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Effect of Sodium Chloride and Boron Stress on Germination Percentage and Amylase Activity in Wheat (*Triticum aestivum* L.)

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Abstract

Soil salinity and boron toxicity are significant abiotic stressors affecting agricultural performance. This study investigates the impact of these stresses on the germination and early seedling growth of the wheat variety HUW 234. Experiments were conducted during the rabi seasons of 2014-15 and 2015-16 using varying concentrations of sodium chloride (NaCl) and boron (B). Results indicated that increasing NaCl concentrations significantly decreased germination percentages and amylase activity, demonstrating the detrimental effects of soil salinity on wheat. Conversely, boron exhibited a more complex relationship: while high concentrations (4.5 and 5.0 mg B/kg soil) negatively affected germination and enzyme activity, an optimal concentration of 2.0 mg B/kg soil enhanced these parameters. These findings highlight the limited tolerance of HUW 234 to high soil salinity and its narrow optimal range for boron. Developing strategies to enhance salt and boron tolerance in wheat, such as genetic improvements and stress management approaches, is crucial for improving productivity in saline and boron-rich soils. Further research into the physiological and molecular mechanisms underlying these responses is essential for designing effective mitigation strategies.

Key words**:** *Triticum aestivum* L., Growth, High boron, Morphology, Saline conditions, Yield

Soil salinity is one of the most significant biotic stressors that negatively affects agricultural performance [1]. Salinity has a dual effect on crop growth. In the first phase, the decreased electrolyte content of the soil diminishes the water supply to plants. In saline soils, a variety of dissolved salts are present including NaCl, $CaSO_4$, Na_2SO_4, $MgCl_2$, Na_2SO_4, KCl and Na_2CO_3 but NaCl is the most soluble and widely found [2-3]. Salinity has an impact on crop growth in two different stages. The first stage involves the reduction of water availability to plants due to the low osmotic potential of soil solution, further resulting in toxicity from ions like Na^+, Cl^- or B at excessive concentrations [4]. Additionally, affecting physiological processes in plants such as photosynthesis by reducing SC and transpiration while disrupting biosynthesis of photosynthetic pigments is salinity [5]. In the second phase, the accumulation of ions like Na^+, Cl^-, or B that are over-concentrated causes ion toxicity [6]. In contrast to Na^+, information about the transport of Cl ions is limited, even though it is one of the most common anions in many salinized soils [7]. Additionally, Cl^- is a crucial micronutrient that regulates the activity of enzymes in the cytoplasm, it is a partner in photosynthesis, and it functions as an anti-ion to maintain the potential of the membrane and have a role in turgor and pH regulation [8-9].

Boron (B) stands as a micronutrient essential in its own right. It wields influence over major metabolic happenings and plant cellular function [10]. Actively growing plant regions that are teeming with cell division and rapid differentiation depend on this element highlighting its indispensable part in growth dynamics. Yet the exact role of B within physiological processes like photosynthesis remains shrouded in mystery, even bordering on contradiction at times without any direct reports showcasing impact of boron on plant photosynthesis [11]; some researchers point towards an indirect link between B and photosynthesis based on findings in soybean crop plants [12]. Both excess [13] and deficiency [14] conditions of Boron paint pictures of reduced photosynthetic rates: the former hints at lowered CO_2 assimilation due to possible oxidative burdens coupled with diminished enzyme activities at photosystems along hampered electron transport [15].

The co-occurrence of salinity and boron toxicity is common, especially in arid or semi-arid regions [16]. However, the literature lacks a clear consensus on how these two stresses interact to affect plant growth and development. Studies have reported varying results, including additive effects [17-18], independence of the interaction [19], and even antagonistic effects [20-21]. Wheat varieties with enhanced salt tolerance are expected to accumulate lower levels of boron when exposed to boron toxicity [22]. Previous research has shown differences in salinity and boron accumulation among wheat cultivars [23]. As a result, selecting appropriate wheat genotypes is crucial for successful crop production with improved yield quality in saline, toxic, or boron-deficient conditions. This study investigates the morphological attributes responses of wheat HUW 234 genotypes, differing in salinity tolerance when exposed to externally applied soil salinity, varying boron levels, and there.

