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Responses of cowpea cultivars to saline stress

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ABSTRACT

The cowpea [*Vigna unguiculata* (L.) Walp] is widely cultivated in Northeast Brazil and stands out for its economic and social importance. Part of the cultivation area is affected by salt stress, which affects the performance of the crop. The effects of salinity can be mitigated with the development of tolerant cultivars. The objective of this work was to evaluate the behavior of cowpea cultivars under different levels of saline stress in the germination and emergence phases of the crop. Two trials evaluating the germination and emergence phases were conducted, under controlled conditions, in a factorial scheme with 11 cultivars and five solution of NaCl with concentrations ranging from 0 to 120 mM. There was a marked difference in the response of the cultivars according to the level of salinity applied. The cultivars BRS Itaim, BRS Novaera, BRS Pajeu, BRS Tumucumaque, Sempre Verde and Pingo-de-ouro show better performance in the germination or emergency phases in conditions of saline stress, which are more promising for the initial establishment of the culture, in the presence of salinity.

Keywords: *Vigna unguiculata*, Genetic improvement, Abiotic stress, Germination, Emergency.

Respostas de cultivares de feijão-caupi ao estresse salino

RESUMO

O feijão-caupi [*Vigna unguiculata* (L.) Walp] é amplamente cultivado no Nordeste brasileiro e destaca-se pela sua importância econômica e social. Parte da área de cultivo apresenta algum grau de estresse salino, o que afeta o desempenho da cultura. Os efeitos da salinidade podem ser mitigados com o desenvolvimento de cultivares tolerantes. Objetivou-se com este trabalho avaliar o comportamento de cultivares de feijão-caupi em diferentes níveis de estresse salino, nas fases de germinação e emergência da cultura. Dois ensaios avaliando as fases de germinação e emergência foram conduzidos, sob condições controladas, em esquema fatorial com 11 cultivares em soluções de NaCl com concentração variando de 0 a 120 mM. Houve significativa diferença na resposta das cultivares em função do nível de salinidade aplicado. As cultivares BRS Itaim, BRS Novaera, BRS Pajeu, BRS Tumucumaque, Sempre Verde e Pingo-de-ouro demonstram melhor desempenho nas fases de germinação ou emergência em condições de estresse salino, sendo estas mais promissoras para o estabelecimento inicial da cultura, na presença de salinidade.

Palavras-chave: *Vigna unguiculata*, Melhoramento genético, Estresse abiótico, Germinação, Emergência.

1. Introduction

The cultivation of cowpea [*Vigna unguiculata* (L.) Walp.] is concentrated in small farms, where it plays a relevant socioeconomic role due to its use as a food of excellent nutritional quality and because it stands out as one of the main sources of income for family farming (Silva et al., 2018). Between 2005 and 2009, Brazilian crops annually generated 1,113,109 jobs, produced food supply for 28,205,327 people and reached the value of US$ 128,968,989 with the commercialization of grains (Freire-Filho et al., 2011). In the 2021/2022 harvest, production was 468,600 tons, in a cultivated area of 64.5 thousand hectares, grown mainly in the northeastern region (CONAB, 2022).

Despite adaptation to water and heat stress, soil salinity and salt content in irrigation water can interfere with the establishment, development and productivity of cowpea (Aquino et al., 2017; Fonseca et al., 2017; Tsague et al., 2017). This abiotic stress is an inherent problem in semiarid and arid zones worldwide (Porto et al., 2019), as exemplified by the saline sodic soils in northeastern Brazil. Moreover, the use of brackish or saline well water for irrigation is the reality for millions of small-scale producers (Porto et al., 2019). Thus, it can be seen that much of the agricultural activity developed in northeastern Brazil occurs under some level of saline stress.

Environments with high levels of soluble salts in the soil solution limit the crop and reduce crop productivity due to the osmotic and ionic effects (Dias et al., 2016). The osmotic effect interferes with the water relations of the plant causing reduced water uptake and transport. The ionic effect interferes in the uptake, assimilation and transport of nutrients and in metabolic processes such as protein synthesis, respiration and photosynthesis (Taiz et al., 2017) Wani et al., 2020). An alternative to overcome these limitations and enable the agricultural use of salinized areas is the use of cultivars tolerant to salt stress (Dias et al., 2016; Coelho et al., 2017). This strategy is relevant because it is less expensive than the recovery of salinized soils (Soares Filho et al., 2016) and can enable the use of saline water in irrigation.

