Original Research

The Use of Municipal Waste Water in Afforestation: Effects on Soil Properties and Eldar Pine Trees

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Abstract

The use of waste water for irrigation is on the rise, particularly in peri-urban areas of developing countries. Effects of municipal waste water application on soil and eldar pine (*Pinus eldarica* Medw.) trees were studied. Two areas irrigated by municipal waste water and well water (for at least 15 years) were selected south of Tehran, Iran. Data was collected using the technique of systematic random sampling with 4 replicates in either or both fields. Observations included the measurement of tree diameter at breast height (d.b.h.), total height, crown length, average crown diameter, basal area and standing volume, needle mineral composition and changes in soil properties. Application of municipal waste water produced better growth in *P. eldarica* as compared with well water. Concentrations of N, P, K, Ca, Mg, Na, Cu, Fe, Mn, Zn as well as the values of pH, EC, SOC, $CaCO_3$ were greater in needles of trees irrigated with municipal waste water than of those with well water. All measured parameters of soil showed their greatest values in the upper layer of soil (0-0.15 m). Irrigation using municipal waste water did not result in toxicity of elements of needles and soil. This study confirms that municipal waste water could be utilized as an important source of water and nutrients in growing *P. eldarica* to increase biomass production.

Keywords: afforestation, irrigation, municipal waste water, *Pinus eldarica*, nutrient

Introduction

Water resources are becoming contaminated due to anthropogenic activities and natural causes, pollution caused by human activities generating industrial and municipal waste waters [1]. The land application of waste water for crop irrigation has emerged as a promising solution [2] due to the potential large volumes of water that can be used for reducing the amount of water extracted from the environment [3]. Types of waste water used for recycling include treated and untreated waste water [4], storm water runoff [5], and domestic and industrial waste water [6].

Establishment of a tree plantation for waste water irrigation has been a common practice for many years. The practice defers ecological degradation by the pollutants in the soil, because trees are long-living organisms that can take up trace elements from the soil, water or air and retain them for a long time [7]. It also creates opportunities for commercial biomass production and sequestration of excess minerals in the plant system [8]. Therefore, the use of waste water in growing woodlots is a viable option for the economic disposal of waste water [9]. Moreover, waste water from municipal origin is rich in organic matter and also contains appreciable amounts of macro and micronutrients [10]. Accordingly, nutrients levels of soil are expected to improve considerably using continuous irrigation with municipal waste water [11, 12].

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Again, waste water may contain variable amounts of heavy metals which could be a source of contamination and be toxic to the soil [13] and plants [14]. Hence, if waste water is to be recycled safely for irrigation the problems associated with it is needed to know [15]. Because of differences in conditions of climatic, vegetation, social, cultural and also changes in qualities of soil and waste water among the different regions and even through a time period in a region, just utilizing the world wide guidelines would be a mistake and in the long-term would damage the soil and water resources; therefore, local researchs needs to be carried out.

There are very few studies from Iran for the effects of irrigation using municipal waste water on soil and tree planting. The objective of this study was to investigate the effects of 15-year municipal waste water application on the growth of eldar pine (*Pinus eldarica* Medw.) trees and mineral accumulation in tree needles and soil.

Materials and Methods

Site Description

The study site is an abandoned agricultural site located in Shahr-e Rey, 5 Km south of Tehran, Iran (Latitude 35º 37' N, Longitude 51º 23' E, 1005 m above sea level). The climate of the site is semi-arid with mild-cold winters and a 7-month (mid-april to mid-november) dry season (Fig. 1). Average annual rainfall and average annual temperature are 232 mm and 13.3ºC, respectively. The highest rainfall appears in March and the lowest in August. The warmest month occurs in August and the coldest in January. The experiment was conducted at two 4 hectare even-aged (15 years) artificial stands of *Pinus eldarica* Medw. The first stand was irrigated with municipal waste water and the second with well water since planting. The irrigation was applied daily based on tree water-use and the potential evapo-transpiration, which varied seasonally in response to the climate. The soils of both fields were clay-loam with 32.5% clay, 34.12% silt and 33.38% sand in the field irrigated with municipal waste water and 28.52% clay, 36% silt and 35.48% sand in the field irrigated with well water. Also, the soils were low in available P and Mg but high in pH (Table 2).

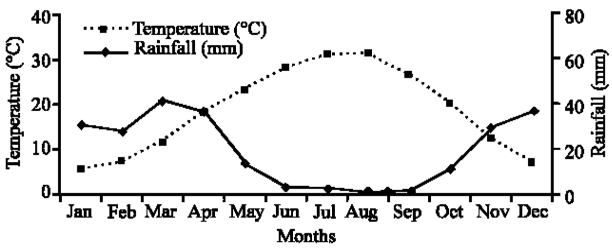

Fig. 1. Embrothermic curve of the study site.

Data Collection of Growth and Plant and Soil Sampling

The study was established in October 2006. Data was collected using the technique of systematic random sampling [16] with 4 replications in either or both fields. Therefore, four plots were identified in each field. Plots were 30 m × 30 m, with tree spacing of 3 m × 4 m. In each plot, diameter at breast height, total height, crown length and crown diameter of total trees were measured and basal area computed. Standing volume of each tree was determined by using form factor (~0.5) and formula made by Zobeyri [17] (Eq. 1).

$$V = 0.4 \cdot D^2 \cdot H \quad (1)$$

...where:
D = diameter at breast height (d.b.h.),
H = total height,
V = standing volume.

