Selcuk Journal of Agriculture and Food Sciences

http://sjafs.selcuk.edu.tr/sjafs/index

Research Article

SJAFS

(2022) 36 (2), 133-138

e-ISSN: 2458-8377

DOI:10.15316/SJAFS.2022.019

The Toxic Effects of Lead on Seedling Growth Development of *Euphorbia Hirta* Forsk (Weed) and *Sporobolus Coromandelianus* (Retz.) Kunth (True Grass)

Faiza UROOJ[1], Muhammad Zafar IQBAL[2], Muhammad SHAFIQ[3,*]

[1,2,3]University of Karachi, Department of Botany, Karachi, Pakistan

ARTICLE INFO

Article history:
Received date: 28.08.2021
Accepted date: 06.05.2022

Keywords:
Heavy metal
Leaf area
Number of leaves
Toxicity
Tolerance

ABSTRACT

Lead is considered a toxic heavy metal and released in the air, water and soils due to auto wheels, industrial and anthropogenic activities which influence on plant growth, fauna and environment. It is hypothesized that plants are capable of showing different responses of toxicity and tolerance to metals stresses. The objective of this study is to investigate the influence of one of the highly toxic heavy metal, lead (Pb) on the seedling growth of native plant species, *Euphorbia hirta* Forsk and *Sporobolus coromandelianus* (Retz.) Kunth in pots as there are very few data available in the literature on this toxicity subject. It is important to compare both genotype under various level of lead treatment. The seedlings of *E. hirta* and *S. coromandelianus* showed different effect when treated with 20, 40, 60, 80, 100 as compared without 0 ppm concentrations of lead. The results of the present studies showed the statistically significant ($p<0.05$) influences of lead 40 ppm treatment on number of leaves, leaf area and seedling dry weight of *S. coromandelianus.* Lead treatment at 60 ppm significantly reduced shoot, root and and total seedling height of *S. coromandelianus*. Lead treatment at 40 ppm also showed significant decreased on shoot, seedling length and number of leaves of *E. hirta.*

The seedlings of *E. hirta* and *S. coromandelianus* were also used for the development of tolerance indices percentage to different level of lead**.** The seedlings of *E. hirta* and *S. coromandelianus* showed changes in values of tolerance indices. Lead treatment at 20 ppm showed a positively decreasing influence on the tolerance indices of *E. hirta* and *S. coromandelianus*. Increase in lead level at 80 – 100 ppm highly decreased the tolerance indices percentage of *E. hirta* and *S. coromandelianus* as compared to control. The seedlings of *S. coromandelianus* showed tolerance (68.38%) as compared to *E. hirta* (50.79%) to lead at 100 ppm. The obtained data could be useful for a wide range of researchers working in this aspect.

1. Introduction

Pollution by heavy metals (Pb, Cd, Cr, Cu, Fe, Hg, Mn and Ni) in the environment is a nationwide and worldwide pollution problem due to industrial, anthropogenic and automobile activities. Lead is considered as a non essential element for plant growh and human beings. The accumulation of heavy metals in air, water and soil has serious influence on plant growth, vegetation and ecosystem balance. Among the heavy metals, Pb has proved toxic element for biota (Iqbal et al. 2001). There is about 235 million hectares land worldwide has been polluted by heavy metals (Bermudez et al. 2012). Air pollutants likewise lead compounds and heavy metals effects the respiratory, vegetation, photo synthetic pigments, root morphology, enzymatic activities of plants, changes in plant communities (Shahid, et al., 2012; Zeeshan et al. 2016; Gautam et al. 2018; Verma et al. 2021). Effects of chronic stress of lead on anatomical structure of Tobacco roots, and tolerance mechanisms in *Salsola passerina* Bunge and *Chenopodium album* L were recorded (Yuan et al. 2011; Hu et al. 2012). The rsearchers have reported that the excess level lead (Pb) against recommended limit showed harmful effects on seed germination, seedling growth and yield of different plant species due to oxidative damage (Jaja and Odoemena 2004; Prasad et al. 2015; Pietrzykowski et al. 2018; Liu et al. 2020).

