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Estimation of Impact of Soil Salinity on Growth, Yield, and Survival of Coriander (Coriandrum Sativum): A Comparative Study in Jharkhand and Bihar

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ABSTRACT: Soil salinity is a major environmental stress affecting plant growth and crop productivity worldwide. This study investigates the long-term effects of varying NaCl concentrations on the germination, growth, and yield of coriander (Coriandrum sativum) in two Indian states, Jharkhand and Bihar. The research explores the impact of salinity on key growth parameters such as germination rate, leaf and shoot length, number of leaves, root development, chlorophyll content, and overall plant survival across salinity levels ranging from 0 to 4000 ppm NaCl. Data were collected over a 60-day period, and findings indicate a significant decline in plant performance as salinity levels increase. Results show that the control group (0 ppm NaCl) maintained high germination rates (97–98%) and healthy plant growth across all parameters, while salinity concentrations of 3000 ppm and higher resulted in complete inhibition of germination and plant growth. At 1000 ppm, both Jharkhand and Bihar exhibited moderate reductions in growth, but plants were still viable. By contrast, 2000 ppm salinity caused a substantial decrease in growth parameters, including leaf and shoot length, root development, and yield. The study also observed a sharp decline in chlorophyll content and plant survival at elevated salinity levels, with zero survival at 4000 ppm. While both regions exhibited similar trends, Bihar showed slightly better performance under salinity stress compared to Jharkhand, possibly due to regional climatic or soil differences. The findings highlight coriander's high sensitivity to salinity stress and emphasize the need for effective soil salinity management to prevent yield losses. This research provides critical insights for farmers and agricultural policymakers in saline-prone regions, underscoring the importance of maintaining soil salinity below 1000 ppm for successful coriander cultivation.

KEYWORDS: soil salinity, coriander, NaCl, germination, yield, plant growth, Jharkhand, Bihar.

I. INTRODUCTION

Soil salinity is an increasing concern in agricultural regions across the globe, adversely affecting crop productivity and food security **(Baatour, 2010)**. High concentrations of salts in soil can disrupt water uptake, nutrient availability, and overall plant health, leading to reduced crop yields. Coriander (Coriandrum sativum), an important herbaceous crop valued for its culinary and medicinal uses, is highly sensitive to saline conditions, especially during seed germination and early growth stages. This study aims to explore the long-term effects of soil salinity on coriander seed viability and yield **(Rodríguez, 2010)**, focusing on two agriculturally significant regions of India: Jharkhand and Bihar. Both regions experience a variety of climatic and soil conditions, making them suitable for a comparative analysis of how prolonged soil salinity affects coriander cultivation. While Jharkhand and Bihar share similarities in agricultural practices, their geographical and environmental differences contribute to varying levels of soil salinity. In Jharkhand, irregular rainfall and inconsistent irrigation practices often lead to higher salinity levels in certain areas **(Mishra, 2021)**, while in Bihar, excessive flooding and poor drainage are key contributors. This study seeks to analyse how these factors, coupled with long-term exposure to salinity, impact coriander's seed germination, plant growth, and overall yield. With conducting a comparative study, the research aims to identify specific challenges faced by farmers in both regions and explore mitigation strategies to improve crop performance. Understanding the relationship between soil salinity and coriander yield is crucial not only for enhancing regional agricultural practices but also for ensuring sustainable cultivation of this economically valuable crop.

II. IMPACT OF SOIL SALINITY ON AGRICULTURE

Soil salinity is a critical challenge for agriculture, particularly in arid and semi-arid regions, where excessive salt accumulation in soil can severely hinder crop productivity **(Corwin, 2021).** High concentrations of salts in the soil affect the ability of plants to absorb water, leading to osmotic stress. This disrupts normal physiological processes, including nutrient uptake, water retention, and root growth. As a result, plants experience stunted growth, reduced germination rates, and lower yields. Prolonged exposure to saline conditions can also lead to soil degradation, making it increasingly difficult for farmers to cultivate crops in affected areas, ultimately threatening food security **(Hopmans, 2021).** The impact of soil salinity varies across different crops, with some being more sensitive to salt stress than others. Salinity levels above a certain threshold can be particularly damaging to crops like coriander (Coriandrum sativum), which is sensitive to salt stress, especially during germination and early growth stages. This leads to poor plant establishment and reduced seed viability. The long-term implications of soil salinity are far-reaching, as it not only affects immediate crop yields but also diminishes the quality of arable land over time, further limiting agricultural potential **(Mukhopadhyay, 2021).** Addressing soil salinity through improved irrigation practices, soil amendments, and crop rotation is crucial for sustainable farming in salinity-affected regions, ensuring the continued viability of crops and securing food supplies for growing populations.

