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Full Length Research Paper

Effects of wastewater irrigation on the growth of two bean spices and soil chemical properties under greenhouse conditions

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This study has the objectives to evaluate the short-term effect of different dilutions of wastewater on the chemical properties of sandy loam and sandy clay soils in two bean species under greenhouse condition. The effect of the irrigation with different wastewater dilutions on the bean crops and their chemical properties were studied. The results showed that the irrigation with wastewater reduced the pH in the sandy loam soil significantly in comparison with sandy clay soil, and this could be due to lower buffering capacity of sandy loam soil as compared to sandy clay soil registering a change in pH increasing. Available N, P and K status, OC and metallic cation content were significantly higher in sandy clay than in sandy loam soils. Generally, sewage water irrigation improved chemical properties and fertility status of both soils. The metallic cations contamination of the bean crops were observed below the maximum permissible limit. However, several folds have been built of metallic cations in soils, fronds and grain of the bean crops indicating that it is possible to increase the metallic cations contamination beyond maximum permissible limit if the waste water is continuously used for irrigating for a long time.

Key words: Wastewater, bean, chemical properties, greenhouse conditions.

INTRODUCTION

The demand for water is continuously increasing in arid and semi-arid countries. Therefore, water of higher quality is preserved for domestic use while that of lower quality is recommended for irrigation. The use of industrial or municipal wastewater in agriculture is a common practice in many parts of the world (Ensink et al., 2002; Kiziloglu et al., 2008). Municipal wastewater is less expensive and considered an attractive source for irrigation in these countries (Al-Rashed and Sherif, 2000; Mohammad and Mazahreh, 2003) and any sources of water which might be used economically and effectively should be considered to promote further development. The total area irrigated with wastewater was conservatively estimated at around 9000 ha (Scott et al., 2004).

Iran, as a semi-arid country, suffers from shortages in water supply for domestic, industrial and agricultural purposes. Water resources in Iran are very limited because of naturally arid and semi-arid conditions. Hence, limited water supplies require careful management for successful agricultural production. The interest in reusing wastewater for irrigation is rapidly growing in Iran as in most countries. Wastewater is a valuable source for plant nutrients and organic matter needed for maintaining fertility and productivity of arid soils (Horswell et al., 2003). The reuse of wastewater for

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Table 1. Characteristics of well and sewage water.

Characteristics	Unit	Tab water	Wastewater
TSS	mg L^{-1}	4.5	85
PH	-Log[H^+]	7.78	7.8
EC	ds m^{-1}	0.51	1.46
Na	me L^{-1}	0.8	10.2
SAR	-------	1.02	6.8
BOD	mg L^{-1}	-------	35

Table 2. Chemical properties of soil prior to experimentation.

Parameter	Unit	Sandy loam	Sandy clay
EC	ds m^{-1}	0.57	0.72
PH	-Log[H^+]	7.5	8.1
CCE	%	44.5	39.8
Available N	%	0.056	0.061
Available p	mg kg^{-1}	18.3	20.5
Available K	mg kg^{-1}	305	348
Zn	mg kg^{-1}	0.68	0.73
Cu	mg kg^{-1}	0.61	0.78
Mn	mg kg^{-1}	4.35	5.87
Fe	mg kg^{-1}	8.7	10.13
Pb	mg kg^{-1}	Trace	Trace
Ni	mg kg^{-1}	Trace	Trace
Cd	mg kg^{-1}	Trace	Trace
OM	%	1.1	1.32

irrigation may potentially create environmental problems if not properly treated and managed (Bahri and Brissaud, 1996; Kiziloglu et al., 2008). Application of treated wastewater for irrigation of plants and crops is gradually becoming a common practice worldwide (Angelakis et al., 2003). Treatment of wastewater, as a segment of water management, usually produces a liquid effluent of suitable quality that can be used for irrigation purposes with minimum impacts on human health or the environment (Qishlaqi et al., 2008; Hofstedt, 2005). In contractual wastewater treatment, noteworthy portions of heavy metals remain in the treated effluent if special advanced treatment is not conducted. Thus, long term effects of irrigation with wastewater might include pollution of ground water and soil with heavy metals (Tyagi et al., 2009). Other impacts of treated wastewater in agriculture include the health impacts of possible contamination of crops by pathogenic bacteria and heavy metals (Jiménez, 2006). Also change in the basic physicochemical properties of soil (soil quality degradation) is another negative impact of wastewater application in agricultural lands (Qishlaqi et al., 2008; Mahmoud et al., 2010). This study has the objectives to evaluate the short-term effect of different dilutions of wastewater on chemical properties of sandy loam and sandy clay soils and assess the chemical build up in two bean spices on pots under greenhouse conditions.

