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CRITICAL SALINITY THRESHOLDS IMPACTING WHEAT GERMINATION: DETERMINING DOSE-DEPENDENT RESPONSES ACROSS VARIETIES

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Abstract

*The study aimed to establish the critical salinity dose that can be tolerated by 16 wheat varieties from Romania under controlled conditions. The tested varieties were Alex, Andrada, Bezostaia, Boema, Arieșan, Ciprian, Esențial, Faur, Glosa, Granny, Fundulea, Miranda, Otilia, Pădureni, Taisa and Transilvania. Critical salinity levels (mM NaCl) were tested respectively D1-100, D2-125, D3-150; D4-175; D5-200; D6-225; D7-250; and control (C) with distilled water. The assessment was made according to first and second principal growth stage on BBCH scale (**B**iologische Bundesanstalt, **B**undessortenamt und **CH**emische Industrie) and the following parameters were calculated: germination percentage (GP), germination index (GI), total germinated seeds (TGS) and relative salt injury rate (RSIR). After 7 days, at 250 mM NaCl, the wheat varieties reached overall the maximum developmental stage of BBCH 07. Lower RSIR was obtained by Andrada variety a result of an increased salinity resistance, while Taisa, Transilvania, and Pădureni proved lower resistance to stress, marked by increased RSIR coefficient. Germination standard parameters highlighted the critical salinity thresholds between 225-250 mM NaCl with different resistance threshold between varieties.*

Key words*: abiotic stress, early growth stages, relative salt injury rate, wheat tolerance.*

INTRODUCTION

Soil salinity is an abiotic stress affecting a significant proportion of agricultural cropland worldwide (Nehra et al., 2024). While the Orient is facing already the harmful effects of salinity (Zaman et al., 2018) and researchers are looking for strategies to adapt and improve plants in the presence of this stressor (Fita et al., 2015), the European continent is facing an expansion of salinization (Daliakopoulos et al., 2016). These worrying aspects sets considerable focus on soil health (Mustafa et al., 2019). Soil health is a concept of real interest (Panagos et al., 2024), as it is an essential and fundamental element in achieving the Sustainable Development Goals (SDGs) of the Sustainable Development Agenda for 2030 adopted by the United Nations (Head et al., 2020). Achieving and maintaining soil health is of high interest, particularly for the second Sustainable Development Goal (SDG 2) of ending global hunger (Lal et al., 2021). By focusing on soil health, the healthy lives and well-being of the population (SDG 3) can be enhanced (Howden-Chapman et al., 2017). Additionally, soil health is closely linked to the sixth SDG which aims to ensure clean water sources. (Bonfante et al., 2020) Indirectly, maintaining soil quality supports SDG 12, which targets responsible consumption and production, as well as SDGs 13 and 15, which focus on climate action and the conservation of terrestrial ecosystems (Mikhailova et al., 2023). Achieving soil health ultimately contributes to SDG 8 and SDG 1 by promoting productive agriculture and generating economic opportunities through employment (Visser et al., 2019).

Salinity effects, on both soil health and as a stress for plants, pose a significant threat to agricultural yields and global food security. In plant organisms, salinity effect is first felt by the osmotic stress onset caused by the altered osmotic potential of soil solution (Soni et al., 2023). This abiotic stress affects all the plants phenological stages (Okon, 2019), but the most sensitive of these are germination and anthesis (El Sabagh et al., 2021), while leaves senescence can set in prematurely (Allu et al., 2014). At the same time, salt stress induces an ionic imbalance (Hualpa-Ramirez et al., 2024), affects photosynthesis (Mahavar et al., 2024), and leads to a reduction in biomass accumulation (Huanhe et al., 2024). All these aspects are reflected in low crop productivity and production, which in the context of climate change and growing population is a real threat to the global food security (van den Burg et al., 2024). The energy source from the daily diet is based on carbohydrate intake (Jequier, 1994). The main sources of carbohydrates and fibers are cereals (McKevith, 2004), among which wheat *Triticum aestivum* L., through its by-products, is a favourite among cultivated species (Kumar et al., 2011). Global wheat production recorded in 2022/2023 exceeded 800 million tons, but forecasts for 2023/2024 and 2024/2025 predict declines (FAO, 2024). Wheat yield varies slightly from year to year depending on ecophysiological conditions (Huzsvai et al., 2022). Under salinity conditions, wheat plants have diverse responses depending on the salinity concentration and the stress exposure time (Negrão et al., 2017). Wheat seed germination is delayed and shoot growth and development are affected by the stressor (Akbarimoghaddam et al., 2011). Germination is a phenological stage highly sensitive to ecophysiological conditions. Saline stress, depending on the concentration, can inhibit the process and even delay it by the onset of water stress and ion toxicity (El Sabagh et al., 2021). Plant height also decreases when wheat is subjected to successive saline treatments (Kandil et al., 2012). Biomass accumulation is also influenced by the low photosynthetic rate caused by prolonged exposure to stress (Paul et al., 2019). Both underground and aboveground organs are affected by a decrease in root biomass and leaf biomass, which ultimately influence crop production (Chourasia et al., 2022). Considering all these aspects, the study of wheat physiological processes in response to salinity is of real interest.

The study aimed to establish the maximum salinity dose that can be tolerated by 16 wheat varieties during germination and early BBCH stages under controlled conditions. The objectives were to conduct daily monitoring of the germination process, calculate the germination percentage and index, assess the impact of salinity stress following relative salt injury rate based on responses of 16 wheat varieties to eight increasing doses.

MATERIALS AND METHODS

The experiment was set up on February 5th, 2024, in the Plant Physiology Department research laboratory of USAMV Cluj-Napoca. The plant material was represented by a collection of 16 wheat *Triticum aestivum* L. varieties from the Agricultural Research and Development Station (ARDS) Turda. The 16 varieties were Alex, Andrada, Bezostaia, Boema, Arieșan, Ciprian, Esențial, Faur, Glosa, Granny, Fundulea, Miranda, Otilia, Pădureni, Taisa and Transilvania. For each variety, 20 seeds per replication were tested in 4 replicates. Each variety was subjected to a salt stress gradient, with seven salinity doses (D_1 - 100 mM NaCl, D_2 - 125 mM NaCl, D_3 - 150 mM NaCl; D_4 - 175 mM NaCl; D_5 - 200 mM NaCl; D_6 - 225 mM NaCl; D_7 - 250 mM NaCl; the results were compared to a control (C) with water.

