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# *The impact of potassium chloride (KCl) on germination and seedling growth of Aegilops neglecta Req. ex Bertol.: implications for salinity tolerance*

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**Abstract.** Soil salinity poses a significant threat to global agriculture, impacting crop productivity and land sustainability. Understanding the mechanisms of salt tolerance in wild relatives of crops holds the key to developing salt-resilient varieties. This study investigates the effects of potassium chloride (KCl), a common salt contributing to soil salinity, on the germination and seedling growth of *Aegilops neglecta* Req. ex Bertol, a wild relative of wheat. Seeds were subjected to varying concentrations of KCl (0 mM, 50 mM, 100 mM, 150 mM, 200 mM, 250 mM, and 300 mM) in controlled laboratory conditions. Germination percentage, germination rate, seedling length (shoot and root), and seedling dry weight were assessed. The results revealed a concentration-dependent inhibitory effect of KCl on all measured parameters. KCl significantly inhibits the germination and seedling growth in the studied genotypes of *A. neglecta* Req. ex Bertol. The observed reductions in germination percentage, germination rate, root length, shoot length, and biomass accumulation are indicative of the stressful effects of KCl on plant development. However, *Aegilops neglecta* exhibits some degree of tolerance to KCl stress, suggesting the presence of underlying salt tolerance mechanisms. Based on the integrated analysis of tolerance and susceptibility indices, genotype BGR43687 was identified as highly tolerant to salinity stress, suggesting its potential utilization as a valuable source for salt tolerance genes in wheat breeding programs.

**Key words:** *Aegilops neglecta* Req. ex Bertol., KCl, salinity, germination, seedling growth, salt stress.

## Introduction

Soil salinity is a major environmental constraint affecting agricultural productivity worldwide, particularly in arid and semi-arid regions (Tarolli et al., 2024). The accumulation of soluble salts in the soil inhibits plant growth through osmotic stress, ion toxicity, and nutrient imbalance (Pandit et al., 2024). The continuous use of irrigation water, coupled with poor drainage and inappropriate agricultural practices, exacerbates the problem, leading to significant economic losses and threatening food security (Parra-López et al., 2025; Balasubramanya & Stifel, 2020).

Potassium chloride (KCl) is a significant contributor to soil salinity in many agricultural areas (Pereira et al., 2019). While potassium is an essential macronutrient for plant growth, excessive concentrations of $Cl^-$ ions can be toxic, disrupting cellular processes and hindering plant development (Johnson et al., 2022). Therefore, understanding the effects of KCl on plant physiology is crucial for developing effective strategies to mitigate the impact of salinity.

Wheat (*Triticum aestivum* L.) is a staple food crop globally, providing a significant portion of the world's calorie and protein intake. However,

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wheat is moderately sensitive to salinity, and its productivity is severely compromised in salt-affected areas (EL Sabagh et al., 2021). Wild relatives of wheat, such as the *Aegilops* species, represent a valuable genetic resource for improving salt tolerance in cultivated wheat (Gorham et al., 1985). *Aegilops* species exhibit considerable genetic diversity and have adapted to various environmenttal stresses, including salinity.

*Aegilops neglecta* Req. ex Bertol. is an annual diploid (2n = 4x = 28) species belonging to the *Aegilops* genus. It is found mostly in the Mediterranean area and Western Asia (Baik et al., 2017). *A. neglecta* Req. ex Bertol. is known for its drought resistance and is a potential source of genes for improving abiotic stress tolerance in wheat (Pour-Aboughadareh et al., 2021). However, information regarding the salt tolerance of *Aegilops neglecta* Req. ex Bertol., particularly its response to specific salt types like KCl, is limited.

Seed germination and seedling establishment are critical stages in the plant life cycle and are highly sensitive to environmental stresses, including salinity (Ghosh et al., 2025). Salt stress can inhibit seed germination by reducing water uptake and disturbing enzymatic activities necessary for the mobilization of stored reserves (Ali et al., 2024). Similarly, seedling growth is severely affected by salinity due to impaired photosynthesis, nutrient uptake, and protein synthesis (Muhammad et al., 2024).

This study aimed to investigate the effects of varying KCl concentrations on the germination and seedling growth of *Aegilops neglecta* seeds.

## Materials and methods

### *Seed material*

Seeds from five *Aegilops neglecta* accessions were obtained from the National Genebank of Bulgaria's working collection (Table 1). Seeds from each accession were selected for uniformity of size and appearance to minimize variations in germination potential.

