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CHLOROPHYLL CONTENT, PHENOLOGY AND MORPHOLOGICAL TRAITS OF WHEAT UNDER SALINITY STRESS

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Abstract

Natural and anthropogenic salinization through intense and progressive periods of drought, as well as due to the use of fertilizers or the soil parental material, leads to degradation of soil quality. In this context, wheat, one of the most important crops, is threatened. Specific objectives include measuring chlorophyll content and morphological parameters such as grain number, fresh and dry biomass for stems and spikes. The experiment was set up in field conditions, in mesocosms, under six saline doses of 15-30-45-60-75 mM NaCl and a control without salt, in five replicates. The results highlighted different effects depending on the tested variety and the applied salinity doses. The most concentrated dose of 75 mM NaCl drastically reduced the values of almost all morpho-physiological parameters in all varieties. Transilvania, Arieșan, Faur, Ciprian, Pădureni, and Bezostaia had higher morpho-physiological parameter values. Otilia is the wheat variety most sensitive to salinity stress. Different tolerance patterns and trends were observed based on the interaction between the variety and salinity dose.

Key words: *abiotic stress, growth, SPAD units, wheat varieties.*

INTRODUCTION

Soil salinization results from water-soluble salt accumulation in the substrate due to environmental factors and anthropogenic activities (Zinck and Metternicht, 2009). This human-induced salinity, also called secondary salinity, involves intensive irrigation practices, malfunctioning drainage systems, or poor farm management practices (Okur and Örçen, 2020). Environmental factors, such as the soil profile (Bui, 2017) and severe drought episodes caused by global climatic changes (Qafoku, 2015), combined with the anthropogenic activities mentioned above, change the soil-water balance (Zinck and Metternicht, 2009), leading to soil salinization. This poses a substantial threat to soil quality and, finally, to plants, having effects on vegetal organisms similar to those caused by drought (Uddin et al., 2016).
The imminent danger of soil salinity is increasingly acute in the context of climate change, posing a significant challenge to global food security because vast regions of arable land are either saline or susceptible to salinity (Butcher et al., 2016).
Salt stress adversely affects plants by inducing osmotic stress and disrupting physiological and metabolic processes, ultimately leading to inhibited growth and alterations in morphological characteristics (Arif et al., 2020). The ultimate consequence is a slow development on the Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie (BBCH) scale or even skipping some growth stages, resulting in plants with premature leaf senescence (Lutts et al., 1996). From an economic perspective, the repercussions of agricultural production have profound implications for global food security (Kopittke et al., 2019). In the contemporary context of climate change and an ever-increasing population, achieving the "zero hunger" sustainable development goal (SDG) of the UN Agenda also means achieving global food security (United Nations, 2024). *Triticum*

aestivum L. is the second most produced cereal, with 783 million tons of global production (Statista, 2023), and stands out as the world's most vital agricultural crop. Wheat, through its by-products, constitutes a large part of the daily diet. Wheat grains and flour are rich sources of nutrients, minerals, vitamins, fiber, and proteins (Yigider et al., 2023). In addition, wheat is a major crop present in almost all crop rotations in agricultural ecosystems globally (Dixon et al., 2009; Giraldo et al., 2019). Therefore, in the current context of massive population growth, the focus on crop cultivation must be increased. Salt stress has varying effects on wheat plant phenological stages. Both BBCH growth and development stage, biomass, and relative chlorophyll content, through which photosynthetic activity can be revealed, are parameters through which the effects of salt stress on wheat plants can be highlighted (EL Sabagh et al., 2021). Wheat root and stem biomass are affected by salinity stress at high concentrations (Ahmadi et al., 2018; Pour-Aboughadareh et al., 2021). The relative water content of wheat leaves is low under salinity stress conditions, even under osmotic regulation (Boyer et al., 2008). Plant water content decreases with increasing salinity (El-Bassiouny and Bekheta, 2005). Abiotic stress effects can vary depending on climatic and soil conditions, but especially on the genetic information of each wheat variety (Hossain et al., 2021). The identification and maintenance of wheat varieties are essential to ensure food security under a changing climate and massive population growth. To provide resilience under salinity conditions it is essential to establish the tolerance of a large germplasm collection. This information is valuable to farmers facing this issue. In addition, improved farming practices and the implementation of advanced technologies can contribute to optimized yields and reduced salinity stress.

In light of the above, the aim of this study was to test and establish ten wheat varieties tolerant to salinity stress in order to provide information necessary for agronomists to address this issue and mitigate its impact. The objective of this study was to assess the morpho-physiological changes induced by salinity. Assessments of leaf relative chlorophyll in the beginning and at the end of the experiment were done. The number of emerging stems, spikes, and grains, fresh and dry biomass for stems and spikes, were also measured and the water content for stems and spikes was determined.

