Azadirachta indica (l.) A. Juss. growth in soils of Korangi and Landhi industrial areas of Karachi, Pakistan.

Syed Atiq-ur-Rehman, Muhammad Zafar Iqbal

Abstract--The growth of *Azadirachta indica* (L.) A. Juss. under natural environmental conditions were studied in soils collected from Khan Towel, Tanveer Garment, One Tech Rubber and One Tech Ply Board factories in the vicinity of Korangi and Landhi industrial areas. A variety of growth variables of *A. indica* were suppressed in industrial soils principally of Khan Towel factory, subsequently One Tech Rubber factory soils as compared to Karachi University soil. Khan Towel factory soil strongly reduced a numbers of growth parameters such as plant height, number of leaves, plant cover, shoot, seedling length, root, shoot, leaf and total plant dry weights and root/shoot ratio whereas, a lot of growth characters were depleted by One Tech Rubber factory soil except leaf area and leaf weight ratio which were noticeably stunted in One Tech Rubber factory soil. Plant cover, shoot length, shoot, leaf and total plant dry weights and leaf weight ratio were retarded in the treatment of Tanveer Garment factory soil while, root, shoot, leaf and total plant dry weights and leaf weight ratio were lessoned by One Tech Ply Board factory soil than University soil.

Key words: *Azadirachta indica*, industrial areas, plant growth, soil pollutants.

1 Introduction

Environmental contamination is a continuous hazard to humankind. The manufacturing of useful products such as pigments, drugs, agrochemicals, plastics, batteries, zinc recovery operations, electroplating and metal surface cleaning agents and emanation of untreated effluents from different industries causes an extensive range of environmental pollution [1]. Miscellaneous kinds of industrial pollutants affected the plants were studied by [2]. Industrial effluents caused damages to vegetation particularly water plants [3].

Relationship among the leading dominant species to edaphic factors indicated that, besides other factors which are responsible for plant growth, physical properties of soil such as, soil strength, bulk density, texture and structure influences greatly on root penetration, growth and yield of various crops [4]. Trace metals present in the environment are hazardous to ecological systems and also to human health and plant growth [5].

Karachi is a biggest city as well as largest industrial city of Pakistan where many small and large industrial units producing useful products and dumping off in soil, water and air and causing large range of harmful material. Ahmed [6] has examined that, Karachi Shipyard and Engineering Works Ltd., produced effluents with very notable concentrations of Pb and Zn. The Pakistan steel discharged a huge amount of toxic effluents which enter into the sea water. The analysis of sea water and sediments from the Bakran Creek showed the presence of high concentrations of heavy metals [6]. These pollutants before causing visible injury to plants generated invisible injury which was due to changes in the normal metabolism of plants [7]. The increase reasons of elements point to that Ca, Ba, Fe, K, Cu and Mn are principally emanated into the atmosphere from soil sources while Pb is frequently owing to manmade media [8]. Rushdi *et al.,* [9] made a model by which can guess the evidence of an ecological contaminant on the surface of soil because of the contaminant being added on dust particles, which are afterward set down on the surface of soil.

Azadirachta indica (L.) A. Juss. (Family Meliaceae) is a small to medium-sized tree. Its common name is Neem. It requires immense amounts of light and annual mean temperatures between 21-32°C. It grows on neutral to alkaline soils and can grow in many assortments of soil types, but it thrives best on well drained deep and sandy soils. The tree has spread to Africa, America, Australia and the islands of the south Pacific. *A. indica* is indigenous to Asia (India, Indonesia, Malaysia, Pakistan, Sri Lanka and Thailand). It has long been recognized for urban

- *Author: Department of Botany, Govt. Degree College, Buffer Zone, Karachi-75850, Pakistan. E-mail: atiq_falcon7663@yahoo.com*
- *Co-Author: Department of Botany, University of Karachi, Karachi-75270, Pakistan. E-mail: mziqbalbotuokpk@yahoo.com*

regreening, agroforestry, fuelwood production, medicinal uses, biopesticides, wood crafting and a lubricant for machinery and in the production of soap, toothpaste and cosmetics.

