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Effect of Heavy Metals on Morphological Growth of Pisum sativum

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ABSTRACT

A significant environmental problem that has an impact on agricultural output globally is heavy metal contamination. The impacts of heavy metals like cadmium (Cd), lead (Pb), cobalt (Co), copper (Cu), nickel (Ni), and chromium (Cr) on the morphological growth of Pisum sativum L. (pea plant) are reviewed and summarized in this paper. Heavy metal stress has a major impact on morphological characteristics such as seed germination, root and shoot length, biomass accumulation, leaf development, and yield qualities. Research indicates that heavy metals interfere with physiological and biochemical processes, leading to oxidative stress, altered cellular structure, and stunted plant growth. Plant tolerance mechanisms, exposure duration, metal type, and concentration all affect how severe the effects are. The present understanding, toxicity mechanisms, and implications for sustainable agriculture are highlighted in this research.

KEYWORDS
Pisum sativum, morphology, phytotoxicity, growth inhibition, heavy metals, and stress physiology

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1. Introduction

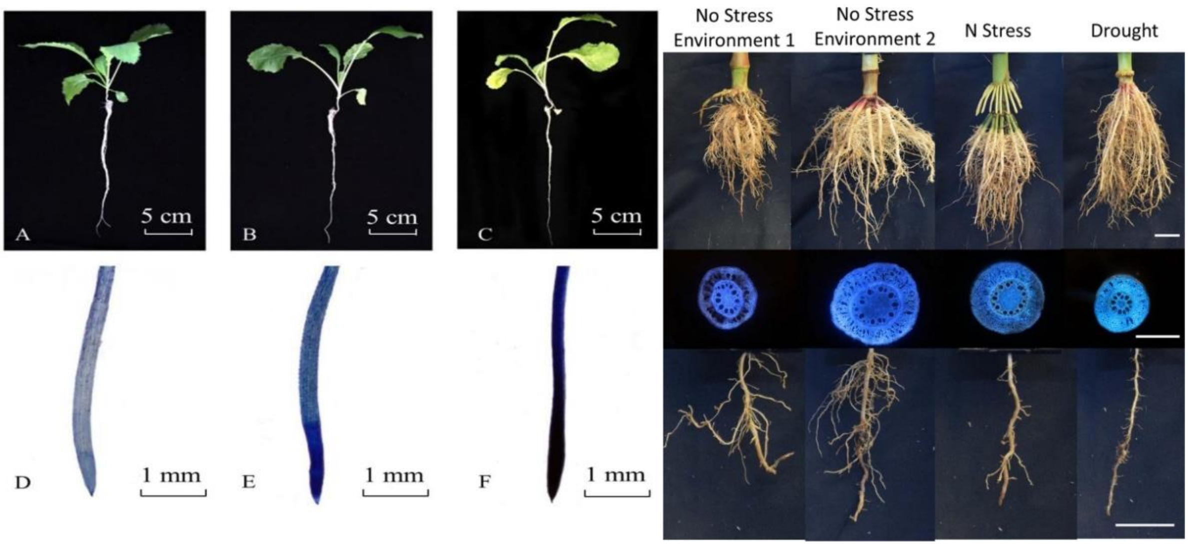
Rapid industrialization, urbanization, and intensification of agriculture have made heavy metal contamination a major environmental issue. Plant growth and food safety are at danger due to heavy metals like cadmium (Cd), lead (Pb), nickel (Ni), cobalt (Co), and copper (Cu) that linger in the environment and build up in soil (Alloway, 2013; Kabata-Pendias, 2011). Heavy metals, in contrast to organic contaminants, are not biodegradable and can linger in soils for extended periods of time before entering the food chain through plant absorption (Gupta, 2013; Sharma & Dubey, 2005).

Adverse morphological, physiological, and biochemical alterations are frequently seen in plants exposed to heavy metals. These include lower biomass, chlorosis, restricted root and shoot growth, and impaired germination (Sharma & Dietz, 2009; Yadav, 2010).

