Original Research Article

Physiological quality in *Leucaena leucocephala* seeds conditioned with potassium nitrate submitted to saline and water stresses

ABSTRACT

Leucaena leucocephala is a species that occurs in semiarid regions capable of developing physiological and biochemical strategies underin adverse environmental situations, such as saline soils and water deficiency. Even so, there are still losses in germination and initial development of plants mainly due effects the abiotic stresses, being necessary with this weto implement have looked for alternatives able to that diminish the impact on the seeds with the use of potassium nitrate. The objective of this work was to evaluate the physiological quality in *L. leucocephala* seeds conditioned in potassium nitrate solution and submitted subjected to saline and water stresses. After scarification, the unconditioned leucine seeds were separated and identified, and the conditioners were immersed in the 1.0 Mmol/L solution of potassium nitrate, 24 hours. The treatments were NaCl: 0; 30; 60; 90; 120 and 150 Mmol/L and the water potential: 0,0; -0.2; -0.4; -0.6, and -0.8 MPa. The seeds were distributed over two leaves of Germitest®, moistened with distilled water 2.5 times the dry weight and incubated in B.O.D. at 25 °C for 10 days. Then, normal seedlings, germination speed index, seedling length and seedling mass were measured. Eleven treatments with four replicates of 50 seeds were used. The design was completely randomized, and the statistical analyzes were done in SAS. The use of potassium nitrate (KNO_3) contributed to the maintenance of the physiological quality of *L. leucochephala seeds* under conditions of saline stress and water restriction.

Keywords: Leucena; water potencial; salinity

1. INTRODUCTION

The *Leucaena leucocephala* (Lam.) bBelongs to the family Fabaceae (Subfamily Mimosidae), is a fast growing specie, is nitrogen fixer and has been highlighted as a promising alternative for the recovery vegetation cover and rehabilitation of degraded areas, since it has symbiosis with nitrogen-fixing bacteria, improving soil fertility [1].

Its use has met a wide variety of demands, including reforestation disturbed areas for erosion control, animal feed, green manuring, fence posts, poles and cellulose. Sowing can be done either by seedlings or directly on the site [2]., HHowever, sowing in saline soils in those regions with a low frequency of rainfall can restrict soil moisture, resultings in slow and irregular emergence, with direct reflexes in the development of seedling [3].

The effects of salinity on germination can be noticed both by interference of salts in the cellular metabolism and by reduction the osmotic potential of seed, causing water stress and making water absorption difficult [4]. Salinity may also cause injury, such as chlorophyll degradation and changes in protein metabolism, important amino acid levels linked to the germination process, and seedling initial development [5].

The presence of water is essential, and its scarcity is one of the adversities encountered by species of plants that develop in saline or dry environments, since availability of water to the seed, as well the speed of absorption, is directly influenced of the water potential difference between seed and soil [6]. Therefore, seeds of species the Fabaceae family even in arid and semiarid regions develop physiological and biochemical strategies capable of developing in adverse environmental situations, such as, in soils with high salt concentration or affected by water deficiency [7,8].

Comment [IFGT1]: It does not sound well.

Due to the severity of losses caused by the effects of saline and water stress on germination and during the initial plant development, alternatives and treatments have been sought to reduce the~~ir~~ impact on seeds. Among the substances ~~with the potential~~able to induce a resistance to these types of stress in ~~the~~ seeds, nitric oxide (NO), inorganic free radical and an extremely versatile biological messenger can be supplied exogenously the seeds through their conditioning in potassium nitrate solutions [9].

Research has demonstrated the involvement of nitric oxide in hormonal signaling [10] and in numerous physiological plant processes, including: protective function against oxidative stress [11]. In seeds, nitric oxide stimulates germination, both under normal conditions and under stress, besides favoring seed dormancy of some species [12] and promoting the elongation and formation of adventitious roots [13].

The objective of this work was to evaluate physiological quality in *Leucaena leucocephala* seeds conditioned in potassium nitrate solution and submitted to saline and water stresses.