The presence of heavy metals in soil also influences on habitant, aquatic life, public health, ecosystem balance and plant growth (Giordani et al. 2005; Yang et al. 2005; Odilara et al. 2006; Joshi et al. 2009; Dribben et

* Corresponding author email: *shafiqeco@yahoo.com*

al. 2011; Shafiq and Iqbal, 2012; Kumari and Deswal, 2017; Gong et al. 2019; Shafiq et al. 2019).

Species description

Euphorbia hirta Forsk (garden spurge) is a weed, belongs to Euphorbiaceae family and characterized by white milky latex. The morphological, phytochemical, ethnopharmacological, and pharma cological information on *E. hirta* as an herb reviewed on account of medicinal purposes (Kumar et al. 2010). The phytochemistry, pharmacological aspects, toxicological potentials of crude ethanolic extracts of *E. hirta* reported in literature **(**Ogueke et al. 2007; Huang et al. 2012**).**

Sporobolus coromandelianus (Retz.) Kunth (true grass) is an annual species of grass and member of Poaceae family (eflora, 2020). *S. coromandelianus* is monocotyledon plan species. *Sporobolus,* Sporo derived from Greek word spora (seed) and bolus (throwing) alluding to the free seed and sometimes forcible manner of its release and common name is small drop seed (AusGrass, 2020). *S. coromandelianus* is a self-sprouting, simple and broad leaves plant species (EOL, 2020). *S. coromandelianus* clumps upto 25 cm tall (Cope, 1999) and its native range is from Eritrea to South Africa, West Indian Oceans, South central China, Jawa, New Guinea, Australia, Namibia, Oman, Sri Lanka, Sudan, Thailand, Yemen, Bangladesh, Afghanistan and native to Pakistan (Kewscience, 2020).

The ever increase of heavy metals in the environment is influencing on the germination and growth of plants. The response of plant growth to abiotic stress has become the subject of great interest in recent years by ecologist. Lead in excess level become toxic element for plants growth. The data on the development of tolerance indices for the native flora in the country is still insufficient. There is dire a need of development of high level of interest in selection of plant species and publication of data on the nature of toxicity and tolerance to metals in plants. Very few studies have been conducted on the effects of lead on the germination and growth of other plants species in Pakistan. The identification of metal tolerant species and plantation in polluted areas might be helpful to lessesn the burden of pollutants from the environment. This study aims to evaluate and compare the effects of lead (Pb) on seedling growth performance of two different plant species, *Euphorbia hirta* Forsk and *Sporobolus coromandelianus* (Retz.) Kunth.

2. Materials and Methods

The seedling growth experiment was conducted in green house of the Department of Botany, University of Karachi, Pakistan. Three uniform size seedlings of *E. hirta* and *S. coromandelianus* were collected from the Karahi University campus after moon soon rain fall season in August. The selected two plant species were transplanted in plastic pots (9.0 cm in depth and 7.0 cm in diameter) having garden loam soil. The fraction of soil was one-part manure and two parts of fine sand. There were six metal treatment (0, 20, 40, 60, 80 and 100 ppm) for each plant species and the experiment was completely randomized. The seedlings were irrigated with fresh solutions of 0, 20, 40, 60, 80 and 100 ppm concentration of Pb prepared with lead acetate. Distilled water was applied to control group. 5 ml of respective treatment after the interval of two days was applied. Every week each pot was reshuffled to avoid the effects of shade, light or any other factors of environment. After two months, seedlings were removed from plastic pots and washed with distilled water. The root, shoot, seedling length, number of leaves, leaf area, and root, shoot, leaves and total seedling dry weight were recorded. The root / shoot, leaf weight ratio, specific leaf area and leaf area ratio were recorded (Rehman and Iqbal, 2009). Seedling dry weight was obtained after drying the samples in an oven at 80 °C for 24 hours.

Tolerance indice (T.I.) was determined on the basis of percentage using the following formula given by Iqbal and Rahmati (1992):

T.I. = Mean root length in metal solution Mean root length in distilled water x 100

Statistical analysis

Statistical comparisons among all treatments for above and below ground dry plant biomass and proportion contributions thereof to overall dry plant biomass was evaluated using one-way Analysis of Variance (ANOVA) and Steffens post hoc test. Assumption of all tests were tested statistically verified. All statistical analysis was performed using SPSS 10.0 (SPSS) Inc., U.S.A.) for windows.

