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Effects of wastewater irrigation on sugar content and morphological traits of sugar beet (*Beta vulgaris* L.)

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ABSTRACT

The response of sugar beet plants in terms of sugar content and morphological traits to nutrient absorption by wastewater irrigation was studied in a split-plot design based on a Randomized Complete Block Design with three replications in experimental field of Shahr-e Kord University, Shahr-e Kord, Iran in 2013-14. The main plots were devoted to irrigation at three levels including (1) irrigation with municipal wastewater at 2-4-leaf stage, (2) irrigation with municipal wastewater at 8-12-leaf stage, and (3) irrigation with conventional water (control). Sub-plots were devoted to four fertilizers including sheep manure, spent mushroom compost (SMC), chemical fertilizer, and no-fertilizer (control). Results showed that wastewater application at 8-12-leaf stage significantly increased single root weight, shoot fresh weight, root length and diameter compared with those irrigated with conventional water. However, Cu and Mn content of the shoot, sugar content, and extractable sugar were not influenced by irrigation treatment whereas the impact of fertilizer treatment was significant on these traits. Among fertilizer treatments, the highest single root weight, shoot fresh weight, root length and diameter were observed in plants treated with sheep manure and irrigated with wastewater at 8-12-leaf stage.

Keywords: municipal wastewater, sugar beet, root length, micronutrient, spent mushroom compost.

INTRODUCTION

A major aspect of attempts to realize sustainable development in countries located in arid and semi-arid regions is sound planning for the practice of conservative management for optimal use of conventional and unconventional water resources. In this regard, the effluent of sewage treatment plants is an alternative recycled resource for agricultural water that can reduce the load on surface water and groundwater resources, thereby mitigating the adverse impacts of overexploitation of water resources (Keremane and McKay 2007). Since wastewater is considered an unconventional resource of water, its application in farming requires special management. Urban wastewater is a rich source of nutrients for plant growth (Weinberg *et al*. 2004). Extensive research has been performed concerning wastewater application. However, it is critical to note that the results of these studies are occasionally inconsistent among various countries so that the researchers in Europe and US have asserted that wastewater demands careful local-based studies.

Nutritional management plays a key role in escalating food production and supply in plants. Organic effluents are a major component of soil fertility with a remarkable role in ameliorating physical, chemical and biological characteristics of the soil and its fertility (Karmaka *et al*. 2007). Organic fertilizers including different types of manure, plant residue, compost, and other organic compounds incorporated with soil. Spent mushroom compost (SMC) refers to the mushroom residues. In the process of edible mushroom

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Table 1. Physical and chemical properties of the soil at 0-30 cm depth

Soil texture	Acidity	EC ($dS\ m^{-1}$)	Organic C (%)	$CaCO_3$ (Equivalent)	N (%)	P	K	Zn	Mg	Cu
						(mg/kg soil)				
Silty-sandy	7.79	0.547	0.723	27.5	0.096	17.4	365	0.63	8.57	0.92

Table 2. Some chemical characteristics of the applied organic fertilizers

Characteristic	Unit	Sheep manure	Spent mushroom compost
Acidity	-	7.76	6.18
Electrical conductivity	$dS\ m^{-1}$	10.39	5.412
Organic carbon	%	27.1	25.5
Nitorgen	%	0.983	1.28
Phosphorous	%	0.412	0.513
Potassium	%	0.525	0.639
Iron	$mg\ kg^{-1}$ soil	127	352
Zinc	$mg\ kg^{-1}$ soil	30.14	99.23
Copper	$mg\ kg^{-1}$ soil	55.29	68.81
Manganese	$mg\ kg^{-1}$ soil	91.28	80.45

production, SMC is typically disposed of as waste, which may cause environmental problems. Therefore, mushroom producers are usually seeking ways to make use of these wastes (Jordan *et al*. 2008). Given the high volume of mushroom substrate wastes and residues, SMC can be a source of organic fertilizer for crop production.

