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Effect of Saline water Soaking on the Nitrogen, Phosphorus, and Potassium Concentrations of Wheat Leaves Under Salt Stress Conditions

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Abstract

The research was conducted in the Field Crops Department, College of Agriculture, Al-Qasim Green University during the 2025-2026 season. The study was carried out to examine the impact of immersed wheat seeds and irrigation with saline water on growth components of wheat under saline stress conditions. The experiment was composed of two elements, the first one was soaking by saline water and the second was saline water with three distinct qualities (1.45, 5.58 and 10.28 dS m⁻¹). The results showed that soaking or immersed the seeds and irrigating with level 1.45 and 5.58 dS m⁻¹ was significantly increased in the concentrations of nitrogen, phosphorus and potassium in flag leaves of wheat plants. Specifically, the average nitrogen was 2.63 %, phosphorus was 1.60 % and potassium was 2.92 %.

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1. Introduction

Salt stress is an abiotic factor that limits the plant growth and productivity especially in arid and semi-arid regions characterized by limited water resources and accumulation of salts in the soil. Salt stress in wheat plants causes osmotic stress and increase in ionic toxicity by accumulation of sodium and chloride ions. Salt stress also affect uptake and balance of nutrients in the plant. This, in turn, adversely affects the physiological and biological processes involved in growth and yield ^[1, 2]. Salt stress induces ionic imbalance in the plant tissues, the increased sodium uptake may compete with potassium and thus interfere with potassium absorption and transport, it may also impair the roots' ability to acquire nutrients from the soil. Changes in the root environment and the metabolic processes controlling nutrient uptake may also influence the availability of phosphorus and the uptake and use of nitrogen. Wheat's ability to maintain ionic balance, particularly to sustain adequate potassium relative to sodium, is regarded as a key mechanism of salinity tolerance, together with osmotic adjustment and the activation of antioxidant defense systems, as reviewed recently ^[3, 4]. Nitrogen, phosphorus and potassium are major nutrients needed for the growth of wheat plants and efficient accomplishment of their vital biological processes. Nitrogen is a component of amino acids, proteins, nucleic acids and chlorophyll, and contributes to the development of the vegetative biomass and assists in preserving the efficiency of photosynthesis. Phosphorus is essential for energy transfer, the formation of phosphate compounds and nucleic acids, and for cell division and root growth. Potassium is involved in osmotic balance, stomatal opening, enzyme activation, ionic balance within cells, and many other processes. Therefore, the changes in the concentrations of these elements in wheat leaves under saline conditions can reflect the degree of impact on the nutritional status of the plant and its ability to adapt to adverse environmental conditions, because leaves are the main sites of photosynthesis, the levels of nitrogen, phosphorus and potassium in wheat leaves are especially important. Furthermore, their mineral status is indicative of one major aspect of the plant's ability to acquire nutrients and use them in growth processes, the increase of salinity can result in the reduction of some elements concentrations due to the perturbations in their uptake and transport. However, the specific response may vary for different plant cultivar, developmental stage, the severity of salinity and the composition of the saline medium. Furthermore, a change in the

concentration of an element in plant tissue does not necessarily indicate a change in the total amount of that element absorbed by the plant as the concentration is also affected by biomass and tissue growth rate. Therefore, the determination of elemental concentrations in leaves considering the experimental conditions and the growth factors, provides a scientific basis for interpretation of wheat response to salt stress [2, 3]. One of the agricultural methods that can be used to reduce the negative effects of salt stress is the technique of soaking seeds before planting. This method is called seed priming and is the treatment of the seeds with water, salt solutions, or solutions of some chemical compounds for a specific period, then planting the seeds after reaching an appropriate level of hydration. This technology is designed to stimulate early metabolic processes in seeds, to improve the rate and uniformity of germination and to improve the ability of seedlings to establish and grow under adverse environmental conditions. [5]. study showed that the soaking of durum wheat seeds in potassium nitrate or zinc sulfate solutions contributed to the mitigation of the negative effects of salinity on germination and the growth of seedlings, and the response varied according to the variety and the level of salt stress, these results point to the significance of investigating seed soaking treatments as one of the potential ways to enhance wheat performance in salinity affected areas. Therefore, in this context, it is necessary to study the effect of soaking of wheat seeds in saline water on the concentration of nitrogen, phosphorus and potassium in wheat leaves under salt-stress conditions.