Experimental conditions were daily monitored, both humidity, temperature, and photoperiod. The average humidity and temperature recorded for the entire experiment were 31.79±0.71% and 23.50±0.19°C. The photoperiod consisted of 11 hours of daylight and 13 hours of darkness. Setting up the experiment involved preparing the seven saline solutions using a high-precision balance. The germination process was carried out in transparent polystyrene Petri dishes (Alom et al., 2016) with a diameter of 9 cm. On the bottom of these plates were placed three 70% cotton disks of 6 cm diameter. The three pads were soaked in 25 ml of water or solution corresponding to the saline dose applied. Subsequently, the 20 seeds of each variant were applied on the wet layer. A volume of 3.5 mL of the dose corresponding to each variant was applied every two days. The germination process was monitored during the experimental period.

Germination percentage (GP), germination index (GI), total germinated seeds (TGS) and relative salt injury rate (RSIR) (Yohannes et al., 2020) were determined in the defining days, i.e.

on the fourth when the seeds reached mean germination time (Duda et al., 2003) and seventh day when the process ended (Woku et al., 2016). These parameters were calculated using the formulas:

$$GP = \frac{NUMBER\ OF\ GERMINATED\ SEEDS}{TOTAL\ NUMBER\ OF\ TESTED\ SEEDS} \times 100$$

$$GI = \frac{DAY\ AFTER\ SOWING \times NUMBER\ OF\ GERMINATED\ SEEDS}{TOTAL\ NUMBER\ OF\ TESTED\ SEEDS}$$

$$RSIR = \frac{GP(control) - GP(saline\ dose)}{GP(control)} \times 100$$

Relative salt injury rate (RSIR) is a parameter that can give details on how salt stress intervenes in the germination process, relating each variant to the performance recorded in the control. All data were recorded in synthetic tables, where the red or dark blue color in each cell indicates the direction of treatment effects. The negative value (marked in red) of the RSIR is associated with a positive effect induced by the application of the dose. In contrast, high positive values (marked in dark blue) indicate a strong negative impact of the doses on the varieties.
The germination percentage (GP) (Kandil et al., 2012) is directly influenced by and related to the total germinated seeds (TGS), while the germination index (GI) (Yohannes et al., 2020) depends on the assessment day and also on the TGS. In this way, the dependence relationship between the parameters is evident through the distribution of the recorded values and mirrors a quantitative analysis of the germination process. All the values were then introduced into a database. Mean values and standard errors were obtained after performing the analyse of variance test using the statistical LSD test analysis with the software RStudio (R Core Team, 2020), based on “psych” (Corcoz et al., 2022; Revelle, 2017; Stoian et al., 2022) and “agricolae” (de Mendiburu, 2019; Stoian et al., 2016) packages. Mean values for all the parameters were then processed using conditional formatting for highlighting lower-higher values. The best performances were marked with the dark red, while the lower values with dark blue. The wheat seed germination and leaf development noted on BBCH growth scale (BBCH Working Group, 2001).

RESULTS AND DISCUSSIONS

Germination parameters-GP, GI and TGS

The GP, GI and TGS gradually decreased with the seven saline stress doses application. However, this aspect outlined in most of the varieties shows some exceptions on the fourth day of germination. These atypical aspects were outlined in the Miranda variety, which reached maximum of these three parameters at C (control), D1 (100 mM NaCl) and even at D5 (200 mM NaCl) (Figure 1). Similarly, Taisa showed same trends at C and D4 (175 mM NaCl), Otilia and Transilvania at D3 (150 mM NaCl) and Pădureni at D2 (125 mM NaCl) and D3. The two doses, D1 and D2, also stimulated the germination of the wheat varieties Andrada and Alex. However, the presence of salt stress did not significantly affect the germination process of Otilia and Taisa. Another interesting aspect is outlined for the varieties Bezostaia, Boema, Esențial, Glosa, Granny and Miranda, where the three parameters were significantly reduced only when exposed to the 250 mM NaCl dose. On the other hand, all the other varieties exhibited a significantly lower performance with the gradual increase of the salt doses. Overall, all cultivars reached at least the GP 95% saline treatment dose. A share of 37.5% from the 16 varieties, Arieșan, Ciprian, Miranda, Otilia, Taisa and Transilvania showed the most uneven GP distributions among the seven treatment doses. It is possible that this aspect outlines the tolerance of each variety to a certain key dose which has a stimulating effect on the process. The low tolerance of Pădureni and Esențial wheat observed in the fourth day is indicated by the fact that they only reach a GP higher than 95% at C and D1. Moreover, the application of higher doses over D4 gradually decrease the parameters analyzed in the case of Pădureni. A lower share of 12.5% from overall varieties, Glosa and Granny, reached a germination percentage higher than 95% only up to D2.
The degree of tolerance, as indicated by the parameter values, increased at D3 for Andrada and Fundulea, and at D4 for Bezostaia and Faur. The most tolerant varieties, after analyzing the values, were Alex and Boema, representing the wheat seeds that registered GP higher than 95% up to the fifth dose of salt

stress. The germination advancement on the fourth day is influenced not only by the salinity stress applied (Maas and Poss, 1989) but also by the genetic tolerance inherent (Amro et al., 2022) to each wheat variety.

ALEX	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	96.25	ab	2.89	ab	19.25	ab
D1	97.50	a	2.93	a	19.50	a
D2	97.50	a	2.93	a	19.50	a
D3	96.25	ab	2.89	ab	19.25	ab
D4	96.25	ab	2.89	ab	19.25	ab
D5	95.00	ab	2.85	ab	19.00	ab
D6	88.75	bc	2.66	bc	17.75	bc
D7	83.75	c	2.51	c	16.75	c

ARIEȘAN	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	98.75	a	2.96	a	19.75	a
D1	92.50	ab	2.78	ab	18.50	ab
D2	91.25	abc	2.74	abc	18.25	abc
D3	92.50	ab	2.78	ab	18.50	ab
D4	96.25	ab	2.89	ab	19.25	ab
D5	90.00	bc	2.70	bc	18.00	bc
D6	90.00	bc	2.70	bc	18.00	bc
D7	83.75	c	2.51	c	16.75	c

