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Research Article

Germination of chief fire seeds cockscomb cultivar under saline stress conditions induced by sodium chloride

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Abstract

Cockscomb plant, Chief fire cultivar, is used as an ornamental, medicinal and non-conventional food plant (NCFP) and is cultivated from the north to the center-west of Brazil; however, these areas suffer from adverse environmental factors such as salinity stress. The objective of this study was to evaluate the seed germination performance and vigor of *Celosia cristata* L. var. Chief Fire seedlings exposed to salinity during the germination phase. To carry out the work, *C. cristata* seeds were sown in gerboxes conditioned to increasing doses of sodium chloride (NaCl), obtained by dissolving the salt in distilled water, obtaining electrical conductivities of 2.0; 4.0; 6.0 and 8.0 dS.m^{-1}, constituting the treatments. An additional group was treated only with distilled water and was used as a control for the experiment. The experiment was conducted in a completely randomized design, with a total of five treatments and four replicates of 25 seeds. The parameters assessed were: first germination count, germination, germination speed index (GVI), mean germination time (MGT), length of aerial part and primary root. The data was submitted to analysis of variance and the means were compared using the Scott-Knott test at 5% significance. Based on the results obtained, it can be concluded that the conditions of salt stress induced by NaCl were not harmful to the germination of *C. cristata*, presenting itself as a species tolerant to water salinity during seed germination, since the variables analyzed showed no signs of deleterious effects as the salt concentration was increased.

Keywords: *Celosia cristata*; germination performance; ornamental plant; seed quality; salt stress; vigor.

Introduction

Approximately 97% of flower and ornamental plant production in Brazil is destined for the domestic market, with the South and Southeast regions and the Federal District being the largest consumer states per capita. However, production is concentrated in the states of São Paulo, Minas Gerais, Rio de Janeiro, Santa Catarina, Rio Grande do Sul, Brasília and Ceará (Instituto Brasileiro de Floricultura [IBRAFLOR], 2024).

According to Paiva and Almeida (2014), the main cut flowers produced from seeds are: Boca-de-leão (*Antirrhinum majus*), Cravinia dobrada (*Dianthus chinensis* x *barbatus*), Crista-plumosa (*Celosia argenta*), Crista-de-galo (*Celosia cristata*), Girassol (*Helianthus annuus*), Lisianto (*Eustoma grandiflorum*) and Áster-da-china (*Callistephus chinensis*).

The Crista-de-galo (*Celosia cristata* L.) is an erect, sparsely branched plant, 30 to 90 cm tall, with green and slightly reddish leaves and ornamental inflorescences in vibrant colors (Lorenzi & Souza, 2015).

As well as having characteristics that enable it to be used as an ornamental plant, in regions of the African, Asian and American continents, especially in South America, its leaves and inflorescences are consumed in vegetable soup, due to their characteristic sweet taste (Molehin et al., 2014).

The successful cultivation of ornamental flowers propagated by seeds requires the use of seeds with high genetic, sanitary, physical and physiological quality (Marcos Filho, 2015).

For a seed to germinate, water is a determining factor, as absorption results in the rehydration of tissues, intensifying the respiratory process and other metabolic pathways that will result in the development of the embryonic axis (Carvalho & Nakagawa, 2012).

According to Murtaza, Ghafoor and Qadir (2006), the inadequate use of water during irrigation management causes soil degradation problems, with salinization being one of the main problems encountered in irrigated areas, especially in arid and semi-arid regions.

According to FAO estimates, 800 million hectares are affected by salinity worldwide, around 6% of the total area of the globe (Food and Agriculture Organization Of the United Nations [FAO], 2020). It is estimated that 20% of the world's total and 33% of irrigated agricultural land is affected by high salinity.

In Brazil, salinization is more common in regions with arid and semi-arid climates where there is less rainfall, and in the south of the country, it occurs in cultivated areas prone to flooding (Pedrotti, 2015). Soil salinity can be caused by different phenomena, whether natural or man-made (Ludwig et al., 2023).