**Table 1.** Geographical coordinates of collected and included in the study *Aegilops neglecta* Req. ex Bertol. genotypes

| № of accessions | Latitude | Longitude | Altitude | Origin |
|---|---|---|---|---|
| BGR43668 | 41°48'44'' | 25°37'14'' | 225 | BGR |
| BGR43678 | 41°46'36'' | 25°20'33'' | 485 | BGR |
| B8000063 | 48°43'48.36'' | 2°18'6.84'' | 35 | FRA |
| BGR43479 | 41°41'58'' | 25°38'11'' | 432 | BGR |
| BGR43706 | 41°59'29'' | 24°54'36'' | 277 | BGR |

### *Experimental design*

The experiment was conducted using a completely randomized design with seven treatments and two replicates per treatment. The treatments consisted of different concentrations of KCl: 0 mM KCl (Control), 50 mM KCl, 100 mM KCl, 150 mM KCl, 200 mM KCl, 250 mM KCl, and 300 mM KCl. KCl solutions were prepared by dissolving analytical grade KCl in distilled water.

### *Germination assay*

Two replicates of 50 surface-sterilized seeds (soaked in 1% sodium hypochlorite for 5 minutes, followed by rinsing with distilled water) were placed on two layers of filter paper with 20 ml of the test solutions. The paper with the seeds was placed in plastic bags to prevent water loss and incubated in a growth chamber with controlled conditions: 20°C temperature, 16/8-hour light/dark photoperiod, and 60% humidity. Germination was scored daily for 14 days. A seed was considered germinated when the radicle protruded at least 2 mm. The following germination characteristics were recorded:

1. Germination Percentage (GP): Calculated as the percentage of seeds that germinated at the end of the experiment: GP = (Number of germinated seeds / Total number of seeds) x 100.
2. Germination Rate index (GRI): Calculated using the formula: GRI = $\Sigma$ (Ni / Di), where Ni is the number of seeds germinated on day i and Di is the number of days from the start of the experiment to day i. A higher GRI indicates a faster germination rate.

3. Mean Germination Time (MGT): Calculated as: MGT = Σ (Ni x Di) / Σ Ni, where Ni is the number of newly germinated seeds on day i, and Di is the number of days from the start of the experiment (Kader, 2005). A lower MGT indicates faster germination.

### *Seedling growth assay*

After 14 days, 10 randomly selected seedlings from each replicate were used to measure the following growth parameters:

1. Root length: Measured from the point of radicle emergence to the tip of the longest root using a ruler (mm).
2. Shoot length: Measured from the point of coleoptile emergence to the tip of the longest leaf using a ruler (mm).
3. Fresh shoot and root weight: Measured immediately after harvesting the seedlings using a precision balance (mg).
4. Dry shoot and root weight: Seedlings were dried in an oven at 80°C for 24 hours until constant weight was achieved, and then weighed using a precision balance (mg).

The method described by Islam & Karim (2010) was used to determine seedling height reduction.

### *Statistical analysis*

Data were subjected to analysis of variance (ANOVA) using SPSS software (version 22). Significant differences between treatment means were determined using Duncan´s multiple range test.

To characterize the response of the genotypes at different salinities and select the most tolerant genotype, the following tolerance and susceptibility indices were calculated using the user-friendly online iPASTIC software: Relative Stress Index (RSI), Mean Productivity (MP), Harmonic Mean (HM), Yield Stability Index (YSI), Geometric Mean Productivity (GMP), Stress Susceptibility Index (SSI) and Stress Tolerance Index (STI), as well as the Yield Index (YI) (Pour-Aboughadareh et al., 2019).

## Results

### *Effects of KCl on germination characteristics*

The results showed a significant ($p < 0.05$) effect of KCl concentration on the germination percentage, germination rate, and mean germination time of *A. neglecta* seeds (Table 2). The highest germination percentage (85%) and germination rate (37.5 % day$^{-1}$) were observed in the control treatment (0 mM KCl) for BGR43687 and BGR43678, respectively. As the KCl concentration increased, both germination percentage and germination rate decreased significantly. At 200 mM KCl, the germination percentage was reduced from 45% (BGR43687) to 0% (BGR43668 and BGR43706), and the germination rate was between 8.59% day$^{-1}$ (BGR43687) and 0% day$^{-1}$ (BGR43668 and BGR43706). At the highest salinity levels of 250-300 mM KCl, only BGR43687 recorded germinated seeds. The other four samples had statistically proven null values for these parameters.

The mean germination time (MGT) increased significantly with increasing KCl concentrations ($p < 0.05$), indicating a delay in germination under higher levels of salt stress. It ranged from 2.31 days for BGR43678 in the control to 8.33 days in the variant with 300 mM KCl (Table 2).