MATERIALS AND METHODS

The experiment was conducted in the greenhouse of the Department of Soil Science, College of Agriculture, Shiraz University. The municipal wastewater used in this experiment was from the wastewater treatment plant of Marvdasht located near the city of Shiraz. The experiment was laid out in factorial completely randomized design with three wastewater purification variants: fresh water irrigation (T1); primary treated wastewater and fresh water in equal proportions (T2); and primary treated wastewater irrigation (T3) on two bean species (red bean and green bean) and two texture soil [sandy loam (SL) and sandy clay (SC) with three replicates].

Primary treatment wastewater is the removal of settable organic and inorganic solids by sedimentation and the removal of floating materials by skimming. Approximately 25-50% of the incoming biological oxygen demand (BOD5), 50-70% of the total suspended solids, and 65% of the oil and grease are removed during the primary treatment, but colloidal and dissolved constituents are not affected (Pescod, 1992; Kiziloglu et al., 2008). Some characteristics of primary treated wastewater and fresh water are shown in Table 1. The primary treated wastewater and fresh water used for preparing various dilutions have total suspended solids (TSS) and pH within safe range for irrigation (Wu et al., 2009) (Table 1). The soil samples were drawn prior to experimentation and at harvest of plant crops and analyzed for chemical properties following standard methods of analysis (Table 2). Soil pH and EC were measured by pH meter and EC meter from saturated soil paste extracted by vacuum pump. Organic carbon (OC) contents in soil were determined by the wet digestion method (Walkley and Black, 1934), total N by the Kjeldhahl method and available P by the method of Olsen et al. (1954). Available K+ was extracted by vacuum pump, from saturated paste and analyzed by flame emission spectrophotometer, metallic cation were extracted by DTPA and analyzed by atomic absorption spectrophotometer (Page et al., 1982). The dry ashing method was used for analyzing the heavy metal contents in crop samples. Each determination was carried out by accurately measuring a sample of 1 g of a ground sample in a crucible. The crucible with its content was placed in a muffle furnace and ashed at 550°C for 7 h. The ash was digested with 5 ml of 20% (V/V) Analar HCl solution. The residue was filtered into 50-ml volumetric flask using Whatman filter paper No. 41 and the solution was made to the mark with deionised water. Atomic absorption spectrophotometry was used for the heavy metal determination. The sandy loam and sandy clay soils used

Table 3. Effect of soil texture, sewage dilutions and vegetable crops on chemical properties of the soils.

Species	Texture	Treatment	pH	EC	OM	Caco$_3$	N	P	K
				ds m^{-1}	----------------%----------------			----------mg kg^{-1}---------	
G	SL	T1	7.62	0.62	1.22	39.8	0.0598	16.7	288
G	SL	T2	7.48	0.856	1.47	36.74	0.073	20.9	283
G	SL	T3	7.21	1.12	1.83	33.23	0.823	26.8	278.9
G	SC	T1	8.14	0.87	1.41	35.8	0.065	18.88	327.6
G	SC	T2	7.95	1.13	1.72	32.98	0.83	24.86	324.2
G	SC	T3	7.78	1.62	2.18	31.27	0.102	29.36	320.74
R	SL	T1	7.59	0.61	1.21	39.6	0.051	15.9	286.5
R	SL	T2	7.43	0.89	1.4	35.68	0.069	20	282.3
R	SL	T3	7.2	1.2	1.78	32.97	0.81	25.1	9
R	SC	T1	8.16	0.84	1.38	36.2	0.062	17.23	327
R	SC	T2	7.93	1.09	1.675	33.85	0.079	22.36	322
R	SC	T3	7.81	1.91	2.12	32.1	0.989	27.45	319

G: Green Bean; R: Red Bean; L: Sandy Loam; SC: Sandy Clay.

Table 4. Effect of soil texture, sewage dilutions and vegetable crops on chemical properties of the soils.