MATERIALS AND METHODS

The experiment was set in the middle of October 2022, in the Agro-Botanical Garden of UASVM Cluj-Napoca field conditions. Ten *Triticum aestivum* L. varieties from the ARDS (Agricultural Research and Development Station) Turda were sown in mesocosms with a diameter of 24 cm, filled with a clay-loam soil type, and subjected to salinity stress with no irrigation regime.

The soil properties are presented in Table 1.

The 10 wheat varieties were Andrada (V1), Arieșan (V2), Bezostaia (V3), Ciprian (V4), Faur (V5), Fundulea (V6), Miranda (V7), Otilia (V8), Pădureni (V9), and Transilvania (V10) from ARDS Turda. A total of 30 *Triticum aestivum* L. seeds, in five replications, were tested under six saline treatments T1-0 mM NaCl, T2-15 mM NaCl, T3-30 mM NaCl, T4-45 mM NaCl, T5-60 mM NaCl, and T6-75 mM NaCl. To avoid saline treatments infiltration into the experimental field, the mesocosms were placed above a polypropylene film hydro insulation system.

Table 1. Soil properties at the beginning of the experiment (Si) and at the end of the experiment in all treatments (T1-T6) with another control (Sf) at the end without treatment or plants

	T1	T2	T3	T4	T5	T6	Si	Sf
pH	6.43 ±0.05	6.45 ±0.03	6.53 ±0.02	6.48 ±0.05	6.67 ±0,10	6.55 ±0.03	6.00 ±0.06	6.35 ±0.08
EC (mS)	70.90 ±1.77	73.38 ±2.99	75.68 ±3.23	79.60 ±2.48	82.95 ±2.08	88.45 ±0.71	63.67 ±0.32	65.37 ±0.45
Humus (%)	3.17 ±0.48	3.62 ±0.49	2.57 ±0.23	2.66 ±0.32	2.89 ±0.25	3.10 ±0.22	3.59 ±0.07	2.74 ±0.09
P-AL (ppm)	29.91 ±6.20	22.59 ±3.00	21.86 ±5.10	24.22 ±2.52	17.90 ±4.59	21.36 ±0.86	10.12 ±0.07	9.50 ±0.10
K-AL (ppm)	121.59 ±13.82	93.38 ±5.97	87.69 ±6.91	93.85 ±7.59	92.75 ±9.92	83.13 ±9.70	81.30 ±0.07	103.43 ±0.10
Total N %	0.13 ±0.02	0.12 ±0.01	0.11 ±0.01	0.12 ±0.01	0.10 ±0.01	0.12 ±0.01	0.14 ±0.00	0.10 ±0.00
Soluble Ca (ppm)	446.27 ±14.33	444.24 ±9.16	466.40 ±13.93	449.24 ±3.35	441.26 ±12.49	456.00 ±4.89	442.03 ±0.26	473.47 ±0.37
Soluble Mg (ppm)	82.00 ±1.41	82.07 ±0.76	81.95 ±0.17	82.74 ±0.21	81.73 ±1.25	81.50 ±0.90	86.57 ±0.11	84.39 ±0.15
Chloride (mg/100 g soil)	16.54 ±0.51	22.16 ±0.89	24.22 ±1.35	26.59 ±1.26	36.15 ±3.03	44.84 ±5.59	15.02 ±0.12	17.72 ±0.12
Exchangeable Na (m.e./100 g soil)	0.31 ±0.10	0.25 ±0.04	0.46 ±0.12	0.40 ±0.06	0.52 ±0.07	0.60 ±0.08	0.36 ±0.03	0.13 ±0.04

Relative chlorophyll content was assessed in two evaluation dates by reading the SPAD units value with MC-100 S/N Apogee Instruments Chlorophyll meter. The parameter was two times assessed on 4 November 2022, at the beginning of the experiment, when plants where in BBCH 11 developmental stage with the first true leaf unfolded, and on 23 May 2023, at the end of the experiment when plants were in the BBCH 51 developmental stage, at the beginning of inflorescence (Meier, 2003).

At the end of the experiment, the total number of plants grown and the spike number of a variety in a treatment were determined for the whole set of replicates. The total stem production biomass per variety per treatment and water content was determined for each set of repetitions. The same way it was proceeded with spikes biomass. As for the wheat grains, they were collected from each entire set of replicates for each variety and treatment to determine their total number. The total biomass productions for stems and spikes were measured using gravimetric methods with an analytical balance before and after the vegetal material samples were subjected to 105°C (ISO, 2015) for 48 hours in a drying oven. The lost water content (WC) was measured, according to the ISO 18134-3 standard method (ISO, 2023), for one gram of fresh stem and spike biomass using the formula:

$$Water\ Content = \frac{Fresh\ biomass - dry\ biomass}{Fresh\ biomass} \times 100$$

Data analysis was done in RStudio console, version 4.0.5. Basic statistics was done with psych package, average and standard errors (SE) were automatically calculated. The Analysis of Variance (ANOVA) table and LSD test were performed with agricolae package (de Mendiburu, 2021; Stoian et al., 2024). All the figures were made with the help of online free tools, produced by Plotly.js (v2.24.1) (Statskingdom, 2024). Therefore, for box plots, the inclusive quartile was set and the median value appears in the figures with statistics LSD test, different letters highlight differences between treatments at $p<0.05$ threshold.

