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GROWTH PERFORMANCE AND CADMIUM (Cd) UPTAKE BY *POPULUS DELTOIDES* AS IRRIGATED BY URBAN WASTEWATER

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A study was conducted to determine growth and uptake of Cd by *Populus deltoides* (poplar) under different irrigation regimes. Three types of irrigation water i.e. municipal wastewater (MW), domestic wastewater (DW) and canal water (CW) was applied to the plants. *P. deltoides* gained maximum plant height (4.40m) under DW irrigation which was 35% and 37% higher than the heights gained under MW (2.85 m) and CW (2.76 cm), respectively. Similarly, average collar diameter in response to DW irrigation (7.41 cm) was also 22% and 34% higher than the diameters gained under MW irrigation (5.81 cm) and CW (4.92 cm). The growth response clearly suggested that wastewater coming either from municipal or domestic source might add nutrients to the soil pool. Maximum diameter under DW was due to highly favourable status of nutrients, organic matter and moderate level of pollutants. Higher uptake of Cd metal (47.02 mg kg^{-1}) in plant was observed mostly under MW followed by DW (39.65 mg kg^{-1}). While, the contribution of CW regarding Cd uptake (30.19 mg Kg^{-1}) by the tree species was significantly low.
Keywords: Wastewater, growth, Cd concentration, *Populus deltoides,* Cd stress

INTRODUCTION

The volume of wastewater is increasing day by day due to over population and spreading industrialization (Kahlown *et al.,* 2006). The global volume of wastewater is more than 1,500 km^3 per year (UWPN, 2007). Big cities are constantly generating huge volume of effluent water which needs proper disposal and management (Ghosh and Singh, 2005). Water resources are becoming scarce and the amount of sewage water is increasing day by day. In peri urban areas, the scope for growing diversified vegetation is worth mentioning. Therefore, it is necessary to seek alternative sources of irrigation to ensure the sustainability of the available resources (Thawale *et al.,* 2006).
According to Ensik *et al.* (2005) use of different types of sewage wastewater for agriculture has become routine practice in different countries. Wastewater coupled with sludge is enriched with nutrients and has been considered a good source to enhance biomass productivity (Paramathma *et al.,* 2003). Presently, wastewater is also being used for growing vegetables and crops to meet the ever increasing demand of city dwellers. Vegetables absorb various heavy metal pollutants such as Ni, Cd, Cr, Cu and/or Zn from the irrigation wastewater (Dwivedi, 2000). These pollutants are serious threat to human health. In such situations, raising of woody vegetation of commercial importance and of environmental/aesthetic values by using city effluents has been reported by Karpiscak and Gottfried (2000).
Such studies are scanty in Pakistan. Present studies have been designed to determine the potential of poplar growth under wastewater irrigation from domestic as well as industrial sources. Keeping in view the severity of the prevailing problem of the wastewater effluents, the study designed was based on the assumptions that the trees actively take up metals and grow well on sewage water: the use of municipal effluent for irrigation would stimulate the growth of the tree as compared to irrigation with canal water. Specific objectives of the study were to study the effects of domestic as well as municipal effluent on the growth of *P. deltoides* and to assess the tolerance ability of the *Populus* species to Cd metals from the effluent water.

MATERIALS AND METHODS

Present research experiment was laid out in randomized complete block design (RCBD) with three treatments i.e. different sources of irrigation comprising of MW, DW, and CW (Quality of different types irrigation water is given in Table 1) with three replications. Total number of plants (*P. deltoides*) used in whole of the experiment were = 6 x 3 x 3 = 54. One-year-old seedling of almost uniform size were planted in spring 2006 at an equal spacing of 2m x 2m from plant to plant and row to row (Hunter, 2001;

Paramathma *et al.,* 2003), with the stocking rate of 2500 trees per hectare (Al-Jamal, 2002). Municipal wastewater was obtained from WASA (Water and Sanitation Agency) drainage channel 1 passing besides the experimental area, Department of Agronomy, University of Agriculture Faisalabad. Domestic wastewater and CW were also available at the experimental site from the source located at University of Agriculture, Faisalabad. Water samples from different irrigational sources were collected at the start of the experiment and after final harvesting (after two years). All samples were collected in polystyrene bottles of one liter capacity. Nitric acid (HNO_3) was added (2 ml L^{-1}) as a preservative in the sampling bottles for further analysis (Jones, 2001). Soil (sandy loam) samples were also taken randomly from each plot prior to start of experiment and were taken to the laboratory for analysis (Table 2).

All experimental plots were irrigated uniformly by flood irrigation system. Irrigation was applied at an interval of 4-10 days throughout the growing season. The parameters used in data collection were plant survival (%), tree height (m), collar diameter (cm) and uptake of Cd (mg kg^{-1}) by *P. deltoides*.