The use of treated sewage in the irrigation of fields may transform some soil and crops features depending on the physical, chemical and biological characteristics of the sewage. In a study by Marjovi and Jahad Akbar (2011), the effect of municipal compost and sewage sludge on the chemical characteristics of the soil as well as the quality and quantity of sugar beet was studied. Results showed that organic fertilizer application significantly improved root yield but decreased sugar content. In another study, irrigation with sewage wastewater on soil properties and yield of clover, pea and wheat showed that the application of sewage wastewater plus NPK fertilizer enhanced both physical and chemical properties of the soil and crop yield compared with groundwater and fertilizer treatment (Singh *et al*. 2012). Application of SMC under greenhouse condition led to the recommendation that the compost can act as an organic source to improve the growth and yield of cucumber (Polat *et al*. 2009). In an assessment of Fe, Zn, Cu, and Mn content of wastewater-irrigated vegetables, it was observed that mint and spinach had the highest Fe and Mn content and carrot had the highest Zn and Cu content, although they did not exceed the limit (Arora *et al*. 2008). In a study on the effect of irrigation with municipal wastewater and mineral fertilizers interaction on wheat, it was stated that the highest yield was obtained from the plants irrigated with 75% wastewater and treated with chemical fertilizers (Mojid *et al*. 2012). It has been reported that compost and organic fertilizers significantly improved shoot growth and enhanced P and K uptake in sugar beet (Walker and Bernal 2008).

The occurrence of the drought in Iran where water is a major constraint on production as well as increased level of organic wastewater production, the present study aimed to determine the response of sugar content and morphological traits of sugar beet to nutritional management under irrigation with wastewater.

MATERIALS AND METHODS

The present study investigated the response of sugar content and morphological traits of sugar beet to nutritional management under the irrigation with wastewater in experimental field of the Department of Agriculture, Shahr-e Kord University (Lat. 32°21' N., Long. 50°49' E., Alt. 2050 m.) in 2013-14. Before sowing, soil samples were taken from 0-30 cm depth and were analyzed to determine chemical and physical characteristics (Table 1). Also, some characteristics of spent mushroom compost (SMC) and sheep manure were determined in a laboratory (Table 2).

The experiment was carried out in split plots based on a Randomized Complete Block Design with three replications. Irrigation as the main plot was set at three levels – (i) irrigation with municipal wastewater at the 2-4-leaf stage in three steps, (ii) irrigation with municipal wastewater at the 8-12-leaf stage in four steps, and (iii) irrigation with conventional water (control). Sub-plots were assigned to fertilizer management in four treatments including the application of sheep manure, SMC, chemical fertilization as recommended by soil test results and sugar beet requirements, and the accumulation of these elements in plant (Malakoti *et al*. 2000) including nitrogen (N) from urea (250 kg ha^{-1}), zinc sulfate (10 kg ha^{-1} $ZnSO_4$), copper sulfate (10 kg ha^{-1} $CuSO_4$), iron sulfate (30 kg ha^{-1} $FeSO_4$), manganese sulfate (15 kg ha^{-1} $MnSO_4$), boron (20 kg ha^{-1} B), and without fertilizer application (control). In treatments fertilized

Table 3. Some quality parameters of well water and municipal wastewater of Shahr-e Kord and the standards recommended by Environment Protection Organization of Iran (2000)

Measured parameters	Unit	Well water	Municipal wastewater	Standard polluting amount in wastewater for agricultural uses
Acidity	-	7.52	7.36	6-8.5
Electrical conductivity	dS m^{-1}	0.305	0.912	-
Sodium	mg L^{-1}	5.75	74.52	-
Total nitrogen	mg L^{-1}	8.5	21	-
Total phosphorous	mg L^{-1}	0.07	18.5	-
Potassium	mg L^{-1}	6.22	36.77	-
Manganese	mg L^{-1}	0.014	0.146	1
Copper	mg L^{-1}	0.008	0.093	0.2
Chlorine	m eq. g L^{-1}	1.21	4.24	1
Organic matter	%	0.09	2.96	-

