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Scientific Article

SEED OSMOPRIMING WITH SALICYLIC ACID ON INDUCTION OF TOLERANCE OF *Cenostigma pyramidale* TO WATER DEFICIT

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ABSTRACT

Cenostigma pyramidale is an endemic species of Brazil, widely spread in the Caatinga biome. The conditions in the semi-arid Northeastern region of Brazil can affect the development of plants due to the irregularity of rainfall, limiting the availability of water and reducing the germination and initial growth of native species. Therefore, seed priming with salicylic acid may mitigate the effects of water stress on plants. The objective of this work was to evaluate the effect of seed osmopriming with salicylic acid as a water deficit attenuator on germination and initial growth of *C. pyramidale* seedlings. A completely randomized design in a 5 × 5 factorial scheme, corresponding to five osmotic potentials (Ψs – 0, -0.3, -0.6, -0.9 and -1.2 MPa) and five doses of salicylic acid (0, 0.5, 1.0, 1.5 and 2.0 mM), with four repetitions of 25 seeds, was used. Germination and initial growth of *C. pyramidale* were compromised by water deficit. Osmopriming of seeds with salicylic acid at a dose of 0.63 mM is an efficient strategy to reduce the effect of water deficit in the germination stage from the potential of -0.2 MPa. The vigor of *C. pyramidale* seeds increased under deficit conditions with the application of salicylic acid, with the concentration varying from 0.5 to 1.0 mM. Osmopriming seeds with 0.87 mM salicylic acid promotes the development of vigorous seedlings under water deficit conditions.

Keywords: catingueira, abiotic stress, phytohormone.

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OSMOCONDICIONAMENTO DE SEMENTES COM ÁCIDO SALICÍLICO NA INDUÇÃO DE TOLERÂNCIA DE *Cenostigma pyramidale* AO DÉFICIT HÍDRICO

RESUMO – A *Cenostigma pyramidale* é uma espécie endêmica do Brasil, com ampla ocorrência na Caatinga. As condições do Semiárido nordestino podem afetar o desenvolvimento vegetal devido a irregularidade das chuvas, limitando a disponibilidade hídrica, podendo reduzir a germinação e o crescimento inicial das espécies. Dessa forma, o uso de estratégias como o condicionamento de sementes com ácido salicílico pode ser uma estratégia para atenuar o efeito do déficit hídrico nas plantas. O trabalho teve como objetivo avaliar o osmocondicionamento de sementes de *C. pyramidale* com ácido salicílico como atenuante do déficit hídrico na germinação e crescimento inicial de plântulas. O experimento foi realizado com delineamento inteiramente casualizado, em arranjo fatorial 5 × 5, sendo cinco potenciais osmóticos – ψo (0; -0,3; -0.6; -0,9 e -1.2 MPa) e cinco concentrações de ácido salicílico (0; 0,5; 1,0; 1,5 e 2.0 mM), com quatro repetições de 25 sementes. A germinação e o crescimento inicial de *C. pyramidale* foi comprometido pelo estresse hídrico. O osmocondicionamento das sementes com ácido salicílico na dose de 0,63 mM é uma estratégia eficiente para reduzir o efeito do déficit hídrico na fase de germinação a partir de potenciais de -0,2 MPa. O vigor das sementes de *C. pyramidale*, sob condições de déficit aumentou com à aplicação de ácido salicílico, com a concentração variando de 0,5 até 1,0 mM. O osmocondicionamento das sementes com a concentração de 0,87 mM favoreceu a obtenção de plântulas vigorosas, sob condições de déficit hídrico.

Palavras-Chave: Catingueira; Estresse hídrico; Fitohormônio.

1. INTRODUCTION

Cenostigma pyramidale (Tul.) Gagnon & G.P. Lewis, commonly known as “Catingueira”, belongs to the Fabaceae family and is endemic to Brazil, is widely found in the Caatinga biome and has several uses, especially the forage and timber potential (Ferreira et al., 2022). It is a species adapted to the conditions of the semi-arid Northeast of Brazil, a region characterized by high temperatures and irregular rainfall, which can compromise the germination and initial establishment of this species, since they are the most sensitive stages to stress conditions (Nóbrega et al., 2022).

