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Role of Nano Biochar in Enhancing Plant Growth under Salinity Stress

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ABSTRACT

Salinity stress is becoming an increasingly serious problem for agriculture, especially in countries with large areas of salt-affected land. It hampers plant growth, reduces nutrient uptake, and ultimately lowers crop yield and quality. This study explores an eco-friendly and innovative approach to help plants cope with saline conditions by using nano-biochar—a specially designed material made from carbon-based compounds.The research involved testing the effects of nano-biochar on plant growth under salt stress. Various plant growth and health indicators were observed over a short period. The results showed that salinity negatively impacted plant development and caused visible signs of stress. However, when nano-biochar was applied, plant growth improved, and many of the harmful effects of salt stress were reduced.Plants treated with nano-biochar showed healthier growth, better stress tolerance, and improved cellular function. This suggests that nano-biochar helps maintain nutrient balance and supports the plant's natural defense mechanisms. The findings highlight its potential as a sustainable solution for enhancing plant resilience in salt-affected soils. Future studies in real field conditions and further research into how this material interacts with plant systems will help establish it as a practical tool for sustainable agriculture.

KEYWORDS: Salinity stress, Nano-biochar, Stress tolerance, Salt-affected soils, Plant growth.

1. INTRODUCTION

India has a rich agricultural history dating back over 10,000 years. Even today, farming supports around 62% of the population and contributes about 20% to the national GDP (Balkrishna et al., 2021). However, modern agriculture faces serious challenges, particularly soil salinity, which is especially severe in arid and semi-arid regions. Salinity affects 6.74 million hectares in India, causing an estimated loss of 16.8 million tonnes of crops annually (Mandal et al., 2009). Globally, it threatens over 96% of rural agricultural land, reducing plant growth and yield (Cramer et al., 2011; Zhang et al., 2023).

Salt accumulation disrupts water and nutrient uptake, damages plant cells, and impairs key processes like photosynthesis and reproduction. In response, researchers are exploring sustainable solutions such as nanotechnology, with nano-biochar emerging as a promising option (Ashraf et al., 2021; Chausali et al., 2021). Derived from natural biomass, nano-biochar has a high surface area and reactivity, helping retain nutrients, manage salt levels, and support root development under stress (Wu et al., 2023).

Studies have shown that nano-biochar improves seed germination, growth, and resilience in crops like wheat, rice, and maize (Premalatha et al., 2022; Zheng et al., 2018). It enhances soil quality by reducing harmful salt indicators and retaining nutrients such as nitrogen and potassium (Sohi et al., 2010; Abd El-Mageed et al., 2020).

This study focuses on wheat (Triticum aestivum L.), a vital food crop in many developing nations, to evaluate the impact of nano-biochar in saline conditions (Ramadas et al., 2019; Wani et al., 2020). By supporting plant health and improving stress tolerance, nano-biochar offers a sustainable, nature-based approach to address salinity and promote resilient agriculture in the face of climate change.

2. MATERIALS AND METHODS

The experimental findings of the present investigation entitled "Role of nano biochar in enhancing plant growth under salinity stress". was carried out at a lab in Noida (Uttar Pradesh) during the month Feb – April.

2.1 Plant material and culture conditions

Wheat seeds were sourced from the Indian Agricultural Research Institute (IARI), New Delhi. They were cleaned with a mild bleach solution, rinsed well with water, and soaked for about 4 hours. After soaking, the seeds were kept in the dark at around 28 °C to sprout. The sprouted seeds were then grown in a controlled environment with a 12-hour light/dark cycle, moderate humidity, and light intensity for 8 days. Once the seedlings grew to a similar height, uniform ones were selected for further use.

2.2 Growth estimation

Seedling growth was checked by measuring the length of roots and shoots. A few seedlings were randomly picked from both control and treated groups. Their roots and shoots were separated, and both their fresh weight and length were recorded. To measure dry weight, the seedlings were dried in an oven for 48 hours at around 65–75 °C.

TABLE 1. Treatment details

Treatments	Treatment details
T1	Control
T2	NaCl
T3	C_3N_4 Chi (B)
T4	NaCl + C_3N_4 Chi (B)

3. RESULT AND DISCUSSION

At the harvest stage, various growth parameters were evaluated, including precise measurements of shoot and root length to assess plant development.

3.1 Shoot length

In this study, nano-biochar treatment resulted in the greatest enhancement in shoot length across all conditions. Under control conditions, shoot growth remained at baseline levels, while nano-biochar alone promoted a significant increase. Salinity stress (NaCl) reduced shoot length; however, the combined application of nano-biochar with NaCl alleviated this reduction, restoring growth to near-normal levels. These findings suggest that nano-biochar effectively supports plant growth and mitigates the adverse effects of salinity stress.

