Colegio de Postgraduados

Foliar application of amino acids improves growth and productivity of radish (*Raphanus sativus* L.)

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ABSTRACT

Objective: Foliar application of amino acids can be an ecological alternative to increase the productivity of horticultural plants. Therefore, the objective of this study was to evaluate the effect of foliar application of the amino acid-based growth promoter VIUSID agro® (VA) on the radish growth and productivity variety 'Red Hazera'.

Design/methodology/approach: An experiment was carried out in a randomized block design with three treatments and five replicates. A control (VA0) and two concentrations of the growth promoter at 1.2- and 1.5-mL L^{-1} were applied in improving leaf area, chlorophyll content, dry and fresh biomass of leaves and tubers, growth rates, and agricultural yield.

Results: The results showed that the foliar application of growth promoter influenced positively on radish growth and productivity, especially the concentrations of 1.5 mL L^{-1} showed higher TCC, TAN, FTB, polar diameter and increased agricultural yield by 21% compared to the control treatments Nonetheless, foliar application of growth promoter at concentration of 1.2 mL L^{-1} improves TDB, CC, LFB, LA and the agricultural yield was 10% high than the control treatment.

Findings/conclusions: Taken together, the results of this study indicated that foliar application of growth promoter is an alternative strategy for increasing radish productivity under garden conditions.

Keywords: amino acids, vegetables, urban agriculture, yield, VIUSID agro®.

Citation: Peña-Calzada, K., Rodríguez-Miranda, D., Calero-Hurtado, A., García-González, M. T., Gato-Martínez, I., Rodríguez-Fernández, J. C., & Meléndrez Rodríguez, J. F. (2025). Foliar application of amino acids improves growth and productivity of radish (*Raphanus sativus* L.). *Agro Productividad*. https://doi.org/10.32854/rs9d8314

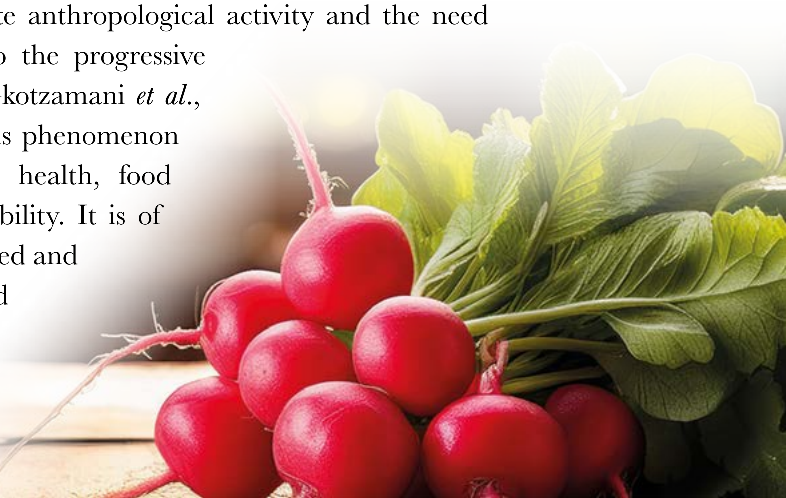
Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: December 28, 2024.
Accepted: March 25, 2025.
Published on-line: May XX, 2025.

Agro Productividad, 18(4). April. 2025. pp: 207-218.

INTRODUCTION

Climate change causing direct and indirect effects, which limiting plant productivity such as drought, uneven rainfall distribution, soil salinization and elevated temperatures, are largely caused by inadequate anthropological activity and the need for intensive agriculture due to the progressive increase in world population (Gkotzamani *et al.*, 2024; Makuya *et al.*, 2024). This phenomenon represents a threat to human health, food security and ecological sustainability. It is of particular concern in marginalized and vulnerable communities around the world, where action is urgently needed to reduce



adverse climate impacts and support the sustainable development goals, especially as they relate to food (Amoak *et al.*, 2022).