Water deficit is a limiting factor for seed germination, since it causes biochemical and metabolic alterations, restricting the hydration capacity of the seed’s internal tissues, as well as respiratory activity and the degradation and mobilization of reserves for the development of the embryonic axis (Leal et al., 2020; Nóbrega et al., 2021a). Moreover, water deficit can induce the production of reactive oxygen species (ROS), leading to oxidative stress to seed tissues (Khan et al., 2019).

Thus, it is necessary to adopt strategies that reduce the effect of water stress, and the priming of seeds with phytohormones is a viable alternative. Among those used, salicylic acid stands out, which acts in several physiological processes, such as in seed germination, from signaling and activation of genes involved in the synthesis of osmoprotective compounds and ion homeostasis, increasing tolerance to stress conditions (Silva et al., 2018; Costa et al., 2021). This behavior has been reported in several species such as *Limonium bicolor* (Liu et al., 2019), *Mesosphaerum suaveolens* (Nóbrega et al., 2020) and *Salvia hispanica* (Costa et al., 2022).

Seed osmopriming is a technique used for seed improvement, which can promote faster and more uniform germination, improving the enzymatic and biochemical activities involved in germination metabolism, being considered an excellent tool for the physiology and management of plants under stress conditions, including hormonal priming (Debta et al., 2023). The beneficial effect of osmopriming on the germination and vigor of seeds of forest species has been reported by some authors, such as in *Peltophorum dubium* (Missio et al., 2018), in *Albizia saman*, *Cedrela odorata*, *Enterolobium cyclocarpum* and *Swietenia macrophylla* (Vilarreal et al., 2020), and in *Poincianella pyramidalis* (Antunes et al., 2021).

The behavior of *C. pyramidale* under water deficit and the effect of seed osmopriming with salicylic acid as a mitigant to the deleterious effects of water deficit on germination and initial growth are incipient in the literature. In this context, the hypothesis is that salicylic acid can mitigate the harmful effects of water stress in this species. The objective of this work was to evaluate seed osmopriming with salicylic acid as a water stress attenuator on germination and initial growth of *C. pyramidale*.

2. MATERIAL AND METHODS

2.1 Experiment location and experimental design

The experiment was performed in the Seed Analysis Laboratory (SAL) of the Center for Agrarian Sciences of the Universidade Federal da Paraíba, Areia, Paraíba, Brazil. The study was conducted during November 2021.

A completely randomized design in a 5 × 5 factorial scheme, corresponding to five osmotic potentials (Ψs – 0, -0.3, -0.6, -0.9 and -1.2 MPa) and five doses of salicylic acid (0, 0.5, 1.0, 1.5 and 2.0 mM), with four repetitions of 25 seeds, was used. Osmotic potentials were obtained from the dilution of polyethylene glycol 6000 (PEG 6000) in distilled water (Vilela et al., 1991).

2.2 Plant material and treatments

The seeds used were obtained from 10 healthy plants free from pest and disease attack, located in the Novo Horizonte I settlement, Várzea, PB (6º 46’ 8” S and 36º 59’ 2” W, altitude 293 m). The climate is type Bsh’ semi-arid hot, dry and rains in summer (Alvares et al., 2013). The seeds were harvested fully ripe, removed from the fruits and put to dry on sheets of newspaper in the shade at room temperature. Afterwards, they were stored in a bottle and sent to SAL for the experiment.

The salicylic acid concentrations were obtained by dilution in 200 mL of distilled water in plastic containers covered with aluminum foil. Then, the seeds were placed to soak for 8 hours at room temperature (25 ºC) and humidity. After the soaking period, the seeds were washed with distilled water to remove the excess salicylic acid.

For the germination test, the seeds were placed on germitest paper, moistened with osmotic solutions in a volume corresponding to 2.5 times the weight of dry paper, shaped into rolls and placed in a BOD (Biochemical Oxygen Demand) germination chamber. The BOD was regulated at a constant temperature of 30 ºC and photoperiod of 8 hours, and the evaluation was performed on the 14th day after sowing (Brasil, 2013).

2.3 Variables analyzed

The first germination count was performed together with the germination test, evaluating the number of germinated seeds on the 7th day (Brasil, 2013). The germination speed index was established from daily counts of the number of germinated seeds and calculated according to the methodology described by Maguire (1962).

The average germination time was determined by daily counting of germinated seeds, with results obtained according to the formula proposed by Labouriau (1983). The average germination speed was obtained in the same way and calculated following the methodology proposed by Labouriau and Valadares (1976).

