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Effects of water supply and salinity stress on the physiological parameters of wheat (Triticum aestivum L.) under controlled environmental conditions

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Abstract

The efficient use of irrigation water is critical for sustainable crop production, especially under increasing climatic stress and limited freshwater availability. In our study, we examined the response of three wheat varieties to different irrigation water quantities and qualities, focusing particularly on the effects of saline water. The experiment was conducted in 2023 at the experimental site of the Hungarian University of Agriculture and Life Sciences, Department of Irrigation and Land Improvement, under a foil-covered tent to eliminate precipitation influence and maintain precise water control. The experimental design consisted of three replications for each treatment. Water supply treatments included three levels based on the soil's total water-holding capacity: 40%, 60%, and 80% (SWS40, SWS60, and SWS80), alongside corresponding saline water treatments (SWS40S, SWS60S, and SWS80S). In the saline treatments, a combination of sodium chloride (NaCl), sodium carbonate (Na_2CO_3), and sodium sulfate (Na_2SO_4) was added to the irrigation water to simulate complex salinity stress.

Throughout the growing season, key physiological parameters were measured, including chlorophyll content (SPAD), leaf area index (LAI), plant height, and total biomass. The results demonstrated that plants irrigated with non-saline water at 80% soil water capacity (SWS80) exhibited the highest values across all measured parameters, indicating optimal growth conditions. Conversely, the saline treatments, particularly at lower water supply levels (SWS40S), led to significant reductions in plant height, SPAD values, LAI, and biomass, highlighting the compounded stress effects of both water scarcity and salinity. These findings underscore the importance of not only adequate water quantity but also irrigation water quality in wheat cultivation under controlled environmental conditions.

• Introduction

Wheat (Triticum aestivum L.) is one of the most widely cultivated cereal crops in the world, serving as a staple food for a significant portion of the global population. It is grown on more than 215 million hectares globally and provides about 20% of the total dietary calories and protein for the world population. In Hungary, wheat remains a dominant arable crop, with an average annual cultivation area of around 1 million hectares. The productivity and quality of wheat are heavily influenced by environmental conditions, particularly water availability. Being moderately drought-tolerant, wheat still requires sufficient water supply during critical growth phases such as tillering, stem elongation, and grain filling.

Climate change and increasing water scarcity pose serious challenges for irrigated agriculture. Moreover, the use of saline water for irrigation, due to freshwater limitations, is becoming more common. However, salinity stress can significantly impair plant physiological processes, leading to reduced growth and yield. Understanding how wheat responds to varying water supply levels and salinity under controlled conditions can inform better water management strategies and ensure sustainable wheat production.

