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Effects of Organic and Amino Acid Fertilization on Growth and Yield of Eggplant (*Solanum melongena* L.)

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Abstract: This study was conducted during the 2023-2024 growing season at the Agricultural Technical College, Northern Technical University, Nineveh Governorate, to evaluate the effects of organic and amino acid fertilization on the vegetative growth and yield performance of eggplant (*Solanum melongena* L.). A randomized complete block design (RCBD) was employed, comprising two fertilizer types (organic and amino acid) and three concentrations (0, 10, and 15 g·L^{-1}), resulting in six treatment combinations, each replicated three times, for a total of 18 experimental units. Statistical analysis was performed using SAS software. Significant improvements were observed in several vegetative and physiological parameters, including plant height, number of branches, stem diameter, and chlorophyll content. Organic fertilization produced the most substantial increases in plant height (43.000 cm), number of branches (5.444 branches·plant^{-1}), stem diameter (16.367 mm·seedling^{-1}), and leaf chlorophyll content (22.723 SPAD), significantly outperforming amino acid fertilization and the control. In contrast, amino acid fertilization resulted in a higher number of fruits per plant (5.888 fruits·plant^{-1}). The interaction between organic fertilization and the 10 g·L^{-1} concentration yielded the highest plant height (52.667 cm) and number of fruits (6.000 fruits·plant^{-1}). Additionally, the combination of organic fertilization and 15 g·L^{-1} concentration significantly increased the number of branches (6.666 branches·plant^{-1}) and chlorophyll content (29.417 SPAD). The stem diameter reached its maximum value (20.050 mm·seedling^{-1}) under amino acid fertilization at a concentration of 10 g·L^{-1}. The control treatment consistently produced the lowest values across all evaluated parameters. These findings demonstrate that both organic and amino acid fertilization can significantly enhance specific growth and yield components in eggplant, with organic fertilizers exhibiting superior overall performance in vegetative traits and amino acids promoting reproductive output. The results highlight the potential of integrating amino acid and organic nutrient management strategies to optimize eggplant productivity under field conditions.

Keywords: *Solanum melongena* L., Eggplant, Organic fertilization, Amino acid fertilization, Vegetative growth, Yield performance, Chlorophyll content

1. Introduction

Solanum melongena L., commonly known as eggplant, is an important vegetable of the *Solanales* eggplant family. It is native to India (Kalloo, 1993; Kumar et al., 2013). The area planted with eggplant crops in Asia is approximately 1.2 million hectares of the 1.8 million hectares planted worldwide (Solberg et al., 2022). According to the Food and Agriculture Organization of the United Nations (FAOSTAT, 2021), in Iraq, the area under eggplant cultivation reached about 8,660 hectares in 2021. The global production of eggplant reached 41.84 million tons, of which 39.17 million tons were produced in Asia. Iraq produced 387,435 tons, with an average productivity of 22.98 tons per hectare (Mahmood, 2012).

Being considered one of the important vegetables in the world after potatoes, tomatoes and cucumbers, eggplant is grown for its fruits that are consumed to contribute to the human diet. It is a source of mineral salts, including iron and vitamins, especially vitamin B (Naujeer, 2009). Eggplant fruits are important by providing the human body with important energy compounds such as carbohydrates, proteins, fats, vitamins, and minerals. Table 1 shows the nutritional composition of 100 g of eggplant fruits (Sharma & Kaushik, 2021).

Table 1. Nutritional composition of 100 g of fresh eggplant fruits

Parameter	Value
Caloric content	24 cal
Water	92.7%
Carbohydrates	4 mg
Protein	1.4 mg
Fat	0.3 mg
Fiber	1.3 mg
Vitamin A	124 mg
Vitamin B1	0.4 mg
Vitamin B2	0.11 mg
Vitamin C	12 mg

Eggplant fruits are considered medically important in the treatment of some diseases, including diabetes, asthma, cholera, dysuria and liver diseases, and they can lower cholesterol in the blood (Gürbüz et al., 2018; Chauhan & Nagaich, 2007). The high rates of use of chemical fertilizers in the cultivation of vegetable crops compared to other crops, due to the possibility of growing them in more than one season per year, have aggravated the negative impact on human health and the environment, especially the residual nitrate, which is considered one of the most dangerous compounds for human health (Abu-Rian, 2010; Al-Chalabi et al., 2023). Therefore, it is necessary to maintain appropriate levels of organic matter in the soil, as it directly provides the necessary nutrients to the plant and indirectly improves the physical properties. Improvements in soil texture, water retention capacity, and cation exchange capacity (CEC) have been observed, all of which enhanced nutrient availability and root development (Olorunfemi et al., 2016; Hameed & Salim, 2022).