In this context, it is crucial to increase food production with strategies that promote environmental conservation. In this sense, the foliar application of beneficial elements, including bioproducts and amino acids, becomes an important option to consider (Peña Calzada *et al.*, 2022). On the other hand, it has been documented that amino acid-based growth promoters can stimulate growth and production in agricultural crops without causing negative impacts on the environment (Matysiak *et al.*, 2020). In addition, recent research has shown that these products can improve the quality of agricultural products when are applied via foliarly (Hu *et al.*, 2023). Moreover, spraying amino acids such as alanine (Ala), arginine (Arg), glutamine (Glu), glycine (Gly), methionine (Met) and proline (Pro) has been shown to be effective in mitigating the effects of abiotic stress in vegetables and grains (Abdelkader *et al.*, 2023; Repke *et al.*, 2022) and can benefit vegetative growth, fruit set, yield, and fruit quality (Almutairi *et al.*, 2022).

Another element to take into account is nitrogen (N), which is among the main elements affecting plant development, physiology and metabolism (Olivera-Viciedo *et al.*, 2024). N assimilation is related to key physiological or metabolic processes in plants, such as photosynthesis, photorespiration, respiration, amino acid synthesis, and the tricarboxylic acid (TCA) cycle (Li *et al.*, 2024). In addition, organic N also favors the ability of plants to cope with biotic and abiotic stresses (Wang *et al.*, 2022), so combined with foliar application of organic N with amino acids can be beneficial.

VIUSID agro is a growth promoter that contains important amino acids such as glycine, tryptophan, alanine, arginine and organic nitrogen in its composition. The effect of the product has been demonstrated in several important crops like that soybean (*Glycine max* L.) (Peña-Calzada *et al.*, 2022), corn (*Zea mays* L.) (Absy *et al.*, 2018; Peña *et al.*, 2021) and multiple species, where vegetables stand out (Peña *et al.*, 2017). In radish, the effect of the product has not been sufficiently studied and this is the first result obtained in the variety 'Red Hazera'.

Therefore, the following hypotheses were presented i) the foliar application of the growth promoter benefits dry mass accumulation, growth rates, as well as total chlorophyll content and yield. ii) the capacity to increase the evaluated variables will be greater as the doses increase. To verify this, the objective of the research was to evaluate the effect of foliar application of the amino acid-based growth promoter (VIUSID agro®) on radish growth and productivity variety 'Red Hazera'.

MATERIALS AND METHODS

Research overview

The research was carried out in the experimental area of the University of Sancti Spíritus José Martí Pérez, located at the coordinates (21° 93' 27.95" N 79° 43' 40.90" W). The variety used was 'Red Hazera', obtained from the seed company with 96% germination. Irrigation was by sprinkling, twice a day. The temperature, humidity and rainfall were recorded by the Provincial Station of Sancti Spíritus, Figure 1. The planting date was March 13, 2023 and was harvested on April 18 of the same year. For substrate preparation,

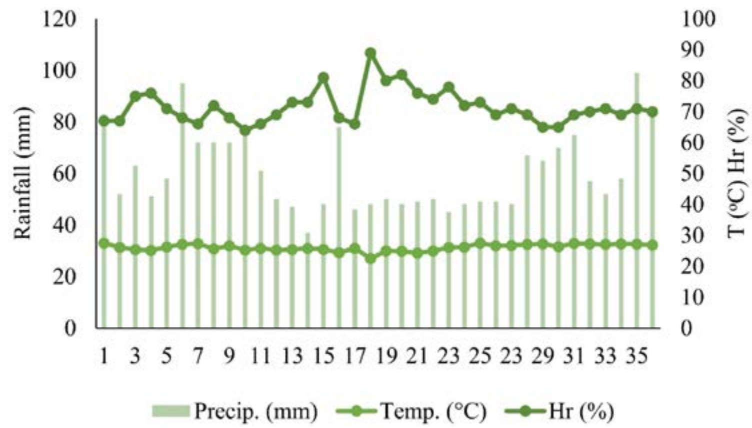


Figure 1. Mean climatic variables, Rainfall (mm), Temperatures (Tem) (°C) and relative humidity (Hr) (%).

irrigation, agro-technology and pest and disease control, the norms established in the technical manual for garden production, intensive orchards and semi-protected garden were followed (Rodríguez *et al.*, 2007).