In saline environments, sodium chloride (NaCl) is the predominant salt, but in protected or open cultivation, fertilizer salts such as nitrogen, potassium and phosphorus fertilizers are the main culprits in the saline effect, as they are used more frequently, the most serious effects occur in protected environments, since there is no leaching by rain (Silva, 2014).

The excess salts present in irrigation water can inhibit the entry of water into the seed, as well as causing damage to its structure, affecting its germination (Almeida, Guaritz, Pinto, & Almeida, 2020). Under conditions of saline stress, the accumulation of NaCl during seed soaking causes the tegument layers to rupture, damaging the embryo and potentially leading to death (Freitas et al., 2013).

The aim of this study was to evaluate the germination performance of seeds and the vigor of *Celosia cristata* L. var. Chief Fire seedlings subjected to salinity during the germination phase.

Materials and Methods

Seeds of *Celosia cristata* L. (Sakata®) from batch 112.073 were used with a germination rate of 97% and 99.9% physical purity, meeting the criteria required by the Ministry of Agriculture, Livestock and Supply (MAPA) for commercialization.

The sodium chloride (NaCl) solutions were obtained from the table of measurements proposed by Richards (1980), the quantities of salt were diluted in distilled water and then their electrical conductivity was measured using a conductivimeter.

To prepare the solutions, 1.0; 2.0; 3.2; 4.4; 5.4 g NaCl L^{-1} were placed in distilled water to obtain five levels of salinity plus a control, which was just distilled water: 0.0 (control); 2.0; 4.0; 6.0; 8.0 dS m^{-1}.

Germination test evaluation

For each treatment, 100 seeds were used, divided into four replicates of 25. They were sown on blotting paper (10.5 cm x 10.5 cm) moistened with saline solution in an amount 2.5 times the mass of the unmoisturized paper, and placed in crystal polystyrene boxes (Gerbox®) (11 cm x 11 cm x 3 cm). The Gerbox® were kept in a germination chamber at a temperature of 30°C, in accordance with the recommendations of the Seed Analysis Rules (Ministério da Agricultura, Pecuária e Abastecimento [MAPA], 2009).

First germination count

Conducted in conjunction with the germination test. It corresponded to the accumulated percentage of germinated seeds on the fifth day after the start of the test.

Germination speed index

Determined in conjunction with the germination test through daily counts of the number of seeds germinated at the same time, calculated according to the formula proposed by Maguire (1962):

$$\mathrm{GSI} = \frac{\mathrm{G_1} + \mathrm{G_2} + \cdots + \mathrm{G_n}}{\mathrm{N_1} + \mathrm{N_2} + \cdots + \mathrm{N_n}}$$

Where GSI = germination speed index

G1, G2 and Gn = number of seeds germinated on the first, second and last day;

N1, N2 and Nn = number of days elapsed from sowing to the first, second and last count.

Mean germination time

The Mean Germination Time (MGT) was obtained using the methodology described by Labouriau (1983). It was carried out simultaneously with the germination test. The number of germinated seeds was counted daily up to the day after sowing, and this index is calculated using the equation:

$$\mathrm{AGT} = \frac{\mathrm{G1T1} + \mathrm{G2T2} + \ldots\ldots\ldots \mathrm{GnTnG1} + \mathrm{G2}.\ldots + \mathrm{Gn}}{\mathrm{G1} + \mathrm{G2} \ldots. + \mathrm{Gn}}$$

Where AGT = is the average time, in days, needed to reach maximum germination.

G1, G2 and Gn = the number of seeds germinated at times T1, T2 and Tn, respectively.

Aerial part and primary root length measurement

Length was measured 14 days after the final count of the germination test. The roots and the hypocotyl of each replicate were separated and measured with a ruler graduated in centimeters. The results were expressed in centimeters (cm).

Statistical Analysis

Data were subjected to analysis of variance (ANOVA), and means were compared using the Scott-Knott test at 5% probability. First count data were transformed using the $\sqrt{x+0.5}$, and germination data were transformed using the arcsine $\sqrt{x/100}$. The other variables were not subjected to transformations. Statistical calculations were performed using AgroR software.