In a study of the pea plant, Jannoura et al. (2014) showed that the addition of organic fertilizers maintained soil fertility and ensured continuous production because those fertilizers gradually release nutrients into the soil. The organic matter in the soil has an important role in maintaining the degree of soil reactivity (pH), which ensures good plant growth and gives it good productivity. Organic fertilization is one of the important factors that greatly affect the growth of plants, especially vegetative plants. Its addition improves the qualities of vegetative growth by providing nutrients and enhancing the plant’s metabolic readiness to synthesize organic compounds. These nutrients can improve the course of vital activities inside the plant, which is reflected in its growth. Adding organic fertilization to plants, whether through soil or via foliar spraying, leads to improved qualitative traits and increased yield per unit area. This can be attributed to the important role of organic fertilization in maintaining the nutritional balance of elements, which promotes cell division and the formation of side shoots. This effect is further enhanced by the presence of acids and effective chelating complexes in the extract (Kannan, 2010).

Humic acid is one of the compounds produced from the decomposition of organic matter, as this acid improves the absorption of nutrients and increases the soil's ability to retain water (Pettit, 2004). Humic acid stimulates many vital processes that lead to increased growth of the plant and the root system, especially vertically, thus enabling the roots to absorb water and nutrients well. This increases the respiration of the root system and the formation of root hairs and the development of chlorophyll, sugars and amino acids (Chen & Aviad, 1990).

Therefore, the current system in many countries of the world is not sustainable with a decrease in productivity over time. Due to the negative impact resulting from the use of chemical fertilizers, it is necessary for many countries to encourage the use of organic fertilizers and humic acid in fertilization to increase production and meet the need of the global agricultural product markets after the deterioration of traditional agriculture. In addition, this can increase economic returns, which leads to increased cultivated areas and production of organic fertilizers, thereby competing with normal production in world markets, especially developed countries. Hence, the use of organic fertilization should be relied on, which is irreplaceable in preserving soil properties and providing nutrients to plants (Arun, 2001).

The research aims to explore the possibility of growing eggplant crops based on organic sources and acids in ground fertilization and spraying on the plant to preserve human health and protect the environment.

2. Materials and Research Methods

The research was conducted during the 2023-2024 growing season at the Agricultural Technical College, Northern Technical University, aiming to study the comparative effect of different levels of fertilization with amino acids and organic fertilization on some growth qualities and yield of eggplant (*Solanum melongena* L.). A randomized complete block design (RCBD) was employed, comprising two fertilizer types (organic and amino acid) and three concentrations (0, 10, and 15 g·L⁻¹), resulting in six treatment combinations, each replicated three times, for a total of 18 experimental units. The area of each experimental unit was 2 × 3.5 m and contained six planting lines. The distance between lines was 50 cm, with 50 cm between rows, leaving a distance of 25 cm between replications along the experimental units. Seeds were manually sown on 20 March 2024, with two to three seeds placed per hole. Then they were covered with a layer of soil and irrigated. Seedlings emerged 10-14 days after planting, after which thinning was performed, leaving one plant per hole when the stage of two to three true leaves took place.

Spraying was carried out with organic fertilizers and amino acids in three concentrations (0, 10, and 15 $g \cdot L^{-1}$) in two batches: the first 15 days after germination and the second 20 days after the first. The solutions were applied to the vegetative parts of the plants until complete wetting to avoid overheating. A manual sprayer with a capacity of 10 liters was used and a diffuser (Bubblegum®) was added to the nutrient solution at a rate of 5 $mL \cdot L^{-1}$ for all experimental units. However, the control treatment was sprayed with water with a diffuser added only (El-Said & Mahdy, 2023). Table 2 shows some physical and chemical properties of the field soil before planting, as they were circumvented in the laboratories of the Nineveh Directorate of Agriculture using the method proposed by AL-Dhami & Al-lamy (2018).

The data were statistically analyzed using the Duncan's polynomial test at a probability level of 0.05 (Duncan, 1955), and the analysis was performed using SAS 9.4 software (SAS Institute Inc., Cary, NC, USA).

