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Seed Quality of Chickpea and Common Bean as a Function of the Application of *Ascophyllum Nodosum* Doses Seaweed Extract

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Abstract

The application of *A. nodosum* based seaweed extract can enhance seed quality. However, the positive results regarding the use of this technology remain unclear. This study investigated the impact of different doses of organomineral seaweed-based fertilizer on the seed quality of chickpea and common bean. A completely randomized design was used with four replications, and the treatments consisted of seed treatments with five doses of *A. nodosum* seaweed extract for chickpea (0, 50, 100, 150, and 200 mL of extract per 100 kg of seeds) and of (0, 125, 250, 375 and 500 mL of extract per 100 kg of seeds) for common bean. After harvest, the seeds were analyzed using the following tests: germination, first count, seedling length, and seedling dry mass. It was concluded that the seed quality of chickpea and common bean was influenced by the addition of *A. nodosum* seaweed extract. Doses of seaweed extract higher than 100 and 250 mL per 100 kg of seeds negatively affected the physiology of chickpea and bean seeds, respectively. The doses of 100 and 250 mL per 100 kg of seeds resulted in higher-quality seed lots of chickpea and common bean, offering valuable insights for future agricultural practices and the advancement of sustainable, cost-effective production.

Keywords: mineral nutrition, organominerals, seed quality, *Ascophyllum nodosum*, *Phaseolus vulgaris*

1. Introduction

Originating from the Middle East, chickpea (*Cicer arietinum*) is widely cultivated and consumed in various regions worldwide, recognized for its culinary versatility and nutritional value (QUEIROGA et al., 2021). This small grain provides a rich source of proteins, fibers, vitamins, and minerals, playing an essential role in the diets of various global cultures (NASCIMENTO, 2016). As for common bean (*P. vulgaris*), it stands out as the second most cultivated legume globally, behind only soybeans. Its grains are highly nutritious, containing proteins, fibers, complex carbohydrates, vitamins, and micronutrients, contributing to the enhancement of food and nutritional security for consumers (SALVADOR & PEREIRA, 2021). Despite this importance, nutritional limitations are one of the bottlenecks that restrict the productivity of both crops worldwide.

Exploring innovative alternatives to optimize the production of these legumes under different cultivation conditions is a strategic approach. In this regard, recent studies have investigated the influence of organomineral fertilizers derived from seaweed on the growth and development of various crops, offering substantial improvements in plant nutrition and vigor (OLIVEIRA, 2019). This research line appears promising for increasing crop productivity and quality, as evidenced by results from a study conducted by Meyer et al. (2021). Their findings concluded that the application of the seaweed-based biostimulant *Ecklonia maxima*, at a dose of 607 mL ha^{-1} applied via foliar spraying at the R1 stage, increased the number of branches, nodes, flowers, and pods in soybean plants, consequently boosting soybean production.

Selecting high-quality seeds is a crucial investment for farmers aiming to expand cultivation areas and improve chickpea and common bean productivity. These seeds ensure a more vigorous start for plants, contributing to a healthier and more efficient crop cycle. In this context, the application of *A. nodosum* seaweed extract may improve seed quality, as the product contains hormones such as auxins, gibberellins, and cytokinins.

Research on the effects of *A. nodosum* application in grain crop seeds remains rare and inconclusive. For example, a study by Santos et al. (2019) found that increasing the concentration of the biostimulant enhanced the germination and seedling development of ornamental sunflower, with 15 mL L of biostimulant yielding the best results for germination percentage, germination index, and reduced germination time, as well as increased plant height and shoot fresh and dry mass compared to the control treatment. Conversely, Santos et al. (2021) observed that *A. nodosum* extract negatively affected the germination performance of bean seeds compared to Scenedesmus acuminatus seaweed extract. In a recent study by Cunha (2022), a dose of 150 mL per 100 kg of seeds, applied to seeds and subsequently sown in greenhouse conditions, resulted in higher-quality soybean seed lots compared to other doses.

