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Germination and development of passion fruit seedlings under saline and water stresses

Abstract – The objective of this work was to evaluate the effects of saline and water stresses on the germination of seeds and of saline stress on the development of seedlings of 'SCS437 Catarina' *Passiflora edulis*. The seeds were germinated on paper moistened with NaCl and PEG 6,000 solutions, at the osmotic potentials of 0.00, -0.25, -0.50, -0.75, -1.00, and -2.00 MPa. The produced seedlings were exposed only to NaCl. The seeds show tolerance to saline stress up to an osmotic potential of -0.75 MPa, while the seedlings present tolerance up to an osmotic potential of -0.50 MPa (10.96 mS cm^{-1}).

Index terms: *Passiflora edulis*, osmotic stress, salt stress, tolerance.

Germinação e desenvolvimento de mudas de maracujazeiro sob estresse salino e hídrico

Resumo – O objetivo deste trabalho foi avaliar os efeitos do estresse salino e hídrico na germinação das sementes, e do estresse salino no desenvolvimento de mudas de *Passiflora edulis* 'SCS437 Catarina'. As sementes foram germinadas em papel umedecido com soluções de NaCl e de PEG 6.000, nos potenciais osmóticos de 0,00, -0,25, -0,50, -0,75, -1,00 e -2,00 MPa. As mudas produzidas foram expostas apenas ao NaCl. As sementes apresentam tolerância ao estresse salino até o potencial osmótico de -0.75 MPa, enquanto as mudas demonstram tolerância até o potencial osmótico de -0.50 MPa (10.96 mS cm^{-1}).

Termos para indexação: *Passiflora edulis,* estresse osmótico, estresse salino, tolerância.

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An important step in the passion fruit production chain is to obtain high quality seedlings with a high productive potential in the field (Petry et al., 2019). However, plants are subject to adverse environmental conditions in the field that can generate physiological responses negatively affecting germination, growth, and development (Taiz & Zeiger, 2017). Among the environmental factors that can cause stress in plants, salinity and water availability stand out.

Salt stress is caused by the excess of salts in the soil, which can be the result of natural processes, or a combination of excessive irrigation with insufficient drainage (Munns & Gilliham, 2015), or the cultivation in areas where the water from surface sources, such as reservoirs and rivers, has a high saline concentration (Cavalcante et al., 2002).

The coast of Santa Catarina and Rio Grande do Sul states presents saline groundwater, which represents a risk for irrigation in the production of seedlings. However, SCS437 Catarina cultivar has shown a high adaptation to the environmental conditions of this region (Petry et al., 2019).

The objective of this work was to evaluate the effects of saline and water stresses on the germination of seeds and of saline stress on the development of seedlings of 'SCS437 Catarina' *Passiflora edulis*.

The study was divided into two experiments. Experiment I was carried out at a seed laboratory in the municipality of Porto Alegre, in the state of Rio Grande do Sul, from June to July 2020. The seed lot was divided into two and tested with polyethylene glycol 6,000 (PEG 6,000) and sodium chloride (NaCl) at six osmotic potentials: 0.00, -0.25, -0.50, -0.75, -1.00, and -2.00 MPa. The experimental design was completely randomized, with four replicates of 25 seeds.

To assess germination, seeds were placed in transparent plastic boxes with paper moistened with NaCl and PEG 6,000 solutions. The boxes were kept in germination chambers at a temperature of 20 to 30°C with a 12-hour light/dark photoperiod. Weekly, the seeds were exposed to the PEG 6,000 and NaCl solutions. The variables measured were the following: germination percentage, average germination time (AGT), and germination speed index (GSI).

Experiment II was carried out in a greenhouse, in the municipality of Eldorado do Sul, in the state of Rio Grande do Sul (30°06'S, 51°39'W), from September 2020 to January 2021, to evaluate the saline stress during the development of seedlings. The experiment was conducted in a randomized complete block design, with four replicates consisting of 16 seedlings, in the same six potentials of Experiment I. For each potential, the electrical conductivity was measured and used as a basis for preparing the irrigation water: 0.00, -0.25, -0.50, -0.75, -1.00, and -2.00 MPa, corresponding to 0.00, 6.12, 10.96, 15.45, 19.00, and 32.2 mS cm^{-1}, respectively.

The saline solution was delivered by an automatic drip irrigation system. During the entire period, the electrical conductivity (EC) of the saline solution irrigated and drained by the substrate was monitored, to avoid the cumulative effect of salt and to ensure that the frequent irrigations carried out with the saline solution promoted the leaching of the excess salt.