In each plot, four trees were selected and at the end of the growing season needle samples of eldar pine trees were taken from the top of crown and the part affected by sunlight [18, 19]. This collection provided 16 needle samples in each treatment. At the end of sampling, one representative needle sample from each plot (by mixing of four samples of each plot) was taken (due to decreasing sample quantity for chemical analysis). Forty eight soil samples were collected under each selected tree by digging profiles at three depths (0-0.15, 0.15-0.3 and 0.3-0.6 m). At the end of soil sampling, three representative soil samples of three depths from each plot were taken by mixing samples of each layer in each plot (due to decreasing sample quantity for chemical analysis) according to Habibi Kaseb [18]. Municipal waste water and well water were sampled daily (3 days in each month) from early June to late November, at three times per day (morning, noon and evening) to make a composite sample of each day.

Laboratory Analysis

Water samples were brought to the laboratory in resistant plastic bottles to avoid adherence to the container wall. They were filtered through 42 mm filter paper and stored at 4ºC to minimize microbial decomposition of solids [20, 21]. Several parameters were measured separately, pH and EC by the procedure described using OMA [22], NH_4-N, NO_3-N, PO_4-P, K, Ca, Mg and Na as per the method given by APHA [23] and Yadav et al. [51]. Copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were estimated by the aqua regia method of Jackson [24] followed by a measurement of concentrations using an Atomic Absorption Spectrophotometer (AAS).

The soil samples were air-dried, crushed, passed through a 2 mm sieve and analyzed for various physico-chemical properties. Soil texture was determined using the hydrometer method according to Bouyoucos [25]. Soil pH and electrical conductivity (EC) were determined in 1:2 soil:water suspension by pH and EC meters [26].

Table 1. Characteristics of municipal waste water and well water.

Parameters	Municipal waste water		Well water		WHO*
	Range	Mean ± SE	Range	Mean ± SE	
pH	7.51 - 7.75	7.63 ± 0.01 [a]	6.69 - 7.62	7.32 ± 0.05 [b]	6.5 - 8.5
EC (dS m^{-1})	1.78 - 2.12	1.91 ± 0.02 [a]	0.54 - 0.67	0.590 ± 0.008 [b]	3
NH4-N (mg l^{-1})	8.1 - 10.24	9.05 ± 0.11 [a]	1.83 - 2.49	2.15 ± 0.19 [b]	1.5
NO3-N (mg l^{-1})	1.58 - 1.89	1.63 ± 0.09 [a]	0.19 - 0.33	0.24 ± 0.08 [b]	3
PO4-P (mg l^{-1})	11.45 -14.13	12.69 ± 0.16 [a]	4.62 - 5.64	5.03 ± 0.01 [b]	–
K (mg l^{-1})	33.06 - 46.31	39.93 ± 0.83 [a]	17.48 - 22.75	19.72 ± 0.36 [b]	–
Ca (mg l^{-1})	235.54 - 296.20	255.22 ± 4.57 [a]	66.70 - 101.57	96.77 ± 1.26 [b]	75
Mg (mg l^{-1})	100.9 - 124	109.85 ± 1.83 [a]	28.9 - 42	35.22 ± 0.79 [b]	50
Na (mg l^{-1})	135.90 - 150.22	140.45 ± 0.20 [a]	30.18 - 41.03	35.18 ± 0.13 [b]	200
Fe (mg l^{-1})	5.44 - 7.25	6.33 ± 0.12 [a]	0.57 - 0.77	0.73 ± 0.01 [b]	3
Zn (mg l^{-1})	2.91 - 4.20	3.30 ± 0.06 [a]	0.38 - 0.56	0.43 ± 0.07 [b]	3
Cu (mg l^{-1})	1.06 - 1.97	1.26 ± 0.03 [a]	0.05 - 0.16	0.09 ± 0.01 [b]	1-2
Mn (mg l^{-1})	3.57 - 6.71	5.01 ± 0.11 [a]	0.29 - 0.78	0.51 ± 0.09 [b]	1

Different superscripts in row indicate significant ($P < 0.01$) difference. Values are mean of eighteen replications (3 days * 6 months) with ± SE.
* World Health Organization (WHO): [27].

Soil organic carbon (SOC) content was determined by the Walkley-Black method [28]. Calcium carbonate ($CaCO_3$) was measured with a calcimeter. Macro and micro-nutrients of soil were extracted after digestion with 3:1 concentrated HCl-HNO_3 and measured by Atomic Absorption Spectrophotometer [14]. Extractable phosphorus was determined by Olson's extraction method [29]. Total N was analyzed using the Kjeldahl method [21].

Fresh weight of some needles from each treatment was recorded immediately after harvest. Dry weight was recorded after oven drying of needles for 72 h at 80°C [20]. Needle samples were washed using tap water, rinsed with distilled water, oven dried at 80°C for 24 h [30], ground in a stainless steel mill and retained for mineral analysis. For determination of macro and micro-nutrients, except P and N, the needle samples were wet-digested as per Jackson [24] and estimated using an atomic absorption spectrophotometer (AAS). Measurement of P content was performed after wet digestion using a UV-VIS spectrophotometer at 450 nm [30]. The N content of needle samples digested in concentrate sulfuric acid was determined by the Kjeldahl method [20, 31].

Statistical Analysis

Average growth parameters, needle nutrients and soil physico-chemical properties of two irrigation treatments:

- T_1: irrigation by municipal waste water;
- T_2: irrigation by well water

...were compared using independent-samples t-test. Soil data were analyzed for differences due to depth in the profile using one-way ANOVA. Simple linear regression analysis was used to determine the relationship between nutrients concentrations in soil liquid phase and planted tree needles. Furthermore, the variations in characteristics of municipal waste water and well water were also tested using independent-samples t-test. All the data were analyzed using the SPSS statistical package.