RESULTS AND DISCUSSIONS

Chlorophyll content in relation to salinity

Relative chlorophyll content is an important parameter in determining how *Triticum aestivum* plants of the 10 varieties are affected by salt treatment. On the first measurement date (Figure 1), the highest value was observed in plants of the Transilvania variety, plants subjected to the most concentrated dose of T6 treatment.

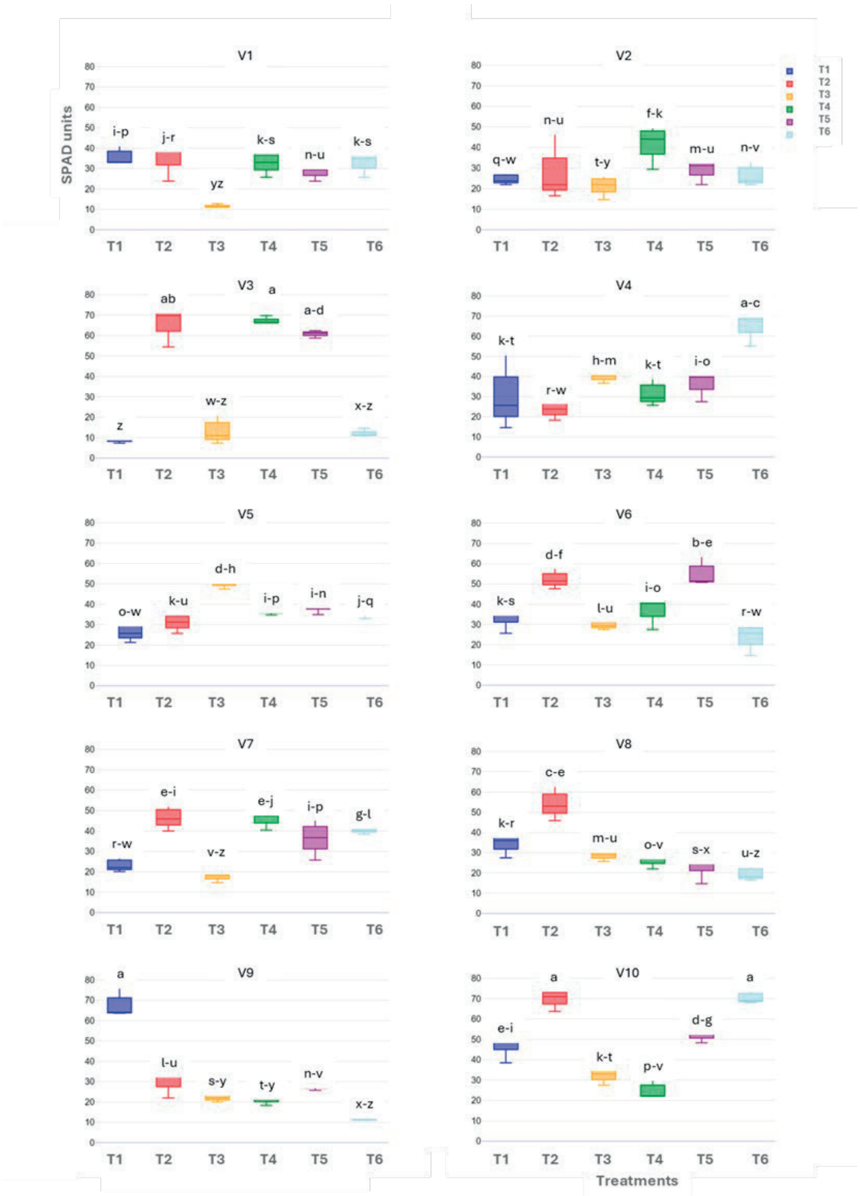

Figure 1. Chlorophyll content in the first assessment

Legend: V1=Andrada, V2=Arieșan, V3=Bezostaia, V4=Ciprian, V5=Faur, V6=Fundulea, V7=Miranda, V8=Otilia, V9=Pădureni, V10=Transilvania wheat varieties; T1=0 mM NaCl, T2=15 mM NaCl, T3=30 mM NaCl, T4=45 mM NaCl, T5=60 mM NaCl, T6=75 mM NaCl saline treatment; ANOVA: F (variety)=14.51, p (variety)<0.001; F (treatment)=20.26, p (treatment) <0.001; F (variety × treatment)=14.75, p (variety × treatment)<0.001

