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Articles

Seaweed-based product on the seed quality of *Mimosa verrucosa* Benth.

Produto à base de algas na qualidade de sementes de *Mimosa verrucosa* Benth

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ABSTRACT

This study evaluated the effects of treating *Mimosa verrucosa* Benth. seeds with a seaweed-based product containing laminarin on seed health and physiological quality. The experiment was conducted under laboratory and greenhouse conditions using Vacciplant® at concentrations of 1.7, 3.3, 5.0, and 6.7 $mL \cdot L^{-1}$, along with a control (sterilized distilled water) and the Captan fungicide. The incidence of fungi, germination, emergence, seedling growth, and dry mass were analyzed. Fungal incidence was determined through detection and identification of the pathogens. Physiological quality was assessed through germination and emergence percentages, first count, and germination and emergence speed indices. The treatment reduced *Penicillium* sp., *Fusarium* sp., *Cladosporium* sp., and *Aspergillus* sp. incidence. No significant differences were observed for germination percentage or speed; however, the 3.3 $mL \cdot L^{-1}$ concentration increased root dry mass. The 6.7 $mL \cdot L^{-1}$ dose promoted greater emergence and faster first count, while 3.3 and 5.0 $mL \cdot L^{-1}$ favored root length and dry mass accumulation. The seaweed-based product enhanced early seedling growth, dry mass accumulation, and emergence rate, standing out as a promising alternative for the treatment of *Mimosa verrucosa* Benth. seeds.

Keywords: Biostimulant; Alternative control; White jurema; Seed pathology

RESUMO

Este estudo avaliou os efeitos do tratamento de sementes de *Mimosa verrucosa* Benth com um produto à base de algas contendo laminarina na qualidade sanitária e fisiológica das sementes. O experimento foi conduzido em laboratório e casa de vegetação, utilizando Vacciplant® (1,7; 3,3; 5,0; 6,7 mL.L^{-1}); controle com água destilada esterilizada e fungicida Captana. Foram analisadas a incidência de fungos, germinação, emergência, crescimento e massa seca das plântulas. A incidência deu-se pela detecção e identificação de fungos. Para a qualidade fisiológica analisou-se o percentual; primeira contagem e índice de velocidade de germinação e da emergência. O tratamento reduziu *Penicillium* sp., *Fusarium* sp., *Cladosporium* sp. e *Aspergillus* sp.. Não houve diferenças significativas na porcentagem e velocidade de germinação, mas a concentração de 3,3 mL.L^{-1} aumentou a massa seca da raiz. A dose de 6,7 mL.L^{-1} promoveu maior emergência e velocidade na primeira contagem. Já 3,3 e 5,0 mL.L^{-1} favoreceram o comprimento e acúmulo de massa seca das raízes. O produto à base de algas favoreceu o crescimento inicial das plântulas, o acúmulo de massa seca e acelerou a emergência, destacando-se como uma alternativa promissora para o tratamento de sementes de *Mimosa verrucosa* Benth.

Palavras-chave: Bioestimulante; Controle alternativo; Jurema branca; Patologia de sementes

1 INTRODUCTION

The Caatinga biome contains a diverse flora composed of numerous species across multiple botanical groups, with members of the Fabaceae family being the most abundant, as reported by Dutra Júnior *et al*. (2022). This family comprises approximately 630 genera and around 18,000 species, with the genus *Mimosa* ranking as the fifth largest within Fabaceae, encompassing about 540 species distributed from Central to South America (Monção *et al*., 2019).

The restoration of degraded areas through the reforestation of native species has gained prominence in recente decades, driven by the increasing demand for sustainable practices (Bezerra *et al*., 2025). Species of the genus *Mimosa* are widely used in reforestation and land restoration programs due to their high genetic diversity and adaptability (Silva *et al*., 2021). They are also employed in agroforestry systems, providing forage for livestock and contributing to soil fertility (Xavier *et al*., 2020).

High-quality seeds play a fundamental role in ecological restoration and conservation projects, aiding in biodiversity recovery and the re-establishment of ecological functions in degraded ecosystems. They also ensure proper plant establishment and development, which are critical for the success of ecological interventions (Frischie *et al*., 2020; Quispe-Melgar *et al*., 2024). Assessing seed quality—including sanitary and physiological analyses—is essential for producing vigorous seedlings with high establishment potential (Frischie *et al*., 2020).