Results and Discussion

Quality of Municipal Waste Water and Well Water

The quality of municipal waste water and well water was assessed for irrigation with respect to pH, EC and contents of macro and micro-elements (Table 1). Results indicated that the waters were alkaline in reaction. The pH of the municipal waste water in various months ranged from 7.51 to 7.75 and for well water 6.69 to 7.62. Based on results of Patel et al. [32], in our examination the tolerance limit of pH for irrigation ranged from 6.0 to 9.0. The electrical conductivity (EC) of municipal waste water ranged from 1.78 to 2.12 dS m^{-1} with the greatest value detected in August. Average EC of municipal waste water (mean of 18 samples) exceeded 1 dS m^{-1} (1.91 dS m^{-1}) indicating the waste water was saline in nature [12]. The pH and EC of the municipal waste water were greater than those of the

Table 2. Significance of depth in soil profile for physico-chemical properties of soil following an extended period (15 years) of irrigation using municipal waste water and well water.

	depth	pH	EC	SOC	$CaCO_3$	N	K	Ca	Mg	Fe	P	Na	Zn	Mn	Cu
	(m)		dS m^{-1}	%		g kg^{-1}					mg kg^{-1}				
Soil treated with T_1	0-0.15	8.22^{a} (0.06)	1.50^{a} (0.04)	1.43^{a} (0.03)	20.38^{a} (0.86)	0.887^{a} (0.059)	3.76^{a} (0.19)	26.41^{a} (0.81)	0.395^{a} (0.024)	25.12^{a} (0.46)	20.00^{a} (0.81)	1.24^{a} (0.05)	175.54^{a} (4.48)	765.20^{a} (23.87)	45.48^{a} (1.61)
	0.15-0.3	8.14^{a} (0.09)	1.33^{b} (0.04)	1.26^{b} (0.05)	18.75^{b} (1.04)	0.735^{b} (0.107)	3.55^{a} (0.22)	25.58^{a} (0.885)	0.364^{ab} (0.030)	23.85^{a} (1.63)	18.25^{b} (0.95)	1.14^{a} (0.06)	149.28^{b} (3.50)	739.45^{ab} (14.04)	42.33^{a} (3.04)
	0.3-0.6	7.91^{b} (0.18)	1.17^{c} (0.04)	0.864^{c} (0.103)	17.69^{b} (1.02)	0.602^{c} (0.056)	3.11^{b} (0.13)	23.96^{b} (0.84)	0.346^{b} (0.013)	21.29^{b} (1.36)	16.50^{c} (1.29)	1.01^{b} (0.07)	125.39^{c} (3.43)	717.82^{b} (9.79)	37.62^{b} (1.57)
ANOVA value	F-value	6.30	56.19	50.66	7.62	13.35	11.96	8.65	4.54	9.54	11.30	12.18	170.96	7.81	13.10
	P-value	<0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01
Soil treated with T_2	0-0.15	7.90^{a} (0.04)	0.875^{a} (0.023)	1.21^{a} (0.14)	17.35^{a} (1.05)	0.615^{a} (0.086)	2.77^{a} (0.14)	19.70^{a} (1.13)	0.319^{a} (0.014)	19.85^{a} (0.74)	16.75^{a} (0.95)	1.07^{a} (0.06)	113.12^{a} (7.20)	667.66^{a} (6.3)	29.68^{a} (0.73)
	0.15-0.3	7.82^{a} (0.10)	0.802^{b} (0.025)	0.872^{b} (0.14)	15.88^{b} (0.29)	0.460^{ab} (0.101)	2.47^{b} (0.19)	17.93^{b} (1.04)	0.302^{a} (0.013)	18.90^{a} (1.40)	14.75^{b} (0.95)	0.895^{b} (0.020)	94.87^{b} (2.59)	642.17^{a} (12.53)	26.97^{b} (1.43)
	0.3-0.6	7.65^{b} (0.15)	0.752^{c} (0.025)	0.602^{c} (0.044)	14.98^{b} (0.76)	0.365^{b} (0.127)	2.15^{c} (0.05)	17.08^{b} (0.78)	0.260^{b} (0.030)	16.52^{b} (1.81)	13.75^{b} (1.25)	0.830^{b} (0.021)	83.03^{b} (6.04)	576.55^{b} (31.27)	24.59^{c} (0.53)
ANOVA value	F-value	6.01	25.06	26.02	9.65	5.57	18.99	7.14	8.58	6.04	8.19	32.80	15.26	22.56	27.00
	P-value	<0.05	<0.01	<0.01	<0.01	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01	<0.01	<0.01	<0.01	<0.01
	P Sig. *	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Range **	6.0-9.0	–	–	–	0.2-5	1.7-33	0.7-36	1.2-15	5-50	100-2,000	–	10-500	200-10,000	5-400

Abbreviations: T_1: municipal waste water; T_2: well water; values are mean of four replications with ± SD in parentheses; different superscripts in column indicate significant difference between various depths in each treatment.

* Shows significant difference of means in 0-0.6 m soil layer between soils treated with T_1 and T_2, ** [39].

well water. The concentration of all the nutrient elements was higher in municipal waste water, with NO_3-N content (1.63 mg l^{-1}) being 6.8 times the content in well water (0.24 mg l^{-1}). The content of NH_4-N in municipal waste water (9.05 mg l^{-1}) was also 4.2 times the content in well water (2.15 mg l^{-1}). On average, available content of PO_4-P, K^+, Ca^{2+}, Mg^{2+}, Na^+, Fe, Cu, Mn and Zn in municipal waste water were greater compared to those in the well water. The greatest nutrient concentrations of municipal waste water were reduced in autumn and increased in summer because of high temperature and evaporation losses of water [30].

