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Utilization of Sewage Effluent for Irrigation of Tree Species

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Abstract: Reuse of treated effluent is a highly valued water source in arid and semiarid regions. This research was performed to study the effects of sewage effluent irrigation on growth of 14 tree species. The experiment was laid out as a split-plot design. Main plots were devoted to irrigation treatments including sewage effluent and borehole water, while the subplots were allocated to tree species. Results showed that there was no significant difference between borehole water and effluent on the tested tree species for all measured growth indices. By the end of the second year of establishment, *Eucalyptus microtheca* was the most promising species with 99 survival percentage, followed by *Eucalyptus camaldulensis* and *Acacia stenophylla*, with 97 survival percentage. Minimum survival percentage (26%) was observed for *Platanus orientalais,* significantly less than all of the tested species. Growth indices of tree species irrigated with effluent was slightly better than the borehole water. Effluent irrigation proved to be more suitable from soil and environmental point of view and *Eucalyptus microtheca*, *Eucalyptus camaldulensis, Acacia stenophylla* and *Tamarix apphylla* were the most promising species suitable for plantation, disposal of municipal effluent and developing green spaces in urban areas.

Key words: Tree species · Growth indices · Survival percentage · Effluent irrigation

INTRODUCTION

Fresh water availability to meet the growing needs of mankind has raised serious concerns in recent years. Efficient allocation of the scarce water resources, development and use of alternative sources of water are possible options to mitigate this problem. Treated wastewater and low-quality water are now considered as potential sources of water to supplement the freshwater supplies. However, the use of reclaimed water as an alternative imposes concerns regarding its suitability to sustainable development due to wastewater usage and application. The reuse of effluent for irrigation involves the application of water to cropland soils which is inherently of lower quality than fresh water. This water may contain high level of salts, toxic ions, heavy metals and organic residues. Accumulation of these pollutants in water and soil poses a threat to agricultural production and the environment [1].

Irrigation of tree crops is not only a practical means of effluent disposal on land but also a method of reusing effluents with minimal health risks [2]. Tree plantations are preferred for producing commercial wood, consuming large amount of wastewater as well as nutrients and reducing movement of wastewater to rivers [3]. An additional benefit of using plantations is the absorption of existing toxic elements in the reclaimed water by the biomass, preventing the food chain from pollution [4].

Hopmans ***et al.*** [5] evaluated the growth and biomass production of seven tree species irrigated with municipal effluent at Wodonga, Australia. He reported that height and diameter of trees varied significantly. At the age of four, mean dominant height of *Eucalyptus grandis*, *Eucalyptus saligna* and *Populus deltoides* × *Populus nigra* ranged from 14.3 to 15.0 m compared to 6.6 to 9.8 m for *Casuarinas conninghamiana*, *Eucalyptus camaldulensis*, *Populus deltoides* and *Pinus radiata*. Wood production of fast-growing species (*Eucalyptus grandis* and *Eucalyptus saligna*) was approximately 139 m^3 ha^{-1}, around 32 m^3 ha^{-1} $year^{-1}$ over a 4-year period.

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Singh and Bhati [6] studied the growth, biomass production and nutrient composition of *Eucalyptus camaldulensis* seedlings irrigated with municipal effluent. They concluded that municipal effluent utilization for raising forest plantation is a better option than agricultural crops. Trees produce more biomass in a short period and do not interfere with human food chain. The increase in seedlings growth and biomass can be achieved by increase in the application rate of municipal effluent at appropriate level because it not only provides supplementary organic matter resources, but also provides valuable amendments in the form of essential nutrients in water and soil of arid and semiarid areas. Biomass production by using municipal effluent as the source of irrigation was about two fold greater compared to the biomass produced by fresh water irrigation [6]. Bhati and Singh [7] reported that seedlings of *Eucalyptus camaldulensis* irrigated with municipal effluent had 13% greater height and %5 greater collar diameter than those irrigated with good water. Suitability of land disposal of wastewater by irrigating crops and biomass production of *Helianthus tuberosus* L. has been reported by Parameswaran [8].

