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# Effect of Enhanced Chromium metal on Seedling Growth of *Pisum sativum* L. Plants

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## Abstract

Chromium (Cr) is one of the most toxic heavy metals contaminating agricultural soils due to industrialization, mining activities, electroplating, leather tanning, textile industries, and improper disposal of industrial wastes. The presence of chromium in agricultural lands adversely affects plant growth and development, leading to reduced crop productivity. The present study investigates the effects of different concentrations of chromium on seed germination and seedling growth of *Pisum sativum* L. (pea), an important leguminous crop. Chromium toxicity significantly reduced germination percentage, root length, fresh and dry biomass, and seed vigor index. Higher concentrations of chromium induced oxidative stress through excessive production of reactive oxygen species (ROS), causing cellular damage and inhibition of physiological processes. Root growth was found to be more sensitive than shoot growth due to direct exposure to chromium ions. The study highlights the detrimental effects of chromium contamination on pea seedlings and emphasizes the need for effective remediation strategies to ensure sustainable agricultural production.

**Keywords:** Chromium toxicity, *Pisum sativum*, heavy metal stress, germination, seedling growth, oxidative stress, potassium dichromate

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## Introduction

Heavy metal contamination has become a major environmental issue due to rapid industrialization and anthropogenic activities. Chromium (Cr) is among the most toxic heavy metals released into the environment through electroplating, leather tanning, textile manufacturing, mining, and metal processing industries (Shanker *et al*., 2005; Sharma *et al*., 2022). Chromium exists primarily in two oxidation states, trivalent chromium [Cr(III)] and hexavalent chromium [Cr(VI)], with Cr(VI) being more mobile, bioavailable, and toxic to living organisms (Panda & Choudhury, 2005; Zayed *et al*., 1998).

Plants exposed to chromium stress exhibit reduced germination, inhibited growth, chlorosis, necrosis, and impaired physiological processes (Dixit *et al*., 2002). Chromium toxicity interferes with nutrient uptake, water balance, photosynthesis, respiration, and enzyme activities, ultimately reducing plant productivity (Bishnoi *et al*., 1993; Ukhurebor *et al*., 2021). Excess chromium also induces oxidative stress through the generation of reactive oxygen species (ROS), causing membrane damage and cellular dysfunction (Alvarez *et al*., 2021; Ashraf *et al*., 2022).

*Pisum sativum* L. (pea) is an important leguminous crop valued for its high nutritional content and nitrogen-fixing ability. However, chromium contamination can adversely affect its growth and development, leading to substantial reductions in crop yield (Tiwari *et al*., 2009). Therefore, understanding the effects of chromium on seedling growth is essential for developing strategies to mitigate heavy metal stress in agricultural systems.

Chromium toxicity has been widely reported to adversely affect plant growth and metabolism. Studies have shown that chromium exposure reduces photosynthesis, respiration, nitrogen fixation, and antioxidant enzyme activities, thereby disrupting normal cellular functions (Bishnoi *et al*., 1993; Chugh & Sawhney, 1996). Chromium accumulation in plant tissues inhibits nutrient uptake and growth processes, leading to chlorosis and growth retardation (Dixit *et al*., 2002; Panda & Choudhury, 2005). Furthermore, chromium induces oxidative stress by generating reactive oxygen species, resulting in membrane damage and protein degradation (Pandey *et al*., 2005; Sharma & Dubey, 2005). It also impairs photosynthetic machinery, chlorophyll synthesis, biomass accumulation, and overall seedling vigor, ultimately affecting plant morphology, physiology, and productivity (Shanker *et al*., 2005; Tiwari *et al*., 2009).

## Materials and Methods

This study was conducted at the Department of Botany, School of Life Sciences, Dr. Bhimrao Ambedkar University, Agra during November and December, 2024. The experimental design included a control (seeds in distilled water) and three treatments (seeds in 50 mM, 75 mM, and 100 mM Chromium concentrations), each with three replicates, providing a comprehensive analysis of germination under varied Chromium concentrations.

**Germination Test**- We selected uniform-sized seeds and sanitized Petri dishes with methanol. Each 9 cm dish contained germination paper and 20 comparable seeds. Distilled water, 50 mM, 75 mM, 100 mM chromium solutions induced germination. Petri dishes, with lids, were kept at room temperature. We counted germinated seeds every 24 hours and on the seventh day, calculating germination percentage. On day seven, radicle length, fresh and dry weights were measured, using specified parameters for the Germination Test.

