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The effects of municipal treated wastewater and sludge on some vegetative characteristics of *Nitraria Schoberi*

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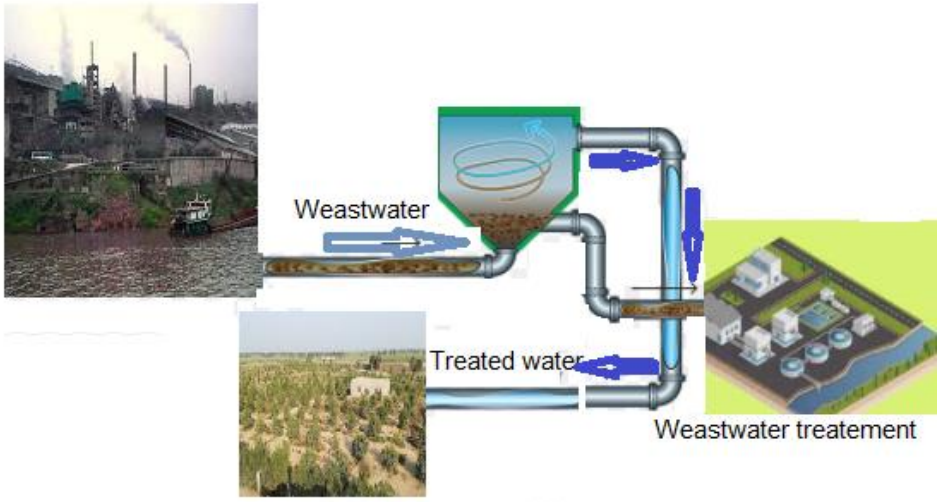
GRAPHICAL ABSTRACT



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ABSTRACT

The present study investigates the effect of treated wastewater and sludge on some vegetative characteristics of the *Nitraria schoberi* plant. This study was conducted in a randomized block template using several treatments include five levels of irrigation with wastewater (0, 25, 50, 75, and 100 %), two types of soil (arable land and desert soil of Meighan desert area), and two levels of sludge (presence and absence of sludge) with 6 repetitions for each treatment. SPSS software was used to perform the statistical analysis of plant morphological characteristics. The results showed that the highest increase in height, collar diameter, and the crown cover was observed when a wastewater level of 100 % was applied in the catchment basin soil of the Meighan desert at both presence and absence treatment of sludge. However, the same characteristics of *Nitraria schoberi* plant for cropland soils in the present treatment of sludge were at wastewater level of 100 % and in the absence treatment of sludge for plant height, collar diameter and crown cover diameter were at wastewater level of 50 %, 100 %, and 75 %, respectively. According to the results, different levels of wastewater have a significant impact on *Nitraria schoberi* plant height and crown cover diameter ($P<0.01$). But different treatments did not show a significant difference in the collar diameter of the *Nitraria schoberi* plant. We can conclude that the use of wastewater should have a favorable effect on plants and soils of the desert area and should protect soil and water resources, but the environmental impact of treatments should be examined.

1. Introduction

A large part of the world is arid and semi-arid regions. The water scarcity crisis is the most important challenge in these areas and therefore, water scarcity compensation methods are of particular importance (Ranjbar. 2018; Mirdeilami et al. 2019). Output water of the urban wastewater treatment plant is a huge source of water that can be used in agriculture and green space. Today, the issue of water scarcity and environmental degradation is one of the biggest problems of human societies. In these conditions, wastewater purification and recirculation are the most important solution in the development of water resources management, which can play an important role in water deficit problems.

The overall goal of the reuse of wastewater in agriculture is to optimize and maintain the availability of water resources by returning wastewater to the land and the rational use of freshwater resources. Experience has shown that significant amounts of materials such as phosphate, potassium, and nitrogen in wastewater, all of which play valuable roles in agricultural fertility, have been effective in increasing crop yields (Feizi. 2009).