The primary source of the harmful effects is oxidative stress brought on by the production of reactive oxygen species (ROS), which harm cellular constituents like proteins, lipids, and DNA (Ahmad et al., 2019; Hall, 2002).

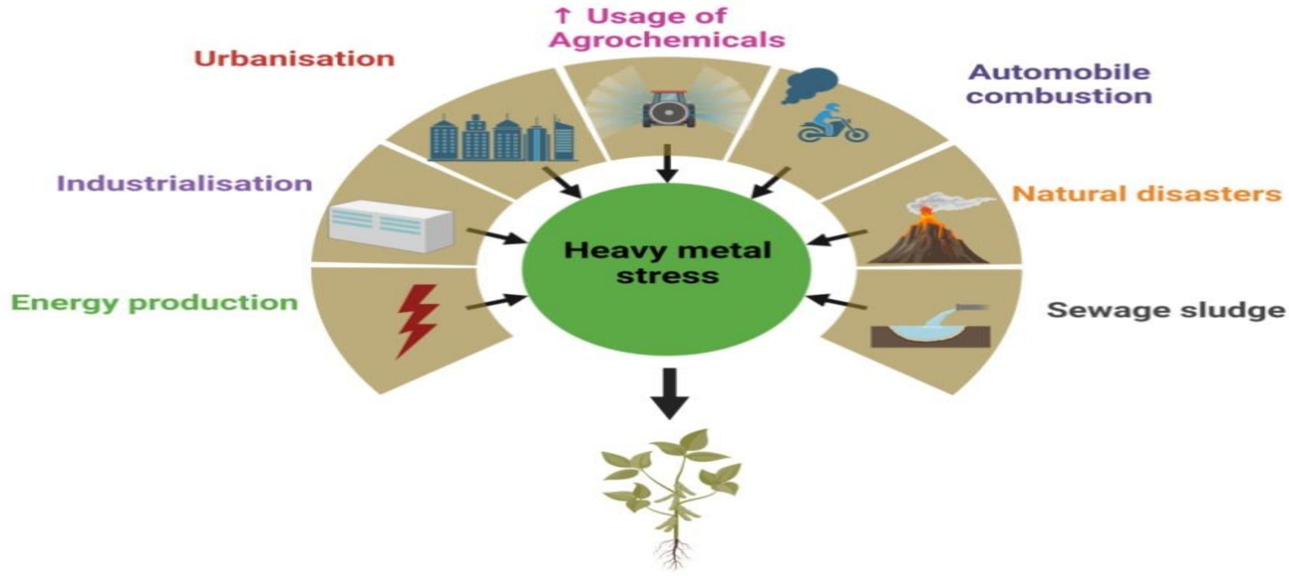
Pisum sativum L., or pea, is a significant leguminous crop that is widely grown due to its high nutritional content and capacity to fix atmospheric nitrogen. It is a good model organism for researching heavy metal toxicity because it is especially susceptible to environmental stress (Singh et al., 2019). Research has demonstrated that the morphological development of pea plants, particularly root elongation and biomass accumulation, is greatly impacted by exposure to metals like lead and cadmium (Liu et al., 2009; Verma & Dubey, 2003).

Heavy metals cause imbalances that impact plant development by interfering with food intake and metabolic activities (Clemens, 2006; Prasad, 2004). Because they come into direct contact with contaminated soil, root systems are frequently the first to be impacted, leading to decreased absorption of water and vital nutrients (Foy, 1984). Additionally, by destroying chloroplast structure and lowering chlorophyll content, heavy metals can interfere with photosynthesis (Ahmad et al., 2019).



Despite these detrimental effects, plants have developed a number of defense mechanisms, such as sequestration within vacuoles, chelation of metal ions, and activation of antioxidant enzymes (Hasan et al., 2009; Tripathi et al., 2007). However, the kind and concentration of the metal affect how efficient these systems are.