In Malir river, some heavy metals of lead, copper and zinc were detected in soil, which influenced on the composition of plant communities [10]. Oguntade, *et al.*, [11] found in the greatest deposition of heavy metals were greater as compared to 0.3 mg kg^{-1} permitted limits in vegetables by Food and Agricultural Organization/World Health Organization/Federal Environmental Protection Agency. Martins, *et al.*, [12] stated that record are displayed poisonous effects in animal fed with plant grown on the increment of sewage sludge.

Various kinds of industries e.g. towel, garment, rubber and ply board etc. in Karachi are playing a critical and harmful role therefore, it is necessary to investigate the effects of polluted soil of industrial regions on growth of *A. indica*. Since this plant is grown in the surrounding of Korangi and Landhi industrial sites.

2 Materials and Methods

The experiment was conducted in greenhouse under the uniform natural environmental situations 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 28-35 °C, 15-23 °C, 21-29 °C and 18-84%, respectively. The weather outlook was mostly sunny with a range of 10:40-11:40 hours sun shine. Healthy and uniform-sized seedlings of *Azadirachta indica* (L.) A. Juss., were chosen from Karachi University Campus and were transplanted into pots of 19.8 cm in diameter and 9.6 cm in depth in soils 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 estates of Karachi. The Karachi University soil was used as a control. 50% soil of the respective locality (including control) was used which were mixed with 50% garden soil (one part manure + two parts fine sand). Since, in the preliminary studies, pure soils of all industries hardly showed adverse effect 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, reshuffling of pots was also done to avoid light/shade or any other greenhouse effects. Daily climatic data, as average atmospheric temperature, atmospheric relative humidity, weather out look and sun shine were noted. Seedlings height, number of leaves and plant cover were recorded after every week for eight weeks. After eight weeks, leaf area of each plant was recoded and all the plants of *A. indica* 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 determined. Root/Shoot ratio, leaf weight ratio, specific leaf area and leaf area ratio were also determined as mentioned in [13].

For soil analysis, two soil samples of each site 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 using 0.05 mm sieve [14]. Maximum water holding capacity (W.H.C.) was measured by the method of [15]. Soil organic matter was determined according to [16]. Calcium carbonate concentration was determined by acid neutralization as described by [17]. Bower and Wilcox [18] methodology was used to determine total soluble salts whereas, soil pH was recorded by a direct MP 220 pH Meter (Mettler, Toledo). Available sulfate in soil was determined by the turbidity method as described by [19], using a colorimeter (Photoelectric Colorimeter AE-11M). Soil analysis for heavy metals was also conducted. 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 and solution volume was made up to 50 ml using distilled water and solution was diluted 10 times for copper, zinc and chromium analyses by atomic absorption spectrophotometer (Perkin Elmer Model No. 3100).

All data was statistically analyzed by ANOVA [20] and DMRT [21] ($p < 0.05$) 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 using the following formula as described in [22].

3 Results and Discussion

The industrial soil of Khan Towel factory brought about marked hindrance in plant height (6.78 cm), (Fig. 1a), number of leaves (21.17) (Fig. 1b) and plant cover (22.63 cm) (Fig. 1c) of *Azadirachta indica* relative to plant height (8.85 cm), number of leaves (27.50) and plant cover (40.67 cm) of University soil. *A. indica* is cultivated for decorative intention as well as sink for pollution in the proximity of the industrial estates [23]. An apparent numbers of growth appearance of *A. indica* were hampered especially shoot, seedling length, root, shoot, leaf, total plant dry weights and root/shoot ratio in Khan Towel factory soil as compared to University soil (Tables 1-2). Khan Towel factory soil which induced impediment in growth of *A. indica* had highest degree of total soluble salts over the University soil (Table 3). Salinity primarily reduced ability of respiration on a legume pea plant species (*Pisum sativun* cv. Lincoln) and faba-bean bacteroids (*Vicia faba* L. var. minor cv. Alborea), in contrast soybean (*Glycine max* L. var.

Williams) was displayed as a salt tolerance species by [24]. Salinity is a major factor reducing plant growth and productivity throughout the world [25].