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Due to the development of the urban and industrial areas, the use of treated wastewater and unconventional water is a sustainable source to cover the water shortage for desertification problems in arid and semi-arid regions. Proper use of municipal wastewater should expand vegetation and prevent environmental pollution. As the wastewaters have nutrients, therefore proper use of wastewater not only should reduce the pollution of surface and groundwater but also should decrease the use of chemical fertilizers (Alves et al. 2006; Almas. 2007; Sabya et al. 2007; Khassi and Koochakzadeh. 2009). For this reason, these resources have been considered as water resources and cheap fertilizer, especially in arid and semi-arid regions of the world (Feizi, 2009). Saybe (1999) studied the effects of irrigation with wastewater on two plants (Mugworts and Atriplex) and showed that the leaf length of these plants was significantly larger in wastewater sludge plots than in the control plots. In Europe, the use of sludge is known as one of the best environmental remedies to restore the affected land. Sludge was used to enrich the soil in the Skyscraper site in Scotland and a mixture of forest trees, grass, and plants were planted. This place is now home to many birds and wild animals (Rusan. 2006). By examining the long-term effects of irrigation with wastewater on quality parameters of forage crops, it was concluded that with proper management of plant growth, soil fertility and productivity would be improved due to an increase of the organic and mineral content (Ghanbari. 2006). Investigating the effects of irrigation with treated domestic wastewater on the quantity and quality of forage millet showed that the performance of fresh forage yield and dry matter of millet did not increase significantly, but irrigation with treated wastewater had no adverse effects on the health and contamination of heavy metals in soil and plants in the conditions of this experiment (Asanoa. 2004). The effects of municipal wastewater along with the soil texture on the growth and yield of the *Nitraria schoberi* plant were investigated at greenhouse conditions. The results of this study showed that wastewater application had a positive effect on stem length and the weight of fresh and dry plants compared to conventional water (Virendra. 2005). Also, the use of treated wastewater and other non-conventional water could have benefits such as providing a cheap and permanent water source, reducing the treatment costs, release part of good quality water for other uses instead of irrigation, reducing the environmental effects of chemical fertilizers, and pesticides and reducing the environmental effects of wastewater disposal from water resources, but it may also have negative biological and ecological effects due to the quantity, composition, and reactivity of the wastewater (Elgallal et al. 2016; Anastasis et al. 2017). It should be noted that excessive use of treated wastewater can also increase the risk of contamination of groundwater and soil (Aránzazu Peña et al. 2019; NawalAbabsa et al. 2019). Reuse of treated wastewater as drinking water is also still not favorable (IranManesh. 1972). Irrigation with treated wastewater for vegetables and cucurbits may transmit the disease to humans. Using treated wastewater for the production of edible plants reduces people's acceptance of produced products with this type of water (Emami.1991). Therefore, the use of non-conventional water for the cultivation of revitalized and fruitless plants is more acceptable.

The desertification phenomenon is one of the most important problems in arid and semi-arid regions of the world. The Meighan desert in the center of Iran is a place where its significant development has caused the environmental crisis. The most important factors in the progress of the Meighan desert are climate change, rainfall deficiency, human activities, geomorphology, and scarcity of water resources which has caused to degrade of a significant portion of vegetation over the last decade (Virendra. 2005).

Nitraria schoberi is a native plant species in the Meighan desert that had a well-grown (established) in the area. This plant should prevent wind erosion and dust emission through the formation of natural Nabkha. The main aim of this study was to investigate the effects of municipal treated wastewater and sludge on the vegetative characteristics of *Nitraria schoberi* shrub as a suitable plant for arid and semi-arid conditions.