**Germination percentage (%)-** Radicle emergence signalled germination. Daily notes marked germination's start and end. A formula calculated daily germination percentage for seven days. (Cokkizgin & Cokkizgin, 2010).

Germination percentage (%) = (Total no of germinated seed)/ (Total no of germinated and non-germinated seed) ×100

**Physiological parameter**- Relative Water Content (RWC): RWC (%) = (FW - DW / FW) × 100, where FW is fresh weight, and DW is dry weight.

2.4 Biochemical parameter- The estimate of total protein was conducted using Bradford's (1976) standard procedure. The standard Chinoy (1939) methodology for estimating starch was adhered to. The estimation of total reducing sugar was conducted using the standard procedure developed by Somogyi, (1952).

## Result

The finding demonstrated that chromium concentrations had a substantial impact on the components that were examined. On the seventh day after sowing, all the parameters in the current study were measured. The results indicate that increasing chromium concentration adversely affected the germination and physiological performance of *Pisum sativum* seedlings. The control treatment (0 mM chromium) recorded the highest values for all measured parameters, with 100% germination, a radicle length of 7.83 cm, fresh weight of 0.50 g, dry weight of 0.14 g, and relative water content (RWC) of 72.00%.

As chromium concentration increased from 50 mM to 100 mM, a gradual decline was observed in all parameters. Germination percentage decreased from 95.25% at 50 mM to 88.71% at 100 mM (Table 3.1, Graph 3.1). Radicle length showed the greatest reduction, falling from 7.83 cm in the control to 2.23 cm at 100 mM chromium (Table 3.1, Graph 3.2). Similarly, fresh weight decreased from 0.50 g to 0.32 g, while dry weight declined from 0.14 g to 0.10 g (Table 3.1, Graph 3.3). Relative water content also showed a slight reduction, decreasing from 72.00% in the control to 68.75% at the highest chromium concentration (Table 3.1).

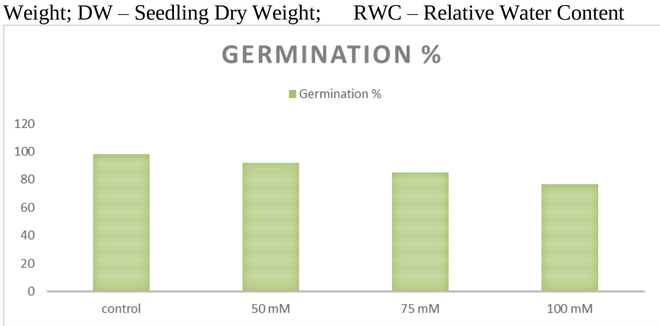
Overall, the data demonstrate that chromium stress negatively influences seed germination, seedling growth, biomass accumulation, and water status in *Pisum sativum*, with the inhibitory effects becoming more pronounced at higher chromium concentrations.

**Table-3.1 Effect of different chromium concentration on Germination % and Physiological Parameters of *Pisum sativum***

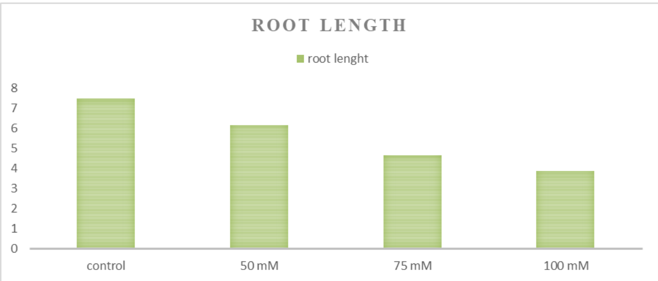
| Species | Treatment | GP | RL | FW | DW | RWC |
|---|---|---|---|---|---|---|
| | **C (0 mM)** | 100 | 7.83 | 0.50 | 0.14 | 72.00 |
| | **X (50 mM)** | 95.25 | 6.15 | 0.46 | 0.13 | 71.73 |
| | **Y (75 mM)** | 90.23 | 4.33 | 0.38 | 0.11 | 69.23 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Pisum sativum*** | **Z (100 mM)** | 88.71 | 2.23 | 0.32 | 0.10 | 68.75 |

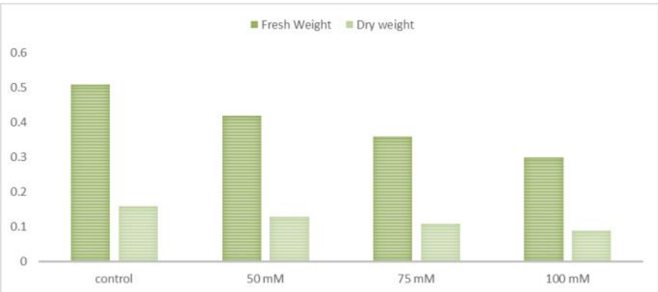
GP- Germination percentage, RL – Radicle Length; FW – Seedling Fresh Weight; DW – Seedling Dry Weight; RWC – Relative Water Content




