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IMPACT OF INDUSTRIAL EFFLUENTS ON GROWTH OF DOMINANT TREE SPECIES OF ISLAMABAD, PAKISTAN

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Abstract

Heavy industrialization has resulted in water pollution and environmental degradation. Ever-increasing pollution adversely affected living organisms on the Earth. The present study was focused on analyzing industrial effluents originating from industrial estate Islamabad (the capital city of Pakistan). Dominant tree-species of Islamabad such as *Acacia modesta*, *Grevillea robusta, Bauhinia variegate* (L.), *Cassia fistula* (L.), *Albizia lebbeck* (L.) Benth., *Syzygium cumini* (L.) Skeels, *Terminalia arjuna* (Roxburgh), *Pongamia pinnata* (L.), and *Melia azedarach* (L.) were selected to examine the tolerance of these tree-species against industrial effluents. One year old uniform saplings of nine selected species were transplanted into soil filled polythene tubes for the experiment. The collected samples of effluents were analyzed for water quality parameters such as electrical conductivity, pH, total dissolved solids, and heavy metals concentration. The pH of effluent sample was low (acidic) whereas electrical conductivity and total dissolved solids were higher than described FAO standards for irrigation water. Results also indicated higher concentration of heavy metals (Mn, Pb, Cr, Zn, Cd, Ni and Mg) in the industrial effluents. Saplings were irrigated with assorted water treatments and their effects on shoot and leaf growth was observed. Analysis of the data indicated decline in growth of all tree species irrigated with effluent based treatments. However, *Acacia modesta*, *Albizia lebbeck*, *Melia azedarach*, *Syzygium cumini,* and *Terminalia arjuna* relatively performed better and showed tolerance against industrial effluents.

Key words: Industrial effluents; Heavy metals; Pollution; Species tolerance; Tree-growth.

Introduction

Clean and healthy environment is essential for survival and well-being of living organisms. Our environment is degrading gradually due to heavy industrialization. Pollutants from various industries have damaging effects on animals and plants (Ikeda *et al.*, 2000). Various parameters of industrial effluents such as temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), and heavy metal contents (i.e., Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) have been found higher than normal at the discharge point of the industries (Singh, 2014).

Large proportions of industrial effluents are organic in nature and carry toxic substances in appreciable amounts (Antil, 2012). Waste water of urban areas also contains toxic metals (Gupta & Mitra, 2002). The wide disparity in metal content of the effluents is a reflection of variability of sources inflowing in the sewage system. Electrical conductivity and TDS of most industrial effluents of Islamabad area were above the critical limits and heavy metal content was also high (Chaudhary *et al.*, 2015).

In Pakistan, domestic and industrial waste water is used to irrigate agriculture crops (Ensink *et al*., 2004). Higher concentration of heavy metals slows down plant growth and reduces metabolic activities in plants (Uzair, 2009). These pollutants have potential to produce chlorosis and necrosis in leaves, destruction of root tips, and damage to physiological systems of plants which could result in stunted growth. Higher accumulation of Cr, Cu, Ni, and Zn was found in plants irrigated with effluents than that of their respective control (Panday, 2006).

Industrial effluents have hazardous effect on plants as well as on humans who consume vegetables and fruits produced using this toxic water (Iyengar & Nair, 2000). Long-term use of industrial effluents for irrigation also results in accumulation of heavy metals in the soil. Concentration of heavy metal above safe limits is injurious for soil health and may lead to high level of heavy metals in plant parts (Mushtaq & Khan, 2010).

Islamabad, the capital city of Pakistan, is being affected by environmental pollution due to drains originating from the Industrial Estate Islamabad (IEI). Because of the lack of strict environmental monitoring in Pakistan, industries dump their solid and liquid wastes in adjacent drains, nullahs, and streams. This waste leaches down into groundwater and raises the level of heavy metals beyond the limits of National Environmental Quality Standards (Gulfraz *et al.,* 2002). Consequently, urban environment is deteriorating. However, plants having an extreme type of physiological adaptation can absorb heavy metals from water and accumulate in their aerial parts (Clemens, 2006). Tree-species may play a role in improving and purifying the urban environment. In Islamabad and adjacent areas dominant species include *Acacia modesta* (Phulai), *Grevillea robusta* (Silver oak), *Bauhinia variegate* (L.) (Kachnar), *Cassia fistula* (L.) (Amaltas), *Albizia lebbeck* (L.) Benth. (Siris), *Syzygium cumini* (L.) Skeels (Jaman), *Terminalia arjuna* (Roxburgh) (Arjan), *Pongamia pinnata* (L.) (Suhk chain), *Melia azedarach* (L.) (Dharek) (CDA, 2015). Present study was intended to examine the effects of industrial effluents on growth of selected tree-species. The key objectives of present study were to (1) determine the elemental composition of industrial effluents of IEI and (2) identify tree-species tolerant to industrial effluents.

