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Effects of Treated Municipal Wastewater on Growth and Yield of Maize (*Zea mays*)

Sayed Roholla Mousavi* and Mahmood Shahsavari**
**Young Researchers and Elites Club, Science and Research Branch,*
Islamic Azad University, Tehran, Iran
***Payame Noor University, PO BOX 19395-3697, Tehran, Iran*

(Corresponding author: Sayed Roholla Mousavi)
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ABSTRACT: The experiment was based on a randomized block design (RCBD) with four replicates, and it was conducted in a field experiment in Aligoudarz (Iran). Irrigation was applied with five different methods as treatments: T1: irrigation with clean water during whole growing period (control); T2: 75% clean water and 25% TMWW; T3: 50% clean water and 50% TMWW; T4: 25% clean water and 75% TMWW; T5: irrigation with TMWW during whole growing period. Results showed that irrigation with treated municipal wastewater lead to significant effect in all characters than control. The highest stem height and diameter were observed in irrigation with 25% well water and 75% TMWW, which was statistically different than other treatments, also similar results were obtained in other growth parameters such as: flag leaf length, flag leaf width, ear diameter and ear length. Number of grain per row, number of row per ear and number of grain per ear significantly increased with use of wastewater. Maximum 1000-seed weight was 303.8g that obtained with use of 75% wastewater. Maximum yield was obtained in T4 that was 25% more than control, According to the results, no significant difference was found between treatments T4 and T5.

Keywords: Irrigation, maize, municipal wastewater, water quality.

INTRODUCTION

Water deficiency is one of the main factors for limiting sustainable agricultural development in most arid and semi arid regions. Nowadays farmers needs to treated municipal wastewater as a source of irrigation water than each other time, Due to increased population and increased need for food, reduced water resources and the need to water transfer in long distances. Treated municipal wastewater is used for reducing water deficiency for irrigation, increase water use efficiency and reduce water resources pollution. In arid and semiarid climates due to the severe pressure on non-renewable water resources, few years drought and the increasing urbanization, optimum use of all available water resources including treated municipal wastewater is considered (Galavi *et al.*, 2010; Fonseca *et al.*, 2007; Mohammad et al., 2007; Jimenez, 2005; Friedel et al., 2000). Recently reuse of treated municipal wastewater as a non-conventional water resources is considered which can compensate the water deficiency partly. Considering that wastewater is contains elements that needed for plant nutrition, determine the correct method of using wastewater is very important to reduce the adverse effects associated with wastewater irrigation, and obtain optimum yield (Mousavi *et al.*, 2013; Wang et al., 2007). Also need to be assessed other outcomes in irrigated with wastewater including elements changes in soil and plant, heavy metals accumulation and other pollutants (Zavadi, 2009; Al-Zoubi *et al.*, 2008; Pollice *et al.*, 2004). Maize (*Zea mays*) is one of the most important crops that have an important role in providing food and protein for humans and livestock directly and indirectly. Maize is cultivated for grain and silage consumption, Also, about 5% of maize production is used for industrial products. It is, possible to obtained high yields of crops without deterioration of their quality by using treated wastewater for the irrigation of crops. In most of the crops that irrigated with treated municipal wastewater yield increased and need to use of chemical fertilizer reduced, and as a result, production costs decreased (Mousavi *et al.*, 2013; Esmailiyan *et al.*, 2008; Jimenez, 2005; Najafi *et al.*, 2003). Alizadeh *et al.*, (2001) reported that growth and yield of corn statistically affected with using reclaimed municipal wastewater, in this study, maximum grain and biomass were obtained of the treatment that was irrigated by wastewater Marten *et al.*, (1985) in a research on yield of corn and canary grass have perceived that irrigation with wastewater has significant increase on digestibility and dry matter of corn in comparison with canary grass, although amount of protein in canary grass is more than corn. Day and Tucker (1997) in the survey on sorghum found that leaf width, grain yield and postponed the sorghum maturity increased in irrigation with wastewater.