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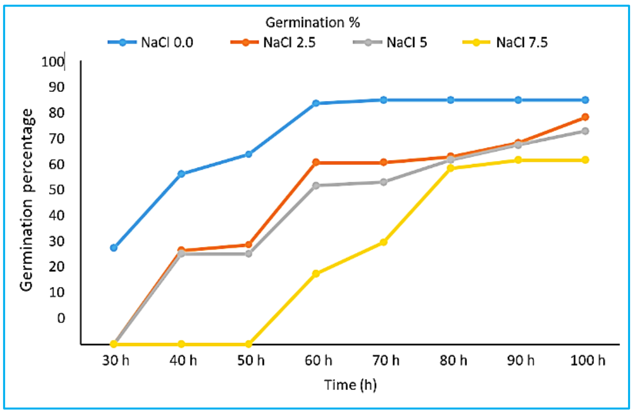
MATERIALS AND METHODS

Experiments were conducted during the rabi seasons of 2014-15 and 2015-16 using the wheat variety HUW 234. The experiments were carried out on the experimental farm of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. Screening of Sodium Chloride (NaCl) Concentration: Various concentrations of NaCl (0, 2.5, 5.0, and 7.5 mg/kg soil) were employed to induce stress conditions in the wheat variety. Initially, the different Sodium Chloride (NaCl) concentrations were applied to sterilized soil, which was then saturated with the salt and allowed to dry. After the soil reached dryness, 30 seeds of the wheat variety HUW 234 were planted in each pot in replicates. The germination percentage of wheat was monitored up to 100 hours from the sowing time. Simultaneously, amylase activity during the wheat seedling stage was analyzed at 60 hours, 80 hours, and 100 hours. Based on the results of these experiments, two Sodium Chloride (NaCl) concentrations, 2.5 mg and 5.0 mg per kg of soil, were chosen for further investigation. Screening of Boron (B) Concentration: Various concentrations of boron (ranging from 0 to 5.0 mg B/kg soil in increments of 0.5 mg) were utilized to induce stress conditions in the wheat variety. The different boron concentrations were initially applied to sterilized soil, which was then saturated with the boron and allowed to dry. Following the soil's dryness, 30 seeds of the wheat variety HUW 234 were sown in each pot in replicates. The germination percentage of wheat was measured up to 100 hours from the sowing time. Simultaneously, amylase activity during the wheat seedling stage was analyzed at 60 hours, 80 hours, and 100 hours. Based on the results of these experiments, two boron concentrations, 2.0 mg and 3.5 mg per kg of soil, were selected for further investigation.

RESULTS AND DISCUSSION

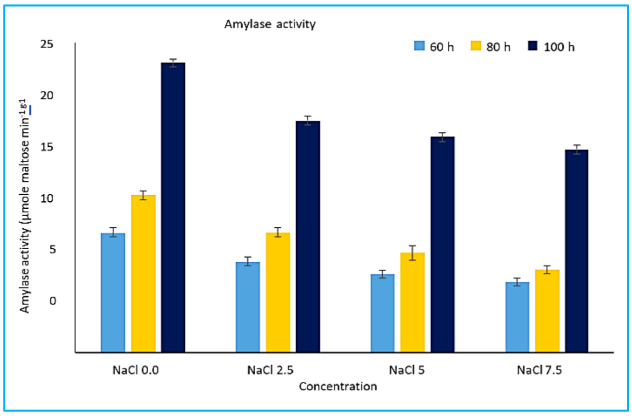
Screening of sodium chloride concentration on germination percentage and amylase activity

The results indicate that increasing concentrations of sodium chloride (NaCl) in the soil had a significant negative impact on the germination percentage of the wheat variety HUW 234 over time. In the absence of NaCl, the germination percentage reached up to 86% after 100 hours. However, with increasing NaCl concentrations of 2.5 mg, 5.0 mg, and 7.5 mg per kg of soil, the germination percentages decreased to 80%, 75%, and 65%, respectively, at 100 hours. This demonstrates the detrimental effect of soil salinity on wheat seed germination. Simultaneously, the amylase activity in the wheat seedlings was analyzed during the early growth stages. Amylase activity increased with time, with the highest increment observed in the absence of Sodium Chloride (NaCl), reaching 23 μmole maltose min^{-1} g^{-1} at 100 hours. In contrast, the lowest amylase activity of approximately 16 μmole maltose min^{-1} g^{-1} was found in wheat seeds treated with 7.5 mg Sodium Chloride (NaCl) per kg of soil. This indicates that increased soil salinity negatively impacts the amylase activity, which is crucial for the breakdown of starch and mobilization of stored nutrients during germination and early seedling growth. Based on these findings, two NaCl concentrations, 2.5 mg and 5.0 mg per kg of soil, were selected for further investigation, as they represent moderate and high salinity levels that significantly impacted the germination and amylase activity of the wheat variety.