Table 2. Physical and chemical qualities of the field soil

Parameter	Value
Soil reaction (pH)	7.57
Electrical conductivity (EC)	0.775 $dS \cdot m^{-1}$
Nitrogen	34.9 $mg \cdot kg^{-1}$
Phosphorus	23.74 $mg \cdot kg^{-1}$
Potassium	186.28 $mg \cdot kg^{-1}$
Soil texture	Sandy

2.1 Treatment Designations

The treatments were categorized into two groups based on the type and concentration of foliar-applied fertilizer. A total of six treatment combinations were included in the study:

Z_0: Control treatment (no organic fertilizer application)
Z_1: Organic fertilizer applied at a concentration of 10 $g \cdot L^{-1}$
Z_2: Organic fertilizer applied at a concentration of 15 $g \cdot L^{-1}$
D_0: Control treatment (no amino acid application)
D_1: Amino acid solution applied at a concentration of 10 $g \cdot L^{-1}$
D_2: Amino acid solution applied at a concentration of 15 $g \cdot L^{-1}$

2.2 Studied Qualities

The vegetative growth and yield readings of the cultivated plants were taken as follows:

(a) Plant height (cm): The height of the plant was measured from the soil surface to the highest peak of the plant using a flexible measuring tape. The reading was taken 60 days after planting.

(b) Number of branches ($branches \cdot plant^{-1}$): The number of branches was determined by direct counting method as the average of five randomly selected plants from the middle of each replicate plot. The reading was taken 60 days after planting.

(c) Number of fruits formed on plants ($fruits \cdot plant^{-1}$).

(d) Stem diameter ($mm \cdot plant^{-1}$): The stem diameter was calculated for each seedling until the end of the experiment for all experimental units.

(e) Chlorophyll content (SPAD units): The chlorophyll content of the leaves was measured using the SPAD-502 device.

3. Results and Discussion

3.1 Influence of Different Levels of Fertilizers on Plant Height

As shown in Table 3, the results of the statistical analysis indicated a significant increase in the height of the eggplant plant with organic fertilizer. The height at this treatment reached 43.000 cm, superior to the treatment of seedlings with control treatment, which reached 32.778 cm. The superiority of compost treatment can be explained by its high content of potassium (K) and nitrogen (N). Potassium is known for its effects on various physiological activities in plants. It plays a huge role in photosynthesis, cell division and the transition of processed substances from source to downstream, thereby affecting the fullness of seeds. It also enhances resistance to water stress, increases resistance to diseases, and enhances protein synthesis and its quality. And the lack of potassium concentration in the plant hinders the absorption of nitrogen and the absorption of carbon in the process of photosynthesis (Wang et al., 2013). The results of the statistical analysis compare the effect of different concentrations of fertilizers and amino acids on the quantitative and qualitative characteristics of eggplant seedlings, showing a significant increase in the height of the plant. At a concentration of 10 $g \cdot L^{-1}$, the highest height of (45.000 cm) was reached, significantly greater than the control treatment (30.778 cm).

Further analysis of the interaction between fertilizer type and concentration showed that the treatment involving organic fertilization at 10 $g \cdot L^{-1}$ resulted in the greatest plant height (52.667 cm). This was significantly higher than all other treatment combinations, including the control, which recorded the lowest height of 27.667 cm. Perhaps the reason for the superiority of organic fertilization in plant height is due to the abundance of necessary nutrients (macronutrients and micronutrients) in it and their effects on photosynthesis and respiration. For example, nitrogen and phosphorus can enter into the synthesis of the necessary deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) nucleic acids to divide cells. This is consistent with the result of Toman et al. (2020) concerning the cucumber plant.

Table 3. Plant height (cm) under different treatments

Concentration ($g \cdot L^{-1}$)	Control Treatment	Amino Aids	Organic Fertilization	Effect of the Concentrations Used
0 (control)	27.667 e	30.000 de	34.667 bcde	30.778 c
10	36.667 bcde	45.667 ab	52.667 a	45.000 a
15	34.000 cde	39.667 bcd	41.667 bc	38.444 b
Effect of fertilizers used	32.778 b	38.444 ab	43.000 a	

Note: Means with the same letter within rows or columns are not significantly different according to Duncan's test at the 0.05% probability level.

3.2 Influence of Different Levels of Fertilizers on Number of Branches

As shown in Table 4, the statistical analysis results show that organic fertilization significantly exceeded the performance of both amino acid treatment and the control in the capacity of the number of branches (5.444 $branches \cdot plant^{-1}$). However, the control treatment produced the lowest value of (1.555 $branches \cdot plant^{-1}$). The superiority of the physical, chemical and biological qualities increases the availability and readiness of many nutrients. These elements can participate in or stimulate various physiological and vital processes (AL-Dhami & Al-lamy, 2018). According to the data in Table 4, the addition of fertilizers at a concentration of 15 $g \cdot L^{-1}$ for all composters has a significant impact on the number of branches, as it gave the highest value of (3.777 $branches \cdot plant^{-1}$), which surpassed the control concentration (2.888 $branches \cdot plant^{-1}$).