Regarding the response capacity of chickpea and common bean seeds to *A. nodosum* seaweed extract application, the international literature lacks sufficient information. Thus, evaluating the seed quality of these crops will not only expand our knowledge of their potential but also provide crucial information for researchers, technicians, and other stakeholders in the supply chain of these promising food crops. Based on this context, this research aimed to evaluate the quality of chickpea seeds (Desi group) and common bean seeds in response to different doses of *A. nodosum* seaweed extract.

2. Materials and Methods

2.1 Seeds Used in the Study and Experimental Conditions

Chickpea and common bean seeds used in the experiments were produced during the winter season of 2023 at the EMATER Experimental Station, located at the geographical coordinates: 16º 19' S latitude and 48º 18' W longitude, with an average altitude of 980 m (COUTO et al., 2013) in Anápolis, GO, Brazil. The region experiences milder winter temperatures, reaching as low as 10ºC, which favors chickpea cultivation. The soil is classified as dystrophic Yellow-Red Latosol (EMBRAPA, 2006) and was amended with 1.5 tons ha^{-1} of dolomitic limestone ("filler" type) three months before planting.

2.2 Soil Preparation and Crop Management

The soil was conventionally prepared with one plowing and two harrowings, followed by the preparation of furrows spaced 0.5 m apart. Basal fertilization was performed using 400 kg ha^{-1} of 04-30-16 fertilizer for both crops.

The chickpea cultivar (Desi group) BRS Hari and the common bean cultivar BRS Estilo were sown at densities of 10 and 12 plants per linear meter, respectively. At 25 days after emergence (DAE), topdressing with urea was applied at 60 kg ha^{-1} in continuous strips parallel to the chickpea and bean rows. Weed control was carried out manually with three weedings. Pest and disease control was not required for chickpeas, whereas for beans, initial pest control was needed for *Diabrotica speciosa* and *Cerotoma arcuata* using the insecticide Decis® (Deltamethrin), and disease control was necessary for anthracnose (*Colletotrichum lindemuthianum*) and angular leaf spot (*Phaeoisariopsis griseola*) using the fungicide Nativo® (Trifloxystrobin + Tebuconazole). Other cultural practices were applied as commonly used for these crops.

2.3 Harvesting and Seed Processing

At harvest, the plants were collected and sun-dried until they reached 12% moisture content. The seeds were then manually threshed to prevent mechanical damage.

Subsequently, the seeds were taken to the laboratory, where they were divided into 300 g lots for each treatment. The seeds were placed in plastic bags, and the seaweed extract was applied using a 5 mL syringe, according to the established doses for 100 kg of seeds.

After application, the bags were inflated with air and then shaken until the seed mass was evenly coated. The treated seeds were then air-dried for 30 minutes and immediately subjected to physiological quality analysis through the following tests:

Germination: Four replicates of 50 seeds each were placed in Germitest paper rolls, moistened with 2.5 times their weight in distilled water, and maintained in a germinator set at 25°C. Evaluations were conducted on the 8th day, following the rules established by the Brazilian Ministry of Agriculture, Livestock, and Food Supply (BRASIL, 2009).

First count: Conducted alongside the germination test, assessing the percentage of normal seedlings on the 5th day of the test, expressed as the percentage of vigorous seedlings.

Seedling length: Four replicates of 10 seeds per treatment were distributed in Germitest paper rolls, moistened with 2.5 times their weight in distilled water. After 8 days, the length of normal seedlings was measured in centimeters, following the methodology established by BRASIL (2009).

Seedling dry mass: Normal seedlings evaluated in the seedling length test were placed in paper bags and then kept in a forced-air circulation oven at 62°C for 48 hours, until reaching a constant weight. The unit of measurement was expressed in grams per seedling (g seedling^{-1}).