2. Materials and methods

2.1. Study area

The Meighan watershed is located in the center of Markazi province, Iran. The area of this basin is 5501 km^2. The seasonal lake of Meighan with an area of 110 km^2 is the lowest elevation point of the basin, where the discharge of seasonal rivers and streams flow radially from around to the basin center (Fig. 1). The most important air masses affecting the Meighan desert are the high-pressure Siberian masses that enter in the winter and reduce the air temperature until -30 °C. Instead, the low-pressure mass that enters this area in the summer helps greatly increase temperature (Ansari and Golabi. 2019). The average rainfall of the study area is 293.4 mm. The average annual temperature in the region is 12.8 °C, with a maximum of 44 ° C and a minimum of -28 °C. The calcareous and clay shale formations of the surrounding heights, especially in the southwest and eastern regions, have a great effect on groundwater recharge. The alluvial thickness in the southwestern Meighan desert is 100 to175 m. The alluvial thickness in the southern Meighan desert is 125 to 150 m. The study area is located in an arid and semi-arid region. The arable land in the Meighan area is becoming desert land due to the expansion of the Meighan desert, consequently, the created dust via desertification is threatening the surrounding villages. Vegetation cover on the margin of the desert is poor. The static level of groundwater decreased in the summer due to the evaporation. To restore vegetation and increase the level of the available water of wetland, since 1986, a part of the treated wastewater effluent outlet of Arak city has been directed to Meighan international wetland (Alaton. 2007).

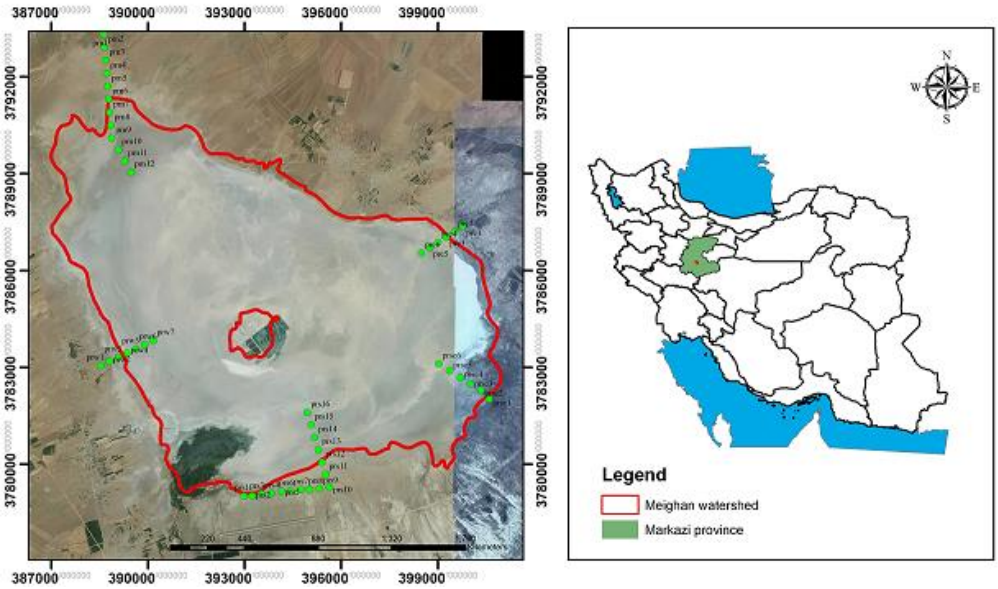

Fig. 1. Location of the study area in Iran and Markazi province.

2.2. Methodology

This study was completely carried out in the template of a randomized block. The effect of the treated wastewater and sludge on morphological characteristics of *Nitraria schoberi* plant was investigated in two soil types. Treatments include five levels of irrigation with wastewater (0, 25, 50, 75, and 100 %), two types of soil (arable land and desert soil of Meighan desert area), and two levels of sludge (presence and absence of sludge) with 6 repetitions for each treatment. 30 sinks with a depth of 70 cm were drilled two meters apart to harvest

the plant. Several sinks were filled with arable and desert soil treated with 1 kg crushed sludge and get ready for cultivation. Soils were applied at two texture levels (sand and clay), irrigation at two levels (wastewater and ordinary water), and irrigation period at two levels (every 5 and 15 days). The treated sludge was prepared from the Arak treatment plant. One-year-old *Nitraria schoberi* plants were collected from the research station of natural resources of Arak province. Before cultivation, the physiological properties of plants (collar diameter, height, and crown-cover diameter) were measured using an electronic caliper and meter. The stem diameter at the soil surface was considered as the collar diameter. The average of the maximum and the minimum diameter of aerial organs of the plant was considered as crown-cover diameter. The treated wastewater was obtained from the treatment plant of Arak and transported to the project site using a tanker. The desired percentage for each treatment was obtained by mixing treated wastewater with usual irrigation water. Irrigation was done in 5 and 15-day intervals using 20 liters of water per plant in each case. The morphological parameters of the plant were re-measured after 3 months of irrigation. SPSS statistical software was used to perform the statistical analysis. The least significant difference test (LSD test) with a 5 % confidence interval was used to investigate the main effects and interaction of the applied treatments on the characteristics of the *Nitraria schoberi* plant.