2. MATERIAL AND METHODS

Seeds of *L. leucocephala* were collected from mature fruits with brown staining from ten matrices, spaced at a distance of 6 meters, located in the vicinity of the municipality of Macaíba - RN (Latitude: -5.86, Longitude: -35.33) in the period from July to August 2017. The region presents Aw tropical rainy climate, with an average temperature of 26 ^{o}C, relative air humidity of 74 % and precipitation of 1,134 mm annually, according to Köppen and Geiger [14].

After collection, the seeds were manually removed from the pods, selected and mechanically scarified, using N^{o}. 100 sandpaper, on side opposite the thread, only to break the tegument. After scarification, the water content of seeds was determined by greenhouse method at 105 ± 3 °C for 24 hours, as recommended by Brazil [15]. And the results were expressed in average percentage of humidity (wet basis).

Then, the unconditioned seeds were separated and deposited in identified glass containers. The conditioned seeds were immersed in glass containers containing the 1.0 Mmol/L solution of potassium nitrate for 24 hours. To simulate the stress conditions, following concentrations of NaCl: 0 were used; 30; 60; 90; 120 and 150 Mmol/L [16], and also the water potentials: 0; -0.2; -0.4; -0.6 and -0.8 MPa, calculated according to the equation proposed by Michel and Kaufmann [17]. After conditioning and under conditions of saline and water stress, the seeds had their physiological potential evaluated through the tests described below.

For germination, four replicates of 50 seeds were used for each treatment, distributed on two sheets of Germitest® type paper towels and covered with a third sheet of the same paper, then rolled into a roller. The substrate was moistened with distilled water (AD) in an amount 2.5 times the dry substrate weight, according to Brazil [15].

Subsequently, paper rolls with seeds that were not conditioned and conditioned with potassium nitrate were subjected to saline stress and water stress separately and incubated in a type germination chamber (Biochemical Oxygen Demand) at 25 °C for 10 days, when final seedlings were counted. Results were expressed as percentage of germination.

The germination speed was carried out in conjunction with the germination test, distributed on two sheets of Germitest® type paper towels and covered with a third sheet of the same paper, then rolled into a roller. The substrate was moistened with distilled water (AD) in an amount 2.5 times the dry substrate weight, according to Brazil [15], with daily counts of seeds that emitted a primary root of at least 2 mm from the first to the tenth day. Determined from the germination velocity index (GVI), calculated according to the formula proposed by Maguire [18].

The dry mass of seedlings was performed with total of ten normal seedlings per experimental unit, randomly taken at the end of germination test, dried for 24 hours in a greenhouse at 105 ± 2 ºC, weighed in precision scale and the results expressed in grams of dry mass of seedlings.

The experiment was carried out in a completely randomized design with four replicates of 50 seeds, using the factorial arrangement scheme: 2 (unconditioned and conditioned with KNO_3) x 6 (NaCl concentrations), for salt stress and 2 conditioned and conditioned with KNO_3) x 5 (osmotic potentials), for water stress. The results were submitted to analysis of variance and, when there was significance, by the F test, submitted to regression analysis. Statistical analyzes were performed using SAS® software [19].

3. RESULTS AND DISCUSSION

According to the analysis of variance, when applying the F test, statistical differences were verified for the variables in which *L. leucocephala* seeds were submitted, both in relation to the conditioning and concentrations in the saline stress (NaCl) and different potentials osmotic (PEG). Significance was also observed for the interaction between the factors, observing different behaviors for physiological analyzes, except for the germination variable, when subjected to saline stress conditioning and interaction, for which there was no significant effect on the evaluated treatments. When the germination of seeds submitted to water stress was evaluated, no difference was found between the means of the evaluated treatments (Table 1).