Developing methods to reduce toxicity and increase agricultural output in polluted soils requires an understanding of Pisum sativum's morphological reactions to heavy metal stress. Thus, the purpose of this study is to examine how heavy metals affect the morphological development of pea plants and to shed light on the mechanisms underlying their toxicity.



Methodology

1. Experimental Design

The effects of three heavy metals—cadmium (Cd), lead (Pb), and copper (Cu)—on the morphological growth of Pisum sativum L. were assessed in a controlled pot experiment using a completely randomized design (CRD) with three replicates per treatment.

2. Plant Material and Growth Conditions

Certified Pisum sativum seeds were carefully rinsed with distilled water after being surface sterilized with a 0.1% mercuric chloride solution. In earthen pots filled with uniform loamy soil, seeds were planted. Regular irrigation and natural environmental conditions were used to grow the plants.

3. Heavy Metal Treatments

Solutions containing heavy metals were made using:

- $CdCl_2$, or cadmium chloride
- Lead nitrate [$Pb(NO_3)_2$]
- CuSO4, or copper sulfate

Various concentrations of treatments were administered:

- Control (0 mg/kg)
- 25 mg/kg is a low concentration.
- 50 mg/kg is a medium concentration.
- Elevated concentration (100 mg/kg)

When the soil was being sown, heavy metals were added.

4. Parameters Studied

At 15, 30, and 45 days after sowing (DAS), the following morphological parameters were noted:

- The percentage of germination
- Length of root (cm)
- Length of shoot (cm)
- The quantity of leaves
- Dry and fresh biomass (g)

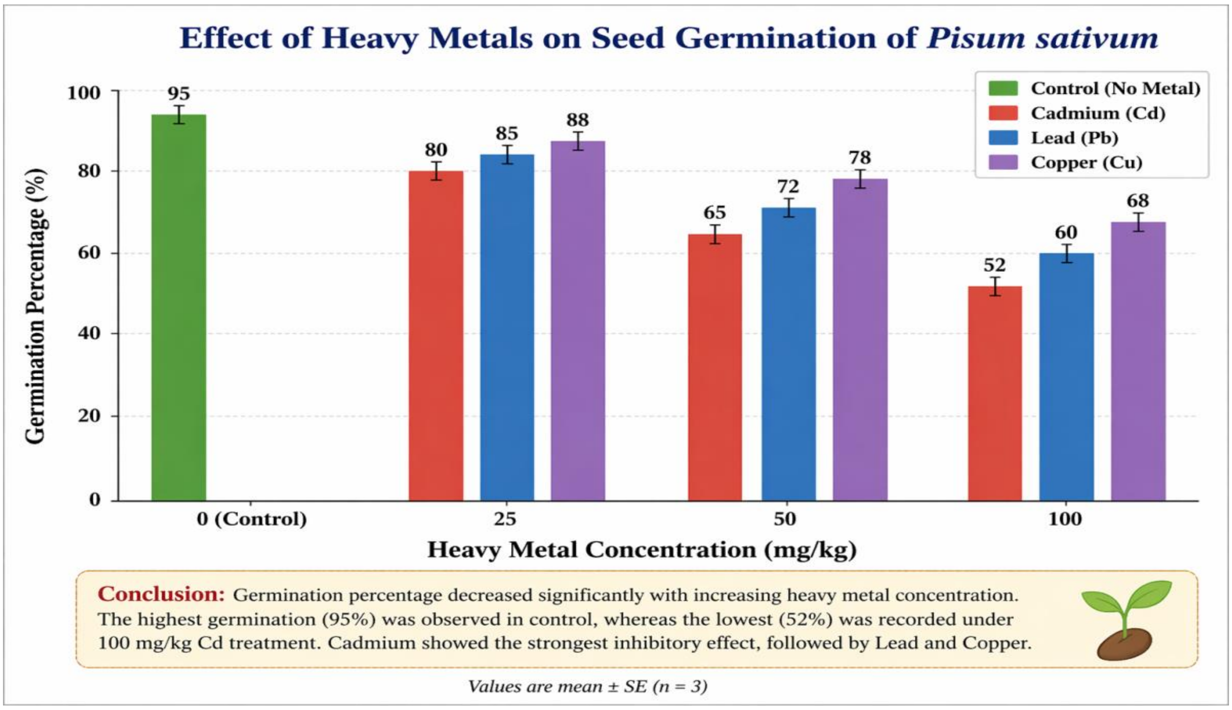
5. Statistical Analysis

One-way ANOVA was used to evaluate the data. Tukey's test was used to assess mean differences at a significance threshold of $p < 0.05$ (Singh et al., 2019).