Although municipal waste water elevated significantly ($P < 0.01$) in all values compared to well water, analysis showed that pH, EC, NO_3-N, PO_4-P, K^+, Na^+ and Cu of well water samples were within the limits as per the standard prescribed for land disposal and should not pose any serious hazard according to threshold values of WHO [27]. However, the contents of NH_4-N and Ca^{2+} of municipal waste water and well water and Mg^{2+}, Zn, Mn and Fe of municipal waste water were on the higher side (Table 1), which could be toxic to soil and plants. Since high quantities of some nutrients were traced in some of the samples, there is a matter of concern that further increase in their contents may be hazardous.

Impact of Municipal Waste Water Irrigation on Soil Properties

In both soils, EC, pH, SOC, $CaCO_3$, macro and micro-elements decreased with soil depth (Table 2). These results are in agreement with the findings obtained later [21, 33]. Since the surface soil was richer in nutrients than the underlying layers, greater accumulation of nutrients in the topsoil layer probably was due to soil texture, surface application of municipal waste water and their retention in soil micelles [30]. Reverse trend about some micro-nutrients has also been reported by Singh and Bhati [30]. This reverse trend might be due to sandy nature, low soil organic carbon and low water holding capacity of the soil.

Independent-samples t-test indicated that application of municipal waste water resulted in an increase (0-60cm soil layer) in pH, EC, soil organic carbon (SOC), $CaCO_3$ and mineral nutrients of soil irrigated by waste water as compared to that by well water (Table 2). This shows that

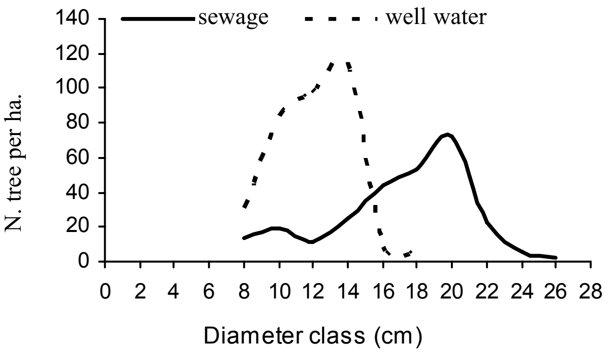

Fig. 2. Distribution of diameter classes for eldar pine trees in two study fields.

municipal waste water influenced soil physico-chemical properties including pH, electrical conductivity (EC), soil infiltration rate, bulk density, porosity and nutrient content [34]. These changes are of considerable significance to the search for sustainable land use and the impact of waste water on soil physical-chemical properties [15]. In fact, the suitability of soils for receiving waste water varies widely, depending on their infiltration capacity, permeability, cation exchange capacities, phosphorus adsorption capacity, texture, structure and type of minerals [35].

The increase in pH and EC of the soil irrigated by waste water may be due to the alkaline nature of municipal waste water [36]. After pH, soil organic carbon (SOC) is the most important indicator of soil quality playing a major role in nutrient cycling [12]. An increase in SOC content of soil may be due to the application of municipal waste water [37, 38].

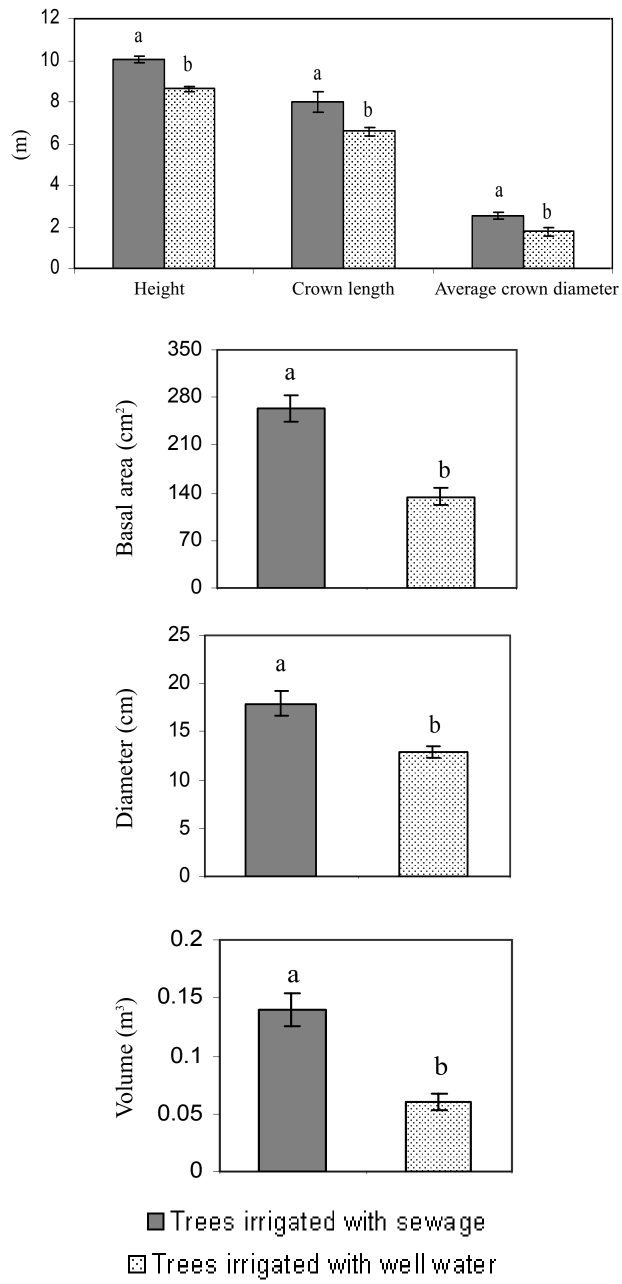

Fig. 3. Effect of municipal waste water application on growth of *P. eldarica* trees, error bars are ± SE.