Experimental design

The experimental design was randomized blocks with three treatments and five replicates. The plots size was 5 m^2. The sowing frame was 0.10×0.05 m. Five plants per plot were randomly marked for a total of 25 plants evaluated per treatment, 75 in the trial and the calculation area was 2.40 m^2.

Treatments and composition of growth promoter

Treatments consisted in a Control (VA0) and the foliar application of the amino acid-based growth promoter VIUSID agro® at concentrations of 1.2 mL L^{-1} (VA1) and 1.5 mL L^{-1} (VA2). The declared composition of the growth promoter VA is: amino acids, Aspartic acid 1.6 %, Arginine 2.5 %, Glycine 2.4 % and Tryptophan 0.5 %, Organic nitrogen 1.8 %, pH 6.80, density 1.14 and net mass 1.14 kg (Peña-Calzada *et al.*, 2022).

VIUSID Agro® application

Applications were made in the morning at 8:30 to 9:30 hours once the dew had evaporated and wind drift was avoided. A total of four application and in an interval of seven days during the crop cycle. A manual back sprayer with a capacity of 8 L was used.

Measurement and determination of variables

Studied variables were evaluated at two moments inside of crop cycle at 23 and 36 days after sowing (DAS), at the same time, last evaluation coincided with the radish harvest.

The number of leaves per plant was counted and recorded. The length and width of the leaves were determined with a 1500×30 mm stainless steel ruler (Format 7647511500). For the dry mass (DM), the stove (MJW WS 100) was used at 60 °C until constant mass and then the DM was determined in a Sartorius digital balance, with a precision of ±0.01 g.

Stem equatorial and polar diameter was measured and recorded with a digital calibrator Digite® model ACC115-006-11 and ±0.03 mm of accuracy.

The fresh mass of all plant organs was determined in a Sartorius digital balance (model BS 124S) with an accuracy of ±0.01 g in each moment evaluated. To calculate the power of the source and the power of the demand (Santos *et al.*, 2010) described below: Source power=Source size (AF)* Source activity (TAN), Demand power=Demand size (ms)* Demand activity (TCR of the tuber). To determine the chlorophyll content, a (TYS-B Chlorophyll Meter) was used, the readings were taken on a clear day without clouds (12-1:00 pm) on the third leaf from apex to base, always in the same orientation and at three points in a triangular form (Peña Calzada *et al.*, 2022).

For harvesting, it was taken into account that all treatments were within the established range, equatorial stem diameter greater than 2.4 cm. For the calculation of yield, the indirect method was used, which consists of determining the production of a plant and then calculating the production per area, taking into account the production per plant and the number of plants per area. The following procedure was used for the growth rates (Table 1).

Statistical analysis

The AgroEstat statistical package (Brabosa & Maldonado, 2015) was used for results analysis. Normality and homogeneity of variance were performed by Kolmogorov-Smirnov Levene tests, respectively. When normality and homogeneity existed, we using a simple analysis of variance (ANOVA) and the Tukey multiple range test ($p<0.05$) for mean comparison.

Table 1. Plant growth index (Santos *et al.*, 2010).

