SALINITY STRESS EFFECTS ON TEN WHEAT VARIETIES MORPHOLOGICAL FEATURES

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Abstract. *Frequent periods of drought and salt stress are a major threat to agriculture, reducing yields of key crops. Salinity stress affects the physiological and biochemical processes in plants, influencing their growth and development. The representative within cereals, wheat, shows a large variance in salinity tolerance, depending on variety and environmental conditions. In this context, an experiment was conducted in order to test the morphological response of ten wheat varieties under salinity stress. Were assessed agronomical important morphological parameters like plant height, spike length and awns length with calliper method. Salinity doses and exposure duration influenced the evaluated parameters. The most vigorous and tolerant wheat plants were Pădureni, with the significant highest mean values for plant height of 66.23±4.92 cm and awns length of 5.97±0.32 cm, both values at the same salinity dose of 60 mM NaCl. Spike length feature registered significant higher mean value of 10.27±0.37 cm for Transilvania wheat at 15 mM NaCl. High salinity sensitivity were observed at Ciprian wheat variety regarding plant height and Bezostaia regarding spike and awns length. Further studied should be focused on testing spring varieties sown in autumn to follow this study finding and to establish if spring wheat varieties treated as winter wheat are more tolerant to salinity or other stress types.*

Keywords: *Abiotic stress, awns, height, spike, vigor, salinity*

INTRODUCTION

Both frequent drought periods and the salinity stress onset pose a major threat to agriculture, leading to reduced yields of essential crops (KAJEED & MUHAMMAD, 2019). More than 90% of the world's population diet is provided by about 30 crop species with varying degrees of salinity resistance (ZÖRB et al., 2019). Among these, with a high degree of salinity tolerance are sugar beet and barley, with high sensitivity, are eggplant, tomato (SHAHBAZ et al., 2012), bean, pea (TRUȘCĂ et al., 2023), and sweet potato (ZÖRB et al., 2019), while potato has a range of tolerance from moderately sensitive to moderately tolerant (ZÖRB et al., 2019).

For the most widely cultivated species, cereals, that are part of the daily diet of individuals, and on which global food security depends (MASENYA et al., 2024), the boundaries between sensitivity and tolerance are fine and require a greater understanding of the physiological responses of plants to applied salt stress (SHAHBAZ & ASHRAF, 2013). Some sources classify maize as moderately tolerant to salinity (TRUȘCĂ et al., 2023), while other researchers place it in the moderately sensitive category (FAROOQ et al., 2015; ZÖRB et al., 2019). It is still unclear the tolerance degree of wheat until now. Wheat has been classified as both moderately tolerant (SADDIQ et al., 2021) and highly sensitive (ZÖRB et al., 2019), and it was also found that rice has high sensitivity especially in the earlier stages of growth (GHOSH & SAIKAT, 2016).

Salinity stress affects plant growth and development through the changes it induces in physiological and biochemical processes (SHAHID et al., 2020). All have a major yield impact and threaten food security (BUTCHER et al., 2016). Of the nutrients it contains, carbohydrates, proteins, and fibers (IQBAL et al., 2022), but also its wide use in food products on the basis of which it can be used, wheat is one of the most widely used cereals (CORNELL & HOVELING, 2020). Over 200 million hectares of agricultural land were covered by wheat crops in 2022

(PEQUENO et al., 2024). Salt stress has various effects on the biochemical processes in wheat plants (OUHADDACH et al., 2018), and their physiological responses differ depending on a combination of factors such as its concentration, time of exposure, environmental factors such as soil and climatic conditions (TRUȘCĂ et al., 2024), and the genetic background of each individual (DIN et al., 2008).

Germination (BIABANI et al., 2013) and anthesis (RANJBAR, 2010) represent two of the most sensitive phenological stages in wheat under abiotic stress. Meanwhile, the osmotic stress installed with salinity, leads to ionic toxic accumulation, therefore the nutrient uptake is disturbed, and the germination process may be delayed or even stopped (HUSSAIN et al., 2019). Then, the growth of wheat plants is influenced by physiological and biochemical changes induced by salinity (ARIF et al., 2020). These strongly affect photosynthesis by reducing Rubisco activity, decreasing the second photosystem (PS II) efficiency, membrane disruption, and reducing leaf surface growth (SELEIMAN et al., 2022). Anthesis is a less tolerant process (GHOSH & SAIKAT, 2016) due to the impact of salinity on stomata and the installed imbalance in nitrogen metabolism (YOUSFI et al., 2013; EL SABAGH et al., 2021). The chain of salinity stress effects is concretized in a series of changes and adaptations in morphological characteristics (WANG et al., 2003) that ultimately affect crop yield (KATERJI et al., 2003).