Species	Texture	Treatment	Fe	Zn	Cu	Mn	Cd	Ni
			---------------------mg kg^{-1}----------------------					
G	SL	T1	6.95	0.573	0.498	4.1	T	T
G	SL	T2	10.23	1.23	1.11	6.88	0.8	0.158
G	SL	T3	12.79	1.95	1.65	8.45	1.4	0.346
G	SC	T1	9.112	0.678	0.711	5.64	T	T
G	SC	T2	14.23	1.632	1.84	9.23	0.65	0.2
G	SC	T3	17.78	2.58	2.48	10.93	1.1	0.43
R	SL	T1	6.9	0.58	0.493	3.96	T	T
R	SL	T2	9.65	1.12	0.98	6.5	0.65	0.146
R	SL	T3	11.3	1.79	1.58	8.1	1.3	0.324
R	SC	T1	8.88	0.61	0.683	5.4	T	T
R	SC	T2	14.7	1.55	1.72	9	0.48	0.187
R	SC	T3	16.88	2.43	2.42	10.88	0.91	0.394

G: Green Bean; R: Red Bean; SL: Sandy Loam; SC: Sandy Clay; T: Trace.

were non-saline, mildly alkaline and calcareous in nature (Table 2). Also, the electrical conductivity (EC) was slight to moderately saline. The metallic cations content were below the maximum permissible limits as prescribed by Chen (2004). The status of available N and P was medium, while K was high in both soils. The DTPA extractable Fe, Cu and Mn were high, while Zn was low in both soils. Data were analyzed statistically by the statistical software called SPSS (Abedi-Koupai et al., 2006).

RESULTS AND DISCUSSION

Effect on soil properties

Chemical properties

The effect of soil texture, wastewater dilutions and vegetable crops on some of the chemical properties of the soils was analyzed (Tables 3 and 4). The decrease in pH was more in the sandy loam soil as compared to sandy clay soil, and this could be due to lower buffering capacity of sandy loam soil as compared to sandy clay soil registering a change in pH (Gelsomino et al., 2006). A decrease in pH of the soil with the use of wastewater dilutions for irrigation might be due to lower pH of wastewater being used for irrigation. Significantly the highest value of EC was observed for sandy clay soil irrigated with wastewater as such as compared to the rest of the treatment combinations indicating a higher build-up of salts in moderately fine textured soil. This could be ascribed to its high salt content with a mean value of 1.46 dS.m-^{1} as against 0.51 dS.m-^{1} of well water, hence contributing more dissolved salts in the soil. Similar results of pH were reported by Malla et al. (2007) and Ganeshamurthy et al. (2008), while that of EC was

Table 5. Metallic cations build up in grain and fronds in sandy loam soil.

Spices	Part of plant	Irrigation treatment	N%	P	K	Cl	Ca	Ni
			----------------------mg kg^{-1}----------------------					
Metallic cations build up in grain in sandy loam soil								
G	Grain	T1	8.46^{E}	0.453^{F}	0.451^{F}	2.987^{E}	N.D	N.D
G	Grain	T2	9.01^{ED}	0.519^{E}	0.534^{E}	3.198^{E}	N.D	N.D
G	Grain	T3	9.54^{CD}	0.567^{D}	0.583^{D}	3.421^{D}	N.D	N.D
R	Grain	T1	10.2^{BC}	0.588^{C}	0.609^{C}	2.9^{C}	N.D	N.D
R	Grain	T2	10.86^{AB}	0.675^{B}	0.723^{B}	3.8^{B}	N.D	N.D
R	Grain	T3	11.54^{A}	0.732^{A}	0.787^{A}	4.7^{A}	N.D	N.D
Metallic cations build up in fronds in sandy loam soil								
G	Fronds	T1	4.83^{D}	0.323^{F}	2.164^{F}	6.328^{E}	N.D	N.D
G	Fronds	T2	5.33^{C}	0.386^{E}	2.264^{D}	6.249^{D}	N.D	N.D
G	Fronds	T3	5.95^{B}	0.438^{C}	2.352^{E}	6.153^{F}	N.D	N.D
R	Fronds	T1	4.08^{E}	0.42^{D}	2.921^{C}	6.8^{C}	N.D	N.D
R	Fronds	T2	6.04^{B}	0.501^{B}	3.056^{B}	7.2^{B}	N.D	N.D
R	Fronds	T3	7.168^{A}	0.576^{A}	3.175^{A}	7.6^{A}	N.D	N.D

N.D: No detection.

reported by Malla et al. (2007). On the other hand, the soils on which red bean was grown recorded a small quantity of EC than green bean grown soils. Available N, P and K status, OC and metallic cation content values were significantly higher in sandy clay than in sandy loam soils. It was further enhanced with wastewater irrigation as such or in its dilution indicating improvement in the fertility status of the soils except buildup of metallic cations in the soil. The increase in N, P and K content of soil with prolonged irrigation was also reported by Masto et al. (2009). Sandy loam soil contained a higher value of $CaCO_3$ content which decreased on application of wastewater as such or in its dilution.