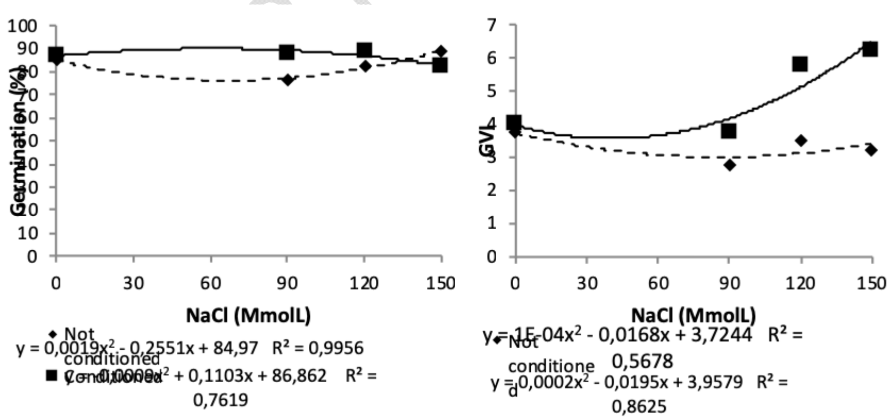
Table 1. Summary of variance analysis for the variables germination (G), germination velocity index (GVI), seedling length (SL) and seedling dry mass (SDM) from unconditioned seeds and conditioned with potassium nitrate subjected to saline and water stresses.

	F values – Saline stress			
Source of variation	G (%)	GVI	SL (cm)	SDM (g)
Conditioning (C)	175,91**	334,67**	387,11**	0,16**
Saline concentrations (S)	21,10^{ns}	34,08**	4,01**	0,08**

(C) x (S)	74,83^{ns}	13,73**	25,97**	0,06**
CV (%)	7,82	14,83	11,83	12,15
F values – Hydrical stress				
Source of variation	G (%)	GVI	SL (cm)	SDM (g)
Conditioning (C)	22,94^{ns}	14,88**	14,21**	0,0016**
Osmotic potentials (O)	26,56^{ns}	51,37**	9,08**	0,0012**
(C) x (O)	28,02^{ns}	55,43**	120,70**	0,0010**
CV (%)	7,53	3,90	1,94	7,45

^{ns} not significant, ** significant at 1% by the F test.

The results of the germination test on conditioned or non-saline seeds (Figure 1 A) show that, despite salinity, there was a positive effect of conditioning on this variable. Although the seeds did not present significant variation with the progressive increase of the salinity of the substrate, it was observed effect of conditioning on the germination of seeds until the concentration of 90 Mmol/L of NaCl, which presented higher germination than the unconditioned seeds. In general, the seeds presented high germination, even when not conditioned. A similar result was verified by Amaro [20], which evaluated *Copaifera langsdorffii* Desf. (Fabaceae) seeds on a substrate moistened with NaCl solution, with a high percentage of germination, around 95 %. The *Leucaena leucocephala* (Lam.) De Wit seeds Cavalcante and Perez [21] added sodium chloride (NaCl) to substrate and observed high germination percentages of the seeds, which reaffirmed ability of the seeds this species to present a high germinative performance even under saline stress conditions.



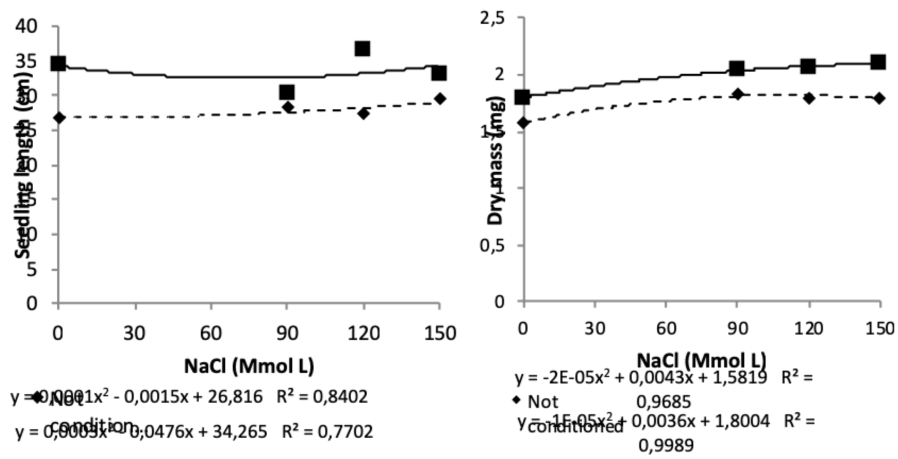


Figure 1. (A) Germination, (B) Germination velocity index, (C) Seedling length, and (D) Dry mass of *L. leucocephala* seedlings from not conditioned seeds conditioned with potassium nitrate to saline stress).