Considering the massive impact of salinity on wheat crop which plays a vital role on assuring the global food security, the researchers aimed to create and adapt different varieties and cultivars that are not affected by this abiotic stress (MONDAL et al., 2021). In this context, the study aim was to test the salinity stress tolerance of ten wheat varieties morphological features with high agronomic importance.

MATERIAL AND METHODS

Ten wheat (*Triticum aestivum* L.) varieties were tested in a field experiment under salinity stress in the season 2022-2023. The biological material consisted of wheat seeds from the Agricultural Research and Development Station (ARDS) Turda (Figure 1). The wheat seeds tested were winter wheat varieties: Andrada, a newer variety that is intended to replace Arieșan, Arieșan (ARDS TURDA, 2024) and Transilvania, a resistant winter wheat (BOTEZAN et al., 1984), created by ARDS Turda. Other winter wheat varieties tested were created by the National Agricultural Research and Development Institute (NARDI) of Fundulea respectively Faur, Fundulea, Miranda, and the early variety Otilia (NARDI FUNDULEA, 2024). The valuable variety tested was Bezostaia, an important genitor used in winter wheat breeding in Romania (LUPU et al., 2011, SĂULESCU et al., 2007). Ciprian is a winter wheat variety created by ARDS Lovrin (ARDS LOVRIN, 2024). The only spring wheat variety tested was Pădureni, a wheat maintained by ARDS Turda (ARDS TURDA, 2024). These seeds were sown in the field, in isolated vegetation pots to avoid the saline solutions infiltration in the Agro-botanical garden of UASMV Cluj-Napoca soil, where the experiment was installed and carried out. The biological material was subjected to salt stress through six doses that can be observed in the experimental design (Figure 1). The morphological parameters of interest were plant height, spikelet, and awns length (Figure 1), and were evaluated at the end of the experiment. Plant height was evaluated with a meter scale, while the spikes and awns dimensions were determined using the calliper method. A database was created by recording the unprocessed values of the assessed parameters. These were refined to obtain mean values and standard errors by the psych package of R.Studio statistical software. The results evaluation was possible only after ANOVA and LSD testing using the agricolae package of the same statistical analysis software (STOIAN et al, 2024).

