Performance of soybean seeds associated with a biostimulant based on the seaweed *Lithothamnium* sp.

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ABSTRACT. Soybeans are one of the world's main crops, and Brazil leads the production of this oilseed, which has diverse uses. Evidence shows that seed treatment with nutrients and/or association with beneficial microorganisms can aid in germination processes and confer positive aspects to seed vigor. Products like the extract of the algae *Lithothamnium* sp., known for their richness in elements such as Ca and Mg, have been used to enhance the performance of economically important crops. In this context, the objective was to evaluate the performance of soybean seeds subjected to different methods of association with *Lithothamnium* sp. extract. The experiment had four treatments: seeds without association with any biologically active ingredient (control); seeds associated with *Lithothamnium* sp. through the physiological conditioning process; seeds associated with *Lithothamnium* sp. through the coating process; and seeds associated with *Lithothamnium* sp. through the physiological conditioning process followed by the coating process. Physiological conditioning was done with moistened paper and incubation at 25° C for 20 hours. In the coating, 1 g of biostimulant was used for 1000 seeds. Germination, seedling emergence, accelerated aging, and emergence speed index tests were performed. The experimental design adopted was completely randomized. The data obtained were subjected to tests of homogeneity of variances and residual normality. Subsequently, analysis of variance was performed, and the means were compared using the student-Newman-Keuls test at a 5% significance level. Statistical analyses were performed using R software. For all items evaluated in soybean seeds, there was an effect of the seed association treatments with the *Lithothamnium* sp.-based product. Coating soybean seeds with *Lithothamnium* sp. benefited final seedling emergence, emergence speed, and germination under stress conditions. Physiological conditioning followed by coating soybean seeds with *Lithothamnium* sp. impaired germination and seedling emergence.

Key words: physiological conditioning; *Glycine max* L.; physiological quality; beneficial microorganisms; coating.

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INTRODUCTION

Soybeans are one of the world's most important agricultural products, used for various purposes, from human and animal feed to biofuel production. Brazil is the world's largest producer of this oilseed, with a record harvest of 169 million tons in the 2024/2025 cycle. This volume represents about 40% of global production, consolidating the country's leadership in the sector (USDA, 2025).

The increase in the production of this species in Brazil is the result of several factors involved in agricultural cultivation. In this scenario, seeds, which represent the beginning of the harvest, bring to the field

The full genetic potential of a material, occupying a prominent position. To further enhance performance, products are added to the seeds. According to Brzezinski et al. (2015), the use of products associated with seeds, such as fungicides and insecticides, can ensure the initial establishment of the plant population. According to Leão-Araújo and Araújo (2024), the use of biological products in seeds, as control agents or even to benefit plant development, has increased significantly in recent years.

The association of seeds with products called biostimulants aims to enhance seedling vigor, promoting rapid initial development and strengthening the root system (Melo et al., 2021). Biostimulants are substances or organisms that stimulate plant growth, and may include enzymes, proteins, hormones, amino acids, bacteria, fungi, other organisms, micronutrients, and inorganic compounds (Du Jardin, 2015, Chiaiese et al., 2018, Shahrajabian et al., 2021, Wadas & Dziugiel, 2020). The use of these products has been gaining prominence in agriculture, reflected in increased commercialization, especially due to the positive effects on plant development (Joshi et al., 2020, Santoyo et al., 2021).

There are reports of the use of biostimulants in all stages of agricultural production, including seed treatment, foliar sprays during plant growth, and post-harvest applications. These inputs act in the regulation and modulation of physiological processes in plants, and can promote growth, reduce the negative effects caused by biotic and abiotic stresses, and contribute to increased crop yields (Galindo et al., 2020, Moradtalab et al., 2019).

Examples of products of this nature are calcareous algae (*Maerl* and *Lithothamnium*), which are basically composed of calcium carbonate and magnesium carbonate and more than 20 trace elements, present in varying amounts, mainly Fe, Mn, B, Ni, Cu, Zn, Mo, Se and Sr (Dias, 2000). According to Cressard (1974), the use of these algae in agriculture is very old, with records dating back to the 17th century. The genus *Lithothamnium* comprises more than 70 species and precise taxonomic identification remains complex and insufficiently explored (Sissini et al., 2022).

