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ORIGINAL RESEARCH PAPER

Initial development of *Lactuca sativa* (lettuce) using a biostimulant and bioactivator for hydroponic purposes

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Abstract: *Lactuca sativa* is a widely distributed *oleracea* species, commonly used in various Western and Asian cuisines. This study aimed to evaluate the initial development of *L. sativa* cv. Psique by applying different concentrations of the commercial biostimulant and bioactivator Vitakelp (mL/L^{-1}) and assessing total fresh weight, total dry mass, root length, and aerial part length of seedlings in two foliar application periods. In the first application, increases were observed in total fresh mass, total dry mass, and aerial part length. In the second application, positive increments were found in total dry mass and aerial part length. The commercial product Vitakelp showed good improvements in the initial development of *Lactuca sativa* seedlings at different concentrations, especially between 2-6 mL/L^{-1}.

Keywords: Lettuce; *Lactuca* genus; Biostimulants; Asteraceae f.; Production; Vegetable-bearing.

1. Introduction

Lactuca sativa (L.), known as "lettuce," is a vegetable belonging to the Asteraceae family and is classified among the widely cultivated and popularly used vegetables in various cuisines worldwide, particularly in the preparation of salads, soups, and vegetable curries (Noumedem et al., 2017). The largest lettuce producers are China, the USA, Spain, Italy, India, Japan, and Brazil (Křístková et al., 2008; Suinaga et al., 2013; Kim et al., 2016). There are many varieties in different colors, sizes, and shapes, and it is through these varieties that lettuces are grouped (Du et al., 2020).

Various cultivars of *L. sativa* are cultivated in different regions, primarily in tropical and subtropical areas. It is known that there is a wide spectrum of local races and ancient varieties of *L. sativa* maintained in gene banks around the world, as discussed by Lebeda et al. (2007). However, various conventional and modern breeding methods are producing new lettuce cultivars that can be adapted to new environments and climates to meet the specific demands of producers and consumers (Křístková et al., 2008).

The high annual consumption of leafy vegetables like lettuce drives producers to increase productivity to meet market demand. The various lettuce cultivars available today feature excellent genetics. To further enhance good harvests, numerous biological inputs and bioactivators are being tested, yielding excellent results by ensuring greater development and increased productivity in less time (Chaski; Petropoulos, 2022). Since lettuce is a leafy vegetable, the usual method of applying these biological inputs is via foliar application. Biologicals provide nutritional supplementation, plant hormones such as auxin, gibberellin, cytokinins, antitranspirants, chitin, and chitosan derivatives, as well as amino acids, N-containing substances, and carbohydrates through supplementation with freshwater or marine algae extracts, essential dissolved macro- and micronutrients, and organic carbon (Gomes Bezerra et al., 2007; Parađiković et al., 2019; Chaski; Petropoulos, 2022).

Studies have demonstrated that the application of biostimulants and bioactivators positively influences the development of lettuce seedlings. Chaski &

Petropoulos (2022) reported good results with the application of a biostimulant containing algae extracts, macronutrients, and amino acids (SW) combined with deficit irrigation. Their findings showed higher plant mass, leaf mass, and increased chlorophyll content in lettuce plants. Similarly, the study by Freire et al. (2004) also observed that foliar application of these products on lettuce promoted a reduction in transplant time, resulting in more vigorous seedlings of high quality.

In this context, it is crucial to evaluate the use of biostimulants and bioactivators applied via foliar spray at different stages of lettuce seedling development. This assessment aims to determine the gains in mass and the development of high-quality seedlings for planting in hydroponic systems or natural soil. Such practices can lead to increased income, reduced product loss, and improved quality of the final product delivered to consumers.

This study aimed to evaluate the morphological parameters in the initial development of the *Lactuca sativa* cultivar Psique under different biostimulant concentrations.

Figure 1. Individuals of *Lactuca sativa* cv. Psique at the initial stage of development used in the experiment. Source: Authors, 2024.

2. Material and Methods

2.1. Lettuce cultivar

The *L. sativa* cv. Psique, produced by Sakata Seed Sudamérica. Data: germination 95%, category S2, and harvest 2021/2021.

2.2. Biostimulant and dosages

The biostimulant and bioactive product used was the commercial Vitakelp® (Satis). The application method was foliar, with application rates for vegetables ranging from 300 to 500 mL ha^{-1}; and 10 to 30 mL 20 L^{-1} of water, with a biweekly application schedule.