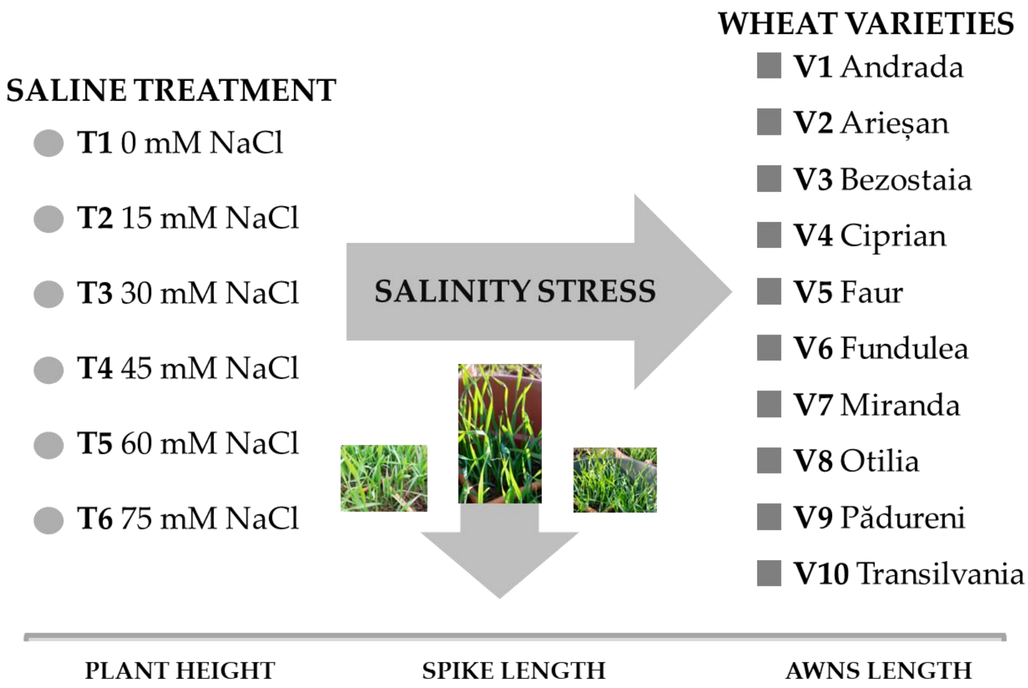

Figure 1. Experimental design

RESULTS AND DISCUSSIONS

Wheat plants height

Plant height is an important parameter analyzed, giving clues about plants growth and nitrogen regime (JIANG et al., 2020), and production of each variety in the context of the 6 saline treatments. It is also a morpho-physiological (Table 1) trait dependent on the genetic background of each individual (KHADKA et al., 2020). The presence of stress and unfavourable climatic conditions can lead to changes in plant growth and development (POONAM et al., 2017). Following the interactions between variety and dose, it was observed that the maximum values recorded in terms of plant height were observed in the variety Pădureni under T4 treatment. A non-significant decrease of 5% and a significant decrease of 12% could be observed in plants of the variety Pădureni treated with T4 and T6 (Table 1). Considering these recorded results, the height may be a characteristic of the variety that does not seem to be affected by the concentrations of the applied saline treatments. Andrada, Ariesan, and Bezostaia recorded the best values only at T1 treatment with 0 mM NaCl. The minimum values recorded for this parameter were in the variety Ciprian subjected to the saline dose T5, with a decrease of about 57% of the maximum recorded. Fundulea is also a variety in which a trend of decreasing values can be observed with increasing saline concentrations. On average,the most tolerant wheat was the Pădureni variety, producing the most developed plant stems (CHEȚAN et al., 2024). In the category of moderately tolerant plants, the varieties Arieșan and Bezostaia were included. Moderately sensitive to these six doses of salt treatment were Andrada, Miranda, Transilvania, and Fundulea, while the lowest yields were recorded for the sensitive varieties Faur, Otilia, and

Ciprian. The values recorded represent the impact of the mix between environmental factors and genes characterizing certain morphological traits (MACKAY, 2001).

Table 1.

Plant height for each wheat variety in relation to salinity gradient

	T1	T2	T3	T4	T5	T6
V1	53.33±0.73 **c**	42.50±2.30 **i-t**	40.07±1.07 **m-u**	42.67±1.93 **i-s**	40.53±0.29 **l-u**	44.07±1.52 **g-p**
V2	52.30±1.74 **cd**	48.33±1.33 **d-h**	48.33±1.30 **d-h**	43.97±0.38 **g-p**	46.80±0.68 **f-j**	43.90±1.10 **g-q**
V3	50±1.73 **c-f**	45.47±1.23 **f-k**	44.67±2.17 **g-n**	42.70±0.90 **1i-r**	44.33±1.45 **g-o**	43.40±2.17 **i-r**
V4	34.73±1.70 **v-y**	37.33±1.20 **u-x**	40.53±0.18 **l-u**	31.63±1.52 **yz**	28.77±3.73 **z**	37.77±1.47 **s-w**
V5	39.2±3.19 **p-w**	43.47±1.29 **h-r**	40.43±0.81 **l-u**	32.73±0.63 **x-z**	37.73±2.73 **t-w**	37.23±0.47 **u-x**
V6	44.90±0.10 **g-m**	45.83±2.94 **f-k**	47±2.61 **f-i**	42.03±4.59 **j-u**	39.83±1.48 **n-u**	31.53±1.64 **yz**
V7	43.6±2.11 **g-r**	46.23±1.52 **f-k**	45.23±1.23 **f-l**	43.40±1.24 **i-r**	41.77±1.30 **k-u**	42.87±0.74 **i-r**
V8	30.73±0.73 **yz**	32.10±0.78 **yz**	41.37±1.02 **k-u**	39.57±1.52 **o-v**	39.03±2.16 **q-w**	34.33±0.38 **w-y**
V9	47.07±2.02 **e-i**	51.93±0.93 **c-e**	52.10±1.10 **cd**	63.23±1.24 **ab**	66.23±4.92 **a**	58.43±0.38 **w-y**
V10	31.63±1.40 **yz**	40.10±0.72 **m-u**	48.40±1.18 **d-g**	48.33±0.24 **d-h**	45.57±0.26 **f-k**	38.90±1.17 **r-w**

Note: Means±SE followed by different letters indicate significant differences at $p<0.05$. Legend: V1=Andrada, V2=Arieșan, V3=Bezostaia, V4=Ciprian, V5=Faur, V6=Fundulea, V7=Miranda, V8=Otilia, V9=Pădureni, V10=Transilvania) tested under each saline treatment (T1=0 mM NaCl, T2=15 mM NaCl, T3=30 mM NaCl, T4=45 mM NaCl, T5=60 mM NaCl, T6=75 mM NaCl) assessed at the end of the experiment. ANOVA: F(variety)=73.03, p(variety)<0.001; F(treatment)=4.25, p(treatment)<0.001; F(variety × treatment)=7.61, p(variety × treatment)<0.001.