Thus, *L. leucocephala* seeds, as well as those of several other species of the Fabaceae family, show resistance or some kind of defense system, capable of synthesizing and accumulating different compounds of small molecular mass such as sugar alcohols, proline and glycine betaine, which are referred to as compatible osmopolymers, osmoprotectants or solutes. And these compounds have an exact function in the plants, being able to be related protection of the plants to abiotic stresses, functioning as a tool for the cellular osmotic adjustment, and protection against oxidative damages under adverse conditions, as in drought and salinity tolerance [22].

However, it was verified that potassium nitrate ~~(KNO$_3$)~~ did not promote seed germination improvement, since these already present high viability even under conditions of salt stress.

It was observed that the rate of germination, length and dry mass of seedlings increased as the substrate concentrations increased, evidencing that the potassium nitrate ~~(KNO$_3$)~~ and salt stress *L. leucocephala* seeds (Figures 1 B, C and D), evidencing that potassium nitrate ~~(KNO$_3$)~~ concentrations helped to reverse and/or minimize the negative effects of salinity in seed germination velocity index and seedling initial development. The plausible explanation for this phenomenon is the possibility of nitric oxide liberators promoting seedling tolerance to salinity by reducing Na^+ and Cl^- transport to leaves and by the ability to compartmentalize these ions in vacuoles to avoid their accumulation in the cytoplasm or cell walls and thus avoid salt toxicity [35].

Formatted: Highlight

This is because the mechanism of action of potassium nitrate acts on the reception of electrons, reducing the nitrite form inside the seeds, reoxidizing the NADPH and increasing the availability of NADP for the reduction of the dehydrogenases of the cycle of pentose phosphate, helping the overcoming of seed dormancy [3]. In addition to being an excellent growth promoter of seedlings, potassium nitrate can also act to maintain balance in plant cells, promoting respiration and metabolism of carbohydrates [23].

Regarding the unconditioned seeds, lower performance was observed in all salinity concentrations when the germination rate, length and dry mass of seedlings were evaluated. As for the variable germination, the vigor of the unconditioned seeds was more affected by the salinity. Evaluating the physiological quality of seeds of *Crambe abyssinica* Hochst. ex R. E. Fr., Nunes et al. [24] found that the increase in saline concentration of the substrate also reduced the rate of germination. This decrease in germination speed was also observed by Sousa Filho [25] in *Erythrina mulungu* Mart ex Benth. (Fabaceae) seeds under saline stress. These results confirm the negative effect of soil salinity on the vigor of seeds of different species, reducing the emergence speed and the growth of the seedlings, generating damages to agricultural production.

Salinity probably interferes with the physiological quality of seeds as well, in terms of reservoir energy expenditure to absorb water and subsequently not reserving the reservoir for other processes, inducing changes in the activities of catalase, polyphenoloxidase and peroxidase enzymes [26]. In studies carried out by Marques et. [27], the effect of saline stress on emergence and establishment of seedlings seems to have been responsible for the inhibition of cotyledonary reserve depletion and embryonic axis growth, since in the analyzes the seedlings presented excessive accumulation of Na^+ and Cl^- ions.

The excess Na^+ and Cl^- ions seem to play a role in reducing the physiological quality of seeds, since they tend to cause a decrease in protoplasmic intumescence (the ions in solution initially cause a decrease in intumescence, and only after absorption and accumulation in the vacuoles and apoplast is that the rate of water absorption is normalized), affecting the enzymatic activity, resulting, mainly, in the inadequate production of energy by disturbances in the respiratory chain [28]. In addition, it is necessary to emphasize its toxic effect, resulting from the concentration of ions in the protoplasm. As the saline concentration increases in the soil solution, there is an increase in the osmotic pressure and, therefore, the plant does not absorb the soil water, causing physiological and morphological disturbances that hinder the survival of the plant in this stress condition [29].

When seeds were conditioned or not subjected to water stress, no changes in seed germination were~~as~~ observed along the reduction of water availability and no differences between the two treatments ~~in~~ for any of the potentials were tested.