2.4 Statistical Analysis

The experiments were design followed a completely randomized design (CRD) with four replications. The treatments consisted of five different doses of *A. nodosum* seaweed extract applied to seeds of chikpea (0; 50; 100; 150; 200 mL per 100 kg) and of (0; 125; 250; 375 and 500 mL per 100 kg) for common bean. The doses of the seaweed extracts tested in the study in both experiments were defined in preliminary studies.

The collected data were subjected to analysis of variance (ANOVA), and the means were fitted to regression models using the software Sisvar 5.6.

3. Results and Discussion

3.1 Chickpea Seed Analysis

According to the results of the variance analysis, the application of *A. nodosum* seaweed extract influenced the seed quality of chickpea (Desi group, cv. BRS Hari) in the germination, first count, and seedling length tests. However, no significant influence of the investigated treatments was detected on the seed quality of common bean in the seedling dry mass test. In general, good precision was observed in the obtained data.

The germination data for chickpea seeds were adjusted to a quadratic regression model, with the dose of 100 mL per 100 kg of seeds yielding the highest seed viability 96% (Figure 1). Beyond this dose, a decline in the percentage of normal seedlings was observed, demonstrating an inhibitory effect of the product on the germination process of chickpea seeds. This effect is likely due to the increased volume of the product applied to the seed mass, which may have favored pathogen proliferation during the test, consequently reducing seed lot viability.

The positive effects of *A. nodosum* seaweed extract on chickpea seed physiology can be attributed to the presence of hormonal compounds such as auxins, gibberellins, and cytokinins, which play a role in seed metabolism (SHARMA et al., 2012). These hormones influence cell division and elongation, as well as stimulate the germination process, directly impacting seedling development (TAIZ & ZEIGER, 2013).

It is worth noting that the highest germination percentage obtained with the 100 mL per 100 kg dose of seaweed extract 96% exceeds the germination standard required by the Brazilian Ministry of Agriculture, Livestock, and Food Supply (MAPA) for the commercialization of chickpea seeds, which must have a germination rate above 80-85% (BRASIL, 2009).

The results of the first count test practically confirmed those of the germination test, with the highest percentage of normal vigorous seedlings (92%) obtained with the 100 mL per 100 kg dose of seaweed extract (Figure 2). On the other hand, higher extract doses of 150 and 200 mL per 100 kg of seeds led to a decline in seed vigor, with respective values of 52% and 44% of vigorous seedlings. These results may be attributed to the hormonal effect of the seaweed extract on seed vigor, as previously explained in the viability test.

It is important to emphasize that the seed vigor test has a direct correlation with field performance, as more vigorous seed lots are better able to withstand stressful conditions such as water deficit and high temperatures, making this test more representative of real agricultural conditions.