with sheep manure and compost, the rate of fertilizer use was determined on the basis of the equivalent nutrients in chemical fertilizer treatment. The amount of available N in sheep manure was assumed to be 50% of its total N content and the amount of available N in SMC was assumed to be 30% of its total N content (Van Kessel and Reeves 2002). In other words, considering sugar beet nutrient needs and soil test results, 250 kg ha^{-1} urea was found to be equivalent to 23 t ha^{-1} sheep manure and 29 t ha^{-1} SMC assuming 0% moisture. Since the compost and sheep manure had 10% moisture, fields were fertilized with 31.9 t ha^{-1} compost or 25.3 t ha^{-1} sheep manure. The municipal wastewater and well water were sampled prior to irrigation to find out their quality (Table 3). To prepare the seed bed, field was plowed by a moldboard plow and disked. After the ridges and furrows were made by a furrower and the map was implemented on the field, fertilization treatments were applied so that manure, compost, and chemical fertilizers were applied in strip form in the middle of furrows at 7 cm depth and covered with soil. One-third of N fertilizer was applied during sowing and the remaining was applied after thinning (2-4-leaf stage) and weeding in two stages (Noshad *et al*. 2012). Monogerm sugar beet seeds were sown in six rows in 12 m^2 plots with 50 cm inter-row spacing and 20 cm distance between plants at 2 cm depth on 27 May to yield the density of about 100 000 plants per ha. Municipal wastewater was supplied from Shahr-e Kord wastewater treatment plant. To determine shoot fresh weight, single root weight, root length and diameter at harvest, two marginal rows and one meter from both ends of the plots were removed and then, plants were sampled from the middle four rows. Samples were sent to the laboratory. In the laboratory, samples were oven-dried at 72°C and sent to the Water and Soil Laboratory of the Agriculture and Natural Resources Research Center of Chaharmahal and Bakhtiari Province to determine the content of some nutrients in shoots.

Data were analyzed by the SAS and MSTAT-C software and means were compared by the least significant difference (LSD) test. The graphs and tables were drawn in MS-Excel software package.

RESULTS AND DISCUSSION

Chemical characteristics of applied organic fertilizers and wastewater

Organic fertilizers

Table 2 presents some of the chemical characteristics of the organic fertilizers used in the present study. Spent mushroom compost had more acidic pH and lower EC than the sheep manure. High EC rate detected in sheep manure depends on various factors including the food regime of the sheep (Casado-Vela *et al*. 2007). Excessive incorporation of sheep manure with soil may increase soil salinity. Higher C/N ratio of sheep manure is related to the fact that its organic matter may not be readily decomposed by microbial activity in an early growing season (Arun, 2002). Given N percent of SMC and sheep manure, it is enough to apply 23 t ha^{-1} sheep manure and 29 t ha^{-1} SMC in order to satisfy N requirement for sugar beet growth. The N content of these fertilizers is mainly in an organic form that is mineralized and released gradually (Eghbal *et al*. 2004). In the present study, SMC had higher Fe and Zn contents than the sheep manure. According to Table 2, organic fertilizers had very high contents of trace elements. Thus, they can be applied to meet sugar beet requirements in the soil since they contain both micro- and macronutrients required by the plants (Handreck 1994).

Wastewater

The quality of well water and treated wastewater was assessed for irrigation against the

Table 4. Mean comparison of the effect of irrigation water type and plant nutrition on Cu and Mn content of sugar beet shoot

Sources of variation	df	Means of squares	
		Cu	Mn
Block	2	2.97^{ns}	8.54^{ns}
Irrigation with wastewater	2	0.32^{ns}	91.51^{ns}
Error (a)	4	4.55	14.12
Fertilizer	3	705.84**	8565.69**
Fertilizer × irrigation with wastewater	6	0.59^{ns}	23.38^{ns}
Error (b)	18	1.19	62.84
Coefficient of variations		4.16	2.60

ns: non-significance
*: significance at $p < 0.05$
**: significance at $p < 0.01$

Table 5. Results of mean comparison for Cu and Mn content of sugar beet shoot as influenced by fertilizer treatments

Fertilizer treatment	Cu content (mg kg^{-1})	Mn content (mg kg^{-1})
Spent mushroom compost	38.02 a	292.79 b
Sheep manure	27.97 b	315.43 a
Chemical fertilizer	20.91 c	256.32 c
No-fertilization	16.17 d	236.94 d

Means with similar letter in each column had no significant difference at $p < 0.01$.

standards of the Environment Protection Organization of Iran (Environment Protection Organization of Iran, 2000). According to the results presented in Table 3, the chemical quality of the effluent wastewater was in accordance with standards defined for agricultural application and would not adversely affect sugar beet at least in short run. Well water and wastewater did not differ significantly in pH which was in acceptable range of irrigation. Indeed, pH of the irrigation water typically varies in the range of 6-8.5.