The same variety recorded on average the highest chlorophyll values compared to the other varieties (Figure 1.). Other high values were recorded in the varieties Pădureni treated with T1, Bezostaia with T4, T2, T6 and Ciprian with insignificant decreases of 3%, 5%, 7%, 14% and 8% compared to the maximum. The fact that Pădureni variety reached the maximum value of relative chlorophyll content only under T1 treatment, indicates the negative influence of salt stress on this parameter. The lowest value recorded at this measurement date was observed in the Bezostaia variety treated with T1, with a decrease of about 87% of the maximum recorded values. Other low values were recorded in plants of varieties Andrada at T3, Bezostaia and Pădureni subjected to T6 treatment. It can be observed that the chlorophyll level is strongly influenced by salinity in varieties Arieșan, Andrada and Pădureni.

Salinity represents an increasingly accentuated and threatening abiotic stress, which is why the need to evaluate the potential of the current germplasm collections as tolerant to it has been highlighted. Testing this germplasm collection allowed the development of reaction patterns in terms of chlorophyll content. The morpho-physiological parameters of all ten wheat varieties assessment highlight the salinity different effects. Monitoring leaf chlorophyll content is the physiological parameter of interest in the evaluation of the salinity tolerance degree of different wheat varieties (Cuin et al., 2010). Changes in leaves relative chlorophyll content reveal the trend whereby long-time exposure to saline treatment affects this parameter evolution in time.

Regarding the relative chlorophyll content of the leaves in the first evaluation date, when plants were in BBCH11 developmental stage, the Transilvania variety stood out (Figure 1). The high values of chlorophyll content recorded in this wheat variety under the second and the most concentrated salt treatment suggest a significantly higher degree of tolerance to salt stress compared to the other varieties. Chlorophyll content represents a parameter of interest, being an indicator of the proper functioning of physiological processes and plant productivity, being related to plant nitrogen content (Bannari et al., 2007). The optimal and vigorous plants growth that ensures production is a consequence of an efficient photosynthesis process (Brestic et al., 2018), which is the reason why the Transilvania wheat variety can be classified, from the point of view of this parameter, in the salinity-tolerant category, with the expectation of recording high values of quantitative parameters. All the other varieties can be classified with a lower degree of tolerance, pointing out that Otilia and Pădureni wheat registered a trend of decreasing chlorophyll content values with increasing salinity treatment.

The values of chlorophyll content decrease with increasing salt treatment and also due to prolonged exposure to salt treatment (Azizpour et al., 2010). The varieties Andrada, Ciprian, Pădureni, and Fundulea were placed in the moderately tolerant category. Varieties Faur, Transilvania, Miranda, and Otilia were more sensitive than the others. For the variety Transylvania, long exposure to salt treatment doses had negative effects, falling from the tolerant group to the opposite extreme.

It can be stated that long-time exposure to salinity stress affects the evolution of chlorophyll content (Figure 2). The values recorded are also a consequence of a combined accumulation of factors including climatic and soil conditions, but also the genetic level of resistance to abiotic stressors of each wheat variety. Similarly, drought stress, which is one of the precursors of salinity, has a negative impact on the chlorophyll content of wheat leaves, an impact that is more pronounced the lower the genetic tolerance of each variety to abiotic stress (Naeem et al., 2015). Once chlorophyll levels are reduced, the photosynthesis process is affected. This is a concerning fact because photosynthesis is a whole physiological system that depends on environmental factors to have the best yields in production (Calzadilla et al., 2022).

On the last date of evaluations, the highest value of relative chlorophyll content was recorded in plants of the variety Andrada V1 treated with 0 mM NaCl, T1 (Figure 2).

