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Eureka Journal of Agricultural Science & Bio-Innovation (EJASB)

ISSN 2760-4969 (Online) Volume 2, Issue 7, July 2026

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INFLUENCE OF AMINO ACID BIOSTIMULANTS ON SEED YIELD, OIL CONTENT, AND PROTEIN PERCENTAGE IN DIFFERENT SESAME CULTIVARS

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Abstract

Background: Sesame (Sesamum indicum L.) is an important oilseed crop from an economic perspective. Amino acid biostimulants have been proposed as a green alternative to enhance the productivity of crops and seed quality. **Objective**: This study was conducted to explore the response of the yield, growth components, seed yield and seed quality traits of three sesame cultivars to application between some concentrations of amino acids under conditions available in Kirkuk-Iraq

Methods: The study was carried in a factorial design based on randomized complete block design with three replications during the 2025 growing season. A field experiment was conducted on three sesame cultivars (Shandweel 3, Giza 32 and Toshka 1) which were sprayed using four concentrations of amino acids(0,2,4 and6 mL L-1).

Results: Cultivar, amino acid concentration and their interaction were significant for all traits ($P \leq 0.05$). Amino-Acids concentration have been considered major bio fertilizer yield components and it appears that distant concentrations of amino-acid are highly influential for seed quality. The maximum capsules per

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plant (84.1), seeds per capsule (72.7) and 1000–seed weight (3.85 g) recorded by Toshka 1 at 6 mL L^{-1} of leaf extract application. The higher seed yield per plant (29.4 g) and total seed yield (1679 kg ha-1) were obtained after the same treatment. The maximum oil and protein content were also 54.1% and 24.7%, respectively. We used principal component analysis (PCA) to show a positive correlation between growth traits, yield components and seed quality characters. **Conclusion**: Foliar application of amino acid biostimulants successfully increased sesame productivity and seed quality, and 6 mL L^{-1} concentration was the most effective. While all the tested cultivars were responsive to rhizobial inoculation, cultivar Toshka 1 was the most responsive and may be recommended for sesame production under Iraqi conditions.

Keywords: Sesame; Amino acid biostimulants; Seed yield; Seed quality; Cultivar response.

INTRODUCTION

Sesame (Sesamum indicum L.) is a traditional oilseed crop with high nutritional and commercial value worldwide, making it one of the oldest domesticated crops. Due to the high contents of oil, protein, essential amino acids, and unsaturated fatty acids in its seeds, sesame serves as an important food crop and a valuable feedstock for pharmaceutical and industrial applications. However, environmental constraints and the differences among cultivars [1] remain important challenges to achieve high productivity and to maintain seed quality. Sustainable agriculture practices in recent years have been more focused on reducing dependence on chemical fertilizers and promoting eco-friendly alternatives. Plant biostimulants have appeared as promising tools to improve crop productivity, nutrient use efficiency, and resistance to adverse environmental conditions with minimum negative ecological consequences [2,3]. Among the various biostimulants, amino acids have received considerable

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attention due to their multifunctional roles in plant metabolism. They are involved in protein synthesis, chlorophyll formation, nutrient chelation, hormonal regulation and several metabolic pathways related to plant growth and development. In addition, amino acids increase photosynthetic efficiency and maintain cellular homeostasis under stress conditions [4]. Several investigations have demonstrated beneficial effects of amino acid-based biostimulants on sesame growth and productivity. Foliar application of amino acids significantly improved plant height, leaf area, photosynthetic pigments, capsule formation, seed yield and oil production. Also, amino acid treatments have been reported to increase protein accumulation and seed quality [5,6]. Amino acids are also good for nitrogen utilization and metabolism. Physiological and transcriptomic analyses showed that the nitrogen assimilation pathways and amino acid metabolism are essential for plant growth and productivity enhancement in sesame [7]. Amino acids are also involved in the improvement of antioxidant defense mechanisms and tolerance to environmental stressors The accumulation of proline and other amino acids has been associated with enhanced drought tolerance and increased scavenging of reactive oxygen species in sesame plants [8]. Recent evidence suggests that amino acid fertilizers may have a positive effect on the rhizosphere ecology, stimulating beneficial microorganisms and improving nutrient availability, and thus improving crop performance and soil health [9]. Biostimulants have been reported to enhance the photosynthetic activity, metabolic processes, antioxidant systems and phenological development of oilseed crops, leading to increased productivity and better seed quality [10,11]. Another important factor affecting the performance of sesame is genotypic variation. The significant differences among sesame cultivars for growth characteristics, yield components, oil percentage and protein accumulation indicate that cultivar specific responses should be considered when testing biostimulant applications [12,13]. Despite the increasing interest in amino acid biostimulants, information on their effects on different sesame cultivars under