Growth rate	Symbol	Formula	Units
Absolute growth rate	TCA	$TCA=(W2-W1)/(T2-T1)$	$(g \cdot day^{-1})$
Leaf area	LA	$LA=(1\times a)f$	(cm^2)
Net assimilation rate	TAN	$TAN^{*}=2(W2-W1)/(AF2+AF1)(t2-t1)$	$(g \cdot cm^{-2} \cdot day^{-1})$
Relative growth rate	TCR	$TCR=2(W2-W1)/(W2+W1)(t2-t1)$	$(g \cdot g^{-1}\ day^{-1})$
Leaf area ratio	RAF	$RAF=\frac{1}{2}(AFI/W1+AF2/W2)$	$(cm^2\ g^{-1})$
Crop growth rate	TCC	$1/AS*(W2-W1)/(t2-t1)$	$(g \cdot cm^{-2} \cdot day^{-1})$
Leaf area duration	DAF	$((IAF1+IAF2)(T2-T1))/2$	(day^{-1})
Leaf area index	IAF	$(AF2-AF1)/As$	
Leaf efficiency index	IEF	Commercial dry mass Leaf area	
Harvest index	IK	Commercial dry mass Total dry mass	

AF=leaf area, T=time, W=dry mass, TAN*: The formula was used because (α) ranged from 1.5 to 2.5.

RESULTS AND DISCUSSION

Effect of treatments on leaf characteristics at 23 and 36 (DAS)

ANOVA showed no significant effect among VA treatments on leaves number per plant in both moments evaluated (Figure 2a). However, leaf area (LA) showed significant differences among VA treatments. At 23 DAS, VA1 reveled higher LA compared with the others VA treatments and significantly increased LA by 30% compared to the VA0 treatments; but VA2 also exhibited increases in LA by 25% than that VA0 doses. Additionality, at 36 DAS, VA1 and VA2 treatments showed similar effects in LA and increasing by 6% in comparison with the VA0 treatment (Figure 2b).

Leaf fresh biomass (LFB) was significantly higher in the VA1 treatment at 23 DAS as compared to the rest treatments. In addition, at 36 DAS, VA1 and VA2 application showed equal effects and increasing LFB by 22% in comparison with the VA treatment (Figure 2c). However, the dry biomass reveled no significant differences in both evaluations (Figure 2d). Similarly, the percentage of leaf moisture (LM) at 23 DAS, no significant differences were found among treatments; while, at 23 DAS, VA1 and VA2 treatments exhibited