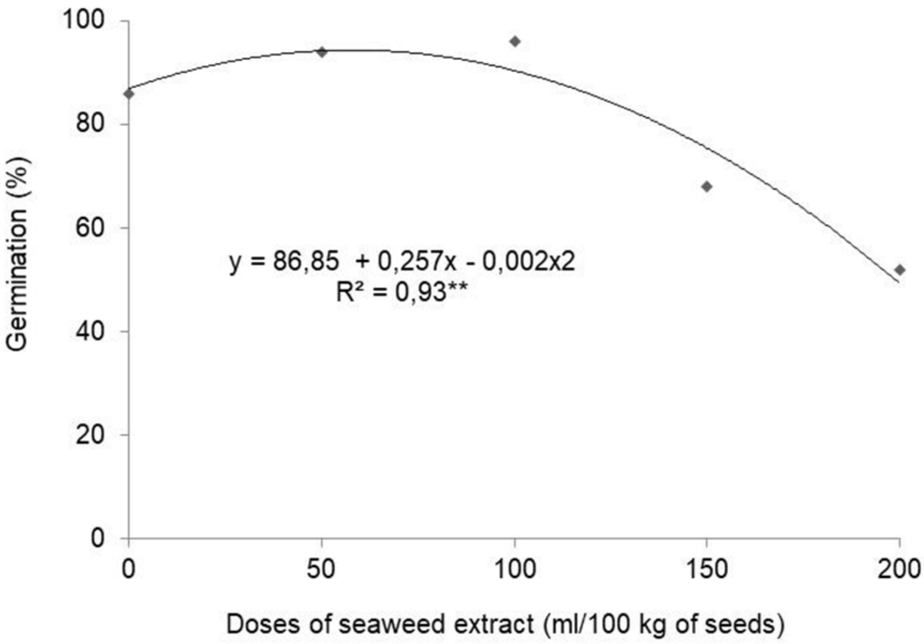

Figure 1. Germination percentage of chickpeas (Desi group, cv. BRS Hari) subjected to different doses of organomineral seaweed fertilizer based on *A. nodosum*

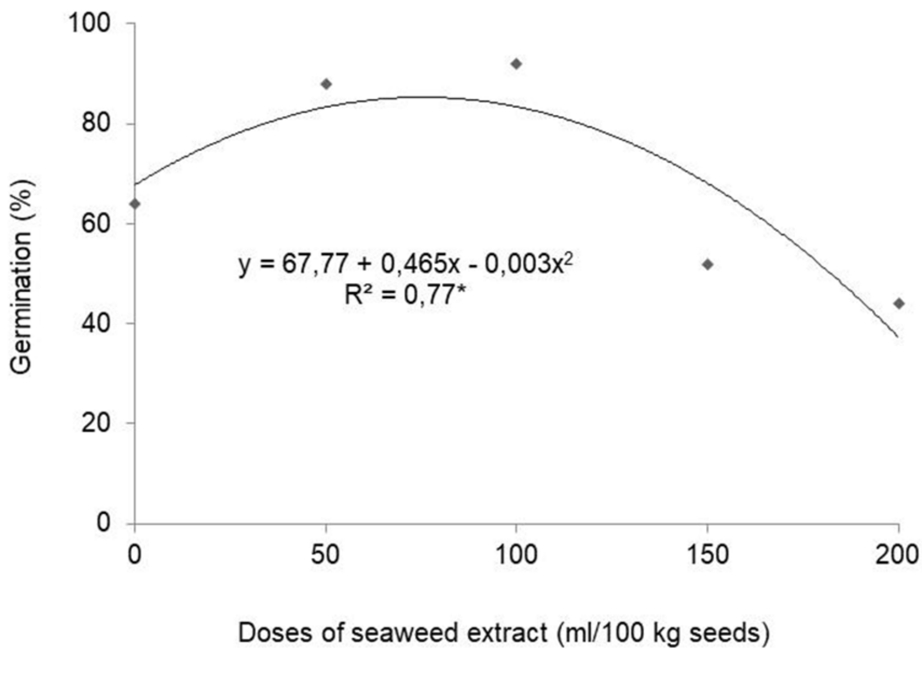

Figure 2. Percentage of normal seedlings from chickpea seeds (Desi group, cv. BRS Hari) in the first count test, subjected to different doses of *A. nodosum* based organomineral seaweed fertilizer

The greatest chickpea seedling length was obtained with the 100 mL per 100 kg seaweed extract dose (5.3 cm), compared to the higher tested doses (Figure 3), confirming the results observed in the germination and first count tests. Regarding the seedling dry mass test, it was not possible to adjust a regression model, although a slight increase in biomass accumulation was observed in seedlings from seeds treated with the lower doses of *A. nodosum* seaweed extract.