Several fungi have been reported to be associated with *Mimosa* seeds, causing significant damage during pre- and post-emergence stages. The main pathogens include *Aspergillus niger*, *Aspergillus flavus*, *Aspergillus glaucus*, and *Rhizopus* sp. (Silva Henrique *et al*., 2021). Infections by *Fusarium* sp. are particularly harmful, reducing germination rates and seed vigor (Pandit; Yadav, 2020). The presence of pathogens in seeds can negatively affect germination and vigor, delaying germinative processes and compromising early plant development—key aspects for successful establishment and growth (Gebeyaw, 2020; Pandit; Yadav, 2020).

The use of chemical fungicides to control plant pathogens may lead to reductions in soil microbial biodiversity, negative effects on non-target organisms, and potential risks to human health (Balla *et al*., 2021), in addition to promoting pathogen resistance (Sá *et al*., 2024). Conversely, biofungicides exhibit greater specificity toward their targets, minimizing collateral damage to other species and supporting ecosystem preservation (Santra; Banerjee, 2020; Cenobio-Galindo *et al.,* 2024).

Alternative control methods, such as the use of seaweed-based products, have gained attention in the market due to the presence of bioactive compounds that enhance plant resistance and inhibit pathogens (Kocira *et al*., 2019). Among these compounds, laminarin—a polysaccharide extracted from brown algae—is widely recognized for its ability to induce plant defense mechanisms, stimulating immune responses through the activation of induced systemic resistance (ISR) and systemic acquired resistance (SAR) pathways, both of which play essential roles in strengthening immunity against pathogens (Jamiołkowska, 2020; Shukla *et al.*, 2021).

Seaweed-based products act as biostimulants, promoting seed germination and improving the physiological status of plants, thereby increasing resistance to environmental and pathogenic stressors and enhancing productivity (Dobrojan *et al*., 2023). The application of laminarin has been associated with the induction of abiotic stress tolerance through modulation of the chloroplast antioxidant system and upregulation of stress-response genes (Wu *et al.,* 2016).

There is limited information regarding the seed health of *Mimosa verrucosa* Benth and its associated pathogens. This knowledge gap underscores the need for further research on management strategies to improve seed quality and ensure proper germination and plant development.

Therefore, the present study aimed to evaluate the effects of treating *M. verrucosa* seeds with a seaweed-based product on their sanitary and physiological quality, contributing to the development of sustainable disease management strategies and enhancing seed vigor.

2 MATERIAL AND METHODS

2.1 Experiment location

The experiment was conducted at the Phytopathology Laboratory (LAFIT) of the Department of Crop Science and Environmental Sciences (DFCA), within the Center for Agricultural Sciences (CCA) of the Federal University of Paraíba (UFPB), Campus II, located in the municipality of Areia, Paraíba, Brazil (6°58’01.1”S, 35°42’48.4”W).

2.2 Seed acquisition

Seeds of *Mimosa verrucosa* used in this study were provided by the Nucleus for Ecology and Environmental Monitoring (NEMA) of the Federal University of Vale do São Francisco (UNIVASF), located in Petrolina, Pernambuco, Brazil. The seeds were collected from selected mother plants in Sertânia, Pernambuco, in 2022. All processing, selection, and storage procedures were carried out by NEMA following the guidelines established in the Rules for Seed Testing of Forest Species (BRASIL, 2013).

2.3 Seed treatment

Seeds were subjected to dormancy breaking by tip removal. Subsequently, surface disinfestation was performed by immersion in a 1% sodium hypochlorite solution for three minutes, followed by double rinsing with sterile distilled water (SDW) (BRASIL, 2013).

The treatments were as follows: (T1) Control (only SDW); (T2) Captan® fungicide (240 g/100 kg of seeds) applied directly onto the seed surface; and four concentrations of the seaweed-based product Vacciplant®: (T3) 1.7 $mL \cdot L^{-1}$, (T4) 3.3 $mL \cdot L^{-1}$, (T5) 5.0 $mL \cdot L^{-1}$, and (T6) 6.7 $mL \cdot L^{-1}$. The seeds were immersed in each treatment solution for five minutes and subsequently used for health, germination, and emergence tests.

