Pak. J. Bot., 41(6): 3125-3138, 2009.

GROWTH OF *LEUCAENA LEUCOCEPHALA* (LAM.) DE-WIT IN DIFFERENT SOIL COMPOSITIONS OF KORANGI AND LANDHI INDUSTRIAL AREAS OF KARACHI, PAKISTAN

SYED ATIQ-UR-REHMAN[1] AND MUHAMMAD ZAFAR IQBAL[2]

Department of Botany,
University of Karachi, Karachi-75270, Pakistan.

Abstract

The growth of *Leucaena leucocephala* (Lam.) de-Wit., were studied in soils collected from four sites viz., Khan Towel, Tanveer Garment, One Tech Rubber and One Tech Ply Board factories in the vicinity of Korangi and Landhi industrial areas under natural environmental conditions. *L. leucocephala* plants grown in 25, 50 and 75% soils of all of the industries demonstrated reductions in many of the growth parameters as compared to plants grown in Garden soil. Principally, 75% Khan Towel factory soil and 50% other factories soils exhibited great inhibition in most of growth characters than Garden soil. Plant cover, leaves and leaflets numbers, leaf area, leaf, total plant dry weights and root/shoot ratio were noticeably suppressed ($p<0.05$) in 25, 50 and 75% Khan Towel factory soil than Garden soil. Substantial retardation ($p<0.05$) in root/shoot and leaf weight ratios were recorded in 25, 50 and 75% Tanveer Garment factory soil. 25, 50 and 75% One Tech Rubber and One Tech Ply Board factories soils literally diminished ($p<0.05$) plant cover and leaf dry weight as compared to Garden soil.

Introduction

Environment is composed of air, water, land, plants and animals. All these constituents are interdependent on one another and maintain a balance in nature. Some time this balance is lost due to various reasons. An undesirable change occurs in physical, chemical and biological characteristics of air, land and water due to pollutants. Environmental pollution is a constant threat to biota including plants. Karachi has three main industrial zones viz., Sindh Industrial Trading Estate, Landhi Industrial Trading Estate and Korangi industrial area which emit toxic pollutants into air, water and soil (Atiq-ur-Rehman & Iqbal, 2007). *Leucaena leucocephala* (Lam.) de-Wit, is a leguminous tree, which belongs to the family Mimosaceae and is cultivated around roadsides and industrial areas of Karachi for ornamental purposes (Atiq-ur-Rehman & Iqbal, 2007) and economically an important plant. It is a rapidly growing tree native to central America, with high protein content in foliage and is used as fodder for feeding livestock. Various kinds of industrial pollutants of rubber factory effluent adversely affected on elemental bioaccumulation and metabolite concentration in component parts of *Triticum aestivum* var. UP-262 plants (Habib & Iqbal, 1996). Cadmium, lead, chromium and zinc treatments greatly affected the seed germination and seedling growth of *L. leucocephala* (Iqbal & Atiq-ur-Rehman, 2002). Naqvi & Khattak (1995) had reported an increased amount of chromium, nickel, copper and lead in the waste effluents from Landhi Industrial Trading Estate. Zinc is an essential plant nutrient but can be a soil contaminant at high concentrations (Polson & Adams, 1970). In soil along the sewage effluents channels of Malir river (Karachi), high amount of lead, copper and zinc were detected, which influenced the composition of plant communities in the area (Qamar-Uz-Zaman & Iqbal, 1994). Due to destructive and hazardous role of towel, garment, rubber and ply board industries etc., it is necessary to investigate the effects of polluted soil of industrial sites on growth of *L. leucocephala*.

E-mail's: [1] atiq_falcon7663@yahoo.com; [2] mziqbalbotuokpk@yahoo.com

Materials and Methods

The experiment was conducted in a greenhouse under uniform natural environmental conditions at the Department of Botany, University of Karachi. The range of maximum temperature, minimum temperature, average temperature and atmospheric relative humidity during the experiment was between 22-31°C, 11-18°C, 17-25°C and 14-88%, respectively. The weather outlook was mostly sunny with a range of 10:30-11:41 hours sun shine. Healthy and uniform-sized seeds of *Leucaena leucocephala* (Lam.) de-Wit, were chosen from Karachi University Campus. Due to hard seed coat, the seeds were slightly cut at one end and were sown in garden soil (loam soil) at 1 cm depth in large pots. The pots were irrigated daily. After about one month period, uniform-sized seedlings were transplanted into pots of 19.8 cm in diameter and 9.6 cm in depth in different soil ratios (25% factory soil + 75% garden soil; 50% factory soil + 50% garden soil; 75% factory soil + 25% garden soil) of Khan Towel, Tanveer Garment, One Tech Rubber and One Tech Ply Board factories. These soils were collected at 0-30 cm depth from Korangi and Landhi industrial regions of Karachi. The garden soil was used as a control. The fraction of garden soil was one part manure and two parts fine sand. In the preliminary studies, pure soils of all industries hardly showed any response to seed germination and seedling growth. There were six replicates for each treatment and the experiment was completely randomized. Only one seedling was grown in each pot and the plants were irrigated daily. Every week, pots were reshuffled to avoid light/shade or any other greenhouse effects. Seedlings height, number of leaves and plant cover were recorded after every two weeks for ten weeks. After ten weeks, number of leaflets and leaf area of each plant were recorded and all the plants of *L. leucocephala* were carefully removed from the pots and washed thoroughly to measure root, shoot and seedling length. Root, shoot and leaves were separated for drying in an oven at 80°C for 24 hours. Oven-dried weights of root, shoot and leaves and total plant dry weight were recorded. Root/Shoot ratio, leaf weight ratio, specific leaf area and leaf area ratio were determined as follows:

$$\text{Root/Shoot ratio} = \frac{\text{Root dry weight}}{\text{Shoot dry weight}}$$

$$\text{Leaf weight ratio} = \frac{\text{Leaf dry weight}}{\text{Total plant dry weight}}$$

$$\text{Specific leaf area } (cm^2\ g^{-1}) = \frac{\text{Leaf area}}{\text{Leaf dry weight}}$$

$$\text{Leaf area ratio } (cm^2\ g^{-1}) = \frac{\text{Leaf area}}{\text{Total plant dry weight}}$$

For soil analysis, the samples were air-dried, lightly crushed and passed through a 2 mm sieve and kept in the laboratory. For mechanical analysis of soil, coarse sand was determined by sieve method using 0.05 mm sieve (Anon., 1951). Maximum water holding capacity (W.H.C.) was measured by the method of Keen (1931). Soil organic matter was determined according to Jackson (1958). Calcium carbonate concentration was determined by acid neutralization, as described by Qadir *et al.*, (1966). Bower & Wilcox (1965) methodology was used to determine total soluble salts whereas, soil pH was recorded by a direct pH-reading meter (MP 220 pH Meter) (Mettler, Toledo). Available sulfate in soil was determined by turbidity method as described by Iqbal

(1988), using a colorimeter (Photoelectric Colorimeter AE-11M). Soil heavy metals were also determined. In this regard, one gram dried soil sample was taken in 50 ml beaker and digested with 5 ml concentrated nitric acid (HNO_3) + 5 ml concentrated perchloric acid ($HClO_4$), heated at 90 °C for 2½ hours. Thereafter, little amount of distilled water was added in the digested residue and filtered through Whatman filter paper No. 42 the volume of filtrate was made up to 50 ml using distilled water and filtrate was diluted 10 times for copper, zinc and chromium analyses by atomic absorption spectrophotometer (Perkin Elmer Model No. 3100).