3. Results and discussion

3.1. Soil properties

The physical and chemical properties of the studied soils were shown in Table 1. According to the results, the cropland soil has lower EC and pH, but it has more organic matter than the Meighan desert soil. The results show that both soils are saline and alkaline, but the salinity and alkalinity of the Meighan desert soil are higher than the studied cropland soil. The texture of cropland soil was loamy - sandy but the Meighan desert soil has a loamy texture.

Table 1. Some physical and chemical properties of soils samples.

Properties	Cropland soil	Meighan desert soil
EC, ds/m	3.16	42.5
pH	7.77	7.95
Clay, %	32.35	8.21
Silt, %	26.46	12.64
Sand, %	41.19	79.15
Texture	Clay loam	Sandy-Loam
Total calcium and magnesium, meq/L	24	109
Calcium, meq/L	9	20
Magnesium, meq/L	15	98
Sodium, meq/L	66.49	1078.85
Organic matter, %	9.4, %	0.15
Potassium, mg/L	412	748
SAR	19.19	120.25

3.2. The chemical properties of the wastewater and sludge

Some chemical properties of the used wastewater are presented in Table 2. Comparison wastewater characteristics with two standards (the University of California and Will Cox diagrams) showed that acidity and total solids of the treated wastewater has a normal range for irrigation, while the electrical conductivity, sodium content, and sodium absorption ratio at the wastewater are much higher than the determined standard range and so it is not suitable for irrigation (Anders et al.2004). According to mentioned standards, the use of this wastewater in arable land can be problematic, but this treated wastewater can be used to irrigate saline plants in desert areas. The chemical properties of the treated sludge were shown in Table 3. The average pH values, moisture, total solids, organic and minerals matter are all based on the permissible standard for use in agriculture. Therefore, the application of this sludge in terms of these parameters is permissible for agricultural purposes. The mean values of sodium and carbon of refined sludge were higher than the standard limit, but the average ratio of these two elements (C/N) as an effective factor is in the range of the standard value (20.4). Overall, the fertilizer value of this sludge is relatively high and contains significant amounts of essential nutrients for the growth of plants and crops. Based on the obtained results, the application of refined sludge as fertilizer for stabilizing plants is beneficial, but the environmental issues (consumption on time and enough) souled be considered. However, its use in the cultivation of edible plants should be cautious.

Table 2. Chemical properties of used wastewater for irrigation at catchment basin of Meighan desert.

Element	Sludge
Total calcium and magnesium, meq/L	115.54
Acidity	5.8
Electrical conductivity, ds/m	9.3
The amount of residual solid, g/L	7.2
Soluble sodium, meq/L	1720.47
The ratio of sodium absorption, meq/L	205.15

Table 3. Chemical properties of used sludge.

Properties	Normal value	Sludge
pH	6-9	7.2
Humidity, %	30-50	32
Solids, %	50-70	62.4
Organic matter, %	25-50	45.2
Mineral matter, %	2-65	49.4
Carbon, %	8-50	62
Nitrogen, %	0.1-3.5	2.2
Phosphorus, %	0.3-3.5	2.21
Sodium, %	0.2-0.5	1.1
Potassium, %	0.1-2.8	0.28
C/N	20	20.2

3.3. The effect of treatments on morphological characteristics of *Nitraria schoberi* plant

The results of the analysis of variance showed that soil type had a significant effect on plant height and crown-cover of *Nitraria schoberi* ($P < 0.01$). The effect of treated wastewater was significant for plant height ($P<0.05$), but not significant was observed for crown-cover and collar diameter ($P < 0.05$). According to the obtained results, the interaction effect of sludge and wastewater was significant ($P < 0.05$) only for the height of the *Nitraria schoberi* plant, but no significant effects were observed for the other studied morphological characteristics (Table 4). Interaction effects of soil and sludge, soil and wastewater and, soil, sludge, and wastewater did not have a significant effect on morphological characteristics of *Nitraria schoberi* plant.

