Revista Ciência Agronômica, v. 53, e20218121, 2022
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Pre-germination treatments in pitaya (*Hylocereus* spp.) seeds to attenuate salt stress[1]

Tratamentos pré-germinativos em sementes de pitaya (*Hylocereus* spp.) para atenuar o estresse salino

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ABSTRACT - Pitaya (*Hylocereus undatus* and *H. costaricensis*) is found in the group of exotic fruits and its cultivation in Brazil is expanding, especially in the semi-arid region of the Northeast. In this region, the problems of water quantity and quality usually cause environmental stresses which limit the survival of plants, especially during germination and seedling establishment. Thus, the objective was to evaluate the mitigating action of pre-germination treatments in pitaya seeds under salt stress. The experiment was conducted in a completely randomized design, in a 2 × 6 factorial scheme, corresponding to two species of pitaya (*H. undatus* and *H. costaricensis*) and six pre-germination treatments (T1 = 0.0 MPa (control); T2 = salt stress (-0.4 MPa); T3 = hydropriming + salt stress; T4 = gibberellic acid + salt stress; T5 = salicylic acid + salt stress; T6 = thiamethoxam + salt stress). After 20 days of sowing, germination, germination speed index, shoot length, primary root length, total dry mass, total soluble sugars and total free amino acids were analyzed. *H. costaricensis* was more tolerant to salinity than *H. undatus*. Salicylic acid stimulated the germination and growth of *H. undatus*, besides increasing the soluble sugar content in *H. costaricensis*. Seed hydropriming attenuated salt stress during germination of *H. undatus* and favored dry mass gain. Gibberellic acid stimulated the germination of *H. undatus* and the growth of *H. undatus* and *H. costaricensis* seedlings, in addition to increasing the levels of soluble sugars in *H. undatus*.

Key words: Attenuators. Cactaceae. Abiotic stress. Germination.

RESUMO - Pitaya (*Hylocereus undatus* e *H. costataricensis*) encontra-se no grupo de frutas exóticas e seu cultivo no Brasil está em expansão, sobretudo na região semiárida do Nordeste. Nessa região os problemas de quantidade e qualidade hídrica normalmente ocasionam estresses ambientais limitando à sobrevivência das plantas, principalmente durante a germinação e estabelecimento de plântulas. Sendo assim, objetivou-se verificar a ação mitigadora de tratamentos pré-germinativos em sementes de pitaya sob estresse salino. O experimento foi conduzido em delineamento inteiramente casualizado, em esquema fatorial 2 × 6, correspondente a duas espécies de pitayas *H. undatus* e *H. costatariciensis* e seis tratamentos pré-germinativos (T1 = 0,0 MPa (controle); T2 = estresse salino (-0,4 MPa); T3 = hidrocondicionamento + estresse salino; T4 = ácido giberélico + estresse salino; T5 = ácido salicílico + estresse salino; T6 = tiametoxan + estresse salino). Após 20 dias de semeadura, analisou-se a germinação, índice de velocidade de germinação, comprimentos de partes aérea e raiz primária, massa seca total, açúcares solúveis totais e aminoácidos livres totais. *H. costaricensis* mostrou-se mais tolerante à salinidade que *H. undatus*. O ácido salicílico estimulou a germinação e o crescimento de *H. undatus*, além de aumentar o teor de açúcares solúveis em *H. costaricensis*. O hidrocondicionamento das sementes atenuou o estresse salino durante a germinação de *H. undatus* e favoreceu o ganho de massa seca. O ácido giberélico estimulou a germinação de *H. undatus e* o crescimento de plântulas desta e de *H. costaricensis*, além disso aumentou os níveis de açúcares solúveis em *H. undatus*.

Palavras-chave: Atenuadores. Cactaceae. Estresse abiótico. Germinação.

DOI: 10.5935/1806-6690.20220034
Editor-in-Chief: Eng. Agr. Dra. Charline Zaratin Alves - charline.alves@ufms.br
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Received for publication 26/07/2021; approved on 21/10/2021
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INTRODUCTION

Hylocereus sp., cactus species with exotic fruit, is native to regions of Mexico and Central and South America (MELLO *et al*., 2015). In Brazil, its cultivation is expanding with production areas in the São Paulo state and in the Northeast, especially in the semi-arid region (ALMEIDA *et al*., 2016). In this region, the climate is characterized by high evapotranspiration rates and low rainfall, so it is a region where surface water scarcity and increased salinity in soils are recurrent, resulting in problems for agricultural crops (BEZERRA *et al*., 2020).