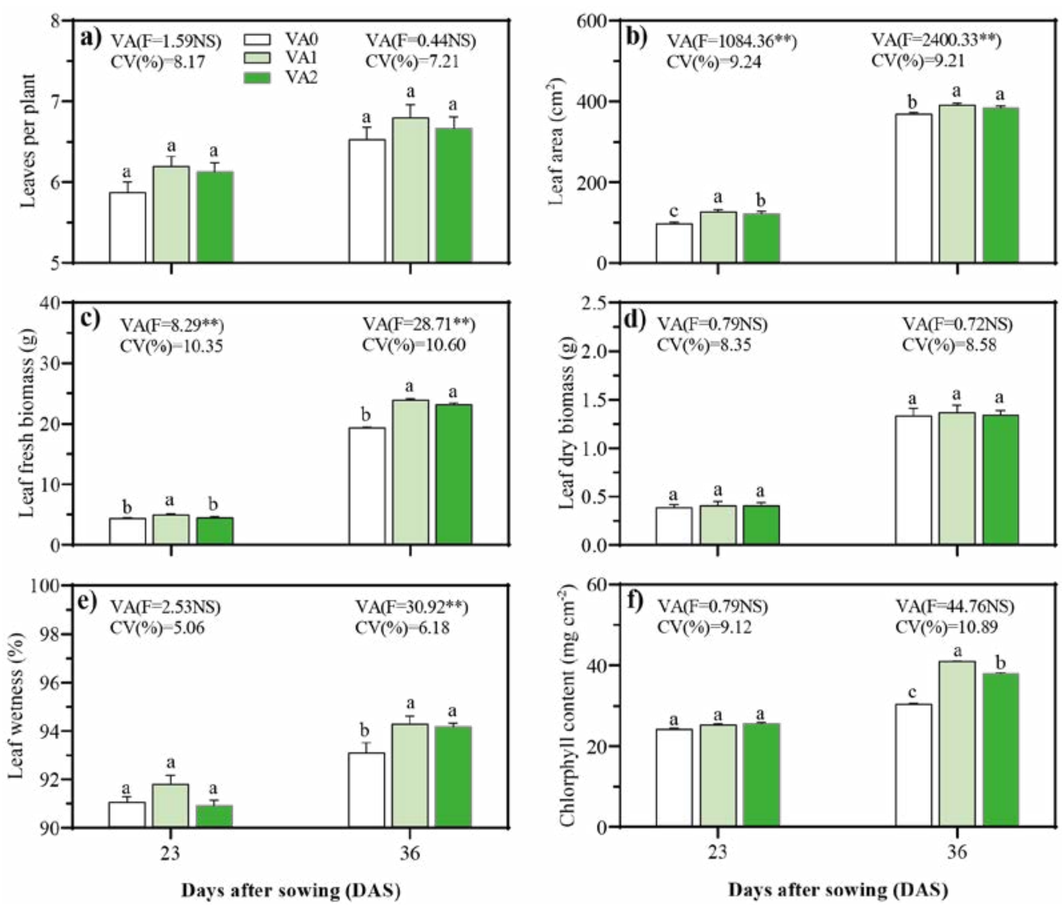


Figure 2. Leaves per plant a), leaf area b), leaf fresh biomass c), leaf dry biomass d), leaf wetness e) and chlorophyll content f) in radish plants at 23 and 36 days after planting (DAS) in function of the three treatments VA0, VA1, and VA2. Unequal letters indicate significant differences within each independent time (23 and 36 DAS), according to Tukey's multiple range test ($p<0.05$).

similar effects and significantly increased LM compared to the VA0 treatment (Figure 2e). Furthermore, leaf chlorophyll content (LCC), no differences were found among treatments at 23 DAS. However, at 36 DAS, LCC was higher in the VA1 application in comparison with the Control and VA2 treatments and increased LCC by 35% compared to the control; nevertheless, at the same time VA2 application increased LCC by 25% respect to the control treatment (Figure 2f).

Foliar application of VIUSID agro® positively influenced in radish growth, probably by the kinds of amino acids containing and lower amount of organic nitrogen. These facts have been linked to antioxidant and growth-stimulating effects, both under normal conditions and under abiotic stresses (Sabagh *et al.*, 2019). In addition, organic nitrogen applied foliar in small doses leads to stimulate plant growth, which resulting in higher dry mass accumulation and yield (Ferrari *et al.*, 2021). Similar findings in radish variety Scarle Globe was previously reports with low doses of VIUSID agro® (Peña-Calzada *et al.*, 2018), which subsequent increases on plant growth and productivity. Furthermore, the foliar application of VA in promoting plant growth and development were observed earlier in plant species such as bean (Peña Calzada *et al.*, 2017), lettuce and beet (Peña Calzada *et al.*, 2024; Pérez-Fernández *et al.*, 2022), soybean (Peña Calzada *et al.*, 2022).

Effect of treatments on tuber characteristics at 23 and 36 DAS

Equatorial diameter of bulb (EDB) not showed significant differences between treatments in the first evaluation; nevertheless, at 36 DAS, the EDB was similar in VA1 and VA2 treatments and revealed significant increases (10 %) in comparison with the VA0 treatment (Figure 3a). In addition, polar diameter (PD) at 23 DAS the best response was achieved by VA2 treatments with significant differences than that VA0 and VA1 treatments; however, VA0 treatments showed higher PD respect to the plants treated with VA1 doses. Similarly, at 36 DAS, the higher PD was in the VA2 treatment, with increasing PD by 45% and 22% in relation to the VA0 and VA1 treatments, respectively; but at the same time, foliar application with VA1 treatment exhibited higher PD compared to the control treatment (Figure 3b).

