error	6	0.015	0.002	0.0929	739.11	24.88
CV (%)		8.735	10.88	24.944	19.123	13.422
s.v	*df*	Grain nitrogen	Grain phosphorus	Grain potassium	Grain iron	Grain zinc
Block	3	0.007	0.062	0.004	0.305	2.666
Treatments	2	0.144*	0.006	0.0009	3.584	1.00
Error	6	0.0137	0.0141	0.0043	14.138	7.666
CV (%)		4.854	18.980	13.216	19.877	15.382

ns, * and ** are not significant, significant at 5 % and 1 % level of probability, respectively

Some researchers believe that increasing the yield in irrigation with wastewater is due to a decrease in pH and increased availability of the elements and a significant amount of organic matter and nutrients such as nitrogen, phosphorus, iron, manganese, potassium, calcium, magnesium. They play an important role in developing plant growth and metabolic processes and improving soil fertility (Sacks and Bernstein, 2011). In this regard, Xu *et al.* (2010) examined the long-term effects (20 years) of treated wastewater on agricultural soils. They reported that the use of wastewater reduces the acidity and the increase of heavy metals. The increase in nutrients in general and iron in particular due to sewage irrigation can be mainly dependent on two factors. First, the presence of nutritive elements in the wastewater and its addition through irrigation with waste water and the second, changes in soil chemical properties due to the use of wastewater.

Table 6. Mean comparison of irrigation treatments on corn traits

Treatments	Plant remains nitrogen (%)	Plant remains phosphorus (%)	Plant remains potassium (%)	Stems and leaves iron (mg kg^{-1})	Stems and leaves zinc (mg kg^{-1})
Well water	1.222 B	0.440 A	1.055 A	112.50 B	30.50 B
Wastewater	1.545 A	0. 457 A	1.435 A	164.50 A	44.50 A
Alternate	1.510 A	0.425 A	1.176 A	149.50 AB	36.50 AB
Treatments	Phosphorus of corn grain (%)	Potassium of corn grain (%)	Nitrogen of corn grain (%)	Grain iron (mg kg^{-1})	Grain zinc (mg kg^{-1})
Well water	0.595 A	0.515 A	2.227 B	20.00 A	17.50 A
Wastewater	0.672 A	0.500 A	2.607 A	18.50 A	18.00 A
Alternate	0.615 A	0.485 A	2.410 AB	18.25 A	18.50 A

Means with different letters on the same column are significantly different (P<0.05) based on LSD test.

Nutrient elements in corn grain

The amount of nutrients including nitrogen, phosphorus, potassium, iron and zinc in corn grain were measured in three treatments. The effect of irrigation water treatment on the amount of these elements except nitrogen in corn grain was not significant in the remaining cases at the 5% probability level (Table 5). Fereidooni *et al.* (2013) investigated the effect of wastewater and nitrogen fertilizer on the concentration of nutrients in sweet corn.

The results of their research showed that irrigation with wastewater in the whole period compared to irrigation with well water increased the concentration of nitrogen and phosphorus in sweet corn seed, but the effect of irrigation with wastewater on the concentration of other elements such as potassium, iron and zinc in sweet corn grain it was not. However, in studying the effects of irrigation with effluent, nitrogen, phosphorus and potassium, iron and zinc elements in shoot and leaf organs were generally affected by wastewater treatment. Rattan *et al.* (2005) reported that with the use of effluent in corn، iron element increased. They also showed that this element was mainly accumulated in the root of the corn plant and was less transmitted to the plant's shoot. They reported that zinc element in corn was increased by application.

The researchers reported that the accumulation of iron in the leaves was higher than the accumulated amounts of iron in the stem and seed. As a result, the greater accumulation of iron in the limb was attributed to the use of this element in the process of photosynthesis. Factors such as the type of element, its concentration in wastewater and soil, the rate of absorption by the plant and the amount of transfer in the organs and tissues of the plant are effective on the accumulation of elements in the plant organs.

The primary reasons for not observing the effect of irrigation water type treatment on the concentration of elements in wheat and corn seeds in this experiment can be attributed to the lowering of these elements in the plant to reproductive organs and their further allocation to vegetative organs and their role in photosynthesis. Other factors can reduce the amount of these elements in the effluent. It should be noted that the tested wastewater is a type of urban wastewater, which generally has a much lower concentration of the elements than industrial waste water. On the other hand, this test has been measured over a period of one year and may yield different obtained in the long time.

Macro elements in the soil

The highest amounts of total nitrogen, potassium and phosphorus soil after harvest of corn were obtained in irrigation with wastewater and alternate treatments respectively, which was statistically different from irrigation with well water (Table 7). Alghobar Mohammed and Suresha (2017) investigated the accumulation of metal in tomato and soil irrigated with sewage water under the influence of treatments of treated and untreated sewage water and well water in soil and plant. The results of their research showed that soil potassium concentration was not affected by sewage treatment, but had a significant effect on nitrogen and phosphorus concentrations. The researchers investigated the effect of wastewater on soil chemical properties, yield and quality of olive oil. The results showed that irrigation with effluent increased nutrients such as phosphorus nitrogen and potassium in soil (Bedbabis *et al.*, 2015).

The results of this experiment and other experiments show that the use of urban wastewater affects the amount of macro nutrients in the soil and increases the entry of these elements into the soil. This increase is due primarily to the higher concentrations of nutrients in the wastewater than to the well water and, in the second place, the effluent properties such as pH and the lower sodium content, which results in the superiority of irrigation with wastewater to the well water and supplies part of the nutrient elements of the plant. These attributes are effective in reducing the use of macromolecular fertilizers. These attributes are effective in reducing the use of chemical fertilizers.

