



Article

The Effect of Salinity Levels and Potassium Fertilization on the Growth of Durum Wheat (*Triticum durum* L.)

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Abstract: The experiment was conducted in the fields of the College of Agriculture at the University of Tikrit, using a completely randomized block design (RCBD), with the aim of studying the effect of salinity levels and potassium fertilizer application on the germination and growth of durum wheat. The experiment included two factors: the first was salinity levels (9, 6, 3) dS/m (S3, S2, S1), respectively, and the second was potassium fertilizer application rates (80, 60, 40, 0 kg K₂O/ha) (K4, K3, K2, K1), respectively. The results showed that higher salinity levels caused a significant decrease in most of the studied traits except for the number of spikes. As for potassium fertilizer application, the (K4) treatment significantly outperformed the others by yielding the highest averages for germination rate (88.4%) and dry weight of the total aboveground biomass (0.049 and 0.36 g for the two treatments, respectively), leaf area (16.90 and 54.40 cm² for the two treatments, respectively), and number of spikes (2.26 spikes/plant), except for the number of tillers. The interaction between the study factors was significant for all traits studied.

Keywords: salinity, potassium fertilizer, wheat.

1. Introduction

Soil salinity is one of the most serious problems facing agriculture in Iraq, particularly in the central and southern regions. This problem hinders agricultural production, as most agricultural lands are subject to varying degrees of salinization due to prevailing climatic conditions such as high temperatures and evaporation, as well as the salinity of irrigation water, vegetation cover, land topography, high groundwater levels, poor soil and water management, and the lack of effective drainage and irrigation networks, among other factors. Its impact on plants is evident through its accumulation in the soil [1]. Soil salinity is considered a major obstacle to sustainable agricultural development, as it imposes severe physiological stress on plants that goes beyond mere water deficiency; As a result, plants face a dual stress: osmotic stress immediately begins by reducing the roots' ability to absorb water, placing the plant in a state of physiological thirst even in the presence of moisture. This is followed in the long term by ionic toxicity, where the excessive accumulation of sodium and chloride ions in plant tissues leads to the impairment of vital metabolic processes, ranging from the destruction of the photosynthetic system and the inhibition of vital enzyme activity to the disruption of cell membranes and the formation of harmful free radicals, which limit the plant's productivity and restrict its growth and development [2].

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The effects of salinity extend to intracellular oxidative stress, ultimately leading to a sharp decline in vegetative growth rates and a marked deterioration in yield indicators (such as grain weight and fruit number). The plant is forced to expend its energy on defense and tolerance mechanisms at the expense of productivity. [3]. Salinity clearly affects growth, physiological traits, and yield characteristics in both salt-sensitive and salt-tolerant plants, resulting in a reduction in the number of branches, dry weight, and relative growth rate in salt-sensitive plants compared to salt-tolerant ones [4]. Furthermore, the application of fertilizers in saline soils has played an important role in increasing yield [5]. Potassium is also a key component in wheat's strategy for adapting to salt stress, as the balanced application of potassium fertilizers makes a vital physiological contribution to counteracting the toxic effects of salts. The mechanism of action of potassium is based on the principle of ionic competition; sufficient concentrations of potassium in the root nutrient medium reduce the uptake of harmful sodium ions and limit their accumulation within the cytoplasm, thereby maintaining cell membrane stability and preventing ionic imbalance. In addition, potassium acts as an active osmotic solute within the cell; maintaining a high concentration of it enhances the plant's ability to lower its water potential, thereby facilitating water uptake from saline soil. Potassium does not merely play a role in osmotic regulation but also improves the process of photosynthesis. It activates biological enzymes and enhances the activity of antioxidants that protect wheat cells from oxidative stress caused by salinity, making it an indispensable component of crop management in areas affected by salinization [6]. The addition of potash fertilizers promotes plant growth, alleviates soil salinity, and increases drought tolerance [7]. Wheat is a crop that is sensitive or moderately sensitive to salinity, and its growth and yield are affected by this factor; therefore, finding ways to reduce the negative effects of salinity on this crop—including the use of fertilizers, particularly potassium fertilizers—is an important means of improving its performance under saline stress conditions. Therefore, the objective of this study is to determine the effect of both salinity levels and potassium fertilization levels on wheat germination and growth.