### *Effects of KCl on seedling characteristics*

KCl also significantly affected the seedling growth parameters of *A. neglecta* ($p < 0.05$). Both root and shoot lengths decreased significantly with increasing KCl concentration. In general, the reduction in shoot length was greater than the reduction in root length. As illustrated in Table 3, there was significant variation in the root and shoot height reductions (RHR, ShHR), respectively, of the studied genotypes, when treated with different doses of KCl. BGR43479 exhibited the lowest RHR, while BGR43678 exhibited the lowest ShHR and SHR at 50 mM KCl. At 100 mM KCl, the mean root growth inhibition was 0.34, and the shoot growth inhibition was 0.45. BGR43678 showed the lowest values for all three parameters. At 150 mM KCl, root growth inhibition was between 41% and 55%, while shoot growth inhibition was between 29% and 100%. BGR43678 had the lowest value at the root, while the lowest degree of shoot growth suppression was recorded at BGR43687. At 200 mM KCl, root height reduction was between 61% (BGR43479) and 75% (BGR43687), while shoot growth suppression was between 57% (BGR43687) and 100% (BGR43668, BGR43706). At salinity levels of 250-300 mM KCl, the degree of root growth suppression ranged from 0.75 (BGR43678, 250 mM KCl) to 1.00 (300 mM KCl, BGR43678, BGR43479, and BGR43706). The extent of inhibition of root and shoot growth was lowest with BGR43687 (250-300 mM KCl) (Table 3).

**Table 2.** Influence of salinization with KCl on germination characteristics in 5 populations of *Aegilops neglecta* Req. ex Bertol.

| № of accessions | Concentration of KCl, mM | GRI, % day$^{-1}$ | MGT, day | G,% |
|---|---|---|---|---|
| BGR43668 | 0 | 34.58b | 2.43b | 80.00b |
| BGR43678 | 0 | 37.5b | 2.31b | 80.00b |
| BGR43687 | 0 | 36.25b | 2.54b | 85.00c |
| BGR43479 | 0 | 25.21a | 3.28a | 70.00a |
| BGR43706 | 0 | 28.00a | 3.50a | 70.00a |
| **Average** | | **32.31** | **2.82** | **77.00** |
| BGR43668 | 50 | 18.00b | 3.91b | 60.00b |
| BGR43678 | 50 | 25.83c | 2.50a | 60.00b |
| BGR43687 | 50 | 29.58c | 2.73a | 75.00c |
| BGR43479 | 50 | 15.47b | 5.33c | 60.00b |
| BGR43706 | 50 | 7.84a | 6.12c | 45.00a |
| **Average** | | **19.35** | **4.12** | **60.00** |
| BGR43668 | 100 | 12.91c | 4.20c | 50.00bc |
| BGR43678 | 100 | 20.83d | 3.46b | 55.00bc |
| BGR43687 | 100 | 17.16d | 3.81bc | 60.00c |
| BGR43479 | 100 | 8.72b | 6.50d | 45.00b |
| BGR43706 | 100 | 0.00a | 0.00a | 0.00a |
| **Average** | | **11.93** | **3.60** | **42.00** |
| BGR43668 | 150 | 4.97b | 6.33c | 30.00b |
| BGR43678 | 150 | 12.38c | 4.16b | 40.00b |
| BGR43687 | 150 | 14.26c | 4.50b | 60.00c |
| BGR43479 | 150 | 4.68ab | 6.66c | 30.00b |
| BGR43706 | 150 | 0.00a | 0.00a | 0.00a |
| **Average** | | **7.26** | **4.33** | **32.00** |
| BGR43668 | 200 | 0.00a | 0.00a | 0.00a |
| BGR43678 | 200 | 7.71c | 5.08b | 35.00c |
| BGR43687 | 200 | 8.59c | 5.45b | 45.00d |
| BGR43479 | 200 | 2.84b | 7.75c | 20.00b |
| BGR43706 | 200 | 0.00a | 0.00a | 0.00a |
| **Average** | | **3.83** | **3.66** | **20.00** |
| BGR43668 | 250 | 0.00a | 0.00a | 0.00a |
| BGR43678 | 250 | 0.00a | 0.00a | 0.00a |
| BGR43687 | 250 | 5.92b | 7.85b | 35.00b |
| BGR43479 | 250 | 0.00a | 0.00a | 0.00a |
| BGR43706 | 250 | 0.00a | 0.00a | 0.00a |
| **Average** | | **1.19** | **1.57** | **7.00** |
| BGR43668 | 300 | 0.00a | 0.00a | 0.00a |
| BGR43678 | 300 | 0.00a | 0.00a | 0.00a |
| BGR43687 | 300 | 3.09b | 8.33b | 20.00b |
| BGR43479 | 300 | 0.00a | 0.00a | 0.00a |
| BGR43706 | 300 | 0.00a | 0.00a | 0.00a |
| **Average** | | **0.62** | **1.66** | **4.00** |

Germination (G, %), Germination rate index (GRI, % day$^{-1}$), Mean germination time (MGT, day)
Means followed by different letters within a column are significantly different at $p < 0.05$ (Duncan's Multiple Range Test).