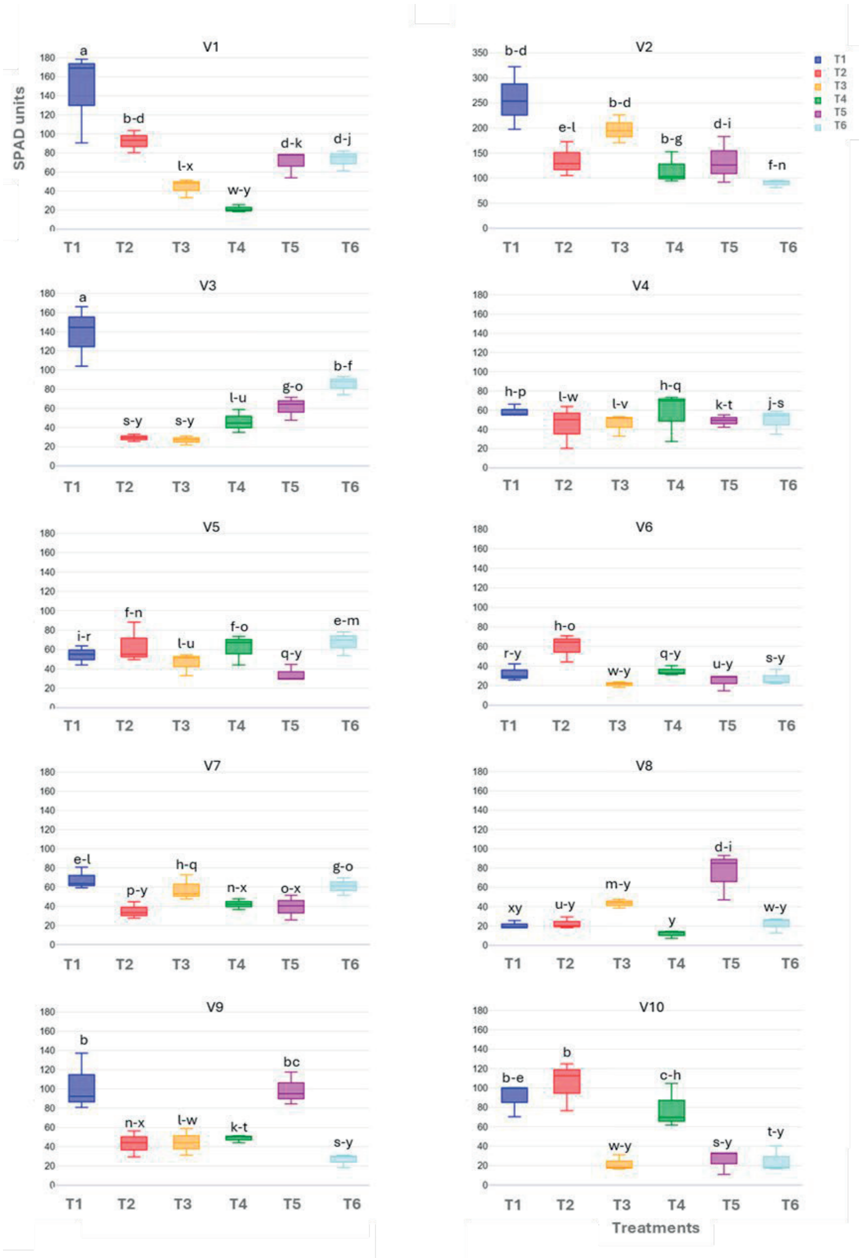

Figure 2. Chlorophyll content in the fifth assessment:
Legend: V1=Andrada, V2=Arieșan, V3=Bezostaia, V4=Ciprian, V5=Faur, V6=Fundulea, V7=Miranda, V8=Otilia, V9=Pădureni, V10=Transilvania wheat varieties; T1=0 mM NaCl, T2=15 mM NaCl, T3=30 mM NaCl, T4=45 mM NaCl, T5=60 mM NaCl, T6=75 mM NaCl saline treatment; ANOVA: F (variety)=19.14, p (variety)<0.001; F (treatment)=22.52, p (treatment)<0.001; F (variety × treatment)=8.65, p (variety × treatment)<0.001.

The top of the highest chlorophyll levels is completed by the values of plants of the variety Bezostaia V3 from T2 with an insignificant decrease of 5 percent from the maximum. High values, but with significant decreases of 28% and 29% compared to the highest value were observed for the varieties Transilvania in T2 and Pădureni in T1. The lowest value was observed in Otilia from T4, with a drastic decrease of 92% compared to the maximum recorded. The same variety treated with T1 and T6, as well as the variety Fundulea from T3, completed the top of the list of minimum values of the measured parameter. At the last measurement date, the best-performing varieties in terms of relative chlorophyll level averages were Arieșan, Andrada, and Bezostaia. On the contrary, the worst performers were Otilia, Fundulea, and Miranda.