Material and Methods

Study area: Present study was conducted in twin cities of Pakistan: Rawalpindi and Islamabad. Industrial effluents were collected from IEI. Islamabad is situated at 33.43˚N, 73.04˚E of the north side of Pothwar region. Its altitude is 540 meters (1,770ft). Islamabad has diverse weather conditions in a year: winter (November-February), spring (March-April), summer (May-June), and rainy monsoon (July-August). In the month of June temperature exceeds 38˚C. The coolest month in the year is January. Sparse snowfall is observed during winter. During the year temperature ranges from -4˚ to 46.1˚C (Anon., 2015).

Methods: Present study was carried out to explore the effects of industrial effluents on growth of selected tree-species. Samples of industrial effluents were collected from three locations (sectors I-10/3, I-9/3 drains, and processed water of I-9 treatment plant) of Islamabad (Table 1). Further two treatments were formulated by diluting collected effluents with distilled water (Table 1). The collected effluent samples were first filtered in the laboratory using filter paper. Filtered samples were analyzed for water quality parameters as described in Environmental Protection Agency guidelines (Anon., 2001). The pH indicates acidity and alkalinity of water that control the solubility of minerals and availability of nutrients to plants. Electrical conductivity is an estimate of total dissolved salts in water. Higher values of EC (irrigation water) negatively affect plant growth (Bernstein, 1975). The pH and EC of collected samples were determined by using conventional methods (Buck *et al*., 2002; Hendrickx *et al*., 1992). Total dissolved solids of effluents were determined based on the principle of Siemens (1889). Heavy metals concentrations in the sample were determined using atomic absorption spectroscopy technique developed by Walsh (1973). Table 1 elucidates the water treatments used in this study.

Growing media for plants was prepared by mixing silt-soil and farm yard manure (FYM). Polythene tubes of size 9×12 inch, with adequate number of holes in the bottom half were filled with the prepared growing media. Saplings of one year old *Acacia modesta*, *Grevillea robusta*, *Bauhinia variegate* (L.), *Cassia fistula* (L.), *Albizia lebbeck* (L.) Benth., *Syzygium cumini* (L.) Skeels, *Terminalia arjuna* (Roxburgh), *Pongamia pinnata* (L.), and *Melia azedarach* (L.) were selected for this study (Table 2). In total, 162 saplings were transplanted in polythene tubes adopting randomized complete block design (RCBD: 3×6×9). Saplings were irrigated according to the treatments mentioned in Table 1.

Plant growth data was recorded from October 2015 to July 2016 (ten months) regarding leaf growth (leaf area and number of leaves) and shoot growth (shoot length and number of branches) as stated in Ahmed *et al.*, 2016. The number of leaves for each plant was estimated by simple counting method as explained by Wood and Roper (2000). Leaf area (cm^2) of selected plants within each treatment was estimated using digital leaf area meter as mentioned by Pandey and Singh (2011) and mean of the data was estimated.

Shoot length (from base to tip) of 162 saplings was determined with measuring tape as described in Cornelissen *et al.* (2003). The change in numbers of branches per plant of selected plants from each treatment was recorded. The collected data was statistically analyzed using Analysis of Variance (ANOVA).

Table 1. Source and formulation of water treatments applied to tree saplings to check their tolerance against industrial effluents.

Treatment	Effluent source	Formulation type (%)
T_1	Industrial area sector I-10/3 Islamabad	Pure (100)
T_2	Industrial area sector I-9/3 Islamabad	Pure (100)
T_3	Industrial area sector I-10/3 Islamabad	Mixed (50:50)*
T_4	Industrial area sector I-9/3 Islamabad	Mixed (50:50)*
T_5	Treated water sector I-9 treatment plant Islamabad	Pure (100)
T_6	Groundwater from the university tube well Rawalpindi	Pure (100)

*****Prepared by diluting collected effluents with distilled water

Table 2. List of tree species selected to test their tolerance against industrial effluents.