The increase in N, P, K, Ca, Mg, Fe, Mn, Cu and Zn concentrations of soil in waste water treatment might be due to their addition through municipal waste water in spite of their high uptake by the growing plants [20]. The addition of these nutrients was found beneficial in nutrient-deficient soil of the arid region. Evidently, while the additional nutrients can be a bonus as additional fertilizer, excess nutrients can have an adverse effect through increasing the vulnerability of plants toward pathogens and therefore needs reduction before application [3]. As Singh and Bhati [30] and Aghabarati et al. [33], in our study, mineral contents of soil did not exceed limit values for concentrations of minerals in soil fixed by Salardini [39] (Table 2), as evidenced by enhanced growth in the trees without any nutritive or morphological problems. Consistent with findings of Li et al. [40] and Singh and Bhati [30], our results also demonstrated that the concentration of Na was greater in soil irrigated by waste water.

Tree Growth Response to Municipal Waste Water Irrigation

Irrigation with municipal waste water for 15 years produced the largest trees in this treatment. The most frequent trees were found at diameter class of 20 cm and 14 cm, respectively grown in fields irrigated with municipal waste water and well water (Fig. 2). In fact, tree growth was greater ($P < 0.01$) in the field irrigated using municipal waste water than in plots irrigated with well water, as indicated by the 17.95 ± 1.33 cm diameter at breast height, 10.04 ± 0.15 m height, 8 ± 0.27 m crown length, 2.53 ± 0.17 m crown average diameter, 264.20 ± 30.02 cm^2 basal area and 0.139 ± 0.013 m^3 standing volume of the trees in the waste-water-irrigated field (Fig. 3). Similarly, an increase in the growth of olive (*Olea europaea*) trees due to irrigation with municipal waste water has been reported by Aghabarati et al. [33]. The study of Stewart et al. [41] also

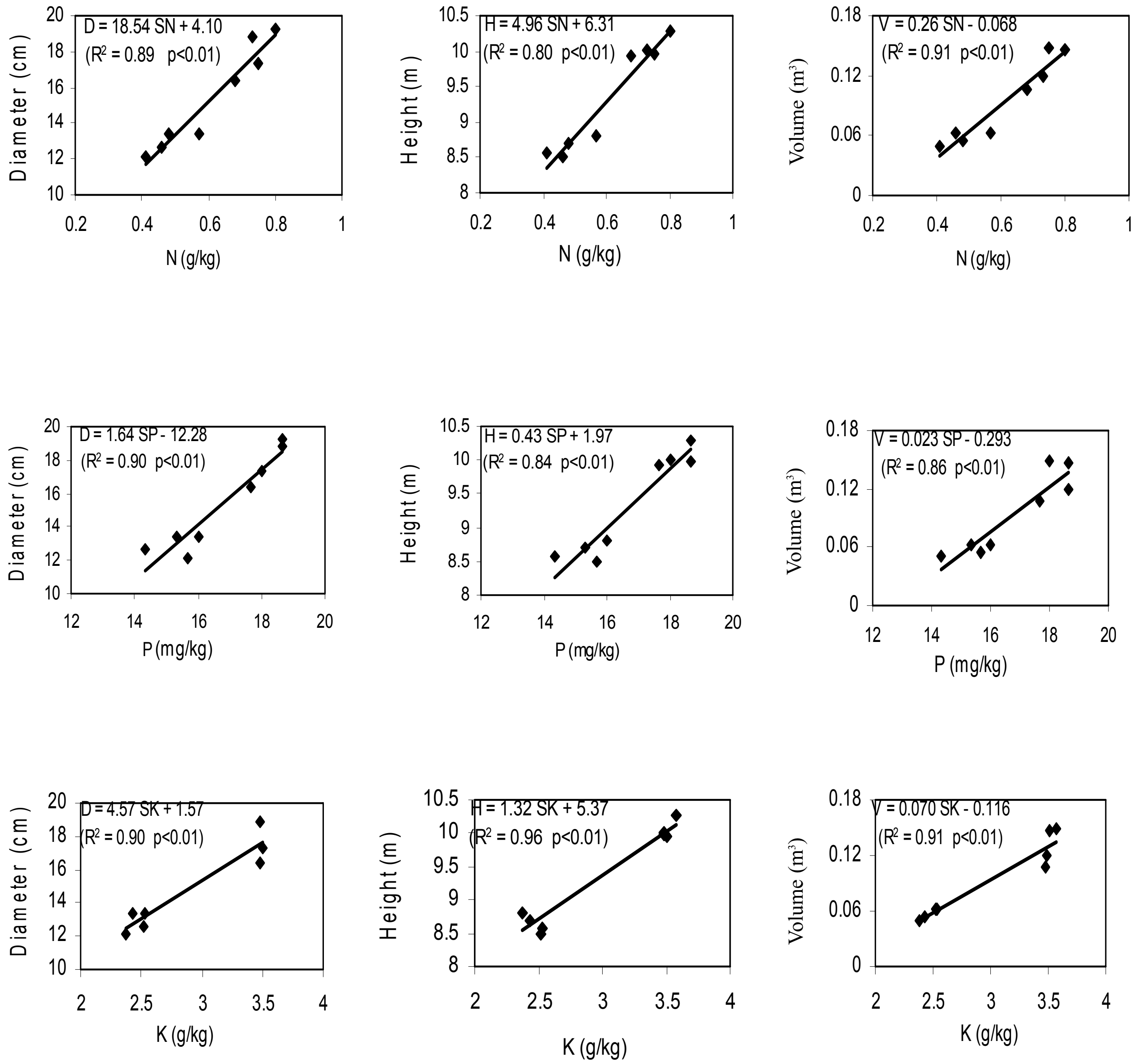

Fig. 4. Relationship between macro-elements of soil with growth characteristics of *P. eldarica* trees.