Wheat spike length

While plant height is a parameter of interest when biomass is to be obtained for bioenergy purposes (ȘANDOR et al., 2015), agricultural production is interested in spike characteristics. The highest value recorded in the measurements of the spike length was observed in Transilvania wheat variety (Table 2), treated with the second dose T2 of the salt treatment of 15 mM NaCl. Arieșan wheat, on the other hand, reached a high value in the first dose with an insignificant reduction of about 7% from the maximum recorded. Plants of Bezostaia variety recorded the lowest values of the parameter. This value was observed in the above-mentioned variety under the T4 treatment, a value of about 61% of the maximum recorded. The top of the low values of spike length was completed by the other Bezostaia plants. On average, Transilvania variety proved to be the most resistant to salinity by obtaining the best yield in terms of spike length. Wheat varieties Arieșan, Pădureni, Andrada, and Miranda were moderately tolerant to salinity, while Faur, Otilia, Fundulea, and Ciprian had low yields, indicating low tolerance. The most sensitive variety was Bezostaia, which recorded a low yield due to the interaction between climatic factors and the applied saline treatment, but also to the morphological characteristics of this variety, namely a spike with very poorly awns (IONESCU et al., 2021).

Table 2.

Spike length for each wheat variety in relation to salinity gradient

	T1	**T2**	**T3**	**T4**	**T5**	**T6**
V1	8.50±0.21**d-g**	8.87±0.38**b-e**	7.07±0.30**j-n**	8.03±0.17**e-i**	8.13±0.55**e-i**	8.53±0.73**d-g**
V2	9.60±0.49**a-c**	8.50±0.29**d-g**	9.33±0.33**a-d**	8.90±0.12**b-e**	8.80±0.21**b-e**	7.73±0.18**f-j**
V3	4.77±0.15**o**	4.53±0.26**o**	4.83±0.17**o**	3.97±0.12**o**	4.00±0.00**o**	4.77±0.18**o**
V4	6.13±0.70**n**	6.43±0.72**mn**	7.20±0.35**i-m**	7.30±0.15**h-m**	7.20±0.21**i-m**	6.77±0.33**k-n**
V5	7.33±0.18**h-m**	7.33±0.23**h-m**	6.97±0.22**j-n**	7.00±0.20**j-n**	7.63±0.48**g-k**	7.20±0.12**i-m**
V6	6.43±0.38**mn**	7.47±0.32**h-l**	6.97±0.38**j-n**	7.33±0.07**h-m**	6.97±0.23**j-n**	6.20±0.92**n**
V7	7.47±0.41**h-l**	8.63±0.41**d-f**	7.80±0.21**f-j**	7.27±0.09**i-m**	7.80±0.17**f-j**	8.23±0.17**e-h**
V8	6.53±0.23**l-n**	6.40±0.15**mn**	7.23±0.09**i-n**	7.20±0.15**i-m**	7.40±0.2**h-l**	7.00±0.12**j-n**
V9	7.33±0.33**h-m**	8.10±0.06**e-i**	8.13±0.18**e-i**	8.63±0.35**d-f**	9.7±0.23**ab**	8.67±0.18**c-f**
V10	8.47±0.45**d-g**	10.27±0.37**a**	9.33±0.48**a-d**	10.13±0.59**a**	10.13±0.07**a**	8.67±0.09**c-f**

Note: Means±SE followed by different letters indicate significant differences at $p<0.05$. Legend: V1=Andrada, V2=Arieșan, V3=Bezostaia, V4=Ciprian, V5=Faur, V6=Fundulea, V7=Miranda, V8=Otilia, V9=Pădureni, V10=Transilvania) tested under each saline treatment (T1=0 mM NaCl, T2=15 mM NaCl, T3=30 mM NaCl, T4=45 mM NaCl, T5=60 mM NaCl, T6=75 mM NaCl) assessed at the end of the experiment. ANOVA: $F(\text{variety})=103.81$, $p(\text{variety})<0.001$; $F(\text{treatment})=3.17$, $p(\text{treatment})<0.050$; $F(\text{variety} \times \text{treatment})=2.80$, $p(\text{variety} \times \text{treatment})<0.001$.

Wheat awns length

Awns length is also an important parameter strongly influenced by the genetic background of individuals (SHARMA & SAIN, 2004) within a variety. The highest values of awns length were recorded in the Miranda wheat variety in the second dose of salt treatment at 15 mM NaCl (Table 3).