The figure shows the germination percentage during the germination stage in the wheat HUW 234 variety under different concentrations of Sodium Chloride (NaCl) at different time intervals

Fig 1 Screening of salt concentration against germination percentage in wheat crop

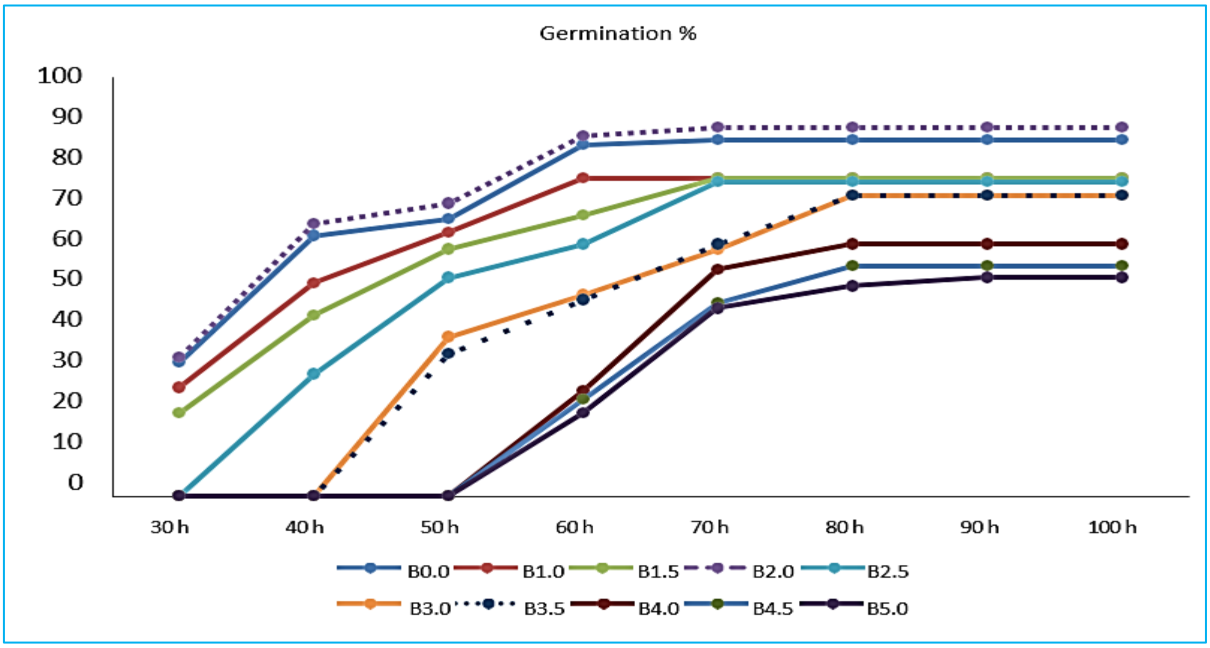


The figure shows amylase activity during the germination stage in wheat HUW 234 under different concentrations of Sodium Chloride (NaCl) at different time intervals. Data represented as mean and SE

Fig. 2 Effect of different NaCl concentration on amylase activity in germinating wheat seeds

Screening of boron concentration on germination percentage and amylase activity

The results showed that the germination percentage of the wheat variety HUW 234 exhibited a significant decline with increasing concentrations of boron in the soil, except at 2.0 mg B kg^{-1} soil, where an increase was observed over time. The maximum germination percentage of 88% was achieved at 2.0 mg B kg^{-1} soil after 100 hours. In contrast, at higher boron concentrations of 4.5 and 5.0 mg B kg^{-1} soil, the germination percentages were considerably lower, reaching only 52% and 52%, respectively, at 100 hours. The amylase activity during the wheat seedling stage also showed a similar trend [24]. The maximum amylase activity of 26 μmole maltose min^{-1} g^{-1} was observed at 2.0 mg B kg^{-1} soil at 100 hours, followed by the control treatment (0.0 mg B kg^{-1} soil). The lowest amylase activity of approximately 13.23 μmole maltose min^{-1} g^{-1} was found in wheat seeds treated with 5.0 mg B kg^{-1} soil. Based on these results, two concentrations of boron, 2.0 mg and 3.5 mg per kg of soil, were selected for further investigation, as they represent the optimal and moderately toxic levels of boron for the wheat variety HUW 234 [25]. The findings from the screening experiments on the effects of sodium chloride (NaCl) and boron concentrations on the germination percentage and amylase activity of the wheat variety HUW 234 provide valuable insights into the physiological responses of wheat to these abiotic stresses. The selected sodium chloride (NaCl) and boron concentrations will be used in subsequent experiments to elucidate the underlying mechanisms and potential strategies for improving wheat tolerance to these stresses [26]. The selected concentrations will be used in subsequent experiments to further explore the underlying mechanisms and potential strategies for enhancing wheat tolerance to these stresses.