The potential of *Lithothamnium* sp. for agricultural use has been demonstrated in the production of seedlings and in the cultivation of horticultural, fruit, oilseed, grain and forage species (Ramos et al., 2023). Some studies reveal a positive effect of *Lithothamnium* sp. in the initial seedling development of species such as *Jatropha curcas* L. (Evangelista et al., 2016), *Passiflora alata* C. (Souza et al., 2007), *Carica papaya* L. (Teixeira et al., 2009, Hafle et al., 2009) and *Coffea arabica* L. (Rodriguez et al. 2017). Other seaweed-based products from other species such as *Codium decorticatum* have been reported as biostimulants to enhance germination percentage and chlorophyll content (Vijayakumar et al., 2019).

The effects of using *Lithothamnium* sp. in agricultural crops depend, among other factors, on the dose used for each species or even genotype (Kapoore et al., 2021, Ramos et al., 2023), which suggests that the forms of association of the product in the seeds may also reveal varied behaviors.

Physiological seed conditioning is a tool used to initiate the seed hydration process and the initial phases of the germination process (Waqas et al. 2019). This activates respiration, sugar digestion, and protein synthesis (Corbineau et al. 2023). This technique is also called priming and has been used to enhance the physiological quality of seeds (Khalaki et al. 2020). This technique can be performed with water or agents that include salts, antioxidants and bioactive molecules, beneficial microorganisms, phytohormones (hormopriming), and nanoparticles (nanopriming) (Pagano et al. 2023).

Seed coating is another way of supplying plant growth-promoting substances to seeds, which can enhance seed quality. The process consists of covering seeds with small amounts of exogenous materials, such as various species of plant growth-promoting bacteria, rhizobia, and *Trichoderma*.

MATERIALS AND METHODS

The experiment was conducted in the Seed Laboratory of the Federal Institute of Goiás – Urutaí Campus. The soybean seeds used were from a batch of the Brasmax Extrema IPRO cultivar, relative maturity group 8.1, indeterminate growth habit, and cycle ranging from 108 to 128 days.

The seed batch was separated into 4 subsamples, each subsample comprising the seeds from the four treatments described below. Treatment 1: seeds without association with any biologically active ingredient (control); Treatment 2: seeds associated with *Lithothamnium* sp. through the physiological conditioning process; Treatment 3: seeds associated with *Lithothamnium* sp. through the coating process; and Treatment 4: seeds associated with *Lithothamnium* sp. through the physiological conditioning process followed by the coating process.

The product used was LTSupra, from the company Supramar. The physical nature of the product is powder, registered with MAPA (Brazil - Ministry of Agriculture, Livestock and Supply) under number ES 0016172-1 as a mixed mineral fertilizer. In the record, the composition is 97% *Lithothamnium* seaweed and 3% calcium and magnesium silicate. The minimum guarantees are total calcium (Ca) = 29%; total magnesium (Mg) = 1.8% and total silicon (Si) = 3%.

In treatment 1, the seeds were subjected to physiological quality tests without any prior procedure. For treatment 2, the product containing *Lithothamnium* sp. in solution was used in the proportion of 30 g for every 4 liters of water, applied directly to the seeds during the conditioning process. For the conditioning process, the soybean seeds were arranged in a single layer on germination paper previously moistened with a biostimulant solution based on *Lithothamnium* sp., in the proportion of 2.5 times the dry weight of the paper. Rolls were made and kept in a Mangelsdorf-type germinator at a constant temperature of 25 ± 0.5 °C in a dark environment. The conditioning period was 20 hours, and then the seeds were dried in an oven with air circulation and renewal at 30 °C.

For the seed coating treatment, identified as treatment 3, 1 g of the product was used for every 1,000 seeds in a Gerbox-type acrylic box. The seeds were previously and superficially moistened with distilled water using a sprayer. After superficial moistening, the seeds were placed in the acrylic box with the powdered product. The seeds were moved until the product adhered completely to the surface of the seeds, in a homogeneous manner.

The last treatment consisted of a combination of the two methodologies mentioned above; the seeds initially underwent the physiological conditioning process and then the coating process.