Root, shoot, and seedling lengths were evaluated at 14 days after sowing. The analysis was performed through images, with the seedlings arranged on a flat surface with a blue background, next to a ruler graduated in cm, with the image captured using a camera with 300 dpi resolution and in jpeg format. Subsequently, the images were processed using ImageJ® software, and adjustments were made to the contour of the seedlings, making it possible to obtain the length of the parts (root, shoot and seedling), with the results expressed in cm (Silva et al., 2020).

2.4 Statistical analysis

The data obtained were subjected to the tests of normality (Shapiro-Wilk) and homogeneity of variances (Bartlett). Subsequently, analysis of variance was applied at 5% probability level using the F test ($p \leq 0.05$), and regression analysis was performed in significant cases. Principal component analysis (PCA) and cluster analysis were also applied to evaluate the interrelationships between the variables and the treatments tested. The statistical program R (R Core Team, 2022) was used to perform the analyses.

3. RESULTS

The interaction between osmotic potentials

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and salicylic acid (SA) concentrations influenced the germination (G%), first germination count (FGC), germination speed index (GSI), average germination time (AGT) and average germination speed (AGS) of C. pyramidale seeds (Table 1).

Osmopriming the seeds with salicylic acid increased the germination of *C. pyramidale* seeds, with the highest percentage (76.2%) occurring at the 0.63 mM SA concentration at an osmotic potential of -0.2 MPa (Figure 1A). The reduction in osmotic potential promotes decreases in germination, and the lowest percentage of germinated seeds (53.7%) occurred at a potential of -1.2 MPa and at a dose of 2.0 mM of SA, representing a reduction of 22.5% compared to the maximum values obtained.

Table 1 - Summary of analysis of variance for germination (G%), first germination count (FGC), germination speed index (GSI), average germination time (AGT) and average germination speed (AGS) of *Cenostigma pyramidale* seeds subjected to different osmotic potentials and salicylic acid concentrations.

Tabela 1 - Resumo da análise de variância referente a geminação (G%), primeira contagem (PCG), índice de velocidade (IVG), tempo médio (TMG) e velocidade média de germinação (VMG) de sementes de *Cenostigma pyramidale*, submetidas a deferentes potenciais osmóticos e concentrações de ácido salicílico.

Sources of variation	DF	Mean squares				
		G%	FGC	GSI	AGT	AGS
Osmotic potentials (Ψs)	4	1222.0**	10412.7**	98.47**	115.64**	0.0166**
Linear regression	1	159.57**	33904.0**	381.04**	409.0**	0.637**
Quadratic regression	1	97.64**	7282.8**	8.88**	46.60**	0.0075**
Salicylic acid (SA)	4	587.26**	1020.0**	4.82**	6.28**	0.010**
Linear regression	1	3640.86**	765.15**	0.33ns	1.13*	0.000001ns
Quadratic regression	1	777.78*	226.83**	5.25**	17.95**	0.031**
Interaction (Ψs × SA)	16	280.91**	324.20**	1.47**	0.97**	0.0016**
Residual	72	19.62	25.07	0.29	0.16	0.00056
CV (%)		6.45	9.69	11.40	7.94	10.28

DF - degree of freedom; CV (%) - coefficient of variation; (*) significant at $p \leq 0.05$; (**) significant at $p \leq 0.01$; (ns) not significant.

The vigor represented by the first germination count indicates that the application of SA increases the quality of the seeds, with the highest value (73.1%) observed under 0.5 mM of SA and at a potential of -0.2 MPa, followed by a decrease of 63.4% in the number of germinated seeds when subjected to an osmotic potential up to -1.2 MPa and at a concentration of 2.0 mM of SA (Figure 1B). The germination speed index (GSI) was higher in seeds subjected to 0 MPa (control treatment) and at a SA concentration of 1.0 mM, with value of 7.42, while the lowest GSI (1.26) occurred at the lowest osmotic potential (-1.2 MPa) and at the maximum concentration (2.0 mM) of SA, with a reduction of 83% (Figure 1C). It indicates that water deficit limits the speed of the germination process, but the application of SA stimulates seed germination more rapidly.

