EFFECTS OF MUNICIPAL SEWAGE ON THE GROWTH PERFORMANCE OF *CASUARINA EQUISETIFOLIA* (FORST. & FORST.) ON SANDY SOIL OF EAST COAST AT KALPAKKAM (TAMIL NADU, INDIA)

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Abstract. Municipal sewage both untreated and treated, that pollutes the water bodies was used growing Casuarinas (*Casuarina equisetifolia* Forst. & Forst.), an exotic bio-shield tree species on sandy soil at Kalpakkam on the East Coast of Indian peninsula; it may help in reducing aquatic pollution as well as in preventing the high tides like Tsunami. Significant increase in growth performance in plant-height, branches, root length and the biomass was recorded in the saplings irrigated with untreated municipal raw sewage (RS) and treated sewage (TS) compared to that irrigated with unpolluted potable water (PW) over a period of 13 months, October 2005 to October 2006. These growth parameters showed close relationship with the nutrient contents of municipal RS, TS and PW, the former being characterized by relatively higher pH, electrical conductivity (µs/cm), total dissolved solids, total suspended solid, total hardness, chloride, sulphate, biochemical oxygen demand, chemical oxygen demand, calcium, magnesium, sodium, potassium, bicarbonates, total alkanity, nitrate, phosphate and carbonates (mg/l) compared to that of the TS and PW indicating profound influence of municipal sewage on the plant growth.
Key words: *Casuarinas; growth; municipal raw sewage; treated sewage*

Introduction

Land application of municipal sewage is a cost-effective method of its treatment and disposal. Wastewater irrigation and the land application of sewage treatment residues (sludge or bio-solids) are traditional practices around the world. In Paris sewage farms existed as early as 1868. The use of sewage effluents for the irrigation of government farms in Egypt has been in implementation since 1915. A survey of current wastewater use practices in developing countries carried out by the United Nations Development Program and World Bank (1990) estimated that some 80% of the wastewater from urban areas in developing countries is currently used for permanent or seasonal irrigation (Cooper, 1991). Untreated wastewater was used to irrigate at least five lakh hectares in Latin America, with over half of this area in Mexico (Rodriguez et al.,1994). Land application using untreated and treated municipal sewage for biomass-production has many benefits (Idelovitch and Michael, 1984; Juwarkar et al.,1995), besides preventing pollution of lotic and lentic ecosystems. Sophisticated treatment technologies like trickling filters, activated sludge processes, aerated lagoons, bio-methanation and incineration, etc. are energy consuming and cost-intensive and beyond the reach of many developing countries. Further, the discharge of treated wastewater enriched with nutrients and other pollutants can cause eutrophication in both lotic and

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lentic systems. This warrants adoption of an appropriate wastewater management system where in twin benefits of treatment and recycling and reuse can be achieved, and ecological development can be promoted.

China and India make significant use of wastewater (Bartone, 1991). Raw sewage used for irrigation in India over a 15-year period was reported to have improved the soil structure (Das and Kaul, 1992; Mathan, 1994), and increased soil nutrients and organic carbon content without increasing heavy metals to toxic levels (Gupta et al.,1998). About 6350 million cubic meter of wastewater is being generated every year from 212 class I and 242 class II towns in India, of which only 36% in class I cities and 14% in class II towns are collected due to limited treatment facilities (Thawale et al., 2006). Rapid infiltration of sewage into sandy soils can result in improvement of its physical, chemical and microbiology quality. The soil and its associated ecosystem components act as physico-chemical and bio-reactors capable of treating or stabilizing pollutants of liquid and solid origin through degradation, adsorption and utilization by trees. The nutrients like nitrogen, phosphates and potassium of sewage along with the micronutrients as well as organic matter present in municipal sewage could be added advantageously to add to the fertility of the soil, along with the irrigation potential of the water. However, application of untreated effluents to land can be carried out with certain precautions as it is not completely free from environmental health risk.