After the treatments were completed, the seeds were subjected to the following tests:

Germination test (G): 200 seeds were used, divided into four replicates of 50 seeds. The seeds were placed between sheets of germination paper. The papers were moistened with water in a volume corresponding to 2.5 times the weight of the dry paper. Rolls were made and kept in a Mangelsdorf-type germinator at 25 ± 2 °C. Evaluations took place on the fifth day, when the first count (PC) data were obtained, and the eighth day after sowing, when the germination data (G) were obtained (Brazil, 2009). The results were expressed as the average percentage of normal seedlings.

Seedling emergence in the field (E): carried out in seedbeds with four replicates of 50 seeds. Irrigation was carried out regularly, and seedling counts were performed eight days after sowing, considering only those with at least 2 cm of shoot (Nakagawa et al., 2018). Data was obtained 15 days after sowing. Results were expressed as an average percentage.

Emergence speed index (ESI): was calculated by summing the number of seeds counted in the previous test daily, divided by the number of days elapsed between sowing and evaluation, according to the formula defined by Maguire (1962):

$$\mathrm{ESI} = \frac{\mathrm{E1}}{\mathrm{N1}} + \frac{\mathrm{E2}}{\mathrm{Ne}} + \cdots + \frac{\mathrm{En}}{\mathrm{Nn}}$$

Where:

E1, E2, En = number of seedlings counted in the emergence tests in the first, second, and up to the last count.

N1, N2, Nn = number of days from the first, second, and up to the last count performed, where emergence stabilized.

Accelerated aging (AA): 200 seeds were used, placed in Gerbox-type acrylic boxes on stainless steel screens, containing 40 mL of distilled water at the bottom. The boxes remained in an oven regulated at 41 ± 0.2 °C for 24 hours (Dutra & Vieira, 2004). After this period, the seeds were subjected to a germination test, with four replicates of 50 seeds. Evaluations were performed on the fifth day after sowing on the paper.

The experimental design adopted was completely randomized. The data obtained were subjected to tests of homogeneity of variances (Levene) and normality (Shapiro-Wilk). Subsequently, analysis of variance (ANOVA) was performed, and the means were compared using the Student-Newman-Keuls (SNK) test at a 5% significance level. Statistical analyses were performed using the R software (R Core Team, 2022).

RESULTS AND DISCUSSION

For all evaluated items, there was an effect of the seed association treatments with the *Lithothamnium* sp.-based product (Table 1). That is, there is a difference in the behavior of the germination process (final percentage, speed, stress tolerance) and emergence (final percentage and speed) of soybean seeds according to the presence or absence of the association and type of association with *Lithothamnium* sp.

In terms of seedling emergence in the field, treatment 4 showed inferior performance (Figure 1A). The other treatments, however, did not show a statistically significant difference in final seedling emergence in the field.

Table 1. Summary of the analysis of variance (ANOVA) for the physiological quality of soybean seeds associated with *Lithothamnium* sp.-based biostimulant.

	First germination count	Germination	Accelerated aging	Seedling emergence in the field	Emergence speed index
P-value (ANOVA)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
CV (%)	4.47	5.17	6.65	8.28	12.83
Residual normality	0.85	0.87	0.85	0.70	0.27
Homoscedasticity	0.73	0.36	0.25	0.66	0.07

Figure 1. Seedling emergence (A) and emergence speed index (B) of soybean seeds subjected to different forms of association with a biostimulant based on *Lithothamnium* sp. and seeds without any association (control).

