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Rocket production using organo-mineral fertilizers as a phosphorus source and plant growth-promoting bacteria

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Abstract

The use of organo-mineral fertilizers in vegetable crops is a promising technology for nutrient supply, particularly when combined with the inoculation of plant growth-promoting bacteria. The objective of this study was to evaluate the biometric parameters and physicochemical quality of rocket crops under the application of organo-mineral fertilizers as a phosphorus source, combined with the inoculation of growth-promoting bacteria. A greenhouse experiment was conducted using a randomized block design with four replications, in a 5 × 2 factorial arrangement consisting of five organo-mineral fertilizer rates (45, 90, 135, 180, and 225 kg ha^{-1} of P_2O_5), either with or without inoculation with plant growth-promoting bacteria. The optimal rate of coffee ground-based organo-mineral fertilizers to enhance production and achieve the highest shoot fresh weight in rocket plants was 176.73 kg ha^{-1} of P_2O_5. The effect of growth-promoting bacteria on rocket crops was significant for root system development, leading to greater growth. Rocket plants exhibited the highest physicochemical quality in terms of titratable acidity when grown under an organo-mineral fertilizer rate of 154 kg ha^{-1} of P_2O_5; however, lower rates are recommended to enhance soluble solids content and pH.

Keywords: *Eruca sativa*; bioinputs; efficient microorganisms; titratable acidity; soluble solids.

Practical Application: The use of coffee ground-based organo-mineral fertilizers as a phosphorus source enables the sustainable production of rocket crops with high physicochemical quality.

1 INTRODUCTION

Rocket (*Eruca sativa*) is one of the most widely consumed leafy vegetables worldwide due to its distinct flavor (Bell & Wagstaff, 2019), high nutritional value, and health benefits (Bueno et al., 2023). Furthermore, this species is among the socially and economically important cultivated plants and has been increasingly present in the Brazilian market (Bueno et al., 2023). Rocket crops have a short cycle and rapid growth, requiring a high concentration of nutrients within a short period (Nascimento et al., 2021). Cultivation requires practices that preserve organoleptic characteristics, as rocket is consumed fresh. Additionally, appropriate fertilizer application is a key factor for growth, efficient production, and plant quality.

Soil fertilizers composed of organic nutrient sources and mineral fertilizers, known as organo-mineral fertilizers, have been used to overcome the limitations of mineral and organic fertilizers and to improve application efficiency (Mumbach et al., 2020). According to Torres et al. (2022), this is a recent technology designed to promote sustainability in vegetable crops by efficiently supplying nutrients to plants. Organo-mineral fertilizers release nutrients gradually and uniformly throughout the crop cycle, improving nutrient use efficiency and yield (Uddin et al., 2025) while also promoting soil health and reducing environmental pollution.

In addition, the disposal of coffee grounds, a by-product of coffee brewing, poses significant environmental challenges, as coffee is widely consumed worldwide and the accumulation of coffee grounds represents a major global waste issue (Barbosa et al., 2024). Therefore, utilizing this by-product as a nutrient source in organo-mineral fertilizers offers both environmental and economic benefits for vegetable production.

Studies have shown that combining organo-mineral fertilizers with certain microorganisms can enhance plant nutrient uptake and production (Santos et al., 2022). According to

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Cassán et al. (2020), plant growth-promoting bacteria generally contribute to biological nitrogen fixation and phosphorus solubilization, induce systemic resistance, and aid in biocontrol against phytopathogens. Thus, this approach is economically and environmentally viable. Examples of species of plant growth-promoting bacteria include *Rhizobium tropici, Azospirillum brasiliense, Pseudomonas fluorescens, and Saccharomyces sp.* (Cândido et al., 2025).

Therefore, information on the application of this technology to rocket production is essential for ensuring profitable and sustainable cultivation, particularly concerning plant nutrition associated with the use of efficient microorganisms. In this context, the objective of this study was to evaluate the biometric parameters and physicochemical quality of rocket crops under the application of organo-mineral fertilizers as a phosphorus source, combined with the inoculation of plant growth-promoting bacteria.

1.1 Relevance of the work

The use of organo-mineral fertilizers derived from coffee grounds as a phosphorus source has shown positive effects on yield, as well as on the biometric and physicochemical parameters of rocket plants. This fertilizer is a promising alternative for vegetable production, particularly when combined with the inoculation of growth-promoting bacteria. Additionally, incorporating coffee grounds as a nutrient source in organo-mineral fertilizers provides environmental and economic advantages, leading to the production of rocket plants with high physicochemical quality.

2 MATERIAL AND METHODS

A greenhouse experiment was conducted in November 2022 at the experimental area of the State University of Goiás, Santa Helena University Unit, in Santa Helena de Goiás, Goiás, Brazil (17°48'49"S, 50°35'49"W, and 595 m altitude) (Figure 1). Climate conditions in the crop environment were monitored daily; data on minimum and maximum temperatures and relative air humidity were collected using a thermohygrometer, and thermal accumulation was estimated in degree-days (DD).

A randomized block experimental design with four replications was used in a 5 × 2 factorial arrangement, consisting of five organo-mineral fertilizer rates (45, 90, 135, 180, and 225 kg ha^{-1} of P_2O_5), either combined or not with inoculation with plant growth-promoting bacteria, resulting in 10 treatments and 40 experimental units. The experimental units consisted of 3-L pots filled with clayey soil typical of the region (Santos et al., 2018); the chemical and textural characteristics of the soil are described in Table 1.