Nitrogen, P, and K are the main nutrients exist in wastewater. The wastewater had a relatively low P content. About 30-50% of P content in wastewater is accounted by wastes and 30-50% is related to detergents released from houses and restaurants (Ritter and Shirmohammadi 2001). The pollution assessment of the treated wastewater showed that the concentrations of anions and cations were below the critical threshold, so they were not a limiting factor for sugar beet growth. The Cl^- content of the wastewater was over the standard because NaCl constitutes a common component of human food regime and passes through our digestion system untouched. The treatment process is not effective in removing chlorides (Metcalf and Eddy 2003).

As far as plants like sugar beet and sugarcane are concerned, a high concentration of Cl^- reduces the yield since it interferes with the metabolism pathway and the translocation of some carbon hydrates within the plant. Also, it was revealed that the wastewater was not too saline to aggravate soil salinity and to cause an imbalance in water uptake by plant and yield loss (Table 3).

Copper and Mn content in sugar beet shoots

Copper content

Copper concentration in sugar beet shoot was significantly (P < 0.01) influenced by fertilization treatments, however the effect of wastewater or fertilizer × wastewater interaction was not significant (Table 4). The highest Cu content in the shoot was related to SMC treatment. Copper content in shoot was increased from 16.17 mg kg^{-1} DW in control to 38.01 mg kg^{-1} DM in plants treated with SMC (Table 5). Spent mushroom compost is an organic source which contains the essential nutrients for plants (Uzun 2004). The second highest Cu content was related to plants fertilized with sheep manure (Table 5). According to Kabata-Pendias and Pendias (2000), typical Cu concentration limit ranges between 5 to 30 mg kg^{-1} DW for different plant species and its toxicity limit is over 40-100 mg kg^{-1} DM. It is observed that Cu concentration in sugar beet shoot did not exceed the toxicity threshold in any fertilization treatments (Table 5). However, since it was near the toxicity limit in plants treated with SMC (Table 5), it should be used cautiously. Copper content of compost does not determine the whole Cu content of the plant. Copper content in shoot depends on the coefficient of Cu availability and coefficient of Cu mobilization (Zheljazkov and Warman 2004). A study on compost-treated soil showed that Cu content in the leaves of *Nigella sativa* L. was increased as compared with control (Akbarnejad 2009). In our study, Cu content in shoot of sugar beet was significantly higher in plants treated with chemical fertilizer than in control (Table 5). Since we applied $CuSO_4$, it can be inferred that a great part of sulfate fertilizers precipitates in lime-rich soils and becomes unavailable to plants (Zheljazkov and Warman 2004). On the other hand, organic fertilizers, especially SMC, contain trace elements, e.g. Zn, Fe, and Cu, and can release these elements gradually over the plant growth period through organic matter decomposition and mineralization, resulting in the build-up of nutrient uptake by the plants. In a study on the effects of SMC (at 0, 15, 30, and 60 t ha^{-1} rates) on yield and micronutrient content of pepper grown in a greenhouse, it was observed

Table 6. Mean comparison of the effect of irrigation water type and plant nutrition on morphological traits and sugar content

Sources of variation	df	Means of squares					
		Single root weight	Shoot fresh weight	Root diameter	Root length	Sugar content	Extractable sugar
Block	2	452.42^{ns}	270.15^{ns}	1.60^{ns}	0.93^{ns}	0.119^{ns}	0.143^{ns}
Irrigation with wastewater	2	129856.87**	3430.06*	254.28**	16.19^{ns}	0.108^{ns}	0.249^{ns}
Error (a)	4	6448.78	323.86	0.422	5.71	0.161	0.192
Fertilizer	3	238068.56**	13864.25**	506.38**	89.34**	0.441**	1.043**
Fertilizer × irrigation with wastewater	6	19478.97**	1126.69*	19.49*	4.36**	0.043^{ns}	0.081^{ns}
Error (b)	18	2023.43	420.43	6.04	0.923	0.101	0.123
Coefficient of variations		5.40	15.72	5.72	2.36	1.59	2.01

ns: non-significance
*: significance at $p < 0.05$
**: significant at $p < 0.01$

Table 7. Mean comparison of the effect of irrigation and fertilization treatments on some traits of sugar beets

