



RESEARCH ARTICLE

The role of amino acids glycine and phenylalanine in some physiological characteristics of guava seedlings newly introduced to Iraq

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Abstract

This work uses environmentally acceptable amino acids as biomolecules to support important physiological processes and increase tolerance to biotic and abiotic environmental challenges in recently imported *Psidium guajava* L. in Iraq. Some amino acids affect the later growth of guava seedlings in a new environment. A fully randomized block design factorial experiment on guava seedlings examined the effects of glycine and phenylalanine at three concentrations each (0, 250 and 500 mg L⁻¹ for glycine and 0, 150 and 300 mg L⁻¹ for phenylalanine). Combining glycine (500 mg L⁻¹) with phenylalanine (300 mg L⁻¹) resulted in significant increases in all guava seedling parameters, surpassing their individual effects. These gains included increased leaf chlorophyll, carbohydrate content and decreased nutrient leaching. The results show that foliar spraying with glycine and phenylalanine improved the physiological and phenological features of guava seedlings. The study found that foliar spraying with glycine and phenylalanine improved guava seedling development, productivity and quality in Iraq.

Keywords: amino acids; glycine; guava; phenylalanine; physiological properties

Introduction

Psidium guajava L. is a perennial evergreen shrub or small tree of the family Myrtaceae, with approximately 5000 species distributed across more than 150 genera worldwide. The plant is quite adaptable to a wide range of ecological zones, as natural development typically occurs in tropical and subtropical climates where conditions favour its active development and fruiting capability. Based on recent estimations, India is first among all the producers, followed by China, Kenya and Brazil; global annual guava output is more than 40 Mt. Well-established in Egypt, Sudan, Palestine, Algeria and the Arab area generally, guava planting exhibits tolerance to elevations ranging from 2000 m above mean sea level (1).

Guava is being introduced into new agroecological zones like Iraq, where successful establishment depends on how well the seedlings adapt to new environmental circumstances, including varying temperatures, nutritional availability and various biotic stressors. These components may hinder early growth and influence plant health, so boosting resistance and maximizing performance requires supportive agronomic strategies.

One effective approach is provided by amino acids as biostimulants. Amino acids are low molecular weight organic compounds consisting of nitrogen, carbon, hydrogen and oxygen. They are major participants in plant metabolism and signal transduction even at low concentrations (2). Apart from their

nutritional worth, amino acids improve plant responses to biotic and abiotic stress, boost nitrogen uptake and activate pathways connected with the synthesis of proteins and carbohydrates, thus increasing photosynthetic efficiency and plant production (3, 4).

Among these, glycine is particularly crucial, as its nonpolar, hydrophilic property allows it to interact in both acidic and basic environments. Glycine is also well-known to increase the absorption of vital nutrients like nitrogen (N), phosphorus (P), zinc (Zn), copper (Cu) and iron (Fe), thereby improving photosynthetic capacity (5, 6). Glycine also helps promote chlorophyll synthesis. Moreover, glycine serves to regulate osmotic pressure, increases protein and enzyme synthesis and modulates plant stress responses by means of the transmission of biochemical signals controlling nutrient transport and homeostasis (7, 8). On the other hand, phenylalanine is a required precursor in both main and secondary metabolic routes. It is a component of the synthesis of phenolic compounds such as lignans and flavonoids, which considerably increase plant structural defenses and resistance to environmental challenges (9). Stress causes phenylalanine to additionally enhance the antioxidant capacity of plant tissues and assist in the synthesis of chlorophyll, hence improving plant health (10, 11). Without adverse effects, foliar application of phenylalanine promotes the generation of antioxidant molecules. Its low molecular weight and strong solubility enable roots and plants to rapidly absorb it, therefore providing a cheap and efficient biostimulant. Glycine and phenylalanine have physiological purposes; hence, their foliar application provides a useful means of

support for newly introduced crops in challenging environments. Therefore, the purpose of this work was to evaluate the capabilities of these amino acids to improve the growth, physiological responses and adaptation of guava seedlings produced for the first time under Iraqi surroundings. Aiming for a basis for environmentally friendly interventions to support sustainable guava farming under local agroclimatic conditions, the study especially focuses on how different concentrations of glycine and phenylalanine affect significant properties including chlorophyll content, carbohydrate accumulation and nutrient retention.

