Impact of Municipal Waste Water on Growth and Nutrition of Afforested *Pinus eldarica* Stands

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1. Introduction

As a whole, water is a most important source for plantations particularly in the dry regions (Mosadegh, 1999). In other hand, wastewater can be used to cover the needs of urban and rural areas and parks as well as industrial complexes to develop green space and to reduce air pollution (Al-Jamal *et al*., 2000; Singh and Bhati, 2005; Sharma, *et al*., 2007). In reality, wastewater except the water resource for irrigating the plantations is an enormous nutrient source, too (Meli *et al*., 2002; Rattan *et al*., 2005). Of course, establishment of trees plantation for waste water irrigation has been a common practice for many years. The practice not only defers ecological degradation by the pollutants in the soil, because trees are long-living organisms which can take up trace elements from the soil, water or air and retain them for a long time (Madejo´n *et al*., 2006). But it also creates opportunities for commercial biomass production and sequestration of excess minerals in the plant system (Sharma and Ashwath, 2006). Therefore, the use of waste water in growing woodlots is a viable option for the economic disposal of waste water (Neilson *et al*., 1989). Moreover, waste water from municipal origin is rich in organic matter and also contains appreciable amounts of macro and micro-nutrients (Gupta *et al*., 1998). Accordingly nutrients levels of soil are expected to improve considerably using continuous irrigation with municipal waste water (Ramirez-Fuentes *et al*., 2002; Rattan, *et al*., 2005). Apart from this, in the case of the utilization of wastewater mixed with harmful heavy metals lead to decrease the toxicity, through a developed rooting system in plantations (Karpiscak *et al*., 1996) and as such, play the important and fundamental role for the environmental protection (Cromer *et al*., 1987; Stewart *et al*., 1990). However, this can not be ignored that the use of wastewater for irrigation purposes might damage the ecosystem because the high toxic concentration and heavy metals (Gupta *et al*., 1998; Brar *et al*., 2000; Yadav *et al*., 2002). The accumulation of heavy metals in soil is related to pH, texture and cation exchange capacity of soil (Datta *et al*., 2000). Therefore, decision about the application of wastewater should be made based on the views of specialties of water, soil, plant and environment of every location (Nagshinepour, 1998).

Iran is a part of arid regions in the world being encountered acute crises owing to the increased population and need of water resources (Tabatabaei, 1998). It is noteworthy saying that thousands liters of domestic, industrial and hospital effluents are daily flowing from Tehran metropolitan area and influence the underground water resources. In the same way, 80 percent of the useful water of the citizens in Tehran is also transformed as municipal effluent (Tajrishi, 1998). On the other side, unplanned expansion and air pollution of Tehran make it unavoidable to increase the green space. In reality, urban green space and green belt around the city can play an effective role in air purification and climate health. Since the lack of water is a limiting factor for development of green space, therefore municipal effluent may be suitable (Torabian and Hashemi, 1999).

Till now inside the country several researches have been conducted about effect of municipal effluent on soil and agricultural crops, but not on softwoods. The objective of this study was to investigate the effects of the 15 years municipal waste water application on the growth of *Pinus eldarica* Medw. trees and the minerals accumulation in the trees needles.

2. Materials and methods

The study site is an abandoned agriculture site located in Shahr-e Rey, 5 Km south of Tehran-Iran (Latitude 35° 37' N, Longitude 51° 23' E, 1005 m above sea level). The climate of the site is semi-arid with mild-cold winters and 7 months (Mid April-Mid November) dry season (Fig. 1). Average annual rainfall and average annual temperature are 232 mm and 13.3° C, respectively. The highest rainfall appears in March and the lowest in August. The warmest month occurs in August and the coldest in January. Experiment was conducted at two 4 hectare even-aged (15 years) artificial stand of *Pinus eldarica* Medw. The first stand was irrigated with municipal waste water and the second with well water since plantation. 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

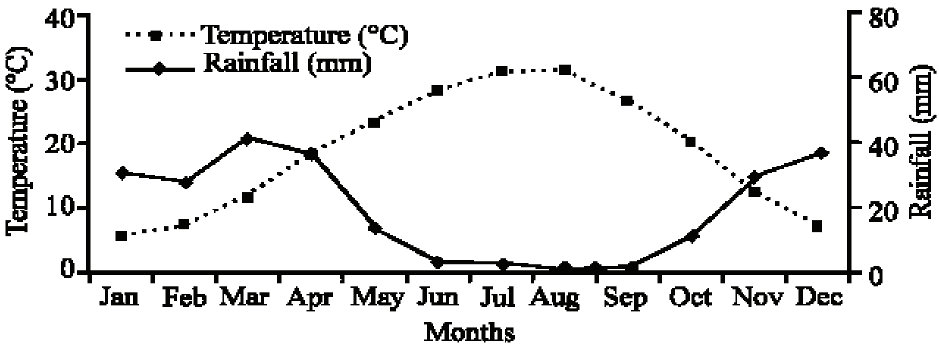

Fig. 1. Embrothermic curve of the study site

The study was established in October 2006. Data was collected using technique of systematic random sampling (Jayaraman, 2000) with 4 replications in either of both fields. Therefore, four plots were identified in each field of irrigated with municipal waste water and well water. Plots were 30 m × 30 m, with tree spacing of 3 m × 4 m (833/ha). In each plot, diameter at breast height (d.b.h.), 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 $V = 0.4 \times D^2 \times H$, made by Zobeyri

(1994). Where, D is diameter at breast height (d.b.h.), H is total height and V is standing volume.