Irrigation with wastewater increased yield of forage sorghum compared with irrigation with well water, wastewater irrigation also increased height, leaves green color and accelerate flowering (Jenkins et al., 1994). Cllap *et al.,* (1987) studied the effects of treated municipal wastewater on maize yield and forage plants in the United States, and concluded that effect of wastewater irrigation in terms of plant needs to nutrients can be competitive with application of chemical fertilizer as ammonium nitrate. Wastewater is contains large amounts of nutrients can be used in agriculture and increase the yield of crops. Increasing amounts of organic matter and soil nutrients under the effects of wastewater application increased plant growth with positive influence on soil physical, chemical, and biological properties (Mousavi *et al.*, 2013; Munir and Ayadi, 2005; Wong *et al.*, 1998; Monte and Esousa, 1992). Al-Zoubi *et al.*, (2008) in a field study, examined effect of sewage sludge on the yield of wheat, maize and peas, reported that wheat yield was not affected in sewage sludge application, but the peas and maize yields significantly increased compared with control by sewage sludge. The object of this study was to evaluate the use of treated municipal wastewater for agricultural purposes, and its effect on maize growth and yield, also evaluating an appropriate method for use of wastewater and well water combined to achieve optimum yield, reducing the accumulation of pollution in the soil and finally, the sustainable use of water resources in the agriculture.

MATERIAL AND METHODS

A. Description of the project site

The experiment was conducted during the 2009 growing season at an experimental field in Aligoudarz, Iran, located in 49º45´ longitude and 33º25´ latitude and, 2024m Altitude from sea level with a cold and semi-arid climate. Annual average temperature in research area was 13.6°C and average rainfall was 407mm. Physical and chemical properties of soil in experimental field were presented in Table 1. Experimental design was a randomized complete blocks with four replicates. The irrigation treatments were: well water in all growing stages as a control treatment (T1); 75% well water and 25% treated municipal wastewater (T2); 50% well water and 50% treated municipal wastewater (T3); 25% well water and 75% treated municipal wastewater (T4); irrigation with treated municipal wastewater in all growing stages (T5). The irrigation treatments are shown in Table 2. Quality of well water and treated wastewater are shown in table 3. Sowing was done as rows in 75cm wide rows with 20cm spacing within-rows with five rows per plot by Single Cross 704 cultivar, (Single Cross 704 was chosen because this cultivar had superiority relative to other cultivar in the last few years in experimental region). There was 2m distance between plots to prevent of water leakage. All operations were done regularly during the growing season.

Table 1: Soil analysis result for physical and chemical characteristics.

Characteristic	Soil depth (cm)	Soil texture	OC (%)	EC (ds/m^{-1})	pH	N (%)	K	P	Zn	Fe	Mn	Cu
							(ppm)					
Value	0-30	loamy	1.75	1.68	7.90	0.07	255	5.02	0.58	4.7	8.5	0.64

Table 2: Method of apply the irrigation treatments.

Irrigation	Treatments				
	T1	T2	T3	T4	T5
First irrigation	WW[1]	WW	WW	WW	TMWW
Second irrigation	WW	WW	TMWW[2]	TMWW	TMWW
Third irrigation	WW	WW	WW	TMWW	TMWW
Fourth irrigation	WW	TMWW	TMWW	TMWW	TMWW
Fifth irrigation	WW	WW	WW	WW	TMWW
Sixth irrigation	WW	WW	TMWW	TMWW	TMWW
Seventh irrigation	WW	WW	WW	TMWW	TMWW
Eighth irrigation	WW	TMWW	TMWW	TMWW	TMWW

1- WW: Well water

2- TMWW: Treated municipal wastewater

B. Crop sampling and calculation

Growth characteristics including stem height, stem diameter, length and width of flag leaf were determined at the end of staminate inflorescence emergence stage. Yield components such as: number of row per ear, number of grain per rows, 1000-seed weight, ear diameter, and ear length were measured after of physiology maturity by selected five plants of each experimental plot randomly. Number of grain per ear was obtained by multiplying the number of row per ear on number of grain per rows. Grain yield were determined by eliminating the marginal effect after drying.

C. Statistical analysis

Data analysis was done by using MSTATC software. The ANOVA test was performed to determine significant ($p \leq 0.01$) treatment effect and the mean values were adjudged by DMRT ($P = 0.01$) method.

Table 3: Quality of well water and treated wastewater (mg/L^{-1}).

