Journal
Of the
Oriental Institute
M.S. University of Baroda

ISSN: 0030-5324
UGC CARE Group 1

EFFECT OF ZINK POLLUTION ON GROWTH, PHYSIOLOGICAL RESPONSES AND BIOCHEMICAL ATTRIBUTES OF PEA (*PISUM SATIVUM*) GENOTYPES

Renu Singh
Department of Botany
T.D.P.G.College, Jaunpur,U.P.
Email- drrenusingh.11@gmail.com

Abstract

Heavy metal pollution in agricultural soils has emerged as a major global challenge affecting crop productivity and food safety. Zinc (Zn), though essential in trace amounts, becomes toxic at elevated concentrations, adversely influencing plant growth and metabolism. The present investigation evaluated the effect of zinc stress on three Pisum sativum genotypes—Arkel, Bonneville, and Azad P-1—under varying Zn levels (0, 50, 100, and 150 mg kg^{-1} soil). Parameters such as germination percentage, growth attributes, chlorophyll content, proline accumulation, lipid peroxidation (MDA), antioxidant enzyme activity (SOD, CAT), and yield traits were assessed. Results indicated a significant decline in growth and photosynthetic pigments with increasing Zn concentration, while proline and antioxidant enzymes showed marked elevation under stress conditions. Among the tested genotypes, Arkel exhibited the highest tolerance to Zn stress through enhanced antioxidant defense and osmolyte accumulation, whereas Bonneville was the most sensitive. The study underscores the importance of genotype selection and physiological screening in mitigating Zn toxicity in agricultural systems.

Keywords: Zinc toxicity, *Pisum sativum*, oxidative stress, antioxidant enzymes, Heavy metal stress.

Introduction

Heavy metals the metallic ions having density greater than five and atomic number greater than twenty-three (Vanadium) except Rubidium, Strancium etc. are non-degradable and are accumulated considerably and their content biomagnified in living organism through the food chain. These are in toxic levels deleterious both to plant and animal systems usually by damaging protein molecules and blocking enzymatic reactions. Heavy metals as Fe or Zn which are otherwise necessary also become hazardous when their levels reach abnormal amounts. Zn has created a biological hazard it is heavy metal with atomic number 30 and atomic weight 65.38 belongs to sub group IIB in the periodic table. The chief source of Zn pollution is chemical compounds used by human activities. Toxic levels of Zn in soil may be caused by its applications by the farmers for the better yield of their crop plants.

Zinc (Zn) is an essential micronutrient for plants, involved in enzyme activation, protein synthesis, and hormone regulation. However, its excessive accumulation in soil poses a serious risk to crop growth and productivity. Elevated Zn levels often result from industrial effluents, mining operations, sewage sludge application, and overuse of fertilizers (Alloway, 2013). When present beyond the optimal range, Zn interferes with the uptake and translocation of other essential nutrients, disrupts photosynthetic machinery, and induces oxidative stress through the overproduction of reactive oxygen species (ROS) (Broadley et al., 2012).*Pisum sativum* L. (garden pea), a cool-season legume, is widely cultivated for its edible seeds rich in proteins and vitamins. The crop contributes significantly to soil fertility through symbiotic nitrogen fixation. However, heavy metal contamination in pea-growing regions has become a constraint, limiting its productivity. The toxic effects of Zn include stunted growth, chlorosis, reduced photosynthesis, and poor yield (Verma et al., 2021).

Plants have evolved various tolerance mechanisms against heavy metal stress, such as activation of antioxidant enzymes (superoxide dismutase, catalase, peroxidase), accumulation of osmolytes like proline, and sequestration of metals into vacuoles (Sharma et al., 2020). However, the degree of tolerance varies among species and even among genotypes within the same species.

Objectives of the study:

1. To assess the effect of Zn stress on germination, growth, and yield of different *Pisum sativum* genotypes.

2. To evaluate physiological and biochemical changes under Zn toxicity.

3. To identify tolerant genotypes for cultivation in Zn-contaminated soils.

Materials and Methods-

The study was conducted under controlled greenhouse conditions. Three widely grown *Pisum sativum* genotypes—Arkel, Bonneville, and Azad P-1—were selected. The experiment was laid out in a Completely Randomized Design (CRD) with three replications for each treatment.