High salinity is the abiotic stress that most affects agricultural production in arid and semi-arid regions, causing losses in the most sensitive stages of plants, such as germination and seedling growth (IBRAHIM, 2016). Due to the lower influx of water caused by the osmotic effect, salt stress affects seed metabolism and leads to inhibition of reserve mobilization (FREIRE *et al*., 2018). However, one of the means to mitigate the effects of this stress is the use of gibberellic and salicylic acids (GUIRRA *et al*., 2020; KERCHEV *et al*., 2020), seed hydropriming (PHAT *et al*., 2017) and priming with thiamethoxam (ALMEIDA *et al*., 2020; CAZARIM *et al*., 2021).

Gibberellic acid is a growth regulator that promotes germination and activates the vegetative growth of the embryo (TAIZ *et al*., 2017). When applied to rice (*Oryza sativa* L.) grown under saline conditions, gibberellic acid increased gibberellin levels in seeds (LIU *et al*., 2018). In oat (*Avena sativa* L.) seeds, it mitigated the effects of salt stress and improved germination and seedling growth parameters (CHAUHAN *et al*., 2019). In sweet sorghum [*Sorghum bicolor* (L.) Moench], it promoted an increase in water absorption and germination of seeds under salt stress (ZHU *et al*., 2019). In pumpkin and onion, it promoted higher germination and initial development of seedlings, even under saline conditions (GUIRRA *et al*., 2020).

Salicylic acid is an organic compound capable of minimizing the harmful effects of salinity on plants (METHENI *et al*., 2018), acting as a signaling agent in stress mitigation (RHAMAN *et al*., 2021). In broad bean (*Vicia faba* L.), it improved germination and reduced the inhibitory effect of salt stress (ANAYA *et al*., 2018). In soybean [*Glycine max* L. (Merr.)] seeds, it promoted better physiological performance under different salinity levels (GHASSEMI-GOLEZANI; FARHANGI-ABRIZ; BANDEHAGH, 2018).

Seed hydropriming has shown efficiency in germination and initial growth of seedlings under salinity conditions. In napa cabbage (*Brassica rapa* L. ssp. *pekinensis*), this treatment mitigated the effects of salinity, increasing germination percentage and growth of seedlings (YAN, 2016). In watermelon [*Citrullus lanatus* (Thunb.) Matsum & Nakai], it accelerated germination and resulted in more uniform seedlings (PHAT *et al*., 2017).

Thiamethoxam is a bioactivator insecticide that can positively affect the vigor of plants and protect them from abiotic stresses (HOUSE; SWANTON; LUKENS, 2021). Rice seeds treated with this product and subjected to cold stress resulted in increased number of normal and longer seedlings (ALMEIDA *et al*., 2014). Storage of common bean (*Phaseolus vulgaris* L.) seeds after treatment with thiamethoxam resulted in an increase in germination percentage (CASTELLANOS *et al*., 2017).

Thus, the objective was to evaluate the action of pre-germination treatments as mitigators of salt stress in germination and initial development of seedlings of the pitaya species *Hylocereus undatus* and *H. costaricensis*.

MATERIAL AND METHODS

Ripe fruits of red-fleshed pitaya (*H. costaricensis*) were acquired at the open markets of the city of Mossoró (RN) (5° 11′ 17” S, 37° 20′ 39” W and 20 m altitude) and ripe fruits of white-fleshed pitaya (*H. undatus*) were brought from Londrina (PR) (23° 17’ 34’’ S, 51° 10’ 24’’ W and 550 m altitude). The seeds were manually extracted, sifted and washed under running water to facilitate the removal of excess mucilage, and then dried on sheets of paper towel in a shaded and ventilated environment for 24 hours. After homogenization, the moisture content was determined by the oven method at 105 ± 3 °C, for 24 hours, using two replicates of 50 seeds (BRASIL, 2009). The results were expressed as a percentage (wet basis). The seeds were placed in hermetically sealed plastic packages and stored in a common refrigerator for 30 days until the experimental phase.