Several growth perspectives were also subdued by applying One Tech Rubber factory soil but declination was highly pronounced in leaf area and leaf weight ratio. In One Tech Rubber factory soil, coarse sand, calcium carbonate and chromium concentrations were greatest magnitude, where water holding capacity was low in quantity comparative to University soil. Considerable extent of coarse sand reduces the ability of water capturing ability ultimately growth is stunted. On varied tillage applications, Liu, *et al.* [26] noted diverse impact on the water retaining ability on orchid in China. An appreciable amount of calcium carbonate (9.8-17.1%) is the characteristic features of arid zone soils [27]. Chromium is a noxious metal for plant growth and its substantial grade in soil is much poisonous. The industrial effluents released from tanneries, plastic and chrome plating have considerable elevated levels of chromium in plants [28].

The soil organic matter was manifestly lesser and zinc concentration was evidently amplified in Tanveer Garment factory soil which might cause reduction in many of the growth variables in *A. indica* as compared to University soil. In those communities which had greater amount of soil organic matter, the water holding capacity of soil was consequently raised due to the colloidal nature of the organic matter [29]. Land production ability, soil fertility and level soil deprivation depends upon an important issue of soil organic matter [30]. Maximum numbers of species of two species group (vascular plants and bryophytes) were noted with some extent where greater moister content, soil pH, grazing intensity was observed with lower tree cover [31]. Increased concentrations of zinc reduced seed germination, root length, seedling length and dry biomass of *Albizia lebbeck* [32]. Oguntade, *et al.* [11] recorded that 20% dye concentration gave the maximum uptake of Manganese (Mn), Iron (Fe) and Zinc (Zn) in the edible shoots of *Amaranthus cruentus* L. in field situation. One Tech Ply Board factory soil deteriorated growth in root, shoot, leaf and total plant dry weight and leaf weight ratio as related to University soil. One Tech Ply Board factory soil had adequate amount of available sulfate and copper in correlation to University soil. Mahoney [33] has noted that ozone and sulfur oxide significantly minimized the leaf area and root shoot ratios in yellow poplar seedlings. Excess content of copper inhibited plant growth and high rate of Cu occurred as a result of the anthropogenic emission of heavy metals into the environment through mining, smelting, manufacturing, agriculture and waste disposal technologies [34]. The root, shoot, leaf and total plant dry weights were strikingly obstructed from the utilization of most of the industrial soils relatively to other growth expressions. In growth of *L. leucocephala* same observations were also reported by [13].

In over all investigation, it would suggest that soil of the industrial areas of Korangi and Landhi is not good for growth of *A. indica* predominantly of Khan Towel factory soil was remarkably detrimental afterward One Tech Rubber factory soil. Atiq-ur-Rehman [23] had exposed that *Prosopis juliflora* growth from seeds of Karachi University and Korangi and Landhi industrial lands were noticeable cramped in Khan Towel factory soil. He also reported that *A. lebbeck* and *L. leucocephala* growth was impeded in 25 and 50% soil ratios of Khan Towel factory soil prominently in more concentration of 75%. The earlier investigations demonstrated that Khan Towel factory soil was injurious after Tanveer Garment factory soil for growth of *L. leucocephala* [13]. Atiq-ur-Rehman and Iqbal [35] had revealed that distinct number of growth faces of *L. leucocephala, A. lebbeck* and *P. juliflora* were also adversely affected by soil extract of Khan Towel factory. Thus, Khan Towel factory soil is a sufficiently deleterious for a great number of the plants. *A. indica* plant exhibited enhancement in certain plant parameters in Tanveer Garment and One Tech Ply Board factory soils. The growth of *L. leucocephala, Thespesia populnea, Peltophorum pterocarpum* and *P. juliflora* (Korangi and Landhi industrial sites population) was better in One Tech Ply Board factory soil comparative to other factories soils [23]. Hence, Tanveer Garment soil mainly of One Tech Ply Board factory soil was somewhat better for *A. indica* growth.

