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Germination dynamics of sesame seeds under salt stress

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Abstract

Sesame crops have large economic potential; however, the scarcity of good quality water in the Semiarid region of the Northeast of Brazil can affect production systems, which requires the search for cultivars that can better be adapted to the local conditions. In this context, the objective of this work was to evaluate the germination dynamics of sesame seed lots subjected to different electrical conductivities of the imbibition solution. The experiment was conducted at the Laboratory of Seeds and Seedling Analysis of the Federal University of Campina Grande, Pombal campus, Paraíba, Brazil. A completely randomized design was used, in an 8×6 factorial arrangement, corresponding to eight seed lots (BRS Seda; BRS Seda (S2); BRS G2 (S1); BRS G2 (S2); BRS G3 (S1); BRS G3 (S2); BRS G4 (S1) and BRS G4 (S2), where S1 and S2 represent the grown environments, saline (2.4 dS m^{-1}) and non-saline, respectively; and six electrical conductivities of the imbibition solution (0.3; 1.2; 2.1; 3.0; 3.9; and 4.8 dS m^{-1}), with four replications. The variables seed germination, vigor, germination speed index, mean time for germination, mean germination speed, and radicle length were evaluated. The sesame seeds are sensitive to salinity, regardless of the lot analyzed and their germination power decreases when they are subjected to high salt concentrations.

Keywords: physiological quality, salinity, *Sesamum indicum* L.

Introduction

Sesame (*Sesamum indicum* L.) is a dicotyledonous plant that belongs to the Pedaliaceae family; it is native to India and is the most ancient oilseed known in the world. Its seeds have high nutritional value and are used as source of edible oil because they contain 44% to 58% oil and considerable contents of proteins (18% to 25%), carbohydrates (13%), fatty acids (83% to 90%), vitamins, minerals, and lignin, which may assist in treatments of some diseases due to their anti-hypertensive, anticancer, anti-inflammatory, antioxidant effects (Tenyang et al., 2017; Liu et al., 2020).

Sesame crops are well spread in Brazil; however, it is concentrated in the states of Mato Grosso, Mato Grosso do Sul, Pará, and Ceará, with higher production in the first (Lacerda, et al., 2020). Despite the Semiarid region in the Northeast of Brazil present favorable edaphoclimatic and soil conditions for the growth of sesame crops, it presents a limiting factor, low water availability, which restricts the growth of agricultural crops, requiring the use of irrigation as an alternative for ensuring the production in this region. However, the available water for irrigation in the region presents high salt contents, mainly NaCl, which limits the production in the region (Lima et al., 2020).

Excess salts due to irrigation water or soil affect the growth, development, and production of plants by increasing the soil osmotic potential and, consequently, affecting the absorption of several essential nutrients to the plant, causing deficiencies of Ca^{2+}, Mg^{2+}, K^{+}, and NO^{3-} induced by the excess of Na^{+} and Cl^{-}, through competition and ionic imbalance (Machado & Serralheiro, 2017). However, the plant responses to abiotic stress conditions (high salinity) vary according to the species, genotype, cultivar, exposure time to these conditions, and plant osmotic adjustment capacity and control of absorption and translocation of these ions (Alvarenga et al., 2019;

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Designh & Kanagaraj et al., 2020).

In this context, germination is one of the critical stages of the plant life cycle because it requires water absorption, which is direct and indirectly involved with the other phases of the germination metabolism, since solubilization and transport of metabolites as reagents in the hydrolytic digestion of reserve tissues only occur in aqueous media (Marcos Filho, 2015). Thus, the objective of this work was to evaluate the germination dynamics of sesame seed lots subjected to different electrical conductivities of the imbibition solution.

Material and Methods

Location of experiment

The experiment was conducted at the Laboratory of Seeds and Seedling Analysis (LABASEM) of the Academic Unit of Agricultural Sciences (UAGRA) of the Center for Agro-Food Sciences and Technology (CCTA) of the Federal University of Campina Grande (UFCG), Pombal campus, Paraíba, Brazil.