The figure shows the germination percentage during the germination stage in the wheat HUW 234 variety under different concentrations of Boron at different time intervals

Fig 3 Screening of boron concentrations against germination percentage in wheat

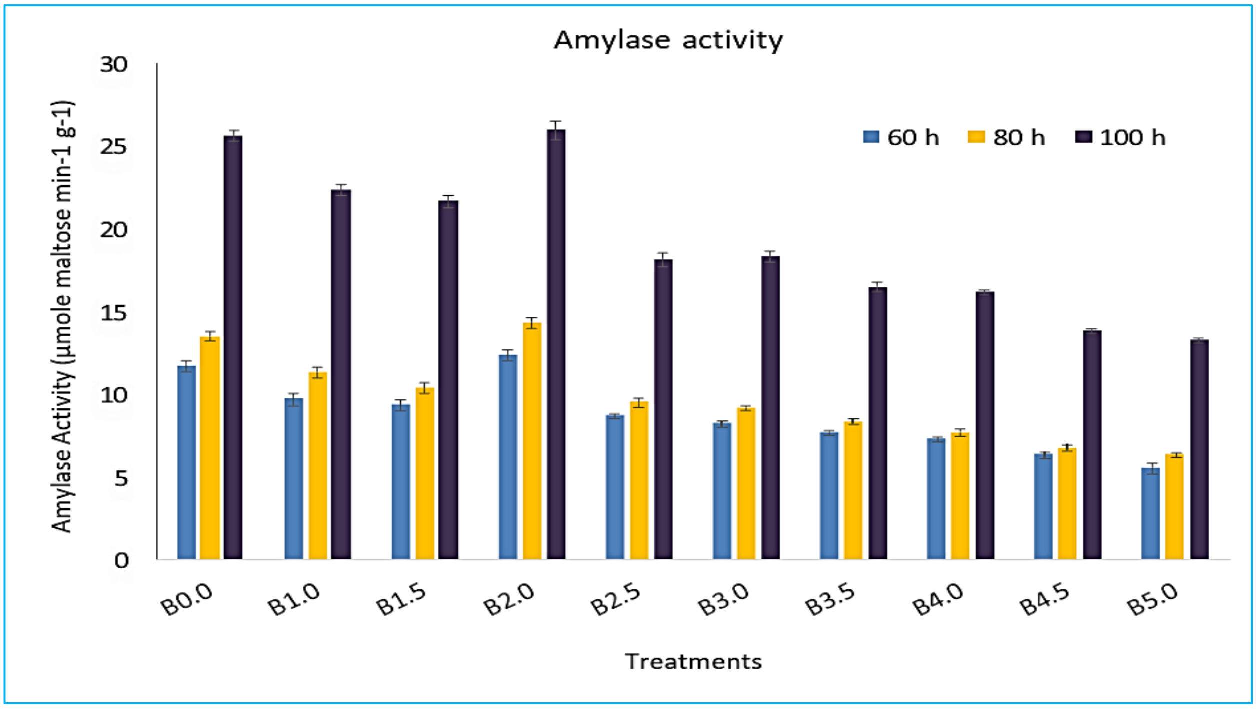


Figure shows amylase activity during the germination stage in wheat HUW 234 under different concentrations of Boron at different time intervals. Data represented as mean and SE

Fig 4 Effect of different boron concentrations on amylase activity in germinating wheat seeds

CONCLUSION

This study investigated the impact of two key abiotic stresses, soil salinity (NaCl) and boron toxicity, on the seed germination and early seedling growth of the wheat variety HUW 234. The results clearly demonstrate that increasing soil salinity, as indicated by higher NaCl concentrations, has a detrimental effect on the germination percentage and amylase activity of this wheat variety. The reduction in these key physiological parameters under salt stress can be attributed to the osmotic and ionic effects of NaCl, which disrupt water uptake and cellular homeostasis, ultimately impairing seed germination and early seedling establishment. In contrast, the impact of boron stress on the wheat variety HUW 234 exhibited a more complex relationship. While excessive boron levels (4.5 and 5.0 mg B kg^{-1} soil) had a negative effect on germination and amylase activity, the optimal boron concentration of 2.0 mg B kg^{-1} soil actually enhanced these physiological parameters compared to the control. This suggests that a moderate level of boron can be beneficial for this wheat variety, likely by stimulating processes such as cell wall formation, membrane integrity, and carbohydrate metabolism. These findings indicate that the wheat variety HUW 234 has a limited tolerance to high soil salinity, but a relatively narrow optimal range for boron requirements. Developing strategies to improve its salt and boron tolerance, such as the use of salt-tolerant rootstocks, application of Osmo protectants, or genetic improvements through breeding and biotechnology, could be crucial for enhancing the productivity and adaptability of this wheat variety in saline-affected and boron-rich regions. Further research is warranted to elucidate the underlying physiological and molecular mechanisms governing the responses of HUW 234 to these abiotic stresses, which could provide valuable insights for designing effective stress management approaches. Evaluating the performance of this wheat variety under field conditions and exploring strategies for mitigating salt and boron stress would be important next steps in ensuring its successful cultivation in challenging environmental conditions.

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