Experimental factors	Single root weight (g)	Shoot fresh weight (g)	Root diameter (mm)	Root length (cm)
Irrigation treatments				
Irrigation with wastewater at 2-4-leaf stage	794.85 b	128.57 ab	87.78 b	36.32 a
Irrigation with wastewater at 8-12-leaf stage	947.91 a	148.17 a	91.87 a	37.03 a
Irrigation with conventional water	750.78 b	114.5 b	82.68 c	34.76 a
Fertilization treatments				
Spent mushroom compost	738.39 c	114.62 b	83.11 c	36.11 b
Sheep manure	998.55 a	160.53 a	96.34 a	40.38 a
Chemical fertilizer	936.06 b	164.26 a	90.66 b	34.6 c
No-fertilizer (control)	653.04 d	82.25 c	79.66 d	33.07 d

Means with similar letter(s) in each column had no significant difference at $p < 0.01$.

that SMC application influenced yield and micronutrients significantly (Onal and Topcuoglu 2003).

Manganese content

According to the results, only fertilizer treatments influenced Mn content in shoot of sugar beet significantly (P < 0.01) and the effect of irrigation as well as interaction of the treatments were not effective on this trait (Table 4). In a study on corn irrigation with wastewater, Alizadeh *et al*. (2001) found that the irrigation did not influence micronutrient concentration in corn. Mean comparison showed that the highest Mn content in shoot was 315.43 mg kg^{-1} DM which was observed in plants treated with sheep manure (Table 5). Manganese content in different plant species is typically in the range of 50-300 mg kg^{-1} DM and the toxicity threshold is over 350-500 mg kg^{-1} DM (Kabata-Pendias and Pendias 2000). As mean comparison revealed, Mn content in sugar beet shoot did not exceed the toxicity threshold in all fertilizer treatments. Akbarnejad (2009) reported that the application of sewage sludge enhanced shoot Mn content of *Nigella sativa* L. significantly. The higher Mn content in shoot of sugar beet plants treated with sheep manure may be related to the fact that sheep manure had higher Mn content than SMC (Table 2). Animal manure application in sugar beet growing can determine final sugar yield by changing some physical and chemical characteristics of the soil. Containing micro and macronutrients, these fertilizers can change the nutrient status of the soil and since they play a role in supplying soil organic matter and improving this physical condition, they can be effective in dictating crop growth pattern and root sugar efficiency (Maidl and Fischbeck 1989).

Sugar beet single root weight

ANOVA results showed that single root weight was influenced by fertilization, irrigation, and their interaction (Table 6). According to mean comparison, the highest single root weight (948.91 g) was obtained in plants irrigated with wastewater at 8-12-leaf stage (Table 7). The suitable contents of N, P, and K nutrients in wastewater can favorably influence root weight. We observed that wastewater had higher amount of macro and micronutrients as compared with conventional water (see Table 3). Therefore, the use of organic and chemical fertilizers along with wastewater can supply a full range of nutrients required by sugar beet and enhance their root weight. The heaviest root (998.85 g) was obtained from sheep manure

Table 8. Mean comparison of the interaction between irrigation and fertilization treatments for some traits of sugar beets