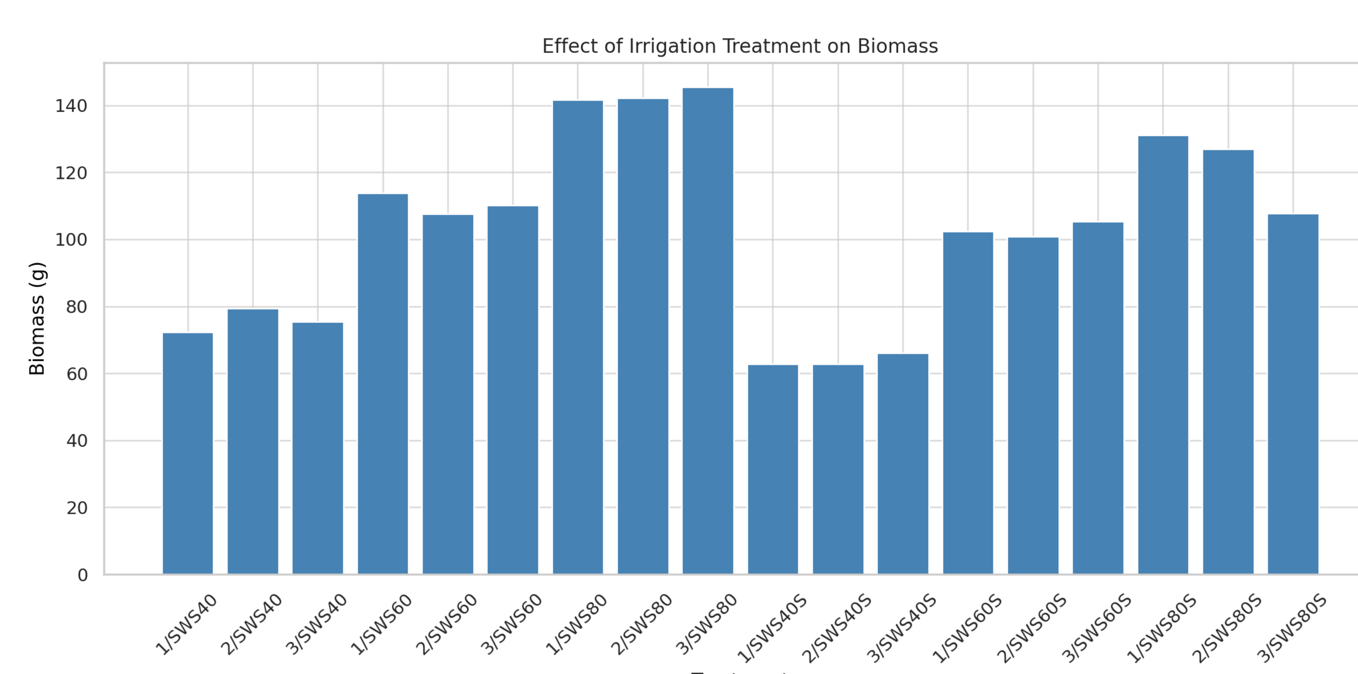
• Material and method

The experiment was conducted in 2023 at the Hungarian University of Agriculture and Life Sciences, Department of Irrigation and Land Improvement, using a foil-covered tent to eliminate rainfall and ensure precise control of irrigation. Three different wheat varieties were tested under six irrigation treatments: three non-saline water supply levels (SWS40, SWS60, SWS80, representing 40%, 60%, and 80% of the soil's total water-holding capacity), and their respective saline counterparts (SWS40S, SWS60S, SWS80S). The saline treatments were prepared by adding a complex mixture of sodium chloride (NaCl), sodium carbonate (Na_2CO_3), and sodium sulfate (Na_2SO_4) to simulate real-world salinity stress. Each treatment was replicated three times. Throughout the growing season, key physiological parameters such as chlorophyll content (measured by SPAD), leaf area index (LAI), plant height, and total above-ground biomass were monitored and recorded.

• Results and discussions

Across all measured parameters, the SWS80 treatment (irrigation to 80% of soil water capacity) consistently produced the highest values. For instance, the average plant height in this treatment was 56.66 cm, and biomass accumulation reached 129.84 g, significantly exceeding the values observed at lower water levels. Similarly, the average grain number per spike was 36.33, with an LAI value of 1.14, indicating vigorous canopy development and efficient photosynthetic capacity.

In contrast, plants under SWS40 (40% of soil water capacity) showed the lowest values, with an average height of 38.7 cm, biomass of 61.2 g, and an LAI of 0.96. These results clearly demonstrate the positive correlation between water availability and physiological development in wheat under controlled environmental conditions.



Salinity treatments generally had a detrimental effect on plant performance, especially at the lower irrigation levels. Under the SWS40S treatment (40% water capacity with salt stress), biomass dropped to 75.63 g and LAI to 1.01, indicating compounded stress effects. However, in higher irrigation treatments (SWS80S), plants maintained relatively high biomass (143.45 g) and grain numbers (34.47), but still slightly lower than their non-saline counterparts.

This pattern suggests that while increased water availability can partially mitigate the negative effects of salinity, the presence of salts such as NaCl, Na_2CO_3, and Na_2SO_4 still imposes physiological limitations on wheat growth. The interaction between water quantity and quality thus plays a crucial role in optimizing crop outcomes.

• Conclusions

The findings underscore the critical role of both irrigation quantity and water quality in wheat production. The highest biomass, grain numbers, and LAI values were achieved under the SWS80 treatment, confirming that optimal water availability supports robust plant development. Conversely, salinity stress negatively affected all growth parameters, particularly under limited irrigation.

These results highlight that sustainable wheat cultivation under controlled conditions must prioritize not only the volume of irrigation water but also its chemical composition. To achieve maximum productivity, especially under climate stress and increasing soil salinity risks, integrated water management strategies are essential.