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The Role of Potassium and Zinc Fertilization on Enhancing Climate Change Tolerance in Wheat Production in Basrah, Iraq

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Abstract

It is estimated that by 2050, food production should increase by 70% to sustain a global population of 9.1 billion people. This research examines the setting interactions of potassium (K) and zinc (Zn) on the salt tolerance of wheat (*Triticum aestivum L.*) in Basrah, Iraq, where salt concentration in soil severely limits agricultural productivity. The experiment was carried out in sandy loam soil of moderate salinity employing a randomized complete block design (RCBD) with the wheat subjected to various nutrient treatments for 3 and 6-day intervals. The data indicates that both K and Zn individually and in combination considerably increased the height and yield of plants above the control. In other words, the control treatment resulted from drastic reductions in growth and yield over time. Nutrient management is essential. Strict salt management and the application of Zn and K increased the growth of wheat significantly more than did saline irrigation without Zn and K. These results highlight the importance of integrated nutrient management in increasing wheat productivity and resilience in regions with high salinity problems to help foster sustainable agriculture with rising environmental burden.

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Introduction

The global population is projected to increase by 34% by 2050, reaching around 9.1 billion, necessitating a 70% rise in food production (FAO, 2005). Modern agriculture faces multiple abiotic stresses, notably salinity, which significantly hampers crop yields by disrupting metabolic processes and causing irreparable damage (Tardieu & Tuberosa, 2010). In Pakistan, about 70% of agricultural soils are zinc deficient, exacerbating potassium deficiencies (Abbas et al., 2009). Zinc is crucial for reducing sodium accumulation and enhancing potassium uptake during salinity stress (Jan et al., 2017). To combat oxidative damage from reactive oxygen species, plants rely on robust antioxidant systems. Improving the availability of potassium and zinc can enhance the salinity tolerance of wheat (*Triticum aestivum L.*), ultimately contributing to agricultural resilience and food security (Hasanuzzaman et al., 2020).

The relationship between potassium (K), zinc (Zn), and salinity stress plays a critical role in determining the resilience of wheat (*Triticum aestivum L.*) under challenging environmental conditions. Wheat plants encounter significant hurdles when subjected to saline environments, largely due to osmotic pressure and ionic imbalances that inhibit water absorption and lead to the accumulation of toxic ions (Jan et al., 2017). These detrimental conditions increase oxidative stress within the plant system, severely compromising growth and development. To protect against cellular damage, wheat relies on osmolytes to stabilize macromolecules and detoxify harmful ions (Bouremani et al., 2023).

Potassium is integral to numerous physiological processes within plants, including photosynthesis, enzyme activation, and the movement of nutrients. However, salinity often drastically reduces the availability of potassium, which can hinder the growth and overall health of plants. Research indicates that maintaining appropriate potassium levels within plant cells is essential for combating oxidative stress induced by salt, preventing subsequent cellular damage. Adequate potassium not only enhances the functionality of antioxidant enzymes but also contributes to the resilience of plants facing salinity stress, underlining its importance for wheat cultivation in saline regions. Studies have shown that potassium helps regulate the K^+/Na^+ ratio, thereby improving the plant's ability to manage sodium toxicity and maintain osmotic balance (Xu et al., 2020; Wang et al., 2013).

Zinc serves as a crucial micronutrient that supports plant development and plays a significant role in stress management under saline conditions. As a cofactor for various enzymes essential for regulating stress responses, zinc helps protect plants against oxidative damage. Furthermore, zinc stabilizes cellular structures and regulates gene expression and protein synthesis, crucial for maintaining cellular integrity (Molnár et al., 2022). Adequate levels of zinc are necessary to fortify plants against oxidative stress, making it an indispensable component of nutrient management strategies in agriculture. The synergistic application of potassium and zinc can provide significant benefits to wheat varieties under salinity stress (Gupta et al., 2024).