The experiment was conducted in a completely randomized design, in 2 × 6 factorial scheme, corresponding to two pitaya species and six pre-germination treatments (T1 = 0.0 MPa (control); T2 = salt stress (-0.4 MPa); T3 = hydropriming + salt stress; T4 = gibberellic acid + salt stress; T5 = salicylic acid + salt stress; T6 = thiamethoxam + salt stress) with four replicates of 50 seeds. The seeds of treatments T3, T4, T5 and T6 were subjected to pre-soaking for 4 h in hydropriming (distilled water), gibberellic acid (150 mg L^{-1}), salicylic acid (1 μM L^{-1}) and thiamethoxam (1 mL kg^{-1} of seeds), respectively. The concentrations of gibberellic and salicylic acids and thiamethoxam were determined based on pre-tests, and 4 h was the time required for significant moisture gain, observed in the soaking curve. After four hours of soaking, the solution was drained and the seeds from each treatment were sown on two sheets of blotter paper, arranged inside transparent acrylic boxes and moistened with water volume equivalent to 2.5 times the dry paper mass weight, under the osmotic potentials of 0.0 MPa for T1 and -0.4 MPa (11.1 $dS.m^{-1}$) for the other five treatments, using sodium chloride (NaCl) solution to simulate salt stress. The potential of -0.4 MPa was chosen based on salinity pre-tests for both species. The electrical conductivity of the solutions was checked with a conductivity meter, and the 0.0 MPa level was obtained using only distilled water to moisten the substrate.

Physiological analyses consisted of the following evaluations: a) germination percentage - performed in four replicates of 50 seeds per treatment, which were sown on blotter paper and placed in a germination chamber, at 25 °C (LONE *et al*., 2014) under a photoperiod of 12 hours. The counts were performed at 20 days after sowing. The results were expressed as a mean percentage of normal seedlings, considering as germinated those with primary root and shoots (BRASIL, 2009); b) germination speed index - performed simultaneously with the germination test, with daily counts performed from the second day after sowing until the twentieth day. The index was calculated by the sum of the ratios of the number of seedlings germinated in the period by the number of days from sowing until they germinated, using the formula proposed by Maguire (1962); c) lengths of shoot and primary root of normal seedlings – at 20 days after sowing, the seedlings were measured with a ruler graduated in centimeters, measuring from the base of the collar to the apex of the seedling for shoot length and from the base of the collar to the tip of the root for the primary root length. The results were expressed in centimeters (cm); d) total dry mass - the seedlings were placed in paper bags, separated by treatment, and dried in a forced air circulation oven at 60 °C for 72 hours. Then, they were weighed on a precision scale (0.001 mg) and the results were expressed in milligrams per seedling (mg $seedlings^{-1}$).

For biochemical analyses, fresh mass samples were obtained from fifteen seedlings per replicate, collected twenty days after sowing. For this, 0.2 g of fresh mass was weighed, placed in tubes, and mixed with 3 mL of 80% ethyl alcohol. Then, the material was automatically macerated for two minutes and kept in a water bath at 60 ºC for 20 minutes. Subsequently, the material was centrifuged for eight minutes, the supernatant was collected, and this extraction process was repeated two more times. At the end, the resulting supernatant was collected and the following determinations were made: a) content of total soluble sugars (TSS) - determined by measuring absorbance at 620 nm following the anthrone method (YEMM; WILLIS, 1954), using glucose as a standard substance. The results were expressed in µmol of $GLU.g^{-1}$ of fresh mass; b) content of total free amino acids (TFAA) – performed by measuring absorbance at 570 nm, following the acid ninhydrin method (YEMM; COCKING, 1955) with glycine as the standard substance, and results expressed in $GLY.g^{-1}$ µmol of fresh mass.

The results were subjected to analysis of variance ($p < 0.05$) and, in case of significance, Tukey test ($p < 0.05$) was applied for the interaction and treatments and t-test ($p < 0.05$) was applied for the species with the statistical program SISVAR® (FERREIRA, 2011).

RESULT AND DISCUSSION

The interaction between pre-germination treatments and the two pitaya species was significant for germination (G), germination speed index (GSI), shoot length (SL), root length (RL) and total soluble sugars (TSS) at 1% probability level ($p < 0.01$) and for total free amino acids (TFAA) at 5% probability level ($p < 0.05$). For total dry mass (TDM), there was no significant interaction, only single effect on pre-germination treatments (Table 1).

Among the two pitaya species, it was observed that, although the germination of *H. costaricensis* was lower than that of *H. undatus* for the control treatment (T1), the latter was sensitive to salt stress of -0.4 MPa (reduction of 33%), while for *H. costaricensis* there was no influence (Table 2).