The average germination time (AGT) indicates that the reduction of osmotic potential prolongs the germination process of the seeds, with the highest value (9.47) observed at -1.2 MPa and at 0 SA dose (Figure 1D). On the other hand, it is possible to observe that seed osmopriming stimulates germination, with the lowest AGT of 2.59 at a concentration of 1.0 mM and at 0 MPa, representing an increase of 72.6% compared to plants with the highest AGT.

The average germination speed (AGS) was higher (0.35) in seeds subjected to an osmotic potential of 0 MPa and a concentration of 1.0 mM of SA, decreasing with the reduction of the potential, and the lowest value of AGS was obtained in seeds subjected to -1.2 MPa and a concentration of 2.0 mM of SA, representing a reduction of 76% when comparing the highest and lowest values obtained (Figure 1E). According to the summary of the analysis of variance (Table 2) for seedling growth, the interaction between osmotic potentials and salicylic acid concentrations was significant for root length, shoot length, and seedling length of *C. pyramidale*.

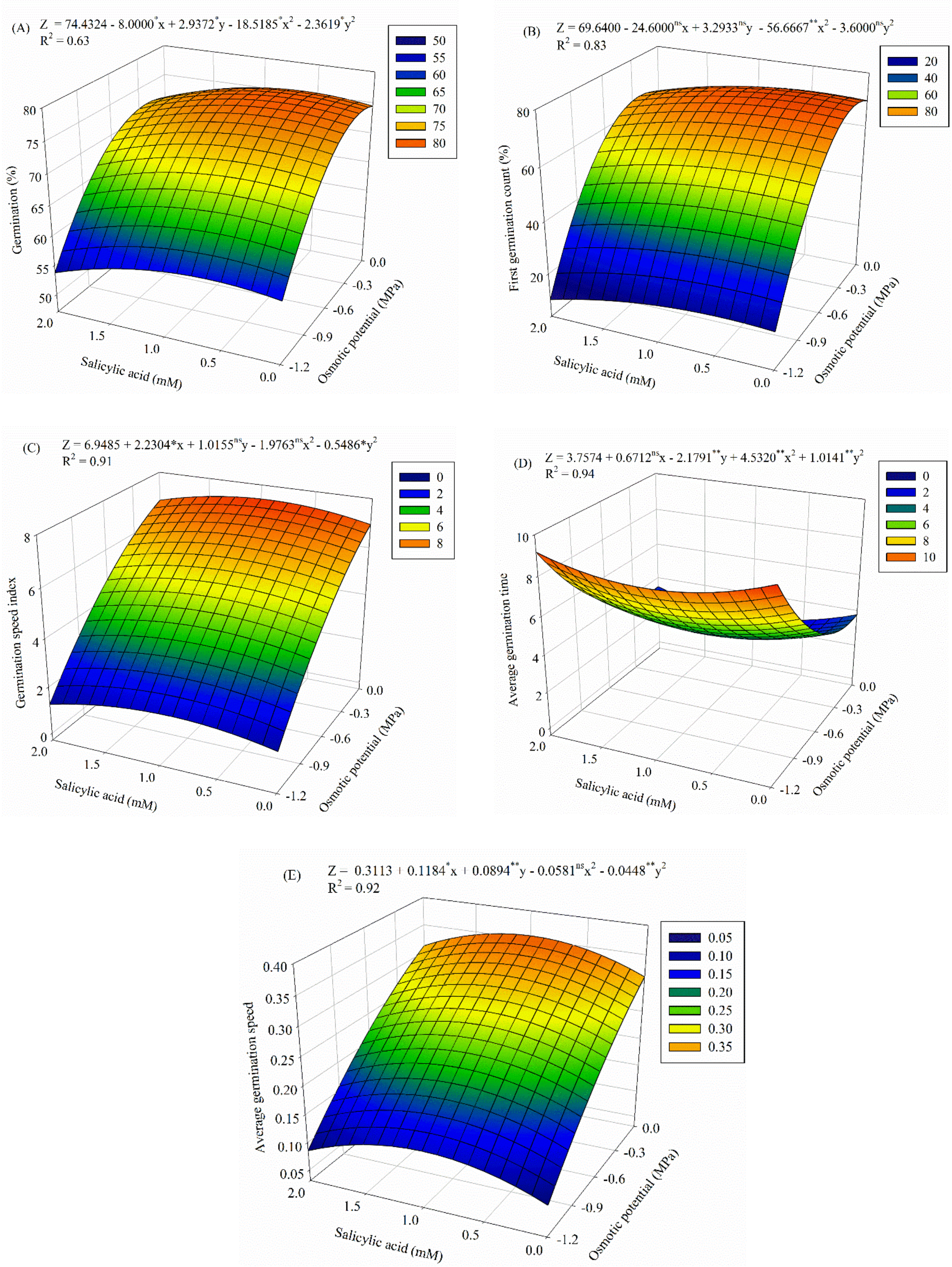

Figure 1 - Germination (A), first germination count (B), germination speed index (C), average germination time (D) and average germination speed (E) of *Cenostigma pyramidale* seeds subjected to different osmotic potentials and salicylic acid concentrations. *, ** - Significant at $p \leq 0.05$ and ≤ 0.01 by F test, respectively.

