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# The Role of Amino Acids Dosage and Their Application Techniques in Increasing the Growth and Yield of Tobacco Plants

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**Abstract:** This study aims to determine the effect of amino acid dosage and application techniques on the growth and yield of tobacco plants. This research was carried out at the TEFA (Teaching Factory) of the Nursery, Department of Agricultural Production, Politeknik Negeri Jember. The study used a Randomized Block Design (RBD) with 2 treatment factors, namely: 1) amino acid dose and application techniques. Observed parameters of tobacco plant growth were as follows: 1) plant height, 2) number of leaves, 3) stem diameter, 4) fresh weight, 5) dry weight, 6) number of harvested leaves, number and 6) harvest weight. Observational data were analyzed using the F-test and the DMRT. The result were: 1) the dose of amino acid given had a very significant on the number of harvested leaves, and a significant on the harvest weight, with the best dose being 500 ml/plant; 2) the application technique has a significant on plant height and stem diameter at 60 days after planting, with the better application technique being foliar application; and 3) the interaction between the amino acid dosage and application technique had a very significant on plant height parameters, with the better treatment being an amino acid dosage of 500 ml/plant by foliar application.

**Keywords:** Amino Acids, Application techniques, Dosage, Growth, Tobacco, Yield

## 1. Introduction

Tobacco (*Nicotiana tabacum* L.) is one of the most important commercial crops worldwide, particularly in developing countries, due to its significant contribution to farmers' income and national economies. The productivity and quality of tobacco are largely determined by vegetative growth characteristics, such as plant height, leaf number, leaf area, and biomass accumulation, which directly influence cured leaf yield and quality. These growth parameters are strongly affected by nutrient management practices, including fertilization strategies and the use of biostimulants (Wadduwage et al., 2024).

In recent years, amino acids have gained increasing attention as plant biostimulants because of their multifunctional roles in plant metabolism. Amino acids are fundamental building blocks of proteins and act as precursors for phytohormones, enzymes, and secondary metabolites involved in plant growth and stress responses. Exogenous application of amino acids has been reported to enhance nutrient uptake efficiency, photosynthetic activity, and carbon–nitrogen metabolism, thereby improving vegetative growth and yield formation in various crops, including tobacco (Francesca et al., 2021; Atero-Calvo et al., 2025).

The effectiveness of amino acid application is strongly influenced by the applied dosage. Appropriate amino acid rates can stimulate cell division and elongation, enhance leaf development, and promote biomass accumulation, which are critical for tobacco yield. However, excessive application rates may disrupt metabolic balance, reduce nutrient uptake efficiency, and negatively affect plant growth and yield. Therefore, crop responses to amino acid application generally follow an optimum dose–response pattern, highlighting the importance of determining suitable application rates for tobacco cultivation (Cheng et al., 2024; Kurt, 2025; Han et al., 2025).

In addition to dosage, the application technique plays a crucial role in determining the efficiency of amino acid utilization by plants. Foliar application allows rapid absorption of amino acids through leaf tissues and is considered particularly effective during critical growth stages, while soil or fertigation applications can enhance root activity and nutrient availability in the rhizosphere. Differences in application techniques may lead to variations in amino acid absorption, translocation, and physiological effectiveness, thereby influencing tobacco growth and yield performance (Cheng et al., 2024; Wang et al., 2025).

Despite increasing interest in amino acid-based biostimulants, information regarding the combined effects of amino acid application rates and application techniques on the growth and yield of tobacco remains limited. A comprehensive understanding of these factors is essential to optimize amino acid use for improving tobacco productivity and ensuring sustainable nutrient management. Therefore, this study aims to evaluate the effects of different amino acid application dosages and application techniques on the growth and yield of tobacco plants.

## 2. Materials and Methods

This research was carried out at the TEFA (Teaching Factory) of the Nursery, Department of Agricultural Production, Politeknik Negeri Jember. While the research time is from June to November 2025. The research materials included tobacco seeds ready for planting, amino acids from lemuru fish, planting media, plants, and inorganic fertilizers. The tools used are cultivation, measuring, and identification tools.

The study used a Randomized Block Design (RBD) with 2 treatment factor, namely: 1) Amino acids (A0 = without amino acids (control); A1 = amino acids 250 ml/plant; A2 = amino acids 500 ml/plant), and 2) Application techniques (T1 = soil application; and T2 = foliar application: 1) without amino acids). After obtaining 6 treatment combinations, each treatment was repeated four times to obtain 24 experimental units (10 plants each).

Control treatment using inorganic fertilizer doses according to SOP = = 6.9 grams N + 5.4 grams P + 6.9 grams K per plant, meanwhile, for amino acids treatment, 30% of the SOP for inorganic fertilizer was used = 2.3 grams N + 1.8 grams P + 2.3 grams K per plant.