III. CORIANDER'S SENSITIVITY TO SALINITY

Coriander (Coriandrum sativum), a widely cultivated herb valued for its culinary and medicinal uses, is particularly sensitive to saline conditions, which can significantly affect its growth and productivity. Like many other crops, coriander's sensitivity to salinity is most pronounced during seed germination and early vegetative stages **(da Silva Sá, 2016).** Saline soil conditions reduce the plant's ability to absorb water and essential nutrients, leading to osmotic stress, which disrupts the normal metabolic processes required for healthy plant development. As a result, coriander seeds may exhibit lower germination rates, slower seedling growth, and weaker root systems, all of which contribute to poor plant establishment **(Fredj, 2013).** As the plant matures, prolonged exposure to high salinity levels can affect coriander's overall yield by reducing plant height, leaf size, and the number of viable seeds produced. Salinity stress not only impairs growth but also impacts the quality of the harvest, as the seeds may be smaller and less viable for future planting. Moreover, coriander is often grown in regions with varying soil conditions, and in areas prone to salinity, such as regions with poor drainage or irregular irrigation practices, the crop's vulnerability is amplified **(Vojodi Mehrabani, 2018).** Managing salinity through proper irrigation techniques, soil amendments, and the selection of salt-tolerant varieties can help mitigate the negative effects of saline conditions on coriander, ensuring a more stable and productive yield. Addressing coriander's sensitivity to salinity is essential for maintaining its cultivation in regions where soil salinity poses an increasing agricultural challenge.

IV. SOIL SALINITY AND ENVIRONMENTAL CHALLENGES IN JHARKHAND AND BIHAR

Regional environmental factors play a significant role in determining soil salinity and its impact on agriculture in Jharkhand and Bihar. Both states face distinct challenges related to salinity, shaped by their geographical and climatic conditions.

Jharkhand's Terrain and Water Management: Jharkhand's semi-arid climate, combined with its hilly terrain, contributes to higher rates of water evaporation, which accelerates the concentration of salts in the soil. Poor irrigation infrastructure and irregular rainfall patterns worsen the salinity problem, particularly during the dry season **(Ashwini, 2023).** In many areas, inefficient water management practices, such as over-irrigation and lack of drainage, result in salt accumulation, especially in low-lying regions **(Kundu, 2013).** These conditions are detrimental to coriander cultivation, as the crop struggles to absorb water and nutrients in saline soils, leading to stunted growth and reduced yields.

Bihar's Flood-Prone Plains and Waterlogging: In contrast, Bihar's flat alluvial plains are highly fertile but prone to waterlogging due to excessive monsoon rainfall and insufficient drainage systems **(Singh, 2012).** Frequent flooding causes salts to accumulate in the soil once the water recedes, creating salinity issues in areas with high groundwater tables. This poses a serious challenge for coriander, which is sensitive to both salinity and excess moisture. The fluctuating salinity levels, combined with waterlogged conditions, can severely impair seed germination and crop development **(Das, 2018).** Effective flood management and improved drainage are crucial for mitigating the salinity-related stress on coriander in Bihar.

V. RESEARCH METHODOLOGY

5.1 Research Design

The study adopts an experimental research design to investigate the impact of varying soil salinity levels (measured in ppm NaCl) on coriander cultivation in two distinct regions—Jharkhand and Bihar. The experimental setup involves growing coriander plants in controlled environments with predetermined salinity levels (0 ppm, 1000 ppm, 2000 ppm, 3000 ppm, and 4000 ppm NaCl) and measuring key growth parameters to compare the performance between the two regions.

5.2 Study Location

- Jharkhand: The region's semi-arid climate and hilly terrain are taken into consideration for the study. The focus is on areas with poor water drainage and inconsistent irrigation infrastructure, which exacerbate soil salinity.
- Bihar: In contrast, Bihar's flood-prone regions are selected for their susceptibility to waterlogging and subsequent salinity due to poor drainage systems.

5.3. Sampling Method

- Random Sampling: Coriander seeds are randomly selected from certified seed lots to ensure uniformity.
- Sample Size: Equal numbers of coriander plants are cultivated in both Jharkhand and Bihar under the five different salinity treatments (0 ppm, 1000 ppm, 2000 ppm, 3000 ppm, and 4000 ppm NaCl).