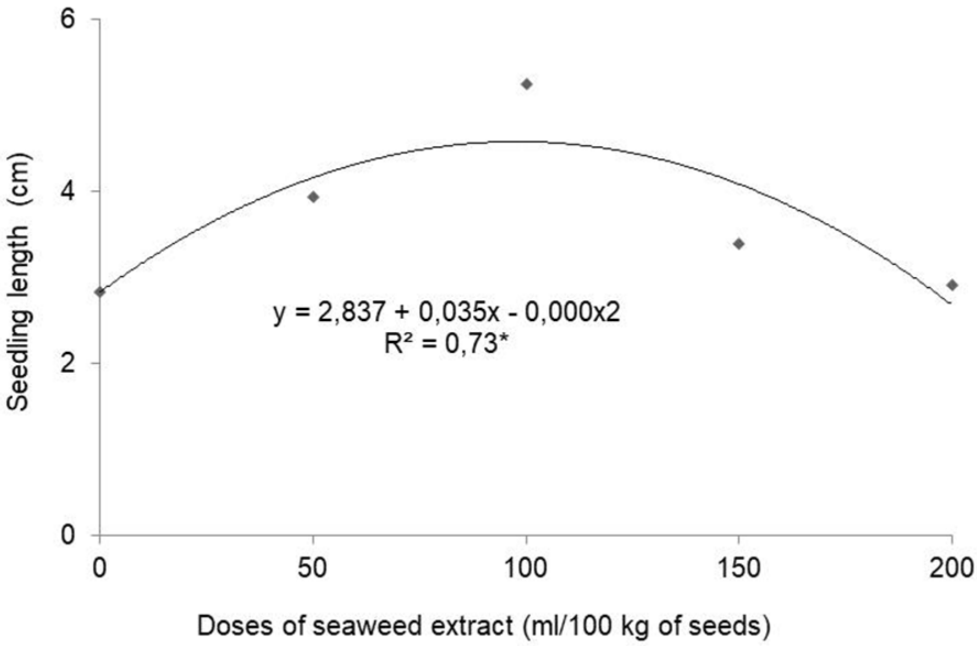

Figure 3. Seedling length from chickpea seeds (Desi group, cv. BRS Hari), subjected to different doses of *A. nodosum* based organomineral seaweed fertilizer

In addition to improving chickpea seed physiology, the addition of *A. nodosum* seaweed extract, which contains plant hormones such as auxin, gibberellin, and cytokinin (SHARMA et al., 2012), may also promote the production of phytoalexins (compounds that induce plant resistance to diseases and pests). This strengthens plant defense mechanisms as well as soil microbiology (TAIZ & ZEIGER, 2013). However, this effect is only observed when the appropriate product dose is applied to the seed mass, namely 100 mL per 100 kg of seeds.

3.2 Common Bean Seed Analysis

The variance analysis results showed that the physiological quality of common bean seeds was influenced by the application of *A. nodosum* seaweed extract, as evidenced by the results of the germination and vigor tests (first count, seedling growth, and seedling dry mass).

For the germination test data, a quadratic regression model was fitted, with the 250 mL per 100 kg seed dose yielding the highest germination percentage 90% (Figure 4), representing a 10% increase in viability compared to the untreated control. The positive effect of seaweed extract on seed physiology may be attributed to the presence of minerals and hormones that influence seed metabolism (SHARMA et al., 2012), particularly auxins.

The stimulation of root growth in bean seedlings may be attributed to the probable presence of auxins in the extract, as this hormone is responsible for cell growth and elongation. This hypothesis was confirmed in a study by Foelkel et al. (2015), in which seaweed extract applied to passion fruit calluses increased the number of roots formed, comparable to results obtained with indolebutyric acid. It is worth noting that auxin is produced in the apical meristems of the shoot and is required in low concentrations for root growth, whereas high concentrations inhibit root development (TAIZ & ZEIGER, 2004). Conversely, at higher tested doses, a decrease in the percentage of normal seedlings was observed due to abnormalities and the loss of seed capacity to generate normal seedlings. These results align with research by Ferreira et al. (2007), who found that the use of seaweed extract impaired nutrient absorption in maize.