All the data was statistically analyzed by ANOVA (Steel & Torrie, 1984) and DMRT (Duncan, 1955) ($p<0.05$) using personal computer software packages Costat version 3.0 and SPSS version 10.0.

Reduction in percentage of growth data was determined in treated soils of the factories relative to control soil as described by Atiq-ur-Rehman & Iqbal (2007).

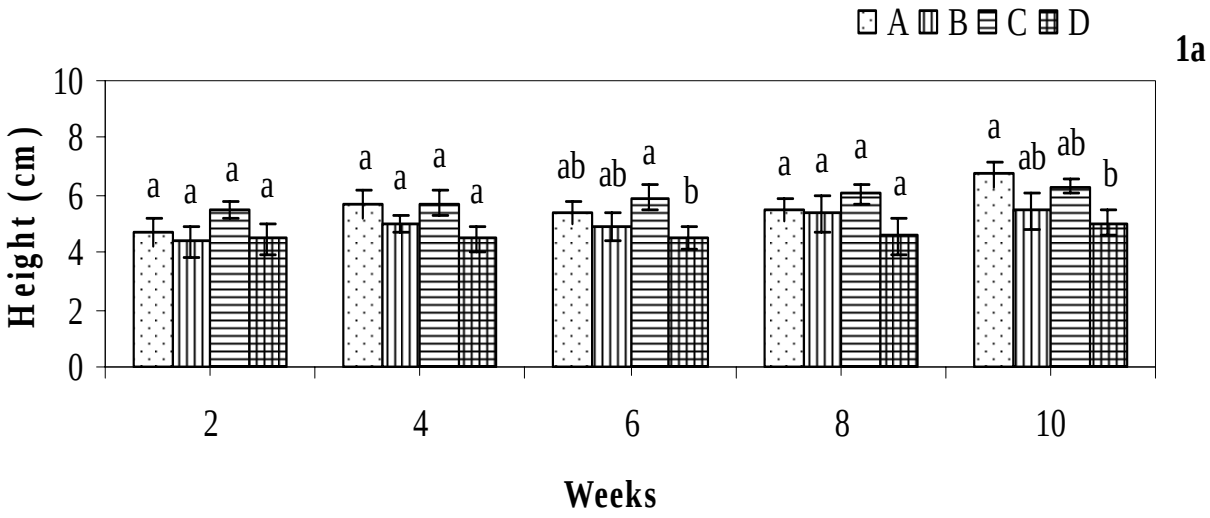
Results

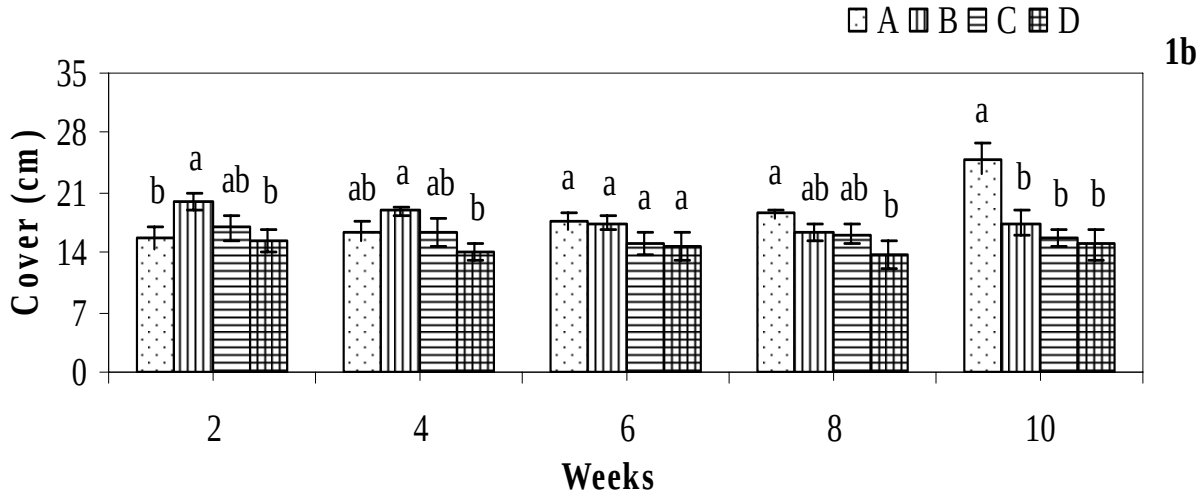
Plant cover and number of leaves of *Leucaena leucocephala* were decreased in 25, 50 and 75% soils of all of the industries as compared to Garden soil. Khan Towel and One Tech Ply Board factories soils significantly reduced plant height, plant cover and number of leaves in 25, 50 and 75% soils. Plant height (5.03 cm) (Fig. 1a) of *L. leucocephala* was greatly reduced ($p<0.05$) in 75% Khan Towel factory soil, whereas plant cover (14.92 cm) (Fig. 1b) and number of leaves (8.33) (Fig. 1c) were prominently retarded ($p<0.05$) by 25, 50 and 75% Khan Towel factory soil than plant height (6.72 cm), plant cover (24.92 cm) and number of leaves (16.83) of *L. leucocephala* in Garden soil.