2.4 Sanitary quality assessment

The seed health test consisted of 100 seeds, divided into 10 replicates of 10 seeds each, in a completely randomized design with six treatments. Seeds were placed in 9-cm Petri dishes lined with two layers of sterile filter paper moistened with SDW. Plates were incubated for seven days at room temperature (25 ± 2 °C) under a 12-hour photoperiod (BRASIL, 2009). Fungal detection and identification were performed using a stereoscopic optical microscope, and identification was based on morphological characteristics compared with descriptions in the literature (Seifert *et al*., 2011).

2.5 Physiological quality assessment

2.5.1 Germination test

The germination test was carried out using Germitest® paper previously sterilized in a drying oven at 160°C for 1 hour. The paper was moistened with SDW in a ratio of 2.5 times its dry weight. The experimental design was completely randomized, with six treatments. A total of 100 seeds were used, divided into four replicates of 25 seeds per treatment, as described in section 2.3, and placed in a controlled B.O.D.

(*Biochemical Oxygen Demand*) chamber under alternating 12-hour light/dark cycles at 25 ± 2°C (BRASIL, 2013).

The variables evaluated included germination percentage (GE), first count (FC), germination speed index (GSI) and percentages of dead seeds (DS). Seeds were considered germinated when a radicle of at least 1 mm emerged. Evaluations were performed daily from the 7th to the 21st day after sowing (BRASIL, 2009).

The germination speed index (GSI) was determined by daily counts of germinated seeds from the beginning of germination until the seedling count stabilized, according to the equation proposed by Maguire (1962).

Seeds classified as dead were those that, at the end of the test, appeared soft but not germinated, often showing signs of microbial contamination. Hard seeds were defined as those that remained unimbibed and rigid by the end of the test.

2.5.2 Emergence test

The emergence test was conducted in a greenhouse using 100 seeds divided into four replicates of 25 seeds per treatment, as previously described. The experimental design was completely randomized with six treatments. Seeds were sown in plastic tubes filled with a commercial substrate (Mecplant®), irrigated daily, and evaluated for seedling emergence from the 7th to the 21st day after sowing. The evaluated variables were emergence percentage (EM), first count (FC), and emergence speed index (ESI).

The ESI was calculated based on daily counts of emerged seedlings. A seedling was considered emerged when the cotyledons were fully expanded. The index was determined according to the equation proposed by Maguire (1962).

2.5.3 Shoot and root length and dry mass

In both the germination and emergence tests, shoot length (SL) and root length (RL) were measured using a ruler graduated in centimeters. For dry mass determination, shoots and roots were placed in Kraft paper bags and dried in a forced-air circulation oven at 65 °C for 48 hours. After drying, samples were weighed on a semi-analytical balance to determine shoot dry mass (SDM) and root dry mass (RDM).

2.6 Statistical analysis

The data were subjected to analysis of variance (ANOVA), and means were compared using the Scott–Knott test ($p \leq 0.05$). Fungal incidence data were previously transformed using ($\sqrt{x} + 1$), as described by Bartlett (1947). Statistical analyses were performed using R® software (R Core Team, 2024).

3 RESULTS AND DISCUSSION

3.1 Result of the analysis of variance (ANOVA)

The analysis of variance (Table 1) revealed a significant effect of treatments on the incidence of *Aspergillus* sp., *Penicillium* sp., *Fusarium* sp., and *Cladosporium* sp. (EPI). In the germination test, no significant differences were observed for germination percentage (GE), first germination count (FGC), germination speed index (GSI), or root length (RL).

Significant differences were found for dead seeds (DS), shoot length (SL), shoot dry mass (SDM), and root dry mass (RDM). In the emergence test, the treatments significantly affected emergence percentage (EM), first emergence count (FEC), shoot length (SL), root length (RL), shoot dry mass (SDM), and root dry mass (RDM), while no significant differences were observed for the emergence speed index (ESI) (Table 1).

Table 1 – Summary of the analysis of variance for fungal incidence and germination and emergence tests of *M. verrucosa* seeds treated with different concentrations of Vacciplant®.