However, as the water potential became more negative, there was a decrease in the rate of germination of *L. leucocephala* seeds conditioned and not conditioned with potassium nitrate (KNO_3), and conditioned seeds presented higher results in relation to unconditioned seeds (Figure 2 A). KNO_3 under water stress showed a significant interaction and showed a positive influence on the evaluations described in *L. leucocephala* seeds (Figure 2A), since conditioning has the function of repairing damaged macromolecules and cellular structures with the activation of metabolic events in stages I and II of imbibition without, however, occurring root protrusion [36]. ~~The p~~Potassium nitrate~~e (KNO_3)~~ also helped to reverse and/or minimize the negative effects of seed germination and initial seedling development, in addition to being a very tolerant to negative water potentials. Thus, the conditioning technique establishes favorable conditions to increase seed germinability and vigor of seedlings [37],~~ thus~~ contributing to high-quality seedlings even under stress conditions [38].

Comment [IFGT2]: It does not sound well

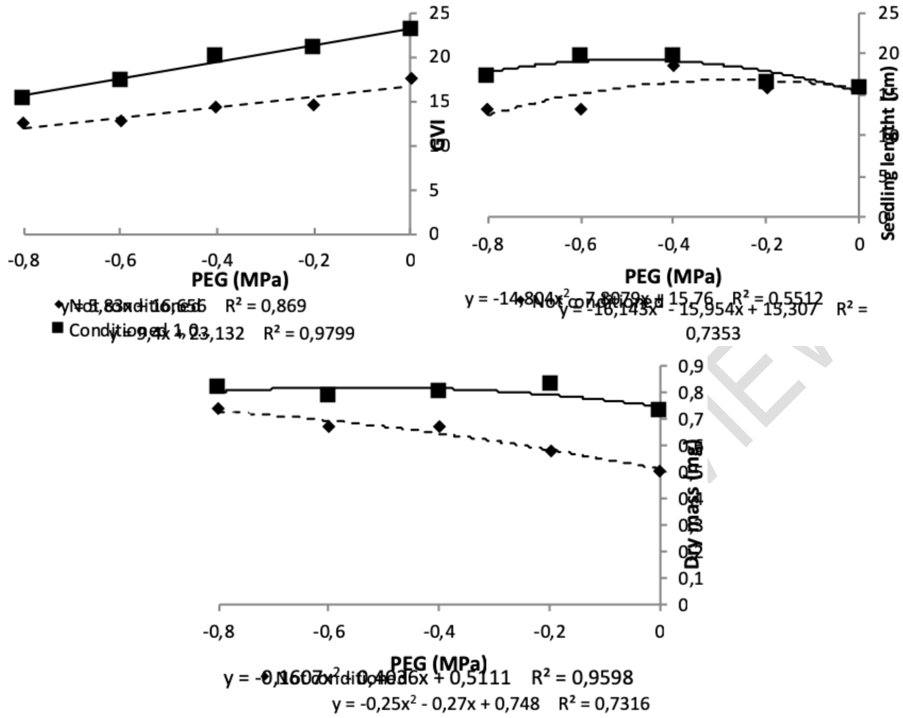


Figure 2. Germination velocity index (A), seedling length (B) and dry mass (C) of *L. leucocephala* from seeds not conditioned and conditioned with potassium nitrate (and submitted to water stress).

Comment [IFGT3]: Please, note that equations are out of figure. This mistake must be corrected by the authors.

When evaluating the viability of *Apuleia leiocarpa* (Vogel) J.F.Macbr. (Fabaceae) in different water potentials, Spadeto et al. [31] also observed that the more negative the potentials, the lower germination speed averages were -0.4 and -0.8 MPa obtained 3.80 and 3.74, respectively. When Felix et al. [34] evaluated the effects of water stress, verified that the germination speed in *L. leucocephala* seeds were reduced when submitted to the most negative water potentials, -0.3 and -0.6 MPa, obtaining a mean of 8.0 and 4.0, respectively.

Therefore, the results of these researchers corroborate with those obtained in this research, indicating the negative effect of reducing the availability of water in substrate on the germination of seeds this species. This fact is probably due to decrease in water availability, which limits imbibition and reduction of seed water intake, reducing the metabolic activities expected during germination phases, slowing down the process of mobilization and utilization reserves, leading to reduction of the rate germination [5].