2. Materials and methods

2.1. Soil

The fields of Al-Qasim Green University's College of Agriculture were used to select soil, Table (1) shows the results of the soil tests that were done before planting, which included physical and chemical studies. In the fall of 2025 and 2026, the agricultural experiment took place. Before planting wheat of the 'IPA99' variety in an experimental unit measuring 9 m² (dimensions 3 m*3 m), the land was prepared by plowing, leveling, and modifying it. In each unit, a seeding rate of 130 kg per hectare was executed in level rows with 20 cm between rows. The fertilizers were applied during planting at rates of 220 kg of nitrogen, 150 kg of phosphorus, and 160 kg of potassium sulfate per acre, respectively.

Table 1: Physical and Chemical Properties of Soil Before Planting

Properties	Unit	Value
pH _e	----	7.60
Ec _e	dSm ⁻¹	3.78
Ca ⁺²	mmol kg ⁻¹	11.84
Mg ⁺²		6.39
Na ⁺		2.95
K ⁺		0.69
Cl ⁻		13.18
HCO ₃ ⁻		9.45
SO ₄ ⁻		5.86
Sand	g kg ⁻¹	308
Silt		325
Clay		367
Texture of soil		Clay Loam
Bulk Density	Mg m ⁻³	1.28
Organic Matter	g kg ⁻¹	4.76
CaCO ₃	g kg ⁻¹	265.40
Cation Exchange Capacity (CEC)	Cmol.kg ⁻¹	25.73

2.2. Treatments

This study included the following treatments:

Three levels of saline water were utilized: Q1 = 1.45 dSm⁻¹ (river water), Q2 = 5.58 dSm⁻¹, and Q3 = 10.28 dSm⁻¹, derived from high salinity water (drainage water Ec = 19.25 dSm⁻¹). Following the preparation of the three levels of saline water, wheat seeds were immersed in same saline water for 12 hours prior to planting. It is represented by the symbols that follow: S₁, S₂ and S₃. Table 2 presents the chemical analyses of the water quality employed in the study. Water quality was utilized for irrigating wheat based on the usage of 50% of the available water.

Table 2: Chemical Analysis of Saltwater Quality.

Properties	Q1	Q2	Q3	Drainage water	Unit
pH	7.39	7.46	7.23	7.49	---
Ec	1.45	5.58	10.28	19.25	dS m ⁻¹
Ca ⁺²	4.63	14.85	23.05	29.03	mmol L ⁻¹
Mg ⁺²	2.19	8.49	15.33	22.67	
Na ⁺	3.28	15.33	24.63	49.69	
K ⁺	0.18	0.24	0.34	0.59	
Cl ⁻	29.89	39.88	79.54	98.87	
HCO ₃ ⁻	2.32	4.65	10.88	13.25	
SO ₄ ⁼	2.88	5.98	14.58	18.63	

2.3. Study indicators (plant)

Wet digestion process is used for conversion of dry plant leaves into liquid solution. The procedure starts by collecting wheat leaves, particularly the flag leaf. The leaves are then rinsed with distilled water to get rid of any dust or dirt. The leaves are dried in a thermal oven at 65–70 °C to constant weight and then finely ground. Then 0.5 g of the obtained leaf powder are digested using a mixture of concentrated sulfuric acid (H₂SO₄) and perchloric acid (HClO₄). The sample is heated in a digestion block until the solution is completely clear. The solution is diluted to a volume of 50 mL with distilled water in a volumetric flask and after cooling it is ready for analysis. Nitrogen content is determined by Micro-Kjeldhal method, phosphorus is determined spectrophotometrically and potassium is determined by flame photometer [6].

The data for the studied parameters were collected and statistically analyzed using a randomized complete block design with a derivational arrangement for each experiment, and using the Genstat program, the value of the least significant difference (L.S.D) was extracted for each parameter to compare the means of the coefficients at a significance level of 0.05.