Table 4. The results of the analysis of variance (mean squares) of yield components in *Nitraria schoberi.*

Sources of change	Crown cover, cm	Collar diameter, mm	Plant height, cm	Degree of freedom
Repeat	43.45	1118.45	27.26	5
Soil	1095.2**	27.34 ns	1223.4**	1
Sludge	60.52**	659.20 ns	11.6ns	1
Wastewater	432.21 ns	840.90 ns	159.15**	4
Soil+ Sludge	41.13 ns	265.40 ns	37.11 ns	1
Soil+ Wastewater	88.20 ns	1184.41 ns	31.40	4
Sludge+ wastewater	66.32 ns	962.80 ns	111.18*	4
Wastewater+ Soil+ Sludge	19.14 ns	1258.85 ns	43.10 ns	4
Error	52.65	1649.60	34.28	69

ns :not significant ; *: P-value< 5 %; **: P-value< 1 %

3.4. The effect of different treatments on the height of *Nitraria schoberi* plant

Duncan's test was used to compare the effects of treatments on the vegetative properties of the *Nitraria schoberi*. According to the results, different levels of wastewater have a significant impact on plant height ($P<0.01$). The Maximum height increase was observed for both soil types at the wastewater level of 100 %, whereas, the lowest height was observed at the wastewater level of 0 %. These results indicate the positive effect of the wastewater treatment on mentioned plant height.

For sludge treatment, the maximum increase in height for the presence and absence of sludge was 12.50 and 7.16 cm, respectively, when irrigation was done via absolute treated wastewater. The lowest increase in the plant height in the two mentioned treatments at the wastewater level of 0 % is 1.16 and 2.80 cm, respectively. The effectiveness of wastewater on increasing the high of several plants was shown by other researchers (Aljalood et al.1993; Yoon and Quan. 2001; Erfani et al.2002; Feizi. 2009). Fig. 2. presents the effect of the sludge on the height of the *Nitraria schoberi* plant. According to the obtained results, no significant effect was observed on the plant high using the sludge at the wastewater levels of 0, 25, 50, and 75 % for Meighan soil, while a significant effect was observed when sludge was applied at the wastewater level of 100 %. In cropland soil, plant height was higher in the absence of sludge for all levels of wastewater.