It is observed that *L. leucocephala* seeds presented high rate of germination in the conditions in which the lowest water restrictions were observed. According to Bewley et al. [5] Seeds such as *L. leucocephala* are tolerant to water stress due to their natural occurrence in semiarid regions, as they acquire biochemical and physiological strategies that can be attributed to membrane repair even in situations of low water potential.

Conditioning with potassium nitrate (KNO_3) has influenced the reversal of harmful changes in cell membranes, caused by inactivation of enzymes and inhibition of protein synthesis [29]. This shows that even under conditions of stress of abiotic origin, *L. leucocephala* seeds had positive effects on the physiological responses involved in the whole germination process, regulating percentage of germination and rate germination, as well as the growth, development and establishment of seedlings.

There was a tendency to increase the length and dry mass of *L. leucocephala* seedlings as the water restriction was increased, regardless of the potassium nitrate (KNO_3) or not. However, the seeds presented different results for length and dry mass of seedlings when compared to conditioned and unconditioned seeds. With the reduction of the water potential, the length of the seedlings resulting from conditioned seeds presented results with a tendency to increase the difference in relation to the unconditioned seeds, indicating an increase in the size conditioned seedlings in relation the untreated seedlings under conditions of lack of water (Figure 2 B). On the other hand, the dry matter of seedlings showed a decrease in the water potential (Figure 2 C), in relation to the uncon solved seeds.

The ability to develop roots and aerial parts, even under conditions of stress and water scarcity, varies widely between species and may be related to the hypothesis of adaptation, due to the proliferation and the increase of the roots increase the capacity of water absorption in a limit situation, or may be related to the growth rate of a given plant [32].

Many proteins that are induced in the early stages of water stress are also involved in root morphogenesis and carbon/nitrogen metabolism, which may contribute to the nullification of stress by increasing root growth [33]. In the case of *L. leucocephala*, the literature reports that it is a plant adapted to inhospitable conditions and such rusticity can favor the tolerance of the seeds under different conditions.

4. CONCLUSION

The use of potassium nitrate (KNO_3) showed a positive action on the reversal of salt stress and the conditioning of the seeds under low osmotic potential, influencing the maintenance of the physiological quality of *L. leucocephala.*

COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration with all authors.

REFERENCES

1. Nogueira NO, Oliveira OM de, Bernardes CA da SM, Bernardes C de O. Utilização de leguminosas para recuperação de áreas degradadas. Enciclopédia Biosfera. 2012;8(14):2121.
2. Cardoso EA, Alves AU, Cavalcante ÍHL, Farias SGG, Santiago FEM. Métodos para superação de dormência em sementes de leucena. Revista Ciências Agrárias. 2012;55(3):220–4. PortugueseAvailable: http://dx.doi.org/10.4322/rca.2012.062
3. Mariano LG, Somavilla A, Silveira AG da, Salamoni AT. Análise de superação de dormência de sementes de *Leucaena leucocephala* e desenvolvimento inicial de

plântulas. Electronic Journal of Management, Education and Environmental Technology. 2016;20(1):398−404. Portuguese. Available: http://dx.doi.org/10.5902/2236117019719

