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To analyze the effect of cadmium on seed germination and metal tolerance index in PEA

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Abstract

Lead, cadmium, arsenic, mercury, chromium, and most agricultural soils on the planet are polluted with these and other heavy metals. Any living thing, from bacteria to humans, may die from exposure to high concentrations of heavy metals. The effects of heavy metals on vegetation would be the subject of this section. When exposed to accessible heavy metals in high concentrations, plant cells release reactive oxygen species and free radicals. Damage to cells and oxidative stress result from unchecked oxidation, which starts a chain reaction involving biomolecules found in cells, such as proteins, lipids, and nucleic acids. Heavy metal exposure causes altered metabolism, stunted development, decreased biomass output, and decreased yield in plants that are susceptible to these pollutants. Tolerance plants have evolved a plethora of responses to heavy metal exposure that help them evade their poisonous effects. Tolerance to heavy metals may be achieved in two main ways: either by converting the metals into harmless forms via detoxification or by sequestering them in a cellular compartment such as the vacuole or the apoplast. In this chapter, we will review the history, function, and effects of heavy metals on plants. Then, we will go over the ways plants fight back against heavy metal stress, and lastly, we will talk about remediation approaches that may be used to get rid of heavy metal contamination.

Keywords: Lead, Cadmium, Arsenic, Mercury, Chromium, Tolerance, Biomass

1. Introduction

To be considered a "heavy metal," a metal or metalloid must have an atomic density five times higher than water. Cadmium, lead, nickel, zinc, cobalt, chromium, iron, arsenic, and mercury are some of the most prevalent heavy metals in the environment. All kinds of life are under danger when heavy metal concentrations are high in the environment. Also covered were heavy metal cleanup techniques, where they come from, and the many Defence systems found in plants that can withstand these contaminants.

Toxic heavy metals are dense metals or metalloids with a reputation for being harmful, particularly in environmental settings. Heavy metals are naturally occurring substances that can become toxic at high enough concentrations to cause harm. These metals can enter the bodies of plants, animals, and humans through various pathways, including inhalation, food, and manual handling. Once inside, they can bind to and disrupt the function of important cellular components. For reasons related to ecology, evolution, nutrition, and the environment, as well as to human health, heavy metal toxicity is becoming an increasingly pressing concern. Their atomic densities are five times or higher than water's, making them a class of metals and metalloids that includes elements like copper, manganese, lead, cadmium, nickel, cobalt, iron, zinc, chromium, iron, arsenic, silver, and platinum.

Environmental factors are the sum of all the things that surround an organism or community of organisms, and they include all the physical factors from the outside world that have an impact on the organisms' ability to grow, develop, and survive. The majority of them may be seen scattered over various rock formations. Heavy metals, an anthropogenic component of the biosphere, were most abundant in soil and aquatic ecosystems as a result of growing industry and urbanization, with only a tiny fraction of this metal being in the atmosphere as vapours or particles. Many heavy metals are thought to be necessary for plant development, therefore their toxicity to plants depends on factors such as the kind of plant, the metal itself, the concentration, the chemical form, and the structure and pH of the soil. Heavy metals like as copper and zinc may activate enzyme processes or function as cofactors in those activities. A relatively high density and relative atomic weight (with an atomic number higher than 20) characterise this element, which exhibits metallic characteristics such as ductility, malleability, conductivity, cation stability, and ligand specificity. Although organisms need trace amounts of heavy metals including cobalt, copper, iron, manganese, molybdenum, nickel, vanadium, and zinc, toxic levels of these elements may be fatal. Environmental pollutants in the air, water, and soil, as well as heavy metals like lead, cadmium, mercury, and as (a metalloid but commonly known as a heavy metal) pose serious risks to all forms of life and have no positive impact on plants and animals. Metals enter the ecological food chain at the producer level and eventually make their way to the consumer level; heavy metal ions mostly come into contact with plants at their roots. Heavy metals are absorbed directly into the leaves in aquatic systems because particles are deposited on the foliar surfaces, exposing the plant body to these ions.