Plant traits in different salinity conditions

In terms of the **total number of stems** developed from the thirty seeds from all five replicates initially germinated, Faur was the best-performing and the low-performing variety was Otilia (Table 2). The values of the Faur variety plants ranged between 29 and 30 plants, registering the maximum average values. These were recorded in plants treated with T2, T5, and T6 doses. This demonstrates the tolerance of the variety even at the last two highest salt treatment concentrations. These performances of Faur are statistically higher than those of Transilvania, Fundulea, Ciprian, Miranda, and Andrada. The worst results were recorded for Otilia, with values in the range 19-24. The minimum values of this variety were observed at T5 and the maximum at T3. The lowest value recorded for this parameter was observed in the variety Fundulea, which represents a decrease of 40% from the maximum recorded in the variety Faur (Figure 3). The stems number could be influenced by the germination capacity, but also by the plants growth and development. Altogether could provide inside for the optimal usage purpose primarily for food or bioenergy (Șandor et al., 2015). In terms of the parameter analyzed St, the varieties Faur, Arieșan, Bezostaia and Pădureni were classified as having a high degree of tolerance to salt stress, recording the highest yields. Transilvania, Fundulea, Ciprian and Miranda were ranked in the moderately tolerant category, while Transilvania and Otilia were moderately sensitive. While the Otilia variety maintains the same trend of reduced tolerance in the presence of this stressor, the Transilvania wheat follows a different trend. This indicates that the germination together with the growth and development processes of Otilia variety are salt stress affected (Adjel et al., 2013).

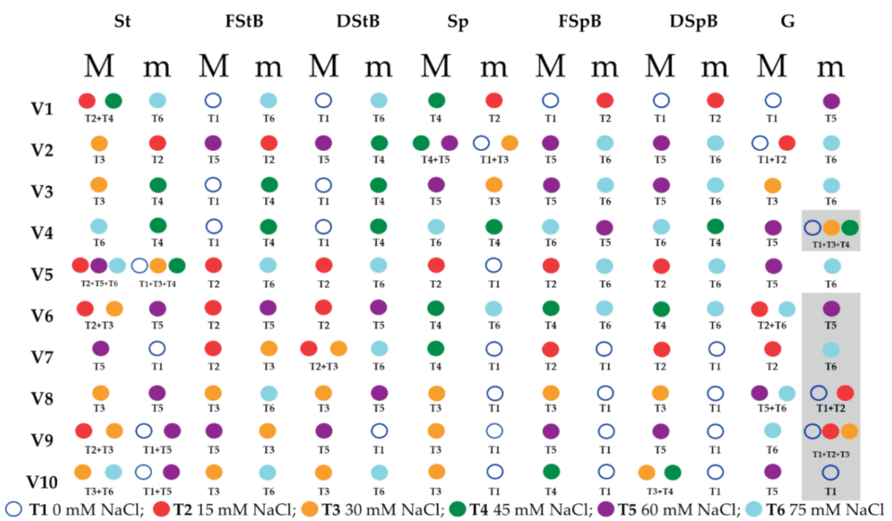

Figure 3. Minimal (m) and maximal (M) performance of wheat varieties morphological parameters in relation with salinity gradient.
Legend: Wheat varieties – V1=Andrada, V2=Arieșan, V3=Bezostaia, V4=Ciprian, V5=Faur, V6=Fundulea, V7=Miranda, V8=Otilia, V9=Pădureni, V10=Transilvania. Parameters: number of stems (St), fresh stems biomass (FStB), dry stems biomass (DStB), number of spikes (Sp), fresh spikes biomass (FSpB), dry spikes biomass (DSpB) and number of grains (G)

Table 2. Number of stems (St), fresh stems biomass (FStB), dry stems biomass (DStB), number of spikes (Sp), fresh spikes biomass (FSpB), dry spikes biomass (DSpB) and number of grains (G) for ten wheat varieties assessed at the end of the experiment

	St	FStB	DStB	Sp	FSpB	DSpB	G
V1	24.00±1.00**cd**	5.44±0.64**bc**	4.84±0.54**bc**	16.17±2.09**cd**	1.81±0.65**bc**	1.56±0.56**b-d**	20.50±10.50**bc**
V2	27.67±0.56**ab**	6.05±0.28**b**	5.25±0.18**b**	24.67±1.54**a**	3.98±0.36**a**	3.57±0.33**a**	71.33±8.11**a**
V3	27.17±1.74**a-c**	5.83±0.52**b**	5.27±0.47**b**	23.33±1.23**ab**	2.20±0.12**b**	1.99±0.10**bc**	27.67±4.25**b**
V4	25.00±1.21**bc**	4.51±0.52**cd**	4.05±0.46**cd**	18.17±2.63**b-d**	0.85±0.11**de**	0.75±0.10**de**	2.33±1.23**c**
V5	29.50±0.22**a**	4.05±0.25**d**	3.59±0.17**d**	14.50±1.45**d**	0.69±0.09**e**	0.60±0.08**e**	3.17±0.70**c**
V6	25.50±1.57**bc**	4.32±0.33**cd**	3.60±0.19**d**	16.17±1.94**cd**	0.80±0.13**de**	0.74±0.12**de**	2.17±0.65**c**
V7	24.50±1.34**bc**	5.21±0.07**b-d**	4.38±0.02**b-d**	21.17±1.45**a-c**	1.24±0.05**c-e**	1.14±0.04**c-e**	4.67±1.69**c**
V8	21.00±0.73**d**	2.73±0.17**e**	2.46±0.10**e**	17.17±1.40**cd**	0.77±0.11**de**	0.72±0.10**de**	5.00±2.57**c**
V9	26.67±0.56**a-c**	7.65±0.67**a**	7.10±0.68**a**	20.00±2.19**a-d**	1.66±0.48**b-d**	1.55±0.46**b-d**	37.50±17.06**b**
V10	25.50±1.77**bc**	5.40±0.36**bc**	4.96±0.31**bc**	19.33±3.69**a-d**	2.23±0.52**b**	2.09±0.49**b**	20.00±7.22**bc**
F	3.82	9.75	11.35	2.48	9.18	9.03	8.84
p	0.001	p<0.001	p<0.001	p<0.050	p<0.001	p<0.001	p<0.001