Materials and Methods

Study area and sample collection

The study was conducted at the College of Agriculture /University of Karbala on guava seedlings of one-year-old seed origin during the period from September 2023 to June 2024, which were planted in polyethylene bags with a capacity of 10 kg inside the plant canopy of the Department of Horticulture with a shading percentage of (50 %) of the intensity of natural light and which is located at the intersection of longitude 44° 06' 58" E and latitude 32° 32' 17" N, and at an altitude of 29 m above sea level, as in Fig. 1.

Experimental design

The study included a factorial experiment with two factors:

Factor 1: Three concentrations of the amino acid glycine (0, 250 and 500 mg L⁻¹).

Factor 2: Three concentrations of phenylalanine (0, 150 and 300 mg L⁻¹).

Thus, the experiment was a factorial experiment with two factors (3 x 3), so the number of factorial treatments is 9, as shown in Table 1. A completely randomized block design with three blocks was used, so the number of experimental units became 27 and each experimental unit consisted of 2 observations; thus, the total number of plants became 54.

The data analysis process was conducted statistically for all the studied traits according to the experimental design using an electronic calculator and the SAS statistical analysis program (version 2012). The arithmetic means of the coefficients were also compared statistically according to Duncan's Multiple Range Test.

Table 1. Experimental coefficients

Treatment Number	Claysine (mg L ⁻¹)	Phenylalanine (mg L ⁻¹)
1	0	0
2	0	150
3	0	300
4	250	0
5	250	150
6	250	300
7	500	0
8	500	150
9	500	300

Environmental conditions and service operations

The study soil was analyzed in the Central Laboratories Unit of the Iraqi Ministry of Science and Technology to show some of its physical and chemical properties. It was found that it is a basic soil (pH 7.73) with a sandy texture, containing 62.00 % sand, while the percentage of silt and clay reached 38.00 %. It is poor in organic matter, which reached 0.073 % and the concentration of each of the main elements, nitrogen, phosphorus and potassium, was 1.8, 0.62 and 2.74% respectively.

Guava seeds were planted in polyethylene bags with a capacity of 10 kg in September 2022. Before planting the seeds, the soil was mixed with peat moss at a volume ratio of 3:1 (soil:peat moss). At the beginning of March, the seedlings were sprayed with the amino acids glycine and phenylalanine with the experimental concentrations, at a rate of one spray every two weeks, with a total of six sprays during the study phase. The spraying process was carried out in the early morning using a hand sprayer with a capacity of 2.5 L, while continuing the agricultural service operations of irrigation and weeding until the end of the study.

Traits studied

Several important traits were recorded during the experimental period in order to assess the morphological and physiological responses of *P. guajava* seedlings to foliar treatments of glycine and phenylalanine. These features were deliberately chosen for their applicability under environmental stress circumstances in relation to plant vigour, metabolic activity and adaptation.

The cell membrane stability index (CMSI), which underlines the integrity of cellular membranes under possible stress circumstances, was one of the main measurements. This parameter