Metallic cations build up

Table 4 shows the average of heavy metal concentration in soil of different irrigation treatments when vegetable crops were irrigated with waste water as such with reference to the control. Considering the mean values of the content buildup of metallic cations irrespective of the crops grown on them, a higher content buildup of Zn (2.58 ppm) and Ni (0.43 ppm) was recorded for sandy clay soil, while the buildup of Cd (1.4 ppm) was comparatively higher in sandy loam soil. Similarly, irrespective of the textural class of the soils buildup of Zn (2.58 ppm), Cu (2.48 ppm), Fe (17.78 ppm), Mn (10.93 ppm), Cd (1.4 ppm) and Ni (0.43 ppm) was relatively higher in soils where green bean was grown. These may be ascribed to differential removal of cations from the soil by the vegetable crops under study (Malla and Totawat, 2006). The increase in DTPA extractable metallic cations was also reported by Rana et al. (2010).

Effect on plant composition

Metallic cations build up in grain and fronds

The content buildup of metallic cations in the fronds and grain of crops when irrigated with waste water as such with reference to the control is given in Tables 5 and 6, and Figure 1. Considering the mean values of the content buildup of metallic cations in the fronds of crops irrespective of the type of crop grown, comparatively higher buildup of Zn (97.6 ppm), Cu (9.7 ppm), Fe (266.4 ppm) and Mn (179.9 ppm) was observed when crops were grown on sandy clay soil. Irrespective of the textural class of the soil, content buildup of Fe, Cu, Mn, and Zn was higher in the fronds of kidney bean. Similar to the content buildup of metallic cations in fronds, comparatively higher buildup of Zn (42.2 ppm), Cu (29.9 ppm), Fe (258 ppm) and Mn (75.3 ppm) was recorded in the grain of crop grown on sandy clay soil. Irrespective of the textural class of the soils, content buildup of Fe, Cu, Mn, and Zn was higher in the fronds of kidney bean. The variations in the content buildup of metallic cations in the soils and vegetable crops may be attributed to a greater variation in the initial values of the metallic cations in the soil prior to experimentation and preferential absorbance of a particular cation by different vegetable crops under study (Sharma and Shukla, 2013). Even if the concentration of heavy metal in sewage effluents is low, the extent of build-up of metals in sewage/waste water-irrigated soils often depends on the period of its application (Malla et al., 2007). In spite of higher content buildup of metallic cations in the vegetable crops, they were all within the safe limit prescribed by WHO (1996).

Table 6. Metallic cations build up in grain and fronds in sandy clay soil.

Spices	Part of plant	Irrigation treatment	N%	P	K	Cl	Ca	Ni
			----------------------mg kg^{-1}					----------------------
Metallic cations build up in grain in sandy clay soil								
G	Grain	T1	9.06^{F}	0.49^{C}	0.48^{C}	3.4^{C}	N.D	N.D
G	Grain	T2	9.69^{E}	0.563^{B}	0.57^{BC}	3.63^{BC}	N.D	N.D
G	Grain	T3	10.3^{D}	0.61^{B}	0.62^{BC}	3.9^{AB}	N.D	N.D
R	Grain	T1	11.4^{C}	0.6^{B}	0.8^{BC}	3.638^{BC}	N.D	N.D
R	Grain	T2	12.6^{B}	0.71^{A}	0.85^{B}	3.884^{AB}	N.D	N.D
R	Grain	T3	14.1^{A}	0.748^{A}	1.2^{A}	4.173^{A}	N.D	N.D
Metallic cations build up in fronds in sandy clay soil								
G	Fronds	T1	5.2^{D}	0.35^{D}	2.3^{C}	7.2^{A}	N.D	N.D
G	Fronds	T2	5.74^{C}	0.418^{CD}	2.40^{C}	7.11^{A}	N.D	N.D
G	Fronds	T3	6.4^{B}	0.48^{C}	2.5^{C}	7^{A}	N.D	N.D
R	Fronds	T1	4.3^{E}	0.8^{B}	3.6^{B}	7.704^{A}	N.D	N.D
R	Fronds	T2	6.3^{B}	0.88^{AB}	3.9^{AB}	7.607^{A}	N.D	N.D
R	Fronds	T3	7.2^{A}	0.9^{A}	4.2^{A}	7.49^{A}	N.D	N.D

N.D: No detection.