2. Materials and Methods

The experiment was conducted in the fields of the College of Agriculture at the University of Tikrit during the 2025–2026 winter season to study the effect of applying different levels of salinity and potassium fertilizer on the germination and growth of durum wheat (variety Dor-29). The experiment was conducted using a completely randomized block design (RCBD) with three replicates, involving two factors: the first factor was the addition of three salinities levels—3, 6, and 9 dS/m. The second factor involved the addition of four levels of potassium fertilizer. The experiment used non-perforated plastic pots with a capacity of 2 kg of soil, filled with a salt-amended mixed soil, where the soil was salinated to the desired levels using diluted brine at levels of 3, 6, 9 decisemens/m (S3, S2, S1). The soil was sprayed with this solution to achieve the three salinity levels, following the method described by [8]. Potassium fertilizer was added to the beds and mixed with the soil one day before planting at rates of 80, 60, 40, and 0 kg of potassium per hectare (K4, K3, K2, K1). The amount added was then calculated based on the bed area. Twenty (20) durum wheat seeds were planted in each bed on November 25, 2025; the seeds were obtained from the Seed Technology Center of the Ministry of Science and Technology. The experiment was irrigated with equal amounts of water for all beds.

The following traits were studied in the experiment:

- 1) **Germination percentage:** calculated by dividing the number of plants visible above the soil surface by the number of seeds sown.
- 2) **Dry weight of the total aboveground biomass at two stages:** This was determined by selecting three plants and drying them in an electric oven at 70°C for 48 hours, one month and two months after germination.

- 3) **Leaf area:** by measuring the length and maximum width of the leaf one month and two months after germination, and calculating the leaf area using the following equation [8, 14]:

$$\text{Leaf area (cm}^2\text{)}: \text{Leaf length} \times \text{maximum width} \times 0.95 \dots\dots\dots(1)$$
- 4) **Number of branches per plant:** Calculated as the average number of branches for three plants from each treatment.
- 5) **Number of spikes per plant:** Calculated by counting the number of spikes on three plants from each treatment.
- 6) The data were statistically analyzed according to the experimental design used, and significant differences were tested using Duncan's multiple-range test at a significance level of 0.05.

3. Results and Discussion

3.1 Percentage of germination (%)

Table (1) shows that salinity levels had a significant effect on the germination percentage and contributed to a significant decrease in this trait as salinity increased; treatment level (9) (9 dS/cm, S3) had the lowest germination percentage, which was 75.27%. This may be attributed to the direct effects of salts on the plant, which include osmotic effects and salt toxicity; this leads to impaired water uptake into the seeds and hinders the process of water absorption and the necessary metabolic transformations of the nutrients present in the endosperm due to increased osmolarity in the soil solution and the high salt concentration. Furthermore, increased salt levels resulting from higher salinity led to a higher concentration of harmful salts within the seed. This increase contributed to seed toxicity by inhibiting cell division and metabolic processes in the seed, resulting in a reduction in seed germination rates and the emergence of seedlings from the soil [9]. Higher potassium levels helped reduce the negative effects of salinity, as the germination rate increased significantly with rising potassium levels; treatment (K4) yielded the highest germination rate of 88.4%. This effect may result from potassium's role in increasing osmotic pressure within the seeds, which facilitates water absorption and induces changes in the nutrient supply for embryo development. Furthermore, potassium reduced the toxic effect by competing for the absorption of harmful salt components, particularly sodium; this is consistent with [10, 11].

A significant interaction was observed between salinity levels and potassium levels; the interactions (K4S1, K2S1, K1S1) yielded the highest germination rate of 95%, while the lowest rate was 65.5% in the K1S3 treatment.