The fertilizer rates applied to the rocket crops were determined based on the organo-mineral fertilizer composition (Table 2), the nutrient requirements of the plants, and soil nutrient availability. The phosphorus (P_2O_5) concentration in the organo-mineral fertilizer was used as a reference to calculate the application rate. The rates applied were 45, 90, 135, 180, and 225 kg ha^{-1} of P_2O_5, corresponding to 25, 50, 75, 100, and 125% of the calculated P_2O_5 requirement, respectively. The amount of fertilizer applied to each pot was calculated based on the pot volume (3 L) and the proportion for each treatment; the fertilizer was applied and incorporated into the soil 18 days before transplanting.

The plant growth-promoting bacteria used for inoculations were obtained from a commercial product (BioStart, Biosphera AgroSolutions), which contained a combination of microorganisms from four genera: *Azospirillum*, *Pseudomonas*, *Rhizobium*, and *Saccharomyces*. The application rate for inoculated treatments was 150 mL 10 m^{-3}. The proportional rate was achieved by diluting the product in the irrigation water volume, which was determined based on the daily reference evapotranspiration (ET_o), and then applied individually and uniformly to each pot at the time of rocket sowing. Seedlings were produced from seeds of the Folha Larga rocket cultivar and transplanted into the pots when they reached approximately 10 cm in height, with two plants per pot maintained throughout the experiment.

A mini-Class A tank was used for irrigation management, installed near the experimental area to determine daily evaporation in the Class A tank, with corrections applied using Equation 1:

$$ECA = 0.7829\ EMT - 0.521 \quad (1)$$

where

ECA: evaporation in the Class A tank (mm d^{-1});

EMT: evaporation of the mini-Class A tank evaporimeter (mm d^{-1}).

The daily evaporation in the Class A tank was used to calculate the reference evapotranspiration (ET_o) using Equation 2:

$$ETo = ECA \times Kp \quad (2)$$

where

ET_o: reference evapotranspiration (mm d^{-1});

ECA: evaporation in the Class A tank (mm d^{-1});

K_p: tank correction coefficient (dimensionless; $Kp = 1.0$).

The crop evapotranspiration (ET_c) was estimated using the standard Food and Agriculture Organization of the United Nations (FAO) method (Allen et al., 2006) with Equation 3:

$$ETc = ETo \times Kc \quad (3)$$

where

ET_c: crop evapotranspiration (mm d^{-1});

ET_o: reference evapotranspiration (mm d^{-1});

K_c: crop coefficient (dimensionless).

The crop coefficients (K_c) used were 0.29 for 0–8 days after transplanting (DAT); 0.52 for 9–16 DAT; 0.93 for 17–24 DAT; and 0.87 for 25–33 DAT, as described by Santana et al. (2016). The water volume applied to each pot was estimated based on the pot area and ET_c. The pots were irrigated using a graduated cylinder, applying volumes determined by the equations according to the crop water requirements at each developmental stage.