Experimental design

A completely randomized design was used, in an 8×6 factorial arrangement, corresponding to eight seed lots (BRS Seda (S1); BRS Seda (S2); BRS G2 (S1); BRS G2 (S2); BRS G3 (S1); BRS G3 (S2); BRS G4 (S1) and BRS G4 (S2), where S1 and S2 represent the growth environments, saline (2.4 dS m^{-1}) and non-saline, respectively; and six electrical conductivities of the imbibition solution (0.3; 1.2; 2.1; 3.0; 3.9; and 4.8 dS m^{-1}), with four replications.

Conduction of the experiment

The seeds used in the experiment were grown in a protected environment in the experimental area of the UFCG, in 20-dm^3 pots filled with a Typic Quartzipsamment soil, with spacing of 1.0 m between rows and 0.8 m between plants. The cultivars used were BRS Seda, BRS G2, G3, and G4; they were grown in non-saline and saline (2.4 dSm^{-1}) environments. The different sesame cultivars were manually harvested at the end of the crop cycle, before their dehiscence, at 90 days after sowing and then taken to the LABASEM, where they were kept for three days. Before the application of treatments, the seeds were washed in running water under a sieve, sanitized with a 2% sodium hypochlorite solution for five minutes to remove contaminants, and maintained on a germitest paper sheet for 30 min to remove the excess water.

Preparation of the imbibition solutions

The saline solutions were prepared by diluting a stock solution with the aid of a bench conductivity meter. The stock solution of 30 dS m^{-1} L^{-1} was composed of a mixture of sodium chloride (NaCl), dehydrated calcium chloride ($CaCl_2.2H_2O$), and hexahydrate magnesium chloride ($MgCl_2.6H_2O$) at the ratio of 7:2:1, respectively; this ratio is predominant in the main water sources available for irrigation in the Northeast region of Brazil (Medeiros, 1992). The electrical conductivities obtained were 0.3 (public water); 1.2; 2.1; 3.0; 3.9; and 4.8 dS m^{-1}.

Variables analyzed

Germination percentage (GP): 4 replications of 50 seeds were placed in Gerbox boxes with dimensions of 11×11×3.5 cm, on two blotting paper sheets previously moistened with the pre-established saline solutions at the proportion of 2.5-fold the dry paper weight and maintained in a germination chamber at 25 °C, as recommended by the Rules for Seed Analysis (BRASIL, 2009). Daily evaluations were carried out by counting and withdrawing normal seedlings from the substrate of each replication, from the third to the sixth day after sowing. The results were expressed in mean percentages of normal seedlings for each lot, according to the expression: GP = (Ni × 100)/Ns, where Ni is the number of germinated seeds and Ns is the number of sown seeds.

First germination counting (FGC): was carried out simultaneously to the germination test; the percentage of normal germinated seedlings was assessed in the third day after sowing. The results were expressed in percentages of normal germinated seedlings through the following expression: FGC = (n * 100) / N, where n is the number of germinated seeds in the first day and N is the number total seeds sown.

Germination speed index (GSI): was calculated according to formula proposed by Maguire (1962): GSI = (G1/N1) + (G2/N2) + (G3/N3) + ... + (Gn/Nn), where G1, G2, G3, ..., and Gn represents the number of seedlings in the first, second, third and last counting and N1, N2, N3, ..., and Nn is the number of days from the sowing to the first, second, third and last counting.

Mean time for germination (MTG): the seeds were incubated in the conditions previously described for the germination test and subjected to daily evaluations of germination from the third to the sixth day after sowing. The results were expressed in days, calculated through the following formula: MTG = (Σ ni ti) / Σ ni, where, ni is the number of germinated seeds per day and ti is the incubation time (days).

Mean germination speed (MGS): was measured through of formula: MGS = 1/t, where t is the mean time for germination; the results were expressed in days.

Radicle length: 4 replications of 10 seeds were placed in Gerbox boxes with dimensions of 11×11×3.5 cm on two blotting paper sheets previously moistened with the saline solutions at the proportion of 2.5-fold the dry paper weight. The seeds were lined on the upper third of the paper, in the longitudinal sense, with the micropyle towards the lower part and the boxes positioned vertically in the germination chambers for three days at 25 °C in the absence of light. The measurements of the primary root of normal seedlings were carried out at the end of this period using a digital caliper; the mean results were expressed in millimeters.