Figura 1- Germinação (A), primeira contagem (B), índice de velocidade (C), tempo médio (D) e velocidade média de germinação de sementes de *Cenostigma pyramidale* submetidas a diferentes potenciais osmóticos e concentrações de ácido salicílico. X e Y – Potenciais osmóticos – ψo e concentração de ácido salicílico - AS, respectivamente; *, ** - Significativo em $p \leq 0,05$ e $\leq 0,01$ pelo teste F, respectivamente.

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Table 2 - Summary of analysis of variance for root length (RL), shoot length (SL), and seedling length (SdL) of *Cenostigma pyramidale* seeds subjected to different osmotic potentials and salicylic acid concentrations.

Tabela 2 - Resumo da análise de variância referente ao comprimento de raiz (CR), da parte aérea (CPA) e de plântulas (CPL) de *Cenostigma pyramidale*, submetidas a deferentes potenciais osmóticos e concentrações de ácido salicílico.

Sources of variation	DF	Mean squares		
		RL (cm)	SL (cm)	SdL (cm)
Osmotic potentials (Ψs)	4	1385.73**	356.48**	3146.4**
Linear regression	1	5330.3**	1379.7**	12134.4**
Quadratic regression	1	2.52ns	0.72ns	0.55ns
Salicylic acid (SA)	4	44.06**	17.88**	116.46**
Linear regression	1	9.71ns	11.24**	41.96**
Quadratic regression	1	145.06**	45.16**	352.0**
Interaction (Ψs × SA)	16	45.92**	13.97**	108.3**
Residual	72	5.74	0.31	8.02
CV (%)		11.9	7.63	8.92

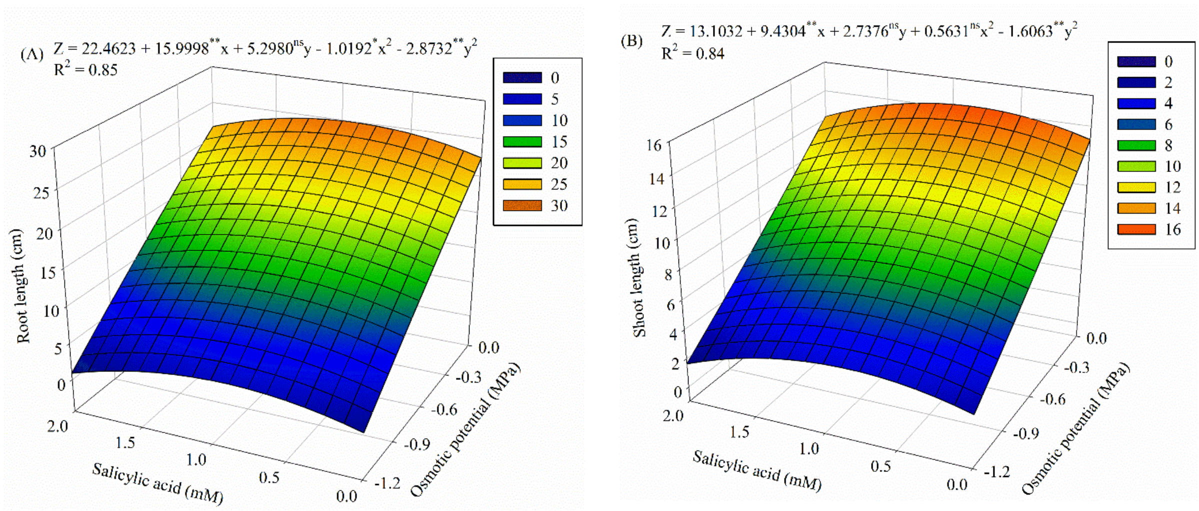
DF - degree of freedom; CV (%) - coefficient of variation; (*) significant at $p \leq 0.05$; (**) significant at $p \leq 0.01$; (ns) not significant.