Results and Discussion

Different species exhibit different responses to salinity, ranging from sensitive to highly tolerant of saline environments (Santana, Carvalho, Souza, Sousa, & Vasconcelos, 2017). Species that are sensitive to excessive salinity are known as glycophytes. On the other hand, plants with higher tolerance to high concentrations of salts in the soil are called halophytes (Peñã, Medina-Hernández, Ghasemi, & Puente, 2020).

The final percentage of germinated seeds (Figure 1A) was not affected by the addition of salt, as all treatments tested remained above 80%.

This result is in contrast to the literature where most species show a sharp decrease in seed germination with increasing salinity of the substrate. Among the ornamentals whose germination is affected by high salinity are *Cryptostegia madagascariensis* Bojer ex Decne. (Cruz, Andrade, & Alves, 2016), *Helianthus annuus* L. (Pacheco et al., 2020), and *Celosia argentea* L. (Freitas et al., 2024).

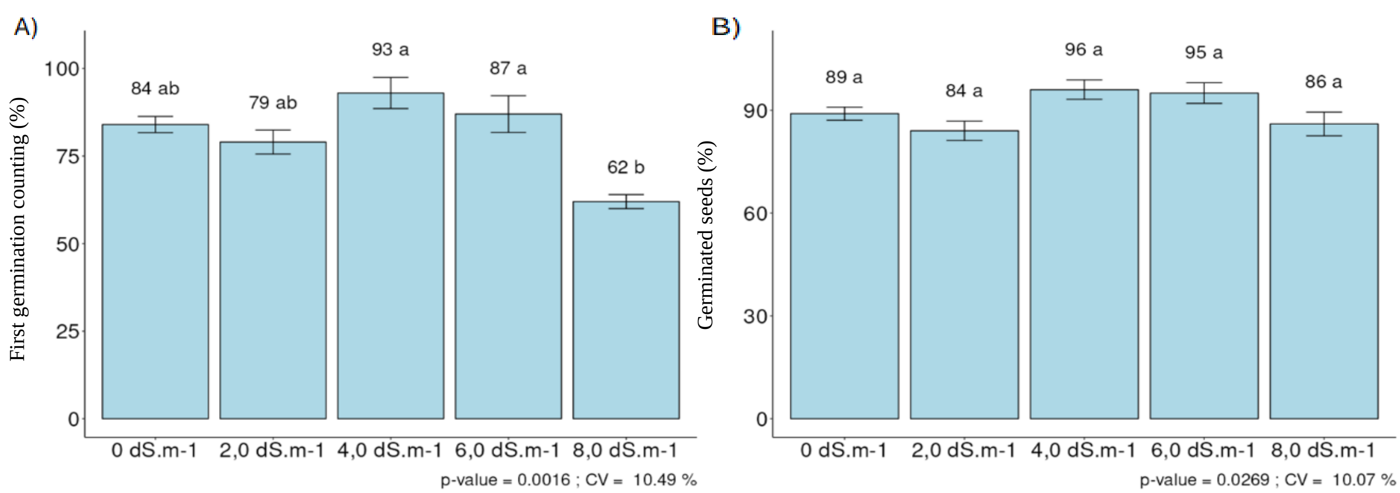

Figure 1 - Percentage of first germination counting (A) and percentage of germinated seeds (B) of *Celosia cristata* L. var. Chief Fire, after 14 days under salt stress induced by NaCl solution with different concentrations (0.0; 2.0; 4.0; 6.0; 8.0 dS m^{-1}).

The germination process of *Celosia cristata* was little affected by salinity levels up to 0.8 dS m^{-1}, which may be an indication of salinity tolerance. This characteristic can also be observed in seeds of cowpea (Vigna unguiculata (L.) Walp.) cultivar 'BR 17 Gurguéia' (Araujo Neto, Nunes, Queiroz, Moreira, & José, 2020).