Statistical analysis

The data obtained were subjected to analysis of variance by the F test and, when significant, the means were subjected to regression analyses for the factor salinity level of the imbibition solution and to the Tukey's test for the factor seed lot, both at 5% probability level, with the aid of the Sisvar® statistical program (Ferreira, 2014).

Results and Discussion

The results of the analysis of variance for germination percentage, seed vigor, germination speed index, mean time for germination, mean germination speed, and radicle length are presented in Table 1. The effect of the interaction between the factors (seed lots and electrical conductivity of the imbibition solution) was significant for all variables analyzed, except for mean time for germination and mean germination speed, which presented significant effect only for the isolated factors. These results denote that the factors analyzed affect the whole germination process of sesame seeds.

Table 1. Summary of analysis of variance for germination percentage (GP), first germination counting (FGC), germination speed index (GSI), mean time for germination (MTG), mean germination speed (MGS) and radicle length (RL) of different lots of sesame seeds as a function of conductivity of the imbition solution, UFCG, 2021.

Source of variation	GL	Medium square					
		GP (%)	FGC (%)	GSI	MTG (days^{-1})	MGS (days^{-1})	RL (mm)
Lots	7	406.04**	3846.5**	10.96**	0.68**	0.004**	502.42**
EC_a	5	173.27**	3446.3**	7.19**	0.60**	0.004**	440.69**
Lots x ECa	35	96.50*	211.90**	1.45**	0.030^{ns}	0.0002^{ns}	27.56**
CV (%)		5.45	16.98	6.59	4.99	4.74	10.93
Average		92.38	60.97	10.61	3.44	0.29	29.38

**significant at 1% probability; *significant at 5 % probability by the F test; ^{ns} not significant; CV (coeficiente of variation); CE_a (Electric conductivity of water).

The germination percentage of sesame seeds showed that all lots presented linear decreasing responses, with 7.59%, 16.97%, 19.14%, 7.82%, 5.49%, 13.08%, 2.35%, and 8.76% lower germination percentage for the seed lots BRS Seda (S1), BRS Seda (S2), BRS G2 (S1), BRS G2 (S2), BRS G3 (S1), BRS G3 (S2), BRS G4 (S1), and BRS G4 (S2), respectively, when comparing the electrical conductivities of the imbibition solution of 0.3 dS m^{-1} and 4.8 dS m^{-1} (Figure 1A).

This result is related to the low water potential in the saline medium, which make the seeds to absorb water slowly, causing irregularities in germination percentage and low establishment of seedlings. Thus, the contrary effect of salinity on germination depends on the decrease of the osmotic potential and ionic toxicity, because salinity increases the osmotic pressure, decreasing water available for absorption, whereas this contrary effect caused by sodium chloride ions affect negatively cell division and stretching during the germination process (Safari et al., 2018).

Nóbrega et al. (2020) evaluated the quality of sesame seeds from different lots grown under different salinity levels and found that the cultivars BRS Seda, BRS G2, and BRS G3 presented seeds with better physiological quality when grown under salinity levels of up to 2.0 dS m^{-1}.

The first germination counting of sesame seeds subjected to salt stress showed that only the lot BRS G4 (S1) fitted to a polynomial equation as a function of the salinity level, reaching the maximum estimate of 77.86% at the water electrical conductivity of 1.1 dS m^{-1}, whereas the first germination counting of the other lots decreased linearly as a function of increases in salt contents in the imbibition solution, with 56.36%, 54.60%, 39.07%, 37.04%, 36.50%, 33.03%, and 31.37% lower number for the lots BRS G2 (S1), BRS G2 (S2), BRS G3 (S1), BRS G3 (S2), BRS Seda (S2), BRS G4 (S2), and BRS Seda (S1), respectively, when comparing the electrical conductivities of the imbibition solution of 0.3 dS m^{-1} and 4.8 dS m^{-1} (Figure 1B).

