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To study the effect of chromium on *Zea mays* seed germination and metal tolerance index

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Abstract

This research evaluated the effects of cadmium on pea using a noval method, looking at germination, seedling growth, pigment development, and enzyme activity. As a test plant, we chose pea (*Pisum sativum* sp.), a significant pulse crops that people eat. The current study used duplicate Petri plates on filter paper to cultivate maize seedlings at varying concentrations of cadmium (0.5, 1.0, 2.0, 4.0, 8.0, and 16.0 ppm). There were noticeable changes in the biochemical and physiological processes. The germination percentage was lower at the high cadmium concentration compared to the control. Plumule and radical lengths, as well as the number of lateral roots, were found to be significantly reduced. As the cadmium concentration increased, we also saw a decrease in the fresh weight, dry weight, and moisture content. As cadmium concentrations increased, a decline in chlorophyll content was observed. Various concentrations of cadmium were found to significantly enhance catalase and peroxidase activity when the test chemical was applied. According to the findings, pea (*Pisum sativum* sp.) seedlings have stunted development due to cd stress inhibiting the activities of peroxidase and catalase. details on the impact of different chromium concentration treatments on the germination of mung bean (*Vigna radiata*) seeds and the performance of seedlings in comparison to the control group.

Keywords: Chlorophyll, Chromium, Lateral Roots, Fruits, Germination

1. Introduction

Factors that contribute to the phytotoxicity of metals include the length of exposure, the plant's nutritional state, its age, the presence of mycorrhizal infection, the degree of toxicity determined by the biological availability of the metals and their interactions with other soil metals. The buildup of heavy metals in soils is a major worry in the agricultural sector because of the damage it may do to soil organisms' health, crop development stunted by phytotoxicity, and food safety and marketability. The following is the sequence in which crop species accumulate less heavy metals: Produce such as leafy greens, roots, and cereal crops. According to Oti Wilberforce and Nwabue (2013) [1], vegetables may take up metals from the soil and from any portion of the plant that comes into contact with air pollution. Because heavy metals may be readily transmitted from edible sections of crops to human food chains, it is important to pay close attention to these discrepancies. According to research by Ivanova *et al*. (2003) [2] and Korkmaz *et al*. (2010) [3], the concentrations in leaves tend to be higher than in roots, while seeds usually have the lowest levels. When heavy metals build up in the environment, they stunt plant development-both at the root and shoot levels-and affect nutrient absorption, homeostasis, and yield. Although the tolerance limits for heavy metal toxicity vary by species and crop type, it is generally known that most heavy metals impair growth. Possible sites of increased metal accumulation include carboxylase exudation and rhizosphere acidification. Plants absorb heavy metals from polluted soil and water, which stunts their development and poses an unspoken danger to people who eat them.

Heavy metals, when present in harmful concentrations, alter the normal pattern of plant development, photosynthetic pigments, protein, amino acids, starch, soluble carbohydrates, and the intake of vital minerals. By generating complexes with O, N, and S ligands, plants are able to affect numerous physiological activities and have various direct and indirect impacts on plant development as a result of heavy metal toxicity. To sum up, heavy metals impede mineral absorption, protein metabolism, membrane function, seed germination, and water relations.

Research conducted by Prasad *et al*. (1999) [4] and Panda and Patra (2000) [5] has shown that heavy metals such as iron, copper, cadmium, zinc, etc. may harm higher plants via oxidative stress. Abiotic stressors, such as water, salt, and heavy metal toxicity, among others, cause plants to release highly reactive free radicals. There is direct evidence linking these ROS to molecular damage in plant cells. According to Gallego *et al*. (1996) [6], Chaoui *et al*. (1997) [7], and Goel (2012) [8], heavy metal toxicity is also linked to the production of reactive oxygen species (ROS), which in turn causes oxidative damage. In biological systems, free radicals may be produced by using certain metals as catalysts. According to Shah *et al*. (2001) [9], biological molecules such as DNA, RNA, proteins, and lipids may be damaged by reactive oxygen species (ROS) due to the peroxidation they induce. When plants experience high levels of reactive oxygen species (ROS) that are unable to be quickly and efficiently scavenged, lipid peroxidation occurs, which in turn hinders plant growth and development. According to Bailly *et al*. (1996) [10], lipid peroxidation may lead to many end products, one of which is malondialdehyde (MDA). Antioxidant enzyme activity and malondialdehyde concentration are therefore often useful physiological markers of plants' stress resistance.