S. No.	Scientific name	Common name
1.	*Acacia modesta*	Phulai
2.	*Grevillea robusta*	Silver oak
3.	*Bauhinia variegate* (L.)	Kachnar
4.	*Cassia fistula* (L.)	Amaltas
5.	*Albizia lebbeck* (L.) Benth.	Siris
6.	*Syzygium cumini* (L.) Skeels	Jaman
7.	*Terminalia arjuna* (Roxburgh)	Arjan
8.	*Pongamia pinnata* (L.)	Suhk chain
9.	*Melia azedarach* (L.)	Dharek

Results and Discussion

Analysis of quality indicators for water treatments is shown in Table 3. The pH of treatments prepared from sector I-9/3 source was more acidic (T4: 6.28 and T2: 6.04) compared to treatments prepared from sector I-10/3 source (T1: 6.39 and T3: 6.49), and treated water (T5: 6.41). Results showed that ground water (T6) had neutral pH (7.05). Electrical conductivity test showed that EC of T5 (24.7) and T2 (22.4) was higher compared to T1 (21.6), T3 (14.95), T4 (21) and T6 (0.13). Total dissolve solids of T5 (16.53) and T2 (15.01) were higher than T3 (10.01).

Generally, lower pH (acidic) and higher EC values were observed for all effluent samples compared to pure ground water. Results of present study coincide with the study of Sial *et al.* (2006) and Chaudhary *et al.* (2015). Chaudhry *et al.* (2015) found acidic pH ranging from 5.33 to 5.96 and very high values of EC and TDS. High values of EC and TDS indicate elevated concentration of salts leading to soil salinity and sodicity that inhibit plant growth.

Table 3. Analysis of water quality of treatments used to irrigate tree saplings.

Quality indicators	T1	T2	T3	T4	T5	T6
pH	6.39	6.04	6.49	6.28	6.41	7.05
TDS (mg/l)	14.49	15.01	10.01	14.08	16.53	0.008
EC (μS/cm)	21.6	22.4	14.95	21	24.7	0.13
Manganese (Mn)	0.84	0.129	0.313	0.043	NIL	NIL
Lead (Pb)	4.601	0.498	3.202	0.439	NIL	NIL
Nickel (Ni)	1.427	2.832	0.658	1.617	1.812	NIL
Chromium (Cr)	1.453	0.718	0.751	0.31	1.006	NIL
Magnesium (Mg)	10.226	12.462	2.284	11.258	8.662	NIL
Zinc (Zn)	0.65	NIL	NIL	NIL	0.381	NIL
Cadmium (Cd)	0.206	0.155	NIL	NIL	0.047	NIL

Analysis of industrial effluents for heavy metals presence indicated variations among treatments (Table 3). The concentration of Manganese (Mn: 0.84), Lead (Pb: 4.601), Chromium (Cr: 1.453), Zinc (Zn: 0.65), and Cadmium (Cd: 0.206) in T1 was higher than T2, T3 and T4. The quantity of Nickel (Ni: 2.832) and Magnesium (Mg: 12.462) was the highest in T2. Manganese and Lead were absent in T5. Zinc (Zn) and Cadmium (Cd) were absent in T3 and T4 (Table 3). The concentrations of Cadmium (Cd: 0.206), Chromium (Cr: 1.453), Manganese (Mn: 0.84) and Nickel (Ni: 2.832) were above the maximum concentrations of trace elements in irrigation water as recommended by FAO (Table 4; Ayers *et al.*, 1985). However, Lead (Pb: 4.601) and Zinc (Zn: 0.65) concentrations were within safe limits as described by FAO (Ayers *et al*., 1985).

Studies regarding water quality in industrial estates of Peshwar, Gujranwala and Hattar Pakistan reported high concentration (above safe limits) of heavy metals in effluents (Rehman *et al.*, 2008; Mushtaq & Khan, 2010). Copper concentration was 6.013 and 9.005 mg/l in effluent samples collected from Peshawar and Gujranwala industrial estates respectively (Rehman *et al.*, 2008). Lead (Pb) quantities in all the samples collected from three industrial estates were very high, ranging from 0.09 to 0.942 mg/l, which were above permissible limit (Rehman *et al*., 2008). The results of present study are also in line with the findings of Mushtaq & Khan (2010) who have reported high concentrations of heavy metals in waste water of Rawalpindi region. Long term use of industrial effluents affects soil health and may lead to enhanced levels of heavy metals in crop plants (Mushtaq & Khan, 2010; Khan *et al*., 2017).