Together, these nutrients enhance growth characteristics while alleviating stress, promoting better physiological responses in wheat plants. For instance, the application of both K and Zn has been shown to improve photosynthetic efficiency, boost antioxidant enzyme activities, and increase overall physiological performance. This relationship underscores the necessity of integrated nutrition management that incorporates both potassium and zinc to improve resilience and yield potential in wheat cultivated in saline environments (Bashir et al., 2023). The interplay between potassium and zinc is vital for mitigating the adverse impacts of salinity stress in wheat. Both nutrients are essential for maintaining cellular homeostasis and function, thereby supporting growth and development under stressful conditions. Effective management of these nutrients can lead to improved wheat performance, offering promising strategies for enhancing agricultural productivity in saline-affected regions (Choudhary et al., 2024). By ensuring adequate nutritional supply, farmers and agronomists can promote wheat resilience and sustain yield in the face of increasing salinity challenges.

The issue of soil salinity in Basrah, Iraq, is a significant environmental challenge that adversely affects agricultural productivity and necessitates comprehensive research and management strategies. The following detailed information outlines the extent of salinity, its causes, and its impact on agriculture in the region. Soil salinity has been a growing concern in Basrah, where increased salinization has rendered substantial areas of agricultural land less productive. In the last 13 years, salinized land has expanded by approximately 6,579.1 km², and in 2003, 34.5% of the total agricultural area was affected by salinity. By evaluating historical data from remote sensing and geographic information systems (GIS), researchers have documented that the situation continues to deteriorate, primarily due to the rising salinity levels in groundwater and soil (Jabbar & Zhou, 2012; Abdulameer et al., 2021).

The necessity of research into the relationship between potassium (K), zinc (Zn), and salinity stress in wheat (*Triticum aestivum L.*) is emphasized by the increasing challenges that modern agriculture faces due to the rising incidence of soil salinity, which directly threatens global food security. The anticipated growth in the global population necessitates that wheat production not only meets current demands but also adapts to the adverse effects of salinity that can significantly compromise crop yields. In light of the complexities surrounding salinity stress faced by wheat crops, the strategic application of potassium and zinc can greatly improve yield and crop quality. The aim of the research project in Basrah, Iraq, is to investigate the interactive effects of potassium (K) and zinc (Zn) on the salinity tolerance of wheat (*Triticum aestivum L.*) under local saline conditions.

Materials and Methods

Study Area

The research was conducted in Al_Zubair/ Alluhais location, a city located in the Basrah province of Iraq. The specific study site encompasses an area of 0.25 hectares (2500 m²) with geographical coordinates of 30°34’08”N latitude and 46°58’14”E longitude.

Soil Characteristics

The soil type in the study area is sandy loam, which is characterized by a balanced mixture of sand, silt, and clay, providing good drainage and aeration. The soil properties of the study area were assessed to evaluate their suitability for agricultural practices. The electrical conductivity of the soil (Ecs) was measured at 2.5 dS/m, indicating moderate salinity levels, while the electrical conductivity of the soil extract

(Ece) was significantly higher at 9.1 dS/m, suggesting elevated salinity that could potentially impact crop growth negatively. Additionally, the soil pH was recorded at 7.61, reflecting neutral to slightly alkaline conditions, which are generally favorable for most crops. To enhance soil fertility, 50 kg of organic matter, sourced from cow manure, was applied to the plot on November 1, 2023. This organic amendment aims to improve soil structure and nutrient availability, thereby supporting healthy crop development.

Irrigation water characterization

Water for agriculture is sourced from groundwater via wells. This strategy provides famers with a dependable and constant water supply, especially in regions with little rainfall. Groundwater utilization has the potential to improve agricultural yields, but concerns regarding the over-usage and pollution of groundwater resources must be addressed with especial attention to water resource management. Moreover, the quality of the marketed water must be tested so that it meets the irrigation requirement and is not detrimental to the soil and plants. As shown in Table 1, irrigation water which has slightly alkaline pH value, with low electrical conductivity is noticeably cheaper and is also of suitable quality to be used for irrigation. Nevertheless, total hardness together with the elevated sodium concentration may hinder plant growth together with the infiltration of water into soil. Additionally, the elevated concentrations of calcium and magnesium may be referred to as hard water. Nitrate and potassium levels are fairly okay, but chloride and sulfate levels ought to be watched closely and lowered. As well, soil and plant damage from low amounts of heavy metals like cadmium, lead, nickel, and selenium should be avoided.

