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The effect of municipal wastewater irrigation on yield and biomass of canola (*Brassica napus* L.) and soil chemical properties

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Abstract

The aim of this study was to test if wastewater irrigation can increase fertilizer use efficiency and improve soil fertility without affecting the quality of soils and plants. The present study was carried out in order to investigate the impact of irrigation municipal wastewater on macro nutrient content of soil, biomass and yield of two varieties of canola (Brassica napus L.viz., SLM046 and Ocapi). The studies were done using Entisols sampled to a depth of 0-30 cm from agricultural fields in Boruojerd province (33°54' N, 48°40' W;1620 m above sea level) in Iran. In this experiment, we have used the experimental lysimeters was designed based on the randomized complete block with three municipal wastewater ratio of 100, 50 and 0% (diluted with irrigation water) and four replicates. The results of this experiment showed municipal wastewater irrigation affected significantly soil chemical properties especially in rhizosphere soil and biomass and yield. Application of municipal waste water increased soil salinity, organic matter, exchangeable Na, K, Ca, Mg, plant available phosphorus and decreased soil pH. It can be concluded that municipal wastewater can be used confidently in the short term in agricultural land both as fertilizer source and to increase fertilizer use efficiency for economical aspect.

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Introduction

In arid and semiarid areas around the world, including the lands of Iran (above 80%) water shortage is one of the most serious environmental problems, which necessitates the search for alternative sources of good-quality water to satisfy this demand. The use of treated wastewater for irrigation is one of the most-readily-available alternative water sources when natural resources are scarce (Hamilton *et al.,* 2007). In many areas of developing countries untreated wastewater flows through channels into rivers where it is diverted by subsistence farmers to small plots of crop grown for nearby urban markets. The public risks of using such contaminated streams for irrigation are obvious (Oron *et al.,* 2007).

Wastewater can have a positive effect on soil and eventually plant growth. However, such wastewater exerting most of the nutrient load and could be used as irrigation water to certain crops, tree and plants that may lead to increase in agricultural produce and plantation. It has a potential to supply (organic) carbon nutrients Nitrogen, Phosphorus, Potassium (NPK) and (inorganic) micro nutrients to support crop/plant growth (Ghanbari *et al.,* 2007; Qadir *et al.,* 2007). Application of wastewater to cropland and forested lands is an attractive option for disposal because it can improve physical properties and nutrient contents of soils . Wastewater irrigation provides water, N and P as well as organic matter to the soils (Bernala *et al.,* 2006).

Canola is an important oil crop growing in many part of the world. Canola rank third in the world and most important vegetable oil source with an annual growth rate exceeding that of palm. Canola is the world's second leading source of protein meals. Worldwide production of canola has increased six fold between 1975 and 2007 by the aim of conventional and modern plant breeding approaches. World roduction is expected to trend further upward over between 2005 and 2015; UN Food & Agriculture Organization (Akbar *et al.,* 2008; Hamilton *et al., 2007*). Canola cultivars appear to be best adapted to the conditions of Iran, however, some cultivars are less tolerant to environmental conditions. Although *Brassica* species produce maximum yield under normal soil and environmental conditions, their growth, seed yield and oil production are markedly reduced due to environmental stresses such as drought, water logging, salinity, low or high temperature, nutrient deficiency or excess (Ashraf and McNeilly, 2004; Burns *et al.,* 1985; Bürün *et al.,* 2006). The objectives of this study were to evaluate chemical soil characteristics and also to evaluate the yields and nutrient contents of two varieties of canola (*Brassica napus* L. viz., Ocapi and SLM046) in response to irrigation with municipal wastewater.

Materials and methods

This study was conducted on experimental lysimeters of Islamic Azad University, Boruojerd Branch at Iran (33°54' N, 48°40' W;1620 m above sea level). The climate in the area is classified as semi-arid. The annual rainfall of 561 mm (mean 1980–2009) falls mostly in the winter. The mean annual temperature ranges from 13.3 to 16.8 °C. The lysimetric experiments were conducted in zero-tension circular lysimeters of 50 (cm) diameter and 150 cm height from the bottom (volume = 0.3 m^3). The bottom of the lysimeter was covered by geo-textile, overlaid with 10 cm river sand with 0.5 - 1 mm grain size, then lysimeters filled by soil and in order to prevent water influx from field to lysimeters, those placed on metal legs (height = 45 cm). After filling lysimeters by clay loam soil, fresh lot of certified seeds of two varieties of canola (*Brassica napus* L.viz., SLM046 and Ocapi) were planted in August 2010 and were irrigated with agronomical water. The experimental design was random complete blocks in three treatments with three repetitions. For each cultivar, there were four replicate lysimeters within each treatment leading to a total of 24 lysimeters. There were three effluents treatment viz., T_1 (control or normal agronomical water), T_2 (50% wastewater), T_3 (100% wastewater) used for growing both cultivars of canola.