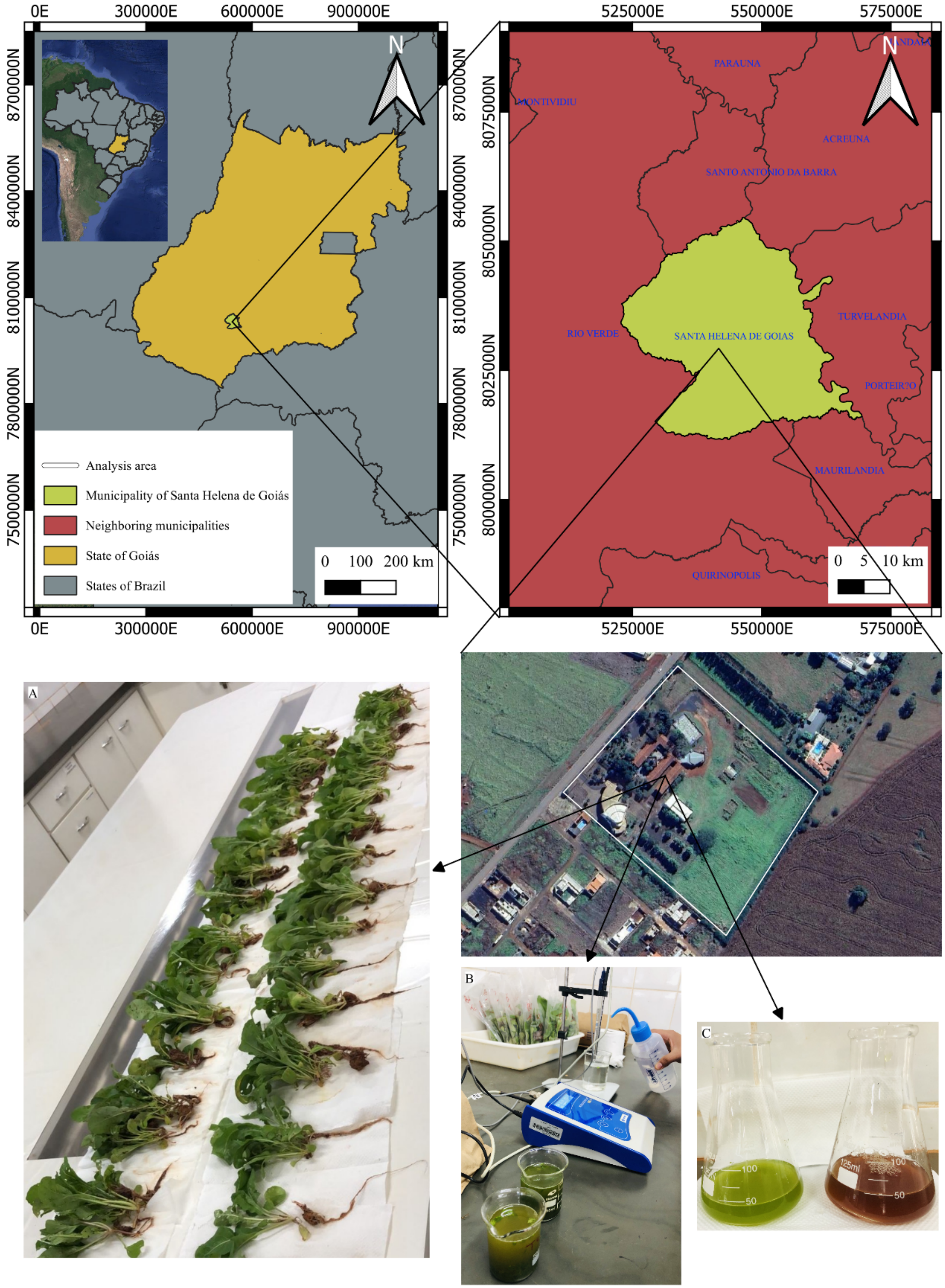


Figure 1. Location of the study area, rocket harvest point, and evaluation (A); pH (B); and titratable acidity analysis (C) of rocket.

The rocket plants were harvested upon reaching approximately 25 cm in height. Biometric and physicochemical characteristics were evaluated at 30 DAT (Figure 1A). Biometric characteristics included plant height (PH) (cm), measured with a ruler; number of leaves per plant; shoot fresh weight (SFW) (g plant^{-1}), measured on an analytical balance; yield (kg ha^{-1}), determined by the ratio between the rocket fresh weight and the pot area, corrected based on plant spacing and population; stem base diameter (mm), measured using a digital caliper; and root fresh weight (g plant^{-1}), measured by weighing the entire root system after separation from the shoot. Physicochemical characteristics included pH, measured directly using a bench pH meter, as described by Instituto Adolfo Lutz ([IAL], 2008) (Figure 1B); soluble solids content (SSC) (°Brix), determined through direct reading of the prepared supernatant in a digital refractometer at 25°C; and titratable acidity (TA), determined by titration with a standardized 0.1 N sodium hydroxide solution, as described by IAL (2008) (Figure 1C).

The data were subjected to analysis of variance at a 5% significance level. The rates of organo-mineral fertilizer applied to the rocket crops were compared using regression analysis, and plants with and without inoculation with growth-promoting bacteria were compared using Tukey's test at a 5% significance level. All statistical analyses were conducted using the SISVAR statistical program (Ferreira, 2019).

3 RESULTS AND DISCUSSION

3.1 Climate variables

Data on maximum and minimum temperatures and crop evapotranspiration (ET_c) in the protected environment during the experimental period are shown in Figure 2A. The maximum temperature ranged from 22.3 to 47.4°C, the minimum temperature ranged from 21.4 to 22.9°C, and the mean temperature ranged from 21.9 to 34.9°C. Figueiredo et al. (2012) reported that the ideal mean temperature for rocket plants varies from 20 to 35°C. Thus, the mean temperature during the experiment was within the ideal range for rocket development. According to Filgueira (2008), rocket quality is better when produced under milder temperatures, as high temperatures cause the leaves to become smaller and more rigid.

The reference evapotranspiration (ET_o) during the experiment ranged from 0.26 to 4.18 mm d^{-1}, varying according to the environmental temperature. The mean crop evapotranspiration (ET_c) was 1.60 mm d^{-1}, varying between 0.24 and 3.16 mm d^{-1} (Figure 2A), with higher ET_c values observed near harvest time. Santana et al. (2016) reported a mean ET_c of 3.36 mm d^{-1} for rocket crops, whereas Cunha et al. (2013) observed ET_c ranging from 1.0 to 5.8 mm d^{-1}. According to Santana et al. (2016), a larger leaf area in rocket plants enables a higher photosynthetic rate, thereby increasing crop evapotranspiration.