**Table 3.** Variation in the degree of reduction of shoot, root, and seedling length at different levels of salinity with KCl in five populations of *Aegilops neglecta* Req. ex Bertol.

| **№ of accessions** | **Concentration of KCl, mM** | **RHR** | **ShHR** | **SHR** |
|---|---|---|---|---|
| BGR43668 | 50 | 0.15a | 0.32c | 0.25b |
| BGR43678 | 50 | 0.18a | 0.03a | 0.10a |
| BGR43687 | 50 | 0.29b | 0.14b | 0.22b |
| BGR43479 | 50 | 0.14a | 0.41c | 0.27b |
| BGR43706 | 50 | 0.19a | 0.61d | 0.39c |
| **Average** | | **0.19** | **0.31** | **0.25** |
| BGR43668 | 100 | 0.39a | 0.45ab | 0.43a |
| BGR43678 | 100 | 0.24a | 0.19a | 0.22a |
| BGR43687 | 100 | 0.44a | 0.23a | 0.34a |
| BGR43479 | 100 | 0.37a | 0.62b | 0.49a |
| BGR43706 | 100 | 0.25a | 0.74b | 0.48a |
| **Average** | | **0.34** | **0.45** | **0.40** |
| BGR43668 | 150 | 0.42a | 0.66b | 0.55b |
| BGR43678 | 150 | 0.41a | 0.30a | 0.35a |
| BGR43687 | 150 | 0.55a | 0.29a | 0.43a |
| BGR43479 | 150 | 0.49a | 0.78c | 0.63bc |
| BGR43706 | 150 | 0.46a | 1.00d | 0.71c |
| **Average** | | **0.47** | **0.61** | **0.54** |
| BGR43668 | 200 | 0.73b | 1.00d | 0.88d |
| BGR43678 | 200 | 0.66a | 0.68b | 0.67a |
| BGR43687 | 200 | 0.75b | 0.57a | 0.67a |
| BGR43479 | 200 | 0.61a | 0.87c | 0.73b |
| BGR43706 | 200 | 0.65a | 1.00d | 0.81c |
| **Average** | | **0.68** | **0.83** | **0.76** |
| BGR43668 | 250 | 0.84ab | 1.00b | 0.93b |
| BGR43678 | 250 | 0.75a | 1.00b | 0.87b |
| BGR43687 | 250 | 0.81ab | 0.64a | 0.73a |
| BGR43479 | 250 | 0.93b | 1.00b | 0.96b |
| BGR43706 | 250 | 0.83ab | 1.00b | 0.91b |
| **Average** | | **0.84** | **0.93** | **0.89** |
| BGR43668 | 300 | 0.88b | 1.00b | 0.94b |
| BGR43678 | 300 | 1.00c | 1.00b | 1.00c |
| BGR43687 | 300 | 0.84a | 0.72a | 0.79a |
| BGR43479 | 300 | 1.00c | 1.00b | 1.00c |
| BGR43706 | 300 | 1.00c | 1.00b | 1.00c |
| **Average** | | **0.94** | **0.95** | **0.95** |

RHR-relative root height reduction, ShHR- relative shoot height reduction, SHR - relative seedling height reduction
Means followed by different letters within a column are significantly different at $p < 0.05$ (Duncan's Multiple Range Test).

Fresh and dry weights of roots and shoots were also significantly reduced by KCl treatment ($p < 0.05$) (Fig. 1). The highest fresh and dry biomass were observed in the control treatment, while the lowest values were recorded in the highest concentrations of mM KCl treatment. Fresh weight of root and shoot, respectively, varied between 34.80 mg plant$^{-1}$ (BGR43687-control variant) and 0.00 mg plant$^{-1}$ (BGR43706-200-300 mM, BGR43678-BGR43668-250-300 mM KCl, BGR43479-250-300 mM KCl) for root and between 93.7 mg plant$^{-1}$ (BGR43687-control variant) and 0.00 mg plant$^{-1}$

(BGR43706-150-300 mM, BGR43678-BGR43668-200-300 mM KCl, BGR43479-250-300 mM KCl) for shoot. Dry weight of root and shoot, respectively, ranged from 4.54 mg plant$^{-1}$ (BGR43687-control variant) to 0.00 mg plant$^{-1}$ (BGR43706-200-300 mM, BGR43678-BGR43668-200-300 mM KCl, BGR43479-250-300 mM KCl) for root and from 18.8 mg plant$^{-1}$ (BGR43687-control variant) to 0.00 mg plant$^{-1}$ (BGR43706-150-300 mM, BGR43678-BGR43668-200-300 mM KCl, BGR43479-250-300 mM KCl) for shoot.