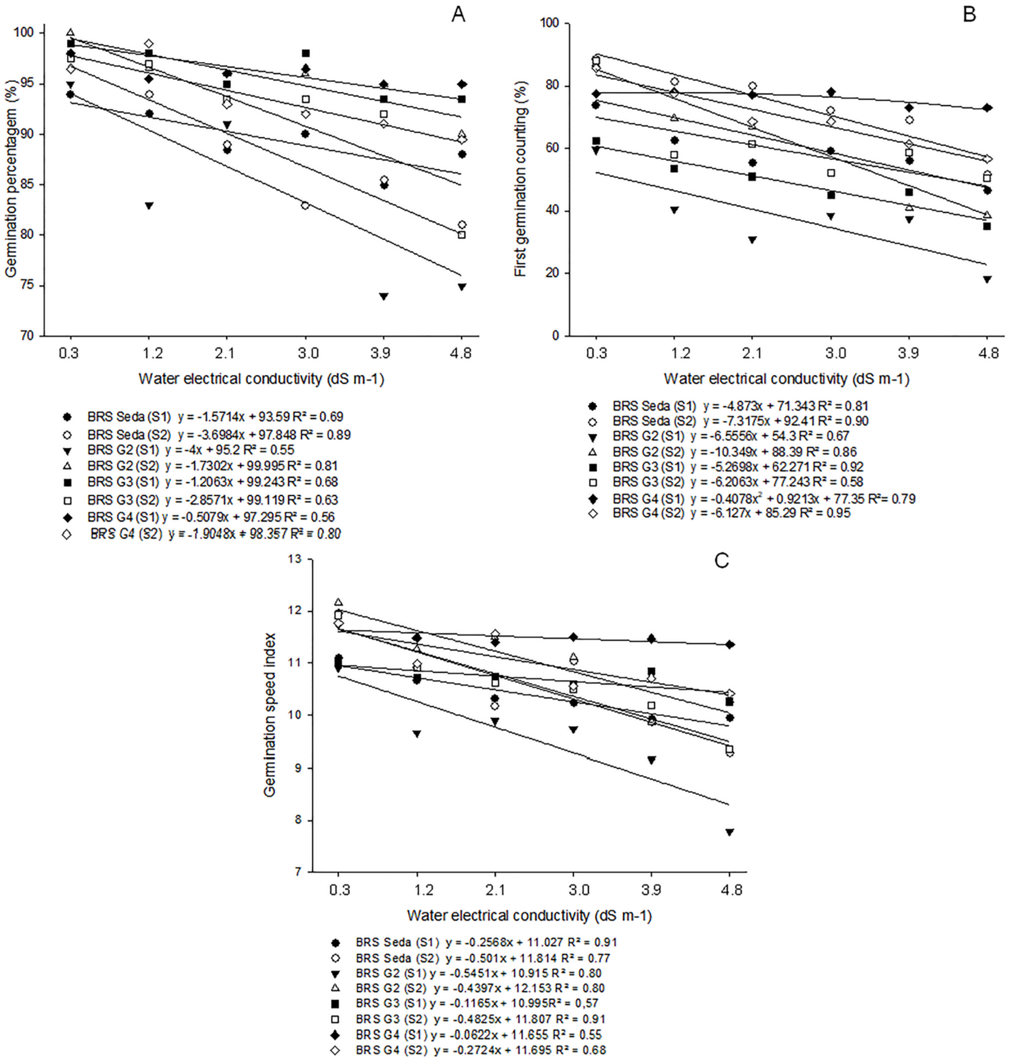

Figure 1. Germination percentagem (A), First germination counting (B) and Germination speed index (C) of diifferent lots of Sesamum indicum L. seeds as a function of the electrical conductivity of the solution imbibition, UFCG, 2021.

Decreases in seed vigor as a function of high salinity levels of the imbibition solution occurred due to the accumulation of toxic ions, mainly Na^+ and Cl^-; this increase of ions changes biochemical processes of seeds, directly affecting the seed vigor and, in the cytoplasm, this excess can inhibit the enzymatic activity in several metabolic pathways (Prisco et al., 2016).