At the end of the experiment, after 140 days, the shoot fresh mass (SFM), root system fresh mass (RFM), shoot dry mass (SDM), root system dry mass (RDM), total fresh mass (TFM), total dry mass (TDM), shoot dry matter/root dry matter ratio (SDM/RDMR), evaluation of seedling quality through the Dickson Quality Index (DQI), and plant survival were evaluated.

The data underwent analysis of variance (ANOVA), and means were compared using the Tukey's test (α=0.05) in the R software version 3.6.1 (R Core Team, 2019). Assumptions for normality, homoscedasticity, and independence of residues were checked and met. It was used Shapiro-Wilk's test for normality and graphs of residues for homoscedasticity and independence.

A significant effect of the osmotic agents and the simulated stress was observed for germination (G), germination speed index (GSI), and average germination time (AGT) (Table 1).

The effects of water stress simulated with PEG 6,000 were more severe on germination, showing a reduction as the osmotic potential became more negative, dropping from 44 to 0%. The highest germination rate was observed when there was no stress. On the other hand, saline stress did not appear to be detrimental at less negative potentials, as it increased the seed germination rate when the osmotic potential changed from 0.00 to -0.25 MPa (from 44 to 57%). At this level, the maximum germination occurred; however, there was no difference compared with the control treatment until the osmotic potential of -0.75 MPa.

The positive effect of NaCl on seed germination at potential -0.25 MPa (6.12 mS cm^{-1}) is consistent with Montaña et al. (2014), who found increased germination at 3.00, 6.00, and 9.00 dS m^{-1} compared with the control treatment. The reduced NaCl effects may be due to the species reported tolerance (Munns & Gilliham, 2015). Since the seeds did not germinate at the -2.00 MPa potential for both osmotic agents, the GSI and AGT were estimated up to -1.00 MPa potential. As indicated in Table 1, NaCl exhibited higher GSI under saline stress conditions at an osmotic potential of -0.25 MPa (0.73). When comparing NaCl and PEG 6,000, NaCl resulted in a higher GSI, indicating a greater susceptibility of seeds to water stress. PEG 6,000 had its highest GSI (0.57) when there was no water stress. For AGT, there was no difference between the treatments, with a range from 20 to 22 days. A different result was observed by Montaña et al. (2014),

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who identified an increase in AGT in response to water and saline stresses.

In the evaluation of saline stress in seedling development, there was a significant difference ($p<0.01$) between NaCl levels for the variable survival, and ($p<0.05$) for fresh and dry root and shoot mass and shoot dry matter/root dry matter (Table 2).

The survival of the plants decreased over the evaluation period, with higher mortality at more negative potentials. At the end of the experiment, the -0.25 and -0.50 MPa potentials (6.12 and 10.96 mS cm^{-1}) showed 96.9 and 85.9% of surviving plants, respectively, not differing from the control treatment, whereas the -0.75 MPa potential had less than 8% of live plants. The seedlings of the -1.00 and -2.00 MPa potential treatments died before the end of the experiment, at 75 and 45 days, respectively.

The variables fresh mass of the root system (RFM) and dry mass of the root system (RDM) decreased as the potential became more negative (Table 2), thus the highest RFM and RDM (6.51 and 1.17 g, respectively) were obtained in the control group. However, for the fresh mass of the aerial parts (SFM) and dry mass of the aerial parts (SDM), the inverse behavior was observed, with greater mass accumulation in the osmotic potential -0.25 MPa, followed by -0.50 MPa. For the shoot dry matter/root dry matter ratio (SDM/RDMR), there was a similar behavior to SFM and SDM, with higher values in the presence of NaCl.

Table 1. Mean values of germination, germination speed index, and average germination time of *Passiflora edulis* submitted to water (PEG 6,000) and salt (NaCl) stresses, at six osmotic potentials: 0.00, -0.25, -0.50, -0.75, -1.00, and -2.00 MPa, in the municipality of Porto Alegre, in the state of Rio Grande do Sul, Brazil, 2020[(1)].