3. Results and Discussion

Despite knowing the phytotoxic effects of heavy metals, which is of global concern, there is a dire need to study about its impacts on native plants. Overall results of different seedlings growth parameters showed that lead is to**xic** element and deleterious for plant growth. The variable responses of a native plant *S. coromandelianus* and *E. hirta* to metal salt likewise lead (Pb) was reorded (Table 1-4; Fig. 1). In the present study the effects of different concentrations 0, 20, 40, 60, 80 and 100 ppm of lead on root, shoot, seedling length, number of leaves, leaf area and seedling dry weights (root, shoot, leaves and total seedling) of *E. hirta* and *S. coromandelianus* were recorded. The lead treatment of 20 ppm showed nonsignificant impact on the root and seedling length of *S. coromandelianus.* The lead treatment of 40 ppm significantly ($p<0.05$) decreased number of leaves and leaf area of *S. coromandelianus*. A rise in concentrations of lead 60 ppm decreased root, shoot, seedling length and biomass production of *S. coromandelianus* as compared control. Lead treatment at 20 ppm indicated toxic effect on shoot, root and seedling height of *S. coromandelianus.* Reduced rate of seed germination and plant growth under stress is mainly due to Pb interference with enzymatic activities seedling dry weights (root, shoot, leaves and total seedling) of *S. coromandelianus* were recorded. Lead treatment at 20 ppm significantly (p<0.05) indicated adverse effect on number of leaves, leaf area, shoot, root, leaf, total plant dry weight, shoot/root, leaf weight ratio, specific leaf area and leaf area ratio of *S. coromandelianus.*

The reduction in root, shoot, seedling length and biomass production of *E. hirta* by concentrations 20, 40, 60, 80 and 100 ppm of lead as compared to control were noted. Air polluion due heavy metals present in soil constitutes negative impacts on tolerance indices of tree (Tripathi et al. 2009). Lead treatment at 20 ppm significantly indicated adverse effect on number of leaves, leaf area, shoot, root, leaf and total plant dry weight of *E. hirta.* A rise in concentrations of lead from 60 to 100 ppm further significantly (p<0.05) decreased root and leaf growth of *E. hirta*. Ghani et al. (2010) studied the similar effect of different concentrations (0, 10, 20 and 30 ppm) of lead toxicity on the growth of two varieties of *Zea maize* (Neelam and Desi) in earthen pots. The different response on root / shoot, leaf weight ratio, specific leaf area and leaf area ratio of *E. hirta* to different concentrations 20, 40, 60, 80 and 100 ppm of lead as compared to control were noted.

The application of Pb at 20 ppm promoted shoot and seedling length of *E. hirta*. Maximum suppression of root length (32.30 cm), shoot length (9.50 cm) and seedling length (41.80 cm) of *E. hirta* were obtained at 80 ppm concentration of lead. Maximum suppressed in number of leaves (13.60) and leaf area (7.43) was found with the lead treatment of 100 ppm. Lead treatment at 60 to 80 ppm produced significant (p<0.05) decrease on seedling growth performance as compared to control. The shoot (0.28 g), root (0.14 g), leaves (0.046 g) and total plant dry weight (0.466 g) of *E. hirta* seedlings exposed with concentrations of Pb at 100 ppm was recorded. These lead toxicity impact on the growth of *Thespesia populnea* were found similar with the results of Kabir et al. (2008). The results for tolerance indices of *Thespesia populnea* progressively decreased with the increasing concentration of heavy metal. Kabir et al. (2011) reported the different values of tolerance indices of *Samanea saman* for Cu, Fe, Pb and Zn. A high percent of decrease was found in seedling growth and above and belowground biomass of both species with the increase in lead treatment.

The tolerance in seedling growth of *E. hirta* and *S. coromandelianus* differed in their sensitivity to lead treatments in range of 20-100 ppm as compared to control (Fig. 1). The seedlings of both species were found resistant to lead tolerance at 20 ppm concentration as compared to control. An increase in concentration of lead treatment from 40 to 100 ppm increased the toxicity and lower the tolerance indices percentage in seedling growth performance of *S. coromandelianus. S. coromandelianus* showed tolerance indices (68.38%). It was noted that the lead treatment of 80 ppm showed (46.75%) tolerance indices in seedlings of *E. hirta* as compared to control.