Observed parameters of tobacco plant growth were as follows: 1) plant height, 2) number, 3) stem diameter, 4) plant fresh weight, 5) plant dry weight, 6) number of harvested leaves, and 6) harvest weight. Observational data were analyzed using the F-test ($p<0.05$ and $p<0.01$) and the DMRT ($p<0.05$).

## 3. Results and Discussion

The result of the analysis of variance showed the effect of amino acids and the application techniques presented in Table 1. Table 1 showed that the dose of amino acids as a single factor had a very significant effect on the number of harvested leaves, had a significant effect on the harvest weight, and had no significant effect on the other parameters. The application techniques as a single factor had a significant effect on the plant height at 60 and 75 dap, and had no significant effect on the other parameters. Meanwhile, the interaction between amino acids dose and application techniques had a very significant effect on plant height 60 dap, had a significant effect on plant height 45 dap, and had no significant effect on the other parameters.

**Table 1.** Analysis of variance of tobacco growth parameters

| Parameters | Plant Age (dap) | Treatments | CV (%) |
|---|---|---|---|

| | | A | T | AxT | |
|---|---|---|---|---|---|
| Plant height | 45 | ns | ns | * | 21.47 |
| | 60 | ns | * | ** | 13.62 |
| | 75 | ns | ns | ns | 16.99 |
| Leaves number | 45 | ns | ns | ns | 7.00 |
| | 60 | ns | ns | ns | 11.00 |
| | 75 | ns | ns | ns | 7.94 |
| Stem diameter | 45 | ns | ns | ns | 11.30 |
| | 60 | ns | * | ns | 9.24 |
| | 75 | ns | ns | ns | 14.31 |
| Plant fresh weight | 80 | ns | ns | ns | 11.67 |
| Plant dry weight | 80 | ns | ns | ns | 21.31 |
| Number of harvested leaves | 97 | ** | ns | ns | 19.11 |
| Harvest weight | 97 | * | ns | ns | 17.61 |

Dap = days after planting; A = amino acids dose; T = application techniques; AxT= interaction between amino acids dose and application techniques; ns: not significant; *: significant at 0.05; **: significant at 0.01.

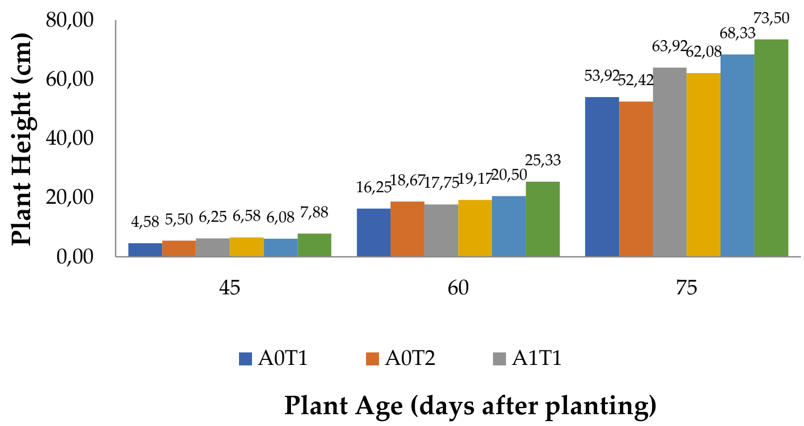
*Plant Height of Tobacco Plant*

Based on Table 1, the analysis results for plant height parameters show a significant difference in application techniques treatment (45 days after planting), and a very significant difference in the interaction between amino acids and application techniques treatment. Further testing with DMRT ($p<0.05$) is presented in Table 2 and Figure 1.

**Table 2.** Results of the DMRT ($p<0.05$) on Plant Height Parameters 45 Days after Planting

| Treatment | Plant height (cm) | |
|---|---|---|
| Foliar application | 84.22 | a |
| Soil application | 72.67 | b |
| DMRT 5% | 4.22 | |

Unequal letters on the same column indicate significant differences within each variable, according to DMRT ($p<0.05$).




Unequal letters indicate significant differences within each variable, according to DMRT ($p<0.05$).
A0T1 = without amino acids by soil application; A0T2 = without amino acids by foliar application; A1T1 = amino acids 250 ml/plant by soil application; A1T2 = amino acids 250 ml/plant by foliar application; A2T1 = amino acids 500 ml/plant by soil application; A2T2 = amino acids 500 ml/plant by foliar application.

**Figure 1.** The Effect of Amino Acids Dose and the Application Techniques on Tobacco Plant Height

Table 2 shows that the results of the DMRT ($p<0.05$) on plant height 45 dap, the foliar application (84.22 cm) is better than the soil application (72.67 cm). Furthermore, based on Figure 1, it can be seen that the result of DMRT ($p<0.05$) show that the A2T2 treatment (amino acids 500 ml/plant by foliar application) provided the best results for plant height at 45 dap (7.88 cm) and 60 dap (25.33 cm), while at 75 dap, the A2T2 treatment provided plant height results (73.50 cm) that tended to be better than other treatments.