Table 4. Recommended maximum concentrations of heavy metals in irrigation water by FAO.

Heavy metals	Recommended maximum concentration (mg/l)
Cd	0.01
Cr	0.10
Mn	0.20
Ni	0.20
Pd	5.00
Zn	2.00

The comparison of treatments regarding their influence on shoot length is presented in Fig. 1. Statistical analysis indicated significant difference in shoot length (cm) between treatments at 5% level of significance (Table 5). Data analysis showed Silver oak had minimum length (1 cm) whereas both Jaman and Kachnar showed maximum increase in shoot length (4 cm) with T1. Jaman and Kachnar showed maximum (13 cm) and (10 cm) change in shoot length with T6. Jaman showed visible tolerance against effluent treatments by showing less reduction in shoot length with T2 (7), T3 (8), T4 (9), and T5 (10) while Siris shoot length was also 6 and 8cm with T2 and T4 respectively. Therefore, Jaman and Kachnar were relatively tolerant to industrial effluents.

The impact of industrial effluents on number of branches was negative (Fig. 2). Statistical analysis revealed significant differences on number of branches at 5% level of significance (Table 5). The data showed that Jaman, Kachnar, Dharek, Siris and Amaltas had minimum number of branches (2) per plant with T1. Phulai and Arjun among nine species had maximum number of branches per plant (13) and (8) respectively with T1. Phulai and Silver oak had maximum number of branches per plant (24) and (15) with T6. Generally, Phulai and Arjun showed the highest tolerance against effluent treatments compared to other species in this study (Fig. 2).

It is evident from results that most species showed minimum leaf area with T1 as presented in Fig. 3. Results showed that Kachnar, Siris and Dharek had minor difference in leaf area with effluents compared to pure ground water. Phulai and Jaman showed minimum leaf area (0.35 and 1.24 cm^2) with T1. Kachnar and Dharek showed maximum leaf area 16.42 and 20.42 cm^2 respectively with T6. Kachnar and Dharek showed high tolerance in terms of leaf area against effluent treatments compared to other species in this study.

Analysis of data showed visible inhibiting effect in number of leaves of Silver Oak, Jaman, Kachnar and Siris with T1 (Fig. 4). Statistical analysis showed significant impact of effluent treatments on number of leaves at 5% level of significance (Table 4). Arjun, Sukh chain, and Amaltas performed better in higher concentration of heavy metals as compared to other species examined in this study (Fig. 4). Arjun had maximum number of leaves per plant (121) and (124) with T4 and T6 respectively. Moreover, Sukh chain has maximum number of leaves with T3. Siris had minimum number of leaves per plant (3) with T1. Arjun and Sukh chain showed highest resistance based on number of leaves per plant to effluent treatments compared to other species in this study.

Results of shoot and leaf growth parameter showed visible decline in growth of selected tree-species irrigated with industrial effluents. Panday (2006) also reported the similar type of results. He reported that plants irrigated with industrial effluents showed symptoms like stunted growth, necrosis and chlorosis in leaves. Similarly, Yoon *et al.* (2006) found that effluents containing heavy metals have negative impact on the growth of plants.

Table 5. Statistical significance of treatments and species on plant growth.

Tests of between-subjects effects						
Growth parameters	**Source**	**SS**	**df**	**Mean square**	**F value**	**P value**
	Corrected model	342.463[a]	13	26.343	13.933	0.000
	Intercept	1280.907	1	1280.907	677.463	0.000
	Treatments	229.870	5	45.974	24.315	0.000
Shoot length	Species	112.593	8	14.074	7.444	0.000
	Error	75.630	40	1.891		
	Total	1699.000	54			
	Corrected total	418.093	53			
	R^2 = 0.819 (Adjusted R^2= 0.760)					
	Source	**SS**	**df**	**Mean square**	**F value**	**P value**
	Corrected model	1699.000[a]	13	130.692	63.494	0.000
	Intercept	3082.667	1	3082.667	1.498E3	0.000
	Treatments	206.000	5	41.200	20.016	0.000
Number of branches	Species	1493.000	8	186.625	90.668	0.000
	Error	82.333	40	2.058		
	Total	4864.000	54			
	Corrected total	1781.333	53			
	R^2 = 0.954 (Adjusted R^2 = 0 .939)					
	Source	**SS**	**df**	**Mean square**	**F value**	**P value**
	Corrected model	1386.899[a]	13	106.685	32.318	0.000
	Intercept	2498.592	1	2498.592	756.892	0.000
	Treatments	101.350	5	20.270	6.140	0.000
Leaf area	Species	1285.549	8	160.694	48.678	0.000
	Error	132.045	40	3.301		
	Total	4017.536	54			
	Corrected total	1518.944	53			
	R^2 = 0.913 (Adjusted R^2 = 0.885)					
	Source	**SS**	**df**	**Mean square**	**F value**	**P value**
	Corrected model	46383.111[a]	13	3567.932	65.762	0.000
	Intercept	39042.667	1	39042.667	719.607	0.000
	Treatments	619.111	5	123.822	2.282	0.065
Number of leaves	Species	45764.000	8	5720.500	105.436	0.000
	Error	2170.222	40	54.256		
	Total	87596.000	54			
	Corrected total	48553.333	53			
	R^2 = 0.955 (Adjusted R^2 = 0.941)					