Table 3. Effect of municipal waste water irrigation on mineral composition of eldar pine tree needles.

	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
	gr kg^{-1}						mg kg^{-1}			
Soil treated with T_1	16. 41[a] (0.27)	0.865[a] (0.058)	5.79[a] (0.50)	6.08[a] (0.27)	1.51[a] (0.12)	0.320[a] (0.027)	99.70[a] (8.58)	22.18[a] (2.13)	14.06[a] (1.19)	2.05[a] (0.22)
Soil treated with T_2	15.47[b] (0.35)	0.710[b] (0.014)	4.49[b] (0.42)	4.64[b] (0.26)	1.28[b] (0.11)	0.198[b] (0.034)	76.82[b] (5.47)	17.00[b] (2.61)	9.06[b] (1.87)	1.50[b] (0.20)
p-value	<0.01	<0.05	<0.01	<0.01	<0.05	<0.01	<0.01	<0.05	<0.01	<0.05
Range *	5-30	1-5	3-30	10-40	1-7	–	40-200	20-100	10-100	2-20

Abbreviations: T_1: municipal waste water; T_2: well water; values are mean of four replications with ± SD in parentheses; different superscripts in column indicate significant differences between T_1 and T_2; * [39].

suggested that the addition of municipal waste water on *Eucalyptus grandis* has been resulted in a doubling of growth rate when compared to *E. grandis* grown in a rain fed site in four years.

The increased growth may be linked to sufficient availability of water and better status of nutrients in soil [42]. Positive correlation between diameter at breast height, height and volume of trees with quantity of N, P and K of soil also supports this inference (Fig. 4). Since municipal waste water contains plant nutrients and organic matter, it may improve the properties of soil for increase in growth and biomass production [43-45]. The increase in growth indicates that waste water application influenced the physiological processes, facilitated early needle initiation and resulted in a net increase in the number of needles. An increase in needles could have captured more solar energy for metabolic use, fixed more CO_2, and produced greater photosynthesis and growth. This hypothesis is supported by Ceulemans et al. [46] and Myers et al. [47].

Changes in Mineral Composition of Needles

The application of municipal waste water significantly increased the macro and micro-elements (N, P, K, Ca, Mg, Na, Fe, Mn, Cu and Zn) concentration of eldar pine tree needles as compared with well water (Table 3). Increases in mineral concentrations may have been due to the effect of nutrient additions through municipal waste water [48]. This result is in agreement with Singh and Bhati [30] and Aghabarati et al. [33], whereas substantially greater above-mentioned mineral concentrations were observed in leaf of *Dalbergia sissoo* seedlings and *Olea europaea* trees irrigated with municipal waste water compared to control. However, Guo et al. [44] and Aghabarati et al. [33] also suggested that a decrease of Mg and Ca, and no difference of Na concentration in leaf of eucalypt and olive tree were treated by municipal waste water. In fact, quantity of nutrient absorption using plants depends on the total quantity of the nutrients applied through waste water application, soil properties and plant type [31].

Mineral concentrations of needles may be ranked from greatest to least as N > Ca > K > Mg > P > Na > Fe > Mn > Zn > Cu. Fe, Mn, Zn and Cu are micro elements and heavy metals that plants need in low values. A high concentration of these metals is toxic to plants [49] because high metal concentrations affect mobilization and balanced distribution of essential elements among different plant parts via competitive uptake [50]. In this study, although municipal waste water application elevated all values compared to well water, the quantity of these elements were within the critical limits indicated by Salardini [39] for plants and were not still hazardous.

The ratios of concentrations of N to P (1.90 ± 0.09), N to Ca (0.270 ± 0.009), N to Mg (1.08 ± 0.07), N to K (0.284 ± 0.020), K to Ca (0.951 ± 0.045), K to Mg (3.82 ± 0.09), P to Ca (0.142 ± 0.007), P to Mg (0.572 ± 0.022), Ca to Mg (4.03 ± 0.15), Fe to Mn (4.50 ± 0.34), Fe to Zn (7.13 ± 0.95), Mn to Zn (1.58 ± 0.12) and Zn to Cu (6.92 ± 0.96) in the needles of municipal waste water trees did not differ with their respective value of 2.04 ± 0.08, 0.334 ± 0.015, 1.21 ± 0.09, 0.347 ± 0.041, 0.974 ± 0.139, 3.54 ± 0.63, 0.163 ± 0.009, 0.595 ± 0.066, 3.63 ± 0.22, 4.59 ± 0.69, 8.70 ± 1.59, 1.90 ± 0.23 and 6.02 ±0.73 (mean ± SD) in the trees of well water treatment. These ratios suggest that the application of municipal waste water did not have a negative impact on the nutrient balance of tree needles [51, 52]. However, the ratios of N to Na (5.15 ± 0.43), K to Na (18.15 ± 1.53), P to Na (2.71 ± 0.20), Ca to Na (19.08 ± 1.34), Mg to Na (4.73 ± 0.28), Fe to Cu (48.74 ± 1.59) and Mn to Cu (10.86 ± 0.81) were reduced and the ratios of K to P (6.69 ± 0.31) were greater in the tree needles of municipal waste water treatment as compared to the corresponding values of 8.00 ± 1.69, 23.27± 5.59, 3.91 ± 0.77, 23.88 ± 4.28, 6.60 ± 1.35, 51.59 ± 3.90, 11.41 ± 1.77 and 5.93 ± 0.60 respectively, in the trees irrigated with well water.