Sources of variation	DF	Mean squares			
		***Aspergillus* sp.**	***Penicillium* sp.**	***Fusarium* sp.**	***Cladosporium* sp.**
Treatments	5	0.303010**	0.065522**	0.039135*	0.48461**
Residual	54	0.032524	0.017318	0.014629	0.04274
CV (%)		14.91	12.57	11.71	18.97
		GE	FGC	GSI	DS
Treatments	5	66.267 ns	64.000 ns	0.40156 ns	66.267**
Residual	18	42.000	40.889	0.40095	3.889
CV (%)		7.52	7.44	5.93	14.26
		SL-G	RL-G	SDM-G	RDM-G
Treatments	5	0.98134*	1.0081 ns	0.0000747*	0.0000446**
Residual	18	0.30381	1.0412	0.000025	0.0000093
CV (%)		6.63	15.19	11.93	17.00
		EM	FEC	ESI	SL-E
Treatments	5	143.067*	115.867*	0.47117 ns	10.0568**
Residual	18	47.333	37.111	0.24601	1.1558
CV (%)		8.80	7.89	10.26	6.40
		RL-E	SDM-E	RDM-E	
Treatments	5	2.80796*	0.0189830**	0.0043056**	
Residual	18	0.74478	0.0007267	0.0003450	
CV (%)		7.27	9.07	17.98	

Source: Authors (2025)

In where: ns, * and ** – Non-significant and significant at $p \leq 0.05$ and $p \leq 0.01$, respectively, according to the F test; CV – Coefficient of variation; DF – Degrees of freedom. Germination percentage (GE), first germination count (FGC), germination speed index (GSI), dead seeds (DS), emergence (EM), first emergence count (FEC), emergence speed index (ESI), shoot length (SL), root length (RL), shoot dry mass (SDM), and root dry mass (RDM) from the germination and emergence tests.

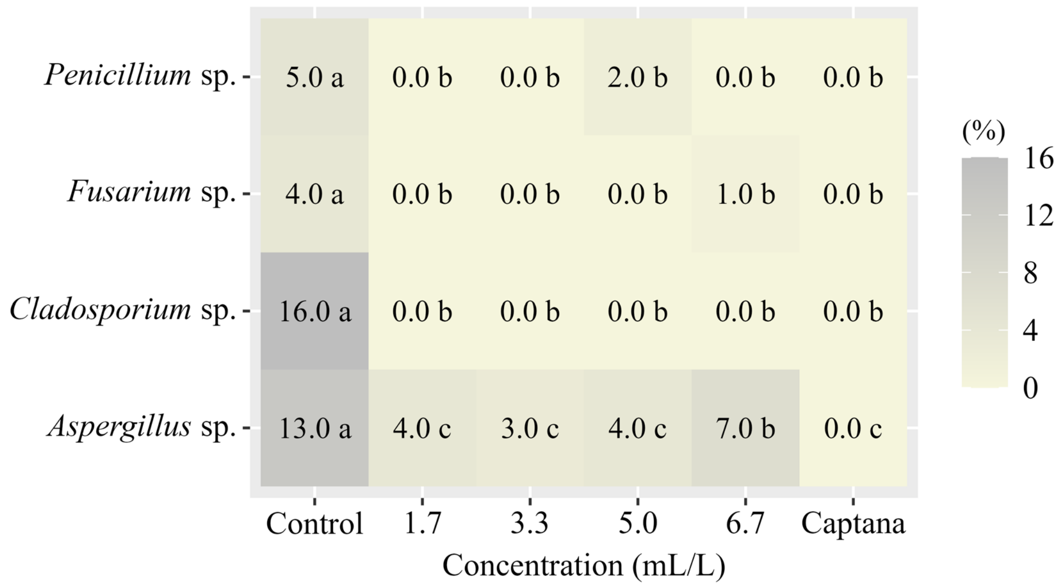
3.2 Seed health quality

The health assessment revealed the presence of four fungal genera associated with *M. verrucosa* seeds: *Penicillium* (5%), *Fusarium* (4%), *Cladosporium* (16%), and *Aspergillus* (13%) (Figure 1).

The incidence of *Penicillium* sp., *Fusarium* sp., and *Cladosporium* sp. was reduced by the seaweed-based treatments, which exhibited antifungal effects compared with the control, with no significant differences relative to the fungicide Captan (Figure 1).