GLOSA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	98.75	a	2.96	a	19.75	a
D1	95.00	a	2.85	a	19.00	a
D2	97.50	a	2.93	a	19.50	a
D3	93.75	a	2.81	a	18.75	a
D4	92.50	ab	2.78	ab	18.50	ab
D5	93.75	a	2.81	a	18.75	a
D6	92.50	ab	2.78	ab	18.50	ab
D7	85.00	b	2.55	b	17.00	b

OTILIA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	93.75	a	2.81	a	18.75	a
D1	90.00	a	2.70	a	18.00	a
D2	90.00	a	2.70	a	18.00	a
D3	95.00	a	2.85	a	19.00	a
D4	88.75	a	2.66	a	17.75	a
D5	90.00	a	2.70	a	18.00	a
D6	90.00	a	2.70	a	18.00	a
D7	90.00	a	2.70	a	18.00	a

ANDRADA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	96.25	a	2.89	a	19.25	a
D1	97.50	a	2.93	a	19.50	a
D2	97.50	a	2.93	a	19.50	a
D3	96.25	a	2.89	a	19.25	a
D4	93.75	a	2.81	a	18.75	a
D5	83.75	b	2.51	b	16.75	b
D6	83.75	b	2.51	b	16.75	b
D7	88.75	ab	2.66	ab	17.75	ab

CIPRIAN	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	100.00	a	3.00	a	20.00	a
D1	97.50	ab	2.93	ab	19.50	ab
D2	93.75	abc	2.81	abc	18.75	abc
D3	93.75	abc	2.81	abc	18.75	abc
D4	95.00	ab	2.85	ab	19.00	ab
D5	90.00	bcd	2.70	bcd	18.00	bcd
D6	86.25	cd	2.59	cd	17.25	cd
D7	83.75	d	2.51	d	16.75	d

GRANNY	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	100.00	a	3.00	a	20.00	a
D1	92.50	ab	2.78	ab	18.50	ab
D2	96.25	ab	2.89	ab	19.25	ab
D3	93.75	ab	2.81	ab	18.75	ab
D4	93.75	ab	2.81	ab	18.75	ab
D5	93.75	ab	2.81	ab	18.75	ab
D6	92.50	ab	2.78	ab	18.50	ab
D7	88.75	b	2.66	b	17.75	b

PĂDURENI	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	96.25	ab	2.89	ab	19.25	ab
D1	98.75	a	2.96	a	19.75	a
D2	90.00	a-d	2.70	a-d	18.00	a-d
D3	90.00	a-d	2.70	a-d	18.00	a-d
D4	91.25	abc	2.74	abc	18.25	abc
D5	87.50	bcd	2.63	bcd	17.50	bcd
D6	86.25	cd	2.59	cd	17.25	cd
D7	81.25	d	2.44	d	16.25	d

BEZOSTAIA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	100.00	a	3.00	a	20.00	a
D1	98.75	a	2.96	a	19.75	a
D2	97.50	a	2.93	a	19.50	a
D3	98.75	a	2.96	a	19.75	a
D4	95.00	a	2.85	a	19.00	a
D5	92.50	a	2.78	a	18.75	a
D6	93.75	a	2.81	a	18.50	a
D7	81.25	b	2.44	b	16.25	b

ESENȚIAL	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	96.25	a	2.89	a	19.25	a
D1	96.25	a	2.89	a	19.25	a
D2	91.25	a	2.74	a	18.25	a
D3	90.00	a	2.70	a	18.00	a
D4	91.25	a	2.74	a	18.25	a
D5	91.25	a	2.74	a	18.25	a
D6	91.25	a	2.74	a	18.25	a
D7	72.50	b	2.18	b	14.50	b

FUNDULEA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	98.75	a	2.96	a	19.75	a
D1	98.75	a	2.96	a	19.75	a
D2	97.50	ab	2.93	ab	19.50	ab
D3	97.50	ab	2.93	ab	19.50	ab
D4	90.00	bc	2.70	bc	18.00	bc
D5	93.75	abc	2.81	abc	18.75	abc
D6	88.75	cd	2.66	cd	17.75	cd
D7	81.25	d	2.44	d	16.25	d

TAISA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	95.00	a	2.85	a	19.00	a
D1	87.50	a	2.63	a	17.50	a
D2	90.00	a	2.70	a	18.00	a
D3	92.50	a	2.78	a	18.50	a
D4	95.00	a	2.85	a	19.00	a
D5	82.50	a	2.48	a	16.50	a
D6	88.75	a	2.66	a	17.75	a
D7	85.00	a	2.55	a	17.00	a

BOEMA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	98.75	a	2.96	a	19.75	a
D1	97.50	a	2.93	a	19.50	a
D2	93.75	ab	2.81	ab	18.75	ab
D3	97.50	a	2.93	a	19.50	a
D4	96.25	a	2.89	a	19.25	a
D5	96.25	a	2.89	a	19.25	a
D6	93.75	ab	2.81	ab	18.75	ab
D7	87.50	b	2.63	b	17.50	b

FAUR	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	98.75	a	2.96	a	19.75	a
D1	92.50	abc	2.78	abc	18.50	abc
D2	95.00	abc	2.85	abc	19.00	abc
D3	97.50	ab	2.93	ab	19.50	ab
D4	87.50	cd	2.63	cd	17.50	cd
D5	93.75	abc	2.81	abc	18.75	abc
D6	88.75	bcd	2.66	bcd	17.75	bcd
D7	81.25	d	2.44	d	16.25	d

MIRANDA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	97.50	a	2.93	a	19.50	a
D1	97.50	a	2.93	a	19.50	a
D2	95.00	a	2.85	a	19.00	a
D3	93.75	ab	2.81	ab	18.75	ab
D4	93.75	ab	2.81	ab	18.75	ab
D5	97.50	a	2.93	a	19.50	a
D6	96.25	a	2.89	a	19.25	a
D7	85.00	b	2.55	b	17.00	b

TRANSILVANIA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	90.00	ab	2.70	ab	18.00	ab
D1	90.00	ab	2.70	ab	18.00	ab
D2	95.00	ab	2.85	ab	19.00	ab
D3	96.25	a	2.89	a	19.25	a
D4	87.50	abc	2.63	abc	17.50	abc
D5	85.00	bc	2.55	bc	17.00	bc
D6	86.25	abc	2.59	abc	17.25	abc
D7	78.75	c	2.36	c	15.75	c