2. Need of the study

The properties of the seeder, plants, and flowers were recorded and progressively diminished in tandem with the increasing amounts of cadmium and chromium in the irrigation water. Thus, according to the study, biomass and harvesting qualities are found when cadmium and chromium are present. Thus, it has been determined that the impact of cadmium and chromium irrigation on pea and maize crops, from seed germination to seed establishment, might be linked to the negative effects of these heavy metals on the crops' ability to regulate ionic stress and ion cytotoxicity. We know that heavy metals like cadmium and chromium, when exposed to plants for an extended period of time, create oxidative stress in the roots. Enzymes and non-enzymes both have their own defensive mechanisms, which proves this. Zinc, iron, and nitrogen are three of the most important plant nutrients, and our research shows that cadmium and chromium interfere with their uptake and distribution in the pea and maize plants we used as experimental subjects. It seems that cadmium and chromium had a negative effect on sugar and chlorophyll concentrations via interfering with the metabolism of the plants.

It is possible that the plants tested had their protein synthesis disrupted due to cadmium and chrome interfering with their nitrogen metabolism. Two heavy metals were shown to have a negative impact on antioxidant enzyme activity, particularly those enzymes that include iron, when exposed to hazardous amounts. It is possible that certain heavy metals were affected by plant iron metabolism. The availability of the two heavy metals investigated may have had a negative impact on the plant's development. Thus, our research has broadened the scope of understanding how varied concentrations of cadmium and chromium affect pea and maize agriculture. Regarding the national economics (socio-economy), food safety for the people, and boosting plant and crop production, it is ideally to grow peas and maize in agroclimatic zones that are either completely free of cadmium and chromium or at least have lower concentrations of these metals.

3. Review of Literature

The effects of cadmium stress (0, 100, and 200 µM Cd) on ten different dill (Anethum graveolens) ecotypes were investigated in a hydroponic growth system. We examined proline, electrolyte leakage, relative water content, and plant development characteristics 30 days following cadmium (Cd) stress. Cd reduced many morphological parameters, including root and shoot dry weights, total dry weights, root lengths, heights, and leaf areas, according to the results. It seems that the Ardabil ecotype was more cadmium tolerant than the others, as it exhibited a larger amount in shoot dry weight, total dry weight, and height compared to the other ecotypes. Under cadmium exposure, all growth indicators declined. In response to cadmium stress, proline levels rose while electrolyte leakage and relative water content fell.

Parvaiz Ahmad *et al*. (2015) [11] 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 Ca is applied, leading to enhanced growth and seed quality.

Behnam Asgari Lajayer *et al*. (2017) [12] Developed and emerging nations alike face the critical environmental issue of heavy metal contamination of soils, water, and air. Polluted soil, water, and air resources, as well as sloppy manufacturing methods, provide a threat of heavy metal contamination to therapeutic plant products. The production of secondary metabolites may be impacted by heavy metal pollution during medicinal plant growth, leading to substantial alterations in both the amount and quality of these chemicals. As a result of their ability to absorb and store metal pollutants in their harvestable leaf, some medicinal and aromatic plants are being investigated as a potential alternative to toxic plant remediation that does not compromise essential oils. To deal with the overproduction of reactive oxygen species (ROS) caused by heavy metals that infiltrated their cells via the foliar and/or root systems, plants use a variety of tactics and intricate networks of anti-oxidative defence mechanisms that are not enzyme-based. Recent studies on medicinal plants' ability to accumulate heavy metals and their effects on secondary metabolite elicitation, toxicity, and detoxification pathways, as well as on international standards for plants and plant-based products, and on the assessment of heavy metal risks to human health in soil-medicinal plant systems, are summarised in this review.

Behnam Asgari Lajayer *et al*. (2019) [13] claimed One of the biggest environmental problems in the world is the buildup of heavy metals (HMs) in the environment, which happens mostly as a result of human activities including mining, industrialization, and urbanisation. The need for new methods is further emphasised by the fact that traditional cleanup tactics, which rely on physical or chemical procedures, are neither cost-effective nor environmentally benign. Phytoextraction, the practice of using plants to remove harmful substances from the environment, has gained a lot of interest in recent decades. This is especially true in the case of heavy metals (HMs). Ornamental plants (OPs) appear to be a better alternative to other plant types, like edible crops and medicinal plants, due to their many benefits, such as reducing pollution from harmful microorganisms (HMs), improving the aesthetics of the environment, creating economic value through by-products, and generally avoiding direct human consumption or other direct uses.

4. Objectives of the study

1. To study the major factors of Shoot Length and Root Length of *Pisum sativum* vs. Cadmium Durations and Levels.
2. To study the Effect of Chromium on *Zea mays* seed Germination and Metal Tolerance Index.