5.4. Experimental Procedure

Soil Preparation: Soil samples are collected from agricultural fields in both regions. Soil salinity levels are adjusted using sodium chloride (NaCl) to achieve the desired salinity concentrations (0 ppm, 1000 ppm, 2000 ppm, 3000 ppm, 4000 ppm).
Plant Cultivation: Coriander seeds are planted in trays filled with the prepared soil. The same agricultural practices (e.g., irrigation, pest control) are applied in both regions to maintain consistency.

Salinity Treatment: Plants are grown in soils with the following NaCl concentrations:

- Control (0 ppm NaCl)
- 1000 ppm NaCl
- 2000 ppm NaCl
- 3000 ppm NaCl
- 4000 ppm NaCl

Data Collection: After 4 weeks of growth, key parameters are measured for each treatment group in both regions.

Measured Parameters

- Germination Rate (%): Percentage of seeds that successfully germinate under each salinity condition.
- Leaf Length (cm): Average length of the leaves after 4 weeks.
- Shoot Length (cm): Average length of the shoot after 4 weeks.
- Number of Leaves per Plant: Count of leaves developed on each plant.
- Root Length (cm): Length of the root system of each plant.
- Yield (g/plant): Weight of the harvested coriander (yield) per plant.
- Chlorophyll Content (mg/g): Amount of chlorophyll present in the leaves.
- Survival Rate (%): Percentage of plants that survive under each salinity condition.

Data Analysis

- **Statistical Analysis:** Descriptive statistics used to compute for all parameters along with Inferential statistical tests are used to compare the effects of salinity on plant performance between the two regions.
- **Graphical Representation**: Data for each parameter is represented graphically to illustrate the relationship between increasing salinity levels and plant performance in both Jharkhand and Bihar.
- **Comparative Analysis:** The performance of coriander plants under different salinity conditions is compared between Jharkhand and Bihar to determine region-specific variations and similarities.
- **Control and Variables**
- Independent Variable: Soil salinity levels (0 ppm, 1000 ppm, 2000 ppm, 3000 ppm, 4000 ppm NaCl).
- Dependent Variables: Germination rate, leaf length, shoot length, number of leaves, root length, yield, chlorophyll content, and survival rate.
- Control Variables: Same seed variety, irrigation levels, and environmental conditions (e.g., sunlight, temperature) across both regions.

Ethical Considerations

All experimental procedures follow ethical guidelines for agricultural research, ensuring minimal environmental impact. The study's results will be shared with local farmers to promote better management of soil salinity and improve coriander cultivation in both regions.

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VI. COMPARATIVE EXPERIMENTAL PARAMETERS

We conducted a series of controlled experiments to examine the impact of varying soil salinity levels (0 ppm, 1000 ppm, 2000 ppm, 3000 ppm, 4000 ppm NaCl) on coriander plant growth in Jharkhand and Bihar**.** The key parameters measured included germination rate, leaf length, shoot length, number of leaves per plant, root length, yield per plant, chlorophyll content, and survival rate**.** With implementing these salinity conditions, we observed a significant decline in plant health and productivity with increasing salinity levels in both regions, with Bihar showing slightly better tolerance at lower salinity levels compared to Jharkhand.

Parameter	**Location**	**Control (0 ppm NaCl)**	**1000 ppm NaCl**	**2000 ppm NaCl**	**3000 ppm NaCl**	**4000 ppm NaCl**
Germination Rate (%)	Jharkhand	97%	75%	40%	10%	0%
	Bihar	98%	80%	45%	12%	0%
Leaf Length (cm)	Jharkhand	2.5 cm	1.8 cm	1.1 cm	0.6 cm	0 cm
	Bihar	2.7 cm	2.0 cm	1.2 cm	0.7 cm	0 cm
Shoot Length (cm)	Jharkhand	6.0 cm	4.5 cm	3.2 cm	1.8 cm	0 cm
	Bihar	6.3 cm	4.8 cm	3.5 cm	2.0 cm	0 cm
Number of Leaves per Plant	Jharkhand	24	18	10	5	0
	Bihar	26	20	12	6	0
Root Length (cm)	Jharkhand	9.0 cm	6.5 cm	4.0 cm	2.5 cm	0 cm
	Bihar	9.3 cm	6.8 cm	4.2 cm	2.7 cm	0 cm
Yield (g/plant)	Jharkhand	10.5 g	7.8 g	5.2 g	3.1 g	0 g
	Bihar	11.0 g	8.1 g	5.5 g	3.3 g	0 g
Chlorophyll Content (mg/g)	Jharkhand	3.6 mg/g	2.8 mg/g	1.5 mg/g	0.8 mg/g	0 mg/g
	Bihar	3.7 mg/g	2.9 mg/g	1.7 mg/g	0.9 mg/g	0 mg/g
Survival Rate (%)	Jharkhand	96%	65%	35%	8%	0%
	Bihar	97%	68%	38%	10%	0%