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Iraqi environmental conditions is still limited. Hence more studies are required to determine the response of different cultivars and to find out the most effective concentrations of amino acids for improving growth and productivity [14].The present study was carried out to evaluate the effect of different concentrations of amino acids on the growth characteristics and yield components of three sesame cultivars and to find out the most responsive cultivar under environmental conditions of Kirkuk, Iraq.

MATERIALS AND METHODS

2.1 Experimental Site

The present study was conducted during the growing season of 2025 on private agricultural fields in Kirkuk Governorate, Iraq. The region has a semi-arid climate with hot summers and low annual rainfall. The experiment was conducted in an open field, using the typical agronomic practices for sesame cultivation in the region. The meteorological conditions in the growing season were deemed favorable for sesame production.

2.2 Plant Materials

The present study was conducted with three cultivars of sesame (Sesamum indicum L.) having different genetic make up and agronomic characters. The cultivars were Shandweel 3, Giza 32 and Toshka 1 which were denoted as V1, V2 and V3 respectively. Certified seeds were obtained from authorized agricultural sources and were visually inspected for uniformity, absence of mechanical damage and symptoms of disease.

2.3 Experimental Design

The experiment was designed as a factorial study within a Randomized Complete Block Design (RCBD) featuring three replications. The first factor was three sesame cultivars and the second factor was four concentrations of amino acid

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biostimulants. Thus, twelve treatment combinations were randomly distributed within each replication, resulting in thirty-six experimental units.

2.4 Amino Acid Treatments

Amino acid biostimulants were applied on the foliage at four concentrations of 0, 2, 4 and 6 mL L^{-1}, which were designated A0, A1, A2 and A3, respectively. The solutions were prepared using distilled water for spraying. Plants without the application of amino acid were used as control treatment.

2.5 Land Preparation and Sowing

Each experimental field was ploughed two times on perpendicular directions followed by levelling and seedbed preparation. The field was divided into 3 m × 3 m (9 m2) plots, with four rows 75 cm apart. In the initial half of May-2025, seeds were sown by hand at a distance of 20cm between the hills. Uniformity of plant population was obtained by thinning the seedlings to one plant per hill after emergence. All the recommended agronomic practices such as irrigation, weed control and pest management were uniformly adopted throughout the experimental period.

2.6 Soil Sampling and Analysis

Composite soil samples were taken from the upper layer (0-30 cm) of the soil in several points of the experimental field before sowing. Samples were air-dried, ground and passed through a 2-mm sieve before analysis. Soil pH and electrical conductivity were determined in a soil-water suspension (1:2.5). Organic matter content, available nitrogen, available phosphorus and available potassium were determined by using standard laboratory methods. Furthermore, soil texture was determined to characterize the experimental site.

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2.7 Fertilization Program

All plots were fertilized with the recommended fertilizer doses for sesame production. Phosphorus fertilizer as triple superphosphate (46 per cent P2O5) and potassium fertilizer as potassium sulphate (50 per cent K2O) were applied in the soil before sowing. Nitrogen fertilizer was supplied in the form of urea (46% N) and was applied in two equal splits, the first after establishment of the seedlings and the second at the onset of flowering. Similar fertilization schedules have been successfully adopted on sesame production studies.

2.8 Foliar Application Procedure

The foliar application was made by a hand operated knapsack sprayer of 20 L capacity. Application continued until the canopy of the plant was thoroughly wet. During the growing season three foliar sprays were given. The first application was applied 30 days after sowing, the second at the beginning of flowering and the third at capsule initiation. Spraying operations were carried out early in the morning to minimize evaporation losses and maximize nutrient uptake.

2.9 Recorded Parameters

Ten plants were randomly selected from the two central rows of each plot for data collection.

2.9.1 Growth Traits

Plant height (cm) was determined from the soil surface to the terminal growing point at physiological maturity. Counted primary branches to determine branches per plant. Standard procedures were used to assess the leaf area and a SPAD-502 chlorophyll meter was used to measure the chlorophyll content.