Cromer *et al.*, [9] reported that irrigation of Monterey pine with wastewater led to substantial increases in tree growth and the concentration of some nutrients in the foliage. Lopez *et al.* [10] reported that olive trees irrigated with treated effluent in Southern Italy caused a yield increase of 50%. Irrigation practice improved fruit characteristics such as weight and flesh to pit ratio which are very important parameters for marketing table olives in comparison to trees grown in rain-fed conditions.

Hassanli *et al.* [11] reported that the irrigation of different tree species with sewage effluent had no adverse effect on soil properties. The soil salinity was reduced from 8.2, 6.8 and 7.0 dS m^{-1} to 1.07, 1.12 and 3.5 dS m^{-1} in the soil layers 0–30, 30–60 and 60–90 cm, respectively. The SAR decreased significantly, while soil pH increased by 0.8 and 0.6 units in the layers 0–30 and 30–60 cm. A total application of 9,335 m^3ha^{-1} of effluent with a nitrogen and phosphorus concentration of 7.9 and 10.3 mg l^{-1}, added 73 and 101 kg ha^{-1} of nitrogen and phosphorus to the soil. Also organic carbon significantly increased. Twenty-five months irrigation with effluent caused a slight increase in soil bulk density and a meager decrease in mean permeability.

This research was carried out to study the utilization of sewage effluent for irrigation of 14 tree species and to evaluate the effects of effluent on survival and growth of the trees.

MATERIALS AND METHODS

This study was carried out from February 2002 to April 2004 in the Marvdasht city sewage treatment station (South of Iran), at a latitude of 29° 47`, longitude of 52° 42`and an altitude of 1604 m above sea level with average annual precipitation of 340 mm and potential evaporation of 2585 mm. The climate is semi-arid with hot and dry summers. Soil texture of the experimental site was silty clay loam for layer 0-30 cm, silty clay from 30 to 120 cm and sandy loam from 180 to 270 cm with poor drainage condition. Soil moisture on volume basis at field capacity was 22.3, 23.9 and 23.5% and at permanent wilting point was 17.4, 18.9 and 19.4% in horizons 0-30, 30-60 and 60-90 cm, respectively.

The experiment was laid out as a split-plot design. The main plots consisted of sewage effluent and borehole water (local underground water) and subplots consisted of 14 tree species including: *Acacia stenophylla, Acer negundo, Ailanthus altissima, Cupressus sempervirens var. horizontalis, Eucalyptus camaldulensis, Eucalyptus microtheca, Fraxinus rotundifolia, Morus alba, Olea europea, Pinus eldarica, Platanus orientalis, Populus alba, Robinia pseudoacacia, Tamarix aphylla*. Treatments were arranged in a completely randomized block design with three replications, each replication containing 16 trees. Hard wood cuttings of *Morus alba* and *Tamarix aphylla* and the seedlings of the remaining species were planted at 2.5 m × 3.0 m spacing in February 2002 and irrigated. Two independent bubbler systems were designed to supply the effluent and the borehole water to plots. Irrigation requirement was determined using pan evaporation from the nearest meteorological station. To mitigate the environmental effects of effluent, a bubbler irrigation system (drip irrigation with higher and continuous discharge) was designed and the volume of irrigation water was measured by volumetric water meters. Irrigation water at an annual rate of 3940 m^3 ha^{-1} in the first year and 5395 m^3 ha^{-1} in the second year was scheduled weekly. The effluent applied in this study was collected from sewage treatment station of Marvdasht city with 50000 populations. Sewage effluent was treated as secondary treatment and classified as a moderate effluent (neither low nor high hazard effluent) and with 0.4 mg l^{-1} B, 7.9 mg l^{-1} N and 10.76 mg l^{-1} P may be classified as a low hazard effluent [12]. More chemical composition of this effluent is reported by Hassanli *et al.* [13]. Although the quality of secondary treatment of effluent from chemical point of view is acceptable for plantation irrigation and for trees the microbiological quality also

Table 1: Chemical characteristics of effluent and borehole water used for irrigation of 14 tree species