The level of tolerance to salt stress varies between species, between cultivars of the same species, and between crop development stages (Deuner et al., 2011; Brito et al., 2015; Dias et al., 2016 For the germination stage, Ravelombola et al. (2017) identified highly salinity-tolerant cowpea genotypes and found that the genotype origin has as influence on salinity response. Sá et al. (2017) evaluated 19 cowpea genotypes and concluded that BRS Pajeu tolerated salt stress up to the level of -0.6 MPa (147 mM NaCl). On the other hand, Coelho et al. (2017) found that the cultivars BRS BRS Tapaihum, BRS Pujante, BRS Acauã and BRS Marataoã have low tolerance to salinity, with limitations in germination and initial seedling growth starting at a concentration of 50 mM NaCl.

The stages comprising germination and seedling emergence are essential for good crop yields, as the final crop stand depends on them. Little has been done to evaluate and develop cowpea genotypes tolerant to salt at the germination phase. Hence, more studies on the germination of seeds under salt stress are needed to understand the effect on the development of cowpea. In light of that, the evaluation of germination in salt solutions is an indicator of the potential performance of seeds in the field where salt stress is present (Dantas et al., 2005).

Given the above, it appears that there is genetic variability for the response of cowpea cultivars to salt stress, with the possibility of identifying more tolerant genotypes. Thus, this work was developed with the objective of evaluating the behavior of cowpea cultivars under different levels of salt stress, in the phases of crop germination and emergence.

2. Material and Methods

To achieve the proposed objective two experiments were conducted in the Seed Laboratory of the Federal University of Western Bahia – Campus Barra. Eleven cultivars were selected for evalution: BRS Aracê, BRS Cauamé, BRS Guariba, BRS Itaim, BRS Marataoã, BRS Novaera, BRS Pajeu, BRS Tumucumaque, BRS Xiquexique, Sempre Verde and Pingo-de-ouro.

The germination phase experiment was set up in an 11 x 5 factorial scheme, with 11 cultivars and five salt stress levels induced by means of a solution with different NaCl concentrations (0, 30, 60, 90 and 120 mM of NaCl). Level 0 (zero) stress was used as a control and consisted of the use of distilled water. The solutions with 30, 60 90 and 120 mM NaCl concentration were obtained by adding 1.75, 3.51, 5.26 and 7.02 $g.L^{-1}$ of NaCl, respectively. The treatments were arranged under Randomized Block Design with three repetitions. The plot consisted of a round transparent plastic disposable container (11 cm diameter x 4.5 cm height), with a 170 mL capacity, having washed sand as substrate, in which 12 seeds were placed between five filter paper disks (three below and two above the seeds). This protocol was adopted due to the seed format and to maintain the NaCl concentration throughout the experiment.

For each container, 7 mL of distilled water or NaCl solution was added in the specific concentration for each treatment. The containers were sealed with parafilm and placed in a B.O.D. germination chamber at 25 ± 1 ºC for 5 days. Every two days, 2 mL of distilled water was added in the control and 2 mL of NaCl solution at the specific concentration in each treatment.

During this period the number of germinated seeds was quantified in each treatment. Also, the amount of germination of 50% of the seeds in the plot (t50) was obtained through modeling with the Time to Event Analysis (*Survival Analysis*). In the latter, modeling was also performed in order to verify the relationship of the salt concentration as a function of germination time obtained by the "survival" (2.39-5) and "multicomp" (1.4-6) package procedures of the R program (3.3.2).

Modeling was also implemented Halothermal time proposed by Bakhshandeh et al. (2020) was also implemented and performed on Microsoft Excel in order to obtain the value of $NaCl_b$ corresponding to the threshold value of saline concentration. On the fourth day after sowing the germination percentage was quantified, considering as germinated the seed that presented a minimum root protrusion of 3 mm. On the fifth day the length of the hypocotyl-root axis was measured using millimeter paper.