The interaction effect between fertilizer type and concentration reveals that the highest number of branches (6.666 $branches \cdot plant^{-1}$) was obtained from the organic fertilization at 15 $g \cdot L^{-1}$, while the lowest number (1.666 $branches \cdot plant^{-1}$) was recorded in the untreated control. This variation is likely due to macronutrients and micronutrients in the fertilizer, which are important in the nutritional balance of elements, leading to increased cell division and the formation of lateral shoots (AL-Dhami & Al-lamy, 2018).

Table 4. Effect of different levels of fertilizers on number of branches ($branches \cdot plant^{-1}$)

Concentration ($g \cdot L^{-1}$)	Control Treatment	Amino Acids	Organic Fertilization	Effect of the Concentrations Used
0 (control)	1.666 cd	3.000 bc	4.000 b	2.888 b
10	1.333 d	3.000 bc	5.666 a	3.333 ab
15	1.666 cd	3.000 bc	6.666 a	3.777 a
Effect of fertilizers used	1.555 c	3.000 b	5.444 a	

Note: Means with the same letter within rows or columns are not significantly different according to Duncan's test at the 0.05% probability level.

3.3 Influence of Different Levels of Fertilizers on Number of Fruits

The results in Table 5 show that there are significant differences in the number of fruits for eggplant seedlings when using different fertilization treatments. When treating seedlings with amino acids, the number of fruits increased significantly (5.888 fruits·plant^{-1}), which is clearly superior to that of the control treatment (2.444 fruits·plant^{-1}). The increase in fruit production can be attributed to the humic acid in potassium humate, which promotes vegetative growth, including plant height and the number of total leaves. Increased processed substances in the leaves and their transfer to the fruiting parts can lead to higher yield. This result aligns with findings of Yaquby et al. (2024) and Alsawaf & Ibraheem (2023), who reported that spraying cucumber plants with humic acid led to an increase in the number of fruits, fruit weight and total yield. In addition, the improvement is perhaps caused by amino acids, which are stimulants of plant activities. Nitrogen contributes to vegetative growth, which enhances carbon metabolism, thereby yielding more fruits (Yildirim, 2007).

The results of the statistical analysis in the Table 5 show that the addition of fertilizers at a concentration of 10 g·L^{-1} outperformed all treatments (4.555 fruits·plant^{-1}), including the control (4.444 fruits·plant^{-1}). The interaction between fertilizer type and concentration shows that amino acids at 15 g·L^{-1} resulted in the highest fruit number (6.000 fruits·plant^{-1}), which is superior to all other combinations, including the control (3.333 fruits·plant^{-1}). These results are similar to those of Safana (2013), who added humic acid to a Dahlia plant, resulting in a significant increase in plant height, number of leaves, leaf area and number of vegetative branches.

Table 5. Effect of different levels of fertilizers on number of fruits (fruits·plant^{-1})

Concentration (g·L^{-1})	Control Treatment	Amino Acids	Organic Fertilization	Effect of the Concentrations Used
0 (control)	3.333 abc	6.333 a	3.667 abc	4.444 a
10	2.333 bc	5.333 ab	6.000 ab	4.555 a
15	1.667 c	6.000 ab	4.333 abc	4.000 a
Effect of fertilizers used	2.444 b	5.888 a	4.666 a	

Note: Means with the same letter within rows or columns are not significantly different according to Duncan's test at the 0.05% probability level.

3.4 Influence of Different Levels of Fertilizers on Stem Diameter

As shown in Table 6, the results of the statistical analysis demonstrate the effect of two types of fertilizers on the growth and yield qualities of eggplant seedlings. The treatment of seedlings with organic fertilizers may significantly exceed that of amino acids and the control treatment in stem diameter (16.367 mm·seedling^{-1}). The control treatment gave the lowest value (14.515 mm·seedling^{-1}). Organic fertilizers can improve both the physical and fertile qualities of the soil, as well as nutrients. These elements have an important role as they participate in or stimulate many physiological and vital processes and activities, which are related to the process of photosynthesis and food processing in the plant and can stimulate cell division and elongation, thereby increasing vegetative growth (Saloom & Al-Sahaf, 2016).