The potential for adverse health impacts of irrigation with wastewater has been addressed in a number of earlier studies. The passage through field vegetation and/or the filtration that accompanies irrigation and subsequent runoff and drainage is expected to reduce the level of parasites and other harmful microorganisms, in addition to the observed changes in chemical concentrations. Effective and appropriate wastewater treatment processes can reduce the health hazards associated with wastewater use. However, Feachem et al. (1983) showed that treated effluent coming through stabilization ponds or conventional treatment plants followed by maturation ponds or sand filtration may be free, or almost free of pathogens.

Untreated sewage was used to irrigate forestry plantations *Tamarix aphylla*, *Eucalyptus camaldulensis* and *Acacia salicina* in Kuwait (Armitage, 1985). Braatz, Kandiah reported that farms such as the El-Gabal El-Asfar located near Cairo where tree plantations of 200 ha irrigated with wastewater was established since 1911 to dispose of the city's untreated sewage (Braatz, 1996). Pioneering studies on the application of treated municipal wastewater on forest lands as a means of purification and groundwater recharge were carried out in central Pennsylvania (U. S. A.) during 1963 to 1977 (F.A.O., 1978). In Murray Darling Basin (New South Wales, Australia) forest tree plantation irrigated with secondary treated wastewater has increased from 500 ha in 1991 to about 1500 ha in 1995 during 1991 to 1997; there are now more than 60 effluent-irrigated tree plantations varying in size from one to several hundred hectares (CSIRO,1995). Braatz and Kandiah (1996) reported that the secondary treatment sewage effluent was applied on three different forest areas of mixed hardwood stand consisting mainly of oaks (*Quercus spp.*), red pine (*Pinus resinosa*) and white spruce (*Picea glauca*). Tree plantations can remove nutrients such as nitrogen and phosphates from land-applied wastewater for their growth without any harmful effect on the environment (Stewart et al., 1990). Using municipal effluent to grow trees in suburban areas in developing countries may help solve the dual problems of wastewater disposal and lack of fuel wood supply (Paliwal et al., 1998; Singh and Bhati, 2004). Banerjee et al. reported on the effects of distillery effluents in the growth of C.

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equisetifolia (Banerjee and Bahal, 2004). However, large scale use of municipal sewage/wastewater for the irrigation of tree-plantations is still relatively limited. Casuarinas *(C. equisetifolia)* or Babool *(A. nilotica*) are important species for fuel wood, and the former being planted now all along the east coast of Indian peninsula as bio-shield to prevent the high tides like Tsunami. The present study reports the growth performance of C. *equisetifolia* irrigated with municipal RS and TS in relation to that of near by PW on the nutrient poor sandy soil at Kalpakkam.

Materials and methods

Description of the study area

The present study was carried on the sandy soil at Kalpakkam (12º 30' N and 80º 10' E) on the east coast of India in the Kancheepuram district of Tamil Nadu. Experimental plots each of size 8 × 5 sq ft were prepared with randomized block design with each treatment comprising of six replicates and separate irrigated channels of municipal RS, TS and PW,. Six saplings of casuarinas were planted in each of the replicate plots. Municipal RS and TS from the Extended Aeration Activated Sludge System of Kalpakkam and PW were channeled to these plots for irrigation for a period of 13 months starting from October 2005 to October 2006.

Physico-chemical analysis

The physico-chemical characteristics – pH, electrical conductivity (µs/cm), total alkalinity, total hardness, total dissolved solids, total suspended solids, 5-days biochemical oxygen demand, chemical oxygen demand, nitrate nitrogen, chloride, sulfate, phosphate, sodium, potassium, calcium, magnesium, bicarbonates and carbonates (mg/l) of municipal RS, TS and that of PW were analyzed using methodology described in (APHA, 1998).

Plant growth measurement

The heights and number of branches of each casuarinas sapling in each replicate plot were recorded every month, and the root length and biomass of each of the saplings were measured at the end of 13 months of the experiment.

