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Growth of *Dalbergia sissoo* in desert regions of western India using municipal effluent and the subsequent changes in soil and plant chemistry

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Abstract

Increasing demand for fodder and fuelwood and the scarcity of a good quality water in arid areas has resulted in a search for an alternative source of water for biomass production. An experiment utilizing municipal effluent in growing *Dalbergia sissoo* was conducted. Five treatments included T_1, municipal effluent at 1 PET (Potential evapo-transpiration) (without plant); T_2, municipal effluent at 1/2 PET; T_3, municipal effluent at 1PET; T_4, municipal effluent at 2 PET; and T_5, canal water at 1 PET. Observations included plant height, collar diameter at one-month intervals and plant mineral composition, mineral uptake and changes in soil properties at 24 months of plant age. Application of municipal effluent produced better growth in *D. sissoo* seedlings. Concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were greater in seedlings irrigated with municipal effluent than those of the seedlings irrigated by the treatment T_5, and positively related with the quantity of irrigation. The concentrations were greatest in foliage compared to the other parts of seedling, with the exception of Cu concentration. Application of municipal effluents resulted in a 2- to 3-fold increase in the concentrations of soil K, Cu, Fe, Mn and Zn, whereas NH_4-N and PO_4-P availability increased by 8.1- and 4.5-fold, respectively. The increase in soil organic carbon was only observed in treatments T_3 and T_4. The accumulations of soil NO_3-N, Na, Cu, Fe, Mn and Zn were more in lower soil layers but the other soil parameters showed their greatest values in the upper soil layer. Irrigation using municipal effluent did not result in toxicity to the seedlings before the age of 24 months. The results suggest that municipal effluent could be utilized, as an important source of water and nutrients in growing *D. sissoo* to increase biomass production in the needs of suburban dwellers. However, a preliminary treatment to reduce excess NH_4-N and PO_4-P will be required before application to the plantation.

Keywords: *Dalbergia sissoo*; Aid region; Municipal effluent; Irrigation; Soil and plant nutrients; India

1. Introduction

The prudent use of limited water supplies is critical for improving the socio-economic conditions of fragile arid areas. Frequent drought leads to depletion of fresh aquifers and causes migration of rural populations to urban areas (Government of India, 2001). These populations are in need of employment, a daily supply of water, fuelwood, and fodder. Increasing industrialization and urbanization in major metropolitan cities in dry areas leads to an increase in the availability and volume of wastewater. This wastewater can be used for the restoration of degraded land, and the growth of vegetation having commercial and environmental value (Dighton and Jones, 1991).

Woody species may utilize wastewater and uptake heavy metals through extensive root systems. Tree

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seedlings thus serve as effective biological sieves, inhibiting contamination of ground water sources (Karpiscak et al., 1996). Tree growth reduces the toxicity of soil and plays an important role in safeguarding the environment (Stewart and Flinn, 1984). Therefore, the use of wastewater in growing woodlots is a viable option for the economic disposal of wastewater. Additional benefits include biomass production and sequestration of excess minerals in the plant system (Neilson et al., 1989).

Dalbergia sissoo is an important multipurpose tree species with the potential to provide timber and soil recapitulation. However, the growth and survival of *D. sissoo* is severely affected by soil and water quality, which may interfere with the success of a forestation program (Gupta et al., 1995). The use of municipal effluent in growing *D. sissoo* in suburban areas could be beneficial for the production of wood and would have aesthetic and environmental benefits as well. The objective of this study was to quantify the growth of *D. sissoo* seedlings and the mineral accumulation in plants and surrounding soil under different levels of municipal effluent application.

2. Methods

2.1. Site description

Experiments were conducted at the experimental field of the Arid Forest Research Insitute, Jodhpur (Latitute 26°45′N, Longitude 72°03E) in Rajasthan, India. The climate of the site is classified in the tropical monsoon type and is characterized by hot and dry summers, hot rainy seasons, warm autumns and cool winters. Summer is characterized by high temperatures and strong winds. The period from mid July to September is the monsoon season, which receives most of the rainfall. The mean annual rainfall is 420 mm and the mean annual pan evaporation is 2025 mm, indicating a high water deficit in the area. The soil is loamy sand (from the coarse loamy, mixed, hyperthermic family of typic camborthides, according to US soil taxonomy) with 82% sand, 12% silt and 5% clay. It has reduced organic matter (0.13%), available PO_4-P (5.00 mg kg^{-1}), NO_3-N (6.00 mg kg^{-1}) and NH_4-N (4.50 mg kg^{-1}). The pH and electrical conductivity (EC) of the soil were 7.61 and 0.75 dSm^{-1} (deci siemen meter^{-1}), respectively.

2.2. Sampling, preservation and analysis of the effluent

Municipal effluent was sampled daily for 7 days during the second week of July and August 1998 (monsoon), December and January 1998–99 (winter) and May and June 1999 (summer) at two-hour intervals (from 6 AM to 6 PM) to make a composite sample of each day. This collection provided 14 samples of municipal effluent in each season. Samples of canal water were collected in triplicate in each season at the time of irrigation. Thus, there were 51 samples, which include 42 samples of effluent and 9 samples of canal water in the year. These samples were brought to the laboratory, filtered through Whatmann 42 mm filter paper, and stored at 4 °C (OMA, 1990). Each sample was analyzed for pH, electrical conductivity (EC), chemical oxygen demand (COD), biochemical oxygen demand (BOD) and concentrations of macro and micronutrients using standard procedures (OMA, 1990). Total dissolved salts (TDS), total solids (TS) and total suspended solids (TSS) were determined gravimetrically, while chemical oxygen demand (COD) was determined by the reflux method, and total alkalinity was determined by the titration method of OMA (1990). Nitrogen and phosphorus were analyzed calorimetrically (Jackson, 1973). Copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were estimated by the aqua regia method of Jackson (1973) followed by a measurement of concentrations using an Atomic absorption Spectrophotometer (model-3110, Perkin-Elmer, Boesch, Huenenberg, Switzerland).

2.3. Experimental design and planting

One-year-old seedlings of *Dalbergia sissoo* from a single provenance were planted in non-weighing, in-filled lysometers of capacity of 8 m^3 (2 m × 2 m × 2 m) in July 1998 (Singh, 2001). The lysometers were filled with soil up to 185 cm, leaving 15 cm space for irrigation. Seedlings were planted in a completely randomized design with three replications, and each lysometers had one seedling. The five irrigation treatments included T_1, irrigation of soil with municipal effluent at 1 PET (potential evapo-transpiration; soil without plant); T_2, irrigation of seedling with municipal effluent at 1/2 PET; T_3, irrigation of seedling with municipal effluent at 1 PET; T_4, irrigation of seedling with municipal effluent at 2 PET; and T_5, irrigation of seedling with canal water at 1 PET. The treatments were initiated in the first week of September 1998 after the proper establishment of the seedlings. Irrigation (treatment) was applied daily based on the potential evapo-transpiration, which varied seasonally in response to the climate. At the time of treatment application, the average seedling height and collar diameter were 50 cm and 0.5 cm, respectively.

2.4. Data collection

Seedlings were measured at monthly intervals for height, collar diameter and the number of branches present. One seedling from each treatment was harvested at 24 months of age. Dry mass of the leaf, stem and roots was recorded after oven drying the samples for 72 h at 80° C.