4. Begum MAJ, Selvaraju P, Venudevan B. Saline stress on seed germination. Scientific Research and Essays. 2013;8(30):1420–3. Available: http://dx.doi.org/10.5897/SRE2013.5600
5. Bewley JD, Bradford K, Hilhorst H, Nonogaki H. Seeds: physiology of development, germination and dormancy. 2013.
6. Cavallaro V, Barbera AC, Maucieri C, Gimma G, Scalisi C, Patanè C. Evaluation of variability to drought and saline stress through the germination of different ecotypes of carob (*Ceratonia siliqua* L.) using a hydrotime model. Ecological Engineering. 2016;95:557–66. Available: http://dx.doi.org/10.1016/j.ecoleng.2016.06.040
7. Elias SG, Copeland LO, McDonald MB, Baalbaki RZ. Seed testing: principles and practices. East Lansing: Michigan State University Press.; 2012. 368 p. Available: http://dx.doi.org/1611860393,9781611860399
8. Guedes RS, Alves EU, Viana JS, Gonçalves EP, Lima CR de, Santos SDRN dos. Germinação e vigor de sementes de *Apeiba tibourbou* submetidas ao estresse hídrico e diferentes temperaturas. Ciência Florestal. 2013;23(1). Portuguese. Available: http://dx.doi.org/10.5902/198050988438
9. Martins CC, Pereira MRR, Lopes MTG. Germinação de sementes de eucalipto sob estresse hídrico e salino. Bioscience Journal. 2014;30(3):318–29.
10. Matakiadis T, Alboresi A, Jikumaru Y, Tatematsu K, Pichon O, Renou J-P, et al. The Arabidopsis Abscisic Acid Catabolic Gene CYP707A2 Plays a Key Role in Nitrate Control of Seed Dormancy. Plant Physiology. 2008;149(2):949–60. Available: http://dx.doi.org/10.1104/pp.108.126938
11. Zheng C, Jiang D, Liu F, Dai T, Liu W, Jing Q, et al. Exogenous nitric oxide improves seed germination in wheat against mitochondrial oxidative damage induced by high salinity. Environmental and Experimental Botany. 2009;67(1):222–7. Available: http://dx.doi.org/10.1016/j.envexpbot.2009.05.002
13. Pereira BLC, De Lima E Borges EE, Oliveira AC, Leite HG, De Carvalho Gonçalves JF. Influência do óxido nítrico na germinação de sementes de *Plathymenia reticulata* Benth com baixo vigor. Scientia Forestalis. 2010;(88):629–36. Portuguese.
14. Köppen W, Geiger R. Klimate der Erde. Gotha: Verlag Justus Perthes. 1928.
15. Brasil. Ministério da Agricultura, Pecuária e Abastecimento. Regras para análise de sementes. Brasília, DF: MAPA/ACS; 2009. 399 p. Portuguese.
16. Betoni R, Scalon S de PQ, Mussury RM. Salinidade e temperatura na germinação e vigor de sementes de mutambo (*Guazuma Ulmifolia* Lam.) (Sterculiaceae). Revista Árvore. 2011;35:605–16. Portuguese. Available: http://dx.doi.org/10.1590/S0100-67622011000400004
17. Michel BE, Kaufmann MR. The osmotic potential of polyethylene glycol 6000. Plant Physiology. 1973;51(5):914–6. Available: http://dx.doi.org/10.1104/PP.51.5.914
18. Maguire JD. Speed of germination-aid selection and evaluation for seedling emergence and vigor. Crop Science. 1962;2:176–7. Available: http://dx.doi.org/http://dx.doi.org/10.2135/cropsci1962.0011183X000200020033x
19. SAS Institute (2011) SAS/STAT Versão 9.3: User's Guide. SAS Institute Inc., 8621.
20. Amaro MS. Germinação de sementes e mobilização de reservas em plantas de copaibasobr estresse hídrico e salino. Tese (Doutorado em Fitotecnia). Universidade Federal do Ceará; 2012. Portuguese.
21. Cavalcante A de MB, Perez SCJG de A. Efeitos dos estresses hídrico e salino sobre a germinação de sementes de *Leucaena leucocephala* (Lam.) de Wit. Pesquisa Agropecuária Brasileira. 1995;30(2):281–9. Portuguese.
22. Hurtado Salazar A. Tolerância ao estresse abiótico (salinidade e seca) e influência de porta-enxertos na qualidade de frutos de *Passiflora* spp. Tese (Doutorado em

Fitotecnia). Universidade Federal de Viçosa; 2016. Portuguese.

23. Brito SF, Bezerra AME, Pereira DS. Efeito da Temperatura e do KNO_3 na germinação de *Acnistus arborescens* (Solanaceae). Floresta e Ambiente. 2016;22(3):406–12. Portuguese.