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 germination rate of Els fruits subjected to cadmium stress rose steadily and peaked on day 14 across all treatment groups. With each treatment group, the germination rate for Elt fruits likewise climbed steadily, reaching its maximum on the 16th day. The findings showed that the maximal germination time for the two types of herbage was unaffected by the cadmium treatment. The Els group showed a substantially different final germination rate after 30 mg L^{-1} treatment compared to the control group, and this rate dropped as the cadmium concentration increased. The final germination rate differed significantly at the 50 mg L^{-1} treatment level of Elt, and the change in the rate was similar to Els, but the trend was not readily apparent. The cadmium stress considerably reduced the fruit vigour of Els in comparison to the control group. As the concentration of cadmium stress increased from 10 to 30 mg L^{-1}, the fruit vigour declined dramatically. Nevertheless, there was no discernible alteration in fruit vigour accompanied by a rise in cadmium content when the stress concentration exceeded 30 mg L^{-1}. When the stress concentration went over 20 mg L^{-1}, the trend of reduction was not immediately apparent. When exposed to cadmium stress, Els fruits took 50% longer to germinate, and the time it took to germinate increased as the quantity of cadmium rose.

The disparity in treatment effects became less apparent when the stress concentration surpassed 30 mg L^{-1}. For half of the Elt fruits, the germination period was unaffected by the cadmium, but it became significantly noticeable when the stress concentration above 50 mg L^{-1}. At stress concentrations higher than 20 mg L^{-1}, the average fruit germination time for Els was noticeably decreased due to cadmium stress, and the inhibitory effect was very apparent. Both Els and Elt showed no change in their average fruit germination time when subjected to cadmium exposure (Figure 3h). Both plants exhibited a declining trend in the fruit-germination-rate index as the quantity of cadmium increased. When the stress concentration exceeded 30 mg L^{-1}, the illuminance treatment group showed a significantly stronger treatment effect than Elt, and Els showed a more significant decreasing trend than Elt. However, this situation was only observed when the grass was treated at 50 mg L^{-1}.