Conclusion

The application of municipal waste water had a positive influence on the growth and production of *Pinus eldarica* trees. Furthermore, the results from the site under study where municipal waste water is being used for about 15 years showed the enrichment of soil with nutrients without excessive accumulation of studied elements in soil and plant. Application of municipal waste water facilitated the availability of valuable essential nutrients and water in soil. Thus, the use of such waste water can effectively increase water resources for irrigation trees in nutrient-poor soil of dry area and create aesthetic and environmental benefits in suburban areas. However, there are factors that need to be considered, for example the concentration of some elements may need to be reduced to a minimum level to avoid any toxic effect in a long-term application. This can be controlled through avoiding entering toxic elements into the waste water and continued monitoring or treatment of waste water before it is let into disposal channel for irrigation.

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References

1. SINGH R.P., AGRAWAL M. Potential benefits and risks of land application of waste water sludge. Waste Manage. **28**, (2), 347, **2008**.
2. HOWE J., WAGNER M.R. Effects of pulp mill effluent irrigation on the distribution of elements in the profile of an arid region soil. Environ. Pollut. **105**, 129, **1999**.
3. TOZE S. Reuse of effluent water-benefits and risks. Agr. Water Manage. **80**, 147, **2006**.
4. SHEREIF M.M., EASA EL-S M., EL-SAMRA M.I., MANCY K.H. A demonstration of wastewater treatment for reuse applications in fish production and irrigation in Suez. Egypt. Water Sci. Technol. **32**, 137, **1995**.
5. ASANO T., MAEDA M., TAKAKI M. Wastewater reclamation and reuse in Japan: overview and implementation examples. Water Sci. Technol. **34**, 219, **1996**.
6. ANDERSON J.M. Current water recycling initiatives in Australia: Scenarios for the 21st century. Water Sci. Technol. **33**, 37, **1996**.
7. MADEJÓN P., MARANON T., MURILLO J.M. Biomonitoring of trace elements in the leaves and fruits of wild olive and holm oak trees. Sci. Total Environ. **355**, 187, **2006**.
8. SHARMA A, ASHWATH N. Land disposal of municipal effluents: Importance of choosing agroforestry systems. Desalination. **187**, 361, **2006**.
9. NEILSON G.H., STEVENSON D.S., FITZPATRICK J.J., Brownlee C.H. Nutrition and yield of young apple trees irrigated with municipal waste water. J. Am. Soc Hortic. Sci. **114**, 377, **1989**.
10. GUPTA A.P., NARWAL R.P., ANTIL R.S. Sewer water composition and its effect on soil properties. Bioresource Technol. **65**, 171, **1998**.
11. RAMIREZ-FUENTESE., LUCHO-CONSTSNTINO C., ESCAMILLA-SILVA E., Dendooven L. Characteristics and carbon and nitrogen dynamics in soil irrigated with waste water for different lengths of time. Bioresource Technol. **85**, 179, **2002**.
12. RATTAN R.K., DATTA S.P., CHHONKAR P.K., SURIBABU K., SINGH A.K. Long-term impact of irrigation with waste water effluents on heavy metal content in soils, crops and groundwater-a case study. Agr. Ecosyst. Environ. **109**, 310, **2005**.
13. SHARMA R.K, AGRAWAL M., MARSHALL F. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotox. Environ. Safe. **66**, 258, **2007**.
14. GASCO´ G., LOBO M.C. Composition of Spanish waste water sludge and effects on treated soil and olive trees. Waste Manage. **27**, (11), 1494, **2007**.
15. EMONGOR V.E., RAMOLEMANA G.M. Treated waste water effluent (water) potential to be used for horticultural production in Botswana. Phys. Chem. Earth. **29**, 1101, **2004**.
16. JAYARAMAN K. A statistical manual for forestry research. FORESPA Publication., pp. 240, **2000**.
17. ZOBEYRI M. Forest Inventory. Tehran University Press, pp. 401, **1994**.
18. HABIBI KASEB H. Forest Pedology. Tehran University Press, pp. 424, **1992**.
19. LETACON F. Une methode originale de prelevemennts foliaires R.F.F. **3**, 196, **1969**.
20. BHATI M., SINNGH G. Growth and mineral accumulation in *Eucalyptus camaldulensis* seedlings irrigated with mixed industrial effluents. Bioresource Technol. **88**, 221, **2003**.
21. YADAV R.K., GOYAL B.,SHARMA R.K., DUBEY S.K., MINHAS P.S. Post-irrigation impact of domestic waste water effluent on composition of soils, crops and ground water-a case study. Environ. Int. **28**, 481, **2002**.
22. OMA. Official Methods of Analysis. 15th ed. Association of Official Analytical Chemists, Arlington, Virginia, USA, **1990**.
23. APHA. Standard methods for the examination of water and wastewater. APHA, AWWA and WPCF. 16th ed., **1992**.
24. JACKSON M.L. Soil Chemical Analysis. Prentice Hall of India Private Ltd., New Delhi, **1973**.
25. BOUYOUCOS G.J. Hydrometer method improved for making particle size analysis of soils. Agron. J. **54**, 464, **1962**.
26. HATI K.M., Biswas A.K., Bandyopadhyay K.K., Misra A.K. Soil properties and crop yields on a vertisol in India with application of distillery effluent. Soil Till. Res. **92**, 60, **2007**.
27. HACH C. Water Analysis Handbook, Loveland, Colorado, USA, pp. 61-62, **2002**.
28. NELSON D.W., SOMMERS L.E. Total carbon, organic carbon and organic matter. In: Bigham, J.M. (Ed.), methods of soil analysis: Part 3. Chemical methods. SSSA, Madison. pp, 961-1010, **1996**.
29. OLSEN S.R., COLE C.V., WATANABE F.S., DEAN L.A. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. In: USDA Circ. 939, USDA, Washington, DC, **1954**.
30. SINGH G., BHATI M. Growth of *Dalbergia sissoo* in desert regions of western India using municipal effluent and the subsequent changes in soil and plant chemistry. Bioresource Technol. **96**, 1019, **2005**.
31. BOZKURT M.A., YARILGA T. The effects of waste water sludge applications on the yield, growth, nutrition and heavy metal accumulation in apple trees growing in dry conditions. Turk. J. Agric. For. **27**, 285, **2003**.