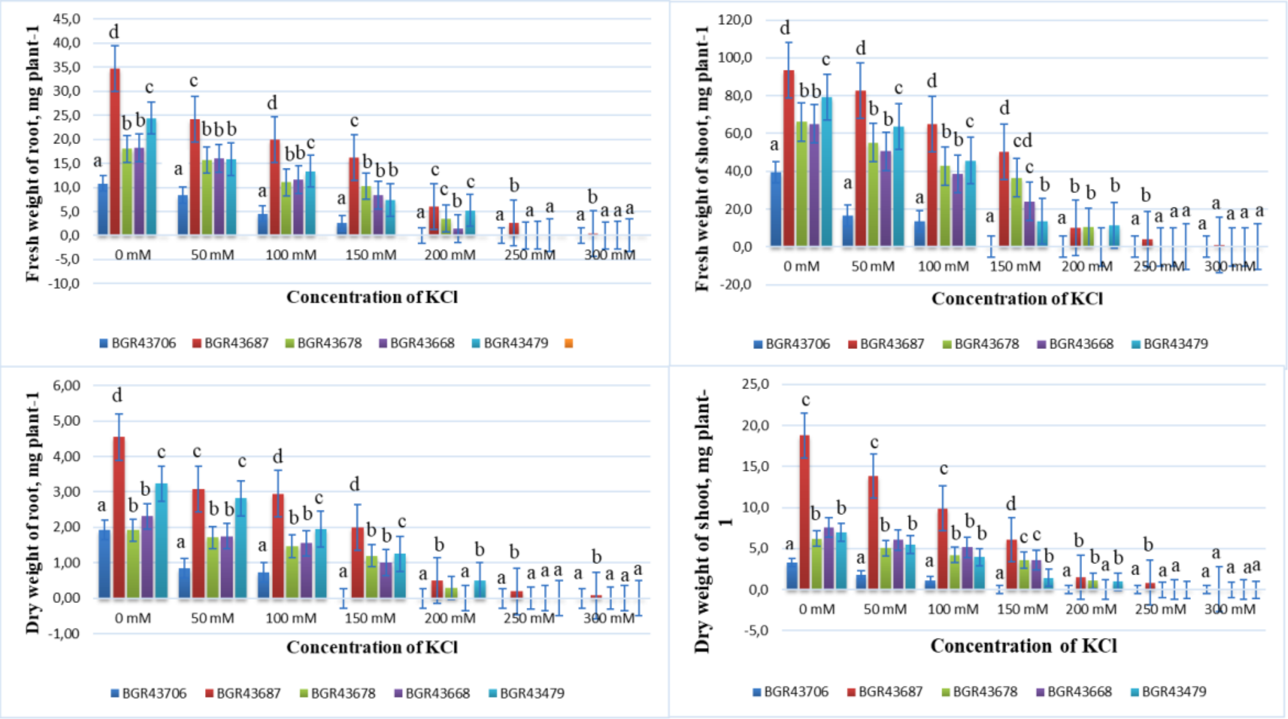

**Fig. 1.** Effect of KCl concentration on the fresh and dry weights of shoots and roots (means followed by different letters are significantly different at $p < 0.05$ (Duncan's Multiple Range Test)

***Variation in tolerance and susceptibility indices***

In Table 4, the variation of tolerance and susceptibility indices in the studied genotypes at different salinity level. The relative change (RC) resulting from salinity stress revealed that genotype BGR43678 displayed negligible changes at 50 mM NaCl, with a respective percent reduction of 17.74% compared to the control. Between 100 mM and 200 mM NaCl, the same genotype showed the least change compared to the other genotypes in the study (Table 4). At the highest level of salinity, the RC varied from 99.47% to 100%.

MP varied from 2.55 to 16.30 at 50 mM KCl, from 2.20 to 14.35 at 100 mM KCl, from 1.65 to 12.45 at 150 mM KCl, from 1.65 to 10.15 at 200 mM KCl, from 1,65 to 9.85 at 250 mM KCl, and from 1.65 to 9.45 mM KCl at 300 mM KCl. The highest values were registered for BGR43687 in all tested solutions of salinity stress. The maximum values for GMP and HM were also noted for BGR43687. The minimum values for SSI were as follows: BGR43678 at 50 mM KCl, BGR43668 at 100 mM KCl, BGR43678 at 150 mM KCl, BGR43678 at 200 mM KCl, and BGR43687 at 250 mM KCl. The maximum values for the SST index were observed in BGR43687 in the six osmotic stress variants that were examined, in comparison to the indices of the other genotypes in the same variants in the experiment. Under osmotic stress between 50 and 150 mM potassium chloride solution, the highest value for the YI index was reported for BGR43687, and for the YSI and RSI indices for the BGR43678 and BGR43668 genotypes, respectively. For strong osmotic stress induced by 200, 250, and 300 mM KCl, the highest values for all three indices were calculated for BGR43687.