Table 1 - Analysis of variance for germination (G), germination speed index (GSI), shoot length (SL), root length (RL), total dry mass (TDM), total soluble sugars (TSS) and total free amino acids (TFAA) of pitaya (*Hylocereus costaricensis* and *H. undatus*) seedlings grown from seeds pretreated and subjected to salt stress

Source of variation	DF	Mean square			
		G	GSI	SL	RL
Species (S)	1	8802.08**	37.84**	0.27**	1.60**
Treatments (T)	5	986.48**	43.07**	0.51**	0.09**
T x S	5	253.68**	4.40**	0.22**	0.06**
Error	36	27.69	0.53	0.01	0.01
CV (%)		10.31	12.76	9.18	16.42
Overall Mean		51	5.72	1.27	0.73

Continuation Table 1

Source of variation	DF	Mean square		
		TDM	TSS	TFAA
Species (S)	1	0.01^{ns}	28.02*	558.01**
Treatments (T)	5	0.33**	26.82**	340.20**
T x S	5	0.07^{ns}	15.44**	45.85*
Error	36	0.05	0.37	5.96
CV (%)		16.83	6.03	8.01
Overall Mean		1.28	10.20	30.52

^{NS}, ** and * = not significant, significant at 1% probability level ($p < 0.01$) and 5% probability level ($p < 0.05$)

Table 2 - Germination and germination speed index (GSI) of pitaya (*Hylocereus costaricensis* and *H. undatus*) seeds pretreated and subjected to salt stress

Treatments	Germination (%)		GSI	
	H. undatus	*H. costaricensis*	*H. undatus*	*H. costaricensis*
T1	83 Aa	45 Ba	12.0 Aa	8.1 Ba
T2	50 Ac	45 Ba	4.6 Ad	4.4 Ab
T3	64 Ab	38 Ba	6.5 Abc	4.8 Bb
T4	71 Ab	39 Ba	7.0 Ab	4.6 Bb
T5	74 Aab	42 Ba	5.4 Acd	5.4 Ab
T6	46 Ac	18 Bb	4.4 Ad	1.7 Bc

[1] Means followed by the same letter, uppercase in the row (species) and lowercase in the column (pre-germination treatments), do not differ statistically from each other by Tukey test at 5% probability level. Control (T1); salt stress: -0.4 MPa (T2); hydropriming + salt stress (T3); gibberellic acid + salt stress (T4.); salicylic acid + salt stress (T5); thiamethoxam + salt stress (T6)

Salt stress reduced the germination of *H. undatus* by 33% compared to the control (T1). Hydroprimed seeds (T3) and those subjected to gibberellic acid (T4) and salicylic acid (T5) had 14, 21 and 24% higher germination compared to those subjected to salt stress of -0.4 MPa (T2), respectively. Seeds treated with salicylic acid obtained means of germination similar to those of the control, while *H. costaricensis* seeds were not influenced by salt stress (Table 2). Thiamethoxam did not promote satisfactory results of germination for the two pitaya species subjected to salt stress, as the association of this insecticide with NaCl may have caused phytotoxic effect on the seeds (Table 2).

The treatment of *H. undatus* seeds with salicylic acid stimulated germination under saline condition. Anaya *et al*. (2018) reported a similar result in broad bean. Salicylic acid under adverse conditions acts as a signaling agent, acting in conjunction with other plant hormones and playing an important role in plant stress mitigation (RHAMAN *et al*., 2021).

The exposure of *H. undatus* seeds to salinity (T2) reduced the germination speed index by 62% when compared to that of the control. For *H. costaricensis* seeds, this reduction was equal to 46% (Table 2). This demonstrates that the vigor of *H. costaricensis* seeds was more affected, under saline conditions, than germination. This fact confirms that the loss of vigor is an event that precedes germination (MARCOS-FILHO, 2015). For this species, pre-germination treatments did not attenuate salt stress according to the results of germination speed index, but *H. undatus* seeds subjected to hydropriming (T3) and gibberellic acid (T4) performed better with respect to this variable, around 41 and 52% better compared to salt stress (T2), respectively (Table 2).

Under stress conditions, hydropriming can promote an increase in germination speed index as the seeds require less water to complete germination (PESKE; VILLELA; MENEGHELLO, 2019). This pre-treatment of seeds also promoted higher germination speed in sunflower (*Helianthus annuus* L.) under different salinity levels (MATIAS *et al*., 2018). Exogenous application of gibberellic acid in seeds can recover the levels of gibberellin, whose biosynthesis is inhibited by salinity (SHU *et al*., 2017). In this context, the application of 0.2 g L^{-1} of gibberellic acid in corn (*Zea mays* L.) seeds subjected to salinity promoted higher germination speed (TSEGAY; ANDARGIE, 2018).