Fertilization and crop management

A comprehensive fertilization regime was implemented to support the growth of the crops in the study area. On November 23, 2023, during the mechanical sowing of wheat, 25 kg of DAP (Diammonium Phosphate)/donum was applied per

Table 1. Chemical and physical properties of irrigated water

Parameters	Unit	Irrigated water
pH	-	7.11
EC	µS/m	9.1
T.H	mg/L	2250
Ca^{+2}	mg/L	570
Mg^{+2}	mg/L	409.9
Na^{+}	mg/L	870.9
K^{+}	mg/L	40.5
Cl^{-}	mg/L	177.2
NO_3^{-}	mg/L	8
SO_4^{-2}	mg/L	795
Cd	mg/L	0.0214
Pb	mg/L	0.0153
Ni	mg/L	0.0441
CO	mg/L	0.0116

2500 m² to supply essential nutrients, particularly phosphorus, for early crop establishment. To address the nitrogen requirements of the wheat plants, urea fertilizer was applied in two doses on December 15, 2023. Totally, 65 kg urea/donum were applied, first dose 25 kg urea/donum at planting and the second dose (40 kg urea/donum). This strategic approach to fertilization aims to optimize nutrient availability and enhance crop performance throughout the growing season.

Cultivation practices

The cultivation process commenced on November 23, 2023, with mechanical ploughing employed to prepare the seedbed effectively. During this phase, two local wheat varieties, BHOUTH 22, were sown. An average seeding rate of 50 kg per 2500 m² was utilized to achieve optimal plant density, promoting healthy growth and development of the crops.

Experimental design

The study utilized a randomized complete block design (RCBD) to evaluate the performance of the two wheat varieties under the specified fertilization treatments. Each treatment was replicated to ensure statistical reliability. Data on crop growth parameters (e.g., plant height, biomass yield, grain yield) will be collected at regular intervals during the growing season.

The experimental field was systematically divided into 12 plots, with each plot measuring 80 m². The treatments included a control group and three fertilization regimes: potassium (K), zinc (Zn), and a combination of K+Zn. Each treatment has three replicated and intervals 3 and 6 days. ensuring consistent application of 250 g L^{-1} for potassium and zinc solutions. The wheat variety used in the study was BHOUTH 22, and a fixed sprinkler irrigation system was employed to ensure uniform water distribution. Additionally, the soil fertilizer used in the farm soil. For potassium, a total of 2 kg per 2500 m² was divided into two parts, with each part utilizing a dosage of 250 g per 100 liters. Similarly, zinc was applied at a rate of 2 kg per 2500 m², also split into two applications, each with a dosage of 250 g per 100 liters. This methodical approach aimed to evaluate the effects of nutrient potassium and zinc supplementation on crop performance effectively.

Statistical analysis

Data will be subjected to statistical analysis using SPSS software (version 20) to evaluate the effects of different treatments on crop performance. ANOVA will be utilized to determine the significance of differences between treatments, with a significance level set at $p < 0.05$.

Results and discussion

Soil properties

Soil tests conducted prior to cultivation revealed several key characteristics that inform the suitability of the soil for agricultural practices. The soil pH was measured at 7.61, indicating neutral to slightly alkaline conditions, which are generally favorable for crop growth. The electrical conductivity (ECe) was determined to be 2.50 dS/m, suggesting moderate salinity levels that may affect plant health. The total carbonate content was recorded at 120.00 g/kg, while the cation exchange capacity (CEC) was found to be 8.48 cmol/kg, indicating the soil's ability to retain essential nutrients. Organic matter content was measured at 5.38 g/kg, contributing to soil fertility and structure. The soil texture was classified as loamy sand, with sand, silt, and clay fractions comprising 830 g/kg, 36 g/kg, and 134 g/kg, respectively. Nutrient analysis showed adequate levels of magnesium (3.1 mg/kg), potassium (52.10 mg/kg), and phosphorus (114.35 mg/kg), while nitrogen content was relatively low at 0.35 mg/kg. Additionally, micronutrients such as iron (17.5 mg/kg) and zinc (17.55 mg/kg) were present in sufficient amounts. Overall, these soil properties indicate a moderate potential for successful crop cultivation, although attention to nutrient management will be necessary to optimize yields.