Figure 1. Mean values and the least significant difference for germination percentage (GP), germination index (GI), and total germinated seeds (TGS) assessed in the fourth day of the germination of all the sixteen wheat varieties subjected to control (C), D1-100 mM NaCl, D2-125 mM NaCl, D3-150 mM NaCl, D4-175 mM NaCl, D5-200 Mm NaCl, D6-225 mM NaCl and D7- 250 mM NaCl. ANOVA: Alex ($F=14.06$; $p<0.001$), Andrada ($F=15.57$; $p<0.001$); Bezostaia ($F=15.99$; $p<0.001$); Boema ($F=6.42$; $p<0.05$); Arieșan ($F=10.85$; $p<0.005$); Ciprian ($F=24.92$; $p<0.001$); Esențial ($F=14.82$; $p<0.001$); Faur ($F=13.05$; $p=0.001$); Glosa ($F=12.94$; $p=0.001$); Granny ($F=5.54$; $p<0.05$); Fundulea ($F=30.39$; $p<0.001$); Miranda ($F=4.46$; $p<0.05$); Otilia ($F=0.52$; $p<0.5$); Pădureni ($F=17.89$; $p<0.001$); Taisa ($F=1.67$; $p<0.5$); Transilvania ($F=7.29$; $p<0.05$)

Conducting the experiment up to the seventh day did not lead to major differences in the values distribution of the three parameters, but about 56% of the varieties did not record significant decreases in their values with increasing salt doses (Figure 2). This may indicate a tendency for Alex, Andrada, Glosa, Bezostaia, Granny, Fundulea, Otilia, Taisa and Transilvania to adapt to the treatments applied. Some of the varieties respectively Alex, Boema, Esențial, Faur, Pădureni and Transilvania had a more successful germination process compared with the control, in some of the variants, with a maximum recorded in the 100-200 mM NaCl concentration range. The general trend was to record the minimum at the most concentrated saline solution, D7 (250 mM NaCl), an aspect characteristic to about 69% of the varieties. Two of them, respectively Glosa and Fundulea performed minimally both below the highest dose and below D3 while Taisa performed weekly below D5.

The variability outlined by the recorded results suggests that the germination process progression, associated with germination percentage (GP), fluctuates in response to both saline dose and wheat variety (Pastuszak et al., 2022). Certain studies indicate that germination can be initiated even at 300 mM, which accounts for the trends observed in several varieties. However, subsequent development on the BBCH scale would no longer be feasible due to the adverse effects on cell division (Munns and James, 2003).

ALEX	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	95.00	a	5.70	a	19.00	a
D1	95.00	a	5.70	a	19.00	a
D2	96.25	a	5.78	a	19.25	a
D3	95.00	a	5.70	a	19.00	a
D4	95.00	a	5.70	a	19.00	a
D5	96.25	a	5.78	a	19.25	a
D6	92.50	a	5.55	a	18.50	a
D7	92.50	a	5.55	a	18.50	a

ARIEȘAN	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	100.00	a	6.00	a	20.00	a
D1	95.00	abc	5.70	abc	19.00	abc
D2	93.75	bc	5.63	bc	18.75	bc
D3	93.75	bc	5.63	bc	18.75	bc
D4	96.25	ab	5.78	ab	19.25	ab
D5	92.50	bc	5.55	bc	18.50	bc
D6	92.50	bc	5.55	bc	18.50	bc
D7	90.00	c	5.40	c	18.00	c

GLOSA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	100.00	a	6.00	a	20.00	a
D1	98.75	a	5.93	a	19.75	a
D2	97.50	a	5.85	a	19.50	a
D3	95.00	a	5.70	a	19.00	a
D4	97.50	a	5.85	a	19.50	a
D5	98.75	a	5.93	a	19.75	a
D6	96.25	a	5.78	a	19.25	a
D7	95.00	a	5.70	a	19.00	a

OTILIA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	96.25	a	5.78	a	19.25	a
D1	93.75	a	5.63	a	18.75	a
D2	90.00	a	5.40	a	18.00	a
D3	93.75	a	5.63	a	18.75	a
D4	88.75	a	5.33	a	17.75	a
D5	86.25	a	5.18	a	17.25	a
D6	92.50	a	5.55	a	18.50	a
D7	87.50	a	5.25	a	17.50	a

ANDRADA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	96.25	a	5.78	a	19.25	a
D1	96.25	a	5.78	a	19.25	a
D2	96.25	a	5.78	a	19.25	a
D3	96.25	a	5.78	a	19.25	a
D4	95.00	a	5.70	a	19.00	a
D5	90.00	a	5.40	a	18.00	a
D6	92.50	a	5.55	a	18.50	a
D7	91.25	a	5.48	a	18.25	a

CIPRIAN	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	100.00	a	6.00	a	20.00	a
D1	100.00	a	6.00	a	20.00	a
D2	95.00	ab	5.70	ab	19.00	ab
D3	97.50	ab	5.85	ab	19.50	ab
D4	97.50	ab	5.85	ab	19.50	ab
D5	93.75	b	5.63	b	18.75	b
D6	87.50	c	5.25	c	17.50	c
D7	96.25	ab	5.78	ab	19.25	ab

GRANNY	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	100.00	a	6.00	a	20.00	a
D1	95.00	a	5.70	a	19.00	a
D2	100.00	a	6.00	a	20.00	a
D3	95.00	a	5.70	a	19.00	a
D4	96.25	a	5.78	a	19.25	a
D5	96.25	a	5.78	a	19.25	a
D6	97.50	a	5.85	a	19.50	a
D7	97.50	a	5.85	a	19.50	a

PĂDURENI	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	96.25	a	5.78	a	19.25	a
D1	98.75	a	5.93	a	19.75	a
D2	88.75	abc	5.33	abc	17.75	abc
D3	93.75	ab	5.63	ab	18.75	ab
D4	92.50	ab	5.55	ab	18.50	ab
D5	85.00	bc	5.10	bc	17.00	bc
D6	88.75	abc	5.33	abc	17.75	abc
D7	78.75	c	4.73	c	15.75	c

BEZOSTAIA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	98.75	a	5.93	a	19.75	a
D1	96.25	a	5.78	a	19.25	a
D2	96.25	a	5.78	a	19.25	a
D3	96.25	a	5.78	a	19.25	a
D4	98.75	a	5.93	a	19.75	a
D5	97.50	a	5.85	a	19.50	a
D6	97.50	a	5.85	a	19.50	a
D7	92.50	a	5.55	a	18.50	a