REFERENCES

[1] S. Raihan, F. Sarwar, M. Azim, O.Y. Khan, and N. Ahmed, "Isolation, characterization and assessment of nickel and cadmium accumulation of bacterial isolates from industrial waste, In: Biotechnol. for Environ. Agric., pp. 143-152. B.C.C. and T. press, University of Karachi, 1995.

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

[3] R.G. Kullberg, "Distribution of aquatic macrophytes related to paper mills effluents in a Southern Michigan Stream," Am. Midl. Nat., vol. 91, pp. 271-281, 1974.

[4] C.J. Gerad, P. Sexton, and G. Shaw, "Physical factor influencing soil strength and root growth," Agron. J., vol. 74, pp. 875-879, 1982.

[5] M. Shafiq, and M.Z. Iqbal, "Tolerance of Peltophorum pterocarpum D. C. Baker Ex K. Heyne Seedlings to lead and cadmium treatment," J. New Seeds, vol. 7, pp. 83-94, 2005.

[6] A. Ahmed, "Toxic wastes of industrial effluents in Karachi, Pakistan," J. Entomol., Karachi Supplement, 6: 31-38, 1987.

[7] Ahmed, S., Ismail, F. and Majeed, J. "Effect of atmospheric pollution on chlorophyll and protein contents of some plants growing in Karachi region," Pak. J. Sci. Ind. Res., 29: 464-467, 1986.

[8] Moustafa, M., A. Mohamed, A. Ahmed and H. Nazmy.. Mass size distributions of elemental aerosols in industrial area. J. Adv. Res., 6(6): 827-832, 2015.

[9] Rushdi, M.M., El-Kilani, M.H. Belal.. Modelling an environmental pollutant transport from the stacks to and through the soil. J. Adv. Res., 1(3):243–253, 2010.

[10] Qamar-Uz-Zaman and Iqbal, M.Z.. Vegetation pattern along the sewage effluents channels of Malir river (Karachi). Turk. J. Bot., 18: 425-430, 1994.

[11] O.A. Oguntade, M.T. Adetunji, and J.O. Azeez, "Uptake of manganese, iron, copper, zinc and chromium by Amaranthus cruentus L. irrigated with untreated dye industrial effluent in low land field," J. Environ. Chem. Eng., vol. 3 no. 4 pp. 2875–2881, 2015.

[12] M.N.C. Martins, V.V. De Souza, and T.D.S. Souza, "Genotoxic and mutagenic effects of sewage sludge on higher plants," Ecotoxicol. Environ. Saf., vol. 124, pp. 489–496, 2016.

[13] S. Atiq-ur-Rehman, and M.Z. Iqbal, "Growth of Leucaena leucocephala (Lam.) de-Wit, in different soils of Korangi and Landhi industrial areas of Karachi, Pakistan," Pak. J. Bot., vol. 39 no. 5, pp. 1701-1715, 2007a.

[14] USDA. "Soil Survey Manual," U.S. Department of Agriculture Hand Book No. 18, U.S. Government Printing Office, Washington, D.C., USA, 1951.

[15] B.A. Keen, "The Physical Properties of Soil," pp. 380, Longman Green and Company, New York, USA, 1931.

[16] M.L. Jackson, "Soil Chemical Analysis," p. 408, Prentice-Hall, Englewood Cliffs, New Jersy, USA, 1958.

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

[18] C.A. Bower, and L.V. Wilcox, "Soluble salts. In: Methods of soil analysis, Part 2: Chemical and Microbiological Properties," C.A. Black, D.D. Evans, L.E. Ensminger, J.L. White, and F.E. Clark (eds.), pp. 933-951, American Society of Agronomy, Inc., Madison, Wisconsin, USA, 1965.

[19] M.Z. Iqbal, "Accumulation of sulfur in foliage of roadside plantation and soil in Karachi city," Ecology, vol. 29, no. 1-5, 1988.

[20] R.G.D. Steel, and J.H. Torrie, Principles and Procedures of Statistics, pp. 172-177, 2nd edition, Mc Graw Hill Book Co., Singapore, 1984.

[21] D.B. Duncan, 1955. Multiple Range and Multiple F-Test. Biometrics, 11, pp. 1-42.