Irrigation water	EC dS m^{-1}	SAR	pH	total N (ppm)	total P (ppm)	K (ppm)	Cl- (ppm)	Na+ (ppm)	B(ppm)
Effluent	1.5	5.1	7.7	7.9	10.76	3.2	257.2	209	0.4
Borehole	2.0	9.9	7.6	11.1	1.78	1.8	270.6	423	0.3

needs to be considered from health point of view. However, microbiological assessment was out of scope of this study. Electrical conductivity, pH, suspended solids (SS), chemical oxygen demand (COD) and biological oxygen demand (BOD) (per 100 ml) of sewage effluent was 1.5 dS m^{-1}, 7.7, 34-40 mg l^{-1}, 52-58 mg l^{-1} and41-48 mg l^{+} respectively. Several chemical characteristics of effluent and borehole water are shown in Table 1. Initial growth indices including survival percentage, height and collar diameter were recorded in June 2002, while final growth indices were collected in January 2004. Statistical analyses were performed using GLM procedures on SAS [14].

RESULTSAND DISCUSSION

Growth indices of trees irrigated with effluent water was not significantly different from those irrigated with borehole water (Table 2) at the end of the experiment, indicating the potential use of effluent water for tree planting. This is in agreement with reports of Singh and Bhati [6], Bhati and singh [7] and Stewart *et al.* [2]. Growth indices of different tree species irrigated with effluent and borehole water was significantly different due to their different growth habits (Table 2) and in agreement with the reports of Hopmans *et al.* [5]. However, most species irrigated with effluent showed higher survival percentage, height and collar diameter, compared with those received borehole water (Table 3). This might be due to nutrient availability and a slightly better quality of effluent compared to borehole water extracted from the groundwater in the experimental site, which ultimately affect the measured growth indices that have already been reported by Hassanli *et al.* [11]. Marvdasht effluent with 44.5 mgl^{-1} BOD, 257 mgl^{-1} Cl and 5 unit SAR is classified as a moderate effluent [12] and with 0.4 mgl^{-1} B, 7.8 mgl^{-1} total N and 10.8 mgl^{-1} total P is classified as a low hazard effluent [4] and more suitable from soil and environmental point of view compared to borehole water.

Survival percentage of *Eucalyptus microtheca* was maximum (98.96%), significantly greater than those of *Olea europea*, *Platanus orientalis*, *Tamarix aphylla*, *Ailanthus altissima*, *Pinus eldarica* and *Acer negundo* (Table 2). *Acacia stenophylla* and *Eucalyptus camaldulensis* were other promising species showing 96.88 survival percentage. However, *Acacia stenophylla* suffered from frost injury (an absolute minimum of -6.2 °C) in January 2002, thus this species is not suitable for cold regions and in agreement with the report of Saadat *et al.* [16]. However, it is an interesting species for plantation with effluent water in tropical areas. *Tamarix aphylla* with 68.5 survival percentage was another species suitable for plantation with effluent water due to its resistance to salinity and high water requirements as reported by Altaf *et al.* [15], Saadat *et al.* [16] and Malik and Sheikh [17]. Hardwood cuttings of this species were used instead of seedlings and this might be responsible for low survival percentage. The survival of *Robinia pseudoacacia* and *Fraxinus rotundifolia* was 94.8 percent. The survival percentage of *Morus alba* was also 89.5. However, due to the poor height, collar diameter, general performance and other growth characteristics, these species are not suitable for plantation with effluent. Low growth rate, necrosis of leaves and morphological disorders were observed in these species irrigated with both effluent and borehole water. *Platanus orientalais* showed minimum survival percentage (26%), significantly less than other species. *Olea europea*, *Acer negundo* and *Ailanthus altissima* showed a poor survival percentage and growth rate. In contrast to the results of olive trees in this study, Lopez *et al.* [10] reported that olive trees irrigated with treated effluent in Southern Italy caused a yield increase and improved fruit characteristics. This difference might be due to soil texture (sandy loam versus to clay loam and poor drainage in experimental site of this study) and the age of trees. *Populus alba* with 83% survival is a desirable species for wood production, however, leaf necrosis was observed indicating its sensitivity to high concentration of sodium and chlorine. Plantation of this species with municipal effluent may be recommended in regions with better soil conditions. Height of *Eucalyptus camaldulensis* was maximum at the end of the experiment and significantly higher than all of the other species (Table 2) indicating the suitability of this species for wood production using sewage effluent and in agreement with Hopmans *et al.* [5].