24. Nunes A da S, Souza LCF de, Scalon S de PQ, Pagnoncelli J. Nitrato de potássio e retirada do pericarpo na germinação e na avaliação do vigor de sementes de crambe. Semina: Ciências Agrárias. 2015;36(3):1775–82. Portuguese. Available: http://dx.doi.org/10.5433/1679-0359.2015v36n3Supl1p1775

25. Sousa Filho PH de, Pereira DP, Marques JB, Moreira ÉFA, Carvalho M, NAVES MF. Efeito do estresse salino na germinação de sementes de *Erythrina mulungu* Mart. ex Benth. Anais do I Seminário de Pesquisa e Inovação Tecnológica. 2017;1(1). Portuguese.

26. Maia JM, Ferreira-Silva SL, Voigt EL, Macêdo CEC de, Ponte LFA, Silveira JAG. Atividade de enzimas antioxidantes e inibição do crescimento radicular de feijão caupi sob diferentes níveis de salinidade. Acta Botânica Brasilica. Portuguese. 2012;26(2):342–9. Available: http://dx.doi.org/10.1590/S0102-33062012000200010

27. Marques EC, Freitas VS, Bezerra MA, Prisco JT, Gomes-Filho E. Efeitos do estresse salino na germinação, emergência e estabelecimento da plântula de cajueiro anão precoce. Revista Ciência Agronômica. 2011;42(4):993–9. Portuguese. Available: http://dx.doi.org/10.1590/S1806-66902011000400023

28. Larcher W. Ecofisiologia vegetal. Editora Rima. 2000. Portuguese.

29. Taiz L, Zeiger E. Fisiologia Vegetal. 3rd ed. Editora Artmed. 2013. 918 p.

30. Lopes JC, Freitas AR de, Beltrame RA, Venancio LP, Manhone PR, Silva FRN e. Germinação e vigor de sementes de pau d'alho sob estresse salino. Pesquisa Florestal Brasileira. 2015;35(82):169. Portuguese. Available: http://dx.doi.org/10.4336/2015.pfb.35.82.631

31. Spadeto C, Mengarda LHG, Paulucio MC, Lopes JC, Matheus MT. Embebição, osmocondicionamento e viabilidade de sementes de *Apuleia leiocarpa* (VOGEL.) J. F. MACBR. Ciência Florestal. 2018;28(1):80. Portuguese. Available: http://dx.doi.org/10.5902/1980509831582

32. Forti, VA, Cicero, SM, Pinto, TLF Efeitos de potenciais hídricos do substrato e teores de água das sementes na germinação de feijão. Revista Brasileira de Sementes. 2009;31(2):63-70. Portuguese. Available: http://dx.doi.org/10.1590/S0101-31222009000200007

33. Masetto TE, Quadros J de B, Ribeiro DM, Rezende RKS, Scalon S de PQ. Potencial hídrico do substrato e teor de água das sementes na germinação do crambe. Revista Brasileira de Sementes. Portuguese. 2011;33(3):511–9. Available: http://dx.doi.org/10.1590/S0101-31222011000300014

34. Felix FC, Araújo FS, Silva MD, Ferrari CS, Pacheco MV. Estresse hídrico e térmico na germinação de sementes de *Leucaena leucocephala* (Lam.) de Wit. Revista Brasileira de Ciências Agrárias. 2018;2(13):e5515. Portuguese. Available: http://dx.doi.org/10.5039/agraria.v13i2a5515

35. Munns R. Comparative physiology of salt and water stress. Plant, Cell and Environment, 2002;25(1):239-250. Available: 10.1590/0034-737X201663010006

36. Bradford, KJ. Manipulation of seed water relations via osmotic priming to improve germination under stress conditions. HortScience. 1986;21(5):1105-1112.

37. Cardoso NSN, Oliveira LM, Fernandez LG, Pelacani CR, Souza CLM, Oliveira ARMF. Osmocondicionamento na germinação de sementes, crescimento inicial e conteúdo de pigmentos de *Myracrodruon urundeuva* fr. Allemão. Revista Brasileira de Biociência. Portuguese. 2012;10(4):457-461.

38. Santos MCA, Aroucha EMM, Maracajá PB, Souza MS, Souza PA. Condicionamento osmótico de sementes: revisão de literatura. Revista Caatinga. Portuguese. 2008;21(2):1-6.