Table 1. Effect of salinity levels and potassium fertilization on the percentage of germination

Salinity Levels	Potassium Levels				Mean
	K1	K2	K3	K4	
S1	95 ^a	95 ^a	90 ^{ab}	95 ^a	93.7 ^a
S2	80 ^c	80 ^c	85 ^{ab}	86.6 ^b	82.9 ^b
S3	65.6 ^e	71.6 ^d	80.3 ^{bc}	83.6 ^{bc}	75.27 ^c
Mean	80.2 ^c	82.2 ^{bc}	85.1 ^{ad}	88.4 ^a	

3.2 Dry weight of the total vegetative mass (g)

Table (2) shows that increasing the salinity level resulted in significant differences in the dry weight of the total vegetative mass, as the dry weight of the plants harvested after one and two months decreased with increasing salinity, and treatment level (9) Deci-Semenz had the lowest dry weight, at 0.0394 and 0.288 (g) for the two time points, respectively, while the treatment at salinity level (3) Deci-Semenz outperformed the others in this trait at both time points. This may be due to the fact that increased salt levels inhibit

absorption by raising soil osmotic pressure, leading to a nutritional imbalance, which in turn affects growth processes and dry matter accumulation [12]. Potassium had a positive effect on plant dry weight under saline stress, as significant differences were observed between fertilizer levels and their effects on this trait; the (K4) treatment outperformed the others by yielding the highest dry weight at both dates, and this treatment did not differ from the (K3) treatment at the second measurement date. This may be attributed to the fact that potassium has a positive effect on promoting photosynthesis, nutrient uptake, carbohydrate synthesis, and the formation of proteins and nucleic acids, as well as maintaining ionic balance, all of which contribute to an increase in dry matter and its accumulation. This is consistent with the findings of [13]. A significant interaction was observed between salinity levels and potassium fertilization levels at both time points, and the two treatments (K3S1 and K4S2) yielded the highest dry weight, amounting to 0.056 g at the first time point, while treatment (K3S1) in the second experiment, with a dry matter weight of 0.466 g.

Table 2. Effect of Salinity Levels and Potassium Fertilization on the Dry Matter Weight of the Vegetative Mass (g) of Wheat

Salinity Levels	First Date				
	Potassium Levels				
	K1	K2	K3	K4	Mean
S1	0.039 ^b	0.043 ^b	0.056 ^a	0.038 ^b	0.044 ^a
S2	0.038 ^b	0.041 ^b	0.050 ^a	0.056 ^a	0.046 ^a
S3	0.038 ^b	0.031 ^c	0.033 ^c	0.055 ^a	0.039 ^a
Mean	0.038 ^c	0.083 ^c	0.046 ^b	0.049 ^a	

Salinity Level	Second Date				
	Potassium Levels				
	K1	K2	K3	K4	Mean
S1	0.338 ^c	0.313 ^d	0.466 ^a	0.386 ^c	0.374 ^a
S2	0.296 ^e	0.343 ^c	0.323 ^d	0.403 ^b	0.341 ^b
S3	0.260 ^f	0.226 ^{fg}	0.346 ^c	0.323 ^d	0.288 ^c
Mean	0.298 ^b	0.294 ^b	0.378 ^a	0.368 ^a	

3.3 Leaf Area (cm²)

Significant differences were observed in the leaf area of the wheat plants measured at both dates, influenced by salinity levels and potassium fertilization levels. Treatment S1 outperformed the others at both time points, yielding the highest leaf area of 17.18 and 50.34 cm² respectively (Table 3), noting that this treatment (S1) did not differ significantly from treatment (S2) at the second time point. This may be due to the role of salts in inhibiting biological processes, including elongation, turgor, and leaf tissue growth, which leads to a reduction in leaf area with increasing salinity.

As for potassium levels, they led to an increase in leaf area, and treatment (K4) the highest averages for this trait, with values of 16.90 cm² for the first measurement and 54.40 cm² for the second measurement (Table 3), as potassium increases turgor and elongation, thereby reducing the effects of salinity [14]. A significant interaction was observed between salinity levels and potassium fertilization levels on leaf area at both sampling dates; treatment (K3S1) yielded the highest value (18.74 cm²) at the first sampling date, while treatment (K4S2) yielded the highest value (59.19 cm²) at the second sampling date (Table 3).