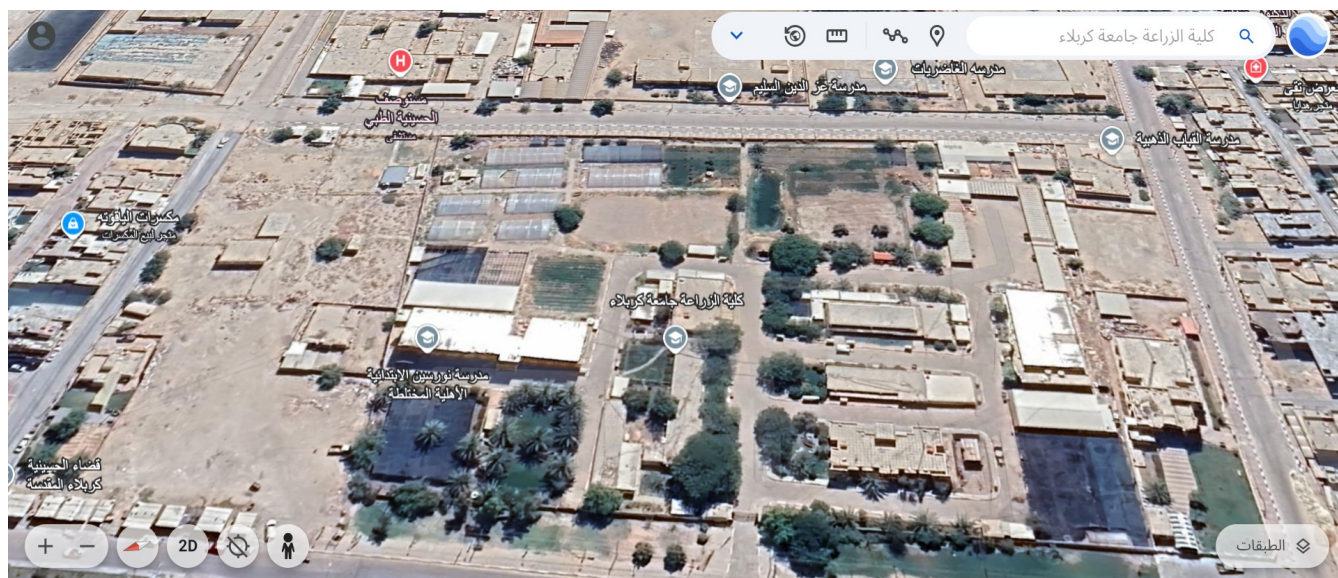


Fig. 1. Study location at College of Agriculture, University of Karbala.

is commonly used to estimate damage at the cellular level and is expressed as a percentage of leakage-derived conductivity, representing the extent of membrane injury.

The stability of the plasma membrane of guava leaf cells was estimated by studying the leakage of substances from the leaf cells before and after damage, through an analysis of their absorption of ultraviolet light, based on a previous report (12). Fully mature, healthy, green leaves from seedlings were cut into 2 cm pieces and placed in 50 cm³ glass bottles at a rate of 20 pieces per bottle. After thoroughly washing the leaves several times with distilled water to remove the surface contaminants, 25 mL of distilled water was added and the bottles were then placed in a water bath at 25 °C for 24 hr. The absorbance of the solutions was measured at a wavelength of 280 nm using a spectrophotometer. The solutions were then returned to their containers and frozen at -4 °C for 24 hr, then allowed to thaw at room temperature. After thawing, they were placed in a water bath at a specified temperature. At 25 °C for 2–3 hr with continuous shaking, the absorbance of these solutions was measured at the same wavelength, and the percentage leakage (%) was calculated using the following equation:

$$\text{Liquid percentage (\%)} = \frac{\text{Absorbance before freezing}}{\text{Absorbance after freezing}} \times 100$$

Furthermore, total chlorophyll content in fresh leaf tissues (mg g⁻¹ wet weight) was measured as chlorophyll levels directly reflect photosynthetic activity and plant vigour.

The chlorophyll a, b and total chlorophyll content of mature guava leaves were estimated (13). Five hundred mg of mature leaf tissue of the study plants was taken, cut into several small pieces with scissors and ground in a ceramic mortar with 10 mL of 80 % acetone until the precipitate was free of green pigment. The filtrate was then separated from the residue using a centrifuge at 1600 rpm for 10 min. The extract was collected in volumetric tubes lined with opaque paper to block light from reaching the chlorophyll and prevent photo-oxidation of the pigment. The volume was then made up by adding acetone. The absorbance of the filtrate was measured spectrophotometrically at wavelengths of 645 and 663 nm. Using the equations below, the concentration of chlorophyll a, b, and total in the plant leaves was estimated on a basis (mg g⁻¹ fresh weight).

$$\text{Chlorophyll A} = [12.7 (\text{D663}) - 2.69 (\text{D645})] \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll B} = [22.9 (\text{D645}) - 4.68 (\text{D663})] \times \frac{V}{1000 \times W}$$

$$\text{Total Chlorophyll} = [20.2 (\text{D645}) + 8.02 (\text{D663})] \times \frac{V}{1000 \times W}$$

Relative water content (RWC) of leaves was calculated in order to investigate the water retention capacity and response to foliar treatments of the seedlings. This percentage-based indicator helps to understand the plant's hydration level as well as its capacity to sustain cellular turgor under different circumstances. Serving as a biochemical marker for energy storage and metabolic efficiency, the study also estimated total carbohydrates in dried leaf samples (µg g⁻¹ dry weight). Usually, enhanced carbohydrate accumulation is associated with better photosynthetic capability and growth performance.