Shoot length was reduced by 35% in *H. costaricensis* seedlings and by 38% in *H. undatus* seedlings grown from seeds without pre-germination treatment and subjected to salt stress with osmotic potential of -0.4 MPa (Table 3). Reduction of growth is an expected physiological behavior in response to the effect of negative osmotic potential that is established around the roots, causing a significant decrease in shoot growth (ZELM; ZHANG; TESTERINK, 2020). *H. undatus* seedlings showed increments of 38%, 75% and 100% in shoot length when subjected to hydropriming, gibberellic acid and salicylic acid, respectively, compared to those under salt stress (T2). In *H. costaricensis*, there was an increase of 55% in the shoot length of the seedlings grown from the seeds pretreated with gibberellic acid. Application of gibberellin usually promotes stem elongation and cell division in several plant species (TAIZ *et al*., 2017).

The root length of *H. undatus* seedlings was not influenced by salt stress (Table 3). On the other hand, *H. costaricensis* seedlings had an increase in their primary root length under salt stress, except for those grown from seeds treated with gibberellic acid, which had greater investment in shoots than in roots. With the decrease in osmotic potential there was also a greater increase in primary root protrusion and lower shoot production in chia (*Salvia hispanica* L.) seedlings (PAIVA *et al*., 2019). Also according to these authors, the results obtained can be attributed to the tolerance mechanism of the species, increasing radicle growth in search of water in the substrate. The investment in root found in *H. costaricensis* may also be related to its tolerance to salt stress, which can be noted by germination results that did not decrease under the effect of this stress (Table 3).

The total dry mass of seedlings showed single effect of the pre-germination treatments, and hydropriming promoted biomass accumulation similar to that found in the control (T1). Thus, it can be noted that previous immersion of seeds in water seems to have provided protection against salt stress (Table 3).

The sugar contents of *H. undatus* and *H. costaricensis* seedlings decreased when they were subjected to salt stress, except for those grown from seeds pretreated with gibberellic and salicylic acids, respectively (Table 4). This behavior differs from what is commonly observed in several species, such as common bean (*Phaseolus vulgaris* L.) (ADDA *et al*., 2014), pea (*Pisum sativum* L.) (GHEZAL *et al*., 2016) and chia (*Salvia hispanica*) (PAIVA *et al*., 2018), which showed an increase in sugar synthesis when subjected to salt stress. The results detected by these authors can be explained by the fact that sugars in these species play a more important role in osmoregulation, which was not verified for the pitaya species. However, the gibberellic acid in *H. undatus* and the salicylic acid in *H. costaricensis* seem to have stimulated this osmoregulation, as they maintained results similar to those found in the control treatment (T1).

Thiamethoxam caused a drastic reduction in sugar levels in *H. costaricensis* seedlings. This result may be related to the reductions in germination and germination speed index as already verified, because the dose used (1 mL kg^{-1} of seeds) caused ionic toxicity associated with salinity and, therefore, led to phytotoxic effect on pitaya seeds, especially those of *H. costaricensis*. This result has already been observed by Almeida *et al*. (2014) in rice seeds, in which the treatment with higher doses led to reduction in germination, probably caused by phytotoxic effect of the product.

The total free amino acid contents increased with the increase in salinity for both species. Although pitaya seeds have significant reserve of carbohydrates (352 g kg^{-1} of seeds) (VILLALOBOS-GUTIÉRREZ *et al*., 2012), these are most likely used for the mobilization of reserves during

Table 3 - Shoot length (SL), primary root length (RL) and total dry mass (TDM) of pitaya (*Hylocereus costaricensis* and *H. undatus*) seedlings grown from seeds pretreated and subjected to salt stress

Treatments	SL (cm)		RL (cm)		TDM (mg)
	H. undatus	*H. costaricensis*	*H. undatus*	*H. costaricensis*	
T1	1.3 Bbc	1.7 Aa	0.5 Ba	0.7 Ac	1.6 a
T2	0.8 Be	1.1 Ab	0.6 Ba	1.0 Aab	1.2 b
T3	1.1 Bcd	1.3 Ab	0.6 Ba	1.1 Aa	1.4 ab
T4	1.4 Bab	1.7 Aa	0.6 Aa	0.7 Ac	1.2 b
T5	1.6 Aa	1.1 Bb	0.6 Ba	1.0 Aab	1.2 b
T6	1.0 Ade	1.0 Ab	0.4 Ba	0.9 Abc	1.1 b