The data in Table 6 show that the addition of fertilizers at a concentration of 10 g·L^{-1} exceeded all other treatments in terms of the stem diameter (18.855 mm·seedling^{-1}), including the control concentration (13.235 mm·seedling^{-1}). According to the results of the statistical analysis, the interaction between fertilizer type and concentration was also found to be statistically significant. The treatment of seedlings with amino acids at 10 g·L^{-1} was superior in the stem diameter of eggplant seedlings (20.050 mm·seedling^{-1}), and the lowest value of (12.073 mm·seedling^{-1}) was observed in the untreated control. The superiority of amino acid fertilization agrees with the findings of (Qian & Hettich, 2017), who sprayed plants with humic acid, which increased the absorption of elements, thereby improving the effectiveness of the enzymatic system and the development of the root system. This finally increased cell division, as humic acid is a complementary source of polyphenols during the early stages of plant growth.

Table 6. Effect of different levels of fertilizers on stem diameter (mm·seedling^{-1})

Concentration (g·L^{-1})	Control Treatment	Amino Acids	Organic Fertilization	Effect of the Concentrations Used
0 (control)	12.073 d	13.943 cd	13.690 cd	13.235 c
10	16.607 b	20.050 a	19.910 a	18.855 a
15	14.867 bc	13.643 cd	15.503 bc	14.671 b
Effect of fertilizers used	14.515 b	15.878 ab	16.367 a	

Note: Means with the same letter within rows or columns are not significantly different according to Duncan's test at the 0.05% probability level.

3.5 Influence of Different Levels of Fertilizers on Leaf Chlorophyll Content

The results presented in Table 7 indicate significant differences in the quality of the chlorophyll content of eggplant seedlings when using organic fertilizers. The percentage of chlorophyll increased when treating seedlings with organic fertilizers in the experiment. The chlorophyll content of the leaves reached (22.723 SPAD), clearly superior to the control treatment, which gave the lowest value in this capacity (19.551 SPAD). These results are consistent with the findings of Ahmad et al. (2016), who reported that organic, bio-based and nitrogen-based fertilizers enhanced the growth and yield of the sapote plant. Organic fertilizers can increase the content of chlorophyll in leaves because they contain a set of nutrients and amino and organic acids, increasing the activity of metabolic and physiological processes and the formation of chlorophyll, as chlorophyll molecules contain nitrogen as a central component.

According to the statistical analysis results in Table 7, the use of fertilizers at a concentration of 15 $g·L^{-1}$ surpassed all the treatments in the quality of chlorophyll content of leaves with (26.414 SPAD), including the control (17.061 SPAD). The analysis also reveals a significant interaction effect between fertilizer type and application concentration. Specifically, the treatment of seedlings with organic fertilizers with a concentration of 15 $g·L^{-1}$ was superior in chlorophyll content (29.417 SPAD), and the lowest value (16.130 SPAD) was given by the control treatment. The increased chlorophyll content in the leaves may be caused by betaines, which play a key role in increasing the chlorophyll content inside the leaves by preventing chlorophyll from breaking down or by cytokinin, which can increase the chlorophyll content in the leaves. In addition, organic fertilizers contain auxins or cytokines that enhance physiological activities and increase the total chlorophyll. These results are consistent with the findings of Trejo Valencia et al. (2018) in relation to the cucumber plant.

Table 7. Effect of different levels of fertilizers on leaf chlorophyll content (SPAD)

Concentration ($g·L^{-1}$)	Control Treatment	Amino Acids	Organic Fertilization	Effect of the Concentrations Used
0 (control)	16.130 f	17.563 de	17.490 de	17.061 c
10	18.297 ed	20.177cd	21.263 c	20.045 b
15	23.827 b	26.000 b	29.417 a	26.414 a
Effect of fertilizers used	19.551 b	21.246 a	22.723 a	

Note: Means with the same letter within rows or columns are not significantly different according to Duncan's test at the 0.05% probability level.

4. Conclusion

Based on the results obtained, it can be concluded as follows:

(a) Spraying plants with organic fertilizers has a significant effect on most of the studied qualities because of their crucial role in the nutritional balance of elements, which can improve cell division and the formation of side shoots. This effect may also be attributed to the presence of organic acids and effective chelating agents within the extract.

(b) The best concentration of amino acids to increase the number of fruits is 10 $g·L^{-1}$ because amino acids can increase the activation of a large number of enzymes that enter into the process of photosynthesis.

(c) A significant interactive effect is observed between fertilizer type and application concentration. Spraying with organic fertilizers at a concentration of 15 $g·L^{-1}$ has a positive role in most of the qualities under present study, as these fertilizers participate in or stimulate many vital activities and processes related to photosynthesis.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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