[22] S. Atiq-ur-Rehman, and M.Z. Iqbal, "Peltophorum pterocarpum (DC.) Baker ex K. Heyne growth in soils of Korangi and Landhi industrial areas of Karachi, Pakistan," J. Basic and Appl. Sci. vol. 5, no. 1, pp. 7-16, 2009.

[23] Atiq-ur-Rehman, S. "Effects of Soil of Industrial Areas on Plants," Ph.D. thesis, 161 p., Department of Botany, University of Karachi, Karachi-75270, Pakistan, 2007.

[24] M. Delgado, F. Ligero, and C. Lluch, "Effects of salt stress on growth and nitrogen fixation by pea, faba-bean, common bean and soybean plants," Soil Biol. Biochem., vol. 26, no. 3, pp. 371–376, 1994.

[25] A. Shereen, S. Mumtaz, S. Raza, M.A. Khan, and S. Solangi, "Salinity effects on seedling growth and yield components of different inbred rice lines," Pak. J. Bot., vol. 37, pp. 131-139, 2005.

[26] Y. Liu, M. Gao, W. Wu, S.K. Tanveer, and X. Wen, "The effects of conservation tillage practices on the soil water-holding capacity of a non-irrigated apple orchard in the Loess Plateau, China," Soil and Tillage Res., vol. 130, pp. 7–12, 2013.

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

[28] U.N. Rai, R.D. Tripathi, and N. Kumar, "Bioaccumulation of chromium and toxicity on growth, photosynthetic pigments, photosynthesis, in vivo nitrate reductase activity and protein content in a chlorococcalean green alga Glaucocystis nostochinearum Itzigsohn," Chemosphere, vol. 25, pp. 1721-1732, 1992.

[29] A.P. Singh, "Seasonal fluctuation of organic matter with relation to moisture retention characteristics and availability of water in salt affected soil (India)," Acta Bot. Indica, vol. 14, pp. 73-76, 1986.

[30] X. Jin, J. Du, H. Liu, Z. Wang, and K. Song, "Remote estimation of soil organic matter content in the Sanjiang Plain, Northest China: The optimal band algorithm versus the GRA-ANN model," Agric. For. Meteorol., vol. 15: pp. 250–260, 2016.