Experimental factors	Single root weight (g)	Shoot fresh weight (g)	Root diameter (mm)	Root length (cm)
Irrigation with wastewater at 2-4-leaf stage				
Spent mushroom compost	788.9 cde	104.73 efg	84.74 ef	36.66 cd
Sheep manure	959.35 b	160.13 bc	94.66 b	41 b
Chemical fertilizer	835.77 cd	169.76 ab	90.87 bcd	34.75 ef
No-fertilizer	595.36 g	79.66 g	80.86 fg	32.9 g
Irrigation with wastewater at 8-12-leaf stage				
Spent mushroom compost	764.68 de	131.05 cde	84.51 ef	37.33 c
Sheep manure	1180.27 a	204.75 a	104.3 a	42.66 a
Chemical fertilizer	1122.51 a	171.26 ab	95.93 bc	35.06 de
No-fertilizer	728.15 ef	85.61 fg	84.73 ef	33.08 g
Irrigation with convention water (control)				
Spent mushroom compost	661.6 fg	108.08 efg	80.09 g	34.33 efg
Sheep manure	856.03 c	116.71 def	90.07 cd	37.5 c
Chemical fertilizer	849.9 c	151.75 bcd	87.17 de	34 fg
No-fertilizer	635.6 g	81.48 bcd	73.4 h	33.23 fg

Means with similar letter(s) in each column had no significant difference at $p < 0.01$.

treatment of and differed significantly from control treatment (Table 7). Also, the second and third highest root weight of 936.06 and 738.39 g were obtained from chemical fertilizer and SMC treatments, respectively (Table 7). Single root weight was lower in plants treated with chemical fertilizer than those treated with sheep manure. It is likely that in chemical fertilizer treatment, the concentration of nutrients is lower in the medium due to plant growth and nutrient leaching at early growth stages, so the plant requirements are not fully satisfied. Also, no-fertilization treatment exhibited the minimum single root weight due to the deficiency of nutrients. The interaction between irrigation with wastewater at 8-12-leaf stage and sheep manure resulted in the highest and the interaction between irrigation with conventional water and no-fertilizer application resulted in the lowest single root weight (Table 8). Brady and Weil (2008) concluded that plant growth was better when they were treated with wastewater than irrigating with well water together with fertilizer. Although their difference was not statistically significant, this increase was attributed to the nutrients and organic matter content in wastewater which improved soil structure and nutrient availability.

Shoot fresh weight

Shoot fresh weight of sugar beet was significantly influenced by fertilizer and irrigation treatments as well as their interactions (Table 6). Irrigation with wastewater at 6-12-leaf stage was related to the highest shoot fresh weight of 148.17 g. The second highest shoot fresh weight was related to irrigation with wastewater at 2-4-leaf stage (Table 7). In a study on the effect of wastewater irrigation regime on alfalfa, Chavez *et al*. (2012) concluded that irrigation with wastewater reduced soil organic matter leaching by 35% and increased alfalfa biomass. Mean comparison implied the significant effect of nutritional system on shoot fresh weight (Table 7). The highest shoot fresh weight was related to chemical fertilizer, but it did not differ from sheep manure significantly (Table 7). In an assessment of the effect of organic fertilizer on barley, Marcote *et al*. (2001) found that manure resulted in the same or even higher yield than chemical fertilizer. The highest shoot fresh weight of sugar beet treated with sheep manure can be related to the manure composition. The interaction between wastewater irrigation and sheep manure at 8-12-leaf stage resulted in the highest shoot fresh weight and the interaction between irrigation with conventional water and control produced the lowest shoot fresh weight (Table 8). In their study on corn and vetch, Mohammad and Ayadi (2004) found that grain and forage weight were increased significantly when P and N fertilizer were incorporated to well water during the irrigation; however, the increase in grain yield and biomass was higher in plants irrigated with wastewater than those irrigated with well water. They concluded that wastewater had other factors than P and N which involved in improving soil fertility.

Root diameter

Sugar beet root diameter was significantly ($P < 0.01$) influenced by fertilization and irrigation treatments and by their interaction ($P < 0.05$, Table 6). The highest root diameter (91.87 mm) was

Table 9. Mean comparison of the effect of fertilizer treatments on sugar content and extractable sugar of sugar beets

Fertilizer treatments	Sugar content (%)	Extractable sugar (%)
Spent mushroom compost	20.26 a	17.5 a
Sheep manure	19.74 b	16.88 b
Chemical fertilizer	19.98 ab	17.4 a
No-fertilizer (control)	20.1 a	17.64 a

Means with similar letter in each column had no significant difference at $p < 0.01$.