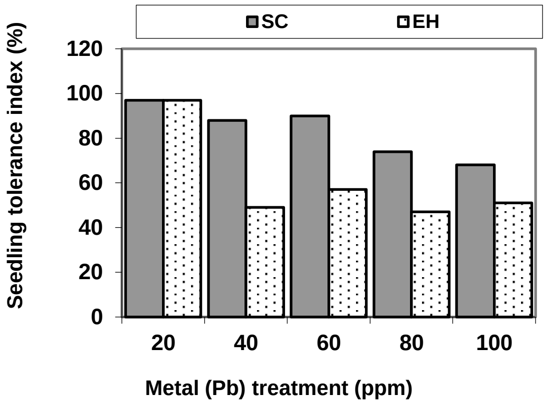

Figure. 1
Seedling tolerance index (%) of SC (*Sporobolus coromandelianus*) and EH (*Euphorbia hirta*) to different concentrations (20, 40, 60, 80 and 100 ppm) of Pb.

Table 1
Effect of lead on seedling growth of *Sporobolus coromandelianus* (Retz.) Kunth and *Euphorbia hirta* Forsk

Treatment lead (Pb) ppm	Shoot length (cm)	Root length (cm)	Seedling length (cm)	Number of leaf	Leaf area (sq. cm)
00	*49.00±1.08a **36.30±2.15a	15.50± 0.51a 20.30± 0.52a	64.50±2.07a 56.60±3.14a	25.10±1.20a 34.50±0.46a	2.20±0.006a 31.00±0.464a
20	44.50±1.07a 40.16±1.20ab	15.00±1.11a 19.60±1.08a	59.50±2.22a 59.76±2.41ab	25.50±2.23ab 33.60±1.74ab	1.60±0.014ab 9.77±0.831ac
40	39.70±0.76ab 40.60±1.50b	13.60±1.45bc 10.00±1.67ab 7.14 ± 0.12a	53.30±1.57ab 50.60±1.46bc	16.30±0.91b 18.60±4.64b	2.00±0.02b 5.31±1.04ab
60	46.60±3.17b 36.30±2.36b	14.00±0.72ab 11.50±1.08b 7.14 ± 0.12a	60.50±3.71b 47.80±3.31a	14.80±2.21b 22.30±3.97bc	1.03±0.016bc 8.22±0.693b
80	38.80±1.47bc 32.30±1.68bc	11.60±1.74b 9.50±1.84bc	50.40±2.74bc 41.80±2.92b	15.30±1.31bc 22.50±3.12c	0.48±0.005b 8.05±0.193bc
100	37.96±2.29c 34.70±4.70c	10.60±0.92c 10.30±1.43c	48.56±2.90bc 45.00±5.71c	12.00±1.02c 13.60±2.27c	0.60±0.042c 7.43±0.732bc

Numbers followed by the same letter in the same column are not significantly different according to Duncan Multiple Range Test at p<0.05 level.
± Standard Error; **Sporobolus coromandelianus* (Retz.) Kunth, ***Euphorbia hirta* Forsk

Table 2
Effect of lead on dry weight of *Sporobolus coromandelianus* (Retz.) Kunth and *Euphorbia hirta* Forsk

Treatment lead (Pb) ppm	Shoot dry weight (g)	Root dry weight (g)	Leaf dry weight (g)	Total dry weight (g)
00	*0.590±0.014a	0.360±0.002a	0.060±0.002a	1.01±0.002a
	**0.290±0.01a	0.200±0.003a	0.051±0.001ab	0.541±0.004a
20	0.420±0.03ab	0.185±0.003ab	0.024±0.002ab	0.629±0.003ab
	290±0.01ab	0.116±0.004ab	0.034±0.001b	0.440±0.004ab
40	0.570±0.03bc	0.300±0.003b	0.060±0.002b	0.930±0.003bc
	0.300±0.02bc	0.640±0.001b	0.045±0.002bc	0.985±0.004b
60	0.380±0.03ab	0.240±0.002ac	0.040±0.02bc	0.660±0.004ac
	0.250±0.03bc	0.098±0.003bc	0.030±0.001ac	0.378±0.003bc
80	0.520±0.05c	0.210±0.003b	0.035±0.002ac	0.771±0.004bc
	0.240±0.02ac	0.140±0.003bc	0.040±0.001bc	0.371±0.004bc
100	0.480±0.03bc	0.230±0.003bc	0.060±0.002ab	0.770±0.003c
	0.280±0.0bc	0.140±0.003c	0.046±0.002c	0.466±0.003c