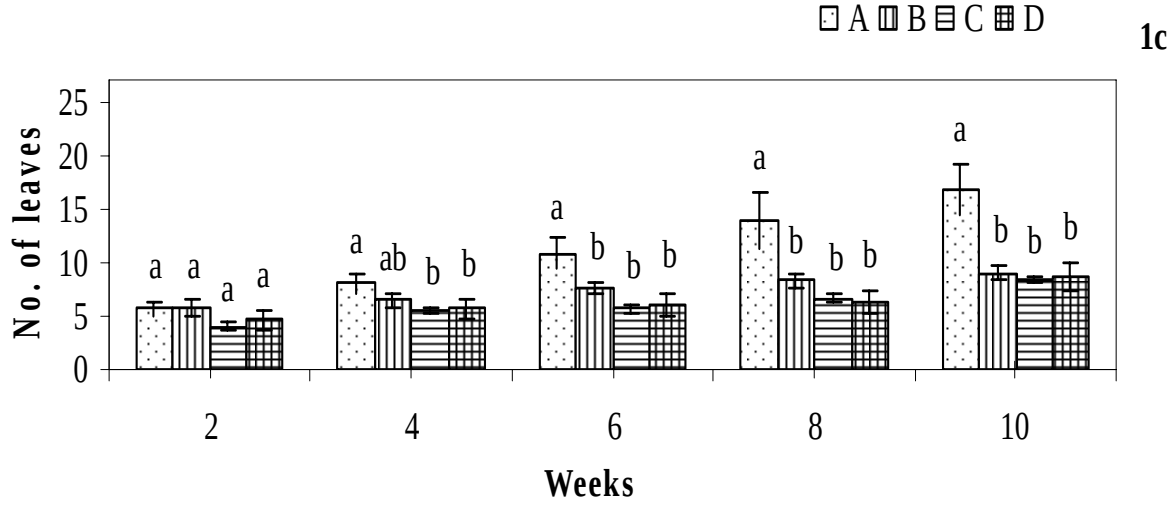
Plant height (6.57 cm) (Fig. 2a) was reduced in 50% Tanveer Garment factory soil as correlated to plant height (6.72 cm) in Garden soil. Plant cover (16.80 cm) (Fig. 2b) was markedly stunted ($p<0.05$) by 50 and 75% Tanveer Garment factory soil as correlated to plant cover (24.92 cm) in Garden soil. 75% Tanveer Garment factory soil obviously reduced the leaves numbers (11.17) (Fig. 2c) comparatively to the number of leaves (16.83) in Garden soil.

Plant height (6.13 cm) (Fig. 3a) of *L. leucocephala* was reduced by 50% One Tech Rubber factory soil related to plant height (6.72 cm) in Garden soil. Plant cover (16.82 cm) (Fig. 3b) was significantly ($p<0.05$) less by 25, 50 and 75% soil, whereas number of leaves (9.67) (Fig. 3c) was clearly reduced ($p<0.05$) by 50% One Tech Rubber factory soil as compared to plant cover (24.92 cm) and number of leaves (16.83) in Garden soil.

The reduction was notable ($p<0.05$) in plant height (4.53 cm) (Fig. 4a) in treatment of 50 and 75% One Tech Ply Board factory soil and plant cover (13.60 cm) (Fig. 4b) ($p<0.05$) in 25, 50% and 75% soil as compared to plant height (6.72 cm) and plant cover (24.92 cm) in Garden soil. The number of leaves were lowered by 25% One Tech Ply Board factory soil (9.50) (Fig. 4c) as compared to number of leaves (16.83) in Garden soil. 25, 50 and 75% soils of Khan Towel, Tanveer Garment, One Tech Rubber and One Tech Ply Board factories reduced a number of growth properties of *L. leucocephala* as compared to Garden soil. 25 and 75% Khan Towel factory soil brought about conspicuous reduction ($p<0.05$) in root and seedling length, whereas shoot length was obviously stunted ($p<0.05$) in 75% soil over Garden soil (Table 1a). Root dry weight was manifestly suppressed ($p<0.05$) in 50 and 75% soil as compared to Garden soil. Number of leaflets, leaf area, leaf and total plant dry weights and root shoot ratio were apparently depleted ($p<0.05$) in 25, 50 and 75% soil.





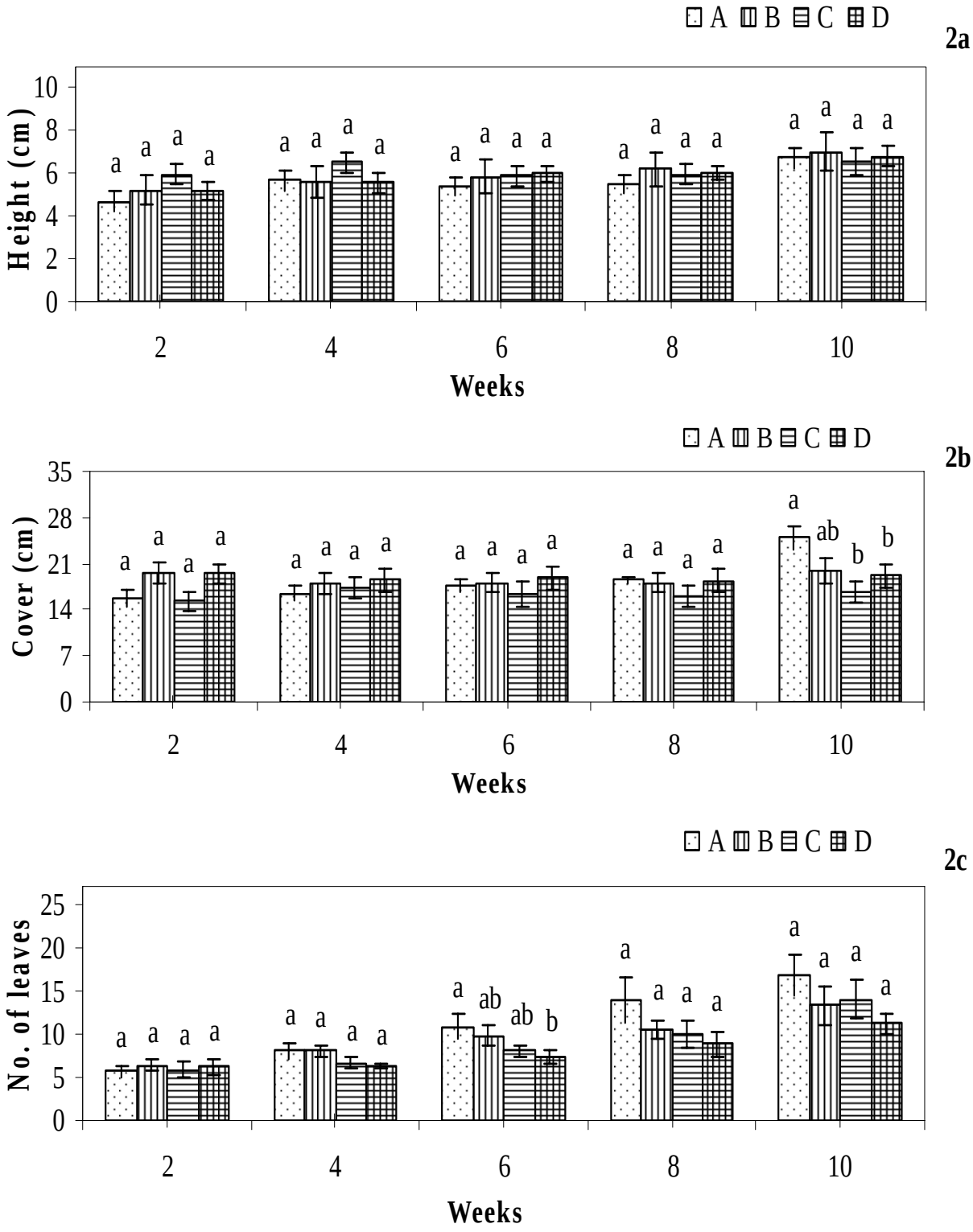


Figs. 1a, b & c: Periodical growth of *Leucaena leucocephala* in Khan Towel factory soil.