Such results are thought to be due to the dose of amino acids (500 ml/plant) given being moderate, thus providing the best effect. In general**, low to moderate doses** of amino acids have a positive effect on increasing plant height. At optimal doses, amino acids act as organic nitrogen sources, precursors for protein synthesis, and stimulators of growth hormone production, such as auxins and gibberellins. These roles enhance apical meristem activity and accelerate cell division and stem elongation, resulting in increased plant height (Ibrahim, 2022; Heidarzadeh, 2025).

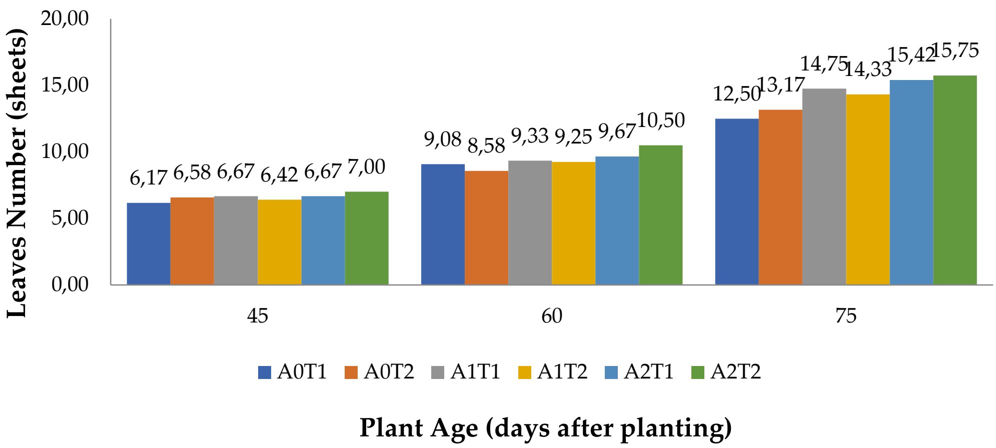
Amino acids play an important role in regulating plant growth and development, including their effect on plant height. As fundamental building blocks of proteins, amino acids are directly involved in cell division and cell elongation processes that determine stem growth. Exogenous application of amino acids has been widely reported to enhance plant height by stimulating vegetative growth, particularly when applied at appropriate concentrations (Lopez and Mohiuddin, 2024; Heidarzadeh, 2025).

The effectiveness of amino acids in enhancing plant nutrient uptake and growth is also strongly influenced by the application techniques, particularly foliar application and soil application. Each technique affects the pathway, rate, and efficiency of amino acid absorption, which in turn determines plant physiological responses and growth performance. Foliar application generally results in a more rapid and pronounced increase in plant height compared to soil application. When applied to leaves, amino acids are directly absorbed through the cuticle and stomata and quickly enter metabolic pathways. These amino acids act as precursors for growth-regulating hormones such as auxins and gibberellins, which stimulate cell elongation and apical meristem activity in the stem. In addition, foliar-applied amino acids enhance chlorophyll synthesis and photosynthetic efficiency, leading to greater assimilate production that supports stem elongation and increases plant height (Cheng et al., 2024; Wang et al., 2025).

Soil application of amino acids influences plant height more gradually. Amino acids applied to the soil improve root growth, stimulate beneficial microbial activity, and increase nutrient availability in the rhizosphere. Enhanced root development improves the uptake of nitrogen and other essential nutrients that support sustained vegetative growth, including stem elongation. Although the increase in plant height may be slower compared to foliar application, soil application contributes to stable and long-term growth (Wang et al., 2025).

*Leaves Number of Tobacco Plant*

The number of leaves is an important indicator of vegetative growth and photosynthetic capacity in plants, and it is strongly influenced by the application of amino acids and the techniques used for their application. Amino acids contribute to leaf formation by enhancing cell division, leaf initiation, and expansion processes, which ultimately increase the total number of leaves produced by a plant. The parameter data for the number of leaves can be seen in Figure 2.




A0T1 = without amino acids by soil application; A0T2 = without amino acids by foliar application; A1T1 = amino acids 250 ml/plant by soil application; A1T2 = amino acids 250 ml/plant by foliar application; A2T1 = amino acids 500 ml/plant by soil application; A2T2 = amino acids 500 ml/plant by foliar application.

**Figure 2.** The Effect of Amino Acids and the Application Techniques on Tobacco Leaves.

Figure 2 shows that a tends to be higher number of leaves is produced at A2T2 treatment (amino acids 500 ml/plant by foliar application) that is 15.75 sheets, followed by A2T1 (amino acids 500 ml/plant by soil application) that is 15.42 sheets, A1T1 (amino acids 250 ml/plant by soil application) that is 14.75 sheets, A1T2 (amino acids 250 ml/plant by foliar application) that is 14.33 sheets, and control (13.17 sheets and 12.50 sheets), at plant age 75 dap.