The relative moisture content of guava seedling leaves was estimated by weighing 20 moist leaves from each experimental unit seedling using a sensitive balance with a sensitivity of 0.0001 g and recording their wet weight (14). They were then immersed in distilled water for 16–18 hr at room temperature (23–25 °C) under low light conditions to saturate the leaves with distilled water. The turgid weight of the leaves at saturation was recorded. The leaves were then dried in an electric oven at 70 ± 1 °C until the weight stabilized. The dry weight of the leaves was recorded and the relative moisture content of the leaves for each treatment was calculated according to the following mathematical relationship.

Relative moisture content of the leaves (%) =

$$\frac{\text{Wet weight} - \text{Dry weight of the leaf}}{\text{Swelling weight} - \text{Dry weight of the leaf}} \times 100$$

From a morphological perspective, seedling height (cm) was noted as a fundamental growth indicator that reflected the combined impact of treatments on vertical development. Furthermore, the number of leaves per plant was recorded, which provides a direct indicator of vegetative development and canopy building.

Finally, main stem diameter (mm) was measured near the base of each plant to assess structural robustness, which correlates with the overall health and mechanical support potential of the seedling. Together, these physiological and morphological traits provide a comprehensive overview of how guava seedlings respond to the exogenous application of amino acids, offering insight into both biochemical enhancement and physical development under new environmental conditions.

Results

Cell membrane stability index (%)

Table 2 shows that the amino acid glycine did not significantly differ in the degree of cell membrane stability, despite a 29.74 % decrease in leaf leaching when increasing the concentration to 500 mg L⁻¹, while the comparison treatment had the highest rate of leaf leaching (31.85 %). The same table shows that 300 mg L⁻¹ of phenylalanine decreased the leaching rate of guava leaves by 23.97 % compared to the comparison treatment, which had the highest leaching rate (37.09 %) and the lowest decrease rate (35.37 %). The two-way interaction between the studied factors showed significant differences, as spraying guava leaves with 500 mg L⁻¹ glycine and 300 mg L⁻¹ phenylalanine resulted in the lowest leaching rate of 22.14 % and a decrease rate of 40.74 % compared to the comparison treatment, which had the highest rate of 37.37 %.

Chlorophyll content of fresh leaves (mg g⁻¹ wet weight).

Table 3 shows that the amino acid glycine significantly affects the total chlorophyll content of guava leaves. Spraying the leaves at 500 mg L⁻¹ gave the highest chlorophyll content, 0.642 mg g⁻¹ and a 9.36 % increase rate compared to the comparison treatment, which recorded 0.587 mg g⁻¹. The same table shows that guava seedling leaves with increasing concentrations of the amino acid phenylalanine had the highest total chlorophyll content, with seedlings treated with 150 and 300 mg L⁻¹ at 0.650 and 0.837 mg g⁻¹ respectively, compared to the control treatment, which had the lowest rate of 0.300 mg g⁻¹. The two-way interaction between the

Table 2. Effect of glycine, phenylalanine and interference coefficients on the degree of stability of cell membrane

Glycine concentration (mg L ⁻¹)	Phenylalanine concentration (mg L ⁻¹)			Average effect of glycine
	0	150	300	
0	37.370 a	32.541 ab	25.643 ab	31.851 a
250	36.552 a	30.722 ab	24.133 b	30.469 a
500	37.360 a	29.716 ab	22.143 b	29.740 a
Average effect of phenylalanine	37.094 a	30.993 a	23.973 b	

Table 3. Effect of glycine, phenylalanine and interference factors on the total chlorophyll content of guava leaves