α: level of significance was 0.05

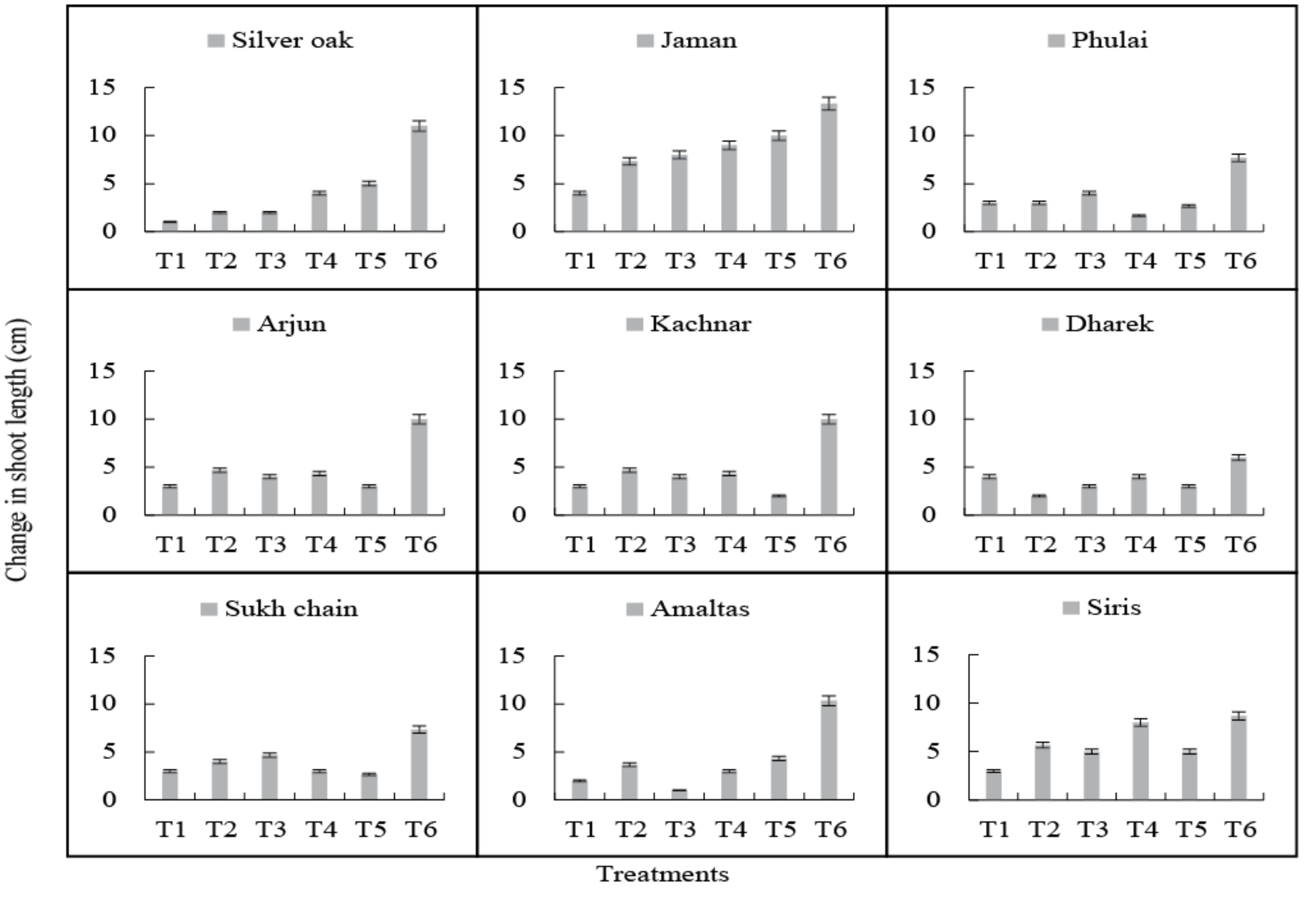

Fig. 1. Impact of effluent treatments on change in shoot length of various tree-species.