ESENȚIAL	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	97.50	a	5.85	a	19.50	a
D1	100.00	a	6.00	a	20.00	a
D2	96.25	a	5.78	a	19.25	a
D3	93.75	a	5.63	a	18.75	a
D4	97.50	a	5.85	a	19.50	a
D5	95.00	a	5.70	a	19.00	a
D6	93.75	a	5.63	a	18.75	a
D7	78.75	b	4.73	b	15.75	b

FUNDULEA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	100.00	a	6.00	a	20.00	a
D1	98.75	a	5.93	a	19.75	a
D2	100.00	a	6.00	a	20.00	a
D3	98.75	a	5.93	a	19.75	a
D4	97.50	a	5.85	a	19.50	a
D5	98.75	a	5.93	a	19.75	a
D6	98.75	a	5.93	a	19.75	a
D7	97.50	a	5.85	a	19.50	a

TAISA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	96.25	a	5.78	a	19.25	a
D1	90.00	a	5.40	a	18.00	a
D2	93.75	a	5.63	a	18.75	a
D3	95.00	a	5.70	a	19.00	a
D4	96.25	a	5.78	a	19.25	a
D5	87.50	a	5.25	a	17.50	a
D6	88.75	a	5.33	a	17.75	a
D7	87.50	a	5.25	a	17.50	a

BOEMA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	97.50	a	5.85	a	19.5	a
D1	98.75	a	5.93	a	19.75	a
D2	97.50	a	5.85	a	19.5	a
D3	100.00	a	6.00	a	20	a
D4	97.50	a	5.85	a	19.5	a
D5	97.50	a	5.85	a	19.5	a
D6	97.50	a	5.85	a	19.5	a
D7	83.75	b	5.03	b	16.75	b

FAUR	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	97.50	ab	5.85	ab	19.50	ab
D1	93.75	abc	5.63	abc	18.75	abc
D2	98.75	a	5.93	a	19.75	a
D3	98.75	a	5.93	a	19.75	a
D4	90.00	bc	5.40	bc	18.00	bc
D5	97.50	ab	5.85	ab	19.50	ab
D6	96.25	ab	5.78	ab	19.25	ab
D7	87.50	c	5.25	c	17.50	c

MIRANDA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	100.00	a	6.00	a	20.00	a
D1	97.50	ab	5.85	ab	19.50	ab
D2	96.25	abc	5.78	abc	19.25	abc
D3	98.75	ab	5.93	ab	19.75	ab
D4	95.00	bc	5.70	bc	19.00	bc
D5	97.50	ab	5.85	ab	19.50	ab
D6	96.25	abc	5.78	abc	19.25	abc
D7	92.50	c	5.55	c	18.50	c

TRANSILVANIA	GP		GI		TGS	
	Mean	LSD test	Mean	LSD test	Mean	LSD test
C	96.25	a	5.78	a	19.25	a
D1	95.00	a	5.70	a	19.00	a
D2	97.50	a	5.85	a	19.50	a
D3	97.50	a	5.85	a	19.50	a
D4	87.50	a	5.25	a	17.50	a
D5	90.00	a	5.40	a	18.00	a
D6	87.50	a	5.25	a	17.50	a
D7	88.75	a	5.33	a	17.75	a

Figure 2. Mean values and the least significant difference for germination percentage (GP), germination index (GI), and total germinated seeds (TGS) assessed in the seventh day of the germination of all the sixteen wheat varieties subjected to control (C), D1-100 mM NaCl, D2-125 mM NaCl, D3-150 mM NaCl, D4-175 mM NaCl, D5-200 Mm NaCl, D6-225 mM NaCl and D7- 250 mM NaCl. ANOVA: Alex (F=0.78; p=0.385), Andrada (F=2.82; p=0.103); Bezostaia (F=0.86; p=0.360); Boema (F=6.63; p<0.05); Arieșan (F=11.43; p<0.005); Ciprian (F=13.05; p=0.001); Esențial (F=12.22; p=0.001); Faur (F=3.75; p<0.1); Glosa (F=2.95; p<0.1); Granny (F=0.33; p=0.572); Fundulea (F=2.62; p=0.116); Miranda (F=9.93; p<0.005); Otilia (F=2.36; p=0.135); Pădureni (F=15.45; p<0.001); Taisa (F=3.10; p<0.1); Transilvania (F=7.18; p<0.05)

The Relative Salt Injury Rate assessment

The parameter performance RSIR varies with the wheat variety, but also with the applied saline dose. Plants salt injury mechanism is complex and influences plant growth and development throughout their lifespan by disrupting various processes starting with germination inhibition (Hao et al., 2021) (Figure 3). The determined value of the parameter also varies with the time exposure to salt stress and the degree of seedling development at the time of measurement. After analysing the data, the impact of salt stress is stronger on the fourth day and tends to decrease with the time and the development of the seedlings. The Andrada variety shows the most interesting aspect, i.e. the plants seem to have an equal or lower RSIR compared to the control up to and including D4, on day 4. On contrast, longer exposure (day 7) to stress decreases RSIR under all saline doses. This may be associated with an adaptation of the plants to the tested doses. At the same time, another interesting aspect was outlined in the varieties Ariesan, Boema and Faur, as well as in the wheat variety Otilia, where D1 had a positive effect, reducing the RSIR both on the fourth day and especially on the seventh day. The outlined aspects highlight a temporal adaptation of certain wheat varieties to certain saline doses. This is due to the wheat plants adaptability through various mechanisms that operate throughout the entire plant organism, starting at cellular level (El Sabagh et al., 2021). A totally opposite aspect was observed at Alex, Bezostaia, Ciprian, Esential and Fundulea, where under D1, the three days' transition increased the RSIR. This shows that, although initially the application of the dose may be stimulating, the effect is diminished to approximately equal or lower performances compared with the control. The RSIR is also obviously stronger in Glosa, Granny and Taisa varieties. RSIR evolution indicates Andrada as the most tolerant wheat in the tested germplasm collection.