Glycine concentration (mg L ⁻¹)	Phenylalanine concentration (mg L ⁻¹)			Average effect of glycine
	0	150	300	
0	0.293 e	0.648 cd	0.821 ab	0.587 b
250	0.272 e	0.573 d	0.829 a	0.558 b
500	0.335 e	0.730 bc	0.861 a	0.642 a
Average effect of phenylalanine	0.300 c	0.650 b	0.837 a	

studied factors showed that guava seedling leaves treated with glycine (500 mg L⁻¹) and phenylalanine (300 mg L⁻¹) had the highest total chlorophyll content (0.861 mg g⁻¹) and the highest increase rate (193.85 %) compared to the control treatment (0.293 mg g⁻¹).

Relative moisture content of leaves (%)

The results of Table 4 show that there were no significant differences between all concentrations of the amino acid glycine used in the relative moisture content of guava leaves, except for the high concentrations (250 and 500 mg L⁻¹) that gave seedlings with the highest moisture content, which did not reach the level of significance compared to the comparison treatment. Also, the single effect of the amino acid phenylalanine was observed. The binary interaction between the studied factors showed that the seedling leaves had the highest relative moisture content when treated with glycine (500 mg L⁻¹) and phenylalanine (300 mg L⁻¹) at a rate of 69.92 %, while the comparison treatment had the lowest rate of 49.22 % and an increase rate of 42.04 %.

Carbohydrate content of seedling leaves (µg g⁻¹ dry weight)

Table 5 reveals that glycine and phenylalanine effects considerably affected guava seedling leaf carbohydrate content. Treating seedlings with 500 mg L⁻¹ glycine resulted in a substantially higher average of 2.520 µg g⁻¹ compared to the control treatment, which had the lowest average of 2.243 µg g⁻¹. The seedlings treated with 150

and 300 mg L⁻¹ phenylalanine showed significant improvements in leaf carbohydrate content, with an average of 2.719 and 2.919 µg g⁻¹ respectively, compared to the control treatment, which had the lowest carbohydrate content (1.468 µg g⁻¹). The binary interaction between glycine and phenylalanine showed significant differences in leaf carbohydrate content. Seedlings treated with 500 mg L⁻¹ glycine and 300 mg L⁻¹ phenylalanine had the highest carbohydrate content (2.966 µg g⁻¹) and increased by 124.01 % compared to the control treatment, which had the lowest content (1.32 %).

Seedling height (cm)

There were no significant changes in seedling height across any single glycine treatments (Table 6). The height of guava seedlings increased, but not significantly, when treated with glycine concentrations (250 and 500 mg L⁻¹) at 131.20 and 134.00 cm per seedling respectively, compared to the comparison treatment, which gave the lowest rate of seedling height (126.44 cm per seedling). The same table shows substantial differences between phenylalanine concentrations. According to the binary interaction between the studied factors, the concentration (150 and 300 mg L⁻¹) caused the highest significant increase in seedling height, at 133.54 and 139.37 cm per seedling, with an increase rate of 12.52 and 17.43 % respectively. The comparison treatment caused the lowest increase in seedling height, at 118.68 cm per seedling.

Table 4. Effect of glycine, phenylalanine and interference coefficients on the relative moisture content of guava leaves

Glycine concentration (mg L ⁻¹)	Phenylalanine concentration (mg L ⁻¹)			Average effect of glycine
	0	150	300	
0	49.223 b	67.863 a	68.154 a	61.747 a
250	51.207 b	68.108 a	68.671 a	62.662 a
500	51.080 b	68.991 a	69.920 a	63.330 a
Average effect of phenylalanine	50.503 b	68.321 a	68.915 a	

Table 5. Effect of glycine, phenylalanine and interference factors on the soluble carbohydrate content of guava leaves (µg g⁻¹ wet weight)

Glycine concentration (mg L ⁻¹)	Phenylalanine concentration (mg L ⁻¹)			Average effect of glycine
	0	150	300	
0	1.324 d	2.522 b	2.882 ab	2.243 b
250	1.355 d	2.765 ab	2.908 ab	2.343 ab
500	1.725 c	2.870 ab	2.966 a	2.520 a
Average effect of phenylalanine	1.468 b	2.719 a	2.919 a	