observed in plants irrigated with wastewater at 8-12-leaf stage (Table 7). Wastewater can increase plant growth and yield by stimulating germination and root growth and enhance water and nutrient uptake (Weinberg *et al*. 2004). We found that sugar beet root diameter differed significantly among fertilization treatments (Table 6). Among fertilizer treatments, treatment with sheep manure was related to the highest root diameter with a significant difference with control (Table 7). The higher root diameter in plants fertilized with sheep manure may be associated with the higher amount of macro- and micro-nutrients in this manure (Table 2). The lower efficiency of SMC is likely to be related to the type of organic matters constituting this compost. The interaction between irrigation and wastewater and sheep manure application at 8-12-leaf stage had led to the highest root diameter and the interaction between conventional water and control exhibited the lowest root diameter (Table 8). In a study on the effect of different irrigation methods and water quality on sugar beet yield, Hassanli *et al*. (2010) found that irrigation with wastewater increased sugar beet root yield and sugar content significantly as compared with conventional water.

Root length

According to ANOVA results, sugar beet root length was influenced by fertilizer treatments and the interaction between fertilization and irrigation (Table 6). Among fertilizer treatments, the highest root length was related to sheep manure treatment (Table 7). The interaction between irrigation and wastewater at 8-12-leaf stage and sheep manure resulted in the highest root length, whilst the lowest root length was obtained from the interaction between conventional water and control (Table 8).

Sugar content

It was found that sugar content was influenced by fertilizer treatments significantly ($P < 0.01$), but the effect of wastewater treatment and wastewater × fertilization was not significant (Table 6). Among fertilizer treatments, the highest and lowest sugar content was associated with SMC treatment (20.26%) and sheep manure (19.74%), respectively (Table 9). Also, no statistically significant difference was observed between SMC, chemical fertilizer, and control (Table 9). Spent mushroom compost is considered as a soil amendment in agricultural production and ecosystem restoration (Uzun, 2004).

Sugar beet root contains 75% water and about 25% dry matter of that about 20% is water-soluble but 5% is water-insoluble that constitutes the insoluble part of the root and is a part of the fibers of the sugar beet root which is called Marc (Winter, 1981). Since all sugar content in the root is not extractable and a part remains in molasses, about 16% of 20% soluble part is in the form of sugar compounds or sucrose that is crystallizable and the remaining 4% is non-sucrose sugars including glucose, fructose, raffinose, etc. Sugar content is calculated as g per 100 g root (Hoffmann *et al*. 2004). On average, 100 mg higher nitrogen in 100 g sugar results in about 0.8% lower sugar content.

Extractable sugar

ANOVA results showed that extractable sugar content was influenced by fertilizer treatments significantly ($P < 0.01$), but the effect of wastewater treatments and fertilization × wastewater interaction was not significant (Table 6). Mean comparison showed that the highest extractable sugar content (17.64%) was observed in control treatment and the lowest (16.88%) in sheep manure treatment (Table 9). Also, plants treated with SMC showed higher extractable sugar content than those treated with sheep manure. Extractable sugar is a function of sugar content and the sugar content of molasses, and it constitutes the most important component of sugar beet economic yield (Noshad *et al*. 2012). Nitrogen reduces sugar content and thereby affects extractable sugar content. Since control plants were not treated with nitrogen, they exhibited a higher level of extractable sugar (Table 9). Table 9 displays that sheep manure reduced extractable sugar content as compared with chemical fertilizer and control because sheep manure kept supplying nitrogen until the harvest of plants. This is an undesirable trait. The amount of extractable sugar as the economic yield of sugar beet is the most important studied trait and forms the basis for comparison as to how treatments affect this crop (Yousefabadi and Abdollahian-Noghabi 2011).

CONCLUSION

Results showed that application of municipal wastewater increased single root weight, shoot fresh weight, root length and diameter of sugar beet compared with those irrigated with conventional water. Furthermore, it was observed that although municipal wastewater contains appropriate amounts of nutrients, application of organic and chemical fertilizers is more effective for accomplishing maximum root weight. Wastewater can be used as a potential source of nutrient supply for plants which also supply organic and chemical fertilizers demands of the plants.

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