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2.9.2 Yield Components

The number of capsules per plant was counted from ten representative plants. The number of seeds per capsule was averaged from ten randomly selected capsules. The thousand seed weight (g) was determined using an analytical balance (0.001 g). Then total seed yield (kg ha-1) and seed yield/plant (g) were computed.

2.9.3 Seed Quality Traits

Oil content (%) was determined by Soxhlet extraction apparatus with n-hexane as the extraction solvent. The extraction was continued for six hours and the percentage of oil was calculated on a dry weight basis. The crude protein content (%) was estimated by the Kjeldahl method based on the total nitrogen content and multiplied by the conversion factor 6.25.

2.10 Statistical Analysis

Data collected from the experiment were analyzed using ANOVA for factorial arrangement in a Randomized Complete Block Design utilizing GenStat software (Version 12.0). The comparison of the dosage application means was performed by Least Significant Difference (LSD) test at 5% probability level ($P \leq 0.05$). Sesame cultivars and amino acid concentrations were also assessed as interaction effects.

RESULTS

3.1 Characteristics of the Experimental Soil and Amino Acid Biostimulant

The physicochemical characteristics of the experimental soil are shown in Table 1. The soil was slightly alkaline in reaction and possessed a low electrical conductivity which is favorable for sesame growth. Also, moderate levels of available nitrogen, phosphorus and potassium were found and the soil texture was clay loam.

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Table 1. The experimental soil's physicochemical characteristics prior to seeding.

Parameter	**Value**
pH	7.42
Electrical conductivity (dS m^{-1})	1.16
Organic matter (%)	1.54
Available nitrogen (mg kg^{-1})	62.8
Available phosphorus (mg kg^{-1})	15.3
Available potassium (mg kg^{-1})	284.6
Soil texture	Clay loam

Values represent the mean of composite soil samples collected from the 0–30 cm soil layer before sowing.

As shown in Table 2, the amino acid biostimulant used in the present study contained relatively high concentrations of total and free amino acids combined with organic nitrogen, potassium and essential micronutrients.

Table 2. Chemical composition of the amino acid biostimulant used in the study

Component	**Content (%)**
Total amino acids	25.0
Free amino acids	18.0
Organic nitrogen	8.0
Potassium (K_2O)	3.0
Iron (Fe)	0.15
Zinc (Zn)	0.08
Manganese (Mn)	0.06
pH	6.50

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Values are based on the manufacturer's specifications of the commercial amino acid biostimulant used in the experiment.

3.2 Effect of Amino Acid Biostimulants on Vegetative Growth Traits of Sesame Cultivars

Table 3. Results of sesame vegetative growth traits affected by sesame cultivars and amino acids concentrations. The results in Table 3 showed that the vegetative growth traits were significantly affected by sesame cultivars, amino acids concentrations and their interactions ($P \leq 0.05$). Increasing amino acid concentration from 0 to 6 mL L^{-1} resulted in gradual increase in plant height, number of branches per plant, leaf area and chlorophyll content. The cultivar Toshka 1 showed the highest vegetative growth among the tested cultivars, especially at the highest concentration of amino acids (6 mL L^{-1}), where the highest plant height (155.6 cm), number of branches per plant (6.5), leaf area (452.3 cm^2) and chlorophyll content (45.6 SPAD units) were recorded. On the other hand, untreated Giza 32 plants recorded the lowest values for these parameters and they were 125.7 cm, 4.1 branches $plant^{-1}$, 346.8 cm2 and 35.9 SPAD units, respectively. In addition, amino acid concentration had highly significant effects on all measured traits ($P < 0.001$). Also, significant interaction between cultivar and amino acid concentration indicated variation in the response of vegetative growth traits among sesame cultivars.

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Table 3. Effect of sesame cultivars and amino acid biostimulant concentrations on vegetative growth traits.