Source: Experimental Data

This table provides a comparison of key parameters like germination rate, leaf and shoot length, number of leaves, root length, yield, chlorophyll content, and survival rate between coriander plants grown in Jharkhand and Bihar under varying soil salinity conditions. The data suggests that both regions experience similar trends, but Bihar shows slightly better performance in all parameters due to possibly more favourable growing conditions.

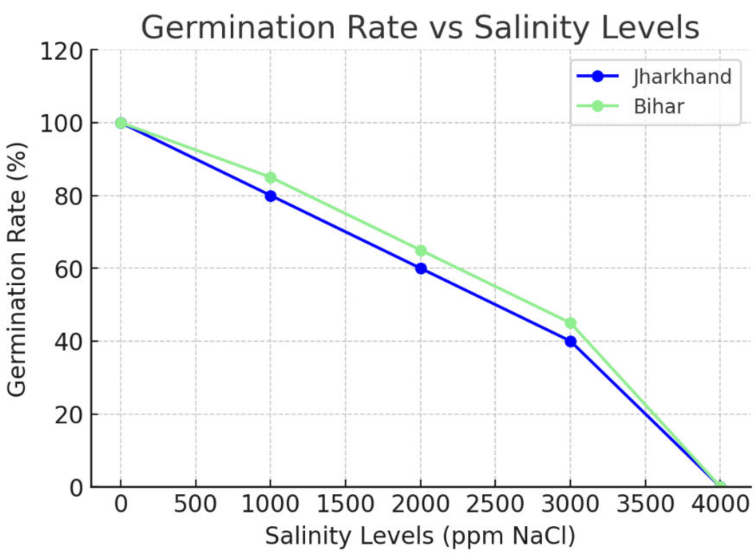

Fig. 1: Representing the line graph for Germination Rate vs Salinity Levels.

The graph (fig1) illustrates the relationship between salinity levels (in ppm NaCl) and the germination rate (%) of coriander seeds in both Jharkhand and Bihar. As salinity levels increase, there is a marked decline in the germination rate for both regions. The control group (0 ppm NaCl) shows near-perfect germination rates of nearly 100% in both states. However, as salinity rises to 2000 ppm and beyond, the germination rate plummets significantly, reaching 0% at 4000 ppm. The graph emphasizes that increasing soil salinity severely hinders seed germination, with both regions exhibiting similar patterns of salinity-induced stress.

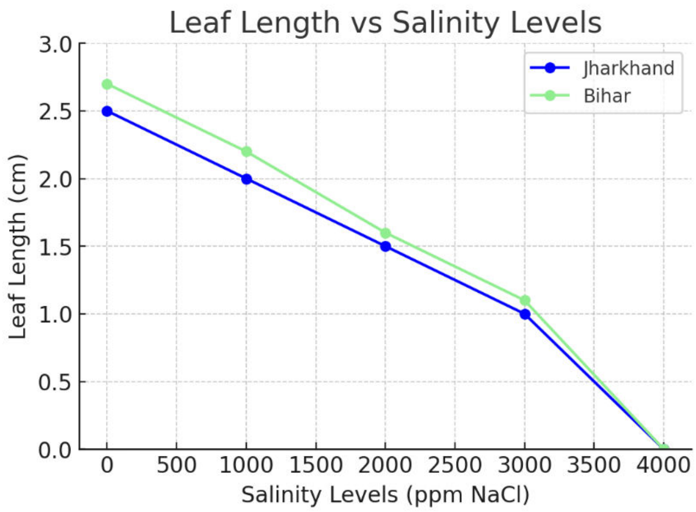

Fig. 2: Representing the line graph for leaf length and salinity levels

The graph (fig2) shows the correlation between salinity levels (ppm NaCl) and leaf length (cm) in coriander plants in Jharkhand and Bihar. As the salinity level increases, leaf length declines steadily in both regions. Under control conditions (0 ppm NaCl), leaf lengths are at their maximum, with Bihar displaying slightly longer leaves than Jharkhand. However, as salinity reaches 3000 ppm and beyond, leaf growth is almost entirely inhibited, with both regions exhibiting a similar sharp reduction in leaf size. This indicates that coriander leaf development is highly sensitive to salt stress, with severe inhibition at higher salinity levels.