Tuber fresh and dry biomass were influenced by the treatments in the two evaluations performed (Figure 3c, d). At 23 DAS the tuber fresh biomass (TFM) was significantly higher in the VA2 treatment respect to the others treatments. However, at 36 DAS the TFM was higher in the VA2 treatment, with increases by 24% and 10% compared to the VA0 and VA1 treatments, respectively; nevertheless, plants treated with VA1 concentration showed higher (13%) TFM in relation to the control plants (Figure 3c). Additionality, tuber dry biomass (TDB) at 25 DAS not exhibited significant differences among treatments; but, in the last assessment foliar application of VA1 and VA2 treatments showed similar effects and increases TDB by 81% relative to VA0 treatment (Figure 3d).

These results are related to the application of the growth promoter since Glycine when applied independently or combined with tryptophan, plays a fundamental role in the formation of total chlorophylls and vegetative growth (Repke *et al.*, 2022). In addition, amino acids in foliar application improve crop yield and quality and increase root volume, which

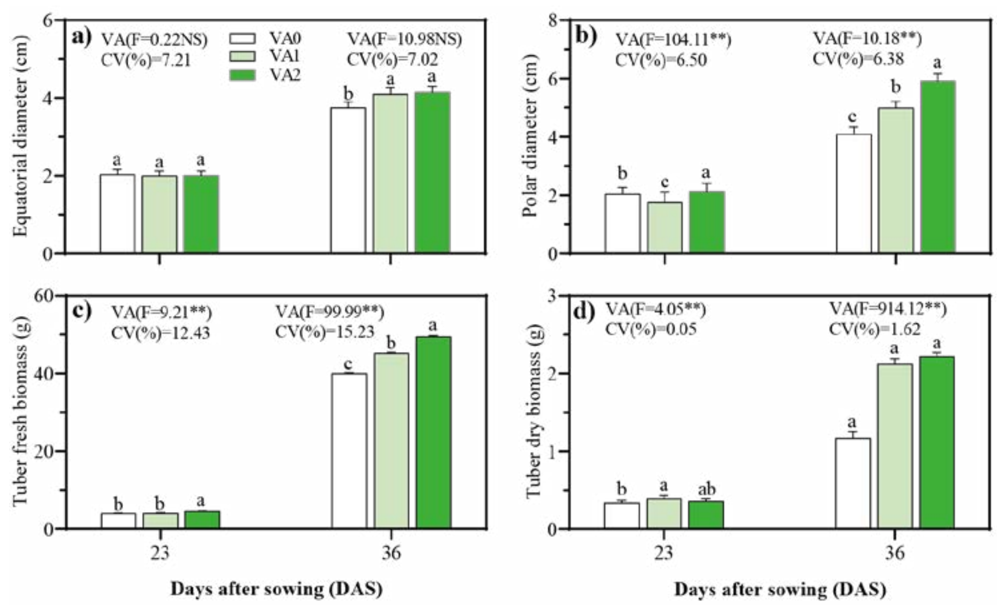


Figure 3. Equatorial diameter a), polar diameter b), tuber fresh biomass c), and tuber dry biomass d) in radish plants at 23 and 36 days after planting (DAS) in function of the three studies treatments VA0, VA1, and VA2. Unequal letters indicate significant differences within each independent time (23 and 36 DAS), according to Tukey's multiple range test ($p<0.05$).

is related to better nutrient uptake, resulting in improved growth and productivity (Mosa *et al.*, 2021; Souri & Hatamian, 2019). Furthermore, foliar application of organic nitrogen improves general crop conditions and favors important processes such as photosynthesis and the bio-assimilates transfer (Dou *et al.*, 2024).