In general, the quality of effluent was slightly better than the borehole water extracted from the groundwater in the experimental site and more suitable from soil and environmental point of view compared to borehole water. Most species irrigated with effluent showed higher

Table 2: The effects of different irrigation water and tree species on measured growth indices of trees after 23 months

Irrigation water	Survival percentage	Height(cm)	Collar diameter (mm)
Effluent	77.23 a	133.537 a	20.69 a
Borehole Water	74.58 a	125.20 a	19.53 a
Tree species			
Acacia stenophylla	96.88ab	199.35 b	19.5 abc
Acer negundo	58.98 d	102.89 ef	14.36 bc
Ailanthus altissima	56.25 d	56.63 gh	51.45 a
Cupressus sempervirens var. horizontalis	88.54 abc	78.74 fg	11.45 c
Eucalyptus camaldulensis	96.88 ab	316.58 a	49.61 ab
Eucalyptus microtheca	98.96 a	181.07 b	30.32 abc
Fraxinus rotundifolia	93.75 abc	112.36 de	17.68 abc
Morus alba	92.50 abc	85.88 f	31.63 abc
Olea europea	52.98 d	45.56 h	12.41 c
Pinus eldarica	72.92 bcd	91.18 ef	20.41 abc
Platanus orientalis	53.13 d	129.43 cd	16.85 abc
Populus alba	82.29 abc	147.79 c	22.73 abc
Robinia pseudoacacia	94.79 abc	79.04 fg	13.11 bc
Tamarix aphylla	71.88 cd	182.49 b	23.74 abc
Interaction	ns	ns	ns

* Means in each column followed by the same letter are not significantly different at P<0.01.

ns Non significant at P<0.01

Table 3: The effects of different irrigation water on growth indices of 14 tree species after 23 months using T-test*φ

	Survival percentage		Height (cm)		Collar diameter (mm)	
Species	Effluent	Borehole Water	Effluent	Borehole Water	Effluent	Borehole Water
Acacia stenophylla	93.75 a	100.00 a	197.11 a	201.58 a	18.62 a	20.38 a
Acer negundo	43.75 a	56.25 a	95.95 a	109.82 a	13.59 a	15.13 a
Ailanthus altissima	45.83 a	52.08 a	63.27 a	49.99 a	15.63 a	13.34 a
Cupressus sempervirens var. horizontalis	83.33 a	93.75 a	88.75 a	68.73 a	12.59 a	10.31 a
Eucalyptus camaldulensis	95.83 a	97.92 a	341.72 a	291.44 a	55.05 a	44.16 a
Eucalyptus microtheca	100.00 a	97.92 a	188.69 a	173.44 a	32.15 a	28.49 a
Fraxinus rotundifolia	95.83 a	93.75 a	113.63 a	111.09 a	17.25 a	18.10 a
Morus alba	95.42 a	93.75 a	89.83 a	81.92 a	16.30 a	13.63 b
Olea europea	50.83 a	54.17 a	43.00 a	52.12 a	12.48 a	12.33 a
Pinus eldarica	58.33 b	87.50 a	83.02 a	99.64 a	15.20 b	25.62 a
Platanus orientalis	35.42 a	16.67 a	128.95 a	129.92 a	15.95 a	17.75 a
Populus alba	91.67 a	75.00 a	156.59 a	139.00 a	25.13 a	20.33 a
Robinia pseudoacacia	93.75 a	95.83 a	78.95 a	79.13 a	12.32 a	13.90 a
Tamarix aphylla	70.42 a	66.67 a	200.06 a	164.92 b	27.45 a	20.02 b