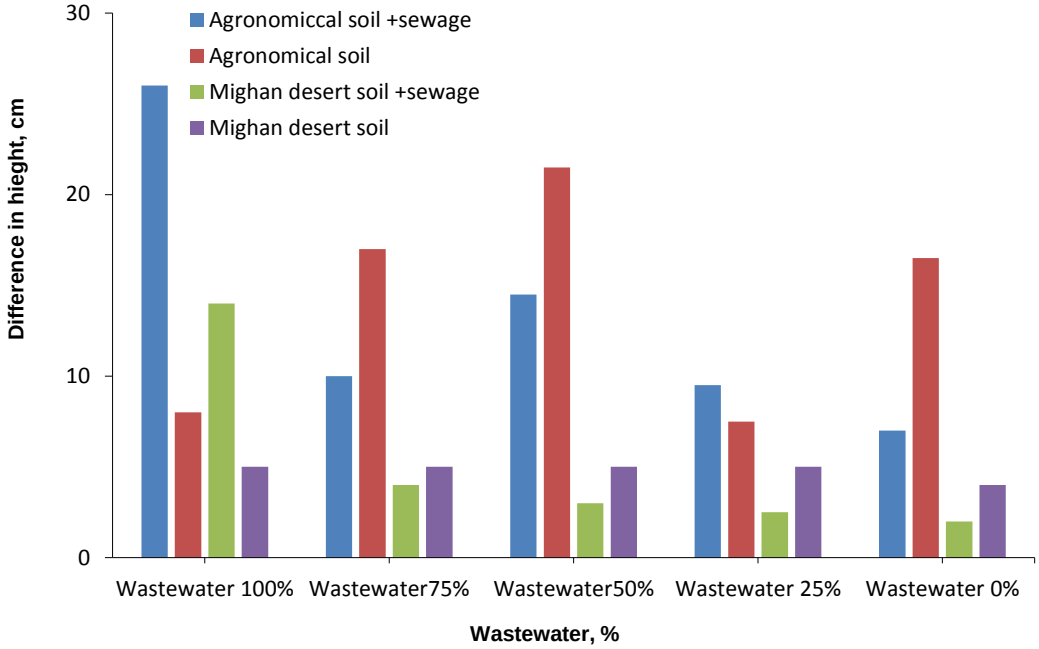

Fig. 2. The difference in height of the *Nitraria schoberi* (Gharadagh) plant at different levels of wastewater.

3.5. The effect of different treatments on collar diameter of *Nitraria schoberi* plant

According to the results of the analysis of variance (Table 4), treatments have not a significant effect on the collar diameter of *Nitraria schoberi* plant. The collar diameter in the soil of the cropland shows higher values than the soil of the Meighan desert. In most cases, the use of the sludge at different levels of wastewater in the soil of the Meighan desert had a major effect on increasing the collar diameter. But this difference is not significant and does not follow a certain trend. In the soil of the cropland, the use of sludge had no significant positive effect on the collar diameter of the plant and the collar diameter at all wastewater levels (except 75 %) was higher than the absence of sludge treatment. Generally, in both sludge treatments (presence and absence of sludge), the highest collar diameter was obtained at the wastewater level of 100 % (2.88 and 2.39 mm, respectively). The lowest collar diameter was observed at a wastewater level of 25 % (0.94 and 0.98 mm respectively). In both sludge treatments for cropland soil, the highest collar diameter was observed at a wastewater level of 100 %, the lowest collar diameter in the absence of treatment of sludge was observed at the wastewater level of 50 %. The lowest collar diameter in the present treatment of sludge was observed at the wastewater level of 75 %. In general, different treatments did not show a significant effect on the collar diameter of the *Nitraria schoberi.*

3.6. The effect of different treatments on the crown cover diameter

According to the results, the studied plant has better growth in different treatments of sludge and wastewater at the cropland soil compared to Meighan soil. The *Nitraria schoberi* has a wider crown cover in cropland soil (Fig. 3). The crown cover was 13.66 cm in the absence of sludge and wastewater level of 75 %, and 8.30 cm in the presence of sludge (Fig. 3). Whereas at the wastewater level of 100 %, the crown cover of the plant was 18.25 and 27.50 cm respectively at the absence and presence of the sludge, which indicates a different effect of sludge and other environmental factors on the expansion of the crown cover in Meighan desert soil.

In cropland, the use of the sludge has always had a positive effect on the crown cover at both sludge treatments and all wastewater levels. In presence of treatment of sludge, crown cover increased compared to the absence of sludge. The lowest crown cover in the cropland was observed in the absence of the sludge and at a wastewater level of 0% (29.50 cm) and the highest crown cover was observed at the presence of sludge and the wastewater level of 100 % that (45.37 cm). The highest crown cover in all studied treatments was observed at a wastewater level of 100 %, but the lowest crown cover was observed at different treatments and different levels (Fig. 4). In the soil of the Meighan desert, the absence of sludge treatment causes the lowest crown cover in the wastewater level of 25 % (2.80cm). At the presence of sludge, the lowest crown cover was observed in the wastewater level of 0 % (2.91 cm). In cropland, for both presence and absence treatment of sludge, the lowest crown cover was observed at the wastewater level of 0 % (30.60 and 29.50 cm, respectively). According to the results, a significant and positive effect of wastewater was observed on the expansion and growth of the crown cover of *Nitraria schoberi* plant (Table 4). Shahriari et al. (2009) had also reported a positive effect of wastewater on stem length, fresh and dry weight of *Nitraria schoberi*. El Jelod et al. (1993) found that watering via wastewater should significantly increase the growth and yield of corn spike and sorghum. They reported a higher yield ratio of forage sorghum compared to forage corn in irritation treatment with treated wastewater. The same results were reported for other plants (Adejumoke et al.2019; Francisco et al.2010). Ghanbari et al. (2001) showed that irrigation with treated wastewater at vegetative growth stages increased yield and yield components of the plant. Table 5 indicates the effects of the soil texture on the studied characteristics of *Nitraria schoberi*. According to the results, also the percent of organic carbon (OC) was significantly higher in sandy soil compared to clay soil, but, no significant effect on plant properties was observed for two soil textures ($P<0.05$).