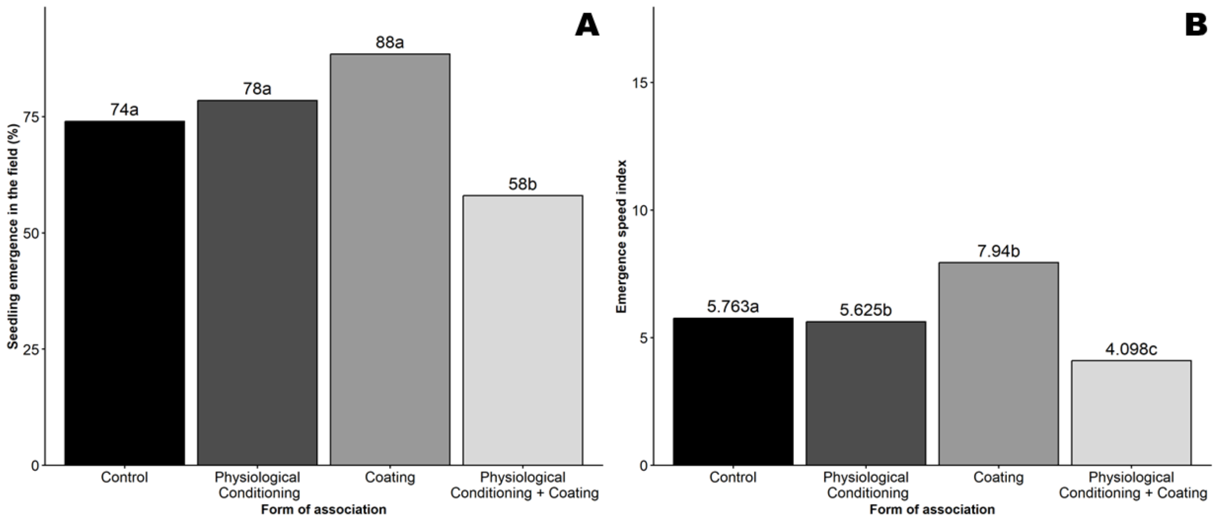
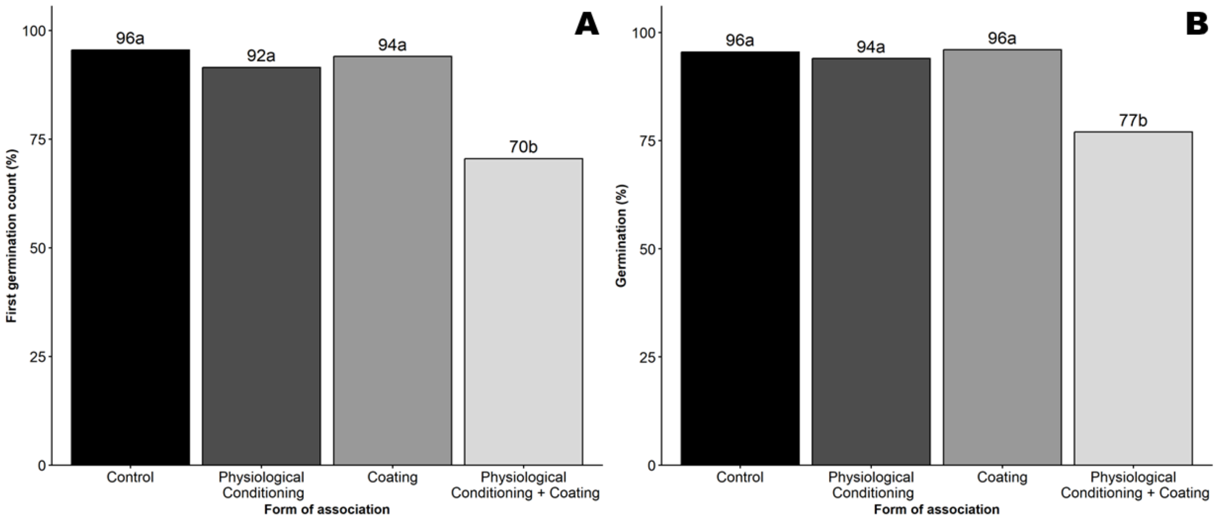


Figure 2. First germination count (A) and final germination count (B) of soybean seeds subjected to different forms of association with a biostimulant based on *Lithothamnium* sp. and seeds without any association (control).



In the work of Evangelista et al. (2016), the effect on the emergence of *Jatropha curcas* seedlings was influenced by the dose of *Lithothamnium* sp. applied to the soil. These authors revealed a linear effect on the seedling emergence response with the application of the biostimulant, with a greater response when higher levels were applied. The authors reported an improvement in microporosity, consequently better water retention capacity, to justify the beneficial effect. Possibly, this same effect was not identified in our study because the application via seed may not have been sufficient to alter the physical characteristics of the soil.