Soil analysis

The soil of the experimental grove is a clay loam. The characteristics of the soil used in the experiments are given in table 1. Soil samples were air-dried, crushed, and passed through a 2-mm sieve prior to chemical analysis. Cation exchange capacity (CEC) was determined using sodium acetate (buffered at pH 8.2) and ammonium acetate (buffered at pH 7.0) according to Sumner and Miller (Sumner and Miller, 1996) . The Kjeldahl method was used to determine organic N and plant-available P was determined by using the sodium bicarbonate method of Olsen (Olsen *et al.,* 1954). Electrical conductivity (EC) was measured in saturation extracts according to Rhoades (Rhoades, 1996). Soil pH was termined in 1:2 extracts, and calcium carbonate concentration was determined according to McLean (McLean, 1982). Soil organic matter was determined using the Smith-Weldon method (Fuentes *et al.,* 2002). Ammonium acetate buffered at pH=7 was used to determine exchangeable cations. Some physical and chemical properties of soil are given in Table 2 (Bremner, 1996; Jones, 2001; Horwitz, 2005).

Wastewater analysis

Wastewater effluents were collected from the various wastewater channels of Boruojerd city are mixed. These effluents were collected only once before the commencement of each growth season in a sufficient quantity, stored in shade and then its known concentrations were supplied to the plants as a soil drench. Fresh dilutions were made before each irrigation. Some chemical properties of the wastewater used for irrigation were determined by the methods described by American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF) were tested by multiple tube fermentation procedure Table 1(APHA, 2005; APHA, AWWA and WEF, 1985; APHA, 1995).

Biomass assessment and Yield assessment

At the prime of vegetative growth (75 days old plants), randomly within each cultivar were taken for first destructive harvest. Plants with their roots intact were carefully removed from the lysimeters and washed under running tap water using sieve. After getting fresh the plants were dried in an electrical oven then weighed the dried plants. When the plants had completed their reproductive growth period, then a final destructive harvest was taken during second week of March 2010. Plants were carefully cut at the soil level and brought to the laboratory in labeled papers-bags for measurements of various yield parameters as: Number of pods per plant, Pods length per plant (cm), Number of seeds per pods, Number of seeds per plant, Seeds weight per plant (g), 100-seed weight (g), Straw weight per plant (g) and Harvest index (Akbar *et al.,* 2008).

Statistical analysis

All data obtained from the effects of different wastewater irrigation on soil and plant chemical properties in contrast to non-wastewater irrigated in the present study were subjected to analysis of variance (ANOVA). The Duncan's multiple range tests were performed for mean comparisons using SAS statistical software (SAS .1982).

Results and discussion

Quality of municipal wastewater

The results of well water and wastewater quality analysis are shown in table 1, and they have been compared by suggested standards of Iran environment conservation organization (E.C.O of Iran, 1999) and FAO water qualitative standard. In consequence, available water was found suitable for irrigation, and evaluation of wastewater pollution (Table 1) described that magnitude of sulfate, PO_4^{3-}, Ca and Mg concentrations were below the critical limits (E.C.O. of Iran, 1999). For evaluation of wastewater microbial pollution determined critical limits have been used (E.C.O. of Iran, 1999). The pH value of full strength wastewater was highly basic. The pH value decreased as different dilutions were made from the concentrated effluents. Similarly, EC was remarkably high in all effluents treatments. The possibility of soil pollution with continues use of wastewater is figured out by the higher concentration of Sodium, Chloride and Sulfate than optimum limits. Electrical conductivity (EC) and concentration of Sodium and Chloride were above optimum level which it may cause toxic outbreak in sensitive plants (Kiziloglu *et al.,* 2008).