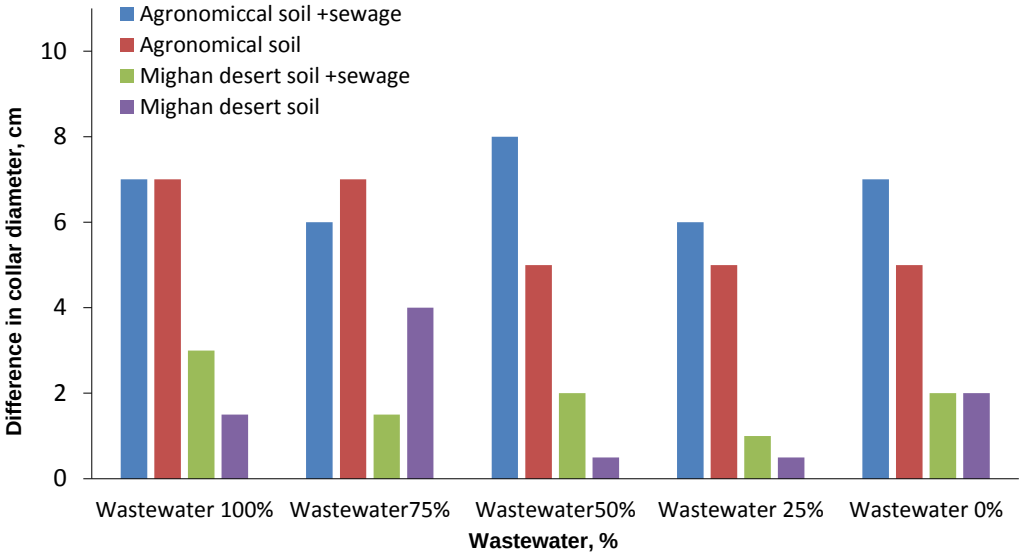

Fig. 3. Diameter difference of collar of *Nitraria schoberi* plant at different levels of wastewater.

Table 5. The effects of treated soil texture on the studied characteristics *of Nitraria schoberi* plant.

Soil and plant properties	Parameter	Soil type	
		Sandy-Loam	Clay loam
The average measured properties of *Nitraria schoberi* plant	Number of plant	5.80 [a]	6.85 [a]
	Stem length, cm	41.40[b]	30.37 [c]
	Root length, cm	37.17[d]	23.22 [f]
	Fresh weight, gr	5.68 [e]	17.42 [d]
	Dry weight, gr	6.22[a]	8.16 [a]
The average measured properties of treated soil	OC, %	6.12 [b]	3.10 [b]
	EC, ds/m	13.95[c]	14.43 [c]
	pH	8.01[d]	8.12 [d]
	Na, meq/L	57.22[e]	57.54 [e]
	Ca+Mg, meq/L	50.54[f]	52.61 [f]

Rows and columns with identical superscript letters are significant at the 5 % level of the LSD test.

4. Conclusions

The results of this study showed that also maximum plant height, collar diameter, and crown cover diameter were observed when 100 % wastewater was applied, but the effects of wastewater and sludge are different based on the level of treatments. Chemical analysis of the studied wastewater compared to global standards indicate that this water is not suitable for irrigation of agricultural lands, but sing wastewater should be useful for decrease water shortage stress and better control of desertification in desert lands. We can conclude that the use of wastewater should have a favorable effect on plants and soils of the desert area and should protect soil and water resources, but the environmental impact of treatments should be examined.

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