The Folha Larga rocket cultivar exhibited a 30-day cycle under the edaphoclimatic conditions of Santa Helena de Goiás, requiring a thermal accumulation of 725.40 DD from transplant to harvest (Figure 2B). Gonçalves Júnior et al. (2019) studied thermal accumulation in rocket crops grown in an open field and observed a 41-day crop cycle and a thermal accumulation requirement from sowing to harvest of 597.10 DD. According

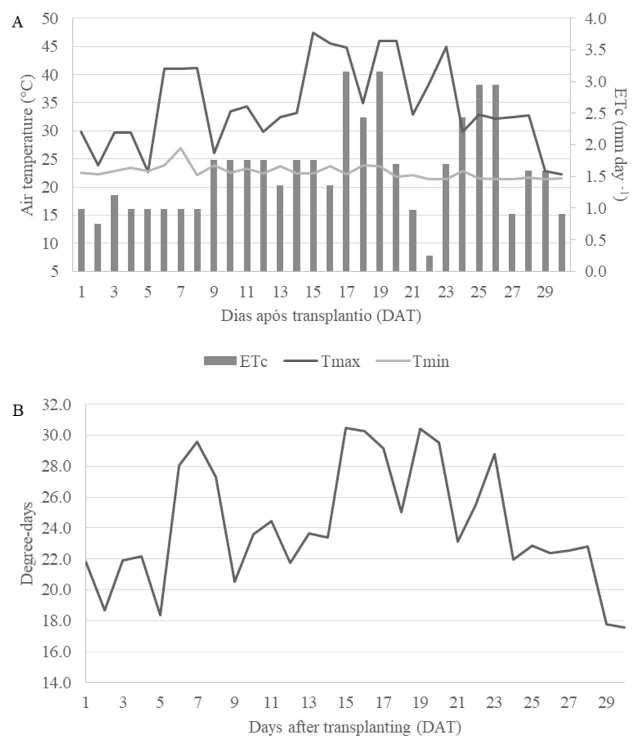


Figure 2. Maximum (T_{max}) and minimum (T_{min}) air temperatures, crop evapotranspiration (ET_c) (A), and the evolution of energy accumulation (degree-days) according to the thermal requirements (B) of rocket crops from November 23 to December 23, 2022.

Table 1. Chemical and textural characteristics of the 0.0–0.2 m layer of the soil used in the experiment.

pH $CaCl_2$ (1:2.5)	P Meh-1	K^+	Ca^{2+}	Mg^{2+}	H + Al	SB	OM	Clay	Silt	Sand
	(mg dm^{-3})		(cmol$_c$ dm^{-3})				(dag kg^{-1})		(%)	
5.3	1.5	17	1.75	0.27	2.15	2.07	14.2	44.5	15.0	40.5

SB: sum of bases; OM: organic matter.

Table 2. Chemical analysis of the organo-mineral fertilizer used in the experiment.

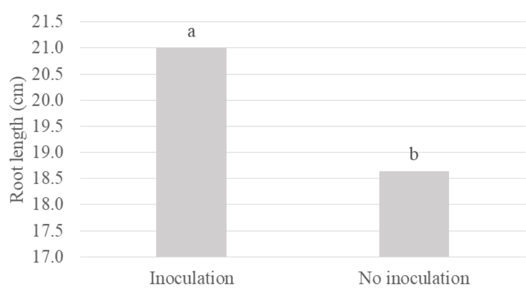
N	P	K	Ca	pH H_2O	Zn	B
(g kg^{-1})				(1:2.5)	mg kg^{-1}	
11.5	16	10.5	95	2.5	150	120

to Barreiros et al. (2021), the determination of DD presupposes the existence of lower and higher basal temperatures, below and above which the plant exhibits no or very reduced leaf expansion.

The highest energy accumulations were observed at 7 (29.60 DD), 15 (30.50 DD), 16 (30.26 DD), and 17 DAT (29.05 DD), whereas the lowest was recorded at 2 (18.70 DD), 5 (18.35 DD), 29 (17.75 DD), and 30 DAT (17.55 DD) (Figure 2B). Thus, the evaluated rocket cultivar exhibited the highest thermal accumulation in the middle of its crop cycle.

3.2 Rocket biometric parameters

The biometric parameters of the rocket crops grown under a protected environment were significantly affected by organo-mineral fertilizer rates, particularly PH, stem diameter (SD), root length (RL), and SFW. The effect of plant growth-promoting bacteria was significant only for RL. Although evaluated at 30 DAT, plant growth-promoting bacteria had a positive and significant effect on root growth, which was approximately 11% higher in inoculated plants (Figure 3).