Numbers followed by the same letter in the same column are not significantly different according to Duncan Multiple Range Test at $p<0.05$ level.
± Standard Error;
**Sporobolus coromandelianus* (Retz.) Kunth, ***Euphorbia hirta* Forsk

Table 3
Effect of lead on root/shoot ratio, leaf weight ratio, specific leaf area and leaf area ratio of *Sporobolus coromandelianus* (Retz.) Kunth and *Euphorbia hirta* Forsk

Treatment lead (Pb) ppm	Root / shoot ratio	Leaf weight ratio	Specific leaf area cm^{-2}/g	Leaf area ratio
00	*0.610±0.0030a	0.059±0.760ab	36.66±2.29a	2.17±0.158a
	**0.680±0.0036a	0.094±0.003ab	607.80±1.74a	57.30±2.29a
20	0.440±0.0036ab	0.038±0.630b	66.66±0.749ab	2.54±0.158ab
	0.400±0.01ab	0.077±0.004b	287.30±4.64ab	22.20±0.949ab
40	0.526±0.0035ac	0.064±0.541b	33.33±2.29b	2.15±0.152b
	2.13±0.02a	0.045±0.001bc	118.00±1.43bc	5.39±0.158bc
60	0.631±0.0037bc	0.060±0.856ac	25.75±0.949bc	1.50±0.891bc
	0.392±0.03ab	0.079±0.003ac	276.00±0.52ac	21.74±3.96ca
80	0.399±0.0036c	0.045±0.145b	13.71±0.714c	0.62±0.8564c
	0.379±0.02b	0.107±0.003c	201.25±0.001bc	21.69±3.966b
100	0.479±0.0035ac	0.077±0.098ac	10.00±0.922ab	0.77±0.098bc
	0.600±0.0036c	0.098±0.003c	161.5246±01.66c	15.94±0.158c

Numbers followed by the same letter in the same column are not significantly different according to Duncan Multiple Range Test at $p<0.05$ level.
± Standard Error;
**Sporobolus coromandelianus* (Retz.) Kunth, ***Euphorbia hirta* Forsk

Table 4
Percentage reduction in shoot length, root length, seedling dry weight and number of leaf of *Sporobolus coromandelianus* (Retz.) Kunth and *Euphorbia hirta* Forsk

Treatment lead (Pb) ppm	Shoot length (%)	Root length (%)	Total plant dry weight (%)	Number of leaf (%)
20	*9.10	3.20	37.70	1.50^{+}
	**10.60^{+}	3.40	2.60	18.66
40	18.00	12.20	7.90	35.00
	11.84	50.70	46.00	82.0^{+}
60	4.80	9.60	34.60	41.00
	18.0	43.30	46.08	30.10
80	20.80	25.00	23.60	39.00
	0.00	53.30	34.70	31.40
100	22.50	31.60	23.70	52.19
	4.40	49.00	60.50	13.86

+ Percentage increase

The harmful effects of lead on seedling growth of *S. coromandelianus* and *E. hirta* was disussed. Seedlings of *S. coromandelianus* exhibited better tolerance to Pb treatments at all treatment as compared to *E. hirta*. The inhibitory impact of lead on seedlings growth were recorded in order *S. coromandelianus*>*E. hirta*. It can be concluded that Pb treatment at higher level produced negative effects on the seedling growth perfomance of both species. Based on toxicity and tolerance indices (%), a great care is required by environmental managers while planting these species in metal contaminated areas.