Amino acids positively affect leaf number by enhancing hormonal regulation, nutrient uptake, and photosynthetic efficiency. Foliar application promotes rapid leaf formation, soil application supports sustained leaf development, and combined application offers the most consistent improvement in leaf number (Al-Janabi, 2021). The application of amino acids promotes leaf number primarily by stimulating meristematic activity in the shoot apical meristem, where new leaves are initiated. Amino acids serve as precursors for protein synthesis and plant growth regulators, such as auxins and cytokinins, which play key roles in leaf initiation and development. Enhanced hormonal activity accelerates the rate of leaf primordia formation, resulting in an increased number of leaves (Hussain et al., 2021; Wu et al., 2021).

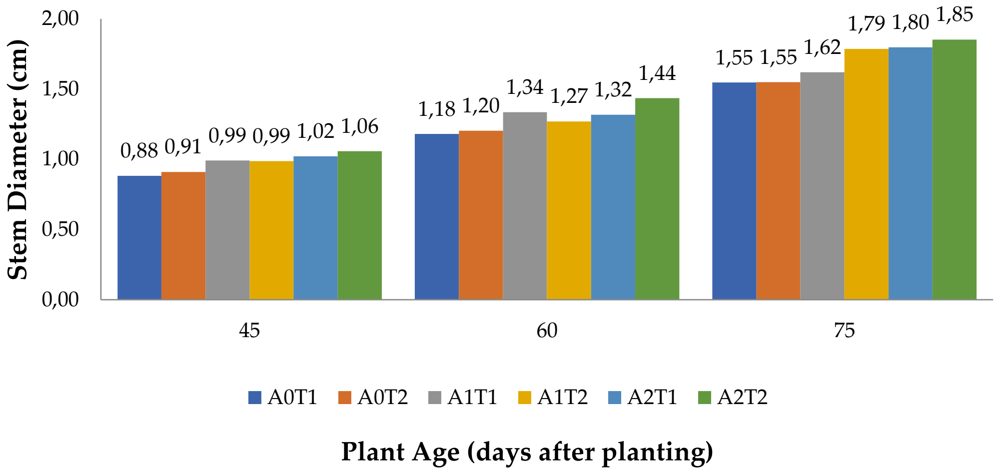
*Stem Diameter of Tobacco Plant*

Stem diameter is an important indicator of plant vigor and structural strength, and it is strongly influenced by nutrient availability and metabolic activity. The application of amino acids, as well as the technique used for their application, plays a significant role in enhancing stem diameter by improving physiological processes related to cell division and cell enlargement in stem tissues. Based on Table 1, the analysis results for plant height parameters show a significant difference in application techniques treatment (60 days after planting). The parameter data for the stem diameter can be seen in Table 3 and Figure 3.

**Table 3.** Results of the DMRT ($p<0.05$) on Stem Diameter Parameters 60 Days after Planting

| Treatment | Stem Diameter (cm) |
|---|---|
| Foliar application | 5.39 a |
| Soil application | 4.93 b |
| DMRT 5% | 0.18 |

Unequal letters on the same column indicate significant differences within each variable, according to DMRT ($p<0.05$)




A0T1 = without amino acids by soil application; A0T2 = without amino acids by foliar application; A1T1 = amino acids 250 ml/plant by soil application; A1T2 = amino acids 250 ml/plant by foliar application; A2T1 = amino acids 500 ml/plant by soil application; A2T2 = amino acids 500 ml/plant by foliar application.

**Figure 3.** The Effect of Amino Acids and the Application Techniques on Tobacco Stem Diameter

Table 3 shows that the results of the DMRT ($p<0.05$) on stem diameter 60 dap, the foliar application (5.39 cm) is better than the soil application (4.93 cm). Further, based on Figure 3, it can be seen that the amino acid dosage and application technique did not significantly affect stem diameter. The average value tended to be higher in the A2T2 treatment (amino acids 500 ml/plant by foliar application) that is 1.85 cm, followed by A2T1 (amino acids 500 ml/plant by soil application) that is 1.8 cm, A1T2 (amino acids 250 ml/plant by foliar application) that is 1.79 cm, A1T1 (amino acids 250 ml/plant by soil application) that is 1.62 cm, and control (1.55 cm), at plant age 75 dap.

The application of amino acids positively affects stem diameter by promoting protein synthesis and enhancing the availability of organic nitrogen required for cambial activity. Amino acids stimulate the activity of the vascular cambium, leading to increased cell division and secondary growth, which results in thicker stems. In addition, certain amino acids function as precursors of plant growth regulators, such as auxins and cytokinins, which regulate radial stem growth and contribute to increased stem diameter (Du Jardin, 2015).