Cordão et al. (2020) evaluated the germination of sesame seeds of the cultivar BRS Seda under saline water and found significant decreases in first germination counting and germination speed index when the seeds were subjected to saline levels of 2.4 and 3.0 dS m^{-1} due to excess salts.

Considering the vigor of the different sesame seed lots, assessed through the seed germination speed index as a function of electrical conductivity of the imbibition solution, it presented similar dynamic to that found for germination, with all lots negatively affected by the increase in salt concentration in the imbibition solution, denoting that the sesame seed lots are sensitive to salt stress. The most affected lots were BRS G2 (S1) and BRS Seda (S2), with decreases of 18.25% and 15.46%, respectively, when comparing the electrical conductivities of 0.3 to 4.8 dS m^{-1}, whereas the lot BRS G4 (S1) was the least affected by the excess salts, with decrease in germination speed index from 11.63 to 11.41, between the highest and the lowest electrical conductivity, thus presenting a decrease of 1.92%. The lots BRS Seda (S1) and BRS G4 (S2) presented a decrease of 8.44% as the excess salts in the imbibition solution was increased (Figure 1C).

High salt levels decrease the seed water absorption capacity, negatively affecting its germination capacity, with delays in germination speed, even when using vigorous seeds; disruption of tegument layers is also common, which cause damages to embryonic axis that can make the seed unviable (Dutra et al., 2017).

Decreases in seeds vigor due to high salinity in the imbibition solution had been found for other crop species, such as *Cucumis sativus* L. (Curcubitacea) (Rocha et al., 2019) and *Ochroma pyramidale* C. (Bombacaceae) (Cruz et al., 2020), and rice cultivars (BRS AG and BRS Pampa) (Cavalcante et al., 2019).

The isolated factors presented significant effect on the mean time for germination of the different sesame seed lots under different electrical conductivities of the imbibition solution; the lot BRS G2 (S1) presented higher mean time for germination, statistically differing from the other lots evaluated, and the lot BRS Seda (S1) presented the lowest mean time for germination, but did not statistically differ from the lots BRS G4 (S1) and BRS G4 (S2) (Figure 2A).

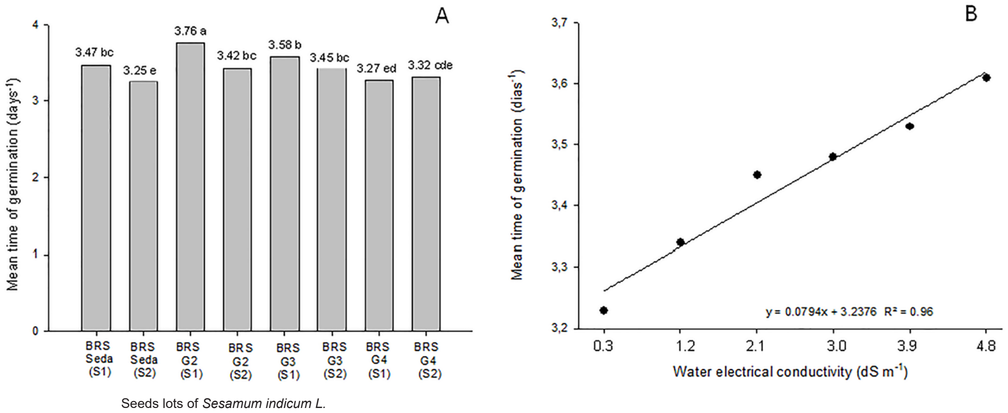

Figure 2. Mean time of germination of diferentes lots (A) of sesame seeds and electrical conductivity (B) of the imbibition solution, UFCG, 2021.

Nóbrega et al. (2020) evaluated the seed quality of different sesame cultivars grown under different saline levels and found that the varieties BRS Seda, BRS G2, and BRS G3 present better physiological quality when grown in saline soils, denoting that these cultivars are more tolerant to stress conditions.