**Graph 3.1 Effect of different chromium concentration on Germination Percentage (%)**




**Graph 3.2 Effect of different chromium concentration on Radical length (cm)**

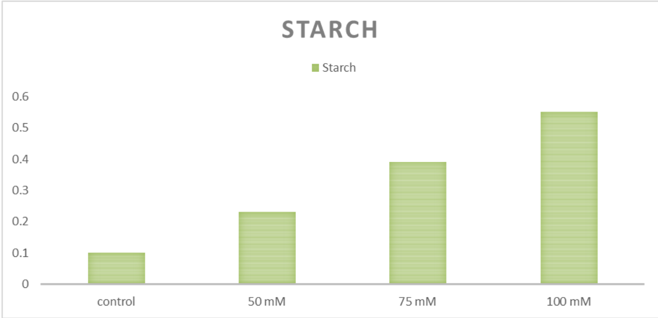



**Graph 3.3 Effect of different chromium concentration on Seedling Fresh weight (gm) & Dry weight (gm)**

**Biochemical Parameter**- As chromium concentration increased, starch content rose, evident in Table 3.2. Treatment Z recorded the highest starch concentration (0.55 mg/ml), while Control had the lowest (0.10 mg/ml) in *Pisum sativum*. Control had the highest RS concentration (0.03 mg/ml), while Treatment Z had the lowest (0.01 mg/ml) in *Pisum sativum* (Table 3.2). Our findings differ from Parida *et al*. (2002), who observed increased reducing and nonreducing sugars in Bruguiera parviflora leaves with higher salt content.

**Table-3.2 Effect of different chromium concentration on Biochemical Parameters of *Pisum sativum***

| Species | Treatment | Protein (mg/ml) | Starch (mg/ml) | Reducing Sugar (mg/ml) |
|---|---|---|---|---|
| ***Pisum sativum*** | **C(0 mM)** | 0.07 | 0.10 | 0.03 |
| | **X(50 mM)** | 0.06 | 0.23 | 0.03 |
| | **Y(75 mM)** | 0.05 | 0.39 | 0.02 |
| | **Z (100mM)** | 0.03 | 0.55 | 0.01 |




**Graph 3.4 Effect of different chromium concentrations on Starch concentration (mg/ml)**

## Discussion

The present study demonstrated that chromium significantly reduced germination, physiological, and biochemical parameters in *Pisum sativum*. Similar findings have been reported by Chugh and Sawhney (1999) and Tiwari *et al*. (2009), who observed substantial reductions in seedling growth under chromium stress.

The greater inhibition of root growth compared to shoot growth may be attributed to direct chromium accumulation in root tissues (Zayed *et al*., 1998). Chromium interferes with cell division and elongation, thereby limiting root development (Dube *et al*., 2003).

The reduction in biomass observed in the present study agrees with the findings of Shanker *et al*. (2005) and Sharma *et al*. (2022), who reported that chromium disrupts nutrient uptake and metabolic activities. Decreased chlorophyll synthesis and impaired photosynthesis under chromium stress have also been documented by Bishnoi *et al*. (1993).

Oxidative stress appears to be one of the major mechanisms underlying chromium toxicity. Chromium exposure stimulates the generation of reactive oxygen species, including superoxide radicals and hydrogen peroxide, which damage cellular components and inhibit normal physiological functions (Verma *et al*., 2009). Although antioxidant defense systems are activated under stress conditions, prolonged chromium exposure can overwhelm these protective mechanisms (Pandey *et al*., 2005).

## Conclusion

The results clearly indicate that chromium toxicity significantly inhibits germination and seedling growth of *Pisum sativum*. Increasing chromium concentrations reduced root and growth, biomass production, and seed vigor. These findings are consistent with previous reports on chromium-induced phytotoxicity (Shanker *et al*., 2005; Singh *et al*., 2013; Tiwari *et al*., 2009). Chromium-induced oxidative stress, nutrient imbalance, and disruption of photosynthesis are the major factors responsible for growth inhibition. Therefore, continuous monitoring of chromium-contaminated soils and implementation of remediation measures are necessary to ensure sustainable agricultural productivity.

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