In the first germination count test, seeds exposed to salt stress reached maximum germination values at concentrations of 0.0, 2.0, 4.0 and 6.0 dS m^{-1}, with 84, 79, 93 and 87% germination, respectively. However, from 6.0 dS m^{-1}, there was a decrease in the percentage of germinated seeds with 62% germination (Figure 1B).

Similar results were observed by Ferreira, Matos, Sena, Oliveira and Sales (2013), working with Cedrela odorata L. seeds, where it was found that saline stress conditions resulted in lower initial seed germination as the concentration of salts used increased.

Regarding the germination speed index (Figure 2), there was a significant decrease of 8.0 dS m^{-1} in the saline solution. It can be observed that the GSI remained similar to the control (2.65) up to the concentration of 6.0 dS m^{-1}. From this solution, a significant decrease was observed in the saline solution of 8.0 dS m^{-1}.

When comparing the percentage and speed of germination, a similar trend is observed. Seeds with the highest germination percentages, 96% and 95%, respectively, also germinated faster (2.83 and 2.75). Results such as these are highly desirable for field seeding, as accelerated germination is critical for rapid seedling establishment (Dan, Dan, Barroso, & Braccini, 2010).

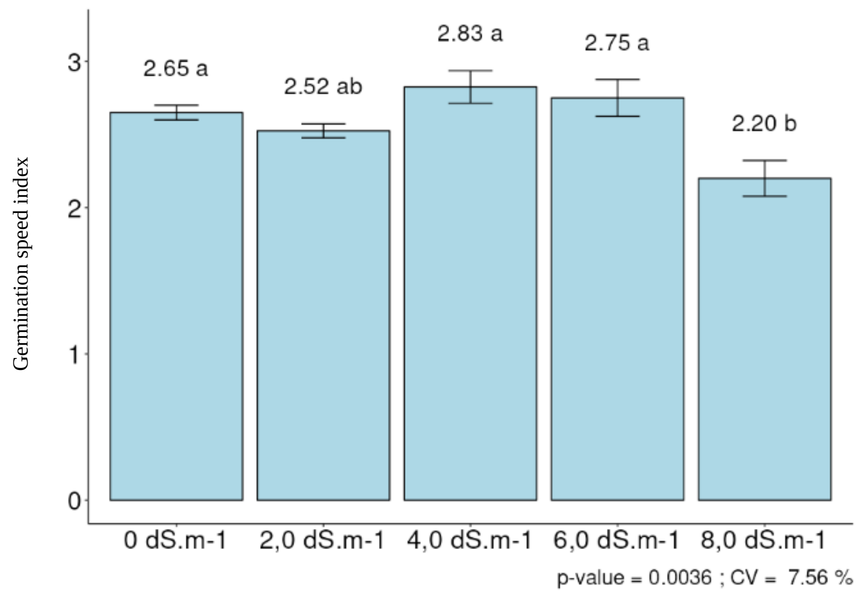

Figure 2 – Germination speed index (GSI) of *Celosia cristata* L. var. Chief Fire, under salt stress induced by NaCl solution of different concentrations (0.0; 2.0; 4.0; 6.0; 8.0 dS m^{-1}).

The lower germination speed index observed in the 8.0 dS m^{-1} saline solution can be explained by the excess salts in the growing medium, which, in addition to causing cytotoxicity, are responsible for dehydration and reduced metabolic activity and synthesis of new seed tissues due to low water availability. This leads to a lower germination rate and, in more severe cases, to the condemnation of the germination capacity (Benedito, Ramalho, Pereira, Silva, & Medeiros, 2020).

Seeds are extremely susceptible to stress, especially during the germination period. Metabolic changes resulting from this stress interfere in such a way as to reduce vigor, reduce the germination process, or even lead to seed death (Queiroga et al., 2022).

The average germination time of *C. cristata* seeds remained proportional for all saline concentrations studied (Figure 3), with no statistical difference among them. Contrary to what has been reported in the literature, the increase in salinity did not affect the average germination time of the seeds.