* Growth indices of each species irrigated with different kinds of water followed by the same letter are not significantly different at P<0.05

φ Each value is the mean of 48 trees

survival percentage, height and collar diameter, compared with those received borehole water (Table 3) indicating the suitability of effluent for tree plantation. Therefore, land based disposal of municipal effluent by irrigating tree crops is feasible in Korbal plain and in the lands around the Marvdasht city sewage treatment station. The quality of effluent in terms of salinity and SAR as shown in Table 1 was slightly better than the borehole water extracted from the groundwater in the experimental site and more suitable from soil and environmental point of view compared to borehole water. However, the quality of effluent from microbiological point of view because of the level of treatment which was secondary treatment was not better than the borehole water. Microbiological analysis of both irrigation waters is out of the scope of this paper.

Table 4: The effects of different irrigation water on height of 14 tree species φ

Species	Initial height (cm)		Height after 18 months (cm)		Height increment after 18 months (mm)		Ratio of height after 18 months to initial height	
	Effluent	Borehole Water	Effluent	Borehole Water	Effluent	Borehole Water	Effluent	Borehole Water
Acacia stenophylla	96.16	85.33	197.11	201.58	100.95	116.25	2.05	2.36
Acer negundo	92.55	110.18	95.95	109.82	3.40	-0.36	1.04	1.00
Ailanthus altissima	163.93	165.97	63.27	49.99	-100.66	-115.98	0.39	0.30
Cupressus sempervirens var. horizontalis	93.75	92.64	88.75	68.73	-5.00	-23.91	0.95	0.74
Eucalyptus camaldulensis	68.26	67.36	341.72	291.44	273.46	224.08	5.01	4.33
Eucalyptus microtheca	76.34	76.01	188.69	173.44	112.35	97.43	2.47	2.28
Fraxinus rotundifolia	94.81	98.35	113.63	111.09	18.82	12.74	1.20	1.13
Morus alba	57.21	61.00	89.83	81.92	32.62	20.92	1.57	1.34
Olea europea	32.71	32.57	43.00	52.12	10.29	19.56	1.31	1.60
Pinus eldarica	72.54	74.51	83.02	99.64	10.48	25.13	1.14	1.34
Platanus orientalis	120.50	133.05	128.95	129.92	8.45	-3.13	1.07	0.98
Populus alba	112.53	115.08	156.59	139.00	44.06	23.92	1.39	1.21
Robinia pseudoacacia	142.19	147.86	78.95	79.13	-63.24	-68.73	0.56	0.54
Tamarix aphylla	16.25	16.57	200.06	164.92	183.81	148.35	12.31	9.95

φ Each value is the mean of 48 trees

Table 5: The effects of different irrigation water on collar diameter of 14 tree species φ.

Species	Initial Collar) diameter (mm		Collar diameter after 18 months (mm)		Growth of Collar diameter after 18 months (mm)		Ratio of collar diameter after 18 months to initial collar diameter	
	Effluent	Borehole Water	Effluent	Borehole Water	Effluent	Borehole Water	Effluent	Borehole Water
Acacia stenophylla	0.53	0.66	18.62	20.38	18.09	19.72	35.13	30.88
Acer negundo	0.85	0.95	13.59	15.13	12.74	14.18	15.99	15.93
Ailanthus altissima	1.86	2.00	15.63	13.34	13.77	11.34	8.40	6.67
Cupressus sempervirens var. horizontalis	0.85	0.87	12.59	10.31	11.74	9.44	14.81	11.85
Eucalyptus camaldulensis	0.71	0.69	55.05	44.16	54.34	43.47	77.54	64.00
Eucalyptus microtheca	0.60	0.56	32.15	28.49	31.55	27.93	53.58	50.88
Fraxinus rotundifolia	0.98	1.13	17.25	18.10	16.27	16.97	17.60	16.02
Morus alba	2.07	1.81	16.30	13.63	14.23	11.82	7.87	7.53
Pinus eldarica	1.49	1.56	15.2	25.62	13.71	24.06	10.20	16.42
Platanus orientalis	1.51	1.97	15.95	17.75	14.44	15.78	10.56	9.01
Populus alba	1.07	1.09	25.13	20.33	24.06	19.24	23.49	18.65
Olea europea	1.03	0.97	12.48	12.33	11.45	11.36	12.12	12.71
Robinia pseudoacacia	1.55	1.50	12.32	13.90	10.77	12.40	7.95	9.27
Tamarix aphylla	1.89	1.84	27.45	20.02	25.56	18.18	14.52	10.88