Farias *et al*. (2023), studying the genus *Mimosa*, reported the presence of *Cladosporium* sp. (16.5%), *Aspergillus* sp. (15.5%), *Fusarium* sp. (7.5%), and *Penicillium* sp. (4.0%), among others, and highlighted that different concentrations of *Eucalyptus globulus* essential oil were effective in reducing fungal incidence. It is important to emphasize that even at low incidence levels, the occurrence of *Fusarium* species can cause infections in seeds and seedlings of forest species, compromising their initial development (Silva *et al*., 2025).

Figure 1 – Heatmap of fungal incidence in *M. verrucosa* seeds treated with different concentrations of Vacciplant®



Source: Authors (2025)

In where: Control (sterile distilled water) and Captan fungicide (240 g/100 kg of seeds). Means followed by the same letter in the row do not differ from each other according to the Scott–Knott test ($p \leq 0.05$).

Regarding the incidence of *Aspergillus* sp., all treatments effectively reduced fungal occurrence in the seeds, showing significant differences compared with the control (Figure 1). The concentrations of 1.7, 3.3, and 5.0 mL·L^{-1} demonstrated similar performance to the Captan fungicide, with no statistical difference between them.

Fungi such as *Aspergillus* sp., *Penicillium* sp., and *Cladosporium* sp. are classified as storage fungi and pose a threat to seed quality, potentially causing deterioration, reduced germination, and seedling mortality (Alomran *et al*., 2020). Therefore, reducing these pathogens is essential to minimize viability loss and preserve seed longevity, preventing damage resulting from high infection rates (Moura *et al*., 2018). The presence of fungi, such as those identified in this study, can lead to damage and abnormalities in seedlings, affecting their development and reducing germination potential and seed vigor, ultimately impacting overall productivity (Nóbrega; Nascimento, 2020).

The mechanism underlying the antifungal activity of seaweed-based products, particularly those with higher laminarin concentrations—remains not fully elucidated (Bahmani *et al*., 2023). However, evidence suggests that their action is related to the induction of systemic resistance mediated by peroxidases elicited by polysaccharides, as well as to the direct toxicity of fatty acids against pathogens (Corato *et al*., 2017).

