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Water and saline stress on germination and growth of white oat seedlings under different temperatures

Estresse hídrico e salino na germinação e crescimento de plântulas de aveia branca sob diferentes temperaturas

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ABSTRACT

Salinity and water deficit are among the main stress situations that affect germination and seedling development in the field. Thus, the objective was to evaluate the germination and growth of white oat seedlings subjected to water and saline stress at different temperatures. The experiment was carried out in a completely randomized design, in a triple factorial

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arrangement, with two osmotic solutions (PEG 6000 and NaCl), five osmotic potentials (-0.2, -0.4, -0.6 and -0.8 MPa) and two temperatures (20 and 25 °C), with four replications of 50 seeds each. Initially, the water content of the seeds was determined. In the treatment effects, germination, first germination count, shoot length, primary root and seedling fresh mass were evaluated. Osmotic potentials lower than -0.2 MPa reduce the germination and growth of white oat seedlings, regardless of the stressor agent and temperature. The simulations of the stress conditions harmed the germination and the initial growth of the seedlings by the decrease of the observed variables. The salt and water stress induced by sodium chloride solution was more drastic than that induced by polyethylene glycol 6000.

Keywords: *Avena* sativa L.; sodium chloride; polyethylene glycol 6000; osmotic potential.

RESUMO

A salinidade e o déficit hídrico estão entre as principais situações de estresse que afetam a germinação e o desenvolvimento das mudas no campo. Assim, objetivou-se avaliar a germinação e o crescimento de plântulas de aveia branca submetidas a estresse hídrico e salino em diferentes temperaturas. O experimento foi conduzido em delineamento inteiramente casualizado, em arranjo fatorial triplo, com duas soluções osmóticas (PEG 6000 e NaCl), cinco potenciais osmóticos (-0.2, -0.4, -0.6 e -0.8 MPa) e duas temperaturas (20 e 25 °C), com quatro repetições de 50 sementes cada. Inicialmente foi determinado o teor de água das sementes. Nos efeitos dos tratamentos foram avaliados a germinação, a primeira contagem de germinação, o comprimento da parte aérea, a raiz primária e a massa fresca das plântulas. Potenciais osmóticos inferiores a -0,2 MPa reduzem a germinação e o crescimento de plântulas de aveia branca, independente do agente estressor e da temperatura. As simulações das condições de estresse prejudicaram a germinação e o crescimento inicial das plântulas pela diminuição das variáveis observadas. O estresse salino e hídrico induzido pela solução de cloreto de sódio foi mais drástico do que aquele induzido pelo polietilenoglicol 6000.

Palavras-chave*: Avena sativa L.; cloreto de sódio; polietilenoglicol 6000; potencial osmótico.*

1. INTRODUCTION

White oat (*Avena sativa* L.) is an important alternative crop for the autumn/winter period, especially in southern Brazil, it stands out for having multiple purposes, being destined to human and animal food, in addition to be widely used in crop rotation systems (Kaspary *et al*., 2015).

Salinity and water deficit are among the main stress situations that affect seedling germination and emergence in the field (Saberali; Moradi, 2019). Under stressful environmental conditions, such as water deficit, salinity, and heat stress, there is an imbalance between the production and removal of reactive oxygen species (ROS) (Veloso *et al*., 2022), which cause membrane lipid peroxidation, DNA damage, protein denaturation, carbohydrate oxidation, and reduced enzyme activity (Li *et al*., 2018; Liu *et al*., 2019).

One of the methods used to determine plant tolerance to stress is the assessment of the germination capacity of seeds under saline stress with sodium chloride (Silva; Queiroz, 2021) and water restriction with polyethylene glycol (PEG) (Barbieri *et al*., 2019).

Studies on seed germination responses under artificial stress conditions provide insights into species' adaptability to natural stress conditions commonly found in agricultural regions (Barbieri *et al*., 2019; Saberali; Moradi, 2019). In addition, the results obtained provide a range of information of high scientific importance, serving as a basis for the producer in the proper management of cultures. Thus, the objective of this work was to evaluate the germination and growth of white oat seedlings subjected to water and saline stress at different temperatures.

2. MATERIAL AND METHODS

The experiment was carried out at the Seed Analysis Didactic Laboratory (LDAS), belonging to the Postgraduate Program in Seed Science and Technology at the Federal University of Pelotas (FAEM/UFPel), seeds used were from the URS Corona cultivar, originating from the field teaching of the university itself.