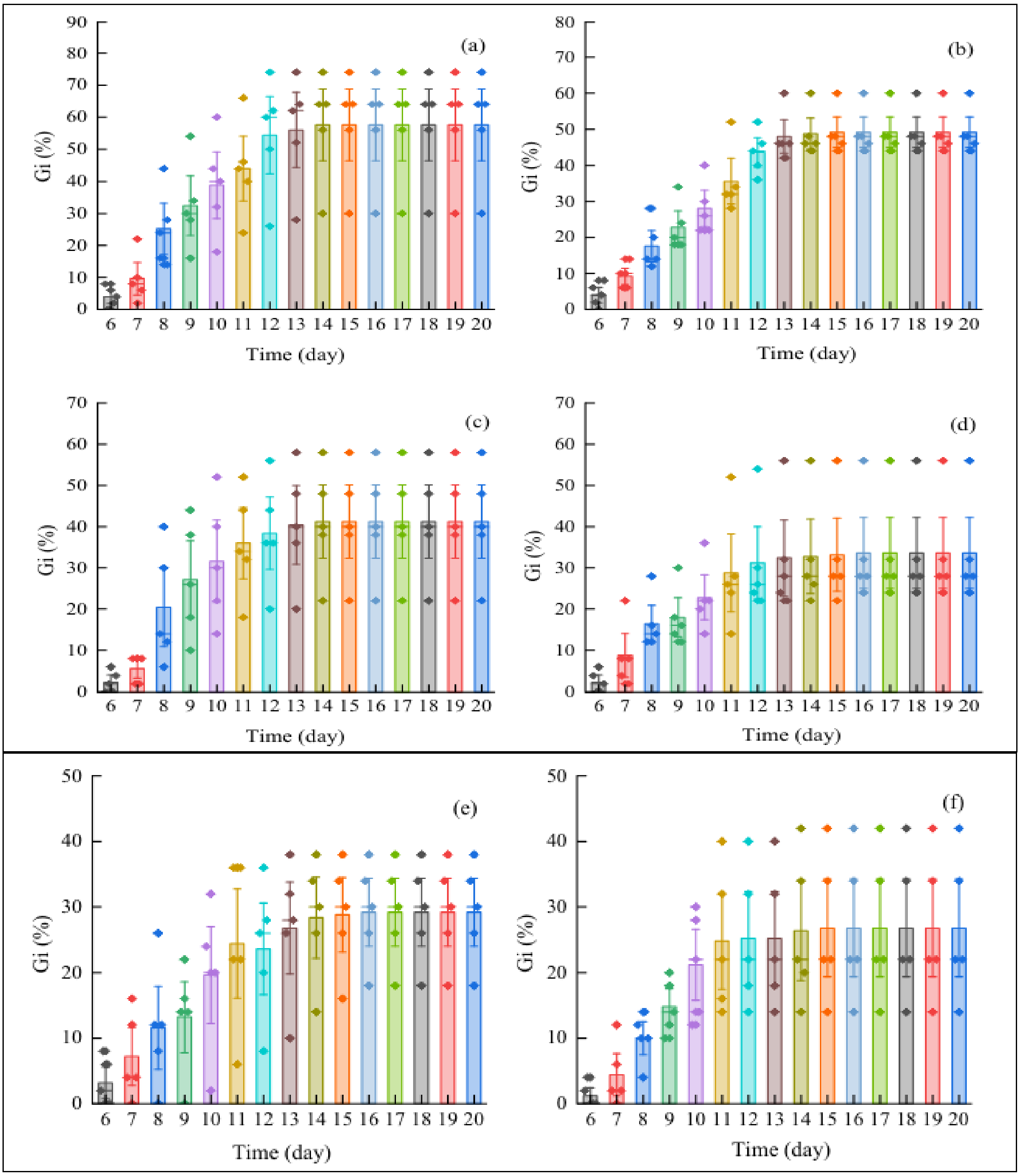

Fig 1: Fruit germination rate for E. sinosubmuticus S.L. Chen under cadmium stress, $p<0.05$: (a) blank control group; (b) 10 mg L^{-1} treatment group; (c) 20 mg L^{-1} treatment group; (d) 30 mg L^{-1} treatment group; (e) 40 mg L^{-1} treatment group; and (f) 50 mg L^{-1} treatment group. The different colored diamonds represent the specific data distribution for each group. Each column represents the cumulative germination rate of the plant.

7. Conclusion

In contrast to stress-inducible enzymes (CAT, POD, MDA, and proline), biochemical compounds like sugar were discovered to be down-regulated, allowing seedlings to withstand stress for longer. A decrease in amylase and metal tolerance (in percentage terms) was seen as cadmium buildup increased. Increases in irrigation intensity and duration were associated with improvements in a variety of crop output metrics, including leaf number, plant biomass, fruiting and seed yield, and more. Consequently, a 49% decline (16 ppm) in the harvest index was also discovered. Along with these issues, pea necrosis and chlorosis may be caused by irrigation water that has a high concentration of cadmium. Finally, in controlled laboratory and field circumstances, *Pisum sativum* L. showed varying degrees of susceptibility to cadmium-contaminated water depending on the length of irrigation.

Among the three most widely used cereal crops, maize (*Zea mays* L.) is a staple food for humans and cattle alike. In certain areas, maize accounts for more than 80% of daily food intake; it is the staple crop of lower-socioeconomic groups and is rich in carbs, lipids, proteins, and many essential vitamins and minerals. Worldwide, maize cultivation is at an all-time high, and the crop produces more grain by weight than any other.

Thus, in order to uncover how chromium-contaminated suppression of water impacts seed germination, establishment, and growth features in petri plates, maize seeds were used. Irrigation levels of chromium trioxide (CrO3) ranging from 1 to 16 ppm with chromium contamination over a short period of time (up to 15 days). Applying chromium-contaminated irrigation at levels up to 16 ppm in clay pots under field settings for up to 90 days. So, chromium toxicity was studied in *Zea mays* to see how it affected the plant's growth, as well as its biochemical, physiological, and biomass properties. The maize seedlings' rapid reactions to different chromium concentrations were shown by exposing the seeds to these concentrations for a short period of time (up to 15 days).

The rapid hydration/imbibition kinetics were determined to reach saturation in 6-8 hours. on the instance of 4 and 8ppm chromium-contaminated water administered during seed germination on petri plates, the germination percentage dropped from 87% to 57% and 43%, respectively. There was a reported decrease of about 57% in seed germination while using a dosage of 16 ppm. When plants were irrigated with water that was polluted with chromium, morphological traits including root and shoot length as well as their biodynamics were seen to be downregulated. Depending on the treatment levels and duration, the look of the roots might be changed, along with a decrease in their volume of development. There was a strong relationship between the amount and length of chromium treatment and the root and shoot biomass/fresh mass. Therefore, the fresh biomass of shoots and roots is significantly impaired by longer treatment durations and higher treatment doses.

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