4. Acknowledgements

The authors are thankful to the Chairperson for providing the space and facilities in the Department of Botany, University of Karachi, Karachi, Pakistan.

5. References

AusGrass, (2020). *Sporobolus coromandelianus* (Retz.) Kunth.https://keys.lucidcentral.org/keys/v3/Aus Grass/ key / AusGrass/ Media /Html/ SPOROBOL /SPOCOR. HTML. Accessed on 25-10-2020.

Bermudez GM, Jasan R, Pla R, Pignata ML (2012). Heavy metals and trace elements in atmospheric fall-out: Their relationship with topsoil and wheat element composition. *Journal of Hazardous Materials*, 214: 447-456.

Cope GT. (1999). Flora Zambesiaca 10:2.

Dribben WH, Creeley CE, Farber N (2011). Low-level lead exposure triggers neuronal apoptosis in the developing mouse brain. *Neurotoxcology and Teratology*, 33 (4): 473-480.

Efloras. (2020). Flora of Pakistan. http://www.efloras. org/florataxon.aspx ?flora_id=5&taxon_id = 1 31 091. accessed on 25-10-2020

EOL (Encyclopedia of Life) (2020). *Sporobolus coromandelianus* (Retz.) Kunth. https://eol. Org /pages/1115660 accessed on 25-10-2020.

Ghani A, Shah AU, Akhtar U (2010). Effects of lead toxicity on growth, chlorophyll and lead (Pb^{2+}) contents of two varieties of maize (*Zea mays* L.). *Pakistan Journal of Nutrition*, 9:887-891.

Gautam M, Pandey B, Agrawal M (2018). Identification of indicator species at abandoned red mud dumps in comparison to residential and forest sites, accredited to soil properties. *Ecological Indicators*, 88:88-102.

Giordani C, Cecchi S, Zanchi C (2005). Phyto remediation of soil polluted by nickel using agricultural crops. *Environmental Manage-ment*, 36: 675-681.

Gong Q, Wang L, Dai TW, Kang Q, Zhou JY, Li ZH (2019). Effects of copper treatment on mineral nutrient absorption and cell ultrastructure of spinach seedlings. *Ying Yong Sheng Tai Xue Bao*. 30(3):941-950.

Huang L, Naikwade NS, Magdum CS (2012). Review on phytochemistry and pharmacological aspects of *Euphorbia hirta* Linn. *Journal of Medicinal Plant Research.*, 6(39):5176-5185.

Hu R, Sun K, Su X, Pan Y, Zhang Y, Wang X (2012). Physiological responses and tolerance mechanisms to Pb in two xerophils: *Salsola passerina* Bunge and *Chenopodium album* L. *Journal of Hazardous Materials*, 205-206: 131-138.

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

Iqbal MZ, Yasmin N, Shafiq M (2001). Effects of salinity on germination and growth of two cultivars of wheat. *Ecoprint*, 8(1): 7-11.

Jaja ET, Odoemena CSI (2004). Effect of Pb, Cu and Fe compounds on the germination and early seedling growth of tomato varieties. *Journal of Applied Science and Environmental Management*, 8: 51-53.

Joshi N, Chauhan A, Joshi PC (2009). Impact of industrial air pollutants on some biochemical parameters and yield in wheat and mustard plants. *The Environmentalist*, 29: 398-404.

Kabir M, Iqbal MZ, Shafiq M (2011). Toxicity and tolerance in *Samanea saman* (Jacq.) Merr. to some metals (Pb, Cd, Cu and Zn). *Pakistan Journal of Botany*, 43: 1909-1914.

Kabir M, Iqbal MZ, Shafiq M, Farooqi ZR (2008). Reduction is germination and seedling growth of *Thespesia populnea* L. caused by lead and cadmium treatment. *Pakistan Journal of Botany*, 40: 2419-2426.

Kewscience (2020). http://www.plantsoftheworld on line.org /taxon/urn:lsid:ipni. org:names: 1696 86-3. accessed on 25-10-2020.

Kumar S, Malhotra R, Kumar D (2010). *Euphorbia hirta*: Its chemistry, traditional and medicinal uses, and pharmacological activities. *Pharma cogn Review*, 4(7):58-61.