ALEX	RSIR	
C	DAY 4	DAY 7
D1	-1.32	1.11
D2	0	-1.39
D3	1.25	0.07
D4	6.32	2.57
D5	4.93	5.12
D6	10.07	5.2
D7	10	4.85

ARIEȘAN	RSIR	
C	DAY 4	DAY 7
D1	10.2	-1.82
D2	5.07	1.18
D3	10.26	6.32
D4	3.75	2.43
D5	7.63	4.93
D6	12.63	8.82
D7	17.83	8.88

GLOSA	RSIR	
C	DAY 4	DAY 7
D1	2.43	1.18
D2	3.75	2.5
D3	7.5	5
D4	7.5	5
D5	8.75	3.75
D6	8.75	3.75
D7	11.25	1.25

OTILIA	RSIR	
C	DAY 4	DAY 7
D1	-10.94	-12.75
D2	-4.09	-1.32
D3	-2.84	-0.07
D4	-2.7	2.63
D5	9.03	8.68
D6	-0.28	2.43
D7	8.95	15.13

ANDRADA	RSIR	
C	DAY 4	DAY 7
D1	0	-4.17
D2	-1.32	-5.56
D3	-2.63	-5.48
D4	-0.13	-1.45
D5	6.51	-6.87
D6	9.08	-2.99
D7	5.2	-2.78

CIPRIAN	RSIR	
C	DAY 4	DAY 7
D1	-4.1	2.63
D2	4.93	3.68
D3	-0.13	-1.38
D4	7.76	5.13
D5	5	1.12
D6	5	2.43
D7	14.14	6.45

GRANNY	RSIR	
C	DAY 4	DAY 7
D1	0	0
D2	2.5	1.25
D3	1.25	1.25
D4	5	1.25
D5	1.25	0
D6	3.75	1.25
D7	10	1.25

PĂDURENI	RSIR	
C	DAY 4	DAY 7
D1	0.07	-4.48
D2	10.75	10.53
D3	-2.78	-1.38
D4	4.17	2.63
D5	5.12	9.01
D6	9.28	7.7
D7	7.82	5.26

BEZOSTAIA	RSIR	
C	DAY 4	DAY 7
D1	-4.23	-0.14
D2	2.3	5
D3	1.32	5
D4	1.11	1.25
D5	2.43	3.75
D6	7.7	3.75
D7	28.25	23.75

ESENȚIAL	RSIR	
C	DAY 4	DAY 7
D1	-1.39	0
D2	6.25	1.18
D3	3.75	1.18
D4	2.5	1.18
D5	7.5	2.43
D6	8.75	4.93
D7	12.5	8.75

FUNDULEA	RSIR	
C	DAY 4	DAY 7
D1	-2.7	2.5
D2	1.25	1.25
D3	3.75	2.5
D4	8.82	5
D5	6.32	2.5
D6	7.63	3.75
D7	19.01	8.75

TAISA	RSIR	
C	DAY 4	DAY 7
D1	2.32	1.25
D2	5.26	3.68
D3	9.21	3.88
D4	11.84	12.78
D5	14.47	16.59
D6	11.84	11.24
D7	10.53	9.86

BOEMA	RSIR	
C	DAY 4	DAY 7
D1	1.25	-1.32
D2	3.75	2.5
D3	2.5	0
D4	2.5	-1.38
D5	10	3.68
D6	5	1.12
D7	7.5	1.25

FAUR	RSIR	
C	DAY 4	DAY 7
D1	-1.38	-2.63
D2	6.32	5
D3	6.38	5
D4	10.13	5
D5	8.88	7.5
D6	11.45	8.75
D7	29.21	18.75

MIRANDA	RSIR	
C	DAY 4	DAY 7
D1	3.75	3.75
D2	1.11	1.25
D3	3.82	3.75
D4	3.82	2.5
D5	-0.14	2.5
D6	5.06	2.5
D7	15.82	6.25

TRANSILVANIA	RSIR	
C	DAY 4	DAY 7
D1	10.2	10
D2	-1.88	2.57
D3	-3.37	2.36
D4	-0.07	2.64
D5	2.46	2.36
D6	4.02	6.66
D7	14.47	13.38

Figure 3. Mean values of relative salt injury rates (RSIR) assessed in the fourth and the seventh day of the germination of all the sixteen wheat varieties subjected to control (C), D1-100 mM NaCl, D2-125 mM NaCl, D3-150 mM NaCl, D4-175 mM NaCl, D5-200 Mm NaCl, D6-225 mM NaCl and D7-250 mM NaCl

The impact of salinity on BBCH development

The plant development on the BBCH scale was influenced by the saline doses. The trend outlined on the fourth day reveals that increasing salt treatment concentrations delayed the seedling growth process. More than half of the varieties reached the highest level of BBCH development, respectively BBCH 10 (Figure 4). Lower rates were observed for the varieties Alex, Andrada, Bezostaia, Boema, Esențial, Faur and Miranda. The development up to BBCH 09 under the influence of D4 dose reflects an increased tolerance of Taisa and Pădureni varieties compared to the variants at all the other doses. Transilvania, Otilia, Fundulea, Granny, Ciprian and Boema were ranked with lower tolerance than the two varieties. An interesting aspect is outlined in Bezostaia, where doses more concentrated than D3 gradually decrease the growth in the fourth day assessment. Most seedlings of this variety range between BBCH 05 and BBCH 07. Another interesting aspect was evidenced in Alex, where a few seedlings were still in BBCH 03 on day 4, at the doses D4, D6 and D7. This indicates a sensitivity of the germination process to high saline doses for this variety. These aspects highlighted the sensitivity of early growth and developmental stages, as defined by the BBCH scale, to salt stress. This sensitivity arises from the osmotic stress and toxicity induced by saline concentrations (El Sabagh et al., 2021), which adversely affect cell division and elongation processes (Terletskaya et al., 2020), particularly during the early growth phases (Baranova and Gulevich, 2021).

The saline doses effect on seedling growth and development is also evident on the seventh day of germination (Figure 5).