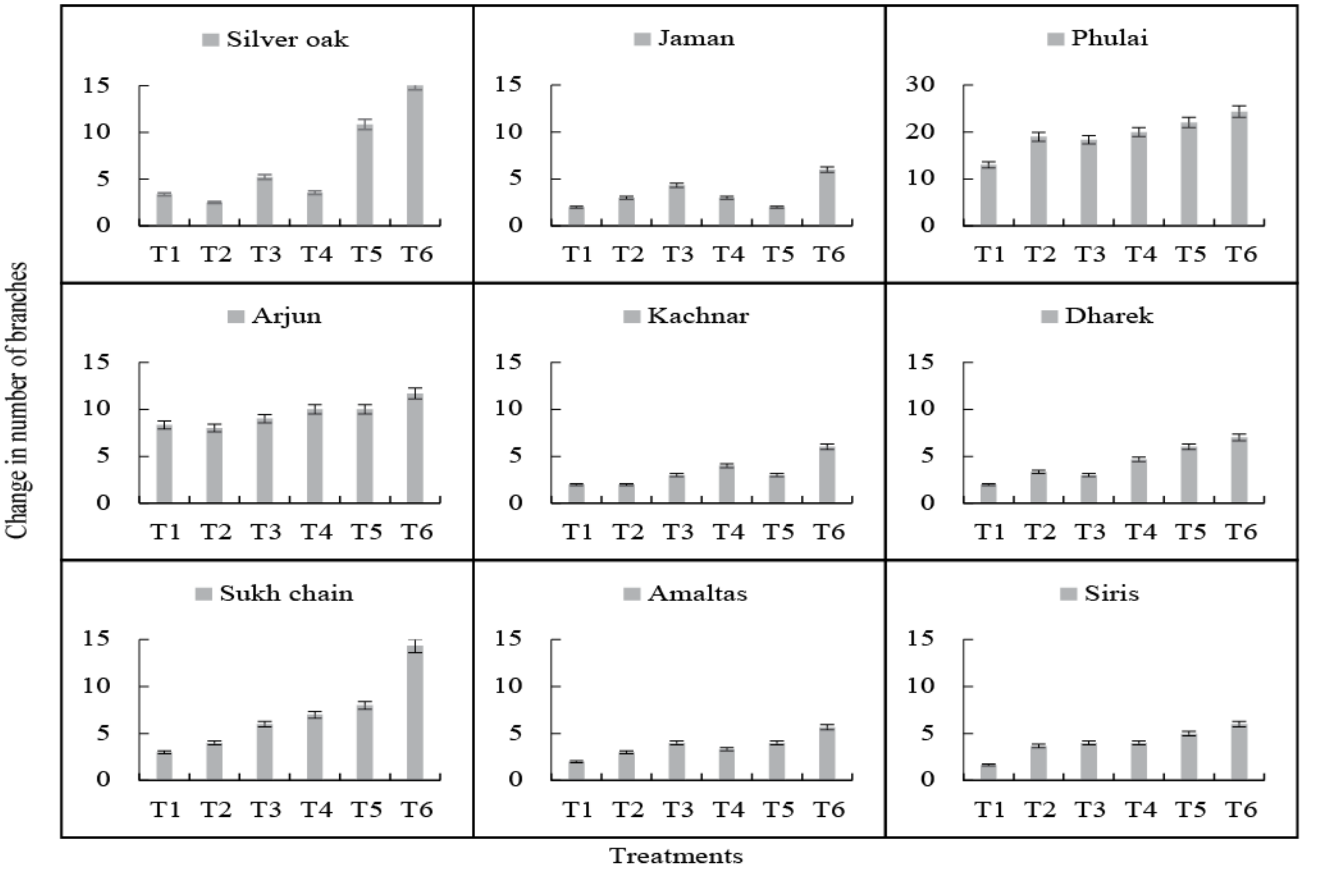

Fig. 2. Impact of effluent treatments on change in number of branches of various tree-species.