3.3 Seed physiological quality

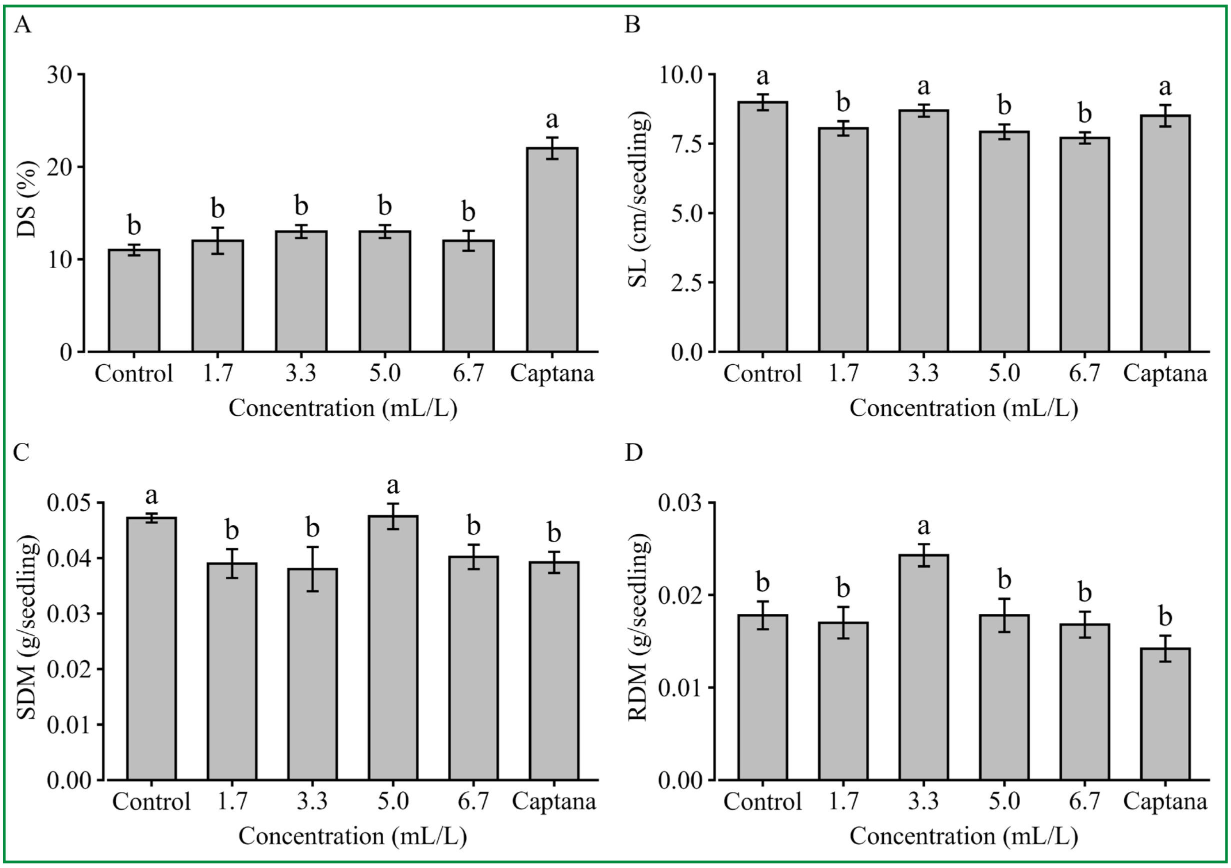
3.3.1 Germination test

In the germination test, regarding the percentage of dead seeds (DS) (Figure 2A), the concentrations of the seaweed-based product and the control showed lower DS rates compared with the fungicide treatment in *M. verrucosa* seeds, the latter showing the highest DS rate, reaching 20%.

The results for shoot length (SL) of *Mimosa verrucosa* Benth. are presented in Figure 2B. No significant effect was observed for the concentration of 3.3 mL·L^{-1} compared with the control and the Captan fungicide. However, these treatments differed significantly from the concentrations of 1.7, 5.0 and 6.7 mL·L^{-1}, indicating variations in shoot development in response to the different treatments.

Seedling performance, based on shoot and root lengths, may be associated with the period of greatest energy consumption, essential for repair and tissue expansion (Zhu *et al*., 2023). Seeds with higher vigor tend to produce more developed seedlings, reflecting the efficiency of repair mechanisms and the mobilization of reserves and synthesis of new tissues during germination (Marcos Filho, 2015).

Figure 2 – A. Dead seeds (DS); B. Shoot length (SL); C. Shoot dry mass (SDM); D. Root dry mass (RDM) in *M. verrucosa* seeds treated with different concentrations of Vacciplant®



Source: Authors (2025)

In where: Control (sterile distilled water) and Captan fungicide (240 g/100 kg of seeds). Means followed by the same letter in the row do not differ from each other according to the Scott–Knott test ($p \leq 0.05$).

Significant differences were observed for shoot dry mass (SDM) (Figure 2C), with the highest values recorded for the 5.0 mL·L^{-1} concentration and the control. In contrast, shoot dry mass accumulation decreased at concentrations of 1.7, 3.3, and

6.7 mL·L^{-1} and in the Captan treatment. This result may be attributed to the ideal conditions of the germination test, which are not always sensitive enough to detect subtle variations in physiological seed quality (Silva *et al*., 2023). Nevertheless, the germination test remains the most direct method for assessing seed viability (Silva Junior *et al*., 2024). Thus, differences in germination performance among treatments may be linked to the fact that the first signs of seed deterioration occur before complete loss of viability (Barbieri *et al*., 2012).