Effect of Irrigation treatment on the soil properties

The pH of the pre-sowing soil was found to be normal (7.76) which is most desirable in agricultural soil. In the field irrigated with municipal wastewater, the pH of soil extract was found to be slightly decreased before sowing from 7.8 to the range of 7.58–7.62 after harvesting (Table 2).This slight pH change can be attributed to the release of exchangeable cations during the mineralization of organic matter. As this is Entisol soil, decrease of pH can increase the solubility of exchangeable cations.Such decrease in the soil pH would enhance solubility and availability of soil nutrients such as phosphorus and micro elements (Mohammad,1986). Other researchers found that soil pH decreased with wastewater irrigation due to the oxidation of organic compounds and nitrification of ammonium (Mohammad and Mazahreh, 2003).

Table 1. The chemical quality of well water and treated wastewater (mgL^{-1}).

	Treatment (Effluents concentrations)			Standard limit of pollutants	
Parameters	T1 (0%)	T2 (50%)	T3 (100%)	E.C.O of Iran	FAO
pH	7.3	7.8	8.6	6-8.5	6-8.5
EC (dSm-1)	1.1	2.8	4.1	1.5	3
Calcium	49.4	101.2	158.9	200	75
Magnesium	26	73.5	111.7	150	100
Sulfate	31.1	271.5	865.7	1000	1000
Chloride	Nil	1.2	4.7	1000	1100
Nitrate	1.05	8.4	24.8	Nil	Nil
Phosphate	1.08	14.8	27.2	15	Nil
Sodium	19	121.7	218	250	-
Potassium	5.6	14.5	20.3	--	-
BOD5	--	60	90.5	100	250
COD	--	75	209	200	400
Total Coliform (MPN/100ml)	-	11	91	1000	1000

BOD5 = Biological oxygen demand. COD = Chemical oxygen demand.

The results showed that there were many differences between treatments on soil sodium concentrations, sodium absorption ratio (SAR) and electrical conductivity (EC). SAR increased in soil solution by wastewater irrigation as maximum value was observed in T2 and T3 (Table 2). Moreover, soil salinity level increased in all wastewater treatments in compare with fresh water. The presence of soluble salt, sodium, magnesium and calcium in the wastewater can increase soil electrical conductivity (García and Hernández,1996; Mohammad,1986; Mohammad and Mazahreh, 2003).

Comparison of results (Table 2) showed that the concentration of N, P, K, S, Ca, Mg and soil organic carbon (O.C %), were significantly affected by irrigation treatments, so that the highest and lowest value of total nitrogen was obtained by irrigation with wastewater in whole growing season and control treatments respectively ($p \leq 0.05$). It explains the importance of wastewater to supply these elements in the soil results from other studies had reported that total soil nitrogen increased under the influence of urban wastewater or wastewater sludge irrigation, and increase in potassium and phosphorus in the soil as a result of wastewater application (Fonseca *et al.,* 2005a; Monnett *et al.,*1996). In some cases wastewater application provides N, P and K up to 4, 8 and 10 times more than forage plants need [28]. Irrigation with municipal wastewater increased total cations concentration of Ca and Mg and soil organic carbon (O.C %), so that the most cations concentration of Mg, Ca and O.C % were obtained in T2 and T3 (Table 2). Zhang *et al.,*(2008) have reported the significant increase in percentage of organic matter and improvement in soil structure as a result of irrigation with wastewater. Kiziloglu *et al.* (2008) also reported an increase of organic matter, N, P, K, exchangeable Na, K,Ca, Mg, S and available phosphorus after irrigation with wastewater.

Table 2. Soil chemical characteristic before and after experiment (0-30 cm).

Parameters	Irrigation treatment			
	Before of experiment	T1	T2	T3
pH	7.8	7.7	7.62	7.58
EC (dSm^{-1})	1.95	1.82	2.8	3.45
O.C (%)	0.261	0.3	0.364	0.41
SAR	8.6	8.4	9.4	10.6
CEC (me/L)	4.6	4.22	5.2	5.3
Total nitrogen (%)	0.04	0.05	0.05	0.06
P (ppm)	1.9	2	4.1	5.6
K (ppm)	180	181	183	187.5
Ca + Mg (me/L)	23	24	26.8	27.1
Na (ppm)	21.3	21.5	25.6	27.4

O.C= Organic Carbon; CEC= Cation Exchange Capacity.