The initial water content of the seeds was previously determined by the oven method at 105 ºC for 24 hours (Brasil, 2009).

To simulate water deficit, polyethylene glycol 6000 (PEG 6000) solutions were prepared according to Villela, Doni Filho and Sequeira (1991). To simulate salt stress, sodium chloride (NaCl) solutions were prepared following the Van`t Hoff equation (Salisbury; Ross, 1992), where Ψos = osmotic potential (MPa), C = concentration (mol L^{-1}), i = isotonic coefficient, R = general gas constant (0.0082 MPa mol^{-1} K^{-1}) and T = temperature (K).

Solutions of PEG 6000 and NaCl were prepared with the following osmotic potentials: 0.0, -0.2, -0.4, -0.6 and -0.8 MPa. The zero potential represented the control, without stress, for which distilled water was used.

The germination test was carried out with four replications of 50 seeds each. The seeds were sown on two sheets of germitest paper moistened with a volume of solution composed of each PEG 600 equivalent to 2.5 times the mass of the dry substrate, at different osmotic potentials, and then covered with another sheet. Subsequently, rolls were made and kept in a germinator (Mangelsdorf model) at a constant temperature of 20 and 25 ºC and a photoperiod of 12 hours.

Evaluations were performed on the fourth (first germination count) and tenth day after sowing, with the percentage of normal seedlings recorded, following the criteria established in the Rules for Seed Analysis (Brasil, 2009).

To evaluate the length of the stem (CP) and primary root (RPP), only normal seedlings were considered, using a graduated ruler, and the results were expressed in centimeters per seedling, using twenty seedlings. Then, the seedlings were weighed to obtain the fresh mass weight, and the results were expressed in g per replicate. The experiment was carried out in a completely randomized design, in a triple factorial arrangement, with two osmotic solutions (PEG 6000 and NaCl), five osmotic potentials (-0.2, -0.4, -0.6 and -0.8 MPa) and two temperatures (20 and 25 °C).

The variables were submitted to the Lilliefors normality test ($p<0.05$) and the Bartlett test ($p<0.05$) to verify normality and homogeneity, respectively. Data were submitted to analysis of variance at a 5% probability level and subsequent regression analysis. When significant, the effects of solutions and temperatures by the F test at 5% of significance, while the effects of osmotic potentials were studied by regression analysis, choosing the appropriate models to represent them in terms of their biological behavior, significance of the model coefficients and the value of the coefficient of determination (R^2).

3. RESULTS AND DISCUSSION

The determination of seed water content as an initial procedure showed 10.2% moisture. This fact is important for the execution of the analyses, since the uniformity of the water content is essential for the standardization of the evaluations and obtaining consistent results, thus admitting greater reliability to the results obtained in the tests (Tunes *et al*., 2008).

For all variables considered, there was a significant interaction between the factors studied (Table 1). It was observed, for the variables, high (GER, FC) and average (SL, PRL, FM) experimental precision, according to the criteria established by Pimentel-Gomes (1985). The result of this statistical parameter gives reliability to the inferences to be made about the average performance of oat seeds in the face of submitted stresses.

The results of seed germination showed a decreasing linear behavior (Figure 2). For both temperatures, the control treatment (0 MPa) had the highest germination percentages (100%). However, seed germination was progressively reduced with decreasing osmotic potentials both for substrates moistened with PEG solution and for NaCl, indicating sensitivity of white oat seeds to the submitted stresses. However, the results of the present work show that white oat seeds do not germinate under saline stress when submitted to the potential -0.8 MPa simulated by the NaCl solution (Figure 1), at the two temperatures tested. It was also noted that in the potentials 0.0; -0.2 and -0.4 MPa, for NaCl and PEG solutions, there was no difference in seed germination at temperatures of 20 and 25 °C.