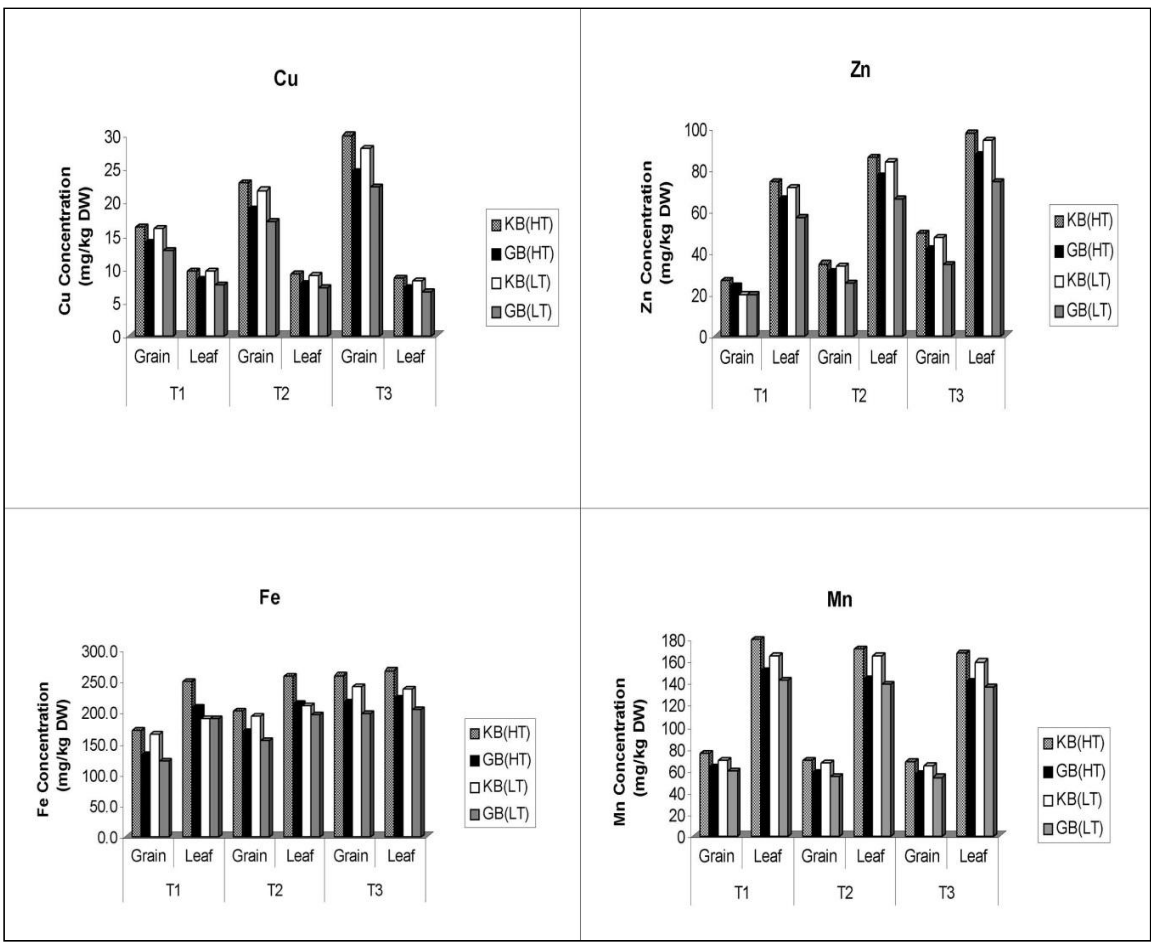

Figure 1. The content builds up of metallic cations in the dry weight of fronds and grain of two beans (KB: Red Bean, GB: Green Bean, HT: Sandy Clay, LT: Sandy Loam).

Conclusions

Generally speaking, sewage water irrigation improved chemical properties and fertility status of both soils. The metallic cations contamination of vegetable crops was observed to be below the maximum permissible limit. However, several folds buildup of metallic cations in soils, fronds and grain of vegetable crops under study indicated that there might be an increase in metallic cations contamination beyond maximum permissible limit if such wastewater is continuously used for irrigation on long term. Thus, timely monitoring of sewage water, soil and crops is essential to maintain soil quality for consumption of safe foods grown on them. Establishment of at least a primary sewage treatment plant is suggested where raw sewage is being diverted for irrigation.

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