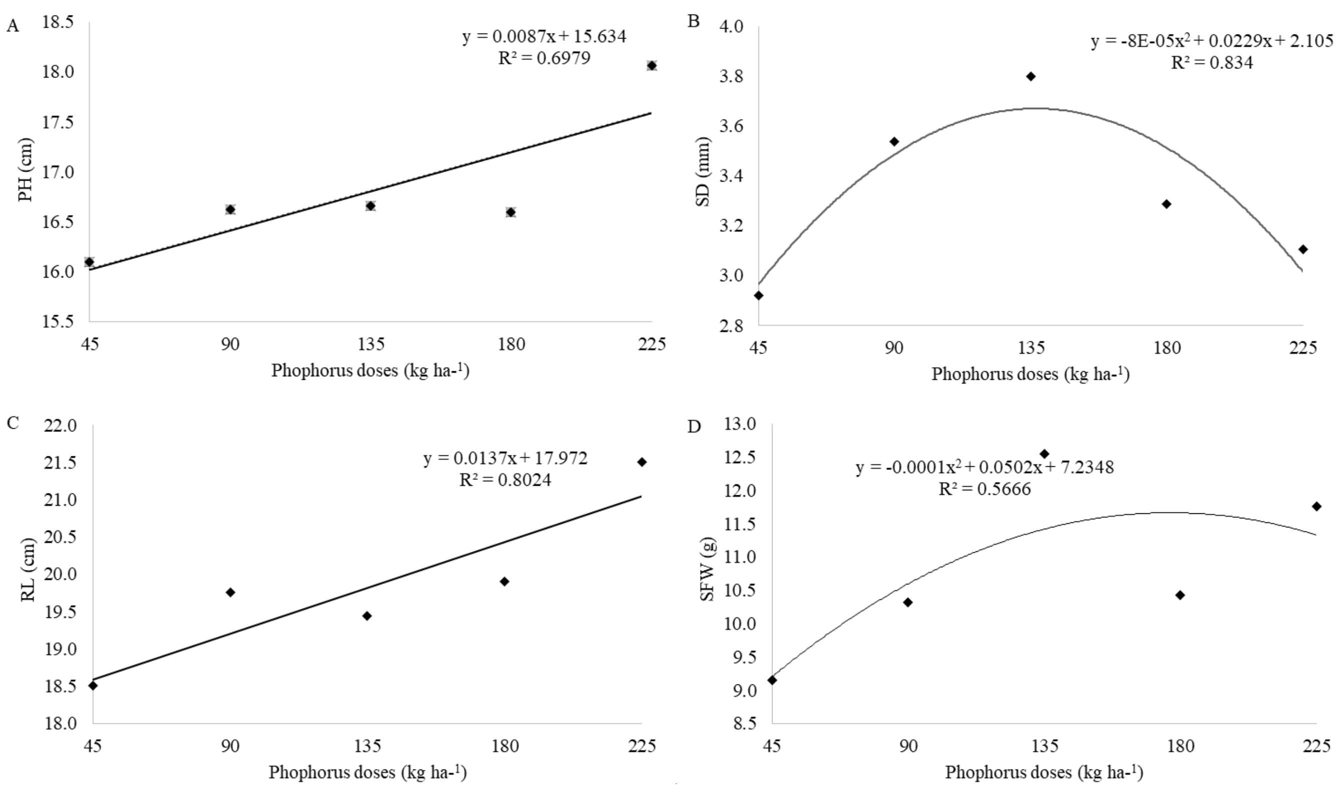
Column with different letters are significantly different by the Tukey's test at a 5% significance level.

Figure 3. Root length of rocket plants with and without inoculation with plant growth-promoting bacteria.

Cândido et al. (2025) reported that root growth is associated with root biomass accumulation due to the secretion of substances by inoculated microorganisms that promote root development. According to Dhiman and Dubey (2017), the complementary effect of inoculants on mineral or organic fertilizer application is attributed to increased microbial activity in the rhizosphere, which enhances hormonal activity in roots and improves nutrient absorption.

PH exhibited a linear increase as the organo-mineral fertilizer rate increased, regardless of inoculation (Figure 4A). The mean PH ranged from 16.09 cm (45 kg ha^{-1} of P_2O_5) to 18.11 cm (225 kg ha^{-1}). Matos et al. (2019) reported heights of up to 17 cm for rocket plants of the same cultivar, whereas Lima et al. (2025) observed heights ranging from 15.27 to 18.49 cm, which are consistent with the results of the present study.

The equation in Figure 4A had a coefficient of determination (R^2) of 0.6979, indicating that PH increased by 0.0087 cm for each additional kilogram of P_2O_5 per hectare. According to Santos and Akiba (1996), high biofertilizer concentrations can induce metabolic deviations associated with the production of defense compounds, potentially delaying the growth, flowering, and fruiting of many plant species. Therefore, the fertilizer rates used did not have deleterious effects on plant development.



PH: plant height; SD: stem diameter; RL: root length; SFW: shoot fresh weight.

Figure 4. Plant height (A), stem diameter (B), root length (C), and shoot fresh weight (D) of rocket plants grown under the effect of phosphorus rates from an organo-mineral fertilizer.

SD (Figure 4B) followed a quadratic polynomial regression in response to the organo-mineral fertilizer rates, increasing up to 136.29 kg ha^{-1} of P_2O_5, where the highest SD (4.41 mm) was observed.

RL (Figure 4C) exhibited a linear increase in response to the organo-mineral fertilizer rates, increasing by 0.0137 cm per additional kilogram of P_2O_5 per hectare. The RL varied from 18 to 22 cm, with a tendency to increase as phosphorus rates increased. These values were greater than those reported by Caixeta et al. (2017), who applied mineral fertilizers and observed RLs ranging from 9.50 to 14.50 cm. Therefore, PH (Figure 4A) and RL (Figure 4C) exhibited similar responses to phosphorus rates, consistent with Santos et al. (2022), who reported that an increase in root biomass enhances nutrient absorption, leading to greater leaf weight accumulation.

SFW ranged from 8.5 to 13 g (Figure 4D), with results fitting a quadratic equation. Increasing phosphorus rates had a positive effect on fresh weight, with maximum weight (11.67 g) observed at 176.73 kg ha^{-1} of P_2O_5. Vieira et al. (2020) applied a 50% organo-mineral fertilizer across different soils for growing cabbage crops and reported fresh and dry weight yields at least 11% higher than those obtained with exclusive mineral fertilizer application, highlighting the importance and effectiveness of replacing mineral fertilizers with organic alternatives in vegetable production.