Root length was superior (24.89 cm) in seedlings subjected to the osmotic potential of 0 MPa and to the concentration of 0.87 mM of SA (Figure 2A). With the reduction of the osmotic potential up to -1.2 MPa and the increase of the concentration of SA up to 1.9 mM, there were decreases of 93.5% in root growth, equivalent to 23.27 cm compared to the highest value obtained.

Shoot length was also superior (14.26 cm) in seedlings subjected to the osmotic potential of 0 MPa and to the concentration of 0.87 mM of SA (Figure 2A). The lowest value was obtained at a potential of -1.2 MPa and the maximum concentration of SA (2.0 mM), causing a reduction of 88.5% compared to the maximum value obtained (12.64 cm), demonstrating that the increase in concentration can increase the effect of water deficit.

Similar to root and shoot lengths, seedling length was greater (39.14 cm) when the seeds were subjected to an osmotic potential of 0 MPa and a concentration of 0.87 mM of SA (Figure 2C). The smallest seedlings (2.55 cm) were obtained when the potential was reduced to -1.2 MPa and with 2.0 mM of SA, indicating a decrease of 93.5% compared to the highest value observed.

The PCA indicates a variability of 94.4% for the first two components (Figure 3). It can be seen that PC1 exposes the greatest variability, 85.2%, with the contributions of the variables of AGS, GSI, RL, SL and SdL with the eigenvector values of 0.3646, 0.3743,



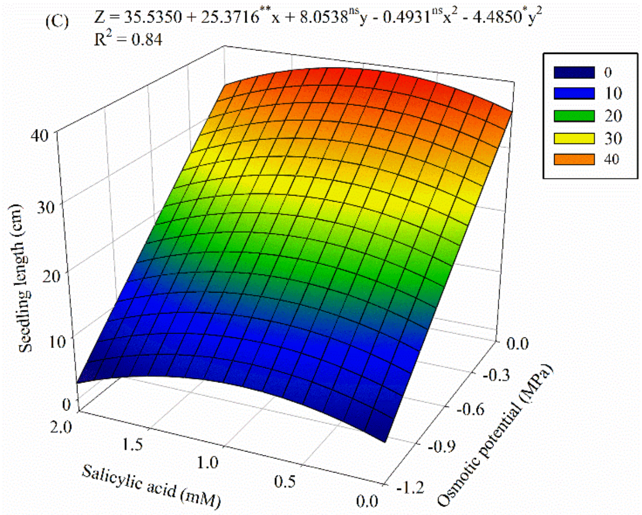


Figure 2 - Root length (A), shoot length (B), and seedling length (C) of *Cenostigma pyramidale* seeds subjected to different osmotic potentials and salicylic acid concentrations. *, ** - Significant at p ≤ 0.05 and ≤ 0.01 by F test, respectively.

Figura 2 - Comprimento de raiz - CR (A), da parte aérea - CPA (B) e de plântulas - CPL (C) de *Cenostigma pyramidale* submetidas a diferentes potenciais osmóticos e concentrações de ácido salicílico. X e Y – Potenciais osmóticos – ψo e concentração de ácido salicílico - AS, respectivamente; *, ** - Significativo em p ≤ 0,05 e ≤ 0,01 pelo teste F, respectivamente.

0.3668, 0.3637 and 0.3664, respectively. The second component (PC2) showed variability of 9.1%, being associated mainly with the contribution of the variables GER and FGC, which have eigenvector values of 0.7962 and 0.3488, respectively. It is noteworthy that, for both components, there was a negative correlation for the AGT variable, with eigenvectors of -0.3653 and -0.059 for PC1 and PC2, respectively.