The experiment during the emergence phase presented the same scheme and design used in the experiment to evaluate the salt stress in the germination phase. However, the plot consisted of a disposable transparent plastic container, without drainage holes, with dimensions of 18 cm length x 11 cm width x 3.5 cm height, filled with washed sand, without any concern with the container sealing. In each plot 12 seeds were sown and then distilled water or NaCl solution was added at a concentration corresponding to each stress level, in an enough amount to raise the sowing substrate to its field capacity. After that, the plots were kept in the laboratory at a temperature of 25 ± 2 ºC and photoperiod of 12 h, for 15 days. The substrate humidity was maintained at the field capacity by adding distilled water to all plots every other day. At each interval of 24 h, the emergence speed index was determined based on the expression presented by Maguire (1962), and the percentage of emergence, on the eighth day after sowing. The seedlings were considered emerged when the cotyledons were emerged on the soil surface with the cotyledonary leaves visible.

For the figures on germination percentage and emergence percentage, the data were transformed to meet the assumptions of the variance analysis, according to Equation 1, presented by Pimentel-Gomes (2009):

$$y = \text{arc sen}\sqrt{x/n} \qquad (1)$$

where: x – is the number of germinated or emerged seeds in each plot; n – is the total number of seeds per plot. Furthermore, in the case of x = 0, the value 0/n was replaced by 1/4n, and in the case of x = n, the value n/n was replaced by 1-1/4n. The data were submitted to analysis of variance, considering all model effects as fixed, except the experimental error and block effect, according to Equation 2, adapted from Cruz et al., (2012):

$$Y_{ijk}: m + B_k + C_i + A_j + CA_{ij} + E_{ijk} \qquad (2)$$

where: Y_{ijk} – is the observed value for the k-th block plot of the combination between the i- th cultivar and the j- th stress level; m – is the overall mean; C_i – is the effect of the i-th cultivar on the observed value Y_{ijk}; A_j – is the effect of the j-th stress level on the observed value Y_{ijk}; B_k – is the effect of the k-th block on the observation Y_{ijk}; CA_{ij} – is the effect of the interaction of the i-th cultivar with the j-th stress level; E_{ijk} – is the error associated with the observation Y_{ijk}.

In case of significant effect for the interaction between the factors, the unfolding of the factor cultivars within the levels of salt stress was performed. The grouping of the means of the main factor and of the unfolded means was performed using the Scott and Knott Grouping Method, at a 5% probability. The data analysis was performed with the help of the Genes and R programs.

3. Results and Discussion

For the germination percentage and germination speed index, the analysis of variance showed a significant effect ($p<0.01$) for the source of variation of cultivars and salt stress. The inexistence of statistically significant effect ($p>0.05$) for the interaction cultivars x salt stress indicates that there is no differential expression between cultivars, facing different levels of stress, for germination percentage and speed of germination. Therefore, the grouping of the means of the cultivars was performed regardless of the stress levels, as shown in Table 1.

By simultaneously analyzing the performance of the cultivars for the germination percentage and the germination speed index, it was possible to gather the cultivar into four distinct groups, according to the classification obtained for each variable, by the Scott-Knott (Table 1). The cultivars Pingo-de-ouro, BRS Pajeu, BRS Aracê and BRS Xiquexique showed superior performance for both variables. The cultivars BRS Guariba and BRS Novaera were in the group with inferior performance for both germination percentage and germination speed index.

The absence of interaction between cultivars and salt stress levels for the variables germination percentage and germination speed index may be due to the criteria used to consider the seeds germinated. The minimum root 3 mm may not be an adequate criterion to detect the difference in expression of the cultivars against the salinity gradient used. The absence of significant interaction between cowpea genotypes and salt stress levels was also observed by Coelho et al. (2017) for germination percentage.