2. Need of the study

This research aims to provide light on the biochemical components involved in the response of seedlings to chromium stress. Specifically, it will examine the up-regulation of stress inducible enzymes such as CAT, POD, MDA, and proline, as well as the down-regulation of sugar. The amylase and metal tolerance (percent) decrease as the greater chromium concentration steadily declines. There was evidence that increased irrigation levels and durations were impacted by losses in flora, cobs, seed output, etc. Consequently, there was a slow decline in the harvest index of around 5.2 percent (16 ppm). In addition to these issues, increased chromium contamination in irrigation water for maize may also induce chlorosis and necrosis. It follows that chromium irrigation hinders the growth of maize crops at every stage, from planting to seed germination. Based on the short-lived irrigation cycle, chromium may damage plants in both laboratory and field settings. Under the impact of cadmium and chroma treatments, biochemical components like protein have been down-regulated and up-regulated, which might fundamentally enable afflicted plants to sustain their viability, in contrast to stress-inducing enzymes like lipid peroxidase, proline, catalase, and peroxidase.

3. Review of Literature

Jameel M. Al-Khayri, *et al*. (2022) [1] The increasing demands of modern life have led to a surge in interest in medicinal plants as a source of herbal medicine. But since these therapeutic plants are exposed to cadmium-rich water and soil as a result of widespread agricultural and industrial activities, they have been identified as a potential source of heavy metal poisoning in people. The very toxic element cadmium (Cd) stunts plant growth and reduces their yields. Symplastic and apoplastic chloride transporters, as well as specialised transporters such HMA, MTPs, NRAMP, ZIP, and ZRT-IRT-like proteins, are used by these plants to absorb Cd. In addition to interfering with several metabolic and physiological processes, Cd also produces reactive oxygen species (ROS), which it uses to achieve its effects. By examining the biochemical changes (alterations in photosynthetic machinery and membrane permeability), as well as the anatomical and morphological changes, research has shown that it negatively impacts several phases of plant development, including germination, vegetative growth, and reproductive stages. To counteract Cd toxicity, plants use a wide range of antioxidant mechanisms, some of which include enzymes and others that do not. In addition, genes involved in signal transduction are altered by the reactive oxygen species (ROS) produced by heavy metal stress. Because of this, the biosynthetic route of the crucial secondary metabolite is changed, which impacts the synthesis of secondary metabolites by either increasing or decreasing the production of metabolites. Topics covered in this review include the amount of Cd present, how plants absorb, store, and transport it, the potential effects on plants' health, and the molecular, physiological, morphological, and biochemical responses of medicinal plants to Cd toxicity. It delves into the omics and biotechnology approaches, including gene editing and genetic engineering, as well as the Cd detoxifying methods shown by medicinal plants. CRISPR-Cas 9 strategy to reduce Cd stress.

Parvaiz Ahmad *et al*. (2015) [2] When plants grow and react to different kinds of stress, calcium (Ca) is a key component. Nevertheless, its role in reducing heavy metal stress in plants is still unknown. In this research, we looked at how cadmium (Cd) absorption was influenced by 50 mM of calcium in mustard plants that had been subjected to lethal doses of Cd (200 mg L^{-1} and 300 mg L^{-1}). Plant stature, root length, dry weight, pigmentation, and protein content were all significantly reduced after Cd treatment. Ca supplementation enhanced the development and biomass production of mustard seedlings exposed to Cd stress. Crucially, Ca treatment not only improved the oil content of mustard seeds from plants stressed by Cd, but it also improved the plants' overall health. Mustard plants exposed to Cd stress had a considerable rise in proline content, while plants treated with exogenously sprayed Ca had a favourable effect on this content. Lipid peroxidation was shown to be elevated in plants treated with varying amounts of Cd; however, by adding Ca, this effect was significantly reduced. The antioxidant enzymes glutathione reductase, ascorbate peroxidase, and superoxide dismutase had their activity amplified by Cd treatment, and the addition of Ca further amplified these effects. Reduced element absorption and increased Cd buildup in roots and shoots were additional effects of Cd stress. Ca, on the other hand, increased the concentration of vital nutrients and reduced Cd accumulation in plants that were stressed by Cd. Based on our findings, mustard plants can better survive the harmful effects of Cd when given Ca, which in turn improves their development and seed quality.