Statistical analysis

ANOVA analysis of the data on height of the saplings grown in municipal RS, TS and PW over 13 months period was computed. Multiple correlation analysis was computed between the height of the saplings grown in RS, TS and PW and the nutrients quality and quantity of sewage and PW over the 13 months period.

Results

Water-quality parameters

Analyses of water quality parameters such as pH, electrical conductivity, and total alkalinity, hardness, dissolved solids (TDS), suspended solids (TSS), Biochemical Oxygen Demand$_5$, chemical oxygen demand, nitrate nitrogen, chloride, sulfate, phosphate, sodium, potassium, calcium, magnesium, bicarbonates and carbonates (mg/l)

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of municipal RS, TS and PW used for irrigation of casuarinas saplings showed that the average concentration of each of the above water quality parameters of municipal RS were higher than that of the TS, both of which were higher than that of the PW (*Table 1*). The average temperature in the RS, TS and PW were 28.1, 28.0 and 27.0 ºC, respectively. The average pH and that of electrical conductivity, TDS, total hardness, chlorides, sulphate, calcium, magnesium, sodium, total alkanity, bicarbonates and nitrates (mg/l) in RS were higher than that of TS and PW. The average TSS, COD, BOD, phosphates, potassium and carbonates in RS were more than six, two, eleven, two, two and four folds higher than that of the TS, respectively and were ninety one, three, sixteen, eight, three and four folds higher than that of the PW, respectively (*Table 1*).

Table 1. *Mean concentration of raw sewage, treated sewage and that of potable water which was used for irrigation*

Physico-chemical parameters	Raw sewage	Treated sewage	Potable water
Temperature (ºC)	28.1	28	27
pH	7.1	6.8	6.73
Electrical Conductivity (µs/cm)	924.6	731.8	613
TDS (mg/l)	584.5	422.8	368.5
TSS (mg/l)	377.1	61.8	4
Total hardness (mg/l)	165.8	109.8	98
Chloride (mg/l)	207.12	131.6	118
Sulphate (mg/l)	33.5	31.3	22
COD (mg/l)	450.2	157.9	133.4
BOD (mg/l)	244.5	20.2	16.5
Ca (mg/l)	37	26.8	20.4
Mg (mg/l)	20.5	11.5	10.7
Sodium (mg/l)	129.4	79.7	41.2
Potassium (mg/)	37	17.1	10.4
Bicarbonates (mg/l)	147.9	95.1	82.1
Total alkanity (mg/l)	198.1	115.8	101.4
Nitrates (mg/l)	34.5	19.5	14.5
Phosphates (mg/l)	1.62	0.7	0.2
Carbonates (mg/l)	2.82	0.7	0.62

Casurina equisetifolia sapling growth

One of the ways to reduce the pollution of the receiving water bodies due to the municipal sewage is its optimum reuse in irrigation of tree plantations. Bio-shield exotic tree, *C. equisetifolia* is widely grown now on the east coast of Indian peninsula to prevent high tides like tsunami waves that lashed the coast during December 26, 2004, and the use of the municipal untreated and treated sewage for irrigation and watering of these tree nurseries and plantations may be useful in better establishment and quick growth of the plantations. Our study revealed that the height of *C. equisetifolia* prior to the irrigation with municipal RS, TS and PW were 25.95 $\pm$ 2.5, 28.4 $\pm$ 4.9 and 25.3 $\pm$ 5.8 cm, respectively. After a month of irrigation with RS, TS and PW the height of the saplings increased to 29.6 $\pm$ 3.2, 32.2 $\pm$ 5.6 and 27.5 $\pm$ 7.0 cm respectively, whereas after three months of irrigation, that of the saplings increased to 52.4 $\pm$ 8.1, 44.9 $\pm$ 9.8 and 41.0 $\pm$ 13.6 cm respectively, after six months of irrigation that has increased further to five, four and four folds, respectively, and after nine months of irrigation that increased to eight, six and six folds, respectively while after twelve months of irrigation that increased to eleven, eight and eight folds, respectively *(Figure 1)*. ANOVA analysis of the plant height grown across the treatments of RS, TS and PW showed significant difference in the height of the saplings between and within treatments, being recorded highest in the former and minimum in the later (*Table 2*). There was significant positive correlation between the height of the saplings and the quality of municipal sewage i.e., RS and TS in the present study ($R^2 = 0.74$, $p < 0.01$). The lower height in the saplings irrigated with PW were most probably due to its relatively low nutrient contents.