Results

1. Effect on Seed Germination

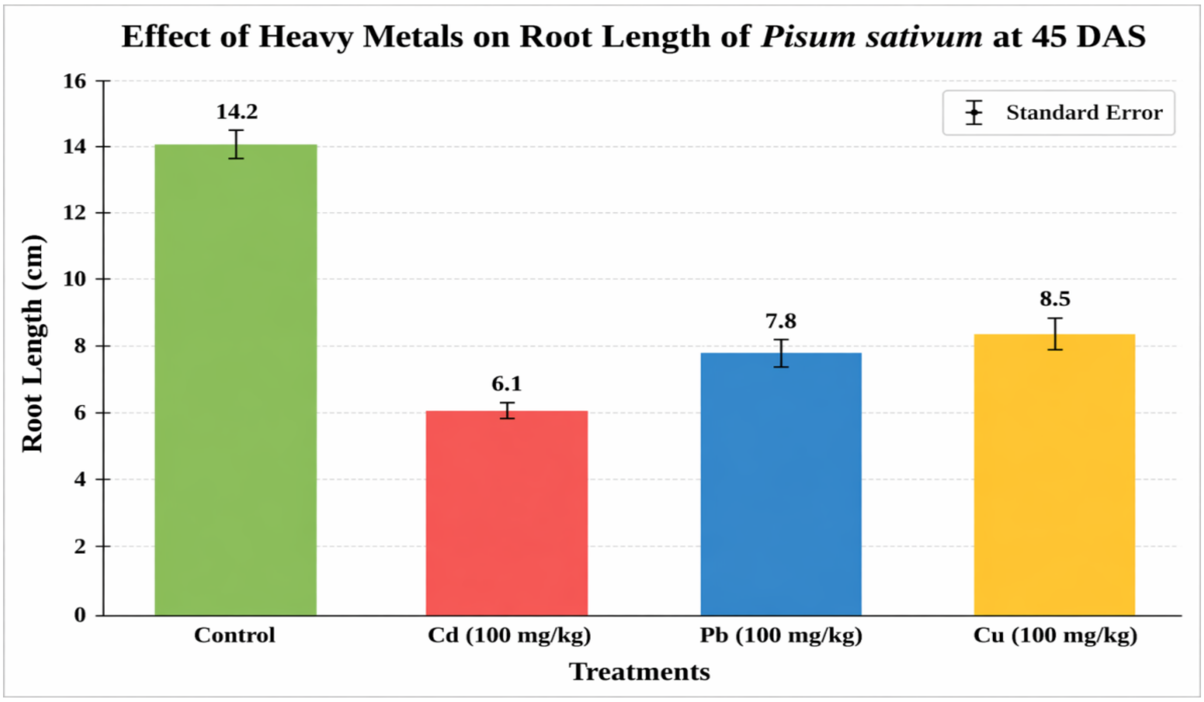
The germination % was greatly impacted by heavy metal treatments. The control group had the highest germination rate (95%), while the 100 mg/kg Cd treatment group had the lowest germination rate (52%). The strongest inhibitory effect was demonstrated by cadmium, which was followed by copper and lead. These results are in line with earlier research showing that Cd affects germination-related enzyme activity (Sharma & Dubey, 2005).