Spadeto, Lopes, Mengarda, Matheus and Bernardes (2012), studying the effects of salt stress on the vigor of garapa seeds (*Apuleia leiocarpa* (Vogel) Macbride), found that the lower the osmotic potential of the substrate, the longer the average germination time of the seeds, as well as a delay in the onset and speed of germination. The same variables were affected by the higher salt concentration in this study.

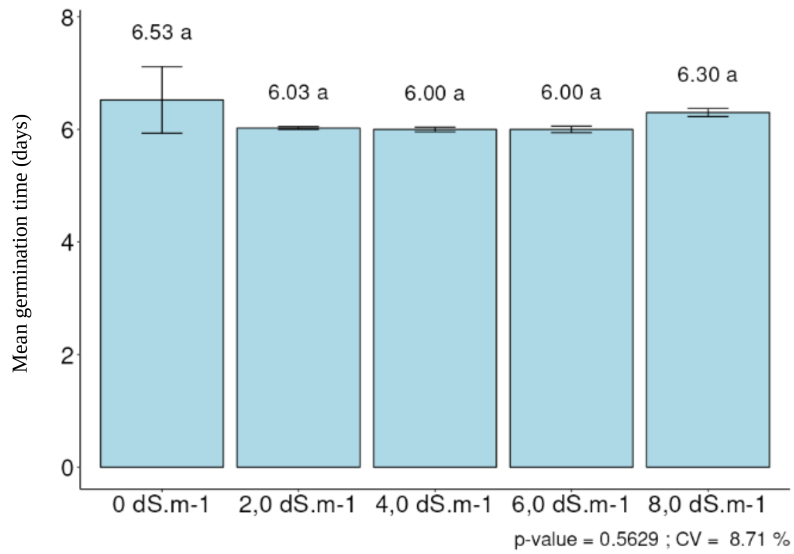

Figure 3 - Average germination time (AGT) of *Celosia cristata* L. var. Chief Fire under salt stress induced by NaCl solution with different concentrations (0.0; 2.0; 4.0; 6.0; 8.0 dS m^{-1})

With regard to seedling length, the control had lower average values for both shoot height (Figure 4A) and root length (Figure 4B). However, there was no significant difference between the treatments for the first variable.

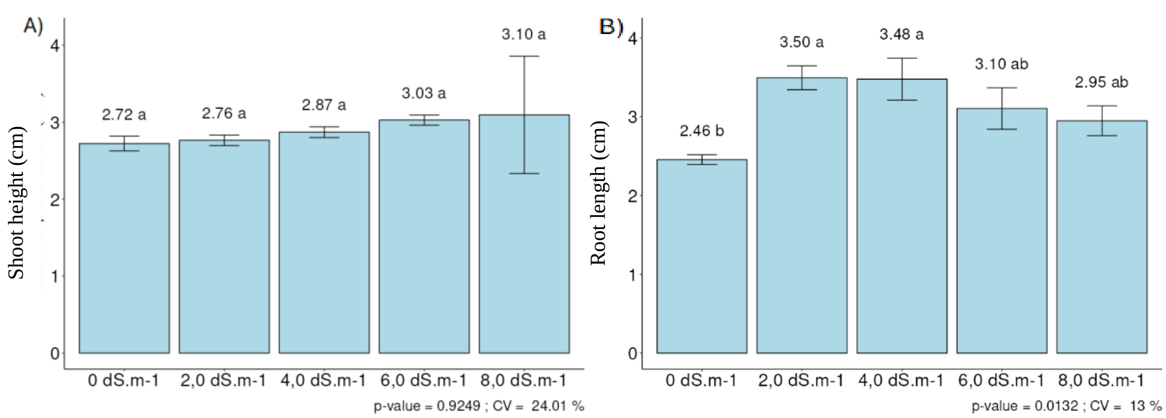

Figure 4 - Shoot height (A) and root length (B) of *Celosia cristata* L. var. Chief Fire seedlings derived from seeds subjected to salt stress induced by NaCl solution at different concentrations (0.0; 2.0; 4.0; 6.0; 8.0 dS m^{-1}).