A = Garden soil; B = 25% factory soil + 75% garden soil; C = 50% factory soil + 50% garden soil; D = 75% factory soil + 25% garden soil.

Statistical significance determined by analysis of variance. Numbers followed by the same letters in each periodical height, cover and number of leaves are not significantly different ($p<0.05$) according to Duncan's Multiple Range Test.

I Standard error.

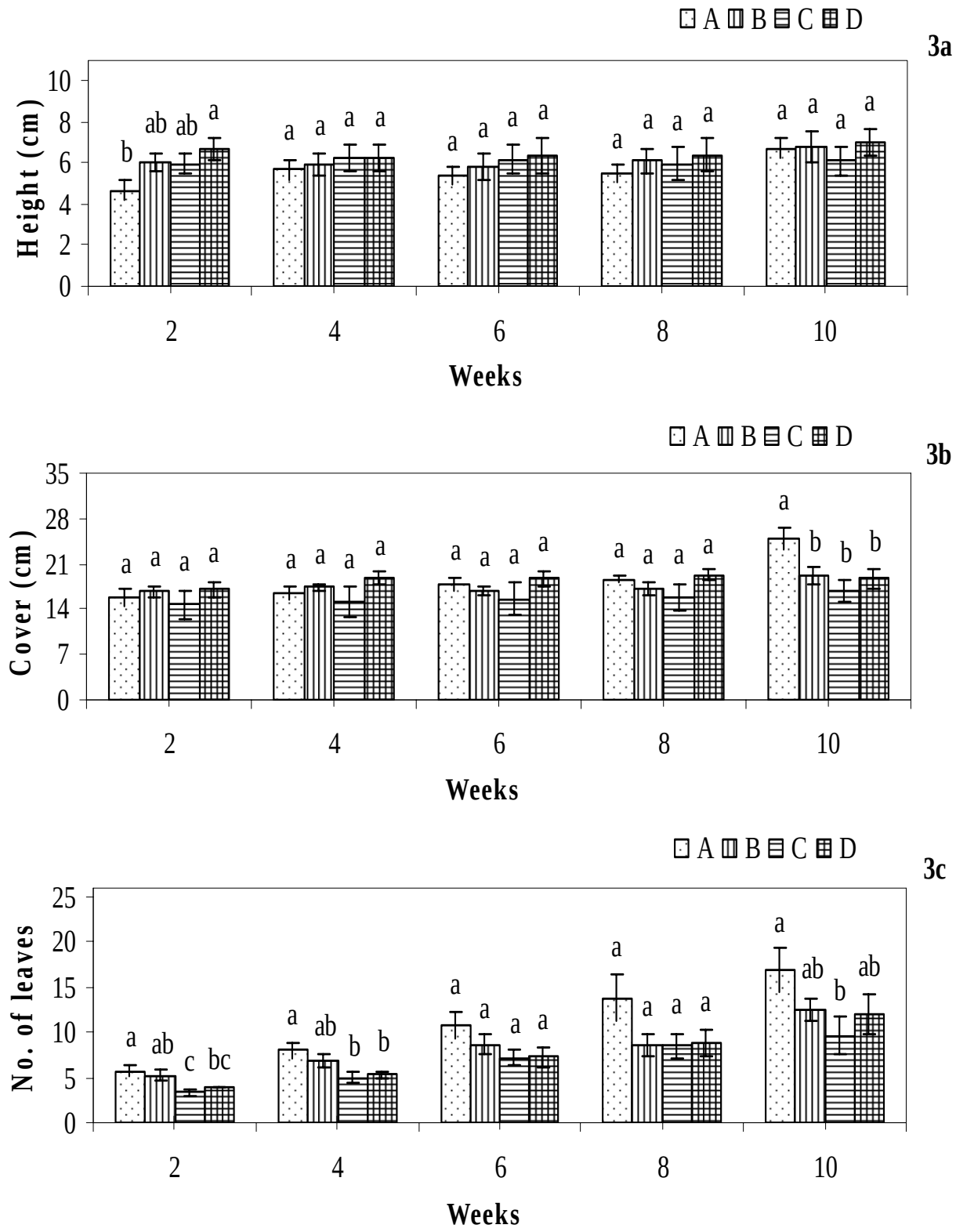


Figs. 2a, b & c: Periodical growth of *Leucaena leucocephala* in Tanveer Garment factory soil.

A = Garden soil; B = 25% factory soil + 75% garden soil; C = 50% factory soil + 50% garden soil; D = 75% factory soil + 25% garden soil.

Statistical significance determined by analysis of variance. Numbers followed by the same letters in each periodical height, cover and number of leaves are not significantly different ($p < 0.05$) according to Duncan's Multiple Range Test.

I Standard error.