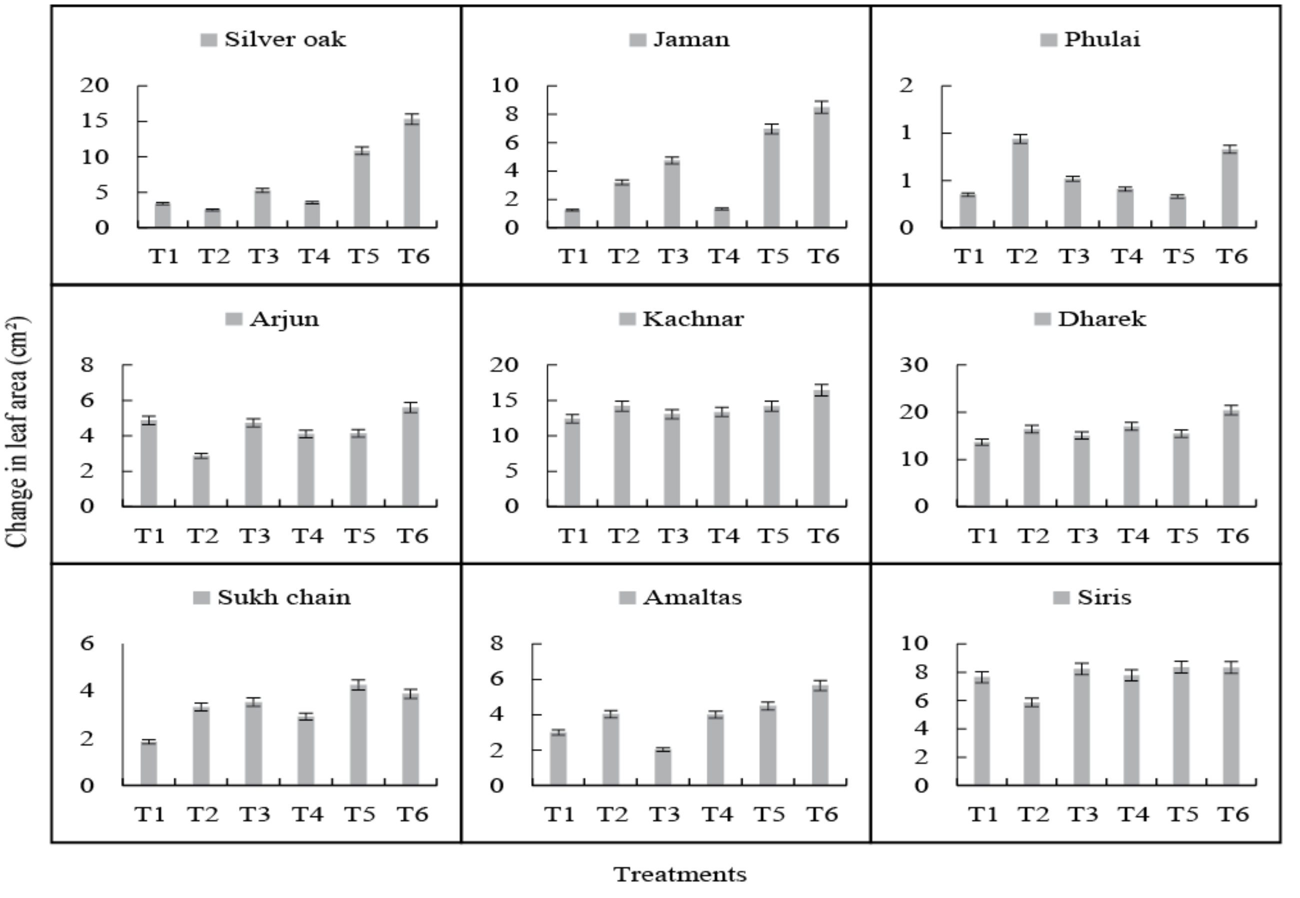

Fig. 3. Impact of effluent treatments on change in leaf area of various tree-species.