Effect of treatments on source power and demand at 23 and 36 DAS

Source potency (leaves, LSP) and demand potency (tuber, TDP) at 23 and 36 DAS were influenced by the treatments. In the first evaluation, the LSP and TDP showed equal effects between VA1 and VA2 treatments and were significantly higher by 51% and 36%, respectively, compared to the control treatment (Figure 4a). Nevertheless, at 36 DAS the response was inverse and in turn influenced by treatments and crop cycle. LSD and TDP was higher in the VA1 and VA2 treatments (without difference between them) and showed increases by 48% and 84%, respectively, relative to the VA0 treatment, (Figure 4b).

Effect of treatments on crop growth rates

The treatments influenced the active growth rates of the crop as TAN, the higher TAN was achieved in the VA1 and VA2 treatments without differences between them and an increased TAN by 52% and 58% as compared to the control treatment, respectively (Table 2). In addition, the net assimilation rate (TAN) showed high values in the treatment VA2 and with significant differences relative to the rest of the treatments and a 48% increase compared to the control (Table 2). Additionally, the relative growth rate (TCR) revealed similar response between VA1 and VA2 treatments and increases in TCR by 23% compared to the control treatment (Table 2).

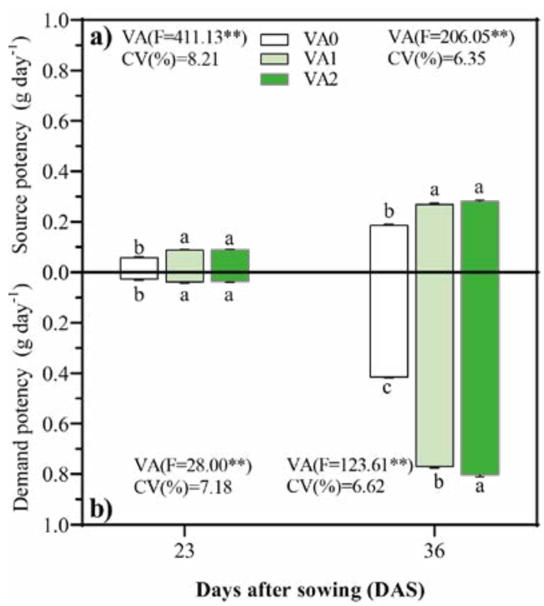


Figure 4. Source potency at 23 and 36 DAS a) and demand potency at 23 and 36 DAS b) in radish plants in function of the three studies treatments VA0, VA1, and VA2. Unequal letters indicate significant differences within each variable, according to Tukey's multiple range test ($p<0.05$).

The TCC was significantly higher in plants that received the VA1 and VA2 treatments compared to VA0, and the increases were 57% than the control. Similarly, leaf area ratio (RAF) was higher in the control treatment and showed significant difference with the other treatments, which indicate that VA1 and VA2 treatments required 6% less area to produce the same biomass amount. Likewise, leaf area duration (DAF) was significantly higher in

Table 2. Effect of treatments on active growth rate, net assimilation rate, relative growth rate, crop growth rate, leaf area ratio, and leaf area duration.

Treatments	TAC ($g \cdot day^{-1}$)	TAN ($g \cdot cm^{-2} \cdot day^{-1}$)	TCR ($g \cdot g^{-1} \cdot day^{-1}$)
VA0	0.1176 b	0.00049 c	0.0815 b
VA1	0.1791 a	0.00069 b	0.0980 a
VA2	0.1860 a	0.00073 a	0.1018 a
VA (F)	262.30**	178.34**	92.88
HSD (5%)	0.0080	0.0071	0.0039
Treatments	**TCC ($g \cdot cm^{-2} \cdot day^{-1}$)**	**RAF ($cm^2\ g^{-1}$)**	**DAF (day^{-1})**
VA0	0.0008 c	142.99 a	13.6262 a
VA1	0.0012 b	136.13 b	13.3501 a
VA2	0.0013 a	133.88 b	12.5441 b
VA (F)	262.30**	10.23**	45.30**
HSD (5%)	0.0001	5.1085	0.2875

Unequal letters in the same column indicate significant differences within each variable, according to Tukey's multiple range test ($p<0.05$).

the VA0 and VA1 treatments with similar effects between them and showed increases DAF by 8% in comparison with the VA2 treatment (Table 2).