Soil Preparation and Zinc Treatments

Pots were filled with 5 kg of sandy loam soil, previously sterilized. Zinc was applied in the form of zinc sulfate ($ZnSO_4 \cdot 7H_2O$) at four concentrations:

T_0 (Control): 0 mg Zn/kg soil

T_1: 50 mg Zn/kg soil

T_2: 100 mg Zn/kg soil

T_3: 150 mg Zn/kg soil

Observations-

- **Germination and Growth Parameters:** Germination percentage, plant height, root and shoot length, fresh and dry weight.
- **Physiological Parameters:** Chlorophyll content (Arnon's method), relative water content (RWC).
- **Biochemical Parameters:**
    - Proline content (Bates method).
    - Lipid peroxidation measured as malondialdehyde (MDA).
    - Antioxidant enzymes: Superoxide dismutase (SOD), Catalase (CAT).
- **Yield Parameters:** Number of pods per plant, 100-seed weight.

Statistical Analysis

Data were analyzed using ANOVA, and mean differences were tested using the Least Significant Difference (LSD) test at $\mathbf{p \leq 0.05}$.

Results

Germination and Growth Response

Germination percentage declined with increasing Zn levels in all genotypes. Maximum reduction was observed in Bonneville at T_3 (150 mg/kg). Plant height and dry matter accumulation followed a similar trend, with Arkel showing the least reduction.

ISSN: 0030-5324
UGC CARE Group 1

Table 1:

Effect of Zn Levels on Growth Attributes of Pisum sativum Genotypes

Genotype	Zn Level (mg/kg)	Germination (%)	Plant Height (cm)	Root Length (cm)	Dry Weight (g)
Arkel	0	95	42.5	15.3	3.25
	50	93	40.2	14.6	3.12
	100	90	36.8	12.1	2.85
	150	85	31.4	10.2	2.40
Bonneville	0	94	41.6	14.9	3.18
	150	78	28.3	9.5	2.10
Azad P-1	0	96	43.1	15.6	3.30
	150	83	30.8	10.8	2.35

Chlorophyll and Proline Content

Chlorophyll content decreased significantly with Zn stress, while proline showed a marked increase, especially in Arkel genotype, indicating osmotic adjustment under stress.

Lipid Peroxidation and Antioxidant Enzymes

Lipid peroxidation (MDA) increased with Zn levels, reflecting oxidative stress. Antioxidant enzymes (SOD and CAT) increased significantly, with Arkel showing the highest activity.

ISSN: 0030-5324
UGC CARE Group 1

Table 2:

Antioxidant Enzyme Activity under Zn Stress

Genotype	Zn Level (mg/kg)	SOD (U mg^{-1} protein)	CAT (µmol H_2O_2 min^{-1} g^{-1} FW)
Arkel	0	12.4	8.6
	150	25.8	16.2
Bonneville	0	11.8	8.2
	150	19.4	13.1
Azad P-1	0	12.6	8.8
	150	22.3	14.5

Yield Attributes

Zn toxicity significantly reduced the number of pods per plant and 100-seed weight. Arkel retained higher yield compared to Bonneville.

Discussion

The present study confirms that excessive Zn adversely affects Pisum sativum by impairing growth and photosynthetic efficiency. The reduction in chlorophyll under Zn stress could be attributed to chlorophyll degradation and inhibition of chlorophyll biosynthesis enzymes (Cakmak, 2000). Increased proline accumulation suggests its role as an Osmo protectant and ROS scavenger. Elevated activities of SOD and CAT under stress indicate activation of antioxidant defense mechanisms to detoxify superoxide radicals and hydrogen peroxide, respectively.

Genotypic variation in Zn tolerance observed in this study aligns with findings of Kumar et al. (2023), who reported differential expression of antioxidant enzymes among pea genotypes under heavy metal stress. Arkel's superior tolerance may be due to efficient ROS detoxification and maintenance of cellular homeostasis.

Conclusion

- High Zn concentrations cause significant reductions in germination, growth, and yield in Pisum sativum.
- Antioxidant enzymes (SOD, CAT) and proline play critical roles in mitigating Zn-induced oxidative stress.
- Among the tested genotypes, Arkel demonstrated the highest tolerance, while Bonneville was the most sensitive.
- These results can aid in the development of Zn-tolerant varieties through breeding and selection programs.

References

1. Alloway, B.J. (2013). Zinc in Soils and Crop Nutrition. International Zinc Association.
2. Broadley, M.R., et al. (2012). Function of nutrients: micronutrients. Springer Science, 191–248.
3. Cakmak,I.(2000). Possible roles of Zinc in protective plant cells from damage by reactive oxygen species. New Phytologists,146,185-205.
4. Kumar, A., et al. (2023). Antioxidant defense and heavy metal stress in legumes. Journal of Plant Stress Physiology, 18(2), 75-84.
5. Sharma, P., et al. (2020). Plant tolerance to heavy metals: Role of antioxidative defense system. Plant Physiology Reports, 25(1), 1-18.
6. Verma, P., et al. (2021). Physiological and biochemical responses of pea under zinc stress. Plant Physiology and Biochemistry, 164, 1-10.