The growth of the primary root was stimulated by increasing the salinity of the solutions from 2.0 dS m^{-1} to the maximum value, with the highest length values achieved in the 2.0 to 6.0 dS m^{-1} solutions, with an average of 3.50, 3.48, and 3.10 cm, respectively. Compared to the control, the average root length increases were 42.27%, 41.46%, 26%, and 19.91%, respectively.

The variable root length also contrasts with results often found in the literature, which often report a gradual reduction in root size due to increased salinity concentration.

Salinity in the soil makes it difficult for the plant to absorb water. One strategy used by plants growing in saline environments to overcome this adversity is the elongation of the root system, as observed in Figure 5. This allows the plant to explore different soil horizons and capture water in otherwise inaccessible locations (Dexter, 2004; Gyssels, Poesen, Bochet, & Li, 2005; Leite et al., 2017).

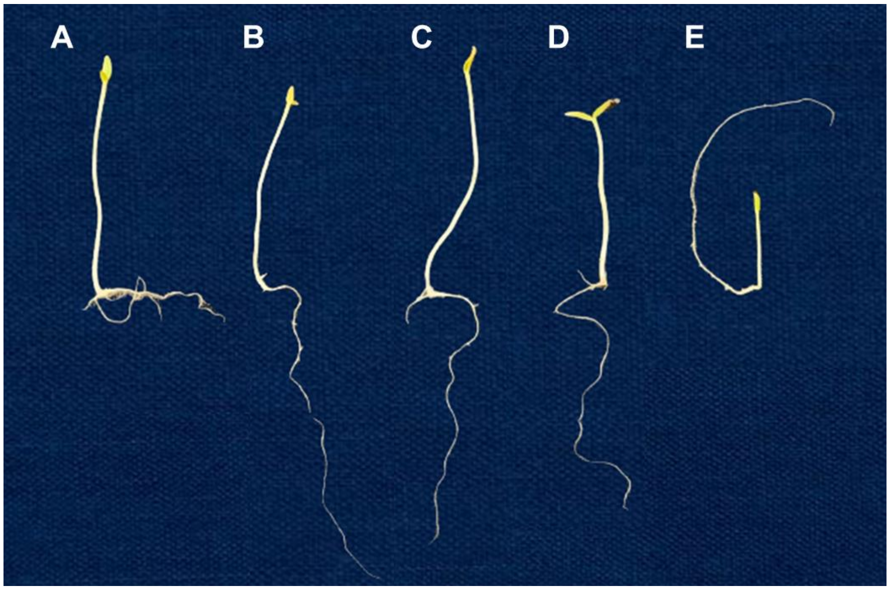

Figure 5. Cockscomb (*Celosia cristata* L.) cultivar Chief Fire seedlings from seeds subjected to salt stress induced by NaCl solution with different concentrations A) 0.0 dS m^{-1}, B) 2.0 dS m^{-1}, C) 4.0 dS m^{-1}, D) 6.0 S m^{-1} and E) 8.0 dS m^{-1}.
Source: Gabriel Cruz Barata.

Conclusions

The results show that the seeds have an overall good tolerance to salinity, with high germination rates even at elevated salt concentrations. This suggests that Celosia cristata var. Chief Fire can be cultivated under adverse soil conditions, expanding its potential for use in regions with high salinity.

Furthermore, although germination speed index and initial germination number decreased at higher salt concentrations (above 6.0 dS m^{-1}), seedling root length increased at intermediate salinity levels (between 2.0 and 6.0 dS m^{-1}). This increase in root length indicates an adaptation of the plant to explore the soil in search of water under stress conditions, an important mechanism for survival in environments with limited water availability.

In conclusion, the results of this study suggest that Celosia cristata var. Chief Fire is a promising species for cultivation in areas affected by salinization. However, further research on later developmental stages and the economic feasibility of large-scale production in saline soils is recommended to confirm these results and expand its applications.

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