2. Effect on Root Growth

- As the concentration of metal increased, root length dramatically fell. 45 DAS:
- Control: 14.2 cm
- Cd (100 mg/kg): 6.1
- Pb (100 mg/kg): 7.8 cm
- Cu (100 mg/kg): 8.5 cm

Under cadmium stress, root development inhibition was most noticeable, most likely as a result of cell division and elongation disruption (Foy, 1984).

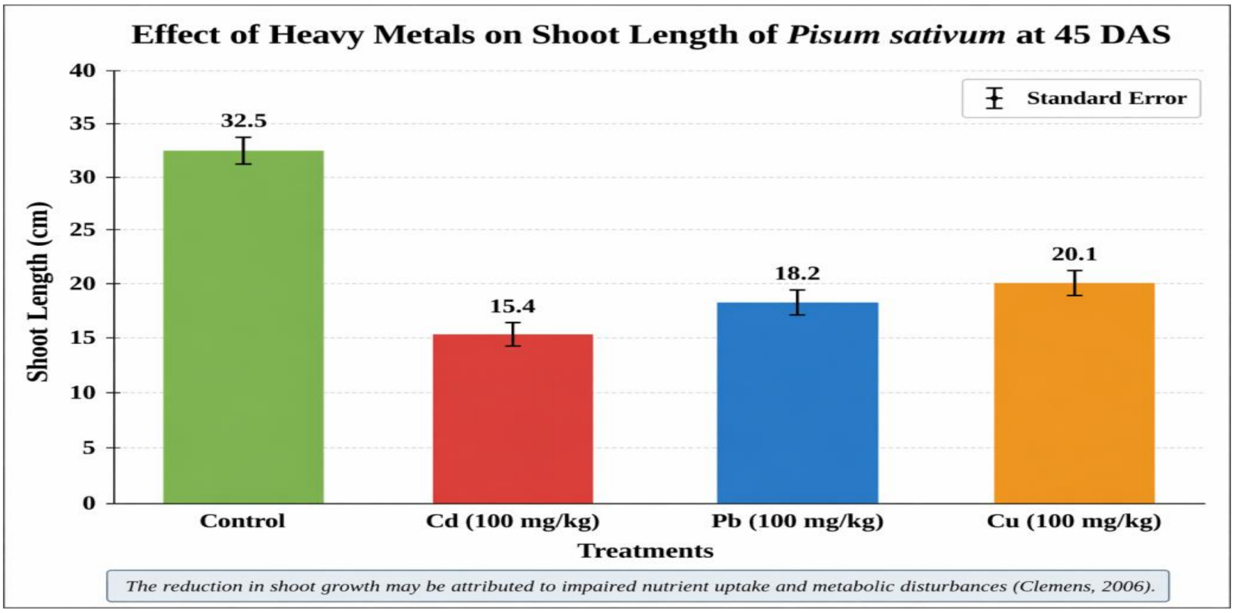


3. Effect on Shoot Growth

A similar downward trend was seen in shoot length: 32.5 cm is the control. • 15.4 cm for Cd (100 mg/kg)

- Pb (100 mg/kg): 18.2 cm
- Cu (100 mg/kg): 20.1 cm

Metabolic disorders and poor food uptake could be the cause of the decrease in shoot growth (Clemens, 2006).



4. Effect on Leaf Development

Under extreme metal stress, each plant's leaf count dramatically dropped. Chlorosis and decreased leaf expansion were signs of poor photosynthesis in plants exposed to high Cd concentrations (Ahmad et al., 2019).

5. Effect on Biomass

As the concentration of metal increased, fresh and dry weight gradually decreased:

- The control plants' maximum biomass
- The lowest biomass observed during Cd treatment