φ Each value is the mean of 48 trees

Based on the results of a T test procedure, *Tamarix aphylla* trees irrigated with effluent attained significantly higher height and collar diameter (Table 3), compared to those irrigated with borehole water, showing its high adaptability to the experiment site and suitability of effluent for irrigation of this species. Collar diameter of *Morus alba* trees irrigated with effluent was also significantly more than those irrigated with borehole water. Such difference might be due to a slightly better quality of effluent water and availability of nutrients in comparison with borehole water as reported by Hassanly *et al.* [11]. On the other hand, in the same analysis, *Pinus eldarica* trees irrigated with effluent showed significantly lower survival percentage and collar diameter compared to those irrigated with borehole water. This might be due to their sensitivity to high concentration of sodium and chlorine. Further investigation is recommended to elucidate these differences. There was no significant differences for the rest of tree species irrigated with effluent compared to those irrigated with borehole water for all measured growth indices (Table 3).

Height increment and ratio of height after 18 months to initial height of *Eucalyptus camaldulensis*, *Tamarix aphylla*, *Eucalyptus microtheca* and *Acacia stenophylla* were high, (Table 4), indicating the suitability of effluent for irrigation of these species. These findings are in agreement with Bhati and Singh [7] who reported that seedlings of *Eucalyptus camaldulensis* irrigated with municipal effluent had 13% greater height in comparison with those irrigated with fresh water. Height increment of *Populus alba*, *Morus alba* and *Pinus eldarica* was moderate and height increment of, *Acer negundo* and *Platanus orientalis* was low. Hight increment of *Ailanthus altissima*, *Robinia pseudoacacia* and *Cupressus sempervirens var. horizontalis* was negative due to decline and dieing back of the trees, indicating the sensitivity of these species to effluent and soil conditions of experimental site. Maximum value of ratio of height after 18 months to initial height belonged to *Tamarix aphylla*, *Eucalyptus camaldulensis*, *Eucalyptus microtheca* and *Acacia stenophylla* respectively, indicating the suitability of effluent for plantation of these species. Ratio of height after 18 months to initial height of *Ailanthus altissima*, *Cupressus sempervirens var. horizontalis* and *Robinia pseudoacacia* was less than one. This was due to dieing back of the trees, indicating the sensitivity of these species to different irrigation water and soil conditions of experimental site.

Collar diameter of all species irrigated with both effluent and borehole water increased after 23 months (Table 5), indicating that land based disposal of municipal effluent by irrigating tree crops is practical. Height increment, the ratio of height after 18 months to initial height, growth of collar diameter and the ratio of collar diameter after 18 months to initial collar diameter of most species irrigated with effluent was greater than those irrigated with borehole water (Tables 4 and 5). This might be due to nutrient availability and a slightly better quality of effluent, which ultimately affect the measured growth indices as reported by Hassanli *et al.* [11]. This is also in agreement with Singh and Bhati [6] who reported that municipal effluent is a good source of water and nutrients for tree biomass production.

CONCLUSION

It was concluded from this study that under water scarcity circumstances in arid and semi arid regions, treated effluent reuse for agricultural practices particularly for tree plantation may be recommended. The growth indices of tree species irrigated with effluent were slightly better than those irrigated with borehole water. Therefore, effluent is more suitable from soil and environmental point of view compared to borehole water. *Eucalyptus microtheca*, *Eucalyptus camaldulensis*, *Acacia stenophylla* and *Tamarix apphylla* were the most promising species, suitable for plantation both for land based disposal of municipal effluent and developing landscapes in urban regions.

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