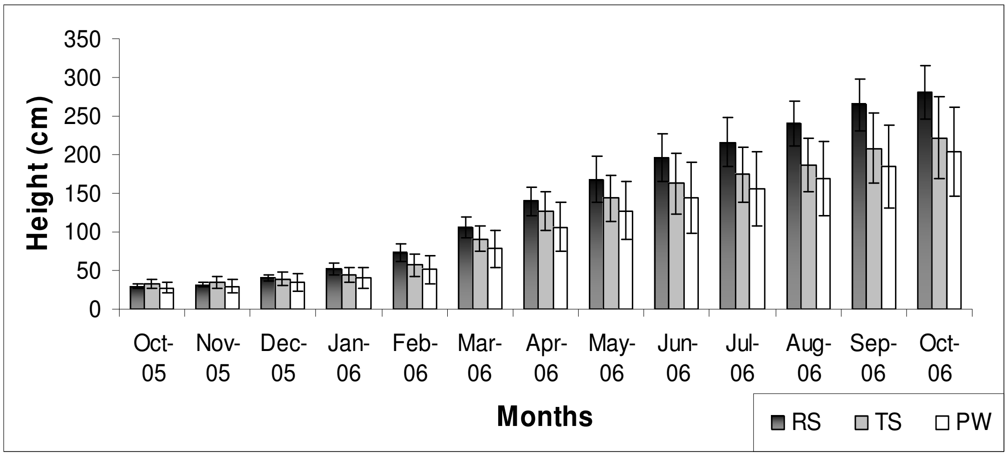

Figure 1. *Variation in the height of the C. equisetifolia across the three different treatments*

Number of individual branches of the *C. equisetifolia* did not appear till the third month of irrigation with municipal RS, TS and PW. After six months of irrigation, the number of branches per sapling was 1.5 + 1.1, 1.5 + 0.9 and 0.1 + 0.3, respectively, and after nine months their cumulative numbers per sapling increased to 2.3 + 0.9, 1.8 + 0.8 and 1.1 + 1.0, respectively, while after twelve months that was further increased to 2.3 + 0.9, 1.5 + 0.5 and 1.3 + 0.4, respectively *(Figure 2)*.

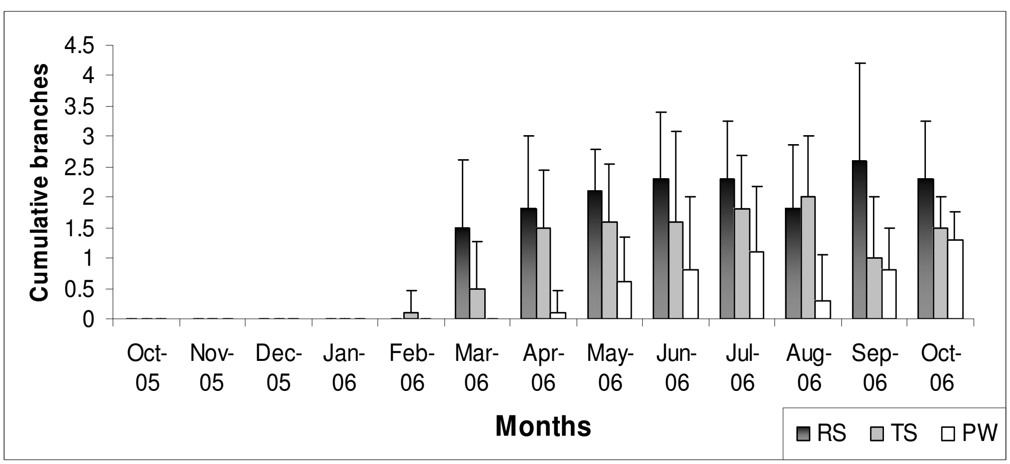

Figure 2. *Variation in the number of branches of the C. equisetifolia across three different treatments*