3.3 Rocket physicochemical quality parameters

Freshness is one of the most important characteristics of rocket plants, as they are sold in their fresh form. According to Batista et al. (2016), plant nutritional management influences the production of sugars and acids in vegetables. The pH of fresh rocket leaves decreased linearly, ranging from 6.1 to 5.7, with a reduction of 0.0008 per additional kilogram of P_2O_5 per hectare (Figure 5A). Pereira et al. (2015) reported a mean pH of approximately 5.6 in organic rocket leaves, whereas Lino et al. (2023) observed low pH values, reaching 5.53, which are consistent with those observed in the present study. Furthermore, Lino et al. (2023) observed a pH decrease with increasing green manure application rates, highlighting the importance of adequate fertilizer application for producing high-quality leafy vegetables.

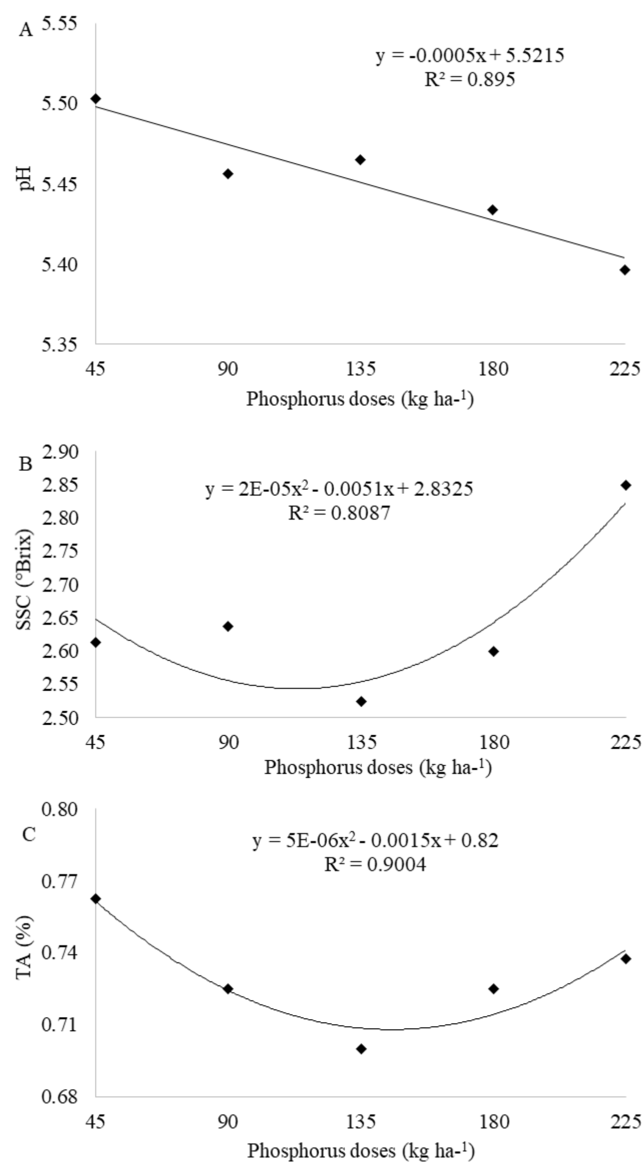
SSC in rocket leaves ranged from 1.4 to 3.6 °Brix, showing a quadratic response to increasing phosphorus rates. The lowest value (2.53 °Brix) was observed at 115.89 kg ha^{-1} of P_2O_5 (Figure 5B). Campos et al. (2013) evaluated the SSC in conventional and organic rocket cultivars, reporting 3.21 and 3.66 °Brix, respectively. Meinerz et al. (2021) reported values ranging from 3.0 to 5.8 °Brix, regardless of storage time.

TA showed a quadratic response to increasing phosphorus rates, reaching its lowest value (0.70%) at 154 kg ha^{-1} of P_2O_5 (Figure 5C). Campos et al. (2013) compared TA in conventional and organic rocket crops, reporting values of 0.50 and 0.40%, respectively. Jardina et al. (2017) observed values ranging from 0.30 to 0.34% in different rocket cultivars. Malic acid content determines the acidity and, consequently, the flavor of rocket leaves, influencing the consumer preference at the time of purchase (Meinerz et al., 2021).

Therefore, the use of coffee ground-based organo-mineral fertilizers as a phosphorus source positively impacts the production, biometric characteristics, and physicochemical quality of rocket plants, making it a promising alternative for sustainable vegetable production.

4 CONCLUSION

The use of coffee ground-based organo-mineral fertilizers proved to be an effective management strategy for increasing rocket crop yield and SFW, with the optimal phosphorus rate of 176.73 kg ha^{-1} of P_2O_5 yielding the best results.



SSC: soluble solids content; TA: titratable acidity.

Figure 5. pH in water (A), soluble solids content (B), and titratable acidity (C) of rocket leaves under the effect of phosphorus rates from an organo-mineral fertilizer.

Inoculation of rocket plants with plant growth-promoting bacteria significantly enhanced root system development, resulting in greater root growth.

The highest physicochemical quality of rocket plants, in terms of TA, was observed at the organo-mineral fertilizer rate of 154 kg ha^{-1} of P_2O_5. However, lower rates are recommended to enhance SSC and pH, thereby improving overall leaf quality.