Osmotic agent	Osmotic potentials (MPA)					
	0.00	-0.25	-0.50	-0.75	-1.00	-2.00
			Germination (%)			
NaCl	44.00 ^{ns} a	57.33 Aa	53.33 Aa	41.33 Aa	12.00 ^{ns} b	0.00 ^{ns} b
PEG 6,000	44.00 a	17.33 Bbc	26.66 Bab	13.33 Bbc	10.66bc	0.00 c
CV (%)			26.10			
			Germination speed index			
NaCl	0.57 ^{ns} ab	0.73 Aa	0.59 Aab	0.44 Ab	0.11 ^{ns} c	-
PEG 6,000	0.57 a	0.19 Bbc	0.31 Bb	0.14 Bbc	0.10 c	-
CV (%)			25.23			
			Average germination time (days)			
NaCl/PEG	20.04 A^{ns}	20.95 A	22.62 A	20.20 A	22.37 A	-
CV (%)			34.76			

[(1)]Means with distinct lowercase letters (osmotic potentials) and uppercase letters (osmotic agents) differ from each other by Tukey's test, at 5% probability.

Table 2. Mean values of survival (S), root fresh mass (RFM), root dry mass (RDM), shoot fresh mass (SFM), shoot dry mass (SDM), total fresh mass (TFM), total dry matter mass (TDM), ratio of shoot dry matter and root dry matter (SDM/RDM), and Dickson quality index (DQI), in the osmotic potentials: 0.00, -0.25, -0.50, -0.75, -1.00, and -2.00 MPa, in the production of 'SCS437 Catarina' *Passiflora edulis* seedlings, in the municipality of Eldorado do Sul, in the state of Rio Grande do Sul, Brazil, 2020[(1)].

Osmotic potential (MPA)	S (%)	RFM (g)	RDM (g)	SFM (g)	SDM (g)	SDM/RDM	TFM (g)	TDM (g)	IQD
0.00	100.00 a	6.51 a	1.17 a	2.87 b	0.69 b	0.60 b	9.38^{ns}	1.87^{ns}	0.42^{ns}
-0.25	96.87 a	4.05 b	0.84 ab	5.16 a	1.13 a	1.34 a	9.21	1.97	0.37
-0.50	85.94 a	3.46 b	0.78 b	4.85 a	0.98 ab	1.24 a	8.32	1.76	0.37
-0.75	7.81 b	-	-	-	-	-	-	-	-
-1.00	0.00 b	-	-	-	-	-	-	-	-
-2.00	0.00 b	-	-	-	-	-	-	-	-
CV (%)	12.90	19.01	18.37	16.50	18.62	13.52	15.19	16.52	7.06

[(1)]Means represented by distinct letters differ statistically from each other within each evaluated variable by Tukey's test, at 5% probability.

Similar results for the reduction of RDM with increasing salinity (0.2 to 8.0 dS m^{-1}) were found by Cavalcante et al. (2002), Bezerra et al. (2016), Nascimento et al. (2017), Andrade et al. (2018). However, increased SFM and SDM in saline environments were not observed by other authors. Andrade et al. (2018) identified that the accumulation of dry mass in aerial parts varies according to the cultivar. They observed that 'BRS GA1' maintained a consistent mass, while 'BRS RC' exhibited a linear decrease of 60% with increasing salinity levels (0.2 to 6.2 dS m^{-1}).

The increase in salinity results in reduced root system mass, hindering plant growth due to the extensive absorption of salts by the roots in saline environments. This phenomenon was explained by Li et al. (2017), who emphasized the critical role of roots as the first line of defense against high salinity. The difference in biomass accumulation between the aboveground part and the root system was elucidated by Taiz & Zeiger (2017), who highlighted that the effects of high salinity on plants occur in two phases: firstly, a rapid response due to the high osmotic pressure at the root-soil interface; secondly, a slower response caused by the accumulation of sodium (Na^+) and chloride (Cl^-) in the leaves.

Regarding total fresh mass (TFM) and total dry mass (TDM), there was no significant difference among the treatments. Similarly, the Dickson Quality Index (DQI) showed no significant difference, with values of 0.42, 0.37, and 0.37 for osmotic potentials of 0.00, -0.25, and -0.50 MPa, respectively.

This study shows that 'SCS437 Catarina' passion fruit seeds can tolerate osmotic potentials of up to -0.75 MPa, indicating that they can germinate and grow in environments with significant salinity levels. However, salt tolerance decreases slightly as the plants develop. Seedlings of this cultivar can survive under saline stress conditions with osmotic potentials of up to -0.50 MPa, or 10.96 mS cm^{-1}, which is considered a cultivar that is tolerant to salt stress according to Ayers & Westcot (1999). However, for the cultivar to produce high-quality seedlings, the ideal osmotic potential is -0.25 MPa.

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