Effect of treatments on plant growth

Table 2 illustrates the effects of different treatments of potassium (K) and zinc (Zn) on the height of wheat over two time intervals: 3 days and 6 days. At 3 days, the control group, which received no treatment, had an average height of 108.89 ± 20.99 cm. The application of potassium increased the height to 117.33 ± 10.44 cm, while zinc treatment resulted in a notable height of 126.33 ± 6.69 cm, indicating its significant positive impact. The combined treatment of K and Zn yielded a height of 119.44 ± 6.81 cm. However, at 6 days, the control group's height decreased to 86.11 ± 6.19 cm, suggesting a decline in growth without nutrient supplementation. In contrast, potassium treatment continued to support growth, reaching 121.11 ± 17.14 cm, while zinc slightly decreased to 119.78 ± 18.87 cm. The combined treatment of K and Zn proved most effective, achieving the highest average height of 126.44 ± 8.80 cm. Overall, the data emphasizes the importance of potassium and zinc in enhancing wheat growth, with the combined treatment yielding optimal results, highlighting the critical role of nutrient management in agriculture.

The results of the statistical analysis showed that there is a significant difference at the 1% level between 3 days and 6 days. This indicates that the growth patterns of wheat plants have varied significantly during this time frame. Additionally, in the treatments at 3 and 6 days, the results indicated that the treatment of zinc alone and the combination of zinc with potassium do not have a statistically significant difference, meaning that the significance level is above 5%. This means that neither zinc alone nor its combination with potassium leads to a notable increase in plant height. These findings suggest that while zinc is beneficial, its impact is not substantial enough to affect growth of height, whether alone or in combination with potassium. In contrast, potassium has a more effective role in increasing plant height compared to zinc. On the other hand, the temporal changes observed between 3 and 6 days have a significant effect on plant growth, highlighting the importance of monitoring growth over

Table 2. Height (cm) of plant in the different treatment

	Treatment		Height
3days	-	Control	108.89±20.99
	K	250 g/ L	117.33±10.44
	Zn	250 g/ L	126.33±6.69
	K and Zn	250 g/ L +250 g/ L	119.44±6.81
6days	-	Control	86.11±6.19
	K	250 g/ L	121.11±17.14
	Zn	250 g/ L	119.78±18.87
	K and Zn	250 g/L +250 g/ L	126.44±8.80

time. Overall, these results emphasize the need for careful consideration of nutrient management strategies in agricultural practices to optimize plant growth and yield.

Effect of treatments on plant growth

Table 3 presents the weight of wheat (in tons per hectare) under different treatments of potassium (K) and zinc (Zn) over two time periods: 3 days and 6 days. After 3 days, the control group yielded 2.63 tons/ha, while treatments with potassium and zinc significantly increased yields to 4.09 tons/ha and 4.87 tons/ha, respectively. The combination of both nutrients resulted in the highest yield of 5.65 tons/ha. However, by 6 days, the control group's yield decreased to 2.33 tons/ha, indicating a lack of growth without treatment. The potassium and zinc treatments also saw declines, yielding 3.67 tons/ha and 3.83 tons/ha, respectively, while the combination treatment yielded 4.33 tons/ha. These results underscore the effectiveness of potassium and zinc in enhancing wheat yield, particularly when used together, but also highlight the need for ongoing nutrient management to maintain growth over time (Alharbi et al., 2024).