[1] Means followed by the same letter, uppercase in the row (species) and lowercase in the column (pre-germination treatments), do not differ statistically from each other by Tukey test at 5% probability level. Control - no stress (T1); salt stress: -0.4 MPa (T2); hydropriming + salt stress (T3); gibberellic acid + salt stress (T4.); salicylic acid + salt stress (T5); thiamethoxam + salt stress (T6)

Table 4 - Total soluble sugars (TSS) and total free amino acids (TFAA) in pitaya (*Hylocereus costaricensis* and *H. undatus*) seedlings grown from seeds pretreated and subjected to salt stress

Treatments	TSS (μmol GLU.g^{-1} FM)		TFAA (μmol GLY.g^{-1} FM)	
	H. undatus	*H. costaricensis*	*H. undatus*	*H. costaricensis*
T1	12.1 Ba	13.4 Aa	21.7 Ac	16.9 Bd
T2	9.3 Ab	9.0 Ab	39.8 Aa	33.4 Bab
T3	6.4 Bc	8.2 Ab	34.0 Ab	23.4 Bc
T4	11.42 Aa	9.1 Bb	36.8 Aab	36.5 Aa
T5	7.5 Bc	13.5 Aa	35.4 Aab	30.5 Bb
T6	9.7 Ab	6.5 Bc	35.8 Aab	21.9 Bcd

[1] Means followed by the same letter, uppercase in the row (species) and lowercase in the column (pre-germination treatments), do not differ statistically from each other by Tukey test at 5% probability level. Control (T1); salt stress: -0.4 MPa (T2); hydropriming + salt stress (T3); gibberellic acid + salt stress (T4.); salicylic acid + salt stress (T5); thiamethoxam + salt stress (T6)

germination, which explains the low levels of total soluble sugars in the seedlings, whose seeds were subjected to stress. However, for osmoregulation there was greater use of protein reserves, which were hydrolyzed into amino acids. This fact may have favored pitaya seeds because they contain a significant amount of protein when compared to other species. While seeds of *Opuntia* sp., which belongs to the same family as pitayas, have 50 g of protein per kilogram of seeds (ENNOURI *et al*., 2005), pitaya seeds contain around 206 g of protein per kilogram of seeds (VILLALOBOS-GUTIÉRREZ *et al*., 2012). Among the pre-germination treatments tested, gibberellic acid was the one that stood out with respect to the increase of free amino acids, with a result similar to that found in seeds under -0.4 MPa stress (T2) for both species.

According to the results obtained in this experiment, salicylic acid promoted better germination performance of *H. undatus* seeds and greater shoot growth in the seedlings. In addition, it stimulated the increase in the content of soluble sugars in *H. costaricensis*, which may be associated with its osmoregulatory effect.

Hydropriming favored the germination of *H. undatus* seeds and also resulted in an increase in seedling dry mass. Conversely, thiamethoxam was not efficient for any of the pitaya species. The dose of this product needs to be properly tested because, when associated with salinity, it can cause toxic effect to the seeds. Therefore, the use of thiamethoxam as a mitigator of salt stress in pitaya seeds requires further investigation.

Gibberellic acid promoted benefits for the germination and shoot growth of *H. undatus* and in the formation (growth) of *H. costaricensis* seedlings. This regulator stimulated the increase in soluble sugar content in *H. undatus* seedlings, which did not occur in the other treatments. Due to the sensitivity of this species to salinity, gibberellic acid probably stimulated more starch hydrolysis in sugars. This fact promotes the energy supply of cells both for germination and for the accumulation of solutes, facilitating the entry of water into the cells during germination. According to Taiz *et al*. (2017), this is possible because gibberellins act on the production of the α-amylase enzyme, whose function is to break down reserve starch into smaller sugar molecules.

CONCLUSIONS

1. *Hylocereus costaricensis* is more tolerant to salt stress than *H. undatus*;
2. Salicylic acid promotes attenuating effect on the germination and growth of *H. undatus* seedlings under condition of salt stress, besides increasing the content of soluble sugars in *H. costaricensis* seedlings;
3. Seed hydropriming promotes salt-stress attenuating effect during germination of *H. undatus* and increases seedling dry mass gain;
4. Gibberellic acid stimulates the germination of *H. undatus*, as well as the growth of *H. undatus* and *H. costaricensis* seedlings, under conditions of salt stress.

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