For the evaluation of the speed of the emergence process, measured by the emergence speed index, treatment 3 showed the highest speed, revealing superior behavior to the other treatments (Figure 1B). The seeds that did not receive any treatment (control) and the seeds from treatment 2 showed intermediate behavior regarding the speed of seedling emergence. The seeds from treatment 4 showed the worst emergence speed index, agreeing with the other evaluations. This beneficial result of using the biostimulant in the coating (T3) can be explained by the fact that biostimulants such as seaweed extracts can be a source of important phytohormones, including gibberellin, auxins, and cytokinins (Stirk et al., 2020).

Gibberellin is especially involved in metabolic recovery in seeds during germination and the synthesis of enzymes that hydrolyze stored reserves (Bewley, 1997), which are directed to the embryonic axis that originates the seedling. A reduction in germination time with exogenous application of gibberellin has already been reported in the literature (Ali and Elozeiri, 2017). Jesus et al. (2020) stated that conditioning greenish soybean seeds with brassinolide, a natural analogue of brassinosteroids, showed better performance in variables related to vigor. Brassinosteroids are plant hormones that signal molecular, physiological, and biochemical responses (Taiz and Zeiger et al. 2017).

For the vigor test that assesses the speed of occurrence of normal seedling formation, first count, the effect was negative in treatment 4 (Figure 2A). There was no benefit for the seeds associated with the algae product compared to those that did not receive treatment.

The same behavior observed in the first count test occurred in the germination test (Figure 2B). There was no difference between untreated seeds and seeds from treatments 2 and 3; only treatment 4 showed a deleterious effect.

According to Ramos et al. (2023), the impacts of algae such as *Lithothamnium* sp. on plant growth and development depend on the dosage used. The negative effect of treatment 4 may be related to the effect of the high concentration of the product, since two methodologies for associating *Lithothamnium* sp. with the seeds were used. Cruz et al. (2008) also reported a negative effect on seedling growth, such as root length, when high doses of *Lithothamnium* (Afertil®) were used.

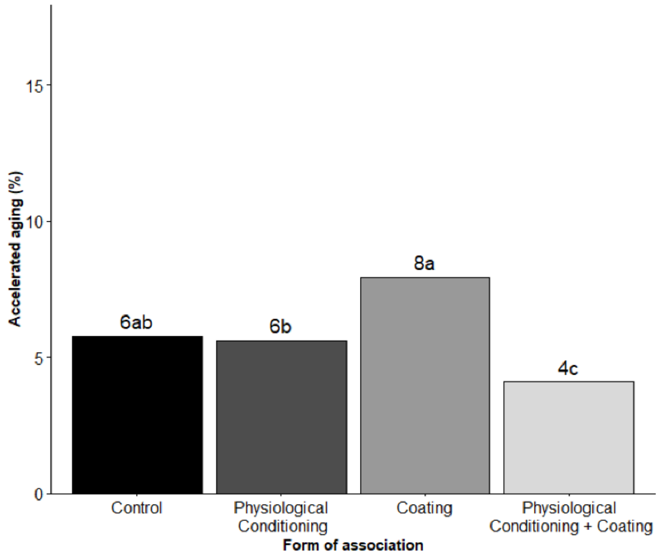
The absence of a positive effect in these cases, first count and germination tests, may be related to the ideal environmental conditions provided in the germination tests, which may overestimate seed quality (Henck et al., 2025) or at least not reflect the varied conditions that may be encountered in the field (Krzyzanowski et al., 2020). According to Marcos-Filho (2015), the germination test provides ideal conditions for the occurrence of the process.

When the tolerance of seeds to the stress provided by the accelerated aging test was evaluated, beneficial behavior was observed in treatment 3 (Figure 3). The seeds from treatment 2 showed intermediate behavior. The seeds from treatment 4, however, showed a sharp drop of 30% in the percentage of normal seedlings after stress.

These results corroborate those of Dmytryk et al. (2015), who revealed beneficial effects on the germination process of wheat seeds, such as a faster rate of occurrence of the process, when associated with biomass extracts of *Spirulina tuvieron*, a microalga.

Tests involving simulations of field conditions (seedling emergence in the field and emergence speed index) or those that express vigor (accelerated aging) are more likely to be influenced by treatments because they assess how the germination process occurs, and are therefore more sensitive to detecting differences (Krzyzanowski et al., 2020).

Figure 3. Accelerated aging of soybean seeds subjected to different forms of association with a biostimulant based on *Lithothamnium* sp. and seeds without any association (control).