Kumari J, Deswal DS (2017). Assessment of air pollution tolerance index of selected plants unveils to traffic roads of Noida, Uttar Pradesh. *International Journal on Emerging Technologies*, 8: 179-184.

Liu YM, Liu DY, Zhang W, Chen XX, Zhao QY, Chen XP, Zou CQ (2020). Health risk assessment of heavy metals (Zn, Cu, Cd, Pb, As and Cr) in wheat grain receiving repeated Zn fertilizers. *Environmental. Pollution*, 257: 113581.

Odilara CA, Egwaikhide PA, Esekheigbe A, Emua SA (2006). Air pollution tolerance indices (APTI) of some plant species around llupeju industrial area, Logos. *Journal of Engineering Sciences and Application*, 4: 97-101.

Ogueke CC, Ogbulie JN, Okoli IC, Anyanwu BN (2007). Antibacterial activities and toxicological potentials of crude ethanolic extracts of *Euphorbia hirta*. *Journal of American Science*, 3 (3): 11-16.

Pietrzykowski M, Antonkiewicz J, Gruba P, Pajak M (2018). Content of Zn, Cd and Pb in purple moorgrass in soils heavily contaminated with heavy metals around a zinc and lead ore tailing landfill. *Open Chem.* 16:1143–1152.

Prasad MNV, Nakbanpote W, Sebastian A, Panitlertumpai N, Phadermrod C (2015). Chapter 23- Phytomanagement of Padaeng Zinc Mine Waste, Mae Sot District, Tak Province, Thailand. Editor(s): Khalid Rehman Hakeem, Muhammad Sabir, Münir Öztürk, Ahmet Ruhi Mermut, Soil Remediation and Plants. Academic Press. pp 661-687.

Rehman SA, Iqbal MZ (2009). The effects of industrial soil pollution on *Prosopis juliflora* Swartz growth around Karachi. *Pakistan Journal of Scientific and Industrial Research*, 52(1): 37-42.

Shafiq M, Iqbal MZ (2012). Impact of Automobile Pollutants on Plants. LAMBERT Academic Publishing GmbH & Co. KG Heinrich-Böcking-Str. 6-8, 66121, Saarbrücken, Germany. 132 pp.

Shafiq M, Iqbal MZ, Kabir M, Farooqi ZR (2019). Poison Land. Vegetation of disturbed and polluted areas in Pakistan. Strategic book publishing & rights agency, U.S.A. 173 pp.

Shahid M, Pinelli E, Dumat C (2012). Review of Pb availability and toxicity to plants in relation with metal speciation; role of synthetic and natural organic ligands. *Journal of Hazardous Materials*, 219-220: 1-12.

Tripathi AK, Tiwari PB, Mahima K, Singh D (2009). Assessment of air pollution tolerance index of some trees in Moradabad city. *Journal of Environmental Biology*, 30: 545-550.

Verma A, Roy A, Bharadvaja N (2021). 13- Remediation of heavy metals using nanophytoremediation, Editor(s): Maulin P. Shah, Advanced Oxidation Processes for Effluent Treatment Plants. Elsevier, 2021, Pages 273-296. doi.org/10.1016/B978-0-12-821011-6.00013-X.

Yang X, Feng Y, Helg Z, Stoffella PJ (2005). Molecular mechanisms of heavy metal hyperaccumulation and phytoremediation. *Journal of Trace Elements and Mediterranean Biology*, 18: 339-353.

Yuan Z, Xiong S, Li C, Ma X (2011). Effects of chronic stress of cadmium and lead on anatomical structure of Tobacco roots. *Agricultural Sciences in China*, 10 (12): 1941-1948.

Zeeshan N, Nasir MS, Nasir A, Shafiullah, Farooqi ZR, Naveed K (2016). Air contamination and its impacts on plants, humans and water of Pakistan. *Journal of Applied Environmental and Biological Sciences*. 6:32-39.

Zulfiqar U, Farooq M, Hussain S, Maqsood M, Hussain M, Ishfaq M, Ahmad M, Anjum MZ (2019). Lead toxicity in plants: Impacts and remediation. *Journal of Environmental Management*,250: 109557. https://doi.org/10. 1016 /j.jenvman.2019.