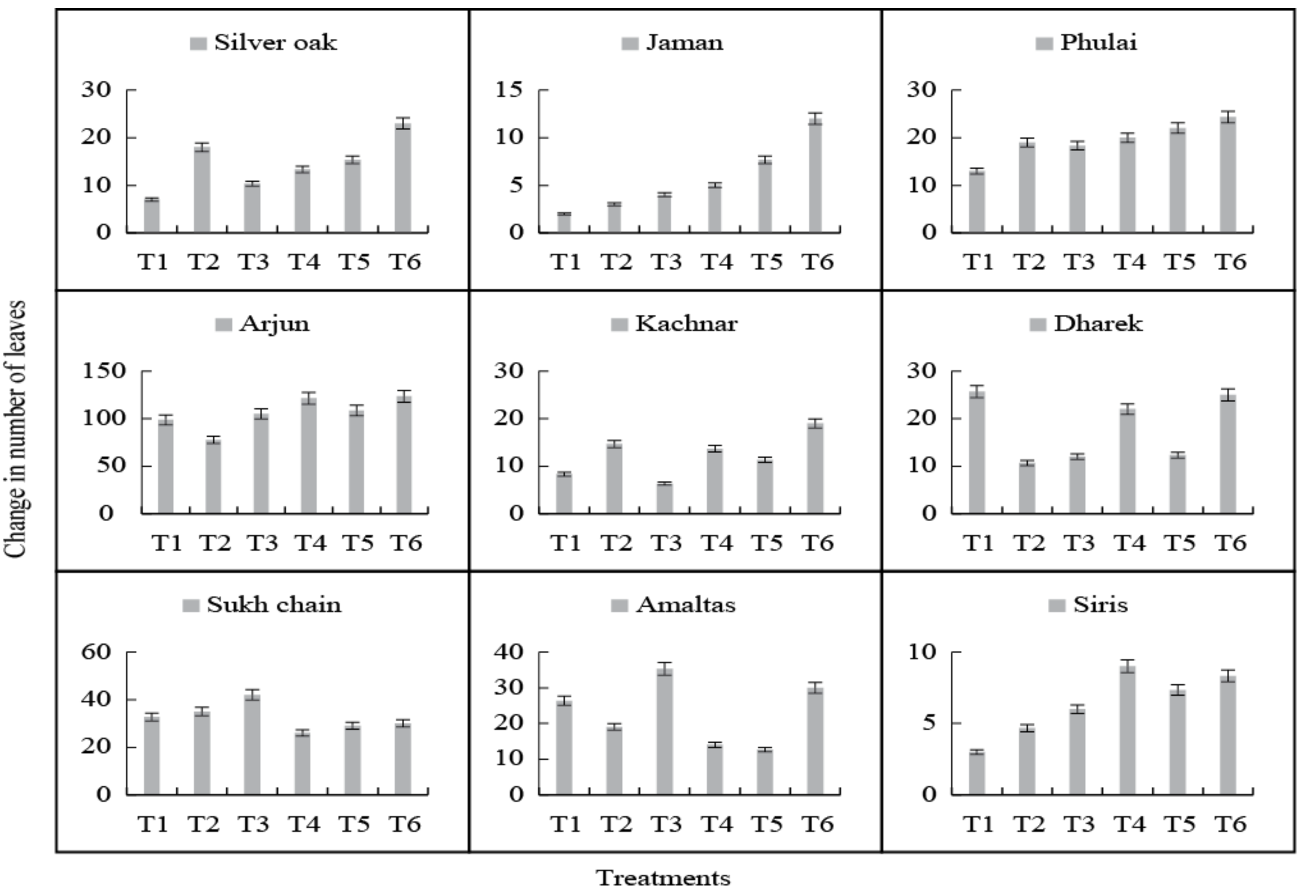

Fig. 4. Impact of effluent treatments on number of leaves of various tree-species.

Conclusions

The results of present study revealed that effluents of industrial estate Islamabad contain higher concentration of heavy metals, low pH (acidic) and higher EC and TDS compared to the standards described by FAO. Furthermore, TDS was also high in treated water by water treatment plant. Heavy metals were also present in treated water. Plant saplings irrigated with industrial effluent showed clear symptoms of toxic effects such as stunted growth, leaf abscission, and decline in number of branches and leaf area. Plant saplings irrigated with diluted effluents (50%) showed less toxicity symptoms. Most species showed normal growth in the absence of heavy metals. Generally, Arjun, Dharek, Jaman, Phulai, and Siris performed relatively better than other species. These species may be considered tolerant to higher concentrations of heavy metals. Therefore, this is recommended that these species may be planted along industrial drains. The efficiency of the water treatment plant (I-9 Islamabad) should be carefully examined by the concerned agency.

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