Statistical analysis showed that there is a significant difference at the 1% level between the results of the 3-day and 6-day fertilization treatments, indicating a substantial impact of time on plant growth. Additionally, only the control group (without fertilizer) showed a significant difference at the 1% level compared to other treatments, emphasizing the effectiveness of the applied fertilizers. In the 3-day period, the combination treatment of zinc and potassium exhibited a significant difference at the 1% level compared to the control group and other treatments, indicating the high efficiency of this combination in the early stages of growth. However, in comparison with other treatments, this combination did not show a significant difference, with a significance level exceeding 5%, suggesting that its advantage may not be sufficiently notable. These findings highlight the importance of timing and specific combinations of fertilizers in agricultural practices and indicate the need for ongoing monitoring and analysis to optimize fertilization strategies.

A noteworthy point is that the results of this study indicate the role of potassium in increasing the height of wheat plants, while there was no significant difference in terms of yield. In other words, the applied potassium only has a more effective role in increasing height.

Potassium (K) and zinc (Zn) play distinct and essential roles in various physiological

Table 3. Production (ton/ha) of plant in the different treatment

Treatment			Production (ton/ha)
3days	-	Control	2.63±0.09
	K	250 g/ L	4.09±0.09
	Zn	250 g/ L	4.87±0.06
	K and Zn	250 g/ L +250 g/ L	5.65±0.28
6days	Control	Control	2.33±0.08
	K	250 g/ L	3.67±0.08
	Zn	250 g/ L	3.83±0.05
	K and Zn	250 g/L +250 g/ L	4.33±0.23

processes critical for plant growth and development. Potassium is a macronutrient associated with the movement of water, nutrients, and carbohydrates within plant tissues. It is involved in enzyme activation, which affects the production of protein, starch, and adenosine triphosphate (ATP), and it also regulates photosynthesis. Additionally, potassium is crucial for regulating the opening and closing of stomata, which controls the exchange of water vapor, oxygen, and carbon dioxide. Adequate potassium levels enhance root growth, improve drought resistance, maintain turgor, aid in food formation, reduce respiration, enhance sugar and starch translocation, increase protein content, build cellulose, and help retard crop diseases (Sardans & Peñuelas, 2021; Wang et al., 2013). Zinc, on the other hand, is a micronutrient and a key component of various enzymes that drive metabolic reactions in plants. It is essential for growth regulation through the formation of auxins and stem elongation (Umair Hassan et al., 2020). Zinc contributes to carbohydrate, protein, and chlorophyll formation and is necessary for starch formation and proper plant development. It also helps regulate photosynthesis by increasing photosynthetic pigments and soluble sugars, and it plays a role in seed and pollen grain regulation (Hamzah Saleem et al., 2022). Furthermore, zinc is involved in protecting plant cells from damage by reactive oxygen species, acting as a protective agent against oxidation. The simultaneous use of zinc and potassium fertilizers has positive effects on the growth and yield of wheat. These two elements synergistically enhance nutrient uptake, increase plant height, and improve grain quality. Potassium aids in better growth by activating enzymes and facilitating the movement of water and nutrients within the plant, while zinc, as an essential micronutrient, enhances the nutritional quality of grains and prevents yield reduction due to its deficiency (Jat et al., 2014; Bashir et al., 2023). Additionally, increased potassium levels can mitigate the negative effects of phosphorus on zinc uptake, thereby contributing to the overall quality and performance of wheat.

Conclusion

This study highlights the critical roles of potassium (K) and zinc (Zn) in enhancing both the height and yield of wheat plants over specified time intervals. The statistical analysis demonstrated significant differences in plant growth between the 3-day and 6-day treatments, emphasizing the importance of timely nutrient application. Notably, while potassium significantly increased plant height, its impact on yield was not as pronounced when compared to zinc, which showed a notable effect on yield but less influence on height. The combined treatment of K and Zn yielded the most favorable results, suggesting that the synergistic effects of these nutrients are crucial for optimizing wheat growth and production. However, the decline in growth and yield observed in the control group over time underscores the necessity of continuous nutrient management to sustain agricultural productivity. In conclusion, these findings advocate for the strategic integration of potassium and zinc in fertilization practices, tailored to the growth stages of wheat. Ongoing research and monitoring are essential to refine nutrient management strategies, thereby maximizing both the height and yield potential of wheat crops in agricultural systems.

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