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REFERENCES

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (2006). *Evapotranspiración del cultivo: Guías para la determinación de los requerimientos de agua de los cultivos*. Food and Agriculture Organization. https://www.fao.org/4/x0490s/x0490s00.htm

Barbosa, N. S., Luz, M. S., Sousa, N. G., & Santos, K. G. (2024). Development and evaluation of slow-release organomineral phosphate fertilizer based on coffee waste. *Ciência e Agrotecnologia*, *48*, Article e018323. https://doi.org/10.1590/1413-7054202448018323

Barreiros, I. T., Oliveira, V. F. S., Minuzzi, R. B., Rover, S., Suzuki, V. M., & Barcelos-Oliveira, J. L. (2021). Temperatura Basal Inferior e Soma Térmica da Rúcula em Sistemas de Produção Convencional e Hidropônico, *Revista Brasileira de Meteorologia*, *36*(1), 107–113. https://doi.org/10.1590/0102-77863610010

Batista, M. A. V., Bezerra Neto, F., Silva, M. L., Ambrósio, M. M. Q., & Cunha, J. L. X. (2016). Atributos de solo-planta e de produção de beterraba influenciados pela adubação com espécies da Caatinga. *Horticultura Brasileira*, *34*(1), 12–19. https://doi.org/10.1590/S0102-053620160000100005

Bell, L. &, Wagstaff, C. (2019). Rocket science: A review of phytochemical & health-related research in Eruca & Diplotaxis species. *Food Chemistry: X*, *1*, Article e100002. https://doi.org/10.1016/j.fochx.2018.100002

Bueno, A. E. P., Arruda, E. M., Brito, S. G., & Riva Neto, D. C. O. (2023). Parcelamento da adubação nitrogenada na cultura da rúcula em solo de textura argilosa. *Scientific Electronic Archives*, *16*(7), 21–28. http://doi.org/10.36560/16720231752

Caixeta, M. M. A., Almeida, M. J., Winder, A. R. S., Darin, E. P., & Buso, W. H. D. (2017). Desempenho da rúcula cultivada em diferentes modos de adubação. *Revista Mirante*, *10*(2), 191–200. https://www.revista.ueg.br/index.php/mirante/article/view/6419

Campos, B., Oliveira, V. S., & Oshiro, A. M. (2013). Avaliação química de rúcula de diferentes procedências. *Revista Interbio*, *7*(1), 54–60. https://www.unigran.br/revistas/interbio/trabalho/791

Cândido, R. S., Silva, P. C., Delmond, J. G., Giongo, P. R., Couto, E. S., Silva, L. I., Ferreira, A. F. A., Araújo, E. S., Valério, C. M. B., & Costa, A. R. (2025). Effects of plant growth-promoting bacteria on the performance of chickpea seedlings. *Food Science and Technology*, *45*, Article e00415. https://doi.org/10.5327/fst.00415

Cassán, F., Coniglio, A., López, G., Molina, R., Nievas, S., Carlan, C. L. N., Donadio, F., Torres, D., Rosas, S., Pedrosa, F. O., Souza, E., Zorita, M. D., de-Bashan, L., & Mora, V. (2020). Everything you must know about Azospirillum and its impact on agriculture and beyond. *Biology and Fertility of Soils*, *56*(1), 461–479. https://doi.org/10.1007/s00374-020-01463-y

Cunha, F. F., Godoy, A. R., Magalhães, F. F., Castro, M. A., & Leal, A. J. F. (2013). Irrigação de diferentes cultivares de rúcula no nordeste do Mato Grosso do Sul. *Water Resources and Irrigation Management*, *2*(3), 131–141. https://www.researchgate.net/publication/320237944_Irrigation_of_different_cultivars_of_rocket_in_Northeastern_of_Mato_Grosso_do_Sul_State_Brazil

Dhiman, S., & Dubey, Y. P. (2017). Effect of biofertilizers and inorganic fertilizers on yield attributes, yield and quality of Triticum aestivum and zea mays in an acid alfisol. *International Journal of Current Microbiology and Applied Sciences*, *6*(7), 2594–2603. https://doi.org/10.20546/ijcmas.2017.606.366

Ferreira, D. F. (2019). SISVAR: a computer analysis system to fixed effects split plot type designs. *Revista Brasileira de Biometria*, *37*(4), 529–535. https://doi.org/10.28951/rbb.v37i4.450

Figueiredo, J. A. A., Inagaki, A. M., Seabra Junior, S., Silva, M. B. D. A., Diamante, M. S., & Aquino, C. R. (2012). *Cultivo de rúcula sob diferentes telados e campo aberto em conduções de alta temperatura e pluviosidade*. Anais do 52º Congresso Brasileiro de Olericultura, Salvador, BA, Brazil.

Filgueira, F. A. R. (2008). *Novo Manual de Olericultura: Agrotecnologia Moderna na Produção e Comercialização de Hortaliças* (3rd ed.). Editora UFV.

Gonçalves Júnior, A. S., Lima, E. A., Brito, A. M., Almeida, P. S., & Brito, V. A. (2019, September 17–19). *Acúmulo térmico na cultura da rúcula (Eruca vesicaria sativa)* [Paper presentation]. Congresso Técnico Científico da Engenharia e da Agronomia, Palmas, TO, Brazil. https://www.confea.org.br/sites/default/files/uploads-imce/Contecc2019/Agronomia/ACUMULO%20TERMICO%20NA%20CULTURA%20DA%20RUCULA%20%28Eruca%20vesicria%20sativa%29.pdf

Instituto Adolfo Lutz. (2008). *Métodos físico-químicos para análise de alimentos* (4th ed.). Instituto Adolfo Lutz.