The leaf efficiency indexes showed higher values in the VA1 and VA2 treatments (similar effects between them) compared to the VA0 treatment, and showed increases of 44% in IEF, 8% in IAF and 31% in IK compared to the control, respectively (Table 3).

The results in growth rates are related to the use of the growth promoter, since it is demonstrated that it increases the dry mass in a time interval and also the distribution of dry mass since similar results were found in Chinese cabbage (Peña-Calzada *et al.*, 2019), tobacco (Peña *et al.*, 2018), and the radish variety Scarle Globe (Peña-Calzada *et al.*, 2018).

Effect of treatments on crop yields

The agricultural yield (AY) was significantly higher with the foliar application of growth promoter as compared to control, in particular VA2 treatment increase AY by 21% and 10% respect to the control and VA1 treatment, respectively; but at the same, this last treatment increasing AY by 10% compared to the control treatment (Figure 5).

These results are associated with the use of the growth promoter based on amino acids and organic nitrogen, as numerous investigations reported benefits of the product on crop growth and yields (Bustamante González *et al.*, 2023; Peña Calzada *et al.*, 2017; Peña *et al.*, 2021). Authors attribute this effect on the productivity of the product to its composition (Romero *et al.*, 2023).

Table 3. Effect of treatments on leaf efficiency index, leaf area index, harvest index, and yield index.

Treatments	IEF	IAF	IK
VA0	0.0039 b	1.6726 b	0.4687 b
VA1	0.0054 a	1.8168 a	0.6058 a
VA2	0.0058 a	1.7800 a	0.6238 a
VA (F)	166.19**	45.30**	87.08**
HSD (5%)	0.0004	0.0383	0.0313

Unequal letters in the same column indicate significant differences within each variable, according to Tukey's multiple range test ($p<0.05$).

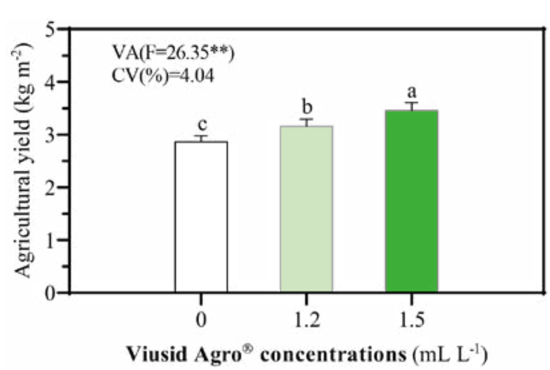


Figure 5. Agricultural yield in radish plants in function of the three studies treatments VA0, VA1, and VA2. Unequal letters indicate significant differences within each variable, according to Tukey's multiple range test ($p<0.05$).

CONCLUSIONS

The foliar application of the amino acid-based growth promoter (VIUSID agro®) influenced positive and directly in radish growth and productivity, resulting in higher leaf area, total chlorophyll content, fresh and dry mass accumulation, growth index and agricultural. Additionality, the spraying of the concentration of 1.5 mL L^{-1} of VA favored the TCC, TAN, FTB, polar diameter and increased agricultural yield by 21% compared to the control treatments Whereas, foliar application of growth promoter at concentration of 1.2 mL L^{-1} enhanced the TDB, CC, LFB, LA and the agricultural yield was higher (10%) than the control treatment. Taken together, the results of this study indicated that foliar application of growth promoter is an alternative ecological to crops management grown under garden conditions.

AKNOWLEDGEMENTS

The authors are grateful to the institutional project: University, urban agriculture and rural communities: an interdisciplinary approach to promote food sovereignty and gender equality (AgroFuturo), code: NA223SS500-035 and to the Master's program in Agricultural Sciences of the University of Sancti Spíritus José Martí Pérez.

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