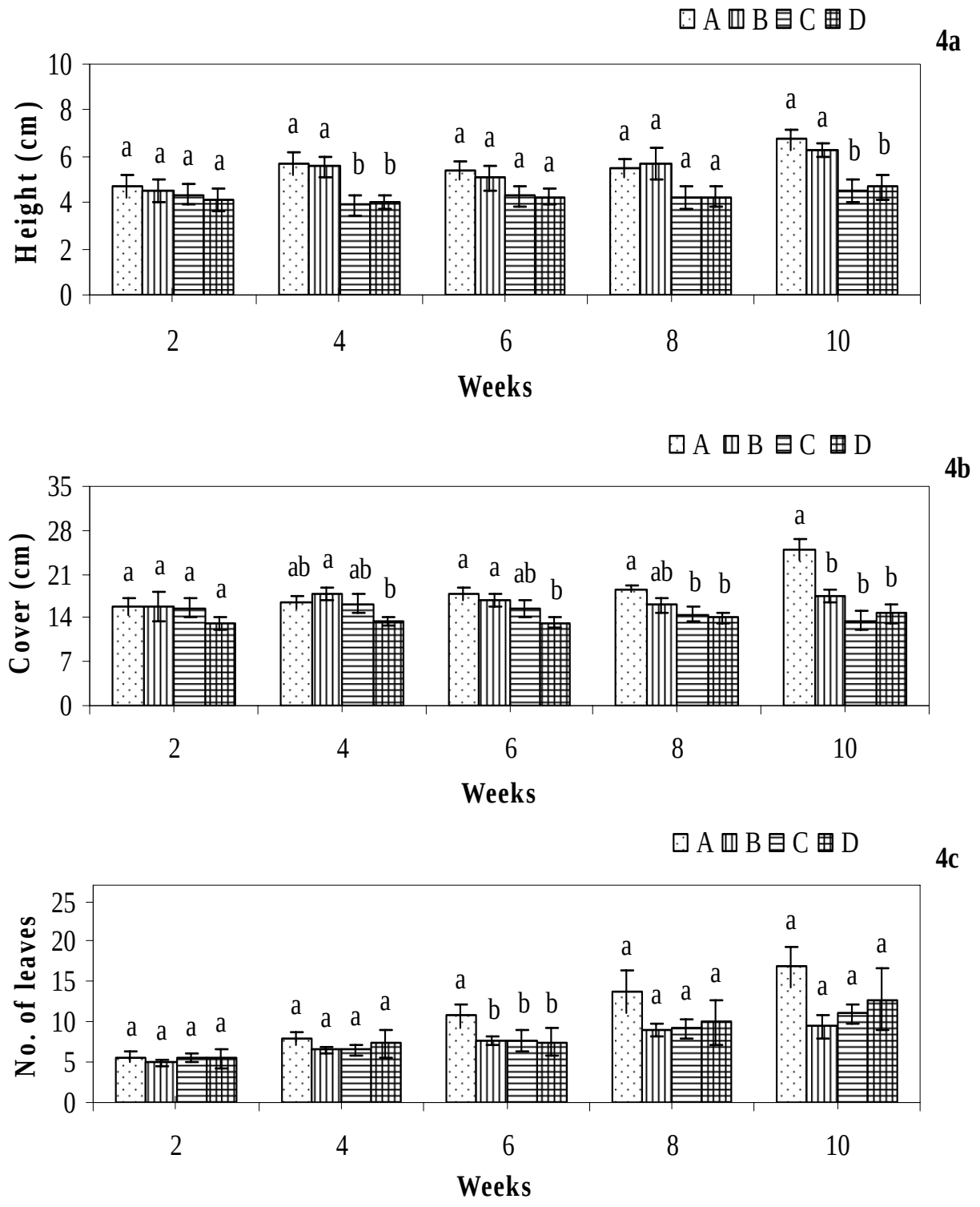


Figs. 3a, b & c: Periodical growth of *Leucaena leucocephala* in One Tech Rubber factory soil.

A = Garden soil; B = 25% factory soil + 75% garden soil; C = 50% factory soil + 50% garden soil; D = 75% factory soil + 25% garden soil.

Statistical significance determined by analysis of variance. Numbers followed by the same letters in each periodical height, cover and number of leaves are not significantly different ($p<0.05$) according to Duncan's Multiple Range Test.

I Standard error.



Figs. 4a, b & c: Periodical growth of *Leucaena leucocephala* in One Tech Ply Board factory soil.

A = Garden soil; B = 25% factory soil + 75% garden soil; C = 50% factory soil + 50% garden soil; D = 75% factory soil + 25% garden soil.

Statistical significance determined by analysis of variance. Numbers followed by the same letters in each periodical height, cover and number of leaves are not significantly different ($p < 0.05$) according to Duncan's Multiple Range Test.

I Standard error.

Table 1a. Growth of *Leucaena leucocephala* in different factories soils.

Soils	Treatments	Root length (cm)	Shoot length (cm)	Seedling length (cm)	No. of leaflets	Leaf area (sq cm)	Root dry weight (g)	Shoot dry weight (g)	Leaf dry weight (g)	Total plant dry weight (g)	Root/Shoot ratio	Leaf weight ratio	Specific leaf area ($cm^2 g^{-1}$)	Leaf area ratio ($cm^2 g^{-1}$)
A	Control	26.47 a ±1.88	10.33 a ±0.90	36.80 a ±2.63	198.83 a ±33.35	19.48 a ±4.35	0.11 a ±0.01	0.03 ab ±0.01	0.10 a ±0.01	0.24 a ±0.03	3.36 a ±0.41	0.41 a ±0.02	197.01 a ±35.67	78.87 a ±11.68
	25%▲	14.28 b ±2.60	8.65 ab ±0.66	22.93 b ±2.38	120.00 b ±10.99	9.24 b ±1.93	0.08 ab ±0.01	0.05 a ±0.01	0.04 b ±0.00	0.16 b ±0.02	1.65 b ±0.21	0.23 a ±0.01	256.49 a ±41.79	56.62 a ±6.93
	50%▲	19.68 ab ±4.41	8.82 ab ±0.33	28.50 ab ±4.31	110.89 b ±3.35	9.54 b ±1.60	0.06 b ±0.01	0.04 ab ±0.00	0.04 b ±0.01	0.14 b ±0.02	1.53 b ±0.17	0.25 a ±0.03	299.32 a ±44.73	74.33 a ±13.07
	75%▲	11.18 b ±3.18	8.00 b ±0.47	19.18 b ±3.55	110.78 b ±18.54	8.96 b ±2.56	0.05 b ±0.01	0.03 b ±0.00	0.03 b ±0.01	0.10 b ±0.02	1.74 b ±0.36	0.22 a ±0.07	188.59 a ±68.67	84.41 a ±19.08
	L.S.D.	9.31	1.86	9.76	58.78	8.31	0.03	0.01	0.03	0.07	0.90	0.12	145.53	39.56
B	Control	26.47 a ±1.88	10.33 a ±0.90	36.80 a ±2.63	198.83 a ±33.35	19.48 a ±4.35	0.11 a ±0.01	0.03 a ±0.01	0.10 a ±0.01	0.24 a ±0.03	3.36 a ±0.41	0.41 a ±0.02	197.01 b ±35.67	78.87 a ±11.68
	25%▲	18.03 ab ±2.89	10.25 a ±1.17	28.28 ab ±3.50	167.33 a ±29.09	14.40 a ±3.36	0.08 a ±0.02	0.06 a ±0.01	0.06 ab ±0.02	0.20 a ±0.05	1.65 b ±0.33	0.30 b ±0.04	269.08 ab ±31.27	76.26 a ±6.41
	50%▲	21.40 ab ±3.67	9.33 a ±0.54	30.73 ab ±3.77	176.89 a ±28.81	14.92 a ±4.71	0.07 a ±0.01	0.05 a ±0.01	0.04 b ±0.01	0.16 a ±0.02	1.50 b ±0.25	0.27 b ±0.03	324.46 a ±41.99	87.73 a ±15.59
	75%▲	14.88 b ±2.86	10.15 a ±0.69	25.03 b ±3.26	151.33 a ±12.00	13.55 a ±2.07	0.07 a ±0.01	0.05 a ±0.01	0.06 b ±0.01	0.18 a ±0.03	1.54 b ±0.29	0.32 b ±0.01	243.66 ab ±27.78	78.77 a ±10.91
	L.S.D.	8.55	2.54	9.79	79.87	11.10	0.05	0.03	0.04	0.10	0.96	0.08	102.04	34.26

A = Khan Towel factory soil; B =Tanveer Garment factory soil.