32. PATEL K.P., PANDYA R.R., MALIWAL G.L., PATEL K.C., RAMANI V.P., GEORGE V. Heavy metal content of different effluents and their relative availability in soils irrigated with effluent waters around major industrial cities of Gujarat. J. Ind. Soc. Soil Sci. **52**, 89, **2004**.
33. AGHABARATI A., HOSSEINI S.M, ESMAEILI A., MARALIAN H. Growth and mineral accumulation in *Olea europaea* L. trees irrigated with municipal effluent. Res. J. Environ. Sci. **2**, (4), 281, **2008**.
34. MATHAN K.K. Studies on the influence of long-term municipal waste water-effluent irrigation on soil physical properties. Bioresource Technol. **48**, 275, **1994**.
35. IVAN F.S., EARL E.A. Soil limitations for disposal of municipal waste waters. Michigan State University Research Report. **195**, 54, **1972**.
36. MITRA A., GUPTA S.K. Effect of sewage water irrigation on essential plant nutrient and pollutant element status in vegetable growing area around Calcutta. Ind. J. Soc. Soil Sci. **42**, 35, **1999**.
37. BADDESHA H.S., CHABBRA R., GHUMAN B.S. Change in soil chemical properties and plant nutrient content under *Eucalyptus* irrigated with waste water water. J. Ind. Soc. Soil. Sci. **45**, 358, **1985**.
38. KUMAR A., YADAV B.R., SINGH S.K., PATHAK H. Effect of mixed industrial effluent on properties of ground water and irrigated soil. J. Ind. Soc. Soil Sci. **46**, 427, **1998**.
39. SALARDINI A. Soil Fertility. Tehran University Press, pp. 440, **1992**.
40. LI T.Y., BAOZHONG P., HOUQIN H., KORONG J., MONGGAE C., DISHEITANE K. Sino-Botswana Government. Experimental irrigation project at Glen Valley Water Care Works, Final report, **2001**.
41. STEWART H.T.L., HOPMANS P., FLINN D.W., HILLMAN T.J. Nutrient accumulation in trees and soil following irrigation with municipal effluent in Australia. Environ. Pollut. **63**, 155, **1990**.
42. LARCHEVÊQUE M., BALLINI C., KORBOULEWSKY N., MONTES N. The use of compost in afforestation of mediterranean areas: Effects on soil properties and young tree seedlings. Sci. Total Environ. **369**, 220, **2006**.
43. EGIARTE G., CAMPS ARBESTAIN M., ALONSO A., RUI´Z-ROMERA E., PINTO M. Effect of repeated applications of waste water sludge on the fate of N in soils under Monterey pine stands. For. Ecol. Manage. **216**, 257, **2005**.
44. GUO L.B., SIMS R.E.H., HORNE D.J. Biomass production and nutrient cycling in *Eucalyptus* short rotation energy forests in New Zealand. I: biomass and nutrient accumulation. Bioresource Technol. **85**, 273, **2002**.
45. LOPEZ A., POLLICE A., LONIGRO A., MASI S., PALESE A.M., CIRELLI G.L., TOSCANO A., PASSINO R. Agricultural wastewater reuse in southern Italy. Desalination. **187**, 323, **2006**.
46. CEULEMANS R.J., PONTAILLER F.M., GUITTET J. Leaf allometry in young poplar stands: reliability of leaf area index estimation, site and clone effects. Biomass Bioenerg. **4**, 769, **1993**.
47. MYERS B.J., THEIVEYANATH S.O., BRIAN N.O., BOND W.J. Growth and water use of *Eucalyptus grandis* and *Pinus radiata* plantations irrigated with effluent. Tree Physiol. **16**, 211, **1996**.
48. MELI S., PORTO M., BELLIGNO A., BUFO S.A., MAZZATURA A., SCOPA A. Influence of irrigation with lagooned urban wastewater on chemical and microbiological soil parameters in a citrus orchard under mediterranean condition. Sci. Total Environ. **285**, 69, **2002**.
49. MACNAIR M.R. Transley review No. 49. The genetic metal tolerance in vascular plants. New Physiologist. **124**, 541, **1993**.
50. SCHAT H., TEN BOOKUM W.M. Metal specificity of metal tolerance syndromes in higher plants. In: Proter, J.A., Baker, J.M., Reeves, R.D.(Eds.), The Ecology of Ultramafic (serpentine) Oils, Intercept Andover, MA, pp. 337-352, **1992**.
51. MALKANATHI D.R.R., MORTSUGU M., YOKOYAMA K. Effect of low pH and Al on absorption and translocation of some essential nutrients in excised barley roots. J. Soil Sci. Plant. Nutr. **41**, 253, **1995**.
52. WHEELER P.M., EDMEADES D.C., CHRISTIE R.A. Effect of aluminum on relative yield and plant chemical concentrations of cereals grown in solution culture at low ionic strength. J. Plant Nutr. **15**, 403, **1992**.