Table 6. Effect of glycine, phenylalanine and interference factors on the height of guava seedlings (cm)

Glycine concentration (mg L ⁻¹)	Phenylalanine concentration (mg L ⁻¹)			Average effect of glycine
	0	150	300	
0	116.43 c	130.13 abc	132.66 ab	126.44 a
250	116.83 c	133.13 ab	143.63 a	131.20 a
500	122.80 bc	137.36 a	141.83 a	134.00 a
Average effect of phenylalanine	118.68 b	133.54 a	139.37 a	

Number of leaves on the plant (leaf)

Table 7 reveals notable variations in the number of seedling leaves depending on the particular treatments of the investigated variables. Treating seedlings with the highest concentration of the amino acid glycine (500 mg L⁻¹) resulted in 188.92 leaves per seedling, against the comparison treatment, which had the lowest number of leaves (169.38 leaves per seedling), indicating a significant increase in the number of guava leaves. The table reveals notable variations in the effects, when different concentrations of the amino acid phenylalanine were utilized. The concentrations (150 and 300 mg L⁻¹) recorded the highest significant increase in the number of leaves, at a rate of 183.27 and 199.00 leaves per seedling respectively, and an increase of 19.37 and 29.61 % respectively, compared to the comparison treatment, which had the lowest number of leaves (153.53 leaves per seedling). It is noted from the data of the two-way interaction between the studied factors that the number of leaves of guava seedlings reached the maximum (207.50 leaves per seedling) when treated with glycine at a concentration of 500 mg L⁻¹ and phenylalanine at 300 mg L⁻¹, while the lowest number of leaves was recorded in the seedlings of the comparison treatment (140.17 leaves per seedling) and an increase rate of 48.03 %.

Main stem diameter (mm)

According to Table 8, there were no significant differences among all treatments of the amino acid glycine for the main stem diameter trait. The higher concentrations (250 and 500 mg L⁻¹) produced seedlings with larger main stem diameters, but they did not reach the level of significance compared to the comparison treatment, whose seedlings had the lowest rate of 9.84 mm per seedling. The two-way interaction between the studied factors that the best diameter of 254 the seedling stems was recorded when the seedling treatment was interacted with a ratio of (500 mg L⁻¹) of glycine with a concentration of (300 mg L⁻¹ 255) of phenylalanine at a rate of (11.00 mm seedling-1 256) while the comparison treatment recorded a rate of (8.76 mm seedling-1 257) and an increase rate of 258 (25.57 %).

Discussion

Foliar spraying with the amino acids glycine and phenylalanine led to a clear effect on improving the physiological and phenological characteristics of guava seedlings studied. By reviewing the data in Tables (3, 5 and 7), the concentration (500 mg L⁻¹) of the amino acid

glycine led to a significant increase in the leaf chlorophyll content, total carbohydrates and the number of leaves. It also led to a decrease, but not to the level of significance, in the cell membrane leaching rate and an insignificant increase in the relative moisture content in guava leaves and in the height and stem diameter of the seedlings, as in Tables (4, 6 and 8). This may contribute to the role of amino acids in improving plant resistance to unfavorable environmental influences and thus playing an important role in increasing the growth in treated plants, especially those newly introduced to the country (15). This was confirmed by a previous study, where they indicated that spraying amino acids on the leaves of many plants led to improving vegetative growth in addition to achieving a significant increase in production (16). The importance of amino acids lies in being a rich source of nitrogen, which is reflected in plant productivity and growth stimulation, whether vegetative or root growth, in addition to improving the absorption of nutrients and increasing photosynthetic efficiency (17).

Many studies confirm these findings, as they found that spraying plant leaves with glycine leads to an increase in biochemical compounds in the leaves, such as carbohydrates and proteins, by increasing the absorption and transportation of nutrients from the soil into the plant (18). The amino acid glycine improves the photosynthetic process by increasing the efficiency of nitrogen utilization (19). Glycine has an important role in improving photosynthetic efficiency and enhancing chlorophyll content, thus improving most growth characteristics by increasing the availability of zinc, manganese, copper and iron (20).