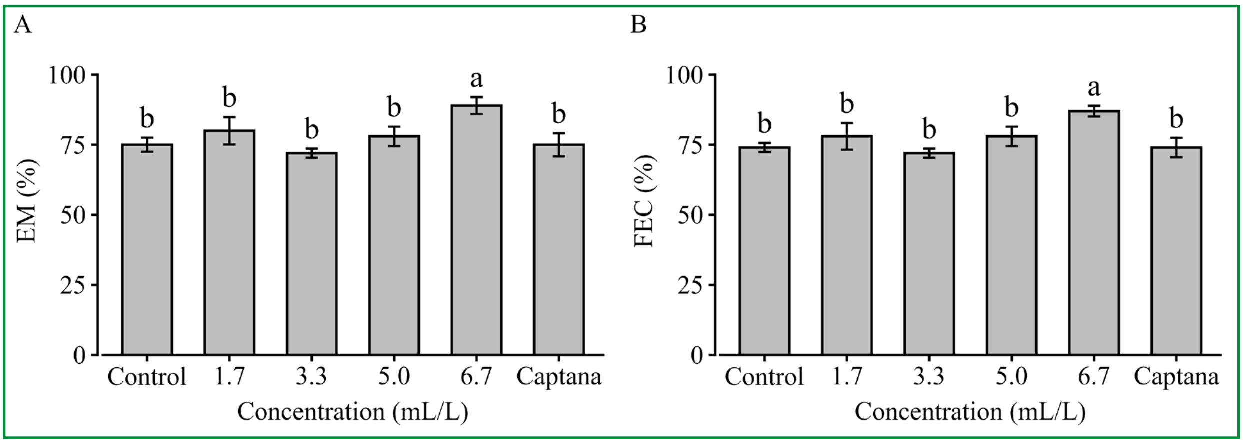
No significant differences were observed for root dry mass (RDM) (Figure 2D) among the concentrations of 1.7, 5.0, and 6.7 mL·L^{-1}, the Captan fungicide, and the control, indicating similar behavior. However, the 3.3 mL·L^{-1} concentration showed the highest root dry mass accumulation, differing from the other treatments. The results for seedling length and dry mass are associated with the beneficial effects of the biostimulant, due to its ability to influence plant hormonal activity, regulating normal plant growth and environmental responses (Silva *et al*., 2008; Dourado *et al*., 2020).

3.3.2 Emergence test

In the emergence test (Figure 3A), the use of the seaweed-based product at a concentration of 6.7 mL·L^{-1} differed from the other treatments, showing the highest emergence rates. This behavior was also observed for the first emergence count (Figure 3B).

It can thus be inferred that the 6.7 mL·L^{-1} concentration used in this study likely influenced the rapid and higher emergence rates observed (above 75%). Studies evaluating the physiological quality of *M. verrucosa*, such as that by Benedito *et al*. (2019), reported similar emergence rates to those found in the present study.

Figure 3 – A. Emergence (EM); B. First emergence count (FEC) in *M. verrucosa* seeds treated with different concentrations of Vacciplant®



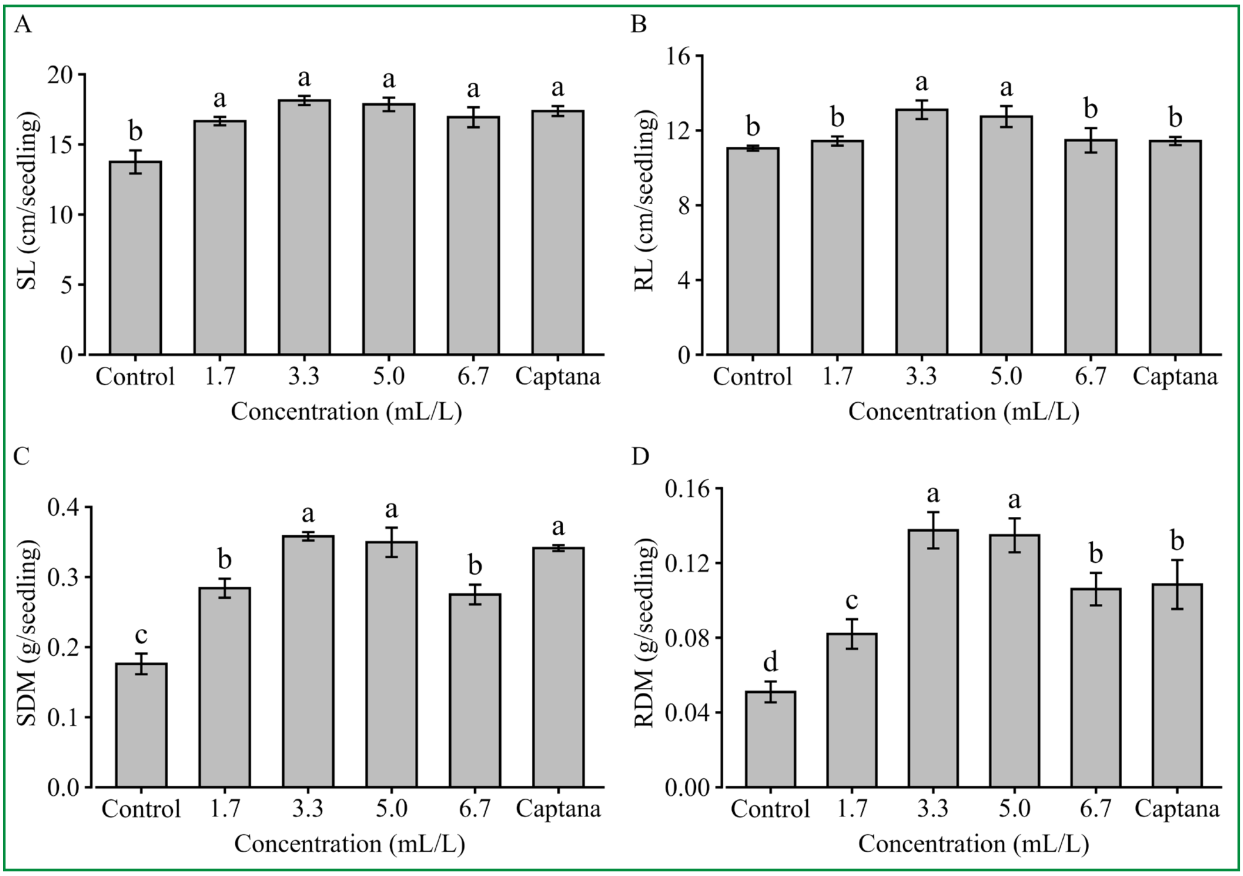
Source: Authors (2025)