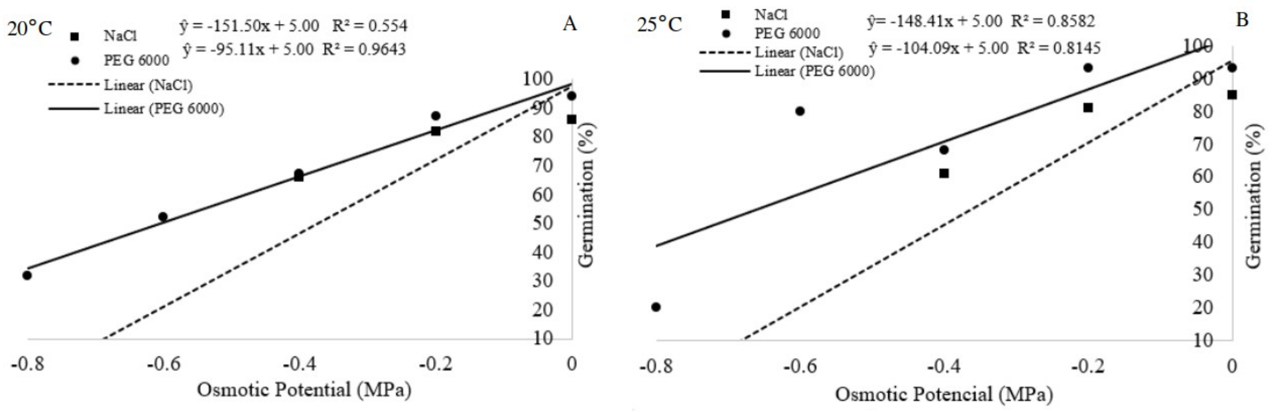
Table 1 – Summary of analysis of variance for the variables germination (GER); first germination count (FC); shoot length (SL); primary root length (PRL) and fresh mass (FM) of white oat subjected to water and saline stress at different temperatures.

Source of variation	GL	GER (%)	Mean squares			
			FC %)	SL (cm)	PRL (cm)	FM (g)
S	1	10.125,00*	9.417,80*	32.52*	666.03*	0.50*
PO	4	17.894,05*	17.187,17*	647.88*	195.96*	6.51*
T	1	39.20^{ns}	952.20*	2.88^{ns}	3.03^{ns}	0.09^{ns}
S x PO	4	2.604,75*	2.372,17*	71.12*	77.43*	1.62*
S x T	1	56.80*	168.20*	15.54*	4.60ns	0.21ns
PO x T	4	229.45*	278.82*	20.67*	3.36 ns	0.38*
S x PO x T	4	204.05*	343.32*	11.38*	5.64*	0.57*
Erro	60					
Averages		57.15	55.35	11.46	6.83	1.08
CV (%)		9.25	7.57	20.00	17.97	19.58

S = Solution; PO = Osmotic potential; T = Temperature; ^{ns}, Not significant, * significant at p ≤ 0.05 by F-test.

Source: Figueiredo (2022).

Figure 1 – Germination (%) of white oat seeds as a function of different osmotic potentials induced by NaCl and PEG 6000 and subjected to different temperatures.



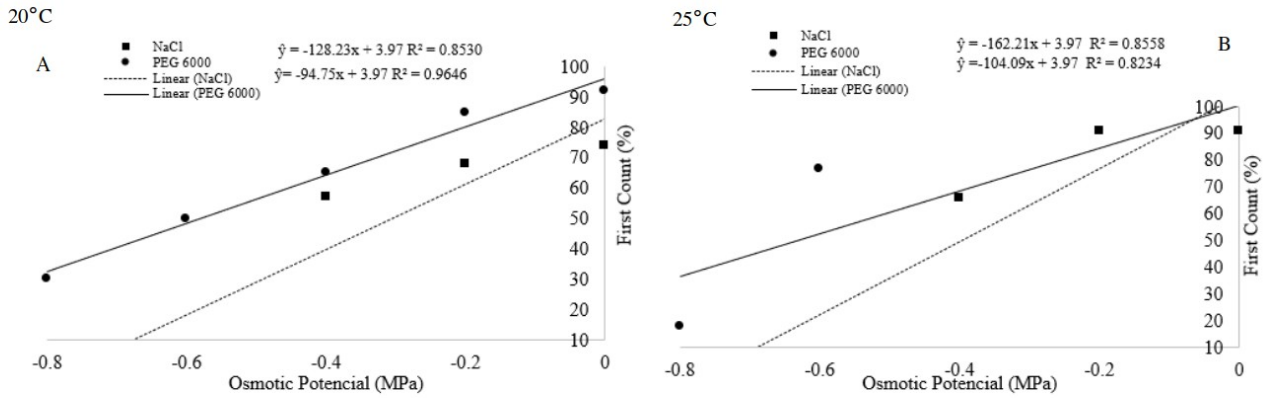
Source: Figueiredo (2022).