The chemical composition of the biostimulant and bioactivator includes Urea (N_2) 15% p/p (168 g L^{-1}), seaweed extract, KCl 1% p/p (11.2 g L^{-1}), total organic carbon 4.5% p/p (50.4 g L^{-1}), and L-amino acids. Its physical nature is a suspension with a density of 1.12 g mL^{-1} and a solute/solvent ratio of 1 mL L^{-1}. The electrical conductivity is expressed as mS/cm^{-1} = 1.0, and the salinity index is 5.0%.

Two applications were performed: The first application was made 10 days after the emergence of *L. sativa* cv. Psique seedlings and the second application was made 12 days after the first. The concentrations used were 0, 2, 3, 4, 5, and 6 mL L^{-1} (*v/v*), with the 0 mL L^{-1} concentration serving as the control (without biostimulant and bioactivator application). Both applications with the product were carried out during the early hours of the day, from 6 to 7 am, using a backpack sprayer with CO_2 pressurization.

The experimental design used was 2x6, with 10 replications. The treatments involved the use of a commercial product with biostimulant and bioactivator functions, Vitakelp® Satis™, and six concentrations: 0, 2, 3, 4, 5, and 6 mL L^{-1}. The experimental unit consisted of trays with 128 cells, and at the time of the evaluations, the central 50 cells of each tray were considered the useful area.

The sowing of Lactuca sativa cv. Psique was carried out in 128-cell trays filled with the commercial substrate Carolina Soil, class CXI, with a pH of 5.5, EC (mS/cm^{-1}) of 0.7, moisture (%m/m) of 70%, density (mg/m^3) of 100, and composition including peat, vermiculite, PFTI, and PFT. Three seeds were placed in the center of each cell at a depth of 1 cm. After germination, thinning was performed, leaving only one seedling per cell. The irrigation system was sprinkler-based, with 5 applications during the day and 2 at night.

2.3. Experimental location

The experiment was conducted at the property of the first author of this study, "*Viveiro de Mudas Horta da Villa*," located at Rua 009, Qd. 15 and 16, Sector

Universitário, in the municipality of Rio Verde, Goiás, Brazil. The climate of the region is humid mesothermal, with two well-defined seasons: a rainy season from October to April and a dry season from May to September. The average annual temperature ranges between 20 and 25 °C.

2.4 Morphological analysis

The evaluations were performed 3 days after each application period. The seedlings were transferred to the Laboratory of Technological Chemistry at the Goiano Federal Institute, Rio Verde, Goiás, Brazil. The evaluated characteristics were total fresh weight (TFW) (g), total dry mass (TDM) (g) using a digital semi-analytical balance, total root length (TRL) (mm), and aerial part length (APL) (mm) using a digital caliper. After fresh analysis, the material was transferred to a forced-air oven at 55 °C for 6 h and then analyzed for dry mass.

2.5 Statistical analysis

The obtained data were subjected to analysis of variance, and when significant, they were further analyzed through regression using the statistical software Sisvar (Ferreira et al., 2019).

3. Results

The following, in Table 1, presents the statistical results of the most appropriate model for the morphological analysis of *L. sativa* seedlings in two evaluation periods, using different dosages of the biostimulant and bioactivator Vitakelp®. Only TFW, TDM, and APL were significant based on the quadratic model.

Table 1. Statistical variation parameters for the first evaluation of the biostimulant and bioactivator on *Lactuca sativa* cultivar Psique seedlings.

SV	Evaluation 1		
	FC	Model	CV (%)
TFW	22.72*	Quadratic	21.36
TDM	17.53*	Quadratic	24.61
TRL	1.25ns	-	15.96
APL	23.22*	Quadratic	11.00

Note: SV = Source of Variation. TFW = Total Fresh Weight; TDM = Total Dry Mass; TRL = Total Root Length, and APL = Aerial Part Length. Source: Authors, 2024.

Figure 2 presents the TFW values from the first application of Vitakelp®. The quadratic model provided the best fit to the data, with the concentration of 6 mL L^{-1} yielding the highest TFW value of 1.66 g.