The mean time for germination as a function of salinity level of the imbibition solution showed a linear decreasing result, i.e., the time required for the seeds to germinate increased as the salinity of the imbibition solution is increased, varying from 3.26 to 3.61 days^{-1}, characterizing an increase of 11.08% from the conductivity of 0.3 to 4.8 dS m^{-1} (Figure 2B).

This increase in mean time for germination occurred due to decreases in the seed water absorption capacity, because water is responsible for rehydrate seed tissues, intensifying their metabolic activity, which culminate in the protrusion of the radicle, characterizing the germination process; thus, the higher the saline concentration of the substrate, the lower the water availability for seeds, prolonging the time required for seed germination (Lechowska et al., 2019).

Similar results were found by Nóbrega et al. (2020) for melon seeds; they reported that the higher the saline concentration at the seed germination, the higher the mean time for germination due the stress, which delays the seed absorption speed of the water, which is essential for germination.

The mean germination speed of the different sesame seed lots showed that the lot BRS Seda (S2) presented higher germination speed, however not statistically differing from the lots BRS G4 (S1) and BRS G4 (S2), whereas the lowest germination speed was found for the lot BRS G2 (S1). The lots BRS Seda (S1), BRS G3 (S1), and BRS G3 (S2) were not statistically different from each other (Figure 3A).

The decreases in mean germination speed of the different sesame cultivars may be connected to several factors, such as loss of seed quality during the seed formation process, since seeds produced in saline media are grown in environments with water restriction, which leads to accumulation of ions in the plant tissues, resulting in a nutritional imbalance that consequently affects the seed embryos. These damages are due to the high absorption of toxic ions that cannot be compartmentalized by the vacuole (Araújo et al., 2014).

Another factor that may explain this difference in the different lots evaluated is the seed physiological process, which is genetically determined during its formation, with genetic characteristics of descendants consisted by the joint of masculine and feminine gametophytes during fertilization; thus, the seed performance during germination is variable between species and cultivars (Marcos Filho, 2015).

Oliveira et al. (2017) evaluated the germination of seeds of different cotton genotypes (BRS Topázio, BRS Verde, and BRS 286) subjected to different NaCl concentrations and found that each genotype presented a different result for mean germination speed; they reported that the germination performance under stress of each species, genotype, or cultivar is intrinsic to the plants, due to their different physical and physiological characteristics.

The data of sesame seed mean germination speed as a function of electrical conductivity of the imbibition solution fitted to a decreasing linear equation; thus, the seed germination speed decreases as the quantity of salts in the imbibition solution is increased, with decrease of 7.98% from the salinity of 0.3 to 4.8 dS m^{-1} (Figure 3B).