In each plot, four trees were selected and at the end of growing season needle samples of *P. eldarica* trees taken from the top of crown and the part affected by sunlight (Letacon, 1969; Habibi Kaseb, 1992). This collection provided 16 needle samples in each treatment. At the end of the sampling, one representative needle sample from each plot (by mixing of four samples of each plot) was taken (due to decreasing of samples quantity for chemical analysis). 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.

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 4 °C to minimize microbial decomposition of solids (Yadav *et al.*, 2002; Bhati and Singh, 2003). Several parameters were measured separately, pH and EC by the procedure described using OMA (1990), NH_4-N, NO_3-N, PO_4-P, K, Ca, Mg and Na as per the method given by APHA (1992) and Yadav *et al.* (2002).

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 (Bhati and Singh, 2003). Samples of needle were washed using tap water, rinsed with distilled water, oven dried at 80 °C for 24 h (Singh and Bhati, 2005), ground in a stainless steel mill and retained for mineral analysis. For determination of macro and micro-nutrients exception P and N, the needle samples were wet digested as per Jackson (1973) and estimated using an Atomic Absorption Spectrophotometer (AAS). Measurement of P content was performed after a wet digestion using UV–VIS spectrophotometer at 450 nm (Singh and Bhati, 2005). The N content of needle samples digested in concentrate sulfuric acid was determined by the Kjeldahl method (Bhati and Singh, 2003; Bozkurt and Yarilga, 2003).

Average growth parameters and needle nutrients of two irrigation treatments (T_1: irrigation by municipal waste water; T_2: irrigation by well water) were compared using independent-samples t-test. The variations in characteristics of municipal waste water and well water were firstly tested for normality using Shapiro-Wilk's test and then by independent-samples t-test. All the data were analyzed using the SPSS statistical package.

3. Results and discussion

3.1 Waste water and well water

Results indicated that the waters were alkaline in reaction (Table 1). 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.* (2004), 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 (Rattan *et al.*, 2005). The pH and EC of the municipal waste water were greater than those of the 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^+ in municipal waste water were greater compared to those in the well water. The most nutrients concentration of municipal waste water were reduced in autumn and increased in summer because of high temperature and evaporation losses of water (Singh and Bhati, 2005).

Although municipal waste water elevated significantly ($P < 0.01$) in all values compared to well water, but the analysis showed that pH, EC, NO_3-N, PO_4-P, K^+, Na^+ 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 (Hach, 2002). However, the contents of NH_4-N and Ca^{2+} of municipal waste water and well water and Mg^{2+} of municipal waste water were on the higher side (Table 1).

Parameters	Municipal waste water		Well water		WHO*
	Range (Min.-Max.)	Mean ± SE	Range (Min.-Max.)	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
NH_4-N (mg l^{-1})	8.1 - 10.24	9.05 ± 0.11 a	1.83 - 2.49	2.15 ± 0.19 b	1.5
NO_3-N (mg l^{-1})	1.58 - 1.89	1.63 ± 0.09 a	0.19 - 0.33	0.24 ± 0.08 b	3
PO_4-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

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): Hach, 2002

Table 1. Characteristics of municipal waste water and well water

3.2 Tree growth

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 on field 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 waste water irrigated field (Table 2). 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.* (2008). The study of Stewart *et al.* (1990) also 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 (Larchevêque *et al.*, 2006). Since municipal waste water contains plant nutrients and organic matter, it may improve the properties of soil for increase in growth and biomass production (Guo *et al.*, 2002; Egiarte *et al.*, 2005; Lopez *et al.*, 2006). 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.* (1993) and Myers *et al.* (1996).