Table 3.

Awns length for each wheat variety in relation to salinity gradient

	T1	**T2**	**T3**	**T4**	**T5**	**T6**
V1	3,70±0.10**l-o**	4.60±0.06**e-l**	4.03±0.33**i-n**	4.53±0.22**e-l**	4.33±0.09**f-m**	4.50±0.35**e-l**
V2	4.23±0.43**f-n**	4.00±0.29**i-n**	4.73±0.12**e-j**	4.83±0.12**d-i**	4.67±0.03**e-k**	4.23±0.32**f-n**
V3	0.17±0.17**r**	0.47±0.03**qr**	1.37±0.41**pq**	0.70±0.06**p-r**	0.67±0.03**p-r**	1.53±0.35**p**
V4	2.97±0.30**o**	3.40±0.26**no**	4.27±0.29**f-n**	3.80±0.15**k-o**	4.07±0.09**i-n**	3.47±0.13**m-o**
V5	3.43±0.13**m-o**	4.17±0.43**g-n**	4.10±0.12**h-n**	4.47±0.12**e-l**	4.77±0.64**e-j**	4.40±0.15**e-l**
V6	3.97±0.03**i-n**	4.03±0.35**i-n**	3.80±0.30**k-o**	4.07±0.23**i-n**	3.90±0.40**j-n**	4.23±0.69**f-n**
V7	4.00±0.40**i-n**	6.20±1.40**a**	4.70±0.21**e-k**	4.47±0.24**e-l**	4.70±0.20**e-k**	4.73±0.19**e-j**
V8	4.30±0.40**f-n**	4.03±0.48**i-n**	4.23±0.09**f-n**	5.00±0.12**c-h**	4.43±0.09**e-l**	4.87±0.19**d-i**
V9	5.27±0.26**b-e**	5.00±0.15**c-h**	5.10±0.12**b-f**	5.73±0.03**a-d**	5.97±0.32**ab**	5.80±0.25**a-c**
V10	4.63±0.27**e-k**	5.10±0.17**b-f**	4.70±0.32**e-k**	5.13±0.37**b-f**	5.07±0.15**b-g**	5.07±0.20**b-g**

Note: Means±SE followed by different letters indicate significant differences at $p<0.05$. Legend: V1=Andrada, V2=Arieșan, V3=Bezostaia, V4=Ciprian, V5=Faur, V6=Fundulea, V7=Miranda, V8=Otilia, V9=Pădureni, V10=Transilvania) tested under each saline treatment (T1=0 mM NaCl, T2=15 mM NaCl, T3=30 mM NaCl, T4=45 mM NaCl, T5=60 mM NaCl, T6=75 mM NaCl) assessed at the end of the experiment. ANOVA: $F(variety)=91.29$, $p(variety)<0.001$; $F(treatment)=5.22$, $p(treatment)<0.001$; $F(variety \times treatment)=1.40$, $p(variety \times treatment)<0.001$.

This was followed by insignificant decreases of 4, 6, and 8% by the variety Pădureni treated with T5, T6, and T4.It can thus be outlined that the variety Pădureni is positively influenced by the increased values of salt treatment. The lowest values of awns lengths were recorded in the Bezostaia variety subjected to all six doses of salt treatment. The lowest value recorded was obtained at T1, with a decrease of about 97% of the maximum recorded. On average, awns length assessment frames Pădureni wheat as the most tolerant to salinity, similar to the trend observed for plant height. At the other extreme, the weakest performances were recorded, maintaining the trend observed for spike length, in the Bezostaia wheat variety which was found to be the most affected by salinity (IONESCU et al., 2021). Wheat varieties moderately tolerant to salt stress, with high values of awns lengths, are Transilvania, Miranda, Otilia, and Arieșan. The lower yields recorded for Andrada, Faur, Fundulea, and Ciprian put them in the moderately sensitive category.

CONCLUSIONS

Both salinity stress treatments and time exposure had effects on the assessed parameters.

The most vigorous and tolerant wheat plants were Pădureni according to the highest mean values recorded for plant height and awns length.

Plant height was a sensitive parameter to the saline doses tested for wheat varieties Faur, Otilia, and Ciprian.

With a high tolerance to the applied doses, Transilvania wheat obtained the highest mean value of spike length.

Bezostaia showed sensitivity to saline treatment spike and awns length by the low average values observed.

It is vital to understand plant responses to salt stress in order to maintain food security, for this reason, therefore it is recommended to test larger sets of varieties and plants over a wider range of applied salt doses.

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