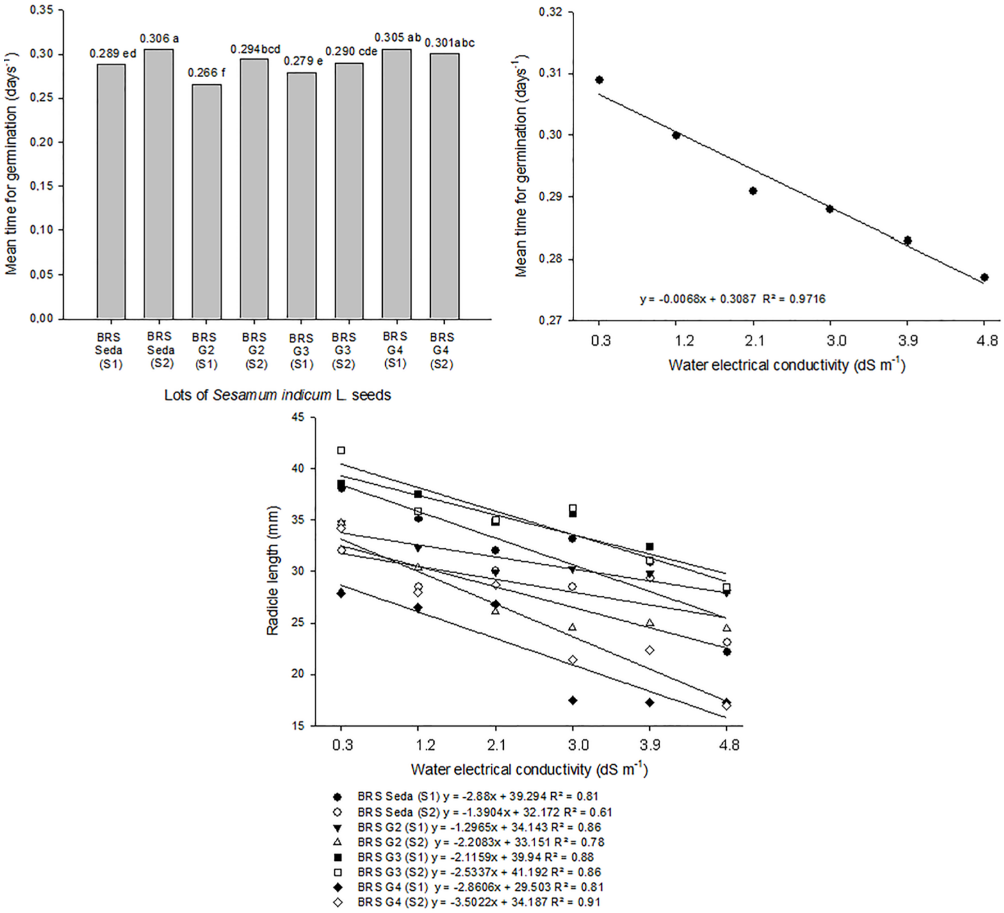

Figure 3. Mean time for germination of differents lots (A) of sesame seeds and electrical conductivity (B) of the imbibition solution and radicle length (C) of diferentes lots as a function of the electrical conductivity of imbibition solution, UFCG, 2021.

The stress due high salt levels significantly affected all parameters associated to the seed germination process and initial development; some selected genotypes present a higher tolerance to this adversity, which is driven by osmotic stress and specific toxicity of some ions; the interaction between these factors culminates in decreases in number of germinated seeds, delays the time for germination, and decreases the mean germination speed (Foti et al., 2018). The decreases in mean germination speed of the different lots evaluated indicate that these seeds have no mechanisms of tolerance to salinity or these resources are inefficient during the initial stages of the systematic process of seed germination (Stefanello et al., 2018).

The radicle length of the different sesame seed lots as a function of electrical conductivity of the imbibition solution showed that excess salts significantly decrease this variable as the saline level was increased; the data presented linear decreasing results, with decreases of 17.28%, 19.70%, 24.22%, 28.19%, 30.58%, 33.72%, 44.93%, and 47.56% for the lots BRS G2 (S1), BRS Seda (S2), BRS G3 (S1), BRS G3 (S2), BRS G2 (S2), BRS Seda (S1), BRS G4 (S1), and BRS G4 (S2), respectively. These results confirm that the different sesame seed lots are sensitive to excess salts, regardless of the production is managed using seeds grown under salt stress or not, both can be negatively affected by salinity during their germination.

The decrease in length as a function of increasing the saline level is one of the first measurable effects of salt stress, because this adversity decreases cell expansion due to a physiological drought and phytotoxicity that result from the high concentration of ions in the protoplasm (Taiz et al. 2017).

Bekele et al. (2017) evaluated the tolerance of sesame seedlings to salinity and found that the performance of seedlings is compromised due to increases in salts; they reported that this effect is associated with the stress condition caused by the salt accumulation, which results in water deficit and can even cause the death of the plant due to ionic toxicity; they also found that the higher the salinity of the irrigation water, the lower the seedling length.

Cordão et al. (2020) found lower results for radicle length when evaluating the germination process of sesame seeds of the cultivar BRS Seda, with maximum values of 25.5 mm when the seeds were subjected to an electrical conductivity of 0.6 dS m^{-1}. Harter et al. (2014) evaluated the germination of *Cucurbita pepo* seeds and found decreases in radicle length as a function of increases in electrical conductivity of the irrigation water.

Conclusions

Sesame seeds are sensitive to salinity, regardless of the lot analyzed, and their germination power decreases when they are subjected to high salt concentrations.

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