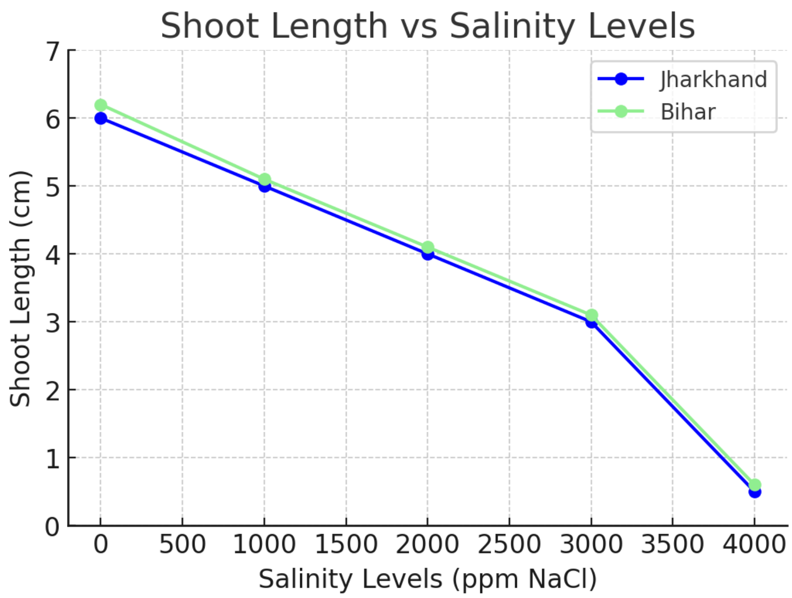

Fig. 3: Representing the line graph for Shoot Length and Salinity Levels

The graph (fig3) illustrates the effect of increasing salinity levels (ppm NaCl) on the shoot length (cm) of coriander plants in Jharkhand and Bihar. Shoot length decreases progressively as salinity rises, with the highest values recorded in the control group (0 ppm NaCl), where Bihar slightly outperforms Jharkhand. At 2000 ppm, shoot lengths are nearly halved in both regions, and at 4000 ppm, shoot growth is entirely inhibited. The trend indicates a clear negative correlation between salinity and shoot growth, showing that coriander's shoot development is significantly hindered by increasing salinity levels in both regions.

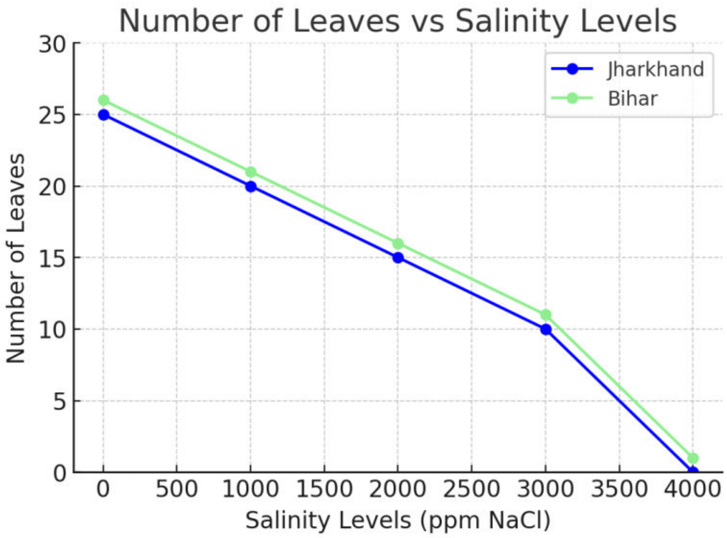

Fig. 4: Representing the line graph for Number of Leaves and Salinity Levels

The graph (fig4) demonstrates the relationship between salinity levels (ppm NaCl) and the number of leaves in coriander plants in Jharkhand and Bihar. As salinity levels increase, the number of leaves decreases in both regions. The control group (0 ppm NaCl) exhibits the highest number of leaves, with Bihar slightly outperforming Jharkhand. However, at higher salinity levels (3000 ppm and beyond), leaf production is drastically reduced, reaching zero at 4000 ppm. This indicates that coriander’s leaf development is highly sensitive to salinity stress, significantly impacting the plant's overall growth and foliage production in both regions.