Table 2. *ANOVA analysis of height of the plants (C. aquesetifolia) across different irrigation treatments*

Source of Variation	**df**	**SS**	**MS**	**F**	**P-value**	**F crit**
Height of the plants:						
Between treatments	12	205859.6	17154.97	75.07326**	5.11E-16	2.183377
Within treatment	2	9264.416	4632.208	20.27139**	6.99E-06	3.402832
Error	24	5484.232	228.5097			
Total	38	220608.2				

**P<0.01

The root length of the saplings of *C. equisetifolia* prior to the treatment with municipal RS, TS, and PW was 14 ± 1.8, 13.1 ± 1.5 and 13.9 ± 3.3 cm respectively, which after 13 months of irrigation, has increased to more than four folds in RS, to about three folds in TS and about three folds in PW *(Figure 3)*.

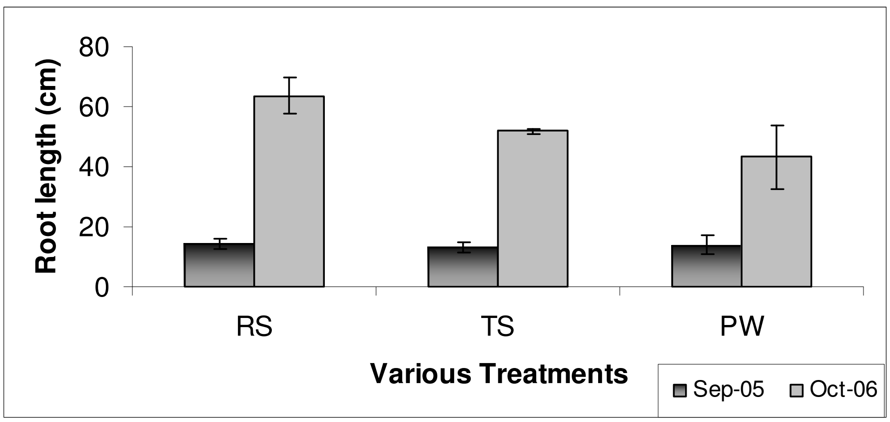

Figure 3. *Variation in root length across different treatments*

Similarly, the average wet biomass of each sapling after 13 months of irrigation of municipal RS, TS and PW were 3.5, 2.4 and 2.0 kg per sapling, respectively *(Figure. 4)*.

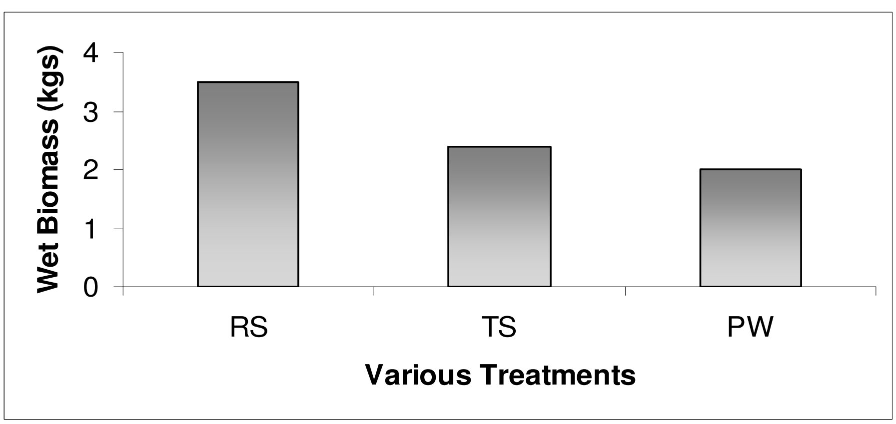

Figure 4. *Variation of the wet biomass (kg) of the C. equisetifolia across different treatments*