Essa Ali *et al*. (2020) [1] A hydroponic experiment was conducted to test the effects of cadmium (Cd) stress on two oilseed rape genotypes, Jiu-Er-13XI and Zheyou-50, which vary in the amount of seed oil they contain. Tolerance to Cd exposure was shown to be influenced by genetics. Although both genotypes were adversely impacted by Cd treatment, the knock-on effects were much more severe in Zheyou-50 (high seed oil concentration) than in Jiu-Er-13XI (low seed oil content). Reactive oxygen species (ROS), which degraded chloroplast structure and reduced photosynthetic pigments, were more abundant in Jiu-Er-13XI compared to Zheyou-50. An rise in MDA concentration indicates a drastic reduction in total fatty acids, particularly 18:2 and 18:3. Under Cd stress, Jiu-Er-13XI plants collected greater Cd content in their roots and shoots compared to Zheyou-50, but a lower quantity of tocopherol (Toc) was found. On the other hand, Zheyou-50 showed reduced sensitivity to Cd stress compared to its competitor.

4. Objectives of the study

1. To analyze the Effect of Cadmium on Seed Germination and Metal Tolerance Index in Pea.
2. To study the Acquisition of Shoot Length, Root Length and Lateral Roots vs. Cadmium Levels.

5. Research Methodology

From 2008 till 2012, the Botany Department (New Block) at the University of Lucknow in Lucknow grew Pisum sativum L. and *Zea mays* L. from seed in petri dishes and clay pots. Seeds were grown on petri dishes with varying doses of cadmium and chromium (1, 2, 4, 8, and 16 ppm) for all early findings. Pea and maize seeds are able to germinate and grow into healthy seedlings when planted in clay pots with dimensions of around 30 cm in diameter and 30 cm in depth. The Pisum sativum plant blooms once a year. Typically, the little spherical seed or seed pod of the plant Pisum sativum is what is known as a pea. Peas are contained inside each pod. Despite its fruit-like botanical classification, it is cooked and eaten like a vegetable. This crop is often cultivated in regions with mild winters and cold springs. Any time between the beginning and end of winter is suitable for planting. As a result, peas are often cultivated as a crop for the cooler months.

It takes several cultivars about sixty days from seed to full maturity. You may easily grow it from seed in slightly acidic, well-drained soil. The common grain crop of the tropics and subtropics, maize (*Zea mays* L.), showed varying degrees of stress tolerance when exposed to extreme conditions. Corn is able to survive and even grow in environments with little soil moisture and high light levels because of the C4 benefits.

For the purposes of data sorting and statistics, Microsoft Excel 2019 was used. A test for normal distribution called the Shapiro-Wilk (S-W) test. The significance of the difference between fruit germination and fruit development was examined using one-way analysis of variance (ANOVA), and for multiple comparisons among different sample means, the least significance difference test was used. A statistically significant difference was shown by a p-value less than 0.05, which was derived from the variance analysis in SPSS 17.0 (SPSS Inc., Chicago, IL, USA), which was used to examine the significance of various treatments.

6. Results and data analysis

The proportion of V. radiata seeds that germinated after being treated with chromium was not significantly different from the control group (Table 1). When compared to the control group, V. radiata plants treated with 25 ppm chromium had a significant impact on root, shoot, and seedling development ($p<0.05$). The findings showed that, in comparison to the shoot length of V. radiata, the root was significantly impacted by all chromium concentration treatments. Findings for V. radiata shoot length followed a pattern comparable to those of root development. The seedling length of V. radiata was shown to be significantly affected by a 100 ppm rise in chromium content. After being treated with 25, 50, 75, and 100 ppm of chromium solution, the seedling size of V. radiata-which comprises the length of the root and shoot-declined from 28.95 cm for the control group to 16.51 cm, 12.43 cm, 8.34 cm, and 8.26 cm, respectively. When exposed to varying concentrations of chromium, seedlings of V. radiata showed a slow but noticeable decline in dry weight compared to the control group. Chrome concentrations up to 100 ppm drastically reduced the seedling dry weight of Verticillium radiata.