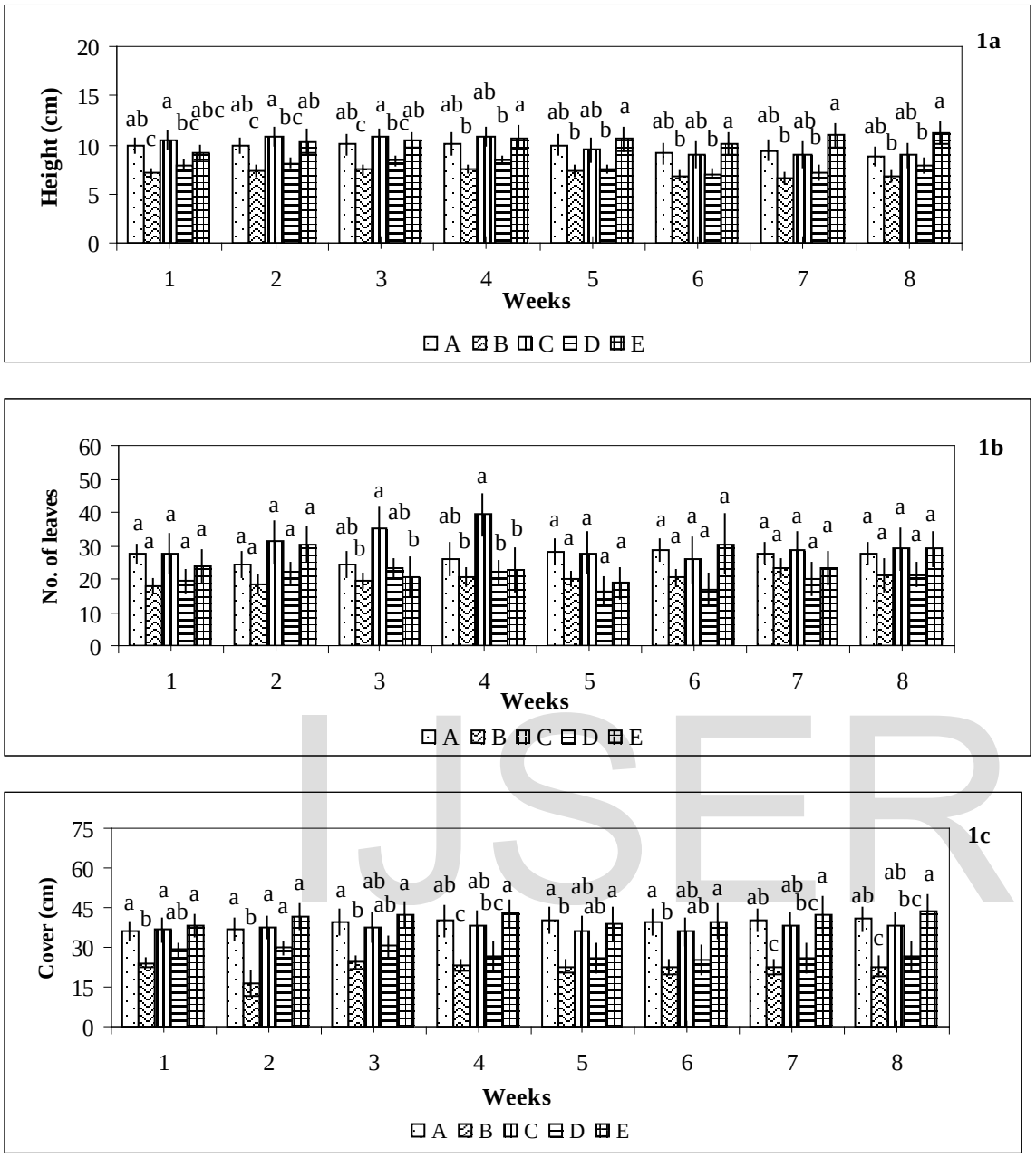
[31] A. Olden, J.K. Raatikainen, and P. Halme, "Grazing and soil pH are biodiversity drivers of vascular plants and bryophytes in boreal wood-pastures," Agric. Ecosys. Environ., vol. 222, pp. 171–184, 2016.

[32] M.Z. Iqbal, and M. Shafiq, "Toxic effects of zinc on different tree seedlings," Pak. J. Sci. Ind. Res., vol. 42, pp. 150-153, 1999.

[33] TM. Mahoney, "Response of yellow poplar seedlings to low concentrations of ozone, SO_2 and NO_2, Environ. Exp. Bot., vol. 26, no. 1, pp. 240-248, 1984.

[34] Y. Yruela, "Copper in plants," Braz. J. Plant Physiol., vol. 17, pp. 145-156, 2005.

[35] S. Atiq-ur-Rehman, and M.Z. Iqbal, "Seed germination and seedling growth of trees in soil extracts from Korangi and Landhi industrial areas of Karachi, Pakistan," J. New Seeds, vol. 8 no. 4, pp. 33-45, 2007b.



Figs. 1a, b & c: Periodical growth of *Azadirachta indica* in soils of different areas.

A = Karachi University; B = Khan Towel factory; C = Tanveer Garment factory; D = One Tech Rubber factory; E = One Tech Ply Board factory.
In each soil type, 50% soil was mixed with 50% garden soil.
Statistical significance was determined by analysis of variance; same letters in a row are not significantly differe ($p < 0.05$) according to Duncan's Multiple Range Test.
☐ Standard error.

Table 1. Growth of *Azadirachta indica* in soils of different areas.