Discussion

The slight increase in temperature in RS recorded during the present study was probably because of its relatively higher microbial activity. Besides, in consistence to the present findings, Singh and Bhati (2003) reported higher concentration of various nutrients in municipal sewage compared to that of the canal water. The decrease in average concentration of the physico chemical parameters of the TS compared to that of RS in the present study was because of extended aeration activated sludge treatment (Balluz et al., 1977). In consistence to the present findings, (Fatma et al., 1998) reported a decrease in physico-chemical concentration in treated wastewater used for irrigation in Egypt. Similarly, (Alhumoud et al., 2003) reported decrease in average values of the water quality parameters – TSS, TDS, BOD, COD, pH, NH_3, phosphates, temperature (°C) in secondary and tertiary wastewater in Kuwait.

The significant increase in the sapling height in the treatment irrigated with municipal RS was probably due to availability of increased organic matter, and both macro- and micro- nutrients, especially total and available N in the municipal sewage (Braatz and Kandiah, 1996). Omran et al. (1998) in corroboration to the present findings, also reported increased growth density and shoot length in Navel Orange trees irrigated with sewage in Egypt. Similarly, increase in water and nutrient availability through effluent application influenced the growth of *A. nilotica* (Singh and Bhati, 2004; Singh and Singh, 2000), that of Eucalyptus (Singh and Bhati, 2003), *Hardwickia binata* (Paliwal et al., 1998), *E. grandis* (Stewart et al., 1990) and *P. radiate* (Sheriff et al., 1986). The sewage or drainage water used after primary treatment for irrigation increased the growth of woodlots with most commonly used species, *C. glauca, E. camaldulensis* and *T. aphylla* (El-Lakany, 1995). In India utilizing raw sewage for irrigation of plantations of *E. tereticornis, Populus deltoides* and *Leucaena leucocephala* showed higher growth than that of the trees irrigated with well water; the eucalyptus being six percent taller after 48 months; the leucaena being 12 percent taller after 36 months; and the poplar being four percent taller after 24 months (Das and Kaul, 1992).

The increase in the number of branches of saplings grown in municipal sewage was probably because of availability of relatively more nutrients present in the sewage compared to that of PW. The availability of water and nutrients probably had positive effects on root growth (Singh and Bhati, 2003; 2004). This may be due to the response of casuarinas saplings to the nutritive elements present in the sewage water. Previous studies showed that the increase in plant growth and yield was primarily related to increased phosphorus uptake (Silber et al., 2005). Thus, increase in the growth performance and biomass of *C. equisetifolia* irrigated with municipal RS and TS compared to that of the PW during the present study is most probably due to the constant supply and continuous replenishment of nutrients like nitrogen and phosphorous to the saplings and improved soil structure in the rhizosphere. (Breaux et al., 1995) in corroboration, reported that addition of sewage with influx of nutrients stimulated biomass production being beneficial to soil formation; Singh and Bhati (2003; 2004) reported higher growth and biomass in seedling of acacia and eucalyptus respectively, which they attributed to the effects of available nutrients, particularly N in the effluent facilitating leaf initiation that converted more solar energy enhancing CO_2 fixation and photosynthate level leading to higher growth and biomass production (Braatz and Kandiah, 1996).

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The higher N conditions result in higher growth of leafy shoots through reinvestment of assimilates towards photosynthetic parts (Li et al., 1991).

Conclusion

Municipal sewage was rich in nutrients; its use in growing tree-plantation is an alternative treatment aimed at achieving the stringent standards for wastewater disposal into the receiving water bodies. Raw sewage and treated sewage can be used for irrigation for growing the bio-shield tree, *C. equisetifolia* on the poor sandy soil of east coast of Indian peninsula as the raw and treated sewage showed increased the growth of the tree during the present study.

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