Results and Discussion

3. Results and Discussion

3-1. Nitrogen (%)

Table (3) illustrates the significant differences in saltwater quality levels and their effect on the nitrogen leaves under salt stress, demonstrating a negative impact. A level of 10.28 dS m⁻¹ (S₃) resulted in the lowest mean nitrogen leaves, at 1.18%, while the control (a river water) recorded the highest mean nitrogen leaves, at 2.17%. The data indicate a significant effect of using saline water quality, River water recorded the highest mean of nitrogen leaves, at 2.12%, while saline water recorded the lowest mean of nitrogen leaves, at 1.42%.

The interaction treatment, which included soaking and saline water quality, recorded the highest mean of nitrogen leaves, totaling 2.63%, while the interaction treatment recorded the lowest mean of nitrogen leaves, at 0.90 %.

Table 3: Effect of soaking and irrigation water salinity on Nitrogen leaves (%).

Soaking by Quality water (S) (dS m ⁻¹)	Quality water (Q)(dS m ⁻¹)			Effect of Soaking
	Q ₁ =1.45	Q ₂ =5.58	Q ₃ =10.28	
S ₁	2.63	2.14	1.75	2.17
S ₂	2.29	1.81	1.62	1.91
S ₃	1.44	1.20	0.90	1.18
Effect Of Quality Water	2.12	1.72	1.42	
L.S.D _(0.05)	S: 0.002 Q: 0.005 S*Q: 0.008			

3.2. Phosphorus (%)

The results shown in Table (4) indicate significant differences in phosphorus leaves (%) under saline stress conditions. The soaking by (5.58 and 10.28 dS m⁻¹) had the worst effect on phosphorus leaves, reaching 0.2 and 0.3 % Sequentially, while the control (a river water 1.45 dS m⁻¹) recorded the highest mean phosphorus leaves, at 0.8%. The same table also indicates a significant effect of irrigation with saline water quality, where the Q₂ achieved a 0.2%, compared to the Q₃ that recorded least mean phosphorus leaves reached to 0.3%. The interaction effect between soaking and saline irrigation water quality is also significant, the highest mean phosphorus leaves, occurring with the interaction 1.6% and the lowest mean with the interaction 0.1%.

Table 4: Effect of soaking and irrigation water salinity on the phosphorus leaves (%).

Soaking by Quality water (S) (dS m ⁻¹)	Quality water (Q)(dS m ⁻¹)			Effect of Soaking
	Q ₁ =1.45	Q ₂ =5.58	Q ₃ =10.28	
S ₁	1.6	0.4	0.4	0.8
S ₂	0.3	0.3	0.2	0.2
S ₃	0.2	0.1	0.1	0.3
Effect Of Quality Water	0.7	0.2	0.3	
L.S.D _(0.05)	S: 0.28 Q: 0.27 S*Q: 0.47			

3-3. Potassium (%)

The results shown in Table (5) revealed significant differences between soaking quality water, indicating a negative impact on the potassium leaves (%) of wheat grown under saline stress conditions. The 10.28 dS m⁻¹ level recorded the lowest potassium leaves at 1.41%, while the second level quality water 5.58 dS m⁻¹ recorded the highest at 1.85%, this value differ significantly from the control (a river water), which recorded 2.65%.

The same table also indicates a significant effect of using saline water quality on potassium leaves, the highest potassium leaves was recorded at 2.47% by using river water, compared to the lowest at 1.60% with saline water Q₃.

Furthermore, the interaction between treatments showed a significant effect between soaking and saline water quality, with the highest potassium leaves reaching 2.92% and the lowest at 0.93%.

Table 5: Effect of Soaking and irrigation water salinity on the Potassium leaves (%).