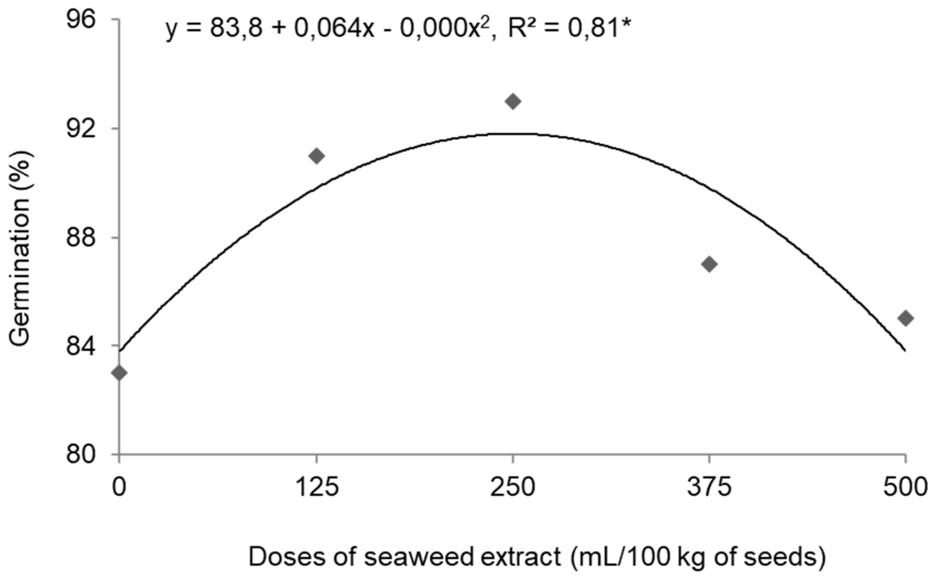

Figure 4. Germination percentage of normal seedlings from common bean seeds (cv. BRS Estilo), subjected to different doses of *A. nodosum* based seaweed extract

The best results for seed vigor, seedling growth, and dry mass were also obtained with the 250 mL per 100 kg dose, confirming the findings of the germination test. The application of higher doses negatively affected these parameters, reinforcing that exceeding the optimal dose can be detrimental to seed quality.

When comparing the highest germination value obtained for common bean seeds treated with the seaweed extract 90% it is evident that this value exceeds the standard required for seed commercialization, which ranges from 80% to 85%, according to the criteria established by Brasil (2009). This confirms the effectiveness of seaweed extract in improving the physiological quality of common bean seeds.

Regarding seed vigor, the results of the first count test showed a similar trend to the germination test, with a quadratic regression model fit. The highest percentage of vigorous bean seedlings (90%) was obtained with the 250 mL per 100 kg seed dose of seaweed extract (Figure 5). Thus, the seed vigor results from the first count were consistent with the germination test results, confirming that seed treatment with seaweed extract is effective in significantly improving seed vigor and viability.

On the other hand, the lowest seed vigor percentage was observed in treatments that used seaweed extract doses above 250 mL per 100 kg of seeds, particularly in the highest dose tested, which resulted in values similar to the untreated control.