In the cluster analysis it is possible to observe the formation of six groups. Group 1 is formed by the osmotic potentials 0 and -0.3 MPa associated with concentrations of 0, 0.5, 1.0, 1.5 and 2.0 mM of SA, related

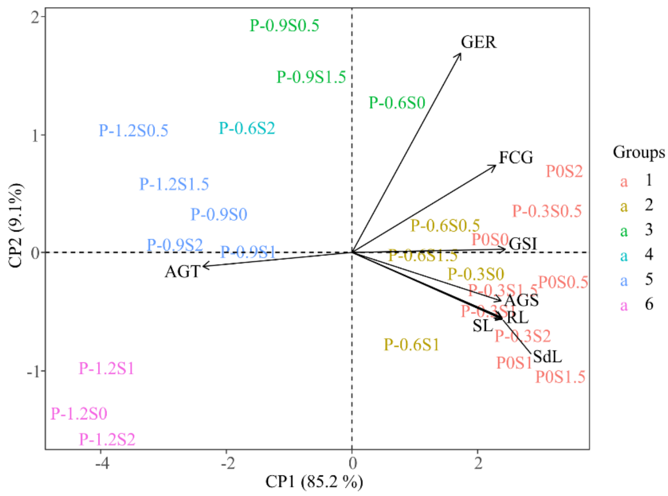


Figure 3 - Principal component analysis for the interrelationships among the variables germination (GER), first germination count (FGC), germination speed index (GSI), average germination time (AGT), average germination speed (AGS), root length (RL), shoot length (SL) and seedling length (SdL) and clustering for the osmotic potentials and salicylic acid doses.

Figura 3 - Análise de componentes principais para as inter-relações entre as variáveis de germinação (GER), primeira contagem (FGC), índice de velocidade (GSI), tempo médio (AGT) e velocidade média de germinação (AGS), comprimento de raiz (RL), da parte aérea (SL) e de plântulas (SdL) e de agrupamento para os potenciais osmóticos e doses de ácido salicílico.

to PC1 and the variables AGS, GSI, RL, SL and SdL (Figure 3). Group 2 is formed by the potential of -0.3 MPa and the 0 concentration of SA and the potential of -0.6 MPa associated with concentrations of 0.5, 1.0 and 1.5 mM of SA, with a strong connection with the variables AGS, FGC and GSI. The third group is represented by the treatments of the -0.6 MPa potential and the 0 mM SA concentration and the -0.9 potential and the 0.5 and 1.5 mM SA concentrations. Groups 4, 5 and 6 are associated with the treatments in which there is interaction between the osmotic potentials of -0.9 and -1.2 MPa with the concentrations of SA tested, correlating with PC2 and the AGT variable.

4. DISCUSSION

The germination of *C. pyramidale* was compromised by the reduction of the osmotic potential of the substrate, indicating that the low availability of water is a limiting factor in the germination process of the seeds. Water deficit affects the biochemical processes involved in germination metabolism, since water is involved in tissue hydration, increased respiratory activity, protein hydrolysis, increased seed volume, and seed coat rupture from root protrusion (Nóbrega et al., 2021a). Thus, the compromise of hydration of seed tissues (Phase I) limits the subsequent biochemical processes, directly affecting germination capacity. In addition, low water availability can trigger excessive production of reactive oxygen species, leading to oxidative stress in seed tissues, causing protein denaturation, lipid peroxidation, and changes in plant cell genes (Khan et al., 2019).

Osmopriming with salicylic acid improves the capacity of the seeds to germinate, increasing tolerance to induced water deficit. Salicylic acid is a compound that acts in the plant defense system, through signaling and activation of genes and modulation of enzymes involved in biochemical and physiological processes, such as in seed germination (Silva et al., 2018; Silva et al., 2024).

Negative effect of water deficit on germination was also observed on the vigor of *C. pyramidale* seeds, with decreases of 63 and 83% in the FGC and GSI values at an osmotic potential of -1.2 MPa, accentuating the effect of water stress on seed quality. Reduced water availability causes changes in germination metabolism, compromising pre-germination metabolic processes, delaying the development of the embryonic axis (Nóbrega et al., 2022).

It is noteworthy that osmopriming with SA improved vigor, promoting a higher number of germinated seeds and higher GSI at the concentrations of 0.5 and 1.0 mM, respectively. The application of hormones such as salicylic acid induces greater tolerance to stress conditions and may accelerate the process of cell division and differentiation of the embryonic axis, assisting in ion homeostasis and membrane integrity (Bahrabadi et al., 2022).