▲ Soil compositions: 25% factory soil + 75% garden soil; 50% factory soil + 50% garden soil; 75% factory soil + 25% garden soil.

Statistical significance determined by analysis of variance. Number followed by the same letters in the same column is not significantly different, according to Duncan's Multiple Range Test. Least significance difference (L.S.D.) values at $p < 0.05$ level.

± Standard error.

Root and seedling length were prominently suppressed ($p<0.05$) from 75% Tanveer Garment factory soil, whereas leaf dry weight was evidently declined ($p<0.05$) by 50 and 75% soil (Table 1a). Root/shoot and leaf weight ratios were conspicuously lesser ($p<0.05$) at 25, 50 and 75% Tanveer Garment factory soil in comparison to Garden soil.

50% One Tech Rubber factory soil produced notable decline ($p<0.05$) in leaf area, root and total plant dry weights of *L. leucocephala* as compared to Garden soil (Table 1b). Leaf dry weight was strikingly confined ($p<0.05$) by 25, 50 and 75% One Tech Rubber factory soil, while root/shoot and leaf weight ratios were distinctly less ($p<0.05$) in 50 and 75% soil. In case of One Tech Ply Board factory, root length, seedling length and leaf area were obviously inhibited ($p<0.05$) by 50% soil (Table 1b). Shoot length, root and total plant dry weights and root/shoot ratio were factually restrained ($p<0.05$) by employ 50 and 75% soil. 25, 50 and 75% soil showed excessive hindrance ($p<0.05$) in leaf dry weight. Leaf weight ratio was strikingly restricted ($p<0.05$) in 25 and 50% One Tech Ply Board factory soil compared to Garden soil.

75% Khan Towel factory soil and 50% other factories soils chiefly reduced many growth variables of *L. leucocephala* as compared to Garden soil (Table 2). Khan Towel factory soil which caused reduction in several growth variables of *L. leucocephala* had highest amount of total soluble salts related to Garden soil (Table 3). Lowest organic matter and highest pH and elevated zinc concentration were found in Tanveer Garment factory soil in relation to Garden soil. The quantity of coarse sand and concentrations of Calcium carbonate and chromium were adequately amplified whereas, water holding capacity was sufficiently low in One Tech Rubber factory soil as compared to Garden soil. The range of available sulfate and copper were excessively high in One Tech Ply Board factory soil than Garden soil.

Discussion

The growth of *L. leucocephala* was conspicuously low in 75% Khan Towel factory soil than Garden soil which might be due to high level of total soluble salts in Khan Towel factory soil as compared to Garden soil. Early seedling stage of rice plants showed that salinity induced a significant repression in seedling growth very soon after transplanting in a saline solution (Shereen *et al.,* 2005). 50% Tanveer Garment factory soil displayed apparent depletion of growth in *L. leucocephala* plant by virtue of lower rate of organic matter, pH and zinc in Tanveer Garment factory soil than Garden soil. Singh (1986) observed that in those plant communities which had higher percentage of soil organic matter, the water holding capacity of soil was consequently increased due to the colloidal nature of the organic matter. The soil pH also has an indirect effect on plants (Walter, 1971). A high percentage decrease in seed germination (27.9%) and seedling length (38.4%) with 125 μg^{-ml} zinc treatment was illuminated in *Peltophorum pterocarpum* as compared with control (Iqbal & Shafiq, 1999). A lot of growth parameters of *L. leucocephala* were adversely affected in 50% One Tech Rubber factory soil which might be due to considerable amount of coarse sand, calcium carbonate and chromium and lower water holding capacity in One Tech Rubber factory soil. Gohar *et al.,* (2003) revealed that soil texture had marked effect on root morphology of cotton plants. An appreciable amount of calcium carbonate (9.8-17.1%) is the characteristic features of arid zone soils (Aubert, 1960). The reduction in plant growth and development especially dry matter of *Triticum aestivum* L. cv. UP 2003 occurred due to uptake of chromium by plants (Sharma & Sharma, 1996).

Table 1b. Growth of *Leucaena leucocephala* in different factories soils.

Soils	Treatments	Root length (cm)	Shoot length (cm)	Seedling length (cm)	No. of leaflets	Leaf area (sq cm)	Root dry weight (g)	Shoot dry weight (g)	Leaf dry weight (g)	Total plant dry weight (g)	Root/Shoot ratio	Leaf weight ratio	Specific leaf area ($cm^2 g^{-1}$)	Leaf area ratio ($cm^2 g^{-1}$)
C	Control	26.47 a ±1.88	10.33 a ±0.90	36.80 a ±2.63	198.83 a ±33.35	19.48 a ±4.35	0.11 a ±0.01	0.03 ab ±0.01	0.10 a ±0.01	0.24 a ±0.03	3.36 a ±0.41	0.41 a ±0.02	197.01 a ±35.67	78.87 a ±11.68
	25%▲	24.33 a ±3.21	9.35 a ±0.95	33.68 a ±3.96	155.89 a ±13.37	13.36 ab ±1.43	0.07 ab ±0.01	0.03 b ±0.00	0.06 b ±0.00	0.16 ab ±0.02	2.53 ab ±0.28	0.38 ab ±0.02	234.23 a ±15.34	87.20 a ±6.44
	50%▲	22.53 a ±3.90	9.43 a ±1.09	31.97 a ±4.23	128.78 a ±29.07	10.02 b ±2.56	0.06 b ±0.01	0.05 ab ±0.01	0.04 b ±0.01	0.15 b ±0.02	1.45 b ±0.55	0.23 c ±0.05	206.78 a ±49.01	56.85 a ±12.30
	75%▲	20.50 a ±4.50	10.35 a ±0.89	30.85 a ±5.06	161.67 a ±26.27	13.44 ab ±2.69	0.07 ab ±0.02	0.05 a ±0.01	0.05 b ±0.01	0.18 ab ±0.03	1.36 b ±0.23	0.30 bc ±0.02	258.80 a ±26.65	80.89 a ±14.20
	L.S.D.	10.36	2.83	11.99	78.42	8.70	0.04	0.02	0.03	0.08	1.14	0.09	100.25	33.99
D	Control	26.47 a ±1.88	10.33 a ±0.90	36.80 a ±2.63	198.83 a ±33.35	19.48 a ±4.35	0.11 a ±0.01	0.03 a ±0.01	0.10 a ±0.01	0.24 a ±0.03	3.36 a ±0.41	0.41 a ±0.02	197.01 a ±35.67	78.87 a ±11.68
	25%▲	22.12 ab ±2.65	8.72 ab ±0.51	30.83 ab ±2.91	116.83 a ±15.07	8.90 ab ±1.69	0.09 ab ±0.01	0.04 a ±0.01	0.05 b ±0.01	0.17 ab ±0.02	2.37 ab ±0.35	0.27 b ±0.05	201.87 a ±10.77	53.02 a ±8.66
	50%▲	14.17 b ±3.88	7.07 b ±0.68	21.23 b ±4.33	139.11 a ±14.24	8.34 b ±1.47	0.06 b ±0.01	0.03 a ±0.00	0.03 b ±0.01	0.11 b ±0.02	2.03 b ±0.45	0.21 b ±0.07	179.04 a ±64.41	76.47 a ±9.56
	75%▲	18.93 ab ±4.95	6.95 b ±0.49	25.88 ab ±5.31	156.44 a ±45.95	11.71 ab ±4.92	0.06 b ±0.01	0.03 a ±0.00	0.04 b ±0.01	0.13 b ±0.03	2.01 b ±0.32	0.33 ab ±0.03	246.33 a ±27.05	83.81 a ±15.39
	L.S.D.	10.45	1.97	11.65	89.15	10.24	0.04	0.02	0.04	0.08	1.13	0.14	116.79	34.27

A = One Tech Rubber factory soil; B = One Tech Ply Board factory soil.