Table 1. Average performance of cowpea cultivars under different levels of salt stress for the variables germination percentage, germination speed index (GSI) and limit value of e valor NaCl for germination ($NaCl_b$) [(1)]

Cultivar	Germination (%) [(2)]	GSI	$NaCl_b$
BRS Aracê	67 a	0.79 a	0.128
BRS Cauamé	54 b	0.75 a	0.038
BRS Guariba	48 b	0.48 b	0.100
BRS Itaim	47 b	0.57 a	1.984
BRS Marataoã	59 a	0.39 b	0.238
BRS Novaera	33 b	0.44 b	1.508
BRS Pajeu	69 a	0.61 a	0.066
BRS Tumucumaque	66 a	0.30 b	0.544
BRS Xiquexique	65 a	0.81 a	0.244
Pingo-de-ouro	73 a	0.76 a	0.533
Sempre Verde	51 b	0.70 a	0.630

[(1)] Averages with the same letter in the column constitute a statistically homogeneous group, by the Scott-Knott test, at 5% probability. [(2)] Data were transformed using the expression. $y = \text{arc sen}\sqrt{x/n}$, where "x" corresponds to the number of germinated seeds in each plot and "n" to the total number of seeds per plot. In the case of x = 0, the value 0/n was replaced by 1/4n and, in the case of x = n, the value n/n was replaced by 1-1/4n.

On the other hand, Ravelombola et al. (2017) found that cowpea genotypes responded differently to salinity environment at the germination stage. The authors observed variation in germination rate reduction from 5.8% for the most tolerant genotype to 94.2% for the most sensitive one. In the unstressed condition the average germination rate among the 151 genotypes ranged from 60.0 to 99.2%. According to Coelho et al. (2017) there is a loss in germination capacity of cowpea varieties from the concentration of 50 mM of NaCl and this fact is associated with the decrease in the speed with which the varieties perform their biochemical, physiological and morphogenetic events necessary for the process of germination and formation of new plants.

On the other hand, Chagas et al. (2018) reported that the germination of the seeds of the cultivar BRS Tracuateua was not affected by concentrations of NaCl between 25 and 100 mM, however, vigor was reduced with a decrease in the germination speed index and seedling length starting at a concentration of 25 mM. It should also be considered that the absence of interaction may be due to the lack of variability among cultivars for germination capacity, according to the criterion adopted, under the conditions in which the experiment was conducted.

Table 1 also presents the value obtained by Halothermal time modeling, proposed by Bakhshandeh et al. (2020). These values represent the performance of the cultivars in relation to their response to salt stress. The cultivar BRS Itaim stood out with the highest tolerance to NaCl presenting an estimated limit of 1.984 mM, followed by BRS Novaera (1.508 mM) and Sempre Verde (0.630 mM). Figure 1 shows the model of the effect of salt stress on each cultivar using Time-to-Event modeling. Figure 1A shows that the cultivars Pingo-de-ouro ($p<0.05$), BRS Aracê ($p<0.05$), BRS Pajeu ($p<0.05$) and BRS Cauamé ($p<0.05$) showed significant variation in germination time in relation to salinity levels, i.e., with increasing NaCl in the medium there was a significant reduction in germination speed, demonstrating that they are sensitive to the salt gradient.

On the other hand, in Figures 1B and 1C the cultivars did not undergo significant variation in germination time with increasing salt concentration: BRS Itaim ($p=0.39$), BRS Tumucumaque ($p=0.29$), BRS Xiquexique ($p=0.32$), Sempre Verde ($p=0.45$), BRS Guariba ($p=0.36$), BRS Marataoã ($p=0.25$) and BRS Novaera ($p=0.66$). This means that these cultivars were tolerant to the increased saline concentration used in the experiment, thus obtaining a good performance under salt stress. In an evaluation of the germination of cowpea cultivars in concentrations up to 200 mM of NaCl. Tsague et al. (2017) verified a sensitive increase in t50 that varied from 2.83 and 14.87 days.

The analyses of variance for the percentage of emergence, emergence velocity index and length of the hypocotyl root axis showed significant effects for the cultivars ($p<0.01$), salt stress ($p<0.01$) and for the interaction between the factors ($p<0.05$). This finding indicates that the cultivars present different responses when subjected to different levels of salt stress, that is, there is a dependence between the effects when subjected to different levels of salt stress, what means that there is a dependence between the effects of the factors cultivar and salt stress.