Cultivar	AA concentration (mL L⁻¹)	Plant height (cm)	Branches plant⁻¹	Leaf area (cm²)	Chlorophyll (SPAD)
Shandweel 3	0	128.4±4.5d	4.3±0.4d	352.7±8.2e	36.8±1.2e
	2	136.9±5.1c	5.1±0.5c	389.4±9.1d	39.7±1.4d
	4	145.3±4.7b	5.8±0.3b	421.8±10.4bc	42.5±1.1bc
	6	152.8±5.3a	6.3±0.4a	446.5±11.7a	44.8±1.3a
Giza 32	0	125.7±3.9d	4.1±0.3d	346.8±7.5e	35.9±1.2e
	2	134.5±4.6c	4.8±0.4c	381.5±8.7d	38.6±1.1d
	4	142.7±4.8b	5.6±0.4b	417.4±10.5c	41.9±1.3c
	6	150.4±5.0a	6.1±0.4a	440.7±11.2ab	44.2±1.2ab
Toshka 1	0	130.8±4.3d	4.4±0.4d	358.6±8.9e	37.2±1.1e
	2	139.4±4.8c	5.3±0.3c	396.3±9.8d	40.4±1.2d
	4	148.9±5.1ab	6.0±0.5ab	430.8±10.9bc	43.1±1.2bc
	6	155.6±4.8a	6.5±0.5a	452.3±10.9a	45.6±1.4a
P-value (Cultivar)		0.012	0.018	0.009	0.015
P-value (AA concentration)		<0.001	<0.001	<0.001	<0.001
P-value (Interaction)		0.041	0.036	0.027	0.031
LSD (0.05)		6.32	0.61	19.7	2.14

Values are presented as mean ± SD. Means with different letters in the same column show significant differences (LSD test, $P < 0.05$). Values that share at least one letter do not differ considerably.

3.3 Effect of Amino Acid Biostimulants on Yield Components

Data in Table 4 revealed that treatment of amino acid greatly enhanced the yield components of sesame cultivars. Cultivar, amino acid concentration and their interaction were significant ($P < 0.05$) on number of capsules per plant, number of seeds per capsule and 1000-seed weight. The yield characteristics increased

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gradually with the increase in the amino acid concentration from 0 to 6 mL L^{-1}. The greatest results were reported for Toshka 1 plants fed with 6 mL L^{-1}, where the capsules plant-1, seeds capsule^{-1}, and 1000-seed weight were 84.1, 72.7, and 3.85 g, respectively. In contrast, untreated Giza 32 plants showed the lowest results (56.9 capsules plant^{-1}, 57.8 seeds capsule^{-1} and 1000-seed weight of 3.20 g). Amino acid concentration had very substantial impacts on all evaluated variables ($P < 0.001$). The considerable interaction between cultivar and amino acid concentration suggested cultivar response variations to amino acid application.

Table 4. Effect of sesame cultivars and amino acid concentrations on yield components.

Cultivar	AA concentration	Capsules plant^{-1}	Seeds capsule^{-1}	1000-seed weight (g)
Shandweel 3	0	58.4±3.1e	59.2±2.5d	3.28±0.09d
	2	66.7±2.9d	63.1±2.3c	3.44±0.08c
	4	74.9±3.5bc	67.8±2.7b	3.62±0.07b
	6	81.6±3.2a	71.5±2.4a	3.79±0.08a
Giza 32	0	56.9±2.8e	57.8±2.1d	3.20±0.08d
	2	64.5±3.0d	61.6±2.4c	3.39±0.09c
	4	72.6±3.1c	66.2±2.6b	3.56±0.07b
	6	79.8±3.3ab	70.1±2.3a	3.74±0.08a
Toshka 1	0	60.7±3.2e	60.4±2.4d	3.31±0.07d
	2	68.9±3.0d	64.7±2.5c	3.49±0.08bc
	4	77.3±3.6b	69.3±2.8ab	3.68±0.09ab
	6	84.1±3.4a	72.7±2.5a	3.85±0.06a
P-value (Cultivar)		0.021	0.013	0.016
P-value (AA concentration)		<0.001	<0.001	<0.001
P-value (Interaction)		0.038	0.027	0.034
LSD (0.05)		4.72	3.11	0.18
Value is mean ± standard deviation (SD). Different letters within the same column indicate significant differences (LSD test at P < 0.05). Values with at least a letter in common are not significantly different from each other.				