ALEX

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C			1.27	6.33	69.62	22.78
D1				34.18	65.82	
D2			2.53	37.97	59.49	
D3		2.56	2.56	48.72	46.15	
D4	2.70	1.35	17.57	50.00	28.38	
D5		8.00	12.00	73.33	6.67	
D6	1.41	12.68	28.17	57.75		
D7	2.82	26.76	29.58	40.85		

ANDRADA

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C			1.3	1.3	63.64	33.77
D1		1.3	0	41.56	57.14	
D2		0	2.56	66.67	30.77	
D3		2.53	20.25	67.09	10.13	
D4		2.6	33.77	61.04	2.6	
D5		25	25	50		
D6		20	32.86	47.14		
D7	4.11	35.62	31.51	28.77		

BEZOSTAIA

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C		11.69	7.79	7.79	49.35	23.38
D1				12.82	74.36	12.82
D2			4	13.33	82.67	
D3			7.89	40.79	51.32	
D4		1.32	23.68	64.47	10.53	
D5		2.67	49.33	48		
D6		40.85	30.99	28.17		
D7		65.45	23.64	10.91		

BOEMA

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C			1.25	1.25	51.25	46.25
D1			2.53	18.99	78.48	
D2			2.6	29.87	67.53	
D3				50	50	
D4		2.56	1.28	91.03	5.13	
D5		4.17	11.11	83.33	1.39	
D6		5.26	22.37	72.37		
D7		27.03	18.92	54.05		

GLOSA

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C					38.75	61.25
D1			1.3	5.19	93.51	
D2				16.88	83.12	
D3			6.76	63.51	29.73	
D4			6.76	93.24		
D5		1.37	9.59	89.04		
D6		5.48	12.33	82.19		
D7		15.49	19.72	64.79		

GRANNY

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C					45	55
D1					100	
D2				2.56	97.44	
D3			1.27	11.39	87.34	
D4			10.53	46.05	43.42	
D5		1.27	5.06	89.87	3.8	
D6		2.6	6.49	90.91		
D7		19.44	23.61	56.94		

FUNDULEA

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C					35.44	64.56
D1			6.49	5.19	88.31	
D2			2.56	16.67	80.77	
D3			6.58	40.79	52.63	
D4		2.78	5.56	86.11	5.56	
D5		0	8.11	91.89		
D6		0	5.48	94.52		
D7		18.75	15.63	65.63		

MIRANDA

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C				1.3	55.84	42.86
D1			2.67	22.67	74.67	
D2			7.89	56.58	35.53	
D3		4.05	14.86	81.08		
D4		1.35	10.81	87.84		
D5		5.19	11.69	83.12		
D6		9.59	9.59	80.82		
D7		30.77	23.08	46.15		

ARIEŞAN

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C				2.56	44.87	52.56
D1				4.29	95.71	
D2			4.05	14.86	81.08	
D3		1.43	4.29	52.86	41.43	
D4		0	5.33	90.67	4	
D5		1.39	4.17	94.44		
D6		2.94	22.06	75		
D7		9.38	15.63	75		

CIPRIAN

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C			1.28	1.28	46.15	51.28
D1			3.9	12.99	83.12	
D2			1.35	13.51	85.14	
D3			2.56	48.72	48.72	
D4			4.17	84.72	11.11	
D5			2.7	95.95	1.35	
D6		5.41	8.11	86.49		
D7		10.45	29.85	59.7		

ESENŢIAL

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C				1.25	52.5	46.25
D1			3.85	15.38	80.77	
D2			4	26.67	69.33	
D3			10.39	49.35	40.26	
D4			14.1	76.92	8.97	
D5		2.7	6.76	87.84	2.7	
D6		5.48	8.22	86.3		
D7		11.43	21.43	67.14		

FAUR

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C			1.27	1.27	60.76	36.71
D1			1.28	19.23	79.49	
D2			4.05	39.19	56.76	
D3			9.46	54.05	36.49	
D4			5.63	88.73	5.63	
D5		2.78	5.56	91.67		
D6		1.43	7.14	91.43		
D7		28.57	19.64	51.79		

OTILIA

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C			5.19	18.18	32.47	44.16
D1				1.27	77.22	21.52
D2				13.75	83.75	2.5
D3			3.8	35.44	60.76	
D4		1.27	3.8	82.28	12.66	
D5		2.86	8.57	87.14	1.43	
D6		1.3	2.6	96.1		
D7		7.14	12.86	80		

PĂDURENI

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C				1.33	6.67	92
D1				4.05	62.16	33.78
D2				2.99	97.01	
D3				9.09	90.91	
D4		1.39		26.39	72.22	
D5		1.41		56.34	42.25	
D6		1.47	1.47	88.24	8.82	
D7			4.35	95.65		

TAISA

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C				2.63	17.11	80.26
D1				1.39	94.44	4.17
D2					100	
D3			2.9	7.25	89.86	
D4		1.49	1.49	20.9	76.12	
D5			1.54	52.31	46.15	
D6			7.46	92.54		
D7		2.94	26.47	70.59		

TRANSILVANIA

	BBCH 03	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10
C					12.5	87.5
D1			1.47		86.76	11.76
D2				8.22	87.67	4.11
D3				31.08	68.92	
D4		1.39		77.78	20.83	
D5			2.86	95.71	1.43	
D6		1.45	4.35	94.2		
D7		1.64	19.67	78.69		

Figure 4. Percentage distribution of BBCH growth stages in the fourth day of germination for all the sixteen wheat varieties subjected to control (C), D1-100 mM NaCl, D2-125 mM NaCl, D3-150 mM NaCl, D4-175 mM NaCl, D5-200 Mm NaCl, D6-225 mM NaCl and D7-250 mM NaC

The most developed growth was seen in the control plants of the Glosa, Granny, Fundulea, Otilia, Pădureni, Taisa and Transilvania varieties, which already had an unfolded leaf. The tolerance of Taisa wheat to salinity was highlighted, at doses from D1 to D4, showed the same degree of development, with seedlings in BBCH 10. Transilvania, Pădureni and Fundulea, varieties whose seedlings, although performing better than other varieties, grew up to BBCH 10 when tested at D3 and lower doses, were significantly less tolerant than Taisa.