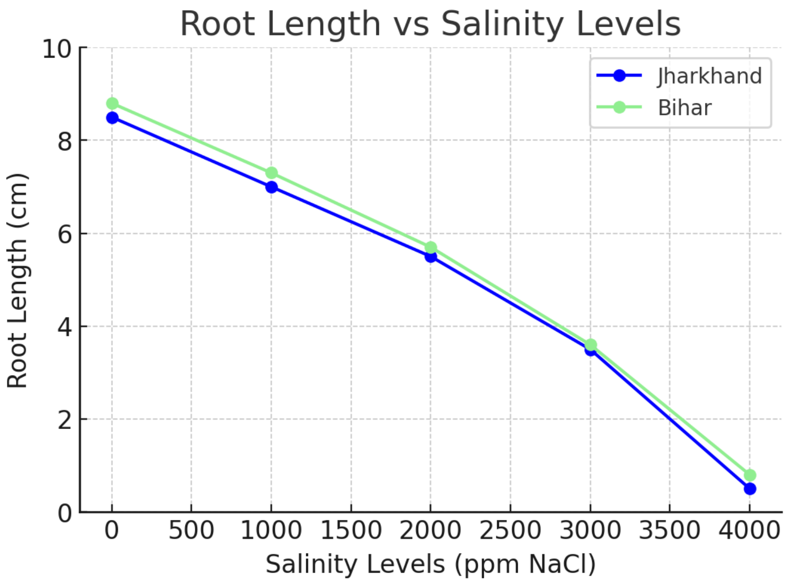

Fig. 5: Representing the line graph for Root Length and Salinity Levels

The graph (fig5) presents the effect of salinity levels (ppm NaCl) on the root length (cm) of coriander plants in Jharkhand and Bihar. As salinity increases, root length decreases steadily in both regions. Under control conditions (0 ppm NaCl), root lengths are longest, with minimal differences between the two regions. However, at higher salinity levels, especially above 2000 ppm, root growth is significantly reduced, reaching zero at 4000 ppm. This highlights the detrimental impact of salinity on root development, a critical aspect of plant health, as roots are essential for water and nutrient uptake in coriander plants.

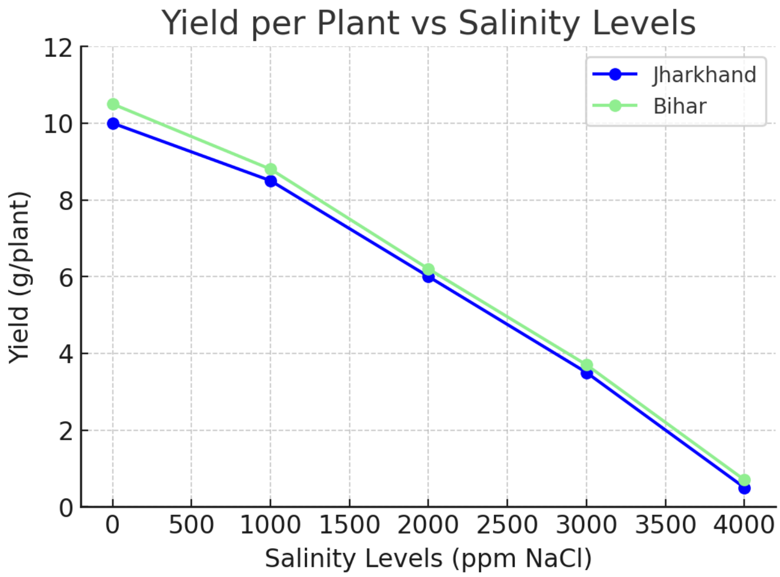

Fig. 6: Representing the line graph for Yield per Plant and Salinity Levels

The graph (fig6) shows the relationship between salinity levels (ppm NaCl) and yield per plant (g/plant) for coriander grown in Jharkhand and Bihar. As salinity increases, the yield per plant steadily declines. Under control conditions (0 ppm NaCl), the highest yield is observed, with Bihar slightly outperforming than Jharkhand. However, as salinity levels rise to 3000 ppm and beyond, the yield decreases sharply, with zero yield recorded at 4000 ppm. This indicates that elevated salinity levels drastically reduce coriander yield, demonstrating the plant's sensitivity to salt stress and highlighting the negative impact of salinity on crop productivity in both regions.