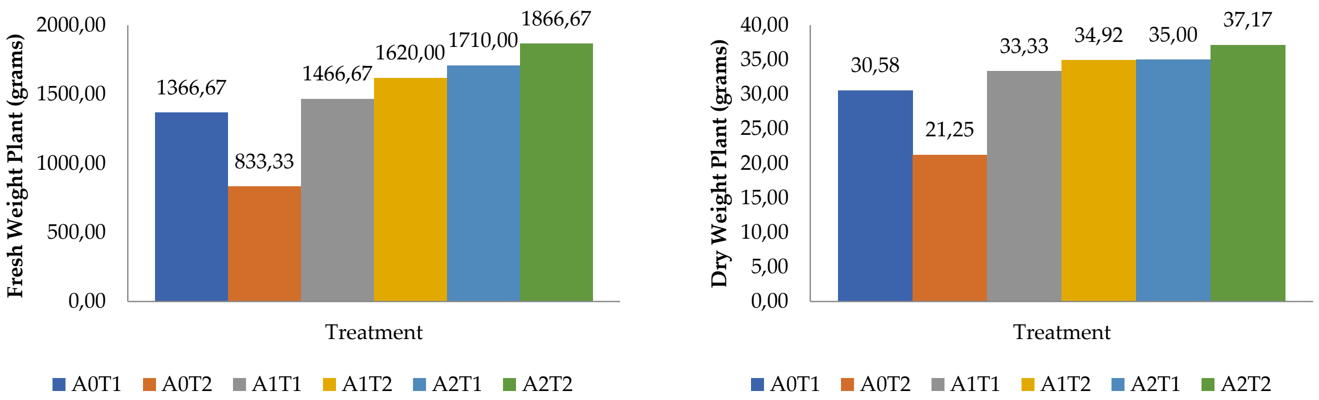
Secondary tissues are extraordinarily complex. The patterns of cell division, apparently under genetic control, are influenced by a whole concert of hormones. Hormonal gradients and seasonal gradients of sugars and amino acids may play a role in these patterns of secondary tissue formation. The activity of mature phloem tissues and the concentrations of auxins, gibberellins, cytokinins, and perhaps of the gaseous hormone ethylene may all be important in regulating the activity of the cambia (Landgren et al., 2023).

The application techniques determine the efficiency of amino acid uptake and its impact on stem thickening. Foliar application allows amino acids to be rapidly absorbed through leaf tissues and directly incorporated into metabolic pathways. This rapid uptake enhances photosynthetic efficiency and assimilate production, providing sufficient carbohydrates and nutrients to support cambial activity and stem thickening. Consequently, foliar-applied amino acids often result in a faster increase in stem diameter compared to other application methods (Cheng et al., 2024).

In contrast, soil application of amino acids influences stem diameter indirectly by improving root development, stimulating beneficial soil microorganisms, and increasing nutrient availability in the rhizosphere. Enhanced root growth improves the uptake of nitrogen, potassium, and calcium, which are essential for cell wall formation and vascular tissue development. Although the response in stem diameter may be slower than with foliar application, soil application supports continuous and stable stem thickening over time (Colla et al., 2017; Wang et al., 2025)

*Plant Fresh Weight and Dry Weight of Tobacco Plant*

Data on the effect of application techniques on the fresh weight and dry weight parameters of tobacco plants can be seen in Figure 4.




(a) (b)

A0T1 = without amino acids by soil application; A0T2 = without amino acids by foliar application; A1T1 = amino acids 250 ml/plant by soil application; A1T2 = amino acids 250 ml/plant by foliar application; A2T1 = amino acids 500 ml/plant by soil application; A2T2 = amino acids 500 ml/plant by foliar application.

**Figure 4.** Fresh Weight (a) and Dry Weight (b) of Tobacco Plant

Figure 4 shows that for the fresh weight parameter of plants, the average tends to be higher in the A2T2 treatment (amino acids 500 ml/plant by foliar application) that is 1866.67 grams, followed by A2T1 (amino acids 500 ml/plant by soil application) that is 1710 grams, A1T2 (amino acids 250 ml/plant by foliar application) that is 1620 grams, A1T1 (amino acids 250 ml/plant by soil application) that is 1466.67 grams, and controls (833.33 grams and 1366.67 grams), at plant age 80 days after planting. While, the plant dry weight parameter, the average also tends to be higher in the A2T2 treatment (amino acids 500 ml/plant by foliar application) that is 37.17 grams, followed by A2T1 (amino acids 500 ml/plant by soil application) that is 35 grams, A1T2 (amino acids 250 ml/plant by foliar application) that is 34.92 grams, A1T1 (amino acids 250 ml/plant by soil application) that is 33.33 grams, and controls (30.58 grams and 21.25 grams).