The reduction in seed germination caused by the decrease in the osmotic potential, induced by NaCl and PEG, may be the result of the osmotic and/or ionic effect thathinders the absorption of water by the seeds or facilitates the penetration of ions into the cells (Silva *et al.*, 2019). Consequently, a high concentration of salts in cells can deactivate enzymes, inhibit protein synthesis, and prevent seed germination (Nasr *et al.*, 2011; Taiz *et al.*, 2017).

Similar results to the present study were also reported by other researchers, who found that salt and water stress reduce the percentage of germination of seeds of various crops, such as *Crambe abyssinica* Hochst (Machado *et al*., 2000; Silva *et al*., 2019), *Vigna unguiculata* L. (Girão Filho *et al*., 2019), *Pisum sativum* L. (Pereira *et al*., 2019), *Chenopodium quinoa* Willd. (Barbieri *et al*., 2019), *Phaseolus vulgaris* L. (Cangussu et al., 2020), *Cicer arietinum* L. (Pimenta *et al*., 2021) and *Avena sativa* L. (Stefanello *et al*., 2024).

As for the first germination count, it was observed that for the temperatures of 20 and 25 °C in the osmotic potential -0.2 MPa, the white oat seeds presented germination of 100 and 85%, respectively, when the substrates were moistened with PEG solution and 68 and 91% with NaCl solution (Figure 3). However, these values reduced as the concentration of NaCl and PEG increased. In the osmotic potential -0.8 MPa for the PEG solution, germination of 30% (20ºC) and 18% (25ºC) was verified, while for the NaCl solution there was no germination of the seeds at any of the temperatures.

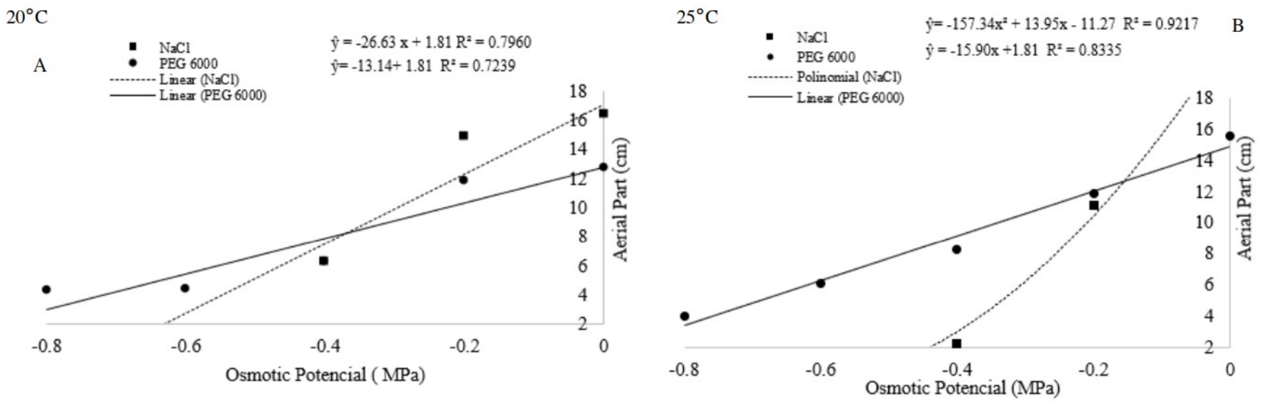
Figure 2 – First germination count (%) of white oat seeds as a function of different osmotic potentials induced by NaCl and PEG 6000 and subjected to different temperatures.



Source: Figueiredo (2022).

For the temperature of 20 °C (Figure 3), shoot lengths as a function of osmotic potentials showed linear behavior for the two solutions tested. In the control treatment (0 MPa), shoot lengths showed values of 16.37 and 12.76 cm, respectively, for PEG and NaCl solutions. However, as the osmotic potential became more negative, the values of shoot lengths decreased, reaching 4.32 cm for seedlings from substrates moistened with PEG at an osmotic potential of -0.8 MPa. As for NaCl at the osmotic potential of – 0.8 MPa, there was no seed germination.

Figure 3 – Length of the shoot of white oat seedlings (cm) as a function of different osmotic potentials induced by NaCl and PEG 6000 and submitted to different temperatures.