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

Higher values of **spikes** were recorded for Arieșan, Bezostaia, and Miranda varieties and no statistical significant between them only compared to Faur variety (Table 2). The maximum value was recorded for the Transilvania variety in T3. The minimum value was recorded for the same variety, with a decrease of about 90% from the highest value. The maximum values of the spikes number for all varieties were obtained in the proportion of about 36% in T4, 27% in T3, 18% in T5, and 9% in T6 and T2 (Figure 3).

The number of spikes is an important quantitative parameter in agriculture, and its monitoring has been useful in selecting wheat varieties capable of flowering and producing grain (Dreccer et al., 2019). Varieties Arieșan and Bezostaia show similar trends of Sp to those observed for the number of spikes, being classified again in the category of those with a high degree of salinity tolerance. Miranda, Pădureni, and Transilvania were also classified in the same category. The fact that Transilvania had a higher yield of spike number, registering a trend opposite to the one observed for the number of stems, suggests that this variety can be grown in saline conditions to produce yield crops, but cannot be recommended for obtaining biomass for biofuel production. Plants of the varieties Ciprian, Otilia, Andrada, and Fundulea were included in the tolerant category. The lowest degree of tolerance to salt stress was observed in the Faur wheat, which recorded a trend opposite to the one observed in the number of stems, which is why the cultivation of this variety under salinity conditions is recommended strictly for biomass production.

The **number of grains** is an important parameter both in agriculture and for improving wheat plants to be as rich and productive as possible. The highest average value of the parameter was obtained in the variety Arieșan, a value significantly higher than all the other values obtained in the other varieties. On the other hand, the lowest mean value recorded was observed in the variety Fundulea with a significant decrease of about 97% from the highest mean value (Table 2).

Wheat stems and spikes biomass in different salinity conditions in different salinity conditions

Regarding the **wheat stem fresh biomass** (FStB), the best performance of the mean values was recorded in the variety Pădureni, with values in the range 6.19-10.54, statistically higher than those recorded in all other varieties (Tabel 2). At the opposite pole, low performances were observed for Otilia with values in the range of 2.44-3.54 (Table 2). The maximum values recorded were reached for Pădureni wheat variety in T5. On the other hand, the lowest value of dry biomass, with a decrease of about 77% compared to the maximum, was reached for the variety Otilia in the treatment with the highest salinity dose. The maximum values of FStB obtained for all varieties were reached as follows: 30% in plants treated with T1 and T2 doses and 20% in those treated with T3 and T5 (Figure 3).

Pădureni wheat maintains a similar trend to those recorded for spike number, fresh stem biomass had maximum values probably due to an increased degree of tolerance to salt stress (Chețan et al., 2024). Ariesan, Bezostaia, Transilvania, and Miranda were included in the moderately tolerant category. Wheat of Ciprian, Fundulea, and Faur varieties are the least tolerant to salt stress, and the most sensitive was Otilia, a variety with approximately the same trend as those observed previously, with the lowest yields.

The **dry biomass** (DStB) of wheat stems is a parameter that maintains, in terms of performance, the same trend visible in the fresh biomass of plant material. Thus, the highest yielding variety was Pădureni, and the lowest-performing was Otilia. The values for dry biomass recorded for the variety Pădureni were in the range of 5.80-9.98 (Table 2), and the maximum could be observed in T5 (Figure 3). The mean dry biomass values of all other varieties and treatments were significantly lower than the highest value recorded (Table 2). The lowest value recorded was reached in Otilia wheat at the fifth dose of salt treatment, with a decrease of about 78% (Figure 3).

The dry biomass of the stems shows approximately the same trends as those recorded for their fresh biomass.