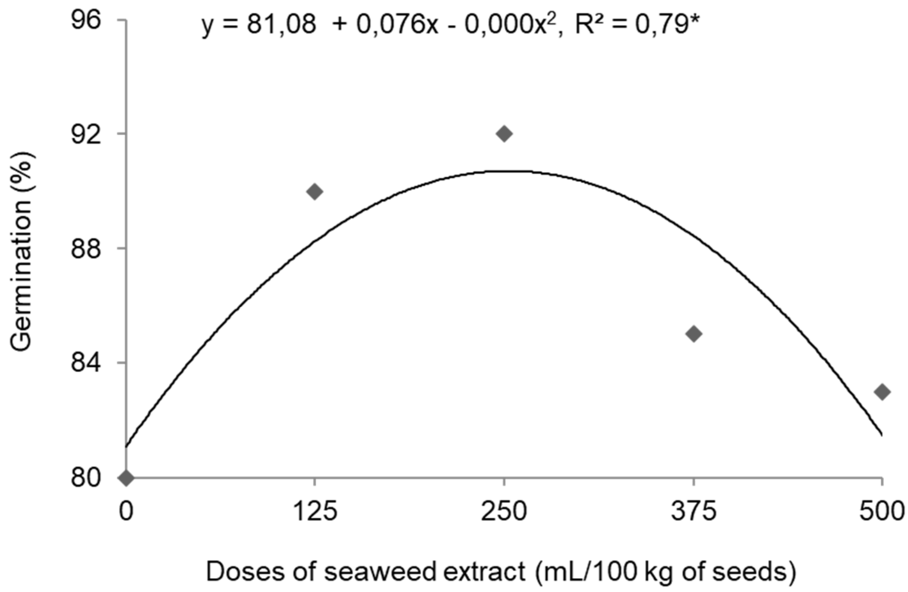

Figure 5. Percentage of normal seedlings (first count test) from common bean seeds (cv. BRS Estilo), subjected to different doses of *A. nodosum* based seaweed extract.

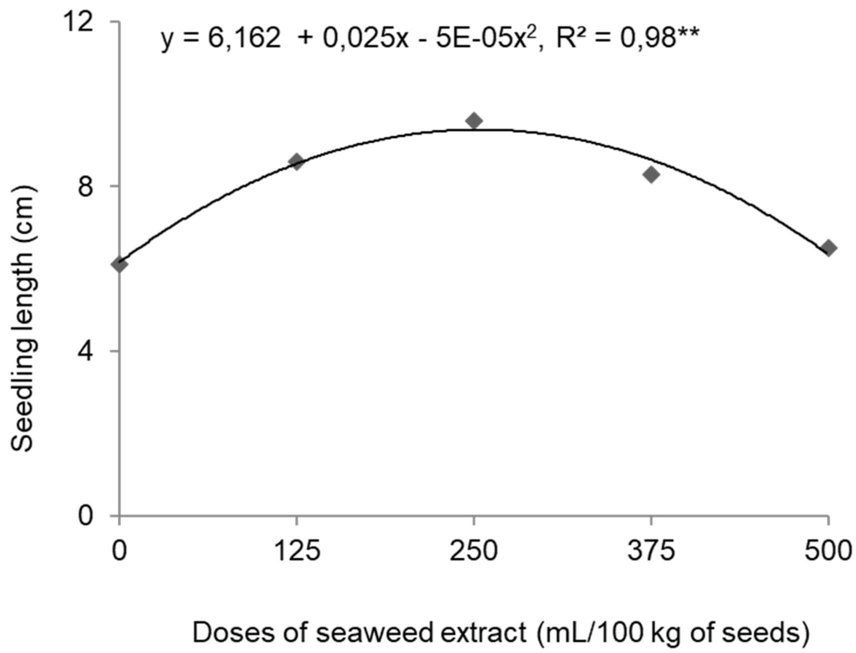

Figure 6. Normal seedling growth from common bean seeds (cv. BRS Estilo), subjected to different doses of *A. nodosum* based seaweed extract