The Plant samples (leaves, stem and roots) were taken separately and were washed with 1% HCl and then with distilled water to remove unwanted material and contaminants and were put on clean plastic sheet for drying. Plant samples were then oven-dried at 65-70°C till constant weight. The dried plant material was ground separately to powder form by Wiley Mill (I mm size) and was stored separately in clean plastic bags for chemical analysis. Plant samples were digested using the procedure adopted by US Salinity Laboratory Staff (1954) and analyzed with standard methods. Ground plant material weighing 0.5g was taken for digestion in a conical flask using 15 ml di-acid mixture (HNO_3:$HClO_4$, 2:1). The material was digested on hot plate until it was colorless. After digestion, the flask was left to cool and the flask volume was made 100 ml by adding deionized water and further analysis was carried out with the help of atomic absorption spectrophotometer (Perkin Elmer Aanalyst 300). Cadmium concentration was determined using the method adopted by (Rashid, 1986). Data were analyzed using software statistix ver. 8.1. The significance of the differences was recorded for 3 types of irrigation sources for growth assessment and metal detection by applying analysis of variance techniques. Fisher's LSD test was applied with probability level ($P \leq 0.05$) to compare the differences of mean values.

RESULTS

The study was designed to determine the growth performance of *P. deltoides* and to assess its potential for uptake of Cd metal under different irrigation regimes. Growth performance was determined by recording the data about plant survival, plant height and collar diameter whereas, uptake of Cd metal was determined by chemical analysis of the plant samples taken from leaf, stem and root portions. The detail of the results is as under.

Growth behaviour: Survival of the plant is one of the basic parameter to study the growth performance of the plants under a given set of environmental conditions. Based on the observations, all plants successfully survived upto 100% with each irrigation source applied. However, there was marked stress on growth because of application of MW.

Different sources of irrigation affected tree height significantly ($P<0.05$). Domestic wastewater gave maximum height of 4.40 m. Municipal wastewater and canal water gave almost similar height of 2.83 m and 2.74 m respectively (Fig. 1). It is interesting to note that there was a marked reduction of 36.36% and 38.23% in height of *P. deltoides* when irrigated with MW and CW, respectively.

Significant differences in collar diameter were observed by three sources of irrigation. Maximum collar diameter of 7.42 cm was noted with DW source followed by MW (5.81 cm) and CW (4.94 cm). Decrease in diameter up to 34% was recorded with CW irrigation. The LSD values, standard error and co-efficient of variance (CV) for plant height and collar diameter are given in Table 3.

Uptake of Cd: Cadmium concentration noted in *P. deltoides* under different sources of irrigation followed the pattern: MW (47.02 mg kg^{-1}) > DW (39.65 mg kg^{-1}) > CW (30.19 mg kg^{-1}). The tree species had much of the Cd concentration in its leaves followed by roots. Relatively less metal concentration was found in stem portion of the plant. All the mean values for metal locations (leaf, stem and root) of the plant were significantly different (Fig.2). Average metal distribution in different parts of *P. deltoides* (leaf, root and stem), decreased from leaf to root and stem with values of (15.6 mg kg^{-1}), (13.96 mg kg^{-1} and (9.39 mg kg^{-1}), respectively.

Table 1. Properties of irrigation effluents with reference to critical limits

Parameters		CW *	DW *	MW *	Irrigation Quality Standards **
pH		7.8	7.9	8.5	6.5-8.4
EC	($dS\ m^{-1}$)	0.36	2.24	5.26	1.5 ($dS\ m^{-1}$)
SAR		0.16	6.63	16.21	8
RSC	($meq\ L^{-1}$)	0	4.40	16.81	1.25 $mg\ L^{-1}$
Ca^{++} + Mg^{++}	($meq\ L^{-1}$)	3.81	8.65	12.43	----
Na^{+}	($meq\ L^{-1}$)	0.23	13.71	40.20	230 $mg\ L^{-1}$
Cl^{-}	($meq\ L^{-1}$)	0.81	80.00	22.00	400 $mg\ L^{-1}$
CO_3^{--}	($meq\ L^{-1}$)	Nil	4.00	Nil	----
HCO_3^{-}	($meq\ L^{-1}$)	2.40	121.42	29.22	400 $mg\ L^{-1}$
Cd	($mg\ L^{-1}$)	0.012	0.018	0.031	0.01 $mg\ L^{-1}$

*CW= canal water; DW=domestic wastewater; MW=municipal wastewater;
** Ref: WHO (1989).

