ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor (RJIF): 8.4
IJAR 2024; 10(7): 29-32
www.allresearchjournal.com
Received: 01-05-2024
Accepted: 05-06-2024

Dr. Preeti Singh
Department of Botany, S.S. Khanna Girls' P.G. College, Prayagraj, Uttar Pradesh, India

Aradhana Pandey
Department of Botany, S.S. Khanna Girls' P.G. College, Prayagraj, Uttar Pradesh, India

Corresponding Author:
Dr. Preeti Singh
Department of Botany, S.S. Khanna Girls' P.G. College, Prayagraj, Uttar Pradesh, India

Lead toxicity in plants: A review

Dr. Preeti Singh and Aradhana Pandey

DOI: https://doi.org/10.22271/allresearch.2024.v10.i7a.11860

Abstract
Heavy metal pollution of soils is a common consequence of agricultural, industrial, and human activity. Lead is one of the heavy metals that can pollute soils and sediments easily. Lead is readily absorbed and accumulates in many plant parts even though it is not a necessary element for plants. Plant uptake of lead is influenced by a variety of physicochemical factors, including root exudation, soi l pH, particle size, and cation exchange capacity. Various toxicity signs in plants, such as chlorosis, reduced development, and blackening of the root system, are caused by excess lead. Lead suppresses photosynthesis, modifies hormonal status, disrupts mineral nutrition and water balance , andalters membrane permeability and structure. This review reports various morphological, physiological and biochemical effects of lead toxicity in plants.

Keywords: Heavy metal, lead, germination, growth, toxicity

Introduction
In recent years, there has been a major increase in environmental pollution as a result of unrestrained development activities, including industrialization and urbanization. The natural ecosystem is constantly at risk due to an overall rise in the concentration of heavy metals. Metals with a density of more than 5 g/cm^3 are referred to as heavy metals. At low concentrations, the heavy metals such as zinc (Zn), nickel (Ni), copper (Cu), vanadium (V), cobalt (Co), and chromium (Cr) are non-toxic. The functions of other heavy metals like arsenic (As), mercury (Hg), silver (Ag), cadmium (Cd), lead (Pb), and aluminium (Al) as nutrients are unknown, and they are somewhat harmful to plants and microbes [2].

Lead, one of the main heavy metals from ancient times, has become increasingly significant as a powerful environmental contaminant. The soft, silvery-white or greyish metal lead (Pb) has an atomic number of 82 and is located in Group 14 (IV a) of the periodic table. The atomic weight and density of lead are 207.2 g/mol and 11.35 g/cm^3 respectively. Lead conducts electricity poorly and is dense, ductile, and very malleable. Besides natural weathering processes the main sources of lead pollution are mining and smelting operations and its combustion, paints, gasoline, pottery, boat building, lead based painting, lead containing pipes, battery recycling, grids, arm industry, pigments, printing of books and the discharge of lead-enriched municipal sewage sludges etc. [33].

Lead is one of the world's most dangerous substances for both humans and the environment, even though many nations have implemented regulations to limit its input. Since many lead contaminants are essential to modern human existence, it is unlikely that lead contamination in soil will decline anytime soon [36].

It has been reported that farmed soils close to industrial regions have significantly higher lea d contents. Lead is deposited in the surface's ground layer, and the depth of the soil controls how much of it is there [6]. Plants may readily absorb it from the soil and store it in different parts of their bodies. Lead uptake by primary producers affects their growth, metabolic functions, and photosynthesis activity. Excess lead accumulation can cause a decrease in root growth by up to 42% [4]. Lead toxicity commonly manifests as chlorosis, rapid suppression of root growth, stunted plant growth, and blackened root systems. Lead suppresses mineral nutrition, water balance, enzyme activity, and photosynthesis [33]. These conditions disrupt the plant's regular physiological processes. Lead may eventually cause cell death at high doses [30].