In where: Control (sterile distilled water) and Captan fungicide (240 g/100 kg of seeds). Means followed by the same letter in the row do not differ from each other according to the Scott–Knott test ($p \leq 0.05$).

Further research is needed to elucidate the chemical composition of the product and whether there is a direct relationship between its concentration and the emergence performance of *M. verrucosa* seedlings. Borba *et al*. (2022) demonstrated through molecular analyses that the use of Vacciplant® promoted not only the expression of genes associated with plant compounds but also protein synthesis.

Regarding the physiological quality evaluated in the emergence test (Figure 4), differences were observed for all measured variables. For shoot length (Figure 4A), except for the control, all other treatments did not differ significantly. For root growth (Figure 4B), the concentrations of 3.3 and 5.0 mL·L^{-1} did not differ from each other and presented higher means than the other treatments—a trend similar to that observed for root dry mass (Figure 4D). For shoot dry mass (Figure 4C), the concentrations of 3.3 mL·L^{-1}, 5.0 mL·L^{-1}, and the fungicide treatment showed the highest averages, differing from the remaining treatments.

Figure 4 – A. Shoot length (SL); B. Root length (RL); C. Shoot dry mass (SDM); D. Root dry mass (RDM) in *M. verrucosa* seeds treated with different concentrations of Vacciplant®



Source: Authors (2025)

In where: Control (sterile distilled water) and Captan fungicide (240 g/100 kg of seeds). Means followed by the same letter in the row do not differ from each other according to the Scott–Knott test ($p \leq 0.05$).

It is important to note that, beyond the antifungal activity of Vacciplant®, the observed results for shoot growth, along with the higher means for root growth at 3.3 and 5.0 mL·L⁻¹, indicate a stimulatory effect on both shoot and root development in *M. verrucosa* seedlings.

The results obtained for SDM and RDM at 3.3 and 5.0 mL·L⁻¹ are particularly relevant, as higher averages for these variables are essential for successful seedling production. These parameters are directly related to vigorous growth and development, contributing to better field establishment. Such variables reflect the plant's photosynthetic efficiency, growth rate, and assimilate distribution among structural organs (Barbosa *et al*., 2013).

Seaweed-based products are widely recognized for their biostimulant action, as corroborated by the results of this study, where the product promoted plant development and biomass increase. Although most studies have focused on agricultural crops, the available evidence, together with the biochemical profile of these compounds, indicates that similar effects can be expected in forest species.

4 CONCLUSIONS

The concentrations of the seaweed-based product were effective in reducing *Aspergillus* sp., *Penicillium* sp., *Fusarium* sp., and *Cladosporium* sp. incidence;

The seaweed-based product enhanced initial seedling growth and dry mass accumulation in germination and emergence tests, in addition to promoting faster and higher emergence rates, standing out as a promising alternative for seed treatment of *Mimosa verrucosa* Benth.

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