Parameter	Source of water	
	Well Water	Wastewater
pH	7.8	8.1
EC (ds/m)	0.04	2.5
Ca	0.80	60
Mg	0.10	40.20
HCO3	1.02	86.30
SO4	0.00	75.02
TDS	68.70	6520
P	0.08	4.20
B	0.10	0.75
S	0.3	80.5
K	0.09	7.15
Cu	0.00	0.005
Mn	0.010	0.04
Zn	0.010	0.021
Fe	0.18	0.29
Cd	0.0001	0.005
Cl	0.21	45.20
Pb	0.001	0.012

RESULTS AND DISCUSSION

A. Effects of treated municipal wastewater on growth characteristics

Results showed that, growth characteristics were significantly affected by treated municipal wastewater treatments (Table 4). Stem height, stem diameter and length and width of flag leaf increased with treated municipal wastewater treatments. Highest stem height was in irrigation with 75% wastewater, and the lowest was obtained in control treatment (irrigation with well water during whole growing period). Maximum stem diameter (19.25mm) was in T4 (irrigation with 25% well water and 75% treated municipal wastewater), stem diameter in irrigation with treated municipal wastewater during whole growing period (T5) was less than irrigation with 25% well water and 75% treated municipal wastewater (T4), but this reduction was not significant. Stem diameter in T5 was statistically more than T1 and T2, and had no significant difference with T3 and T4. Highest flag leaf length was obtained with irrigation with 100% treated municipal wastewater (37.55cm) and 25% well water and 75% treated municipal wastewater (37.50cm) that was approximately 12.7% more than control. Highest and lowest flag leaf width was found in 75% treated municipal wastewater and control respectively (Table 6). According to the results use of wastewater increased all measured characters compared with control. Soil structure, permeability and fertility increased by irrigation with treated municipal wastewater due to the available macro and micro nutrients and organic matter (Cllap *et al.*, 1987).

Soil physical properties such as: hydraulic conductivity, aggregate stability, ventilation, porosity, water holding capacity increased with organic matter available in wastewater. Plant growth increased with use of wastewater due to improved nutrients ability to absorb. Moazzam-Khan *et al.*, (2009) in the survey found that sunflower growth characteristics were substantially increased by treated wastewater.

Galavi *et al.*, (2009) reported that the existence of specific nitrogen and potassium in wastewater improved the plant growth, cell reproduction and plant resistance and eventually stem diameter increased in sorghum. In several studies a positive effect of treated municipal wastewater has been reported on the growth of different plants (Al-Zoubi *et al.*, 2008; Fonseca *et al.*, 2007; Fonseca *et al.*, 2005; Alizadeh *et al.*, 2001; Al-Jaloud *et al.*, 1995).

Table 4: Effects of treated municipal wastewater on maize growth characteristics.

SOV	DF	Stem height (cm)	Stem diameter (mm)	Flag leaf length (cm)	Flag leaf width (cm)	Ear diameter (cm)	Ear length (cm)
Replication	3	345.73 ^{ns1}	4.133 ^{ns}	5.97 ^{ns}	0.017 ^{ns}	0.024 ^{ns}	2.067 ^{ns}
Irrigation	4	3167.00**	13.075**	18.39**	0.883**	0.149**	15.51**
error	12	367.56	2.008	3.38	0.054	0.009	0.38
CV (%)		9.99	8.14	5.21	4.95	3.99	3.72