Effects of lead on biochemical properties of plants

Many different types of enzymes involved in diverse metabolic pathways are affected by lead. Lead's interaction with enzyme-SH groups is primarily responsible for the suppression of enzyme activity that lead exerts [18]. Lead ions strongly block α-amino levulinate dehydrogenase, an essential enzyme for the formation of chlorophyll [25]. The oxidoreductase enzyme Chloramphenicol acetyl transferase (CAT) converts hydrogen peroxide into water and molecular oxygen in addition to eliminating dangerous peroxides. Cuttings and seedlings showed a considerable increase in CAT activities at lower lead concentrations and a decrease at higher lead concentrations. Decreased production of the enzyme, altered subunit assembly, or inactivation of the enzyme by reactive oxygen species (ROS) could all be reasons for reduced CAT activity at increased lead concentrations [37]. Even at a 5μM dose of lead nitrate, the activity of ribulose-bis-phosphate carboxylase/oxygenase was suppressed in spinach leaf homogenates. It was discovered that lead is very specific in membrane degradation and also for inhibiting the function of ATP synthetase/ATPase [35]. Lead also prevents the reductive pentose phosphate pathway's enzymes from functioning [11]. However, in whole plants, separated leaves, isolated protoplasts, and mitochondria, a stimulation of respiration is seen at lower concentration of lead [26]. Inhibition of respiration is observed with increasing lead concentrations [28]. Disconnection of oxidative phosphorylation appears to be the cause of lead's inhibitory action at higher concentrations [22]. It has been observed that lead affects the flow of electrons via the electron transport system [21].

Effects of lead on germination and growth

Lead is regarded as a typical protoplasmic toxin that is tiny, slow-acting, and cumulative. Lead contaminated soils result in a dramatic drop in agricultural productivity, which poses a major challenge to agriculture [16]. It has been reported that germination and growth can be negatively impacted by lead exposure in plants, even at the micromolar level [17]. *H. vulgare, E. argyi, S. alterniflora, P. alepensis, O. sativa*, and *Z. mays* have all been reported to exhibit lead-induced suppression of seed germination. Lead at relatively low concentrations severely inhibits seed germination. At higher concentrations, lead exerts detrimental effects on the radical length and hypocotyl in *E. argyi* [13]. Lead decreases germination percent, germination index, root/shoot length, tolerance index and dry mass of roots and shoots [20]. Increasing levels of lead concentration in tomato seedlings had a detrimental effect on the growth, fresh biomass, and growth tolerance index of the root, shoot, and leaves. Other investigations of the predicted lead concentrations found similar results: Fresh and dry biomass of root, shoot, and leaf is significantly reduced in *Z. mays* and *P. sativum* [3]. A high concentration of lead decreased the seed germination and seedling growth of wheat (*T. aestivum*) [31]. Lead's ability to interfere with the enzymes amylase and protease may inhibit germination [29]. The root exhibits increased inhibition, which could be due to its higher lead level [19]. An increased number of secondary roots per unit root length can also be seen in swollen, twisted, short, and stubby roots due to lead toxicity [17]. According to reports, *A. sativum* roots exposed to lead for 48–72 hours showed signs of damaged plasma membranes, darker nuclei, loss of cristae, endoplasmic reticulum, and dictyosomes. **[14]** High levels of lead exposure can also limit the biomass of plants [32]. Plants under high lead poisoning stress showed clear signs of growth inhibition, with dark purplish abaxial surfaces on fewer, smaller, and more brittle leaves [13].

Effect of lead on photosynthesis, fruits, and flowers

Plant survival depends on photosynthesis. Lead poisoning adversely affects the process of photosynthesis. Lead-exposed plants exhibit a reduction in photosynthetic rate due to partial chloroplast ultra-structure, limited synthesis of chlorophyll, plastoquinone, and carotenoids, blocked electron transport, reduced activity of Calvin cycle enzymes, and Carbon di-oxide shortage from stomatal closure. Lead alters the lipid makeup of plants, with chlorophyll B being more impacted than chlorophyll A [34]. Lead nitrate modifies the structure of chlorophyll in *Ceratopyllum dersum* plants by reducing their photocatalytic activity [27]. The plant cells exhibited a decrease in grana stacks, a decrease in stroma quantity in comparison to the lamellar system, and a lack of starch grains. Lead prevents plants from absorbing vital elements like iron and magnesium, which in turn prevents chlorophyll synthesis. Its affinity for protein N-and S-ligands causes damage to the photosynthetic system. [1] Lead-treated plants exhibit enhanced chlorophyll breakdown as a result of elevated chlorophyllase activity [5]. Lead decreases the maximum photochemical efficiency and potential activity of PS II reaction centers in the two populations of *M. floridulus* [15]. The cytochrome b/f complex, photosystem-1 (PS I), and the donor and acceptor sites of photosystem -2 (PS II) have all been shown to have lead effects [7]. It is well acknowledged that compared to photosystem -2 (PS II), photosystem-1 (PS I) electron transport is less susceptible to lead suppression. [23] Fruits and flowers grow differently when photosynthesis is disrupted [24]. Plants contaminated with lead produce fewer flowers. At 600 and 1800 ppm Pb contamination levels, less flowers were produced. [10] Lead exposure stops the synthesis of carbohydrates in vegetables by lowering the sucrose content. [2] It has been observed that the development of tomatoes is affected by lead pollution, while the vitamin C concentration remains unaffected [8]. Lead and Cooper promote lipid peroxidation, disrupt membrane integrity, reduces growth and photosynthesis and inhibit mineral nutrition in citrus (*Citrus aurantium* L.).[9] At higher concentrations, lead decreased the sunflower plants' dry matter, number of leaves, and height [12].