Soaking by Quality water (S) (dS m ⁻¹)	Quality water (Q)(dS m ⁻¹)			Effect of Soaking
	Q ₁ =1.45	Q ₂ =5.58	Q ₃ =10.28	
S ₁	2.92	2.74	2.28	2.65
S ₂	2.25	1.71	1.60	1.85
S ₃	2.23	1.06	0.93	1.41
Effect Of Quality Water	2.47	1.84	1.60	
L.S.D _(0.05)	S: 0.020 Q: 0.053 S*Q: 0.077			

It is shown (see tables above) that pre-treatment of wheat seeds in saline solutions, saline irrigation causes a reduction in nitrogen concentration in wheat leaves due to the effect of salinity on osmotic stress and ionic imbalance, which disrupts nitrogen uptake and assimilation in the plant, high salt concentrations in the root zone can inhibit water uptake, affect root growth, the activity of ion transporters and the efficiency of nutrient translocation into the aerial parts of the plant, Furthermore, salinity may disrupt nitrate reduction and nitrogen assimilation into amino acids and proteins, influencing nitrogen concentrations in the leaves [2]. This was supported by the experimental study of [7] on wheat plants under sodium chloride stress which revealed that salinity disturbs nitrogen metabolism, the study also found that potassium addition improved nitrogen uptake and assimilation and decreased the sodium to potassium ratio. These results suggest a physiological relationship of ionic homeostasis and nitrogen use efficiency of wheat plants under salt stress. The effect of salinity on phosphorus concentration in wheat leaves, the decline in leaf phosphorus concentration might be due to changes in root growth and nutrient uptake under saline conditions, as well as the effects of salinity on the availability and mobility of phosphorus in the soil. Phosphorus is a crucial element for the generation of energy carriers like ATP and plays a role in metabolism and root growth. Therefore, a deficit in the supply or uptake of phosphorus can restrict the efficiency of plant growth and development. In their review on salinity tolerance in wheat, [2] observed that salt stress causes disturbances in ionic balance and affects the uptake of mineral elements and physiological processes associated with plant growth. This view could explain the observed decrease in phosphorus levels, and note that the effect of salinity on phosphorus availability is also dependent on soil characteristics and the composition of the irrigation water.

Regarding the effect of salinity on potassium concentration in wheat leaves, a decrease in potassium levels is an important potential response to salt stress, this is because of the important role of potassium in osmotic potential, enzyme activation, ionic balance and stomatal function. Saline water treatment, especially high sodium water, might negatively affect the uptake of potassium and its movement to the leaves in wheat plants. This is because of interference with ion

transport mechanisms and the physiological competition of sodium and potassium ions. According to ^[2], sodium accumulation in plant tissues may affect the uptake of potassium. Moreover, maintaining a proper $K^+:Na^+$ ratio is a major mechanism of salinity tolerance in wheat. This balance can be disrupted, which can impair cellular functions and processes related to growth and photosynthesis. These findings agree with the results of ^[7] who found that potassium supplementation in wheat plants improved ionic balance and nitrogen uptake under salt stress. This highlights the significance of the interaction between potassium and nitrogen when considering wheat response to salinity rather than the diminishment of each element as a response entirely independent of the other.

Seed priming in saline water and subsequent irrigation with the same water provides a sequential exposure to salt stress, the response begins with the water-uptake and germination stages of the seed and continues after sowing as the roots are exposed to saline irrigation water, this can affect radicle growth, root system development, ionic balance and the efficiency of nutrient uptake ^[8]. studied the impacts of different wheat seed priming methods on germination and emergence under different levels of salinity. Their findings showed that the priming effect is dependent on the priming agent and salinity level. Some priming treatments were successful in improving germination and seedling growth under salt-stress conditions.

Moreover, the use of water of different quality and electrical conductivity can help to meet the plant's nutritional requirements. Dissolved ions in saline water, such as calcium, potassium and sulfates (Table 2), can help the plant to resist salt stress ^[9, 10].

Conclusions

Salinity reduced the concentration of nitrogen, phosphorus and potassium in wheat leaves, which could be attributed to the negative effect of salt stress on the nutrient uptake and balance within the plant. This decrease in nutrient concentration could be related to the effect of salinity on root growth and the efficiency of the roots to absorb nutrients and translocate them to the leaves. The combination of seed priming with saline irrigation of the same composition might lead to the plant being subjected to continuous salt stress – from germination to subsequent growth stages – because the response of nutrient elements depends on the salinity level, the type of salts and the specific growing conditions.

Conflict of Interest

The authors declare no conflict of interest.

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