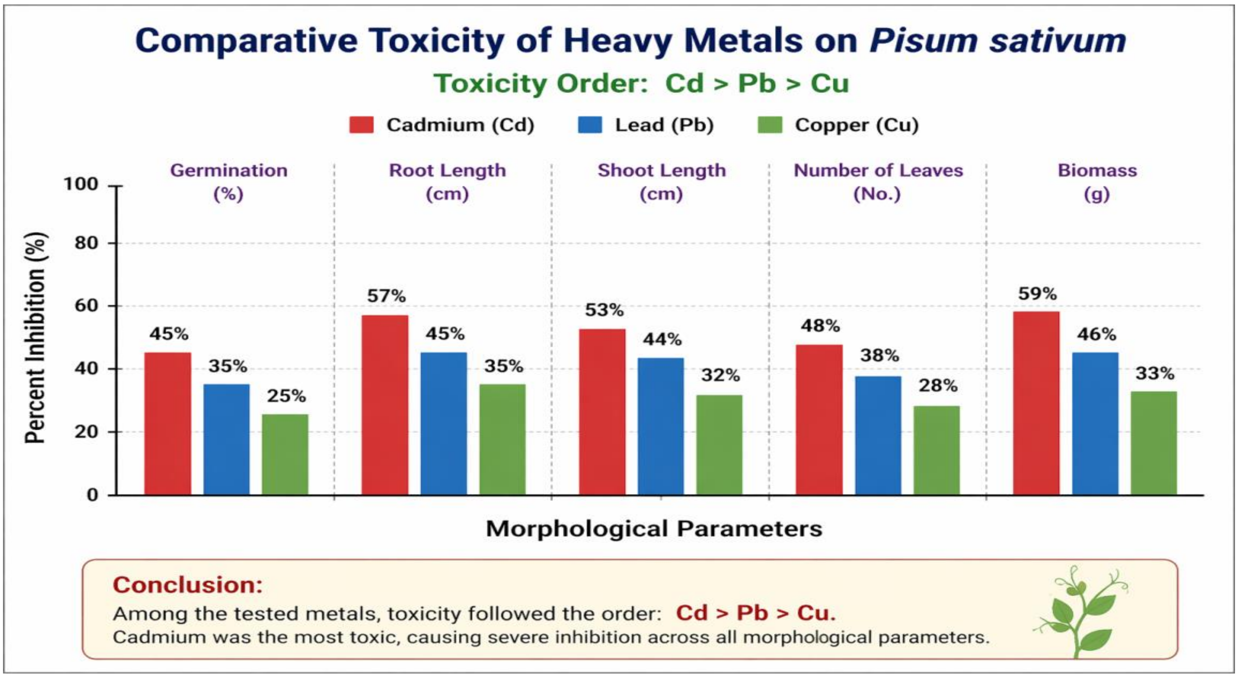
The cumulative detrimental effects of heavy metals on plant development and metabolism are reflected in this decrease (Prasad, 2004).

6. Comparative Toxicity of Metals

The order of toxicity for the measured metals was as follows:

Pb > Cu > Cd

The most harmful element was cadmium, which severely inhibited all morphological characteristics.



Conclusion

The current study unequivocally shows that heavy metals significantly impair Pisum sativum L. morphological growth. Among the main conclusions are: • Seed germination is significantly reduced when exposed to severe metal stress.

- Severe suppression of root and shoot growth, especially when exposed to cadmium
- A reduction in the quantity of leaves and obvious signs like chlorosis
- A decrease in biomass that suggests poor overall plant growth

Higher doses were shown to cause more severe damage, indicating that the degree of toxicity was concentration-dependent. Cadmium was the most dangerous metal among those examined, followed by copper and lead.

Treatment	Germination (%)	Root Length (cm)	Shoot Length (cm)	Biomass (g)
Control	95	14.2	32.5	12.5
Cd 25 mg/kg	80	10.5	25.3	9.8
Cd 50 mg/kg	65	8.2	20.4	7.2
Cd 100 mg/kg	52	6.1	15.4	5.1
Pb 100 mg/kg	60	7.8	18.2	6.3

Cu 100 mg/kg	68	8.5	20.1	7.0

These results emphasize how crucial it is to keep an eye on and control heavy metal contamination in agricultural soils. In order to guarantee food security, the study also highlights the necessity of creating crop types that are resistant to metals and implementing sustainable soil management techniques.

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