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SALINITY-INDUCED GROWTH INHIBITION IN SOME LEGUMES: PHYSIOLOGICAL EFFECTS AND SOIL AMELIORATION APPROACHES

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ABSTRACT
Soil salinity is a major abiotic stress affecting plant health and crop productivity globally. This study investigates the effects of three salt concentrations (10 g/L, 20 g/L, and 30 g/L NaCl) on the growth of Vigna radiata (mung bean), Cicer arietinum (chickpea), and Pisum sativum (pea). Results showed that plant growth and survival decreased significantly with increasing salinity levels. Pea plants demonstrated greater salt tolerance compared to mung and chickpea. Salinity-induced symptoms included leaf chlorosis, stunted growth, and reduced photosynthesis. The findings highlight the critical thresholds of salt tolerance in these legumes and underscore the need for improved soil and water management practices to mitigate salinity stress in agriculture.

Keywords: *Salinity stress, Vigna radiata, Cicer arietinum, Pisum sativum, Soil sodicity, Salt tolerance, Physiological drought*

INTRODUCTION
Salinity and sodicity are widespread soil degradation issues affecting over 400 million hectares globally, with significant agricultural implications (FAO, 2008), including 45 million hectares of irrigated land. High concentrations of sodium chloride disrupt osmotic balance, nutrient uptake, and soil structure, severely reducing crop yields (Rengasamy, 2010).
The present study focuses on evaluating the tolerance of *Vigna radiata*, *Cicer arietinum*, and *Pisum sativum* to increasing levels of salt stress. Identifying physiological responses and survival thresholds can guide effective soil management and cropping strategies under salinity stress (Munns & Tester, 2008).
Soil salinization is a growing threat to agriculture, affecting over 400 million hectares worldwide, including 45 million hectares of irrigated land. High salinity levels, especially sodium chloride (NaCl), impair plant physiological processes such as nutrient uptake and photosynthesis, ultimately leading to reduced growth and productivity. Salt stress manifests in two phases—osmotic stress and ionic toxicity—resulting in symptoms like chlorosis, leaf burn, and premature senescence (Verma & Solanki, 2021). Plants are also affected by dissolved salts in runoff water. Sodium and chloride ions separate when salts are dissolved in water. The dissolved sodium and chloride ions, in high concentrations, can displace other mineral nutrients in the soil. Plants then absorb the chlorine and sodium instead of needed plant nutrients such as potassium and phosphorus, leading to deficiencies. The chloride ions can be transported to the leaves where they interfere with photosynthesis and chlorophyll production. Chloride accumulation can reach toxic levels, causing leaf burn and die-back.

Plant growth responds to salinity in two phases: a rapid, osmotic phase that inhibits growth of young leaves, and a slower, ionic phase that accelerates senescence of mature leaves. Salt stress is a condition where excessive salts in soil solution cause inhibition of plant growth or even their death.
The aim of this study is to evaluate the salt tolerance of three legume species: *Vigna radiata*, *Cicer arietinum*, and *Pisum sativum*. These legumes are essential sources of protein and are widely cultivated in semi-arid and arid regions where salinity is often a limiting factor. Understanding their tolerance levels will aid in developing salt-resilient cropping systems (Verma & Solanki, 2022).

MATERIALS AND METHODS

2.1 Plant Material and Setup

Vigna radiata, *Cicer arietinum*, and *Pisum sativum* seeds were grown in indoor pots. Uniform soil and controlled lighting were maintained throughout the 4-week period.

2.2 Salinity Treatments

Salinity treatment viz groups are as T1: 10 g/L NaCl, T2: 20 g/L NaCl and T3: 30 g/L NaCl. Each group had 3 replicates per species. In a secondary experiment, saline water was alternated with fresh water every third day.