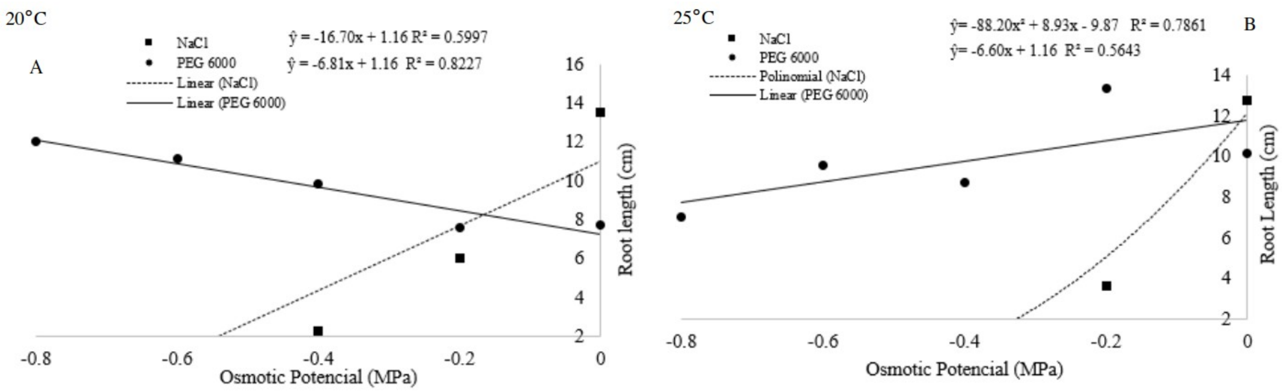
Source: Figueiredo (2022).

As for the temperature of 25 °C, the levels of osmotic potentials in PEG solutions showed linear and quadratic behavior for NaCl (Figure 4). As there was a reduction in the osmotic potential of the solution (PEG and NaCl), that is, a greater number of salts and less water availability, there were reductions in the length of the shoot of the seedlings. It was observed that the seeds submitted to the PEG and NaCl solutions, originated seedlings with larger shoots in the control treatment (0.0 MPa), and in the osmotic potential -0.2 MPa. In the osmotic potential -0.4, -0.6 and -0.8 MPa there was a significant difference between the osmotic agents used, and the plants from substrates moistened with PEG had the highest values of seedling length.

Primary root length in oats showed a linear decrease in response to increasing water and salt stress at 20 °C, and quadratic behavior for NaCl and linear for PEG at 25 °C (Figure 4). The increase in osmotic potential induced by NaCl and PEG negatively affected root growth. Based on the mathematical models, NaCl caused a greater deleterious effect on root length, with malformation of this structure, with average lengths smaller than those of seedlings subjected to PEG solutions at all osmotic potentials, since the root is the first organ of the plant to come into contact with the saline solution that is easily absorbed by the roots of higher plants and transported to other plant organs, causing osmotic stress, toxic damage and nutritional imbalance (Cha-Um *et al.*, 2007; Siringam *et al*., 2009).

In recent years, climate change has significantly impacted the growth, development, and yield of agricultural crops, not only because it influences abiotic stresses, but also because it can intensify biotic stresses (Cuadra *et al.,* 2018). Therefore, there are several factors that can increase and reduce productivity, one of these factors may be the saline concentration present in the soil and water restriction, among other factors (Marcovitch, 2010).

Figure 4 – Primary root length (cm) of white oat seedlings as a function of different osmotic potentials induced by NaCl and PEG 6000 and subjected to different temperatures.



Source: Figueiredo (2022).

Inhibition of root growth is considered the main response in plants subjected to saline stress (Maia *et al.,* 2010), since they are the most vulnerable organs, given that they are directly exposed to the effects of salinization (Munns; Tester, 2008). The increase in saline concentrations causes a reduction in the water potential of the tissues, causing growth restriction, since the rates of cell elongation and division depend directly on the process of cell wall extensibility (Ashraf; Harris, 2004), resulting in changes in morphology, inhibition of elongation and growth of lateral roots (Rubbinigg *et al*., 2004).

4. CONCLUSION

According to the results obtained, it can be concluded that the stress simulation conditions impaired the germination and initial growth of white oat seedlings due to the decrease in the observed variables. Saline and water stress induced by the sodium chloride solution had a more pronounced impact than that induced by polyethylene glycol 6000.

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