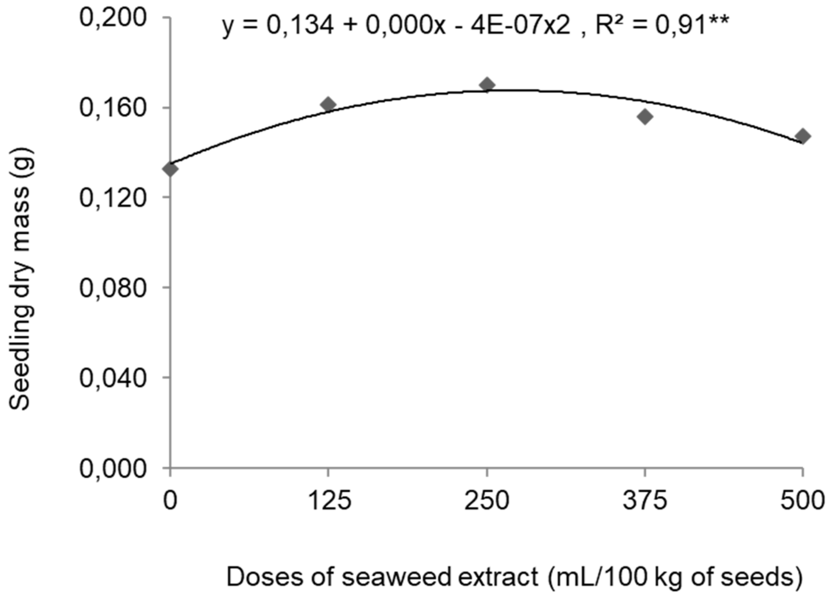

Figure 7. Dry mass of normal seedlings from common bean seeds (cv. BRS Estilo), subjected to different doses of *A. nodosum* based seaweed extract

The results of the seedling length test (Figure 6) and seedling dry mass test (Figure 7) showed trends similar to those observed in the germination and first count tests. In both tests, the 250 mL per 100 kg seed dose of seaweed extract led to the highest root growth (8.2 cm) and dry matter accumulation (0.170 g). The other tested doses showed lower quantitative values, particularly the highest tested dose, which produced results comparable to the control treatment. Based on the applied tests, it can be concluded that the 250 mL per 100 kg seed dose was the optimal dose of *A. nodosum* based seaweed extract for common bean seeds (cv. BRS Estilo), significantly improving seed viability and vigor.

3.3 Considerations

Although this study focused on the effects of seaweed extract on beans and chickpeas, it is important to consider that its effectiveness may vary across different crops due to physiological and environmental factors. Research involving wheat, corn, and vegetables could expand the understanding of the applicability of these biostimulants, consolidating their use in different agronomic contexts (SHUKLA et al., 2019).

In addition to promoting plant growth, seaweed extracts also have a positive impact on soil microbiota. Studies show that these compounds can influence microbial diversity and activity, creating a more favorable environment for nutrient cycling and soil health (DU JARDIN, 2015). To deepen this understanding, future research could explore these interactions in greater detail through microbiological analyses.

The promising results of this research reinforce the need to assess the continuous use of seaweed extracts over multiple growing seasons. Long-term studies would help identify potential prolonged impacts on soil fertility and crop productivity, providing a stronger foundation for agronomic recommendations (CHEN et al., 2021).

The large-scale adoption of biostimulants depends not only on their agronomic benefits but also on their economic feasibility. Although this study has demonstrated the physiological gains that contribute to production, it is essential to consider the cost of these products. Research indicates that the investment may be offset by increased productivity and reduced reliance on synthetic fertilizers (POVERO et al., 2016). In this regard, a detailed cost-benefit analysis would be crucial to guide future studies and their practical application.

4. Conclusions

The application of *A. nodosum* based organomineral seaweed extract influences the seed quality of chickpea and common bean.

A. nodosum seaweed extract doses exceeding 100 and 250 mL per 100 kg of seeds negatively affect the viability and vigor of chickpea and bean seeds, respectively.

The doses of 100 and 250 mL per 100 kg of seeds provide higher-quality seed lots for chickpea and common bean, respectively, improving seed physiological quality.

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Authors contributions

Sample: Prof. IRT was responsible for study design and revising. Sirs RGV, ABF, NM de BC and AMSF were responsible for data collection. Prof. IRT drafted the manuscript and Profs. GCST, CFL and JHM revised it. All authors read and approved the final manuscript. In this paragraph, also explain any special agreements concerning authorship, such as if authors contributed equally to the study.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.