Since algae extracts can be a source of phytohormones (Stirk et al., 2020), *Lithothamnium* sp. associated with soybean seeds in our work may have favored the germination process of seeds in a more pronounced deterioration process, as simulated in the accelerated aging test. Mortele et al. (2008) had already reported a more pronounced and effective effect of applying bioregulators based on cytokinin, auxin and gibberellin in soybean seeds exposed to stress conditions.

CONCLUSION

Coating soybean seeds with *Lithothamniu*m sp. benefited final seedling emergence, emergence speed, and germination under stress conditions. Physiological conditioning followed by coating soybean seeds with *Lithothamnium* sp. impaired germination and seedling emergence.

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REFERENCES

Bewley, J. D. (1997). Seed germination and dormancy. *The plant cell*, 9(7), 1055. DOI: https://doi.org/10.1105/tpc.9.7.1055

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. (2009). Regras para análise de sementes. Brasília: Mapa/ACS, 399p.

Brzezinski, C. R.; Henning, A. A.; Abati, J.; Henning, F. A.; França-Neto, J. D. B.; Krzyzanowski, F. C.; Zucareli, C. (2015). Seeds treatment times in the establishment and yield performance of soybean crops. *Journal of Seed Science*, 37, 147-153. DOI: https://doi.org/10.1590/2317-1545v37n2148363

Corbineau, F.; Taskiran-Özbingöl, N.; El-Maarouf-Bouteau, H. (2023). Improvement of seed quality by priming: concept and biological basis. *Seeds*, 2(1): 101-115. DOI: https://doi.org/10.3390/seeds2010008

Chiaiese, P.; Corrado, G.; Colla, G.; Kyriacou, M. C.; Rouphael, Y. (2018). Renewable sources of plant biostimulation: microalgae as a sustainable means to improve crop performance. *Frontiers in plant science*, 9, 1782. DOI: https://doi.org/10.3389/fpls.2018.01782

Cressard A. P. (1974). Les repercussions de l'exploitation Industrielle des sables et graviers sur l'environnement marin et sur les activités economiques du domaine maritime. Publication du Dept. Ressources Minerales, 37p.

Cruz, M.; Hafle, M.; Ramos, P. (2008). Desenvolvimento do porta-enxerto de tangerineira "Cleópatra". *Revista Brasileira de Fruticultura*, 30(2): 471-475. DOI: https://doi.org/10.1590/S0100-29452008000200035

Dias, G. T. M. (2000). Granulados bioclásticos: algas calcárias. *Revista Brasileira de Geofísica*, 18, 307-318. DOI: https://doi.org/10.1590/S0102-261X2000000300008

Dutra, A. S.; Vieira, R. D. (2004). Envelhecimento acelerado como teste de vigor para sementes de milho e soja. *Ciência Rural*, 34, 715-721. DOI: https://doi.org/10.1590/S0103-84782004000300010

Du Jardin, P. (2015). Plant biostimulants: Definition, concept, main categories and regulation. *Scientia Horticulturae*, 196, 3-14. DOI: https://doi.org/10.1016/j.scienta.2015.09.021

Dmytryk, A.; Roj, E.; Wilk, R.; Chojnacka, K.; Gorecki, H. (2014). Effect of new biostimulators on the initial phase of plant growth. Przemysl Chemiczny, 93(6), 1020-1025.

Evangelista, A. W. P.; Vieira, M. A.; Alves Júnior, J.; Brasil, E. P. F.; Casaroli, D. (2016). Seedling production of *Jatropha curcas* L. in substrates fertilized with *Lithothamnion*. *Bioscience Journal*, (32)1: 132-139.