The results also agreed with a study in which treating apple plants with glycine showed a significant increase in the length and diameter of the main stem as well as an increase in the leaf area and total chlorophyll content compared to the comparison treatment (21). In addition to an increase in the content of nitrogen, phosphorus, potassium, calcium, iron, zinc, manganese and boron was observed in the plant leaves compared to the comparison treatment. These results also agree with another study, which reported that glycine improves the photosynthetic process in leaves by enhancing nitrogen, potassium, magnesium and zinc compared to the comparison treatment (22). Application of glycine to basil leaves led to an improvement in plant height, root fresh weight and chlorophyll content, along with an increase in micro and macro nutrients such as nitrogen, calcium, potassium, phosphorus, iron and zinc (23).

Table 7. Effect of glycine, phenylalanine and interaction factors on the number of leaves of guava seedlings (leaf)

Glycine concentration (mg L ⁻¹)	Phenylalanine concentration (mg L ⁻¹)			Average effect of glycine
	0	150	300	
0	140.17 d	175.50 bc	192.50 ab	169.38 b
250	154.00 cd	181.50 abc	197.00 ab	177.50 ab
500	166.43 bcd	192.83 ab	207.50 a	188.92 a
Average effect of phenylalanine	153.53 b	183.27 a	199.00 a	

Table 8. Effect of glycine, phenylalanine and interference coefficients on the diameter of the main stem of guava seedlings (mm)

Glycine concentration (mg L ⁻¹)	Phenylalanine concentration (mg L ⁻¹)			Average effect of glycine
	0	150	300	
0	8.76 d	10.05 bc	10.71 ab	9.84 a
250	8.94 d	10.68 c	10.98 a	9.86 a
500	8.54 d	10.17 bc	11.00 a	9.90 a
Average effect of phenylalanine	8.74 c	9.96 b	10.89 a	

The concentrations (150 and 300 mg L⁻¹) of the amino acid phenylalanine caused a significant increase in most of the physiological and phenotypic traits studied. This is due to the fact that the amino acid phenylalanine added to the leaves regulates the activity of antioxidant enzymes such as CAT, SOD and POD and significantly improves the photosynthetic process, thus improving plant growth by increasing the activity of antioxidants and oxidative enzymes, especially in plants grown under unfavorable environmental conditions by overcoming harmful abiotic stresses, thus increasing total chlorophyll content and reducing the effect of oxidative compounds (10).

Phenylalanine acts as a precursor for many phenolic compounds such as flavonoids, lignans, tannins and benzoides, which makes this amino acid contribute significantly to plant defense under adverse conditions (24). Positive results have been observed in several studies on the foliar application of phenylalanine in soybean (*Glycine max*) (25), sage (*Salvia officinalis*) (9), tomato (*Solanum lycopersicum*) (26) and cucumber (*Cucumis sativus*) (27). Biologically active amino acids such as phenylalanine have important physiological effects on plants and can play roles as antidotes to adverse environmental conditions by controlling the opening and closing of stomata, regulating transport and activating enzymes, as well as maintaining the balance between oxidation and reduction processes (28).

Conclusion

The research results confirmed the positive effect of spraying guava seedling leaves with the amino acids glycine and phenylalanine on some physiological and morphological characteristics. Treatment with these amino acids showed a significant improvement in physiological activity through the role of amino acids in stimulating basic metabolic processes in the plant, thereby improving some of its physiological and morphological characteristics, which confirms the practical importance of glycine and phenylalanine as effective tools to enhance the physiological growth of guava seedlings and thus increase productivity and improve the quality of its production under the conditions of the holy city of Karbala, Iraq. These results can be used later in developing food security strategies by introducing plant species with high economic value for the first time and successfully in Iraq.

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Authors' contributions

CKJA contributed to the conceptual design of the study, supervised the experimental procedures and participated in the data interpretation and manuscript revision. SGSB was responsible for conducting the laboratory and field experiments, data collection, statistical analysis and drafting the initial manuscript. Both authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interests to declare.

Ethical issues: None

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