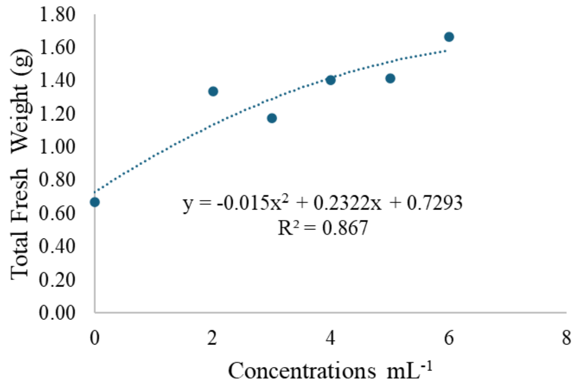

Figure 2. Total fresh weight of *Lactuca sativa* cv. Psique plants were evaluated in the first period under different Vitakelp® concentrations. Quadratic model. Source: Authors, 2024.

Figure 3 shows that the best concentration was 5 mL L^{-1}, with the quadratic model fitting the data, yielding the highest APL value of 53 mm.

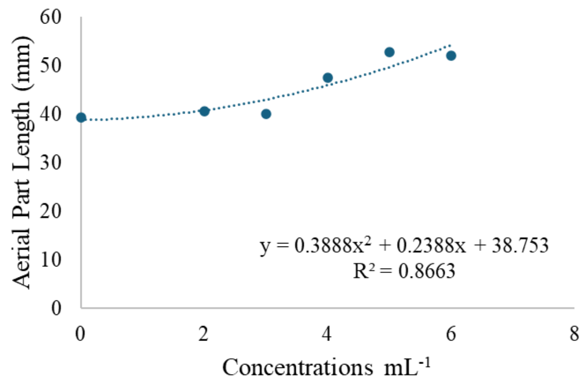

Figure 3. Aerial part length of *Lactuca sativa* cv. Psique at different concentrations of the biostimulant and bioactivator Vitakelp® in the first evaluation period. Quadratic model. Source: Authors, 2024.

For TDM in the first evaluation, the biostimulant and bioactivator Vitakelp® showed the greatest increase at concentrations of 5-6 mL L^{-1}, with no significant distinction between the two (Figure 4).

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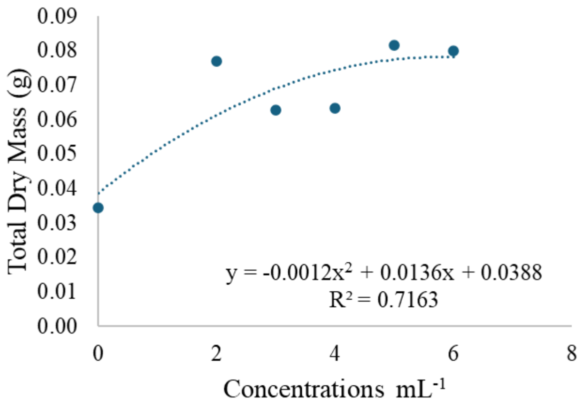

Figure 4. Total dry mass of *Lactuca sativa* cv. Psique plants were evaluated in the first period under different concentrations of Vitakelp®. Quadratic model. Source: Authors, 2024.

The following, in Table 2, presents the statistical results of the most appropriate model for the morphological analysis of *L. sativa* seedlings in two evaluation periods, using different dosages of the biostimulant and bioactivator Vitakelp®. In the second evaluation period, the product Vitakelp showed significant increases in TDM and APL in *L. sativa* cv. Psique seedlings.

Table 2. Statistical variation parameters for the second evaluation of the biostimulant and bioactivator on *Lactuca sativa* cultivar Psique seedlings.

SV	Evaluation 2		
	FC	Model	CV (%)
TFW	3.78ns	-	24.75
TDM	7.12*	Quadratic	23.35
TRL	1.13ns	-	14.40
APL	10.56*	Quadratic	10.55

Note: SV = Source of Variation. TFW = Total Fresh Weight; TDM = Total Dry Mass; TRL = Total Root Length, and APL = Aerial Part Length. Quadratic model. Source: Authors, 2024.

Figure 5 shows that the use of the biostimulant and bioactivator formulation Vitakelp® for APL demonstrated potential increases at concentrations of 5-6 mL L^{-1}, with values of 62-61 mm, showing no significant difference between the two.