▲ Soil compositions: 25% factory soil + 75% garden soil; 50% factory soil + 50% garden soil; 75% factory soil + 25% garden soil.

Statistical significance determined by analysis of variance. Number followed by the same letters in the same column is not significantly different, according to Duncan's Multiple Range Test. Least significance difference (L.S.D.) values at $p < 0.05$ level.

± Standard error.

Table 2. Percentage reduction in growth of *Leucaena leucocephala* grown in soils of different factories in comparison with control soil.

Treatments	Soil▲	Plant height	Plant cover	No. of leaves	Root length	Shoot length	Seedling length	No. of leaflets	Leaf area	Root dry weight	Shoot dry weight	Leaf dry weight	Total plant dry weight	Root/Shoot ratio	Leaf weight ratio	Specific leaf area	Leaf area ratio
	25%	18.9	30.1	46.5	46.1	16.3	37.7	39.6	52.6	27.3	66.7+	60.0	33.3	50.9	43.9	30.2+	28.2
A	50%	6.0	37.0	50.5	25.7	14.6	22.6	44.2	51.0	45.5	33.3+	60.0	41.7	54.5	39.0	51.9+	5.8
	75%	25.1	40.1	48.5	57.8	22.6	47.9	44.3	54.0	54.5	0.0	70.0	58.3	48.2	46.3	4.3	7.0+
	25%	4.6+	20.5	20.8	31.9	0.8	23.2	15.8	26.1	27.3	100.0+	40.0	16.7	50.9	26.8	36.6+	3.3
B	50%	2.2	32.6	16.8	19.2	9.7	16.5	11.0	23.4	36.4	66.7+	60.0	33.3	55.4	34.1	64.7+	11.2+
	75%	1.5+	23.2	33.6	43.8	1.7	32.0	23.9	30.4	36.4	6.7+	40.0	25.0	54.2	22.0	23.7+	0.1
	25%	0.9+	23.0	25.7	8.1	9.5	8.5	21.6	31.4	36.4	0.0	40.0	33.3	24.7	7.3	18.9+	10.6+
C	50%	8.8	32.5	42.5	14.9	8.7	13.1	35.2	48.6	45.5	66.7+	60.0	37.5	56.8	43.9	5.0+	27.9
	75%	4.5+	24.9	28.7	22.6	0.2+	16.2	18.7	31.0	36.4	66.7+	50.0	25.0	59.5	26.8	31.4+	2.6+
	25%	7.0	29.7	43.6	16.4	15.6	16.2	41.2	54.3	18.2	33.3+	50.0	29.2	29.5	34.1	2.5+	32.8
D	50%	32.6	45.4	34.6	46.5	31.6	42.3	30.0	57.2	45.5	0.0	70.0	54.2	39.6	48.8	9.1	3.0
	75%	30.5	40.6	23.8	28.5	32.7	29.7	21.3	39.9	45.5	0.0	60.0	45.8	40.2	19.5	25.0+	6.3+

A = Khan Towel factory soil; B = Tanveer Garment factory soil; C = One Tech Rubber factory soil; D = One Tech Ply Board factory soil.

▲ Soil compositions: 25% factory soil + 75% garden soil; 50% factory soil + 50% garden soil; 75% factory soil + 25% garden soil.

+ Percentage increase.

Table 3. Soil characteristics of garden and industrial areas soils.

Sites	Coarse sand (%)	*W.H.C. (%)	Organic matter (%)	$CaCO_3$ (%)	Total soluble salts (%)	pH	Available sulfate (μg^{-g})	Cu (μg^{-g})	Zn (μg^{-g})	Cr (μg^{-g})
A	21 c ±1	37 ab ±0	4.3 a ±0.3	12.8 e ±0.2	3.8 d ±0.2	8.1 ab ±0.0	24 d ±1	0.016 b ±0.004	0.062 b ±0.004	1.194 c ±0.083
B	24 c ±2	29 c ±3	2.1 b ±0.2	29.5 b ±1.5	14.0 a ±2.0	8.0 ab ±0.1	575 a ±13	0.023 b ±0.012	0.033 c ±0.001	4.139 b ±0.093
C	47 b ±0	31 bc ±2	0.9 c ±0.0	24.5 c ±0.5	8.0 c ±0.0	8.3 a ±0.1	108 c ±23	0.008 b ±0.002	0.090 a ±0.002	4.229 b ±0.111
D	88 a ±1	17 d ±3	1.1 c ±0.1	36.5 a ±2.5	12.0 ab ±0.0	8.2 ab ±0.1	401 b ±11	0.002 b ±0.002	0.019 d ±0.002	6.899 a ±0.978
E	26 c ±2	40 a ±0	3.3 a ±0.4	17.5 d ±1.5	9.0 bc ±1.0	7.8 b ±0.2	608 a ±45	0.074 a ±0.002	0.003 e ±0.002	1.404 c ±0.406
L.S.D.	5	7	1.1	5.4	3.7	0.4	86	0.020	0.008	1.742

A = Garden soil; B = Khan Towel factory soil; C = Tanveer Garment factory soil; D = One Tech Rubber factory soil; E = One Tech Ply Board factory soil.

*W.H.C. = Water Holding Capacity.

Statistical significance determined by analysis of variance. Number followed by the same letters in the same column is not significantly different, according to Duncan's Multiple Range Test. Least significance difference (L.S.D.) values at $p < 0.05$ level.

± Standard error.

Diverse growth perspectives of *L. leucocephala* was literally less in 50% One Tech Ply Board factory soil which might be caused due to high content of available sulfate and copper. Mahoney (1984) exposed that ozone and sulfur oxide significantly reduced the leaf area ratio and root shoot ratio of yellow poplar seedlings. The indices of tolerance for both Cu and Fe application exhibited that *Albizia lebbeck* seedlings were less tolerant, particularly at higher concentrations (Iqbal & Rahmati, 1992).