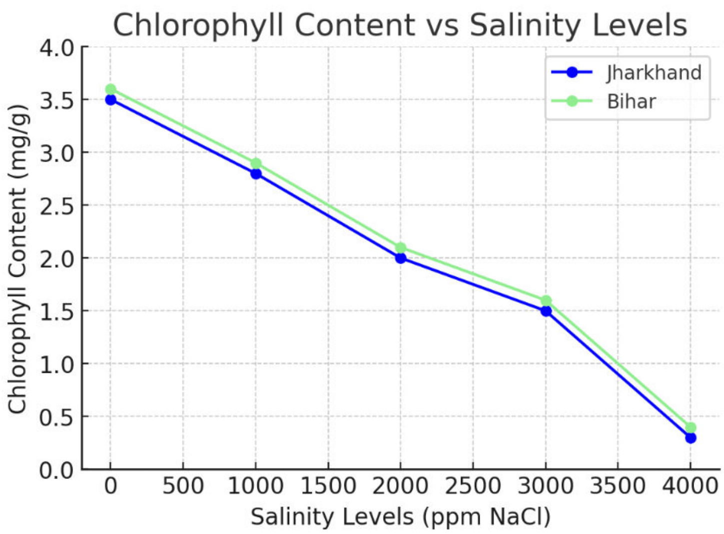

Fig. 7: Representing the line graph for Chlorophyll Content and levels

The graph (fig7) illustrates the relationship between salinity levels (ppm NaCl) and chlorophyll content (mg/g) in coriander plants from Jharkhand and Bihar. As salinity increases, chlorophyll content decreases steadily in both regions. Under control conditions (0 ppm NaCl), chlorophyll content is highest, with slight variations between the two regions. However, as salinity reaches 3000 ppm and beyond, chlorophyll levels drop sharply, with near-zero content at 4000 ppm. This demonstrates the adverse effects of high salinity on photosynthesis, as reduced chlorophyll content limits the plant's ability to capture light, ultimately impacting overall growth and productivity.

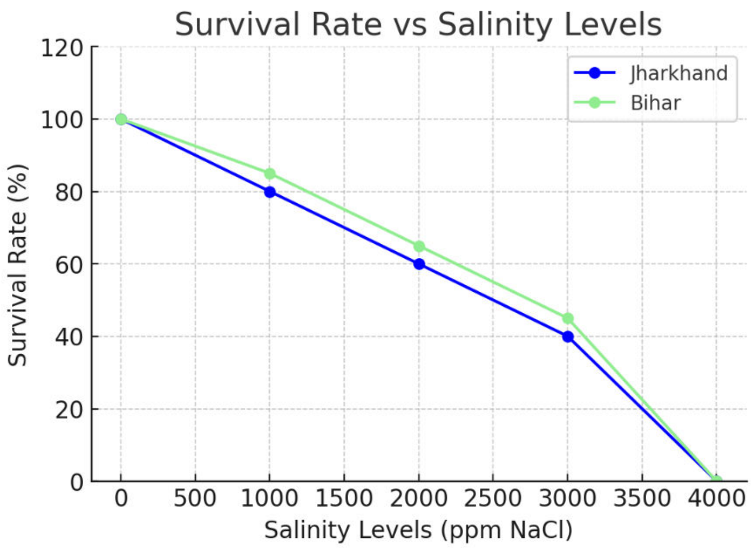

Fig. 8: Representing the line graph for Survival Rate and Salinity Levels

The graph (fig8) illustrates the effect of salinity levels (ppm NaCl) on the survival rate (%) of coriander plants in Jharkhand and Bihar. As salinity increases, the survival rate declines sharply in both regions. Under control conditions (0 ppm NaCl), survival rates are nearly 100% in both states. However, with increasing salinity, especially beyond 2000 ppm, survival rates drop significantly, reaching zero at 4000 ppm. This indicates that coriander plants are highly sensitive to salt stress, and high salinity levels severely hinder their ability to survive, which underscores the importance of salinity management for successful cultivation.

VII. FINDINGS

Germination Rate: The germination rate of coriander seeds declined significantly with increasing salinity levels in both Jharkhand and Bihar. While the control group (0 ppm NaCl) exhibited a high germination rate of approximately 97–98%, the rate dropped sharply to 0% at 4000 ppm in both regions. This demonstrates the high sensitivity of coriander seeds to elevated salinity, emphasizing the need to manage soil salinity for successful crop germination.