The ranking of each genotype was influenced by the application of different indices, resulting in varied effects on its position relative to the entire group (the table is not presented). To identify the most suitable genotypes, the Average Summary Ranks (ASR) were calculated for all indicators. The minimum values for ASR were as follows: 2.09 and 1.82 at 50 mM and 100 mM KCl for BGR43668, respectively. At the highest osmotic stress between 250 and 300 mM KCl, the minimum value for ASR was calculated for BGR43687 and the maximum for BGR43706, respectively.

**Table 4.** Tolerance and susceptibility indices at different salinity levels of five genotypes of *Aegilops neglecta* Req. ex Bertol.

| Genotype | Yp | Ys | RC | MP | GMP | HM | SSI | STI | YI | YSI | RSI | ASR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 mM KCl | | | | | | | | | | | | |
| BGR43706 | 3.30 | 1.80 | 45.45 | 2.55 | 2.44 | 2.33 | 1.84 | 0.08 | 0.28 | 0.55 | 0.72 | 4.73 |
| BGR43687 | 18.80 | 13.80 | 26.60 | **16.30** | **16.11** | **15.92** | 1.08 | **3.52** | **2.14** | 0.73 | 0.97 | **2.18** |
| **BGR43678** | 6.20 | 5.10 | **17.74** | 5.65 | 5.62 | 5.60 | **0.72** | 0.43 | 0.79 | 0.82 | 1.09 | 2.91 |
| **BGR43668** | 7.60 | 6.10 | 19.74 | 6.85 | 6.81 | 6.77 | 0.80 | 0.63 | 0.94 | 0.80 | 1.07 | **2.09** |
| BGR43479 | 7.00 | 5.50 | 21.43 | 6.25 | 6.20 | 6.16 | 0.87 | 0.52 | 0.85 | 0.79 | 1.04 | 3.00 |
| 100 mM KCl | | | | | | | | | | | | |
| BGR43706 | 3.30 | 1.10 | 66.67 | 2.20 | 1.91 | 1.65 | 1.55 | 0.05 | 0.23 | 0.33 | 0.59 | 4.73 |
| BGR43687 | 18.80 | 9.90 | 47.34 | **14.35** | **13.64** | **12.97** | 1.10 | **2.53** | 2.03 | 0.53 | 0.93 | 2.18 |
| **BGR43678** | 6.20 | 4.20 | 32.26 | 5.20 | 5.10 | 5.01 | 0.75 | 0.35 | 0.86 | 0.68 | 1.19 | 3.00 |
| **BGR43668** | 7.60 | 5.20 | 31.58 | 6.40 | 6.29 | 6.18 | 0.73 | 0.54 | 1.07 | 0.68 | 1.20 | **1.82** |
| BGR43479 | 7.00 | 4.00 | 42.86 | 5.50 | 5.29 | 5.09 | 0.99 | 0.38 | 0.82 | 0.57 | 1.00 | 3.27 |
| 150 mM KCl | | | | | | | | | | | | |
| BGR43706 | 3.30 | 0.00 | 100.00 | 1.65 | 0.00 | 0.00 | 1.52 | 0.00 | 0.00 | 0.00 | 0.00 | 4.73 |
| BGR43687 | 18.80 | 6.10 | 67.55 | **12.45** | **10.71** | **9.21** | 1.03 | **1.56** | 2.07 | 0.32 | 0.94 | **1.91** |
| **BGR43678** | 6.20 | 3.60 | 41.94 | 4.90 | 4.72 | 4.56 | 0.64 | 0.30 | 1.22 | 0.58 | 1.69 | 2.18 |
| **BGR43668** | 7.60 | 3.60 | 52.63 | 5.60 | 5.23 | 4.89 | 0.80 | 0.37 | 1.22 | 0.47 | 1.38 | 2.09 |
| BGR43479 | 7.00 | 1.45 | 79.29 | 4.23 | 3.19 | 2.40 | 1.21 | 0.14 | 0.49 | 0.21 | 0.60 | 3.91 |
| 200 mM KCl | | | | | | | | | | | | |
| BGR43706 | 3.30 | 0.00 | 100.00 | 1.65 | 0.00 | 0.00 | 1.09 | 0.00 | 0.00 | 0.00 | 0.00 | 3.91 |
| BGR43687 | 18.80 | 1.50 | 92.02 | **10.15** | **5.31** | **2.78** | 1.00 | 0.38 | 2.08 | 0.08 | 0.95 | **1.91** |
| **BGR43678** | 6.20 | 1.10 | 82.26 | 3.65 | 2.61 | 1.87 | 0.90 | 0.09 | 1.53 | 0.18 | 2.11 | 2.27 |
| **BGR43668** | 7.60 | 0.00 | 100.00 | 3.80 | 0.00 | 0.00 | 1.09 | 0.00 | 0.00 | 0.00 | 0.00 | 3.73 |
| BGR43479 | 7.00 | 1.00 | 85.71 | 4.00 | 2.65 | 1.75 | 0.94 | 0.10 | 1.39 | 0.14 | 1.70 | 2.45 |
| 250 mM KCl | | | | | | | | | | | | |
| BGR43706 | 3.30 | 0.00 | 100.00 | 1.65 | 0.00 | 0.00 | 1.02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.45 |
| BGR43687 | 18.80 | 0.90 | 95.21 | 9.85 | 4.11 | 1.72 | 0.97 | 0.23 | 5.00 | 0.05 | 2.28 | **1.36** |
| **BGR43678** | 6.20 | 0.00 | 100.00 | 3.10 | 0.00 | 0.00 | 1.02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.36 |
| **BGR43668** | 7.60 | 0.00 | 100.00 | 3.80 | 0.00 | 0.00 | 1.02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18 |
| BGR43479 | 7.00 | 0.00 | 100.00 | 3.50 | 0.00 | 0.00 | 1.02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.27 |
| 300 mM KCl | | | | | | | | | | | | |
| BGR43706 | 3.30 | 0.00 | 100.00 | 1.65 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.45 |
| BGR43687 | 18.80 | 0.10 | 99.47 | 9.45 | 1.37 | 0.20 | 1.00 | 0.03 | 5.00 | 0.01 | 2.28 | **1.36** |
| **BGR43678** | 6.20 | 0.00 | 100.00 | 3.10 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.36 |
| **BGR43668** | 7.60 | 0.00 | 100.00 | 3.80 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18 |
| BGR43479 | 7.00 | 0.00 | 100.00 | 3.50 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.27 |