Fresh weight and dry weight are key indicators of plant growth, biomass accumulation, and physiological performance. The application of amino acids, along with the technique used for their application, significantly influences both fresh and dry biomass by enhancing metabolic activity, nutrient uptake, and photosynthetic efficiency. Amino acid application positively affects fresh weight by increasing cell division, cell expansion, and water retention in plant tissues. Amino acids contribute to osmotic regulation and improve membrane stability, allowing plant cells to maintain higher turgor pressure. This results in increased tissue hydration and greater accumulation of fresh biomass. Moreover, amino acids stimulate chlorophyll synthesis and photosynthetic activity, leading to enhanced production of photoassimilates that support rapid vegetative growth (Du Jardin, 2015; Rossi and Huang, 2025).

In terms of dry weight, amino acids enhance biomass accumulation by promoting protein synthesis and improving nitrogen use efficiency. As structural components of enzymes and cellular proteins, amino acids support the formation of stable organic matter such as carbohydrates, proteins, and cell wall materials. Improved nutrient uptake, particularly nitrogen, phosphorus, and potassium, increases carbon assimilation and its allocation to plant organs, resulting in higher dry matter accumulation (Colla et al., 2017; Liu et al., 2024).

The application technique plays a crucial role in determining the magnitude of these effects. Foliar application allows amino acids to be rapidly absorbed through leaf tissues and directly utilized in metabolic pathways. This leads to a faster increase in fresh weight due to immediate physiological responses, such as enhanced photosynthesis and leaf expansion. Foliar application is especially effective in increasing fresh biomass under conditions of limited root nutrient uptake (Du Jardin, 2015).

In contrast, soil application of amino acids contributes more substantially to dry weight accumulation by improving root development and nutrient availability in the rhizosphere. Amino acids stimulate microbial activity and act as natural chelating agents, enhancing the availability and uptake of essential nutrients that support sustained biomass formation. Although the response may be slower than foliar application, soil-applied amino acids promote long-term increases in dry matter production (Colla et al., 2017).

*Number of Harvested Leaves and Harvest Weight of Tobacco Plant*

Yield quantity and harvest weight are key indicators of crop productivity and are strongly influenced by physiological efficiency, nutrient uptake, and biomass partitioning. The application of amino acids, together with the technique used for their application, plays an important role in enhancing both the number of harvestable units and total harvest weight. Based on Table 1, the analysis results show that the amino acids dose as a single factor had a significant difference in the number of harvested leaves and had a very significant differences on harvest weight. The parameter data for the number of harvested leaves and the harvest weight can be seen in Table 4 and Figure 5.

**Table 4.** Results of the DMRT ($p<0.05$) on Stem Diameter Parameters 60 Days after Planting.

| Treatment | Number of Harvested Leaves (sheets) | Harvest Weight (grams) | DMRT (p<0.05) |
|---|---|---|---|
| Amino acids 500 ml/plant | 60.57 a | 783.75 a | 3.459 |
| Amino acids 250 ml/plant | 46.29 b | 517.36 b | 3.558 |
| Control | 42.36 c | 486.71 c | |
| DMRT (p<0.05) | | | |

Unequal letters on the same column indicate significant differences within each variable, according to DMRT ($p<0.05$)

**Figure 5.** Number of Harvest Leaves (a) and Harvest Weight (b) of Tobacco Plant

Based on Table 3, it can be seen that administration of amino acids at a dose of 500 ml/plant gave the best results on the number of harvested leaves (60.57 sheets), compared to a dose of 250 ml/plant (46.29 sheets) and the control (42.36 sheets). Further, Figure 5 show that that the average parameter for the number of harvested leaves tends to be higher in the A2T2 treatment (amino acids 500 ml/plant by foliar application) that is 16.14 sheets, followed by A2T1 (amino acids 500 ml/plant by soil application) that is 14.14 sheets, A1T2 (amino acids 250 ml/plant by foliar application) that is 12.39 sheets, A1T1 (amino acids 250 ml/plant by soil application) that is 11.57 sheets, and controls (11.57 sheets and 8.79 sheets). While, the harvest weight parameter, the average also tends to be higher in the A2T2 treatment (amino acids 500 ml/plant by foliar application) that is 229.66 grams, followed by A2T1 (amino acids 500 ml/plant by soil application) that is 162.21 grams, A1T2 (amino acids 250 ml/plant by foliar application) that is 137.36 grams, A1T1 (amino acids 250 ml/plant by soil application) that is 129.41 grams, and controls (129.27 grams and 106 grams).