Jardina, L. L., Cordeiro, C. A. M., Silva, M. C. C., Sanches, A. G., & Araújo Júnior, P. V. (2017). Desempenho produtivo e qualidade de cultivares de rúcula em sistema semi-hidropônico. *Revista de Agricultura Neotropical*, *4*(1), 78–82. https://doi.org/10.32404/rean.v4i1.1399

Lima, J. S. S., Bezerra Neto, F., Carmo, I. D. J. S., Silva, J. P. P., Santos, E. C., Azevedo, M. C., Rodrigues, G. S. O., & Frutuoso, R. M. S. (2025). Optimizing roostertree biomass for arugula production in semi-arid regions. *Revista Caatinga*, *38*, Article e12604. https://doi.org/10.1590/1983-21252025v3812604rc

Lino, V. A. S., Bezerra Neto, F., Santos, E. C., Guerra, N. M., Lino, F. K. K. S., & Silva, J. P. P. (2023). Post-harvest indexes and colour parameters from arugula–beet intercropping under green manuring and population density. *Revista Ciência Agronômica*, *54*, Article e20228560. https://doi.org/10.5935/1806-6690.20230059

Matos, E. R., Costa, A. R., Silva, P. C., Silva, F. F., Costa, A. M., & Vidal, V. M. (2019). Agro industrial waste as source of N for the production of Eruca sativa. *Australian Journal of Basic and Applied Sciences*, *13*(1), 17–22. https://doi.org/10.22587/ajbas.2019.13.1.3

Meinerz, M. J. A. O., Santos, E. C., Porto, V. C. N., Lima, R. K. B., & Silva, F. S. O. (2021). Qualidade química e físico-química de rúcula orgânica em função do período de colheita e armazenamento. *Revista em Agronegócio e Meio Ambiente*, *14*(3), Article e8320. https://doi.org/10.17765/2176-9168.2021v14n3e8320

Mumbach, G. L., Gatiboni, L. C., Bona, F. D., Schmitt, D. E., Corrêa, J. C., Gabriel, C. A., Dall'Orsoletta, D. J., & Iochims, D. A. (2020). Agronomic efficiency of organomineral fertilizer in sequential grain crops in southern Brazil. *Agronomy Journal*, *112*(4), 3037–3049. https://doi.org/10.1002/agj2.20238

Nascimento, C., S., Nascimento, C., S., & Cecílio Filho, A. B. (2021). Doses and split nitrogen fertilizer applications on the productivity and quality of arugula. *Revista Caatinga*, *34*(4), 824–829. https://doi.org/10.1590/1983-21252021v34n409rc

Pereira, E. M., Santos, Y. M. G., Leite Filho, M. T., Fragoso, S. P., & Pereira, B. B. M. (2015). Qualidade pós-colheita de frutas e hortaliças cultivadas de forma orgânica. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, *10*(2), 56–60. https://doi.org/10.18378/rvads.v10i2.3441

Santana, M. J., Ribeiro, A. A., & Mancin, C. A. (2016). Evapotranspiração e coeficientes de cultura para a alface e rúcula cultivadas em Uberaba, MG. *Revista Inova Ciência & Tecnologia*, *2*(2), 7–13. https://periodicos.iftm.edu.br/index.php/inova/article/view/34

Santos, A. C. V., & Akiba, F. (1996). *Biofertilizante líquido: uso correto na agricultura alternativa* (1st ed.). Universidade Federal Rural do Rio de Janeiro.

Santos, H. G., Jacomine, P. K. T., Anjos, L. H. C. Oliveira, V. Á., Lumbreras, J. F., Coelho, M. R., Almeida, J. A., Araújo Filho, J. C., Oliveira, J. B., & Cunha, T. J. F. (2018). *Sistema Brasileiro de Classificação de Solos* (5th ed.). Embrapa Solos.

Santos, H. L., Silva, G. F., Carnietto, M. R. A., Oliveira, L. C., Nogueira, C. H. C., & Silva, M. A. (2022). Bacillus velezensis associated with organomineral fertilizer and reduced phosphate doses improves soil microbial—chemical properties and biomass of sugarcane. *Agronomy*, *12*(11), Article 2701. https://doi.org/10.3390/agronomy12112701

Torres, J. L. R., Silva, G. G., Charlo, H. C. O., Loss, A., Lemes, E. M., & Vieira, D. M. S. (2022). Lettuce crop fertilized with organomineral source of phosphorus and micronutrients. *Horticultura Brasileira*, *40*(4), 393–402. http://dx.doi.org/10.1590/s0102-0536-20220407

Uddin, M. K., Saha, B. K., Wong, V. N. L., & Patti, A. F. (2025). Organo-mineral fertilizer to sustain soil health and crop yield for reducing environmental impact: a comprehensive review, *European Journal of Agronomy*, *162*, Article 127433. https://doi.org/10.1016/j.eja.2024.127433

Vieira, D. M. S., Camargo, R., Torres, J. L. R., Silva, A. A., Lana, R. M. Q., & Carvalho, F. J. (2020). Growing vegetables in succession in different soils and doses of phosphorus in an organomineral fertilizer. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *24*(12), 806–813. http://doi.org/10.1590/1807-1929/agriambi.v24n12p806-813