Based on the unfolding of the effect of the cultivar within each level of the salt stress factor, one can observe a significant difference ($p<0.01$) for the length of the hypocotyl-root axis between the cultivars, in the control treatment and in the stress levels with concentrations of 30, 60 and 90 mM of NaCl. In the Table 2 is the grouping of the means of the cultivars within each stress level.

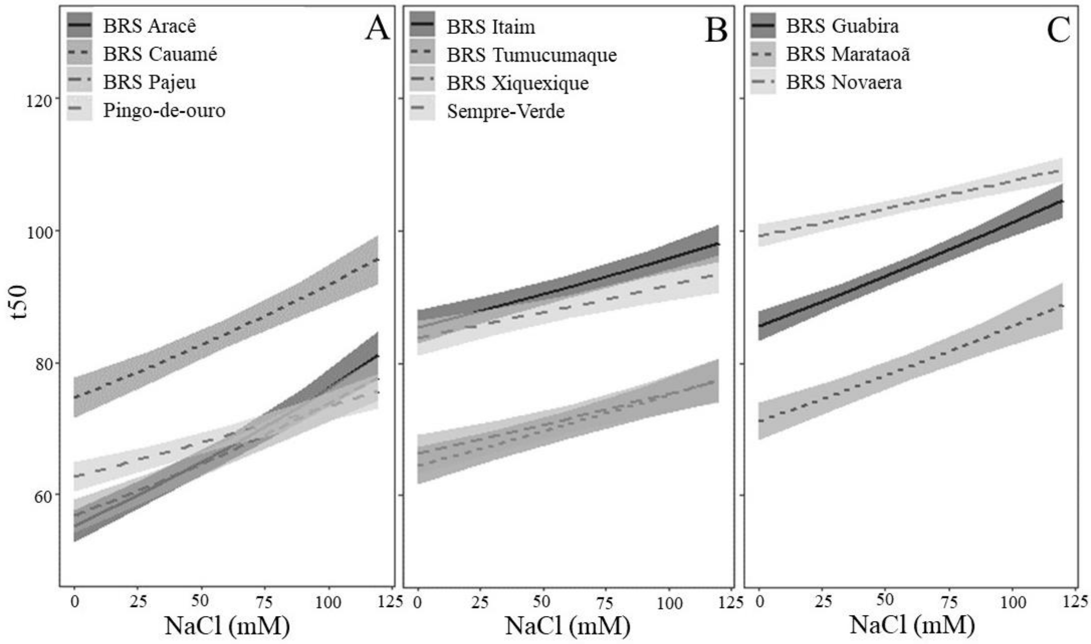

Figure 1. Time-to-event analysis obtained in the evaluation of cowpea cultivars under different levels of salt stress. a) BRS Aracê, BRS Cauamé, BRS Pajeu and Pingo-de-ouro. b) BRS Itaim, BRS Tumucumaque, BRS Xiquexique and Sempre Verde and c) BRS Guariba, BRS Marataoã and BRS Novaera.

Table 2. Averages of hypocotyl-root axis length (cm) obtained in the evaluation of cowpea cultivars, under different levels of salt stress[(1)]

Cultivar	Salt stress level (mM) of NaCl				
	0	30	6,0	90	120
BRS Aracê	11.7 a	11.6 a	10.3 a	6.5 b	4.8 a
BRS Cauamé	10.6 a	9.1 b	7.8 b	5.2 b	4.0 a
BRS Guariba	7.7 b	8.6 b	5.5 b	4.9 b	3.9 a
BRS Itaim	10.8 a	10.0 b	9.9 a	9.2 a	5.5 a
BRS Marataoã	12.1 a	9.7 b	7.6 b	6.5 b	4.6 a
BRS Novaera	9.1 b	7.4 b	6.9 b	6.3 b	4.0 a
BRS Pajeu	11.4 a	11.6 a	10.7 a	8.5 a	5.9 a
BRS Tumucumaque	10.3 a	8.8 b	8.5 b	6.5 b	4.8 a
BRS Xiquexique	8.2 b	9.0 b	10.4 a	6.1 b	5.0 a
Pingo-de-ouro	13.5 a	13.5 a	11.1 a	8.2 a	6.1 a
Sempre Verde	12.1 a	11.2 a	10.4 a	8.5 a	5.0 a
Average	10.68	10.05	9.00	6.95	4.87

(1) Averages with the same letter in the column constitute a statistically homogeneous group by the Scott-Knott test at 5% probability.