ALEX

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C		1.3			83.12	15.58
D1		1.3	6.49	32.47	59.74	
D2		1.28	12.82	41.03	44.87	
D3	1.3	1.3	11.69	49.35	36.36	
D4		10.67	29.33	46.67	13.33	
D5	1.37	2.74	50.68	45.21		
D6	2.74	2.74	86.3	8.22		
D7	8.22		89.04	2.74		

ANDRADA

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C					82.67	17.33
D1	1.3		15.58	49.35	33.77	
D2	1.27	2.53	30.38	36.71	29.11	
D3		2.53	37.97	51.9	7.59	
D4	3.95	1.32	80.26	13.16	1.32	
D5		2.5	92.5	5		
D6	3.9	2.6	92.21	1.3		
D7	1.3	3.9	94.81			

BEZOSTAIA

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C				1.25	87.5	11.25
D1			1.32	55.26	42.11	1.32
D2		2.63	6.58	36.84	53.95	
D3	1.32	3.95	9.21	60.53	25	
D4		6.33	36.71	51.9	5.06	
D5	2.6	6.49	58.44	32.47		
D6	5.19	14.29	80.52			
D7	18.03	13.11	68.85			

BOEMA

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C				1.28	79.49	19.23
D1		1.27	7.59	45.57	45.57	
D2		1.32	11.84	64.47	22.37	
D3			29.49	55.13	15.38	
D4	1.27	2.53	46.84	43.04	6.33	
D5		1.33	90.67	8		
D6	2.6	2.6	93.51	1.3		
D7	7.79	6.49	84.42	1.3		

ARIEȘAN

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C				2.53	58.23	39.24
D1			1.32	38.16	60.53	
D2			3.85	46.15	50	
D3			10.81	63.51	25.68	
D4			3.9	88.31	7.79	
D5		2.67	34.67	61.33	1.33	
D6	4.17		90.28	5.56		
D7		5.56	94.44			

CIPRIAN

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C				1.28	69.23	29.49
D1				34.21	65.79	
D2			4	34.67	61.33	
D3			2.53	64.56	32.91	
D4			12.16	81.08	6.76	
D5			35.06	64.94		
D6		1.32	89.47	9.21		
D7			98.63	1.37		

ESENȚIAL

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C					63.29	36.71
D1			5.06	15.19	79.75	
D2			6.41	50	43.59	
D3			5.13	66.67	28.21	
D4			50	46.15	3.85	
D5	1.3	3.9	67.53	27.27		
D6	0	2.67	94.67	2.67		
D7	1.39	8.33	90.28			

FAUR

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C					63.75	36.25
D1			1.25	35	63.75	
D2			6.58	55.26	38.16	
D3			14.47	55.26	30.26	
D4			43.42	52.63	3.95	
D5		2.7	71.62	25.68		
D6		2.74	93.15	4.11		
D7	3.08	10.77	63.08	23.08		

GLOSA

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C					7.5	92.5
D1				11.54	87.18	1.28
D2			2.56	23.08	74.36	
D3				65.79	34.21	
D4			10.53	86.84	2.63	
D5			28.57	71.43		
D6			84.42	15.58		
D7		2.53	96.2	1.27		

GRANNY

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C					28.75	71.25
D1				7.5	92.5	
D2			2.53	16.46	81.01	
D3			0	50.63	49.37	
D4			6.33	91.14	2.53	
D5			18.75	81.25		
D6			58.23	41.77		
D7			100			

FUNDULEA

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C					26.25	73.75
D1			3.9	7.79	88.31	
D2			3.8	22.78	73.42	
D3			2.56	42.31	55.13	
D4		1.32	18.42	71.05	9.21	
D5			64.1	35.9		
D6		2.6	77.92	19.48		
D7	2.74	4.11	91.78	1.37		

MIRANDA

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C					53.75	46.25
D1		1.3	3.9	15.58	79.22	
D2			7.59	43.04	49.37	
D3		1.3	22.08	74.03	2.6	
D4			84.62	15.38		
D5		1.28	89.74	8.97		
D6	1.28	3.85	94.87			
D7		9.33	90.67			

OTILIA

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C					29.11	70.89
D1				2.5	97.5	
D2			1.25	28.75	70	
D3		1.27	13.92	59.49	25.32	
D4			68.83	29.87	1.3	
D5		2.78	91.67	5.56		
D6			96.1	3.9		
D7		5.97	94.03			

PĂDURENI

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C			1.3	0	10.39	88.31
D1			2.56	3.85	92.31	1.28
D2			1.45	8.7	89.86	
D3			2.56	39.74	57.69	
D4			1.33	64	34.67	
D5		4.29	12.86	81.43	1.43	
D6			57.75	42.25		
D7			83.56	16.44		

TAISA

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C					20.78	79.22
D1		1.35	2.7		95.95	
D2		0	1.35	6.76	91.89	
D3		0	4.05	17.57	78.38	
D4		1.49	4.48	41.79	52.24	
D5			3.13	96.88		
D6			45.59	54.41		
D7			86.96	13.04		

TRANSILVANIA

	BBCH 05	BBCH 06	BBCH 07	BBCH 09	BBCH 10	BBCH 11
C			4	0	6.67	89.33
D1			0	1.43	94.29	4.29
D2			1.37	5.48	89.04	4.11
D3		1.37	0	17.81	80.82	
D4			6.85	63.01	30.14	
D5			54.79	43.84	1.37	
D6			64.29	14.29	21.43	
D7			95.38	4.62		

Figure 5. Percentage distribution of BBCH growth stages in the seventh day of germination for all the sixteen wheat varieties subjected to control (C), D1-100 mM NaCl, D2-125 mM NaCl, D3-150 mM NaCl, D4-175 mM NaCl, D5-200 Mm NaCl, D6-225 mM NaCl and D7-250 mM NaC

Among the growth delayed seedlings were those of the Alex and Bezostaia varieties, which under higher concentrations of D3 reached maximum BBCH 07. With even lower performance than these, Andrada and Boema reached maximum BBCH 07 at higher concentrations than D4. The high dose of salt stress affects cell division and growth, which is why germination is delayed or even stopped (El Sabagh et al., 2021).

CONCLUSIONS

By monitoring and evaluating germination through the analyzed parameters, it was observed that the earlier stage of germination was more sensitive to salt stress. Additionally, the temporal evolution of the parameters is associated with a tendency for seedlings to adapt to lower saline concentrations in most of the tested varieties.

The RSIR evaluation at two distinct stages of germination revealed an adaptive response over time to saline stress, reflected in the reduced impact. Furthermore, the Andrada wheat variety performed well under saline conditions, while Taisa, Transilvania, and Pădureni experienced negative effects in the presence of saline stress, marked by an increase in RSIR.

The progression along the BBCH scale was significantly influenced by the saline stress application, particularly at higher concentrations. Prolonged exposure to the highest saline concentration until the seventh day of germination indicated a trend of reduced tolerance across all varieties, with most achieving a maximum development stage of only BBCH07.

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