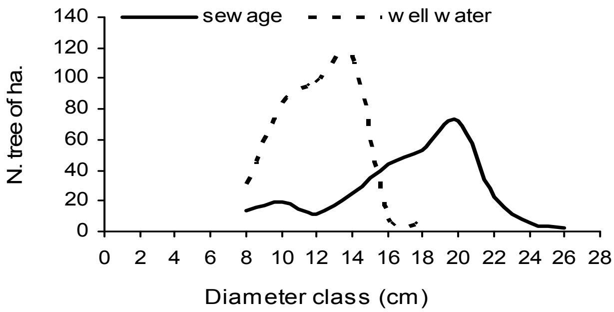

Fig. 2. Distribution of diameter classes for *P. eldarica* trees in two irrigation types

Irrigation type	Diameter at breast height (cm)	Height (m)	Crown length (m)	Crown diameter (m)	Basal area (cm^2)	Standing volume (m^3)
Trees irrigated with waste water	17.95 [a] (1.33)	10.04 [a] (0.15)	8.0 [a] (0.27)	2.53 [a] (0.17)	264.20 [a] (30.02)	0.139 [a] (0.013)
Trees irrigated with well water	13.50 [b] (0.5)	9.02 [b] (0.10)	7.3 [b] (0.12)	1.90 [b] (0.20)	135.0 [b] (20.5)	0.65 [b] (0.09)

-Different superscripts in column indicate significant difference of each tree attribute between two irrigation types.
-Values in parenthesis are ± SE.

Table 2. Effect of municipal waste water and well water on growth of *P. eldarica* trees

3.3 Mineral composition of needles

The application of municipal waste water significantly increased the macro-elements (N, P, K, Ca, Mg, Na concentration of *P. eldarica* trees needle as compared with well water (Table

3). Increases in minerals concentration may have been due to the effect of nutrients addition through municipal waste water (Meli *et al*., 2002). This result is in agreement with Singh and Bhati (2005) and Aghabarati *et al.* (2008), whereas a substantially greater above-mentioned minerals concentration were observed in leaf of *Dalbergia sissoo* seedlings and *Olea europaea* trees irrigated with municipal waste water compared to control. However, Guo *et al.* (2002) and Aghabarati *et al.* (2008) had 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 nutrients absorption using plant depends upon the total quantity of the nutrients applied through waste water application, soil properties and type of plant (Bozkurt and Yarilga, 2003). The minerals concentration of needle may be ranked from greatest to least as N > Ca > K > Mg > P > Na.

	N	P	K	Ca	Mg	Na
	-------------------------------- gr 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)
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)
p-value	<0.01	<0.05	<0.01	<0.01	<0.05	<0.01
Range *	5-30	1-5	3-30	10-40	1-7	------

Abbreviations: T_1: municipal waste water; T_2: well water; values are mean of four replications with ± SD in parentheses; different superscripts in column indicates significant difference between T_1 and T_2; * Salardini (1992)

Table 3. Mineral composition of *P. eldarica* trees needle by affected by municipal waste water and well water

4. Conclusion

Our study displayed that all growth parameters measured in *P. eldarica* trees were statistically greater in effluent-irrigated area than in well-watered area. As a whole, the use of municipal effluent in irrigations can be an overflowing resource from the nutrient elements required for plants (Yadav *et al*., 2002; Mapanda *et al*., 2005; Toze, 2006). As a matter of fact, high nutrient concentrations in effluent, compared to those in well water, cause the nutrient accumulation in the soil (Stewart and Flinn, 1984; Phillips *et al*., 1986; Stewart *et al*., 1990; Keller *et al*., 2002; Selivanovskaya *et al*., 2002; Emongor and Ramolemana, 2004) and makes easy the access of plants to the high nutrient concentration (macro and micro elements) and increases their growth. Accordingly, in agreement with our findings the results of Stewart and Flinn (1984, on *Pinus eldarica*), Phillips *et al*. (1986, *Pinus eldarica*), Ostos *et al*. (2007, on *Pistacia lentiscus*) show that faster growth of tree occurs in the effluent-irrigated areas. This is mostly due to high nutrient concentration in effluent. It may be also noted that the nutrient contents in the municipal effluent is more than needed by plants whereas in the such conditions trees can produce greater biomass (Fitzpatrick *et al*., 1986; Martinez *et al*., 2003; Sing and Bhati, 2005; Guo *et al*., 2006). Regarding the differences indicated above and positive effects of effluent on the growth of *P. eldarica*, it can be recommended that the produced huge municipal effluent in south of Tehran can be used for accomplishment of plantation projects and for development of rural and urban green spaces and green belts around the city and for reduction of air pollution, too. It is necessary to clarify that the decision for each location should be made based on accurate management, chemical, physical and microbial characteristics of water, soil and plant, according to international standards.

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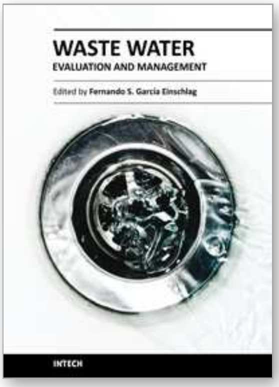

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Fresh water resources are under serious stress throughout the globe. Water supply and water quality degradation are global concerns. Many natural water bodies receive a varied range of waste water from point and/or non point sources. Hence, there is an increasing need for better tools to asses the effects of pollution sources and prevent the contamination of aquatic ecosystems. The book covers a wide spectrum of issues related to waste water monitoring, the evaluation of waste water effect on different natural environments and the management of water resources.