Table 1: Effects of chromium on different growth parameters of Vigna radiata

Treatments (ppm)	Seed Germination (%)	Root length (cm)	Shoot length (cm)	Seedling Length (cm)	Seedling dry weight (g)	Root length/shoot length Ratio
00	100.00±0.00a	11.82±0.66a	17.13±0.66a	28.95±1.48a	0.090±0.006a	0.675±0.025b
25	100.00±0.00a	7.41±0.07b	9.06±0.07b	16.51±0.31b	0.066±0.001b	0.823±0.51a
50	100.00±0.00a	4.81±0.46c	7.62±0.46c	12.44±8.34c	0.046±0.004b	0.630±0.32bc
75	100.00±0.00a	2.78±0.08d	5.72±0.08d	8.34±0.23d	0.040±0.005c	0.502±0.25cd
100	100.00±0.00a	2.52±0.16d	5.71±0.16d	8.27±0.27d	0.030±0.005d	0.453±0.06d

Values followed by the same letters in same column are not significantly different ($p<0.05$) according to Duncan's Multiple Range Test.

Chromium tolerance was different in the V. radiata seedlings treated with the metal compared to the control group. Compared to the control group, V. radiata showed a high level of tolerance to chromium treatment at 25 ppm. At 50 ppm, V. radiata seedlings showed the best proportion of chromium tolerance indicators. The seedling tolerance indices for V. radiata were found to be the lowest at 100 ppm when treated with chromium. When exposed to25,50, and 75 ppm of chromium concentration, seedlings of V. radiata showed a 52.91 percent, 44.48 percent, and 32.42 percent reduction in tolerance, compared to the control, respectively.

In V. radiata, seedling Vigour index was positively correlated with chromate treatment. An increase in chromium concentration was associated with a decrease in the seedling Vigour index. Treatments ranging from 25 to 100 ppm of Cr resulted in a gradual decline in the Seedling Vigour Index (S.V.I.) for V. radiata, as shown in Figure 38. The 100-ppm chromium group showed substantially reduced seedling Vigour indices of V. radiata as compared to the control group. Results showed that seedling Vigour index in V. radiata seedlings treated with 25, 50, 75, and 100 ppm of chromium decreased by 1651.10 percent, 1244.40 percent, 834.40 percent, and 827.70 percent, respectively, compared to the control group (2895.30 percent).

7. Conclusion

Because of alterations in their physiological and biochemical activities, plants grown in soils contaminated with heavy metals have stunted growth. This is particularly true in cases when the heavy metal in question does not contribute positively to plant development and growth. Multiple studies have shown that heavy metals, even when used responsibly, may have harmful impacts on plants, animals, and other forms of life beyond certain thresholds. Thus, it is crucial to enhance research into the effects of heavy metals on plants and related fields in order to preserve the planet's ecological balance. There are two sides to the coin when it comes to plants and heavy metals: on the one hand, plants are vulnerable to the harmful effects of heavy metals, and on the other, plants have internal systems that protect them from harm and help them detoxify polluted soil and water. Heavy metals impact photosynthetic pigments as well as growth pigments, according to our review. Using hyperaccumulator plants in a bioremediation/phytoremediation process to remediate heavy metal contaminated soil is an efficient way to eliminate the toxicity of heavy metals that build up in soil. To cure soils contaminated with heavy metals, plants utilises a variety of phytoremediation methods; the most popular of them is phytoextraction, which guarantees full removal of the contaminant.

One example of an abiotic stress that reduces crop yield is heavy metal pollution of farmland. Plants have been engineered to be resistant to heavy metals via the use of genetic engineering and new genome editing techniques. Attacking the first stage of heavy metal absorption by plants is one way to combat heavy metal toxicity in plants. Heavy metal transport across cell membranes and inside cells remains a mystery; further research into membrane proteins, such as ion channels and pumps, is needed to unravel this molecular mystery. The enormous biomass of heavy metal accumulators, such B. napus and B. juncea, makes them ideal for use in phytoremediation. An important but often overlooked part of phytoremediation is finding a way to get rid of the heavy metals that plants acquire in a way that doesn't harm the environment by improperly handling the plant biomass. The variety of soil microbes and the rhizosphere microbes, which influence the solubility of heavy metals, should also be the subject of future research. Endophytes, which are non-pathogenic bacteria found inside plant organs, might potentially be targeted for their ability to give resistance to heavy metals. Initiating public awareness and creating strict legislation to curb the anthropogenic production of these heavy metals is an essential responsibility of government and environmental protection organisations. In order to attain a pollution-free environment and ecological harmony, it is crucial to have information about the detrimental effects of heavy metals on plant development. This knowledge is essential for improving plant growth and production.

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