Yp- shoot dry weight under control, mg/plant, Ys- shoot dry weight under salinity condition, RC-relative change, MP-Mean productivity, GMP-Geometric mean productivity, HM-Harmonic mean, SSI-Stress susceptibility index, Stress tolerance index, YI-Yield index, YSI-Yield stability index, RSI- Relative stress index, ASR-average sum of ranks

## Discussion

This study demonstrates that increasing concentrations of KCl significantly inhibit the germination and seedling growth of *Aegilops neglecta* Req. ex Bertol. The observed reductions in germination percentage, germination rate, root length, shoot length, and biomass accumulation are consistent with the detrimental effects of salinity stress on plant development. The results obtained in this study align with those reported by other scientists studying different crops (Desheva et al., 2024; Dadach et al., 2023a,b; Joseph et al., 2021; Wali et al., 2020; Dehnavi et al., 2020; Solangi et al., 2018).

The reduction in germination percentage and germination rate under KCl stress can be attributed to several factors. Inhibition of water uptake due to osmotic stress is a primary mechanism by which salinity hampers germination (EL Sabagh et al., 2021). High salt concentrations reduce the water potential of the soil solution, making it difficult for seeds to imbibe water, which is essential for initiating germination (Iric & Bikmaz, 2024). Additionally, KCl toxicity can interfere with the enzymatic activities required for the mobilization of stored reserves within the seed, hindering germination (Zhang et al., 2023a; Dadach et al., 2023; Sghayar et al., 2023). The Cl-ions can disrupt the activity of amylases and other hydrolytic enzymes, leading to a reduced supply of energy and building blocks for germination (Maurus et al., 2005; Farooq et al., 2015; Kumar & Khare, 2015).

The reduced root and shoot growth observed under KCl stress in the studied genotypes is likely due to a combination of factors, including osmotic stress, ionic toxicity, and nutrient imbalance. Osmotic stress can limit cell elongation and division, thereby inhibiting root and shoot growth. Excessive accumulation of K+ and Cl- ions in plant tissues can disrupt cellular homeostasis and interfere with nutrient uptake and transport (Lindberg & Premkumar, 2024; Zhou et al., 2024). It is known that salinity can interfere with the uptake of other essential nutrients, such as nitrogen, phosphorus, and calcium, further contributing to growth inhibition (Grattan & Grieve, 1998; Zhang et al., 2023b).