Table 2. Chemical properties of soil at the test site prior to application of wastewater

Parameters	Soil depth (cm)		
	0-15	**15-30**	**30-45**
EC ($dS\ m^{-1}$)	1.8	0.97	1.19
pH	8.3	8.1	7.9
Organic matter (%)	0.77	0.40	0.39
Saturation (%)	33	35	34
Total N (%)	0.035	0.037	0.040
Avail. P ($mg\ kg^{-1}$)	2.10	2.38	2.41
Avail. K ($mg\ kg^{-1}$)	130	125	178
DTPA Extracted Cd ($mg\ kg^{-1}$)	0.04	0.04	0.02

Table 3. Level of significance among means of plant height and collar diameter

	LSD at $P \leq 0.05$	Standard Error	CV (%)
Plant Height	0.5540	0.2726	21.60
Collar Diameter	0.9803	0.4824	15.53

Table 4 Level of significance among means for Cd uptake

	LSD at $P \leq 0.05$	Standard Error	CV (%)
Treatment	0.0.6	0.28	
Plant parts	0.0.6	0.28	4.62
Treatment x Parts	1.04	0.49	

DISCUSSION

The water originated from a community when littered with a variety of refuse and loaded with diversity of wastes is called wastewater (UWPN, 2007). This type of wastewater is not very toxic and can be utilized for agricultural use. Domestic effluents are blend of solid containing soluble and suspended matter of human and animal sources, mixed with vegetable and fruits refuse and residues of other domestic utilities such as soaps, oils, and other chemicals etc. This type of wastewater is eco-friendly and the impurities are of organic nature (Bashir *et al.,* 2006). Previous studies revealed that DW is rich in organic matter and nutrients, which resultantly increases productivity of biomass (Paramathma *et al.,* 2003).

Results of the present study also revealed that *P. deltoides* grew well when irrigated with DW followed by MW and CW. According to Ecolotree (2004) *Populus sp*. irrigated with contaminated ground water, attained 4.5 meter height in two growing seasons. Tap roots of the trees penetrated into the soil up to a depth of 3 meter. In the present study, *P. deltoides* got the height of 4.4 m under DW irrigation in two years. The study elucidated the potential use of DW and MW in poor soils. As the DW effluents are rich in essential nutrients (Paramathma *et al.,* 2003) and therefore, resulted in luxuriant growth. Results of the previous studies reported by Chaturvedi (1985, 1986) and Ecolotree

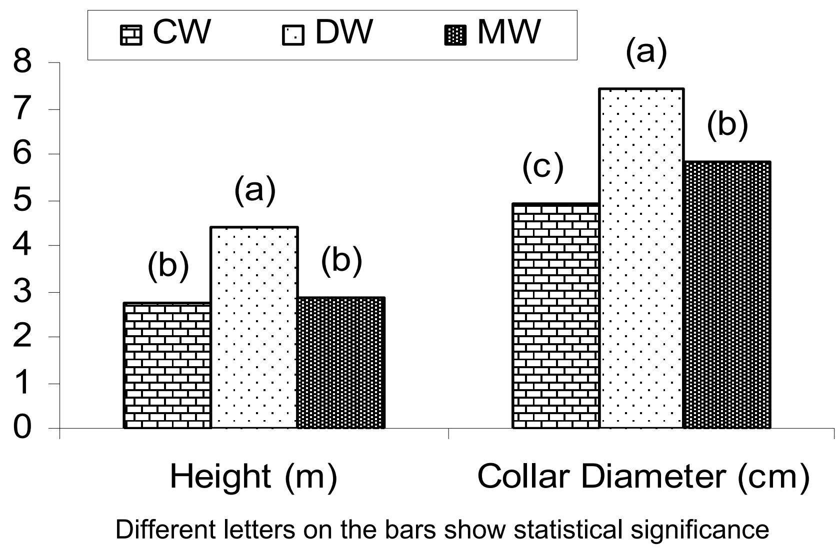

Figure 1. Growth behaviour of *P. deltoides* under different sources of irrigation