1- ns= Non significant and ** = p < 0.01

B. Effects of treated municipal wastewater on yield and yield components

Yield and yield components of maize were significantly affected by irrigation with treated municipal wastewater (Table 5). Comparison of means showed that ear length and diameter increased in irrigation with treated municipal wastewater. Highest and lowest ear length and diameter was in irrigation with 25% well water and 75% treated municipal wastewater and control respectively (Table 6). Result showed that number of row per ear significantly increased with wastewater, as maximum number of row per ear was 13.25 that obtained with use of 75% wastewater minimum number of row per ear (9.75) was in control treatment. Number of row per ear in irrigation with 100% treated municipal wastewater was significantly less than irrigation with 25% well water and 75% treated municipal wastewater; it seems that, this trait decreased with too much use of wastewater. Number of grain per row and grain per ear significantly affected by wastewater treatments, maximum number of grain per row (37.75) and grain per ear (499.8) was obtained with use of 75% treated municipal wastewater, that statistically were more than other treatments. Comparison of means showed that 1000-seed weight increased by wastewater treatments. Use of treated municipal wastewater increased grain weight in compare with control treatment, so that the highest 1000-seed weight (303.8g) was obtained irrigation with 75% treated municipal wastewater and the lowest (209.5g) was obtained with irrigation with well water during whole growing period (control) (Table 6). Grain yield significantly affected by treated municipal wastewater treatments (Table 5), as significantly increased in irrigation treatments with treated municipal wastewater. Maximum yield was 8488 kg/ha^{-1} that obtained in T4; it was 25% more than control (Table 6). Use of 100% treated municipal wastewater (irrigation with wastewater during whole growing period) had no significantly difference with use of 75% treated municipal wastewater (Table 6). This suggests that high use of wastewater not only had no positive effect on yield, even yield may be reduced. Soil physical properties and its fertility were improved with use of wastewater and thus yield increased by improving the nutrients ability to absorb. Wastewater is rich in nutrients such as nitrogen, phosphorus, potassium, calcium, zinc and iron, and is an important nutritional source for plants (Mousavi *et al.*, 2013; Zavadil, 2009; Tarrason *et al.*, 2008; Wong *et al.*, 1998; Cllap *et al.*, 1987). Hussain *et al.*, (1996) investigated the effect of treated wastewater irrigation and nitrogen on yield and nitrogen use efficiency in wheat and conclude that yield and nitrogen use efficiency in the plots were irrigated with treated wastewater, were much higher than the plots that irrigated with well water only. Valmis *et al.*, (1985) found that barley grain yield increased by adding certain amounts of wastewater to the soil, but then too, had no effect on grain yield.

Table 5: Effects of treated municipal wastewater on yield and yield components of maize.

SOV	**DF**	**Number of row per ear**	**Number of grain per rows**	**Number of grain per ear**	**1000-seed weight (g)**	**Grain yield (kg/ha-1)**
Replication	3	0.133 ^{ns1}	0.333 ^{ns}	466.20 ^{ns}	227.733 ^{ns}	12458.33 ^{ns}
Irrigation	4	7.450**	51.800**	31630.32**	6644.80**	3314187.50**
error	12	0.550	3.000	958.99	67.567	196104.16
CV (%)		6.39	5.14	7.88	3.15	5.79

1- ns= Non significant and ** = p < 0.01

Table 6: Mean comparison of effects of treated municipal wastewater on growth and yield of maize.

	Treatments				
Traits	**T1**	**T2**	**T3**	**T4**	**T5**
Stem height (cm)	160.30b[1]	172.80b	184.30ab	222.50a	220.30a
Stem diameter (mm)	15.00b	16.00ab	18.25a	19.25a	18.50a
Flag leaf length (cm)	32.75b	34.00ab	34.75ab	37.50a	37.55a
Flag leaf width (cm)	4.150b	4.350b	4.625b	5.200a	5.150a
Ear diameter (cm)	2.075d	2.200cd	2.300bc	2.500ab	2.525a
Ear length (cm)	14.25c	15.25bc	16.08b	18.55a	18.63a
Number of row per ear	9.750c	10.750bc	12.000ab	13.250a	12.250ab
Number of grain per row	29.75b	30.75b	33.25b	37.75a	37.00a
Number of grain per ear	292.0c	330.5bc	374.3b	499.8a	469.0a
1000-seed weight (g)	209.5d	230.8c	263.8b	303.8a	296.3a
Grain yield (kg/ha^{-1})	6375c	7088bc	7875ab	8488a	8438a

1- Rows means followed by the same letter are not significantly different at 0.01 probability level

CONCLUSION

Irrigation with treated municipal wastewater increased growth, yield and yield components of maize due to due to available nutrients. Maximum growth rate and yield of maize was obtained in irrigation with well water and treated municipal wastewater integrating than the irrigation with well water and wastewater during whole growing period. Treated municipal wastewater can have a positive influence on yield and growth of maize at all stages due to rich nutrients and organic matter. According to the results the use of combined wastewater and well water suggested for get maximum yield.

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