Effects of wastewater effluents on biomass and Yield parameters

The final results showed that use T2 for irrigation increased plant characteristics to compare with agronomical water (T1) of both cultivars of canola. But highest 1000 seed weight (1.92 g), Straw wt. per plant (42.7 g) and Seeds weight per plant (75.2 g), Were obtained with SLM046 under irrigation by T2 (Table 3). The increase in plant growth in the treatment T2 and T3 over treatment T1 can be attributed to the presence of high organic matter content in the liquid fertilizer that improves the soil structure and availability of nutrients (Shatanawi, 1994). However, percent increases in various treatments were significantly higher and different from one another when compared with T1. In T1 treatment plants, significantly increases in biomass were recorded, for instance, fresh weight of shoot was reduced by 53% and 42%, while dry weight of shoots was reduced by 43% and 64% in SLM046 and Ocapi cultivars respectively. Yield parameters responded to the applied concentrations of wastewater and shown significant increases in treated plants. There were found increases in the number of pods per plant (24.2% in SLM046; 18.5% in Ocapi), seeds per pods (25% in SLM046; 28% in Ocapi), seeds per plant (21% in SLM046; 20% in Ocapi), seed weight per plant (34.4% in SLM046; 32.8% in Ocapi), and in the harvest index (44% in SLM046; 37% in Ocapi). It was thus noticed that both canola cultivars were almost equally affected by the wastewater, although cultivar Ocapi proved slightly more sensitive to water pollutants than cultivar SLM046 (Table 3).

Table 3. Effects of wastewater on yield attributes of canola.

Yield parameters	Canola Cultivars	Treatment (Effluents concentrations)		
		T_1 (0%)	T_2 (50%)	T_3 (100%)
Pods per plant	SLM046	234 b ± 8.2	289 a ± 8.9	269 ab ± 6.7
	Ocapi	229 b ± 10	271 a ± 5.6	268 ab ± 8.32
Pod length per plant (cm)	SLM046	6.4 c ± 0.75	7.7 a ± 0.31	7.2 b ± 0.3
	Ocapi	5.4 c ± 0.73	6.9 a ± 0.26	6.0 b ± 0.36
Seeds per pod	SLM046	13.9 c ± 0.79	16.8 a ± 0.45	14.8 b ± 0.31
	Ocapi	13.1 b ± 0.8	15.6 a ± 0.46	15.1 ab ± 0.34
Seeds per plant	SLM046	3767 c ± 198.5	4996 a ± 174	4451 b ± 89.3
	Ocapi	3604 c ± 221.7	4792 a ± 141	4325 b ± 81.9
Seeds weight per plant (g)	SLM046	67.7 b ± 2.04	75.2 a ± 2.2	74.2a ± 1.31
	Ocapi	65.2 b ± 2.42	70.1 a ± 2.04	69.77 a ± 1.24
1000 seed weight (g)	SLM046	1.42 b ± 0.01	1.92 a ± 0.004	1.71 ab ± 0.004
	Ocapi	1.38 b ± 0.008	1.85 a ± 0.005	1.66 ab ± 0.005
Straw wt. per plant (g)	SLM046	34.1 b ± 1.63	42.7 a ± 1.08	39.2 ab ± 1.65
	Ocapi	32.6 b ± 1.85	40.2 a ± 1.3	40 ab ± 1.55
Harvest index	SLM046	1.65 b ± 0.024	2.38 a ± 0.024	2.02 ab ± 0.028
	Ocapi	1.60 b ± 0.022	2.20 a ± 0.02	1.98 a ± 0.008

It is suggested that the increase in Canola yield resulted from; increase of treated wastewater application rate causing higher nutrient inputs, higher uptake and accumulation of nutrients, mainly of N and P and occurrence of macro and micronutrients in the effluent which can neutralize the undesirable effect of high Na concentrations in treated wastewater. Moreover, the often described antagonistic effect between Na and K was more pronounced under low K concentrations in soil (Burns *et al.*,1985; Soumare *et al.,* 2003; Vasudevan *et al., 2010*).

Conclusion

Use of municipal wastewater for irrigation has gain importance throughout the world due to limited water sources and costly wastewater treatment for discharge. Municipal wastewater contains high amount of organic matter, nutrients and some heavy metals which are toxic to plants beyond a certain limit. Municipal wastewater irrigation affects the physical and chemical properties and increase the fertilizer use efficiency of the soils, yields and also mineral contents in the plants. In Iran, encountering the problems of water scarcity and high cost of fertilizers, municipal wastewater could be successfully use for irrigation. Findings indicate that, the use of municipal wastewater with physical treatment could increase water resources for irrigation may prove to be beneficial for agricultural production (Chang *et al.,* 1997; Rusan *et al.,* 2007).

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