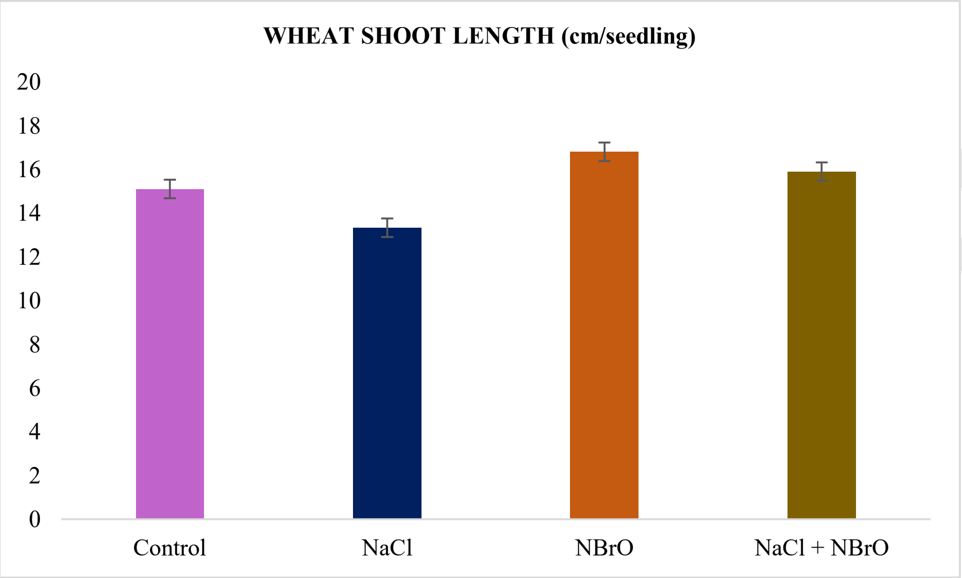

Fig 1. Impact on shoot length under various treatments

3.2 Root length

In this study, nano-biochar treatment led to the highest increase in root length across all treatments. Under control conditions, root growth remained at baseline, whereas nano-biochar alone significantly enhanced root development. Salinity stress (NaCl) caused a notable reduction in root length; however, the combined application of nano-biochar with NaCl improved root growth compared to NaCl alone. These results indicate that nano-biochar not only promotes root development under normal conditions but also helps mitigate the negative effects of salinity stress on root growth.

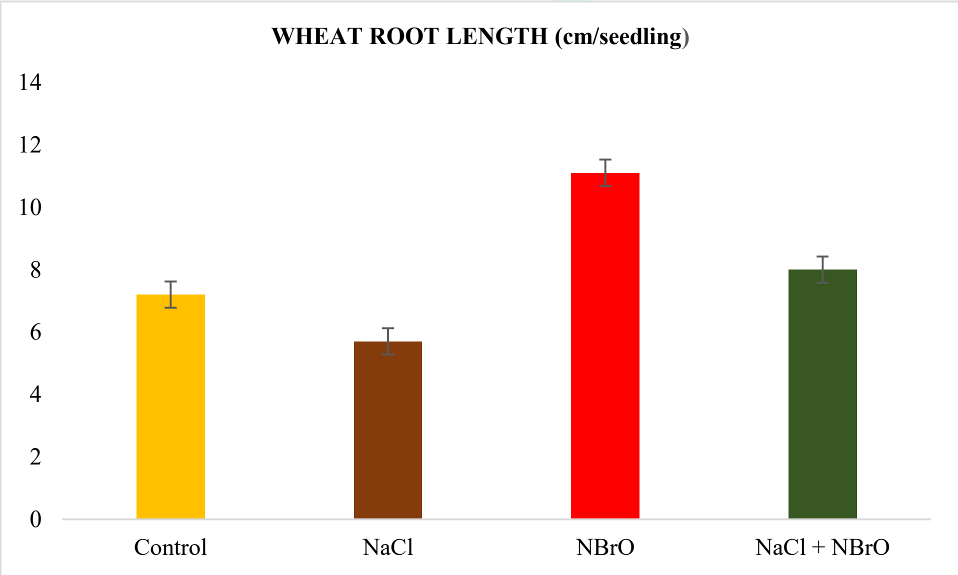

Fig 2. Impact on shoot length under various treatments

CONCLUSION

Biochar, especially in its nano-sized form, is gaining attention as a powerful and sustainable tool for improving agricultural productivity. Its ability to enhance soil properties and promote healthier plant growth makes it particularly valuable in addressing challenges like soil salinity, which severely limits crop yield in many regions. This study demonstrated that nano-biochar significantly boosted both shoot and root growth in wheat plants. Under normal conditions, nano-biochar improved plant development beyond the baseline, while under salt stress, it effectively mitigated the negative impacts of salinity, helping plants maintain growth closer to healthy levels.

The combined treatment of nano-biochar with saline conditions showed that nano-biochar can reduce salt toxicity and improve nutrient availability, thereby supporting plants in stressful environments. These findings highlight nano-biochar's dual role: improving soil health and enhancing plant resilience to abiotic stressors like salinity. Given its natural origin and eco-friendly characteristics, nano-biochar offers a practical approach for farmers to improve crop performance sustainably, especially in salt-affected soils. Ultimately, incorporating nano-biochar into farming practices could contribute to more resilient agricultural systems, better food security, and sustainable land management in the face of environmental challenges.

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