Galindo, F. S.; Pagliari, P. H.; Buzetti, S.; Rodrigues, W. L.; Santini, J. M. K.; Boleta, E. H. M.; Rosa, P. A. L.; Nogueira, T. A. R.; Lazarini, E.; Filho Teixeira, M. C. M. (2020). Can silicon applied to correct soil acidity in combination with *Azospirillum brasilense* inoculation improve nitrogen use efficiency in maize?. *PLoS One*, 15(4): e0230954. DOI: https://doi.org/10.1371/journal.pone.0230954

Hafle, O. M.; Santos, V. A. D.; Ramos, J. D.; Cruz, M. D. C.; Melo, P. C. D. (2009). Produção de mudas de mamoeiro utilizando Bokashi e Lithothamnium. *Revista Brasileira de Fruticultura*, 31, 245-251. DOI: https://doi.org/10.1590/S0100-29452009000100034

Henck, A. U.; Pivetta, P.; Nunes, U. R.; Balensiefer, I. C.; Ferrazza, C. M. (2025). Root protrusion as a vigor test for canola seeds under different levels of water availability. *Semina: Ciências Agrárias*, 46(4): 1025-1038. DOI: https://doi.org/10.5433/1679-0359.2025v46n4p1025

Joshi, B.; Chaudhary, A.; Singh, H.; Kumar, P. A. (2020). Prospective evaluation of individual and consortia plant growth promoting rhizobacteria for drought stress amelioration in rice (*Oryza sativa* L.). *Plant and Soil*, 457(1): 225-240. DOI: https://doi.org/10.1007/s11104-020-04730-x

Labouriau, L. G. *A germinação das sementes*. Washington: Secretaria Geral da Organização dos Estados Americanos, 1983. 174 p.

Krzyzanowski, F. C.; França-Neto, J. D. B.; Gomes-Junior, F. G.; Nakagawa, J. (2020). Testes de vigor baseados em desempenho de plântulas. *Vigor de sementes: conceitos e testes*, 601p.

Maguire, J. D. Speed of germination: aid in selection and evaluating or seedling emergence and vigour (1962). *Crop Science*, 2(2): 176-177. DOI: https://doi.org/10.2135/cropsci1962.0011183X000200020033x

Melo, G. B.; Silva, A. G.; Perin, A.; Braz, G. B. P.; Andrade, C. L. L. (2021). Tratamento de sementes com doses do bioestimulante à base de algas. *Brazilian Journal of Development*, 7(1): 1418-1431. DOI: https://doi.org/10.34117/bjdv7n1-097

Moterle, L. M.; Santos, R. F. D.; Braccini, A. D. L.; Scapim, C. A.; Barbosa, M. C. (2008). Efeito da aplicação de biorregulador no desempenho agronômico e produtividade da soja. *Acta Scientiarum. Agronomy*, 30, 701-709. DOI: https://doi.org/10.4025/actasciagron.v30i5.5971

Kapoore, R. V.; Wood, E. E.; Llewellyn, C. A. (2021). Algae biostimulants: A critical look at microalgal biostimulants for sustainable agricultural practices. *Biotechnology Advances*, 49, 107754. DOI: https://doi.org/10.1016/j.biotechadv.2021.107754

Khalaki, M.; Moameri, M.; Asgari Lajayer, B.; Astatkie, T. (2020). Influence of nano-priming on seed germination and plant growth of forage and medicinal plants. *Plant Growth Regulation*, 93(1): 13-28. DOI: https://doi.org/10.1007/s10725-020-00670-9

Leao-Araujo, E. F.; Araujo, F. G. (2024). Cultivando sustentabilidade: O uso de microrganismos nas sementes e na agricultura. *Revista Seed News*, Ano XXVIII, 6, 52-55.

Pagano, A.; Macovei, A.; Balestrazzi, A. (2023). Molecular dynamics of seed priming at the crossroads between basic and applied research. *Plant Cell Reports*, 42(4): 657-688. DOI: https://doi.org/10.1007/s00299-023-02988-w

R CORE TEAM. (2022). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. Disponível em: <https://www.R-project.org/> Acesso: 29/10/2025.