Conclusion

Increased human activities are the reason behind the continuous build-up of lead in the environment. Lead is a non-essential element for plants, yet it accumulates in different parts of plant and impairs a number of physiological functions. Gene expression, respiration, mineral nutrition, membrane structure and characteristics, and photosynthesis are examples of such physiological activities. The accumulation of lead in the soil also reduces the germination percentage, germination index, growth of seedlings, root/shoot length, tolerance index, and as well as dry mass of roots and shoots. Moreover, lead accumulation causes biochemical changes in fruits and flowers due to chlorosis.

Controlling heavy metal pollution, particularly lead pollution, is the duty of the government, the public and different environmental agencies. Since industry is the primary source of dangerous chemical releases into the environment, government regulatory authorities must impose stringent measures on it. To remove hazardous contaminants from the environment, advancement is necessary to create noval, ecologically acceptable remediation techniques that can lessen lead toxicity. These methods will help reduce the amount of lead present in both terrestrial and aquatic environments. Moreover, more focused researches are required to assess lead toxicity and the efficacy of bioremediation techniques because of the growing human population and activities.

Acknowledgement
The authors are highly thankful to the principal Prof. Lalima Singh (S.S. Khanna Girls' P.G. College, Prayagraj) and the CURIE - DST, New Delhi for their invaluable suggestions and support.