RESULTS

Table 1: Salinity treatment and symptoms

Treatment	Species	Average Height (cm)	Survival Rate (%)	Visible Symptoms
Control	All species	14.2 ± 0.5	100%	None
T1 (10 g/L)	Pea	12.5 ± 0.3	100%	Mild spotting
	Chickpea	11.4 ± 0.6	90%	Yellowing, leaf curl
	Mung bean	10.8 ± 0.8	85%	Pale leaves
T2 (20 g/L)	Pea	10.2 ± 0.7	80%	Leaf burn, slowed growth
	Chickpea	9.3 ± 0.5	70%	Wilting, stunted growth
	Mung bean	8.6 ± 0.9	60%	Significant chlorosis
T3 (30 g/L)	All species	<5.0 (all)	0%	Complete die-off by Week 2

- 30 g/L NaCl: All plants initially showed slow growth but died within a few weeks.
- 20 g/L NaCl: Growth was comparable to the 10 g/L group initially, but salt injury symptoms such as leaf spotting and wilting emerged within 10 days.
- 10 g/L NaCl: Growth was moderately affected, but plants remained alive longer. Pea plants exhibited the greatest resilience, while mung showed the slowest growth.

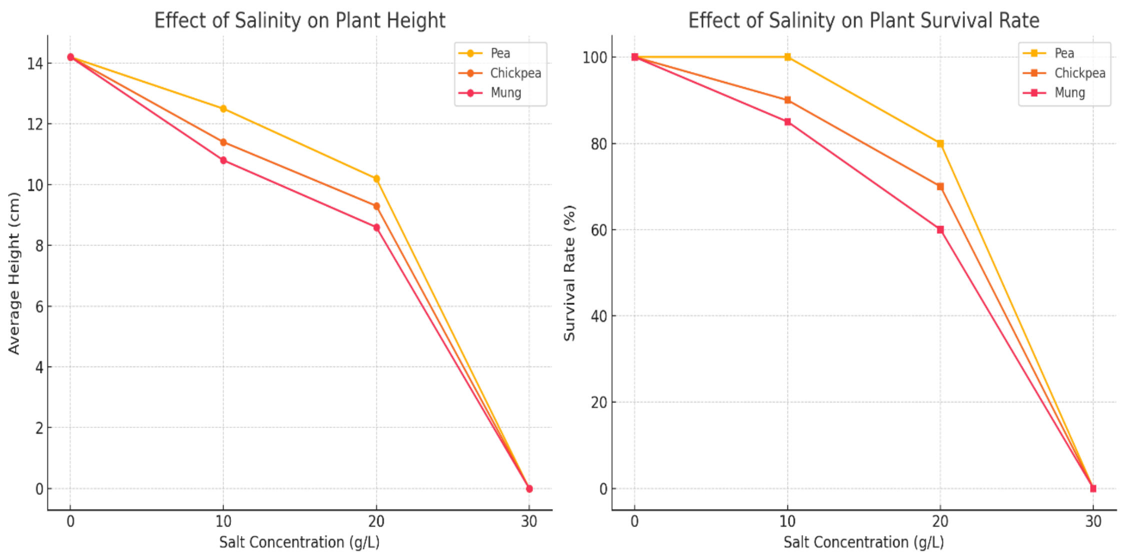
Common salt injury symptoms observed:

Leaf tip burn and marginal necrosis, Chlorosis, Stem dieback, Reduced flower and pod formation, Needle tip burn and marginal leaf burn, Discoloured foliage, Nutrient deficiencies, Early leaf drops or premature fall colour were observed. While the control group (tap water) displayed healthy growth and pod development.

4. Statistical Analysis

A one-way ANOVA was conducted to evaluate differences in plant height and survival rate across treatments. Post hoc tests confirmed statistical significance between groups (Zar, 2010) (Graph 1 & 2).

- **Plant height ($p < 0.01$)** showed a significant decrease with increasing salt concentration.
- **Survival rate ($p < 0.05$)** also significantly differed between treatments.
- Post hoc Tukey's HSD test confirmed that all salinity levels were statistically distinct from each other in terms of impact on plant growth.