Ramos, E. P.; Ferreira, T. R.; Aguiar, D. B.; Alves, F. L.; Dousseau-Arantes, S. (2023). *Lithothamnion* sp. as biostimulant in plant cultivation. Pesquisa Agropecuária Tropical, 53, e76273. Disponível em: https://www.redalyc.org/journal/2530/253074416026/html/

Rodriguez, W. D. M.; Evangelista, A. W. P.; Alves Júnior, J.; Honorato, M. V. (2017). Growing of coffee seedlings on different substrates and fertilized with *Lithothamium*. *Revista Facultad Nacional de Agronomía de Medellin*, 70(2): 8177-8182. DOI: https://doi.org/10.15446/rfna.v70n2.64522

Rocha, I.; Ma, Y.; Souza-Alonso, P.; Vosátka, M.; Freitas, H.; Oliveira, R. S. (2019). Seed coating: a tool for delivering beneficial microbes to agricultural crops. *Frontiers in Plant Science*, 10, 1357. DOI: https://doi.org/10.3389/fpls.2019.01357

Santoyo, G.; Guzmán-Guzmán, P.; Parra-Cota, F. I.; Santos-Villalobos, S. D. L.; Orozco-Mosqueda, M. D. C.; Glick, B. R. (2021). Plant growth stimulation by microbial consortia. *Agronomy*, 11(2), 219. DOI: https://doi.org/10.3390/agronomy11020219

Shahrajabian, M. H.; Chaski, C.; Polyzos, N.; Petropoulos, S. A. (2021). Biostimulants application: A low input cropping management tool for sustainable farming of vegetables. *Biomolecules*, 11(5), 698. DOI: https://doi.org/10.3390/biom11050698

Sissini, M. N.; Koerich, G.; de Barros-Barreto, M. B.; Coutinho, L. M.; Gomes, F. P.; Oliveira, W.; Costa, I. A.; Nunes, J. M. C.; Henriques, M. C.; Vieira-Pinto, T.; Torrano-Silva, B. N.; Oliveira, M. C.; Gall, L. L.; Horta, P. A. (2022). Diversity, distribution, and environmental drivers of coralline red algae: the major reef builders in the Southwestern Atlantic. *Coral Reefs*, 41(3), 711-725. DOI: https://doi.org/10.1007/s00338-021-02171-1

Souza, H. A.; Mendonça, V.; Ramos, J. D.; Ferreira, A. E.; Alencar, R. D. (2007). Doses de *Lithothamnion* e diferentes substratos na produção de mudas de maracujazeiro 'Doce'. *Revista Caatinga*, 20(4): 23-30.

Stirk, W.A.; Rengasamy, K.R.R.; Kulkarni, M.G.; Van Staden, J. (2020). Plant Biostimulants from Seaweed. *In The Chemical Biology of Plant Biostimulants* (eds D. Geelen and L. Xu). DOI: https://doi.org/10.1002/9781119357254.ch2

Taiz L.; Zeiger E. (2017) *Fisiologia Vegetal*. 6. ed. Porto Alegre: Artmed.

Teixeira, G. A.; Souza, H. A.; Mendonça, V.; Ramos, J. D.; Chalfun, N. N. J.; Ferreira, E. A.; Melo, P. C. (2009). Produção de mudas de mamoeiro formosa em substratos com doses de lithothamnium. *Revista da FZVA*, 16(2), 220-229.

USDA. Department of Agriculture. Foreign Agricultural Service (USDA FAS). Serviço agrícola estrangeiro do USDA. USDA FAS, 2025. URL: https://ipad.fas.usda.gov/countrysummary/default.aspx?id=BR&crop=Soybean. Access: 16 set. 2025.

Waqas, M.; Korres, N. E.; Khan, M. D.; Nizami, A. S.; Deeba, F.; Ali, I.; Hussain, H. (2019). Advances in the concept and methods of seed priming. In: HASANUZZAMAN, M.; FOTOPOULOS, V. (eds.). Priming and Pretreatment of Seeds and Seedlings. *Singapore: Springer Nature*. Singapore Pte Ltd., p. 11–41. DOI: https://doi.org/10.1007/978-981-13-8625-1_2

Wadas, W.; Dziugieł, T. (2020). Changes in assimilation area and chlorophyll content of very early potato (*Solanum tuberosum* L.) cultivars as influenced by biostimulants. *Agronomy*, 10(3), 387. DOI: https://doi.org/10.3390/agronomy10030387

Vijayakumar, S.; Durgadevi, S.; Arulmozhi, P.; Rajalakshmi, S.; Gopalakrishnan, T.; Parameswari, N. (2019). Effect of seaweed liquid fertilizer on yield and quality of *Capsicum annum* L. *Acta Ecologica Sinica*, 39(5), 406-410. DOI: https://doi.org/10.1016/j.chnaes.2018.10.001

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