Table 7. The results of variance analysis of the effect of irrigation treatments on soil

		(Mean of square)				
s.v	*df*	Total nitrogen	Phosphorus	Potassium	Iron	Zinc
Block	3	0.00002	0.412	71.63	0.0007	0.0002
Treatments	2	0.0002	2.822*	1782.3	0.007	0.00003
Error	6	0.00004	0.298	503.22	0.0057	0.0002
CV (%)		11.453	19.155	5.920	18.154	10.259
s.v	*df*	Copper	Chrome	Lead	Cadmium	
Block	3	0.0015	0.00004	0.0128	0.00009	
Treatments	2	0.0012	0.00013	0.0198	0.0001	
Error	6	0.0048	0.00004	0.0082	0.0006	
CV (%)		18.316	18.181	9.196	18.181	

ns, * and ** are not significant, significant at 5 % and 1 % level of probability, respectively

Micro-nutrient elements in soil

Iron, zinc and copper in soil samples were evaluated after corn harvesting by three irrigation treatments and the results were not significant at 5% probability level (Table 7 and 8). Alghobar Mohammed and Suresha (2017) the accumulation of metals in soils and tomato from the city of Missoor (Karnataka, India) was affected by treatment of treated and untreated wastewater and well water. The results of this study showed that iron, copper and zinc concentrations in soil were not affected by sewage treatments. Silva *et al.* (2016) found that irrigation with sewage resulted in an increase in the accumulation of elements such as iron, manganese, zinc, copper and soil boron relative to fresh water irrigation.

One of the main factors influencing the use of effluent on the concentration of nutrients in the soil is its application time, because it generally results in increased concentrations of nutrients in the soil in the long term (more than a decade), But in the short term, similar results were not observed. Another point about the tested soil is pH, the effect of wastewater on the amount of these elements is usually found in acidic and neutral soils earlier than semi-alkali or alkaline soils. Another factor is the concentration of the elements in the waste water, which is usually very small in urban wastewaters, but in industrial and semi-industrial waste water they are high and can reach toxic levels in the medium or long term for plants. In this study, factors such as the short duration of wastewater use, acidity and soil texture (especially clay content) can lead to no significant difference in the concentration of these elements in the soil, as a result of treatment of wastewater and well water.

Heavy elements in soil (Pb, Cd and Cr)

The levels of heavy metal such cadmium, lead and chromium in soil were measured in all three treatments after corn harvesting. The effect of irrigation treatments such as irrigation with wastewater, alternative and well water on the elements mentioned in soil at 5% probability level was not significant (Tables 7 and 8). Any change in the concentration of metal in the soil depends on the concentration of the metal in the wastewater, which depends on the source of the wastewater, the application rate, plant harvest, and occasionally leaching. Of course, various reports suggest increasing the concentration of some heavy metals in the soil following the application of wastewater. For example, according to Chen *et al.* (2009) report, 50 years irrigation with wastewater has significantly increased the concentration of cadmium, lead, nickel, zinc and copper relative to the reference soil (irrigated with well water). The pH of the soil affects the solubility and transfer of heavy elements. Munir *et al.* (2007) reported that irrigation of forage plants with urban wastewater for 2 to 10 years increased zinc, copper, iron and manganese concentrations in the soil. Therefore, the long-term use of industrial or municipal wastewater in irrigation can lead to the accumulation of heavy metals in soil and agricultural plants (Singh *et al.*, 2010).

According to the results of the concentration table of the elements in the wastewater of the treatment plant, it was found that the concentration of these elements was very low. Of course, because the tested waste is of urban origin and generally does not enter industrial waste, this is normal. Also, the period of wastewater use in this experiment was short-term, while in other studies, researchers who chose long-term intervals generally observed a change in the concentrations of the elements in the soil. The use of semi-refined municipal wastewater can be recommended in a short or medium term with proper management for irrigation of forage and cereal crops.

Table 8. Mean comparison of irrigation treatments on soil traits

Treatments	Total nitrogen (%)	Phosphorus (mg kg^{-1})	Potassium (mg kg^{-1})	Iron (mg kg^{-1})	Zinc (mg kg^{-1})
Well water	0.0525 B	1.975 B	354.75 B	0.375 A	0.1625 A
Wastewater	0.0675 A	3.650 A	393.75 A	0.460 A	0.1575 A
Alternate	0.0600 AB	2.950 A	388.25 AB	0.415A	0.1575 A
Treatments	Copper (mg kg^{-1})	Chrome (mg kg^{-1})	Lead (mg kg^{-1})	Cadmium (mg kg^{-1})	
Well water	0.370 A	0.1025 A	0.915 A	0.04 A	
Wastewater	0.400 A	0.1025 A	0.997 A	0.04 A	
Alternate	0.370 A	0.1125 A	1.055 A	0.04 A	

Means with different letters on the same column are significantly different ($P<0.05$) based on LSD test

Conclusions

Although the use of effluent as a water source has been available for decades, it is still considered an unconventional source. It has always been associated with concerns about the entry of heavy elements into the soil and plant. The results of this experiment showed that at the time of use wastewater in agriculture, the concentration of wastewater elements and the type of wastewater purified from the urban or industrial point of view should be considered. In this experiment, the source of wastewater was urban wastewater, which generally had a low concentration of heavy elements and its results in corn cultivation showed no increase in heavy and non-heavy elements in the soil and plant. The results of the experiment showed that the use of wastewater can help increase the concentration of nutrients in the soil and plant, and improve plant performance and increase yield. Therefore, urban wastewater can be considered as a sustainable source of water in arid areas and provided part of the country's need for water in the agricultural sector through comprehensive management in the country.

Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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