Amino acids application positively affects yield by improving plant metabolic activity and reproductive development. Amino acids serve as building blocks of proteins and as precursors of enzymes and plant growth regulators that control flowering, fruit or leaf development, and assimilate translocation. Enhanced photosynthetic efficiency and nitrogen use efficiency increase carbohydrate and protein synthesis, which supports the formation and development of harvestable organs, ultimately increasing yield quantity and harvest weight. The amino acids play a role in providing the nutrients plants need. Apart from that, it also plays a role in binding nutrients so that they are easily absorbed by plants, as well as enhancing rates of photosynthesis, protein synthesis, and carbohydrate production (Du Jardin, 2015; Shahrajabian et al., 2022; Wardati et al., 2024).

Exogenous application of amino acids, particularly up to an optimal dose level, significantly enhances crop productivity and quality by improving physiological and metabolic processes. They serve as direct sources of nitrogen, promote protein synthesis, and enhance nutrient uptake through chelation (Showmya et al., 2023; Shabani et al., 2025).

The application techniques significantly influence the effectiveness of amino acids in increasing yield. Foliar application allows amino acids to be rapidly absorbed and directly utilized in physiological processes during critical growth stages, such as flowering, fruit set, or leaf expansion. This rapid uptake enhances assimilate availability and improves sink strength of harvestable organs, resulting in increased harvest weight and, in some crops, a higher number of harvestable units or harvest cycles (Wang et al., 2025).

Meanwhile, soil application of amino acids contributes to yield improvement by enhancing root development, stimulating beneficial microbial activity, and increasing nutrient availability in the rhizosphere. Improved root nutrient uptake supports sustained plant growth and ensures a continuous assimilate supply during reproductive or harvest stages. Although yield response may be slower compared to foliar application, soil application plays a crucial role in maintaining stable yield formation and increasing total harvest weight over time (Colla et al., 2017).

The control treatment (without amino acids) in this study used inorganic fertilizer with a dose according to the SOP, namely 6.9 grams N + 5.4 grams P + 6.9 grams K per plant. Meanwhile, in the amino acid dose treatment, both by foliar application and soil application, the dose of inorganic fertilizer used was 30% of the SOP dose. The research results show that the amino acid dose treatment is better than the control. This is in line with research by Wardati et al. (2026) that the amino acid fertilizer is able to replace the role of inorganic fertilizer by 70%.

## 4. Conclusions

Based on the results of the analysis and discussion, the following conclusions can be drawn::

1. The dose of amino acid given had a very significant effect on the number of harvested leaves, and a significant effect on the harvest weight, with the best dose being 500 ml/plant.
2. The application technique has a significant effect on plant height and stem diameter at 60 days after planting, with the better application technique being foliar application.
3. The interaction between the amino acid dosage and application technique had a very significant effect on plant height parameters, with the better treatment being an amino acid dosage of 500 ml/plant by foliar application.

## References

Al-Janabi, Yaseen & Mohammed, Nihad & Hamdan, M. (2021). The Effect of Amino Acids and The Date of Planting on Some Growth Characteristics of The Three Varieties of Maize. IOP Conference Series: Earth and Environmental Science. 904. 012064. 10.1088/1755-1315/904/1/012064.

Atero-Calvo S, Navarro-Leo´n E, Polo J and Ruiz JM (2025) Physiological efficacy of the amino acid-based biostimulants Pepton 85/16, Pepton origin, and Nutriterra in lettuce grown under optimal and reduced synthetic nitrogen fertilization. Front. Plant Sci. 16:1645768. doi: 10.3389/fpls.2025.1645768

Cheng, J., Cheng, J., Sun, R., Cao, S., Wang, X., & Yang, H. (2024). Foliar application of amino acid biostimulants increased growth and antioxidant activity of *Epipremnum aureum*. *Cogent Food & Agriculture*, *10*(1). https://doi.org/10.1080/23311932.2024.2321680

Colla, G., Rouphael, Y., Lucini, L., Canaguier, R. & Stefanoni, W., 2017. Biostimulant action of protein hydrolysates: Unraveling their effects on plant physiology and microbiome. *Frontiers in Plant Science*, 8, 2202. https://doi.org/10.3389/fpls.2017.02202

Du Jardin, P., 2015. Plant biostimulants: Definition, concept, main categories and regulation. *Scientia Horticulturae*, 196, pp.3–14.

Francesca S, Barone A, Rigano MM. One Plant-Based Biostimulant Stimulates Good Performances of Tomato Plants Grown in Open Field. *Biology and Life Sciences Forum*. 2021; 3(1):30. https://doi.org/10.3390/IECAG2021-09703

Han Han, Jinhua Zhang, Qiang Meng, Qiang Xu, Yanjie Li, Ling Li, Hongguang Liu, Rui Cai, Ping Gong, Fulvic acid-amino acid organic fertilizer: Optimal co-application, sustainable remediation, and yield improvement strategies for aline-alkaline cotton fields in Xinjiang, Industrial Crops and Products, Volume 237, 2025, 121984, ISSN 0926-6690, https://doi.org/10.1016/j.indcrop.2025.121984.