Treatments▲	Root length (cm)	Shoot length (cm)	Seedling length (cm)	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	9.93 a ±0.60	19.45 ab ±1.00	29.38 a ±1.21	69.91 a ±10.63	0.29 ab ±0.06	0.36 a ±0.05	0.38 a ±0.09	1.03 a ±0.20	0.80 a ±0.10	0.42 a ±0.06	164.60 b ±23.46	62.21 b ±3.30
B	11.27 a ±1.82	13.83 c ±1.28	25.10 a ±2.69	76.70 a ±25.41	0.10 b ±0.03	0.14 c ±0.02	0.13 b ±0.04	0.37 c ±0.08	0.74 a ±0.12	0.31 a ±0.06	551.85 a ±214.03	190.73 a ±60.64
C	15.00 a ±3.07	18.67 ab ±1.96	33.67 a ±4.92	84.33 a ±29.30	0.34 a ±0.11	0.31 ab ±0.08	0.31 ab ±0.08	0.96 ab ±0.25	0.98 a ±0.14	0.34 a ±0.02	243.61 ab ±45.53	80.86 b ±15.26
D	13.43 a ±1.41	15.00 bc ±1.11	28.43 a ±2.00	35.94 a ±8.87	0.16 ab ±0.04	0.15 bc ±0.04	0.14 b ±0.05	0.45 bc ±0.13	1.04 a ±0.11	0.28 a ±0.05	298.35 ab ±35.60	82.50 b ±18.31
E	13.53 a ±1.25	20.83 a ±2.11	34.37 a ±2.35	81.22 a ±14.66	0.26 ab ±0.06	0.27 abc ±0.07	0.28 ab ±0.09	0.81 abc ±0.20	1.06 a ±0.22	0.34 a ±0.02	328.00 ab ±33.58	113.06 ab ±15.91
L.S.D.	5.32	4.54	8.49	56.94	0.19	0.16	0.21	0.53	0.42	0.14	293.66	87.46

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

▲ 50% soil + 50% garden soil in all soil types.

Statistical significance was determined by analysis of variance; numbers followed by the same letters in the same column are not significantly different, according to Duncan's Multiple Range Test. LSD = least significance difference, value at $p < 0.05$ level.

± Standard error.

Table 2. Percentage reduction in growth of *Azadirachta indica* in soils of different factories in comparison with control soil.

Treatments▲	Plant height	No. of leaves	Plant cover	Root length	Shoot length	Seedling length	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
A	23.4	23.0	44.4	13.5+	28.9	14.6	9.7+	65.5	61.1	65.8	64.1	7.5	26.2	235.3+	206.6+
B	0.9+	5.5+	5.6	51.1+	4.0	14.6+	20.6+	17.2+	13.9	18.4	6.8	22.5+	19.0	48.0+	30.0+
C	10.7	22.4	34.1	35.2+	22.9	3.2	48.6	44.8	58.3	63.2	56.3	30.0+	33.3	81.3+	32.6+
D	25.8+	5.5+	7.9+	36.3+	7.1+	17.0+	16.2+	10.3	25.0	26.2	21.4	32.5+	19.0	99.3+	81.7+

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

▲ 50% soil + 50% garden soil in all soil types.

+ Percentage increase.

Table 3. Soil properties of Karachi University 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	58 b ±0	27 b ±0	2.0 b ±0.3	17.8 c ±0.3	5.9 c ±0.7	8.4 a ±0.0	8 d ±0	0.002 c ±0.002	0.029 bc ±0.017	6.066 a ±0.046
B	24 d ±2	29 b ±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 b ±0.001	4.139 b ±0.093
C	47 c ±0	31 b ±2	0.9 c ±0.0	24.5 b ±0.5	8.0 c ±0.0	8.3 a ±0.1	108 c ±23	0.008 bc ±0.002	0.090 a ±0.002	4.229 b ±0.111
D	88 a ±1	17 c ±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 c ±0.002	0.019 bc ±0.002	6.899 a ±0.978
E	26 d ±2	40 a ±0	3.3 a ±0.4	17.5 c ±1.5	9.0 bc ±1.0	7.8 b ±0.2	608 a ±45	0.074 a ±0.002	0.003 c ±0.002	1.404 c ±0.406
L.S.D.	5	8	0.8	5.4	3.8	0.4	86	0.020	0.027	1.738

A = Karachi University 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 was determined by analysis of variance; numbers followed by the same letters in the same column are not significantly different, according to Duncan's Multiple Range Test. LSD = least significance difference, value at $p < 0.05$ level.