Table 3. Effect of salinity levels and potassium fertilization on leaf area (cm²) of wheat

Salinity Levels	First Date				
	Potassium Levels				
	K1	K2	K3	K4	Mean
S1	15.71 ^b	15.68 ^b	18.74 ^a	18.61 ^a	17.18 ^a
S2	13.21 ^c	13.59 ^c	17.34 ^a	17.11 ^a	15.31 ^b
S3	6.21 ^e	8.38 ^d	9.33 ^d	14.99 ^b	9.73 ^c
Mean	11.71 ^c	12.55 ^c	15.14 ^b	16.90 ^a	

Salinity Levels	Second Date				
	Potassium Levels				
	K1	K2	K3	K4	Mean
S1	46.51 ^c	47.21 ^c	53.07 ^b	54.59 ^b	54.34 ^a
S2	44.11 ^d	49.3 ^c	47.53 ^c	59.19 ^a	50.03 ^a
S3	31.33 ^e	34.43 ^e	42.76 ^d	49.43 ^{bc}	39.48 ^b
Mean	40.65 ^c	43.64 ^c	47.78 ^b	54.40 ^a	

3.4 Number of tillers and number of spikes per plant

Salinity levels had a significant effect on the number of branches but did not significantly affect the number of spikes (Table 4). Treatment (S1) yielded the highest number of branches (4.66 per plant), while treatment (S3) yielded the lowest (3.40 per plant). Potassium fertilization, however, did not significantly affect the number of tillers per plant but did significantly affect the number of spikes per plant, with treatment (K4) yielding the highest value for the number of spikes at 2.26 spikes per plant. A significant interaction was observed for both traits; treatments K3S1 and K4S2 yielded the highest number of branches at 4.6 branches per plant, while treatment K4S2 yielded the highest number of spikes per plant at 2.46 spikes per plant.

Table 4. Effect of salinity levels and potassium fertilization on the number of branches and the number of spikes per plant.

Salinity Levels	First Date				
	Number of branch				
	Potassium Levels				
	K1	K2	K3	K4	Mean
S1	5.21 ^a	5.26 ^a	4.2 ^b	4.0 ^b	4.66 ^a
S2	4.32 ^b	4.16 ^b	4.6a ^b	4.6a ^b	4.42 ^a
S3	3.06 ^c	3.46 ^c	3.3 ^c	3.8 ^c	3.40 ^b
Mean	4.2 ^a	4.29 ^a	4.03 ^a	4.13 ^a	

Salinity Levels	Second Date				
	Number of branch				
	Potassium Levels				
	K1	K2	K3	K4	Mean
S1	2.0 ^b	1.8 ^b	2.0 ^b	2.2 ^a	2.0 ^a
S2	1.85 ^b	2.06 ^b	1.6 ^c	2.46 ^a	1.99 ^a
S3	1.71 ^c	1.66 ^c	1.4 ^c	2.13 ^a	1.72 ^a
Mean	1.58 ^b	1.84 ^b	1.66 ^b	2.26 ^a	

From the above, we conclude that elevated salinity levels caused a clear decline in most growth traits of durum wheat, and that potassium fertilization plays a key role in

mitigating the harmful effects of salinity by improving growth traits through its positive impact on all vital processes within the seed and the plant.

4. Conclusions

This study clearly demonstrates the significant challenges posed by increasing soil salinity levels to the growth and vitality of durum wheat (*Triticum durum* L.), as high salinity levels resulted in a clear and significant decrease in most of the growth parameters studied (such as the percentage of germination, total shoot dry weight, leaf area, and number of tillers), as a result of the osmotic stress and toxic effects caused by salts, which hinder vital processes and the normal uptake of water and nutrients.

In contrast, potassium fertilization demonstrated high efficacy and played a crucial strategic role in mitigating these negative effects and alleviating a significant portion of salt-induced stress; high potassium treatments, particularly the highest level (K_4)—to a significant improvement in the efficiency of physiological processes within the plant and seeds, leading to enhanced germination rates, increased dry matter accumulation, expanded leaf area, and a higher number of spikes per plant.

Accordingly, this study concludes that the application of potassium fertilizer at adequate levels is a vital and necessary agronomic management practice for mitigating the damage caused by soil salinization, thereby contributing to enhancing wheat plants' tolerance to salt stress and improving their yield and growth performance in areas affected by salinization.

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