Heidarzadeh, Ali. (2025). RETRACTED ARTICLE: Role of amino acids in plant growth, development, and stress responses: a comprehensive review. Discover Plants. 2. 10.1007/s44372-025-00322-0.

Hussain S, Nanda S, Zhang J, Rehmani MIA, Suleman M, Li G, Hou H. Auxin and Cytokinin Interplay during Leaf Morphogenesis and Phyllotaxy. Plants (Basel). 2021 Aug 21;10(8):1732. doi: 10.3390/plants10081732. PMID: 34451776; PMCID: PMC8400353.

Ibrahim M (2022) Role of Endogenous and Exogenous Hormones in Bioactive Compounds Production in Medicinal Plants via In Vitro Culture Technique. Plant Hormones - Recent Advances, New Perspectives and Applications. IntechOpen. Available at: http://dx.doi.org/10.5772/intechopen.102814.

Kurt, Dursun. (2025). Responses of tobacco plants after the exogenous application of L-aspartic acid. Journal of Plant Nutrition. 10.1080/01904167.2025.2591186.

Landgren, Craig R, Ness, Bryan, Plant Growth, 2023, EBSCO Knowledge Advantage, https://www.ebsco.com/research-starters/science/plant-growth#bibliography

Liu Y, Gao J, Zhong M, Chen L, Zhang W. Effects of Phosphorus and Potassium Supply on Photosynthetic Nitrogen Metabolism, Nitrogen Absorption, and Nitrogen Utilization of Hydroponic Rice. *Agronomy*. 2024; 14(8):1726. https://doi.org/10.3390/agronomy14081726

Lopez MJ, Mohiuddin SS. Biochemistry, Essential Amino Acids. [Updated 2024 Apr 30]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK557845/

Rossi S, Huang B. 2025. Regulatory mechanisms of amino acids for improving plant tolerance to drought and heat stress – a review. Grass Research 5: e033 https://doi.org/10.48130/grares-0025-0035

Shabani E, Zivdar S, Rahnama Ghahfarokhi A, Danaeifar A, Davoudi Arshad M. Foliar application of Si-aminochelate: a strategy for increasing P uptake and antioxidant properties of strawberry. BMC Plant Biol. 2025 Dec 9;25(1):1690. doi: 10.1186/s12870-025-07735-9. PMID: 41366309; PMCID: PMC12690900.

Shahrajabian, M. Hesam & Cheng, Qi & Sun, Wenli. (2022). The Effects of Amino Acids, Phenols and Protein Hydrolysates as Biostimulants on Sustainable Crop Production and Alleviated Stress. Recent Patents on Biotechnology. 16. 319-328. 10.2174/1872208316666220412133749.

Sowmya R. S., Vishal G. Warke, Girish B. Mahajan, Uday S. Annapure, Effect of amino acids on growth, elemental content, functional groups, and essential oils composition on hydroponically cultivated coriander under different conditions, Industrial Crops and Products, Volume 197, 2023, 116577, ISSN 0926-6690, https://doi.org/10.1016/j.indcrop.2023.116577.

Wadduwage J, Egidi E, Singh BK, Macdonald CA. Impacts of biostimulants on crop yield and biological activity under drought conditions. *J Sustain Agric Environ*. 2024; 3:e12093. https://doi.org/10.1002/sae2.12093

Wang H, Wang H, Zong J, Hao J, Xu J, Qu M, Li T, Han Y. Effects of Foliar and Root Application of Different Amino Acids on Mini-Watermelon. *Horticulturae*. 2025; 11(8):877. https://doi.org/10.3390/horticulturae11080877

Wardati, I., Fatimah, T., Kusuma, S. I., Erdiansyah, I., Galushasti, A., & Nur, F. M. (2025). Increasing the Sugarcane Growth and the Brix Value of Sugarcane Sap by Providing Sugarcane Root Bacteria and Amino Acids. *International Journal of Agricultural Industry and Food Technology*, *1*(1), 25–31. Retrieved from https://jaiftech.sinergis.org/index.php/ainfoty/article/view/5

Wardati, I., Irawan, T. B., Fatimah, T., & Wilujeng, E. D. I. (2026). The Effects of Amino Acids Application Techniques of on Tobacco (Nicotiana tabacum L.) Plant Growth. *International Journal of Agricultural Industry and Food Technology*, *2*(2), 54–60. Retrieved from https://jaiftech.sinergis.org/index.php/ainfoty/article/view/29

Wu, Wenqi, Kang Du, Xiangyang Kang, Hairong Wei, The diverse roles of cytokinins in regulating leaf development, *Horticulture Research*, Volume 8, 2021, 118, https://doi.org/10.1038/s41438-021-00558-3