It was found that the soils of the industrial areas of Korangi and Landhi are noxious for plant growth, predominantly at enhanced concentration of 50 and 75%. Khan Towel factory soil showed most detrimental effects at different soil ratios particularly at high concentration of 75%, subsequently One Tech Ply Board factory soil intensively influenced the growth of *L. leucocephala* in different soil compositions especially at 50% soil. Atiq-ur-Rehman (2007) demonstrated that *A. lebbeck* was greatly affected in 75% Khan Towel and One Tech Ply Board factories soils. He had also noted that *Azadirachta indica* growth from plants of Karachi University were prominently injurious by Khan Towel factory soil. The past studies exhibited that Tanveer Garment factory thereafter Khan Towel factory soil drastically affected the growth of *L. leucocephala* plants (Atiq-ur-Rehman & Iqbal, 2007). *Thespesia populnea* and *L. leucocephala* were considerably retarded by Tanveer Garment soil extract (Atiq-ur-Rehman & Iqbal, 2006). They also reported that *A. lebbeck* and *P. juliflora* which were collected from the Karachi University location badly affected in One Tech rubber and One Tech Ply Board factories soil extracts, respectively. Similar results were also recorded by Atiq-ur-Rehman & Iqbal (2009). They reported that One Tech Rubber factory soil followed by Tanveer Garment factory soil was severely harmful for growth of *P. pterocarpum* as compared to Karachi University soil. All the industrial soils particularly Khan Towel factory soil was deleterious for the growth of *L. leucocephala.*

References

Anonymous. 1951. *Soil Survey Manual.* U.S. Department of Agriculture Hand Book No. 18 (U.S. Government Printing Office, Washington, D.C.).

Atiq-ur-Rehman, S. 2007. *Effects of soil of industrial areas on plants.* Ph.D. Thesis, Department of Botany. University of Karachi, Karachi, Pakistan. 161 pp.

Atiq-ur-Rehman, S. and M.Z. Iqbal. 2006. Seed germination and seedling growth of trees in soil extracts from Korangi and Landhi industrial areas of Karachi, Pakistan. *Journal of New Seeds,* 8(4): 33-45.

Atiq-ur-Rehman, S. and M.Z. Iqbal. 2007. Growth of *Leucaena leucocephala* (Lam.) de-Wit, in different soils of Korangi and Landhi industrial areas of Karachi, Pakistan. *Pakistan Journal of Botany,* 39(5): 1701-1715.

Atiq-ur-Rehman, S. and M.Z. Iqbal. 2009. *Peltophorum pterocarpum* (DC.) Baker ex K. Heyne growth in soils of Korangi and Landhi industrial areas of Karachi, Pakistan. *Journal of Basic and Applied Sciences,* 5(1): 7-16.

Aubert, L. 1960. Arid Zones Soils; study of their formation, characteristics utilizations and conservations. In: *The Problem of Arid zone,* UNESCO Publications, Paris, pp. 115-137.

Bower, C.A. and L.V. Wilcox. 1965. *Soluble salts. Methods of soil analysis* (Eds.): C.A. Black, D.D. Evans, L.E. Ensminger, J.L. White and F.E. Clark. Part 2, American Society of Agronomy, Inc., Madison, Wisconsin, 933-951.

Duncan, D.B. 1955. Multiple Range and Multiple F-Test. *Biometrics,* 11: 1-42.

Gohar, Z.N., R. Ahmad and H. Gul. 2003. Growth and development of cotton roots at various soil textures under saline conditions. *Pakistan Journal of Botany,* 35: 949-959.

Habib, I. and M.Z. Iqbal. 1996. Irrigational impact of rubber factory effluent on elemental bioaccumulation and metabolite concentration in component parts of *Triticum aestivum* var. UP-262. *Scientific Sindh,* 3: 59-71.

Iqbal, M.Z. 1988. Accumulation of sulfur in foliage of roadside plantation and soil in Karachi city. *Ecology,* 29: 1-5.

Iqbal, M.Z. and K. Rahmati. 1992. Tolerance of *Albizia lebbeck* to Cu and Fe application. *Ekologia (CSFR).* 11: 427-430.

Iqbal, M.Z. and M. Shafiq. 1999. Toxic effects of Zn on different tree seedlings. *Pakistan Journal of Scientific and Industrial Research,* 42: 150-153.

Iqbal, M.Z. and S. Atiq-ur-Rehman. 2002. Effects of Cd, Zn, Cr and Pb on seed germination and seedling growth of plants. *Pakistan Journal of Environmental Sciences,* 1: 47-53.

Jackson, M.L. 1958. *Soil Chemical Analysis.* Englewood Cliffs, NJ: Prentice- Hall, pp. 408.

Keen, B.A. 1931. *The Physical Properties of Soil.* New York: Longman Green and Company, pp. 380.

Mahoney, T.M. 1984. Response of yellow poplar seedlings to low concentrations of ozone, SO_2 and NO_2. *Environmental and Experimental Botany,* 26(1): 240-248.

Naqvi, R.R. and M.I. Khattak. 1995. Study of metals chromium, nickel, copper and lead in the waste effluents of Landhi Industrial Estate of Karachi. In: Abstracts *4th National Symposium on analytical and environmental chemistry.* August 27-30. 1995. Department of chemistry. University of Peshawar. Pakistan. Pp. 23.

Polson, D.W. and M.W. Adams. 1970. Differential response of navy beans to zinc. l. Differential growth and elemental composition at excessive zinc levels. *Journal of Agronomy,* 62: 557-560.

Qadir, S.A., S.Z. Qureshi and M.A. Ahmed. 1966. A phytosociological survey of the Karachi University Campus. *Vegetatio,* 13: 339-362.

Qamar-Uz-Zaman and M.Z. Iqbal. 1994. Vegetation pattern along the sewage effluents channels of Malir river, Karachi. *Turkish Journal of Botany,* 18: 425-430.

Sharma, D.C. and C.P. Sharma. 1996. Chromium uptake and toxicity effects on growth and metabolic activities in wheat, *Triticum aestivum* L. cv. UP 2003. *Indian Journal of Experimental Biology,* 34: 689-691.

Shereen, A., S. Mumtaz, S. Raza, M.A. Khan and S. Solangi. 2005. Salinity effects on seedling growth and yield components of different inbred rice lines. *Pakistan Journal of Botany,* 37: 131-139.

Singh, A.P. 1986. Seasonal fluctuation of organic matter with relation to moisture retention characteristics and availability of water in salt affected soil (India). *Acta Botanica Indica,* 14: 73-76.

Steel, R.G.D. and J.H. Torrie. 1984. *Principles and procedures of statistics*: Mc Graw Hill Book C., Inc., Singapore, 172-177.

Walter, H. 1971. *Ecology of Tropical and Sub Tropical Vegetation.* Oliver and Boyd-Edinburgh, UK, 539.

(Received for publication 20 December, 2008)