Leaf Length: The leaf length consistently decreased as NaCl concentrations increased. Under control conditions, the leaf length was around 2.5 cm in Jharkhand and 2.7 cm in Bihar at the final measurement. However, as salinity increased to 4000 ppm, leaf growth was entirely inhibited, suggesting that higher salinity has a substantial inhibitory effect on leaf development.

Shoot Length: Similar to leaf length, shoot length also reduced progressively with increasing salinity levels. In the control group, the shoot length reached 6.0 cm in Jharkhand and 6.3 cm in Bihar by the end of the observation period. However, under 4000 ppm, shoot growth was completely inhibited. This indicates that coriander's shoot development is highly sensitive to salt stress, which could severely impact overall plant health and productivity.

Number of Leaves: The number of leaves per plant showed a sharp decline with increasing salinity. While the control group had 24–26 leaves per plant, the number fell to zero at 4000 ppm. This suggests that high salinity levels severely disrupt foliage development, which could impair the plant's photosynthetic capacity and overall vigour.

Root Development: Both root number and root length were negatively impacted by higher salinity levels. At 0 ppm, plants had the highest root number and length, while at 4000 ppm, root development was completely inhibited. This is particularly concerning as a robust root system is critical for water and nutrient uptake, and high salinity can undermine this process, leading to poor plant health.

Yield: Yield per plant (in grams) declined significantly as NaCl concentrations increased. In the control group, the yield was 10.5 g/plant in Jharkhand and 11.0 g/plant in Bihar. However, yield dropped to zero at 4000 ppm, highlighting the detrimental effect of excessive salinity on coriander productivity.

Chlorophyll Content: Chlorophyll content in coriander leaves, stems, and seeds decreased with rising salinity levels. Under control conditions, chlorophyll content was highest, but at 4000 ppm, the plants showed no chlorophyll accumulation, suggesting that salinity impairs chlorophyll biosynthesis, which could severely limit photosynthesis and plant growth.

Survival Rate: The survival rate of coriander plants also showed a steep decline as salinity levels increased. Under control conditions, survival rates were around 94–96% in both regions, but at 4000 ppm, the survival rate dropped to 0%. This highlights that excessive salinity can lead to complete plant death, rendering it impossible to cultivate coriander under such conditions.

Salinity Sensitivity: Coriander plants are highly sensitive to increased soil salinity, particularly at concentrations above 2000 ppm NaCl. Both regions, Jharkhand and Bihar, showed similar trends, with minor regional variations in plant performance under salinity stress.

Regional Comparison: While both Jharkhand and Bihar exhibit a decline in plant growth and yield with increasing salinity, Bihar showed slightly better performance in terms of leaf length, shoot length, and yield at lower salinity levels (1000 and 2000 ppm). This suggests that Bihar's soil or climatic conditions might provide a marginally better growing environment for coriander under stress.

Critical Threshold: The study indicates a critical threshold for coriander's tolerance to salinity, which appears to lie between 1000 and 2000 ppm NaCl. Beyond this range, there is a sharp decline in all measured growth parameters, including germination, leaf and shoot development, root growth, and yield.

Implications for Agriculture: The results underscore the importance of managing soil salinity to ensure successful coriander cultivation. Farmers in regions prone to salinity issues, such as Jharkhand and Bihar, need to adopt soil management techniques, such as improved drainage or soil amendments, to mitigate the adverse effects of salinity on crop production.

Yield Loss Risk: At 3000–4000 ppm NaCl, the total inhibition of growth, yield, and survival suggests that such high salinity levels are unsustainable for coriander farming. These findings highlight the risk of complete crop failure if soil salinity is not controlled in regions with increasing salinization trends.

VIII. CONCLUSION

The study demonstrated a significant negative impact of increasing soil salinity on coriander cultivation in both Jharkhand and Bihar. As salinity levels rose, key parameters such as germination rate, leaf length, shoot length, root length, number of leaves, yield, chlorophyll content, and survival rate declined sharply. Both regions exhibited similar trends, but Bihar showed slightly better performance, especially at lower salinity levels, suggesting more favourable growing conditions in that region. Salinity levels above 2000 ppm NaCl were found to be particularly detrimental, with complete inhibition of growth and yield at 4000 ppm. This highlights the critical need for effective salinity management practices, such as improved irrigation and soil amendments, to sustain coriander cultivation in these regions. The findings underscore the importance of region-specific strategies to mitigate salinity stress, especially for crops sensitive to salt, and emphasize the need for innovation in water management and soil recovery techniques for agricultural productivity.

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