Besides affecting the quality, the water deficit slowed down the germination process, and the longest time and the lowest speed of germination were observed at a potential of -1.2 MPa. This effect may be associated with the high viscosity of polyethylene glycol, hindering the absorption of water by the tissues and the diffusion of O_2, delaying the process of membrane reorganization and, consequently, seed germination (Silva et al., 2023).

However, it is noteworthy that the osmopriming of seeds with salicylic acid increased vigor, promoting greater speed in those subjected to the concentration of 1.0 mM. The soaking of seeds in salicylic acid can induce an increase in the production of osmoprotective compounds, reducing the damage caused by water deficit in internal tissues, enabling faster germination under stress conditions (Nóbrega et al., 2021b).

This beneficial effect on germination and vigor of seeds subjected to stress was also found by Silva et al. (2018), who found that the 1.0 mM concentration of SA increased the quality of seeds of *Ocimum basilicum* produced under saline conditions. Liu et al. (2019) concluded that osmopriming *L. bicolor* seeds with SA at a concentration of 0.08 mM increases germination under stress conditions. Nóbrega et al. (2021b) found that priming with a concentration of 1.71 mM of SA attenuated the harmful effect of water stress on germination of *Cereus jamacaru*. Silva et al. (2024) pointed out that the treatment of *Cucumis melo* seeds with 50 µM of SA mitigated the effect of salt stress on germination and seedling emergence.

As in the germination of seeds, osmopriming with salicylic acid contributed to increasing the vigor of *C. pyramidale* seedlings, promoting greater tolerance to water deficit. This effect is attributed to the fact that SA acts by inducing the production and accumulation of osmoprotective substances and stimulating ionic homeostasis, resulting in more vigorous seedlings, a fact observed by Nóbrega et al. (2020) in *M. suaveolens*, for which the soaking of seeds at concentrations of SA increased tolerance during the initial growth of seedlings.

The germination and initial establishment stages are the most sensitive of the plant to stress conditions, as water restriction can cause losses in quality and even seedling death. Thus, the application of salicylic acid can induce greater resistance to water deficit and promote tissue protection, helping in the processes of cell elongation and division, resulting in more vigorous seedlings (Costa et al., 2022).

This beneficial effect of seed osmopriming with salicylic acid on initial seedling growth was also observed by Costa et al. (2021; 2022) in *S. hispanica*, for which the 1.0 mM concentration of SA stimulated seedling length under salt and water stress. In *C. jamacaru*, the application of 1.0 mM of SA stimulated seedling growth up to -1.2 MPa (Nóbrega et al., 2021b).

The principal components analysis contributes to the understanding of the relationship between the treatments and the variables analyzed, and it is possible to highlight that the application of salicylic acid was effective in reducing the effects of water stress on germination and vigor of seeds and seedlings of *C. pyramidale*. During germination, salicylic acid can induce gibberellic acid biosynthesis, as well as amylase and α-amylase enzyme activity, and reduce the expression of genes involved in abscisic acid synthesis, providing hormonal balance, which enables germination even under low water availability conditions (Liu et al., 2019).

Given the results it is possible to highlight that the osmopriming of *C. pyramidale* seeds with salicylic acid may be a viable strategy to improve germination and obtain vigorous seedlings, with greater tolerance to water deficit conditions, enabling a faster initial establishment of this species.

5. CONCLUSION

Water stress compromises the germination process of seeds and the initial growth of *C. pyramidale*. Seed osmopriming with salicylic acid is an efficient strategy to reduce the effect of water deficit on germination and seedling stages.

Salicylic acid concentration of 0.63 mM increases the germination of *C. pyramidale* seeds, while concentrations of 0.5 to 1.0 mM increase their physiological quality. Application of 0.87 mM salicylic acid allows for vigorous seedlings under water deficit conditions.

AUTHOR CONTRIBUTIONS

J.S.N. - Conceptualization, ivestigation, writing, original draft; L.G.S. and M.E.M.S. - Investigation, writing, original draft; R.L.A.B. - Project administration, supervision, writing, review and editing; G.S.L. - Funding acquisition, validation, supervision, writing, review and editing; L.A.A.S. - Funding acquisition, validation, writing, review and editing; T.I.S. - Resources, investigation, validation; F.E.S. - Methodology, visualization, writing, review and editing.

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