In all stress levels, except for the one of 120 mM NaCl concentration, the performances of two groups of cultivars were constituted. The cultivars Pingo-de-ouro, Sempre Verde and BRS Pajeu stood out in the best performance group at all stress levels. For the stress level of 120 mM NaCl, there was no significant difference among cultivars. Possibly, the stress level was severe enough not to allow the detection of variability among cultivars. Figure 2 illustrates the length of the hypocotyl-root of the cultivars BRS Marataoã and Sempre Verde. One can observe the smaller reduction of the hypocotyl-root axis of the cultivar Sempre Verde compared to BRS Marataoã, between the control and the 90 mM of NaCl stress level, corroborating the conclusions obtained from Table 2.

In this study, the average reduction in the length of the hypocotyl-root axis when comparing the 90 mM NaCl level with the control was 35%, ranging from 15% for the cultivar BRS Itaim to 51% for the cultivar BRS Cauamé. For the cultivars Epace-10, Pitiúba and Canapu Dantas et al. (2005) observed a reduction in hypocotyl length of 70.3, 68.1 and 55.6%, respectively, when subjected to solutions of 100 mol.m-3 of NaCl. Maia et al. (2012) found that root length was reduced between 25 and 56%, depending on the cultivar, when comparing 100 mM NaCl concentration to the control treatment. Nunes et al. (2019) observed that the cultivar BRS Marataoã showed a reduction in root length at the stress level corresponding to 10 mM NaCl, showing high sensitivity to salt stress. For the concentration of 200 mM of NaCl, Deuner et al. (2011) observed that there was only the beginning of primary root protrusion, not being possible to measure this character.

According to Araújo et al. (2012) the reduction in root and hypocotyl length is associated with the decrease in osmotic potential that causes difficulty for the seed and seedling to absorb water from the medium. However, Maia et al. (2012) reported that ionic toxicity seems to be more associated with root growth inhibition than salinity-induced water deficit. According to them, external NaCl concentration equal to or greater than 25 mM may be sufficient to induce ionic toxicity.

Coelho et al. (2017) also pointed to the negative effect of Na^+ and Cl^- on enzyme production and activation, and cell division and differentiation as a probable cause of the reduction in germination and initial growth of cowpea seedlings. Increased electrolyte leakage and cell death at the root apex, associated with increased phenol peroxidase activity and reduced catalase and ascorbate peroxidase activities are also possible causes of reduced root growth (Maia et al., 2012).

Table 3 shows the mean values of the percentage of emergence of the cultivars within each level of salt stress. The analysis of the groups of averages allows us to highlight the cultivars Pingo-de-ouro and BRS Tumucumaque which were on the top group at the 30, 60 and 90 mM NaCl stress levels and the BRS Pajeu, which showed the lowest reduction in the percentage of emergence (41%) when compared to the 90 mM NaCl concentration to the control. At the other extreme was the cultivar Sempre Verde with 84% reduction, compared to a general average of 65%.

In Figure 3, one can observe the differentiated response of cowpea cultivars to increasing salt concentration, as evidenced by statistical analysis. The greater capacity for emergence and development of seedlings is of the cultivar Pingo-de-ouro compared to the cultivar BRS Cauamé, as the level of salt stress increases. The unfolding of the means of the speed of emergence index of the cultivars within each level of salt stress in presented in Table 4.

The cultivars Pingo-de-ouro and BRS Tumucumaque belong to the group with better performance in stress levels with concentrations of 30, 60 and 90 mM of NaCl. These cultivars, together with BRS Pajeu, also presented the lowest reduction rates for the character being discussed, with a magnitude of 37% or 38%, when compared to the 90 mM NaCl concentration to the control. The higher the emergence speed index, the greater is the speed of emergence, which allows inferring that cowpea cultivars with these characteristics are more tolerant to salt stress in the emergence phase (Almeida et al., 2012). This greater tolerance of some cultivars under salt stress is associated with lower Na^+ in leaf tissues and retention of this ion in the roots (Alves et al., 2015).