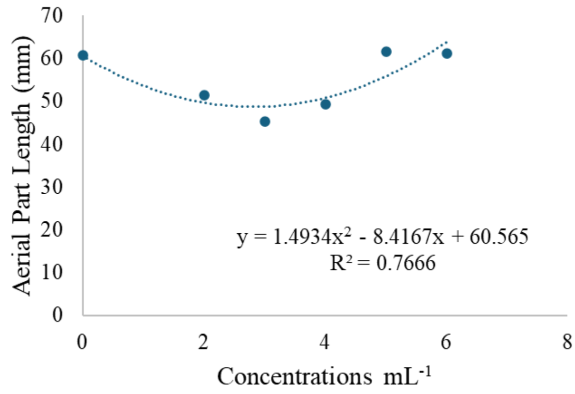

Figure 5. Aerial part length of *Lactuca sativa* cv. Psique plants in the second evaluation under different concentrations of the biostimulant and bioactivator Vitakelp®. Quadratic model. Source: Authors, 2024.

Figure 6 shows that the quadratic model best fitted the data for TDM values in the second evaluation using different concentrations of Vitakelp® in *L. sativa* cv. Psique plants. The concentration of 2 mL L^{-1} resulted in the highest increase in dry mass, with a value of 0.16 g.

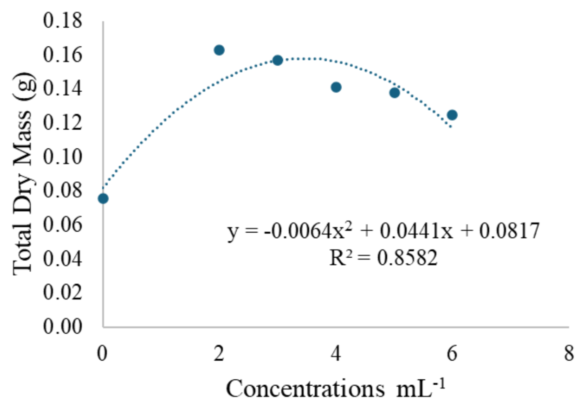

Figure 6. Total dry mass of *Lactuca sativa* cv. Psique plants in the second evaluation were treated with the foliar biostimulant and bioactivator Vitakelp®. Quadratic model. Source: Authors, 2024.

4. Discussion

Our results showed a significant effect for most of the morphological analyses, both for the first and second applications of the biostimulant and bioactivator Vitakelp®. Similar results were reported by Gomes Bezerra et al. (2007) using two biostimulants, Fertiactyl GZ®, and Ruterr AA®, composed of algae extract and hormones, on the *Lactuca sativa* cv. Babá-de-Verão. In this study, the researchers observed increases in aerial dry mass, root dry mass, and root length at the highest concentration (0.75%) using Fertiactyl GZ®. In this study, the number of leaves was also significant at the concentration of 0.75%, with 5-6 leaves per plant. The attributes of increased fresh and dry mass and aerial part length are important parameters, as levels of N, K_2O, and KCl are closely linked to the development of these parameters in economically important plants. Supporting our discussion, Radin et al. (2004) further emphasize that these nutrients play a crucial role in the initial development of seedlings, stimulating root and aerial part growth. Additionally, N and K are elements that are highly demanded throughout the cultivation cycle in all lettuce cultivars. Vendruscolo et al. (2016) found that the use of the biostimulant Stimulate® at a concentration of 3.33 mL L^{-1} promoted the production of more vigorous seedlings in lettuce cv. Salad Bowl.

Other studies using foliar application of biological stimulant products have not shown satisfactory results. In a study using algae extract, amino acids, and nutrients (Gold Carrier® and Panta 100®) on curly lettuce cv. Vanda, Limberger & Gheller (2012) tested three foliar applications but did not observe significant differences in the evaluated parameters for plant mass and plant diameter. However, the number of leaves showed a significant difference only for the biostimulant Panta 100®.

5. Conclusion

Based on the evaluated characteristics of lettuce seedlings of the Psique cultivar using the biostimulant and bioactivator Vitakelp®, it can be concluded that the product, at different concentrations—particularly 2-6 mL L^{-1} — enhanced morphological traits and mass gain, resulting in higher-quality seedlings in both application periods.

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Author's Contributions

João Vitor Nogueira de Souza: project drafting, experiment design, final article writing, and publication. *Antonio Carlos Pereira de Menezes Filho*: co-advisor, laboratory analyses, article translation, final revisions, and publication. *Matheus Vinícius Abadia Ventura*: advisor, statistical analysis, article writing, and publication.

Ethics

The authors declare that there are no conflicts of interest.