Wheat production depends mainly on the qualitative and quantitative performance of the wheat spikes. The best performance of the average values of the **wheat spikes fresh biomass** was recorded in plants of the variety Arieșan, and the lowest in wheat of the variety Faur with a significant decrease in average values of about 83% (Table 2). The maximum values recorded for FSpB were reached by wheat variety Arieșan in T5 (Figure 3). With a decrease of about 98% of the maximum, the minimum values were observed for Transilvania variety in T1. Plants of all varieties and all treatments reached the maximum in proportion of 30% in T5 treatment, 20% in T4, 20% in T2, 10% in T3, 10% in T6, and another 10% in T1.

Fresh spike biomass registered higher values for Arieșan wheat variety and it can be considered to have the highest degree of tolerance to salinity, and it can be recommended for growth when salts are present in the soil. The varieties Transilvania, Bezostaia, Andrada, and Pădureni can be classified according to their FSpB values as moderate resistant to salt stress. Miranda, Ciprian, Fundulea, and Otilia showed moderate sensitivity to salinity, while the lowest values of FSpB was recorded in the most sensitive variety, Faur. The salt stress sensitivity trend of Faur wheat, both in stem and spike biomass, suggests that this variety is not recommended to be grown under salinity conditions. The spike dry biomass shows similar trends in the varieties compared to the fresh spike biomass.

The highest average value of **dry biomass** of wheat (DSpB) was recorded in Arieșan, which is significantly higher than all the others. The lowest average value was observed in Faur, with a decrease of about 83% from the highest value recorded (Table 2). The Arieșan variety maintains the same trend as for the determined fresh biomass, recording the maximum dry biomass value at T5. At the opposite pole, the minimum of the recorded values was observed also in the Transilvania variety in T1.

Wheat stem and spike water content in different salinity conditions

In terms of the average **stems water content**, the highest average value was recorded for Miranda and is higher than Pădureni, Transilvania, and Otilia (Figure 4.). The lowest average water content, with a reduction of about 53% from the highest value, was observed in Pădureni. The maximum value of water content was recorded in Fundulea variety of wheat, treated with the second dose of salt treatment. At the opposite pole, the lowest value, with a decrease of about 84% of the maximum, was recorded for the variety Pădureni in T4.

The highest value for **spike water content** parameter was recorded at Andrada variety. Lower values compared to the highest average value recorded were observed for Fundulea, Miranda, Otilia, Pădureni, and Transilvania.

The spike water content does not maintain the same trends as in stems. Thus, the most tolerant wheat varieties to the six doses of salt treatment were Andrada, Faur and Ciprian. A similar trend to the previously analyzed parameter can be observed in the variety Ariesan which remains moderately tolerant to salinity. Bezostaia was also in the same category. Pădureni, Miranda, and Fundulea are moderately sensitive, while the most sensitive to salinity was Otilia, showing a similar pattern compared to the other parameter.

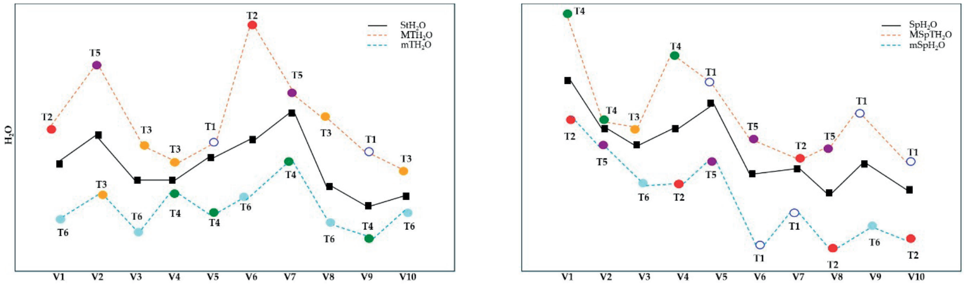

Figure 4. Stems water content (StWC) and spike water content (SpWC) for ten wheat varieties
Legend: V1=Andrada, V2=Arieșan, V3=Bezostaia, V4=Ciprian, V5=Faur, V6=Fundulea, V7=Miranda, V8=Otilia, V9=Pădureni, V10=Transilvania. Upper line – Maximum recorded for each parameter; Middle black line – average recorded for each parameter; Lower line – minimum recorded for each parameter

CONCLUSIONS

The parameters assessment values outline the plant responses variability to salinity stress.
Transilvania and Arieșan wheat variety can be classified, based on leaf relative chlorophyll content, in the salinity-tolerant category.
The varieties Faur, Arieșan, Bezostaia and Pădureni had high number of stems.
Varieties Arieșan and Bezostaia registered the higher number of spikes.
Arieșan variety had the higher fresh spike biomass.
Andrada, Faur and Ciprian registered the most higher spike water content.
The results highlighted the importance of nutrition and environmental conditions, including salinity stress, in chlorophyll synthesis and physiological mechanisms as integrated parts of plant growth and development.
Salinity stress threat is increasing, especially in the context of rapidly expanding populations and drastic climate change.

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