Direct interference in the formation of the aerial part of the caupi bean due to the high sensitivity to saline environments is reported by Coelho et al. (2017) for the cultivars BRS Tapaihum, BRS Pujante, BRS Acauã and BRS Marataoã. For these cultivars, the authors found that there was no formation of the aerial parta t concentrations of 50, 100, 150 and 200 mM of NaCl. Using irrigation water with levels of electrical conductivity varying from 0 to 7.5 dS.m^{-1}, Almeida et al. (2012) found a reduction in seedling emergence and the emergence speed index.

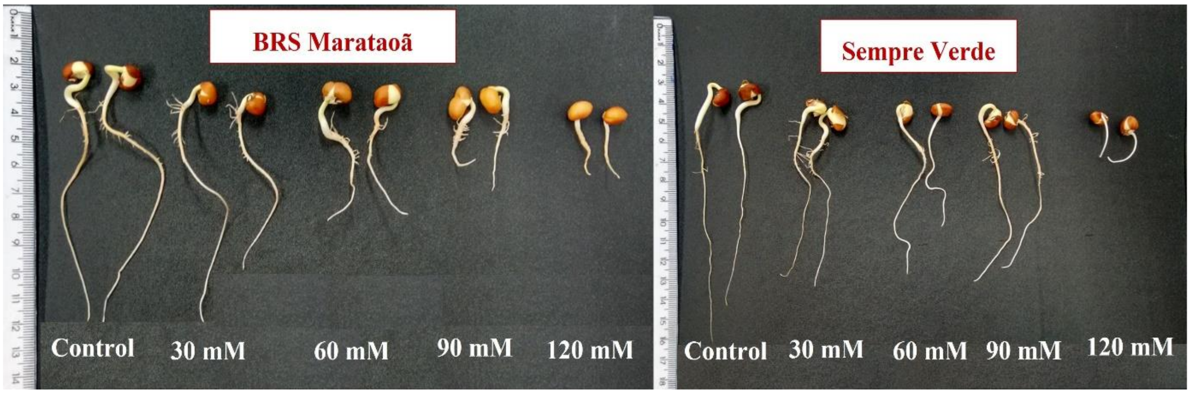

Figure 2. Length of the hypocotyl-root axis of seedling of the cultivars BRS Marataoã and Sempre Verde, under different levels of salt stress, days after sowing

Table 3. Mean of emergence percentage obtained in the evaluation of cowpea cultivars, within different levels of salt stress [(1)]

Cultivar	Stress level (mM NaCl) [(2)]				
	0	30	60	90	120
BRS Aracê	59 b	55 b	47 a	21 b	8 a
BRS Cauamé	61 b	47 b	24 b	22 b	8 a
BRS Guariba	50 b	34 b	20 b	15 b	8 a
BRS Itaim	48 b	65 a	41 a	8 b	8 a
BRS Marataoã	73 a	61 a	29 b	18 b	8 a
BRS Novaera	66 a	62 a	24 b	21 b	8 a
BRS Pajeu	82 a	69 a	17 b	48 a	8 a
BRS Tumucumaque	66 a	68 a	40 a	34 a	8 a
BRS Xique-xique	68 a	50 b	47 a	17 b	8 a
Pingo-de-ouro	79 a	79 a	52 a	44 a	8 a
Sempre Verde	70 a	58 a	43 a	11 b	8 a
Average	65.63	58.90	34.90	23.54	8

[(1)] Data transformed using the expression $y = \text{arc sen}\sqrt{x/n}$, where "x" corresponds to the number of germinated seeds in each plot and "n" to the total number of seeds per plot. In the case x = 0, the value 0/n was replaced by 1/4n, and in the case of x = n, the value n/n was replaced by 1-1/4n. [(2)] Averages with the same letter in the column constitute statistically homogeneous groups by the Scott-Knott test at 5% probability.