The reductions in fresh and dry weight under KCl stress are indicative of reduced photosynthetic activity and overall biomass accumulation (Zheng et al., 2021; Wali et al., 2020; Lucini et al., 2016). Salinity stress can impair photosynthetic efficiency by damaging chloroplasts, inhibiting $CO_2$ fixation, and reducing chlorophyll content (Wang et al., 2024; Hameed et al., 2023). Furthermore, the energy expenditure associated with ion homeostasis and detoxification under salt stress can divert resources away from growth and development (Balasubramaniam et al., 2023; Ma et al., 2020).

The study demonstrated that *A. neglecta* Req. ex Bertol. exhibited a certain degree of tolerance to KCl stress. This was evidenced by the fact that at the high concentration (200 mM), a significant proportion of the seeds of the genotypes studied (except BGR43668 and BGR BGR43706) still germinated (between 20-45%) and seedlings were able to survive, albeit with reduced growth, while at the highest concentration (300 mM KCl), one of the genotypes studied survived. This finding indicates that *Aegilops neglecta* Req. ex Bertol. possesses specific physiological mechanisms that enable it to withstand salt stress. Therefore, future research should focus on identifying the specific physiological and molecular mechanisms underlying salt tolerance in *Aegilops neglecta* Req. ex Bertol.

The yield of dry matter is directly proportional to the rate of plant growth and the accumulation of biomass; consequently, it serves as a reliable metric for evaluating salt tolerance. The estimation of dry matter production under specific saline conditions facilitates the calculation of crop yield and potential economic returns in salt-affected areas (Diego et al., 2010; Tao et al., 2021). Therefore, the dry weight data obtained under different KCl salinity stresses were utilized to calculate the tolerance and susceptibility indices. This approach provides a valuable tool for the screening and ranking of genotypes based on their performance under saline and non-saline conditions (Mubushar et al., 2022; Kumawat et al., 2017; Hassan et al., 2016). In this study, MP, STI, GMP, and HM were used as indicators of salt tolerance, SSI and RC were used as indicators of salt susceptibility, while YI, YSI, and RSI were used to evaluate genotypic stability in the stressful condition. Genotypes with higher STI, MP, GMP, and HM values are considered more tolerant to salinity stress (Pour-Aboughadareh et al., 2019). The findings of the study revealed that genotype BGR43687 exhibited the highest level of salt tolerance when subjected to gradually increasing concentrations of KCl ranging from 50 to 300 mM, in comparison to the other genotypes. The higher values of SSI are associated with genotypes that demonstrate reduced tolerance to stress. As indicated by the findings of this index, genotype BGR43706 was identified as the most sensitive genotype to all concentrations of KCl that were tested. At the highest doses of 250–300 mM KCl, all genotypes except BGR43687 were considered sensitive. The three stability indices (YI, YSI, and RSI) used to assess genotypic stability under salt conditions showed that BGR43687 exhibited the highest level of stability when subjected to salinity levels ranging from 200 to 300 mM KCl. The Average Summary Ranks (ASRs) used in the study to select potentially superior genotypes indicated that the BGR43687 genotype exhibited superior salt tolerance based on dry weight. This suggests that it possesses genetic mechanisms that enable it to maintain growth and biomass production under saline conditions. In contrast, the BGR43706 genotype showed the lowest tolerance and the highest susceptibility to salinity stress. This indicates that this genotype is more sensitive to the negative effects of salinity on growth and development.

It is important to note that the response of plants to salinity can vary depending on the specific salt composition. Different salt ions have different mechanisms of toxicity, and the relative proportions of different salts can influence the overall impact of salinity on plant growth (Zhao et al., 2020). Further research is needed to investigate the response of *Aegilops neglecta* Req. ex Bertol. to other salt types, to gain a more comprehensive understanding of its salt tolerance mechanisms.

## Conclusions

This study demonstrates that KCl significantly inhibits the germination and seedling growth in the studied genotypes of *Aegilops neglecta* Req. ex Bertol. The observed reductions in germination percentage, germination rate, root length, shoot length, and biomass accumulation are indicative of the stressful effects of KCl on plant development. However, *Aegilops neglecta* Req. ex Bertol. exhibits some degree of tolerance to KCl stress, suggesting the presence of underlying salt tolerance mechanisms. Understanding these mechanisms is crucial for exploiting the genetic potential of *Aegilops neglecta* Req. ex Bertol. for improving salt tolerance in cultivated wheat. Future research should focus on identifying the specific physiological and molecular traits that contribute to salt tolerance in *Aegilops neglecta* Req. ex Bertol. and utilizing this knowledge to develop salt-tolerant wheat varieties.

Based on the integrated analysis of tolerance and susceptibility indices, genotype BGR43687 was identified as highly tolerant to salinity stress, suggesting its potential utilization as a valuable source for salt tolerance genes in wheat breeding programs.

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