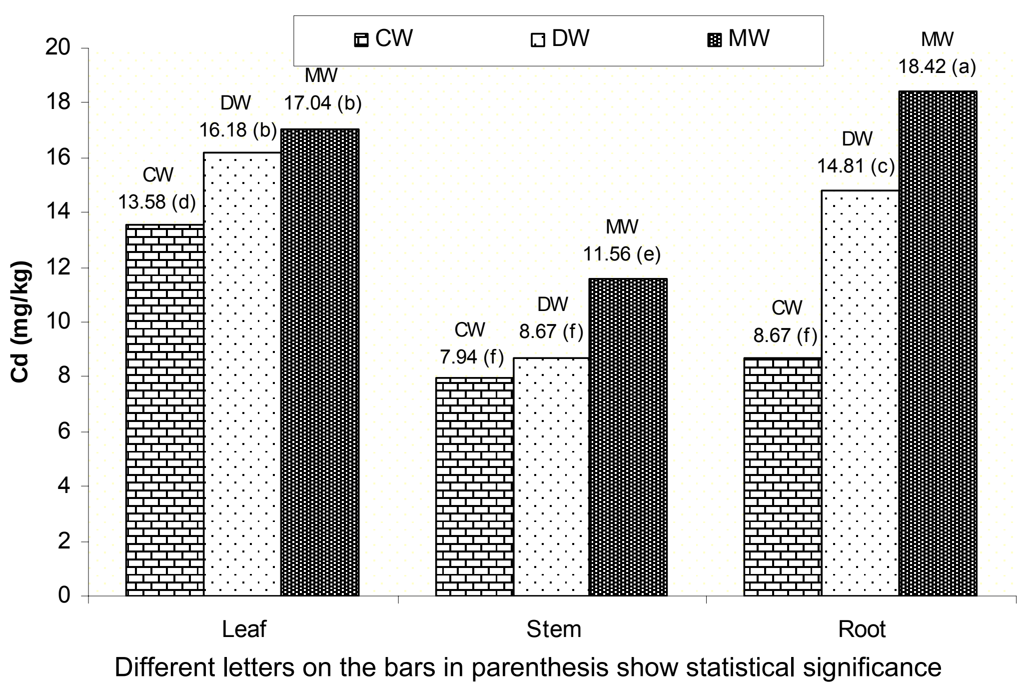

Figure 2. Cd partitioning in leaf, stem and root of *Populus deltoides*

(2004) also stated similar positive results by the use of DW.

Our findings suggested that average collar diameter gained by *P. deltoides* under MW irrigation was less than the collar diameter gained under DW irrigation but greater than that gained by CW. The results clearly suggested that wastewater coming from either source of irrigation i.e. municipal or domestic enhanced the plant growth. Relatively smaller collar diameter under MW might be due to stress of pollutant matter present in it. Maximum diameter under DW might be due to highly favorable status of nutrients, organic matter and moderate level of pollutants (Singh and Bhati, 2005). Karpiscak and Gerald (2000) also reported high growth rate in various tree species grown under wastewater irrigation. Our results indicated that the effluents had affected the physiological processes resulting in fast growth, leaf initiation and net growth of the plants. Stewart *et al*. (1990) revealed that MW doubled the growth of *E. camaldulensis* when compared to *E. grandis* in a rainfed sites.

Cadmium is known to be one of the major contaminants in environmental pollution. It is highly toxic metal which deteriorates air and water quality especially in urban areas with smoky vehicles and industrial exhausts (Shah *et al.*, 2008). Kahlown *et al.* (2006) reported that irrigation of raw (untreated) wastewater caused accumulation of Cd in edible plants. However, it did not harm plant growth at low concentration. Decrease in root growth has been reported by Zou *et al.* (2008) in the presence Cd. There had been 22 % decrease in collar diameter of *P. deltoides* under MW irrigation than that of recorded under DW. The plant showed pronounced growth stress when irrigated with MW. This stress might be due to the presence of Cd beyond the permissible limit (Table 1). According to Farooqi *et al.* (2009) *Albizzia* species showed poor and stunted growth with high Cd concentration in the irrigation sources.

Sepher and Ghorbanli (2006) reported detrimental and additive effects of salinity and high contents of Cd in both soil and water medium. Our results are contrary to those of Sepehre and Ghorbanli (2006) as the tree species responded well and gave good growth even with high concentration of Cd (Fig.2). High concentration of Cd greatly inhibited root growth especially in dicot species (Inouhe *et al.,* 1994). Liu *et al.* (1992) reported that higher concentration of Cd inhibited biosynthesis of chlorophyll. Cieslinski *et al.* (1996) observed relatively more weight loss in leaves of strawberry than that of root due to stress of high Cd concentration.

Trees are potentially able to deposit the absorbed metals Cd, Cu and Zn in root and foliar portions of the plant (Brunner *et al.,* 2008). Figure 2 showed similar trend of translocation of the absorbed metals to the leaf and/or root in plant. Leaf injury is caused by aerial deposition of metal pollutants. Accumulation of metal is negatively correlated with the viability of the plants. As a characteristic feature of deciduous trees, surplus metals are accumulated into older leaves prior to shedding. In this way, they add the metals back into the soil (Utriainen *et al*., 1997). Metal accumulation in leaves needs proper management to avoid recycling and moving back into the soil. Woody plants show decline in chlorophyll a/*b* ratio (Sheoran *et al.,* 1990). Previous studies confirm our findings.

CONCLUSION

Domestic wastewater enhanced the growth of *P. deltoides* as the plant gained maximum height (4.40 m) and collar diameter (7.42 cm) followed by MW and CW. Higher Cd metal uptake was noted in the plant when it was irrigated with MW (47.02 mg Kg^{-1}) followed by DW (16% less uptake) and CW (36% less uptake). Maximum Cd was recorded in leaves (15.6 mg kg^{-1}) followed by root (13.96 mg kg^{-1}) and stem (9.39 mg kg^{-1}).

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