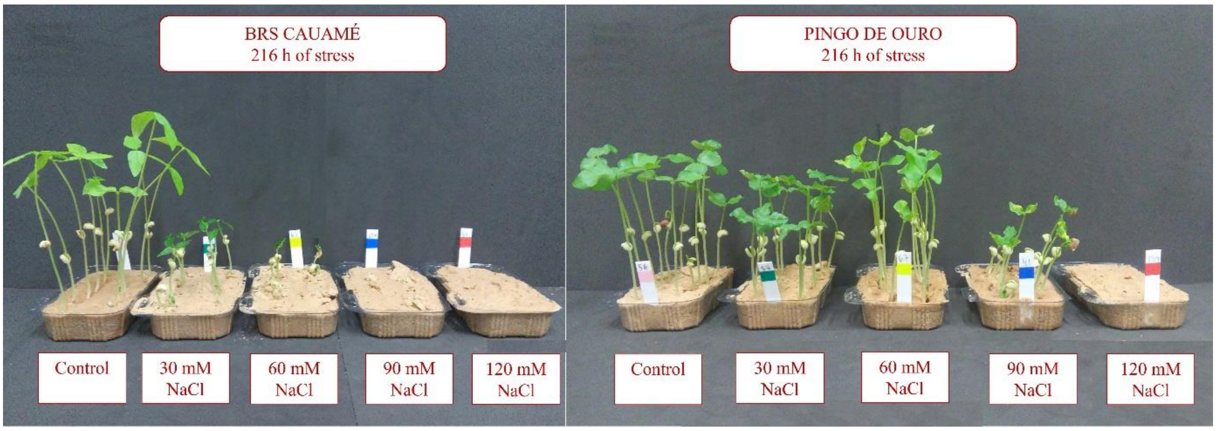

Figure 3. Emergence and development of seedlings of the cultivars BRS Cauamé and Pingo-de-ouro, at different levels of salt stress, 216 hours after sowing.

Table 4. Mean of the emergence index obtained in the evaluation of cowpea cultivars, under different levels of salt stress

Cultivar	Stress level (mM NaCl) [(1)]				
	0	30	60	90	120
BRS Aracê	0.31 b	0.35 a	0.29 a	0.15 b	0.09 a
BRS Cauamé	0.32 b	0.28 b	0.21 b	0.19 b	0.05 a
BRS Guariba	0.29 b	0.22 b	0.20 b	0.15 b	0.04 a
BRS Itaim	0.32 b	0.38 a	0.28 a	0.07 b	0.10 a
BRS Marataoã	0.43 a	0.33 a	0.24 a	0.20 b	0.03 a
BRS Novaera	0.38 a	0.38 a	0.17 b	0.18 b	0.05 a
BRS Pajeu	0.47 a	0.41 a	0.18 b	0.29 a	0.09 a
BRS Tumucumaque	0.40 a	0.40 a	0.26 a	0.25 a	0.12 a
BRS Xiquexique	0.38 a	0.33 a	0.30 a	0.17 b	0.07 a
Pingo-de-ouro	0.46 a	0.43 a	0.32 a	0.29 a	0.10 a
Sempre Verde	0.39 a	0.35 a	0.30 a	0.15 b	0.02 a
Média	0.38	0.35	0.25	0.19	0.07

[(1)] Means followed by the same lower case letter in the column constitute a statistically homogeneous group by the Scott-Knott test at 5% probability.

It was evidenced that the performance and classification of cultivars under salt stress conditions varies according to the characteristic under analysis and the level of stress considered. Considering the general performance under salt stress conditions, BRS Itaim, BRS Novaera and Sempre Verde excelled in the germination phase and BRS Pajeu, BRS Tumucumaque and Pingo-de-ouro in the emergence phase. In a next step, these cultivars should be evaluated in more robust experiments, under more representative conditions to confirm their superiority for crop establishment under salt stress conditions.

4. Conclusions

There is a differentiated response among the cowpea cultivars during the germination and emergence phases under salt stress conditions. The cultivars BRS Itaim, BRS Novaera, BRS Pajeu, BRS Tumucumaque, Sempre Verde and Pingo-de-ouro show superior performance in the germination or emergence phases under salt stress conditions.

Authors' Contribution

Vanessa Silva Romanoski: data collection, data interpretation and writing article; Paulo Roberto de Moura Souza Filho: orientation, statistical analysis, data interpretation and review; Adérico Júnior Badaró Pimentel: orientation, experiment setup, statistical analysis, data interpretation and review.

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