References

1. Ahmed A, Tajmir Riahi HA. Interaction of toxic metal ions Cd^{2+}, Hg^{2+} and Pb with light–harvesting proteins of chloroplast thylakoid membranes. An FTIR spectroscopic study. J Inorg Biochem. 1993;50(4):235-243.
2. Beak KH, Chang JY, Chang YY *et al*. Phytoremediation of soil contaminated with cadmium and/or 2,4,6–Trinitrotoluene. J Environ Biol. 2006;27:311-316.
3. Çimrin KM, Turan M, Kapur B. Effect of elemental sulphur on heavy metals solubility and remediation by plants in calcareous soils. Fresenius Environ Bull. 2007;16(9):1113-1120.
4. Collin S, Amritha B, *et al*. Bioaccumulation of lead (Pb) and its effects in plants: A review. J Hazard Mater Lett. 2022;3:100064.
5. Drazkiewicz M. Chlorophyll–occurrence, functions, mechanism of action, effects of internal and external factors. Photosynthetica. 1994;30:321-331.
6. De Abreu CA, De Abreu MF, De Andrade JC. Distribution of lead in the soil profile evaluated by DTPA and Mehlich-3 solutions. Bragantia. 1998;57:185-192.
7. Farouk SN, Muhammad A. The effect of lead on plants in terms of growing and biochemical parameters: A review. MOJ Eco Environ Sci. 2018;3(4):265-268.
8. Fazel MS, Sathyanarayan S, Satish PN, Muthanna L. Effect of paper mill effluents on accumulation of heavy metals in coconut trees near Nanjangud, Mysore District, Karnataka, India. Environ Geol Water Sci. 1991;17(1):47-50.
9. Giannakoula A, Therios I, Chatzissavvidis C. Effect of lead and copper on photosynthetic apparatus in citrus (*Citrus aurantium* L.) plants. The role of antioxidants in oxidative damage as a response to heavy metal stress. Plants. 2021;10:155.
10. Hadi F, Aziz T. A mini review on lead (Pb) toxicity in plants. J Biol. Life Sci. 2015;6(2):91-101.
11. Hampp R, Ziegler H, Ziegler I. Influence of lead ions on the activity of enzymes of reductive pentose phosphate pathway. Biochem Physiol. Pflanz. 1973;164(5-6):588-595.
12. Hung NM, Hiep NV, Dung BN, Hai NX. Lead accumulation in different parts of okra plant (*Abelmoschus esculentus*). ARPN J Agric Biol Sci. 2014;9(6):190-194.
13. Islam E, Liu D, Li T, *et al*. Effect of Pb toxicity on leaf growth, physiology and ultrastructure in the two ecotypes of *Elsholtzia argyi*. J Hazard Mater. 2008;154(1-3):914-26.
14. Jiang W, Liu D. Pb–induced cellular defense system in the root meristematic cells of *Allium sativum* L. BMC Plant Biol. 2010;10:40.
15. Jianqiao Q, Xueding J, *et al*. Effects of Lead Pollution on Photosynthetic Characteristics and Chlorophyll Fluorescence Parameters of Different Populations of Miscanthus floridulus. Processes. 2023;11(5):1562.
16. Johnson MS, Eaton JW. Environmental contamination through residual trace metal dispersal from a derelict lead-zinc mine. J Environ Qual. 1980;9:175-179.
17. Kopittke PM, Asher CJ, Kopittke RA *et al*. Prediction of Pb speciation in concentrated and dilute nutrient solutions. Environ Pollut. 2008;153(3):548-554.
18. Levine MB, Stall AT, Barrett GW, *et al*. Heavy metal concentration during ten years of sludge treatment to an old–field community. J Environ Qual. 1989;18(4):411-8.
19. Liu T, Liu S, Guan H *et al*. Transcriptional profiling of Arabidopsis seedlings in response to heavy metal lead (Pb). Environ Exp Bot. 2009;67(2):377-386.
20. Mishra S, Srivastava S, Tripathi R, *et al*. Lead detoxification by coontail (*Ceratophyllum demersum* L.) involves induction of phytochelatins and antioxidant system in response to its accumulation. Chemosphere. 2006;65(6):1027-39.
21. Miles CD, Brandle JR, Daniel DJ, *et al*. Inhibition of PS II in isolated chloroplasts by lead. Plant Physiol. 1972;49(5):820-825.
22. Miller RJ, Biuell JE, Koeppe DE. The effect of cadmium on electron and energy transfer reactions in corn mitochondria. Physiol. Plant. 1973;28(1):166-171.
23. Mohanty N, Vass I, Demeter S. Copper toxicity affects Photosystem II electron transport at the secondary quinone acceptor, QB. Plant Physiol. 1989;90(1):175-9.
24. Opeolu O, Adenuga OO, Ndakidemi PA, Olujimi OO. Assessment of phytotoxicity potential of lead on tomato (*Lycopersicon esculentum* L.) planted on contaminated soils. Int J Phys Sci. 2010;5(2):68-73.
25. Prassad TK. Mechanisms of chilling–induced oxidative stress injury and tolerance in developing maize seedlings: changes in antioxidant system, oxidation of proteins and lipids, and protease activities. Plant J. 1996;10(6):1017-1026.
26. Parys E, Romanowaska E, Siedlecka E *et al*. The effect of lead on photosynthesis and respiration in detached leaves and in mesophyll protoplasts of Pisum sativum. Acta Physiol Plant. 1998;20:313-322.
27. Rebechini HM, Hanzely L. Lead–induced ultrastructural changes in chloroplasts of the hydrophyte *Ceratophyllum demersum*. Z Pflanzenphysiol. 1974;73(5):377-386.
28. Reese RN, Roberts LW. Effects of cadmium on whole cell and mitochondrial respiration in tobacco cell suspension cultures (*Nicotiana tobacum* L. var. xanthi). J Plant Physiol. 1985;120(2):123-130.
29. Sengar RS, Gautam M, Sengar RS *et al*. Lead stress effects on physiobiochemical activities of higher plants. Rev Environ Contam. Toxicol. 2008;196:73-93.

30. Seregin IV, Ivanov VB. Physiological aspects of cadmium and lead toxic effects on higher plants. Russ J Plant Physiol. 2001;48(4):523-544.
31. Singh P. Toxic effect of lead (Pb) on seed germination & seedling growth of wheat (*Triticum aestivum* L.). J Nat Res Dev. 2016;11:25-31.
32. Singh R, Tripathi RD, Dwivedi S *et al*. Lead bioaccumulation potential of an aquatic macrophyte *Najas indica* are related to antioxidant system. Bioresour Technol. 2010;101(9):3025-3032.
33. Sharma P, Dubey RS. Lead toxicity in plants. Braz J Plant Physiol. 2005;17(1):35-52.
34. Stefanov K, Seizova K, Popova I *et al*. Effects of lead ions on the phospholipid composition in leaves of *Zea mays* and Phaseolus vulgaris. J Plant Physiol. 1995;147(2):243-256.
35. Tushu I, Brouillette JN. Metal ion inhibition of corn root plasma membrane ATPase. Phytochemistry. 1987;26(1):65-69.
36. Yang YY, Jung JY, Song WY, Suh HS, Lee Y. Identification of rice varieties with high tolerance or sensitivity to lead and characterization of the mechanism of tolerance. Plant Physiol. 2000;124:1019-1026.
37. Verma S, Dubey RS. Lead toxicity induces lipid peroxidation and alters the activities of antioxidant enzymes in growing rice plants. Plant Sci. 2003;164(4):645-655.