Graph 1 & 2: Effect of salinity on hight of plants and survival %

1. **Effect of Salinity on Plant Height:** Shows how increasing salt concentrations reduced the average height of pea, chickpea, and mung plants.
2. **Effect of Salinity on Plant Survival Rate:** Highlights the declining survival rates of the three legume species as salinity increases, with total mortality at 30 g/L.

DISCUSSION

The results affirm that salinity significantly inhibits legume growth, aligning with existing studies on salinity stress (Taiz & Zeiger, 1998; Saleem et al., 2011). Salt stress reduced plant height and survival, primarily due to osmotic stress and ionic toxicity (Taiz & Zeiger, 1998). Na^+ and Cl^- interfere with chlorophyll biosynthesis and photosynthesis, as shown in other legume studies (*Abelmoschus esculentus* – Saleem et al., 2011; *Phaseolus vulgaris* – Seemann & Critchley, 1985).

Soil sodicity leads to swelling and dispersion of clay particles, impairing permeability and air exchange (Qadir & Oster, 2004). This affects root aeration and microbial health, further limiting plant productivity. Salt stress impacts photosynthesis by disrupting chlorophyll synthesis and stomatal conductance. Additionally, ion toxicity and nutrient imbalance due to Na^+ and Cl^- accumulation in plant tissues further degrade plant health. Soil affected by salinity and sodicity suffers from reduced permeability and aeration, especially under high sodium levels. The swelling and dispersion of clay particles compromise soil structure, further inhibiting root growth.

While *Pisum sativum* showed relatively better tolerance, *Vigna radiata* and *Cicer arietinum* were more susceptible, dying at higher salinity levels. This suggests the need to select or genetically modify salt-tolerant varieties, or employ remediation techniques such as gypsum application and leaching.

Salt stress affected plant morphology and physiology, leading to decreased height, survival, and vigor. Pea was the most salt-tolerant, possibly due to better osmoregulation or Na^+ compartmentalization. Mung was the most sensitive species.

Soil sodicity, primarily due to high sodium concentrations, leads to dispersion and compaction. This reduces infiltration, increases bulk density, and limits root aeration.

6. Mitigation and Improvement Strategies for Sodic Soils:

Reclamation Techniques

1. **Gypsum Application:** Calcium from gypsum replaces sodium ions on soil particles, allowing leaching of sodium (Richards, 1954; Qadir et al., 2007).

2. **Organic Matter Addition:** Compost and green manures improve soil aggregation and microbial activity (Diacono & Montemurro, 2010).
3. **Leaching:** Deep percolation of water removes salts from the root zone (Ayers & Westcot, 1985).
4. **Drainage Improvement:** Subsurface drainage facilitates salt removal and reduces water logging (Abrol et al., 1988).

7. Management Practices:

- Use salt-tolerant cultivars and crop rotation to minimize yield losses.
- Employ mulching to reduce surface evaporation and salt accumulation.
- Maintain optimal irrigation schedules and avoid over-irrigation.

8. Prevention of Salinization and Sodicity:

Table 2: Guideline used for present experiment

Irrigation Water Salt Level (g/L)	**Risk of Salinization**	**Use Guidance**
< 0.5 g/L	No risk	Safe for all irrigation
0.5 – 2 g/L	Slight to moderate	Use with soil monitoring and leaching
> 2 g/L	High risk	Use only with proper drainage and gypsum management

- Use **blending or treatment of saline water** before irrigation.
- Conduct **periodic soil testing** to monitor EC and SAR.
- Avoid **irrigation during high evaporation** periods to reduce salt deposition.

Proper irrigation management and regular soil monitoring prevent salinity buildup (Maas & Hoffman, 1977). Water with EC <0.5 dS/m is preferred to minimize salt accumulation in the root zone.

CONCLUSION

Salinity and sodicity severely inhibit legume growth. Among tested plants, pea showed higher resilience, while mung and chickpea were more susceptible. Effective soil reclamation using gypsum, leaching, and proper irrigation management can significantly improve sodic soil productivity. Future studies should explore genetic improvement and microbial-assisted strategies for enhancing salt tolerance in crops.

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