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3.4 Effect of Amino Acid Biostimulants on Seed Yield

Seed yield per plant and total seed yield were substantially impacted by sesame cultivars, amino acid concentrations and their interaction ($P < 0.05$) as shown in Table 5. The yield parameters were increased gradually by increasing the amino acid concentration from 0 to 6 mL L^{-1}. The maximum seed output per plant (29.4 g) and total seed yield (1679 kg ha^{-1}) were recorded for Toshka 1 plants treated with 6 mL L^{-1} amino acids, whereas the lowest values were obtained for untreated Giza 32 plants (17.9 g $plant^{-1}$ and 1047 kg ha^{-1}, respectively). In addition, the amino acid concentration had extremely significant impacts on both attributes ($P < 0.001$). The substantial interaction between cultivar and amino acid concentration showed the variation in responsiveness of sesame cultivars to amino acid application.

Table 5. Effect of amino acid biostimulants on seed yield.

Cultivar	AA concentration	Seed yield $plant^{-1}$ (g)	Total seed yield (kg ha^{-1})
Shandweel 3	0	18.6±0.9e	1080±42f
	2	21.8±1.0d	1264±51e
	4	25.3±1.1bc	1457±55bc
	6	28.7±1.2a	1623±60a
Giza 32	0	17.9±0.8e	1047±39f
	2	21.1±0.9d	1228±48e
	4	24.5±1.0c	1412±54c
	6	27.8±1.2ab	1584±58ab
Toshka 1	0	19.4±0.9e	1123±45f
	2	22.7±1.0d	1315±52d
	4	26.1±1.1bc	1506±57bc
	6	29.4±1.1a	1679±64a
P-value (Cultivar)		0.009	0.011
P-value (AA concentration)		<0.001	<0.001
P-value (Interaction)		0.023	0.019
LSD (0.05)		2.18	87.6

Value is mean ± standard deviation (SD). Different letters within the same column indicate significant differences (LSD test at P < 0.05). Values with at least a letter in common are not significantly different from each other.

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3.5 Effect of Amino Acid Biostimulants on Seed Quality Traits

Seed oil and protein contents were considerably ($P < 0.05$) modified by sesame cultivars, amino acids concentrations and their interaction as shown in Table 6. Both quality metrics increased gradually with increasing amino acid content from 0 to 6 mL L^{-1}.The maximum oil content (54.1%) and protein content (24.7%) were recorded in Toshka 1 plants treated with 6 mL L-1 amino acids, while the lowest values were obtained from untreated Giza 32 plants which recorded 46.7% oil and 19.8% protein. Amino acid concentration also showed extremely significant impacts on both attributes ($P < 0.001$) demonstrating the positive function of amino acid treatment in increasing seed quality characteristics. The substantial relationship between cultivar and amino acid concentration also revealed that the reaction of oil and protein accumulation was different among the tested sesame cultivars.

Table 6. Effect of amino acid biostimulants on seed quality traits.

Cultivar	AA concentration	Oil content (%)	Protein content (%)
Shandweel 3	0	47.2±1.3d	20.4±0.8d
	2	49.6±1.1c	21.7±0.7c
	4	51.4±1.2b	22.8±0.8b
	6	53.3±1.0a	24.1±0.9a
Giza 32	0	46.7±1.2d	19.8±0.7d
	2	48.9±1.1c	21.1±0.8c
	4	50.8±1.0b	22.4±0.7b
	6	52.7±1.1a	23.8±0.8a
Toshka 1	0	47.8±1.2d	20.9±0.8d
	2	50.4±1.2bc	22.0±0.8c
	4	52.3±1.1ab	23.4±0.7ab
	6	54.1±1.1a	24.7±0.8a
P-value (Cultivar)		0.016	0.024
P-value (AA concentration)		<0.001	<0.001
P-value (Interaction)		0.044	0.031
LSD (0.05)		1.72	1.15

Value is mean ± standard deviation (SD). Different letters within the same column indicate significant differences (LSD test at $P < 0.05$). Values with at least a letter in common are not significantly different from each other.

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3.6 Principal Component Analysis of Growth, Yield, and Seed Quality Traits

To further describe the correlations among the observed variables and treatment combinations, a principal component analysis (PCA) was conducted (Figure 1). The PCA biplot showed the special relationship between growth features, yield components and seed quality factors. Productivity related variables such as capsules plant-¹, seeds capsule-¹, 1000 seed weight, seed yield plant-¹ and total seed yield were highly correlated and pointed in the same direction. Oil and protein contents were also positively correlated in the same way. The distribution of treatment combinations showed varied clustering patterns among the studied sesame cultivars and amino acid concentrations, which indicates that the cultivars responded differently to amino acid administration.

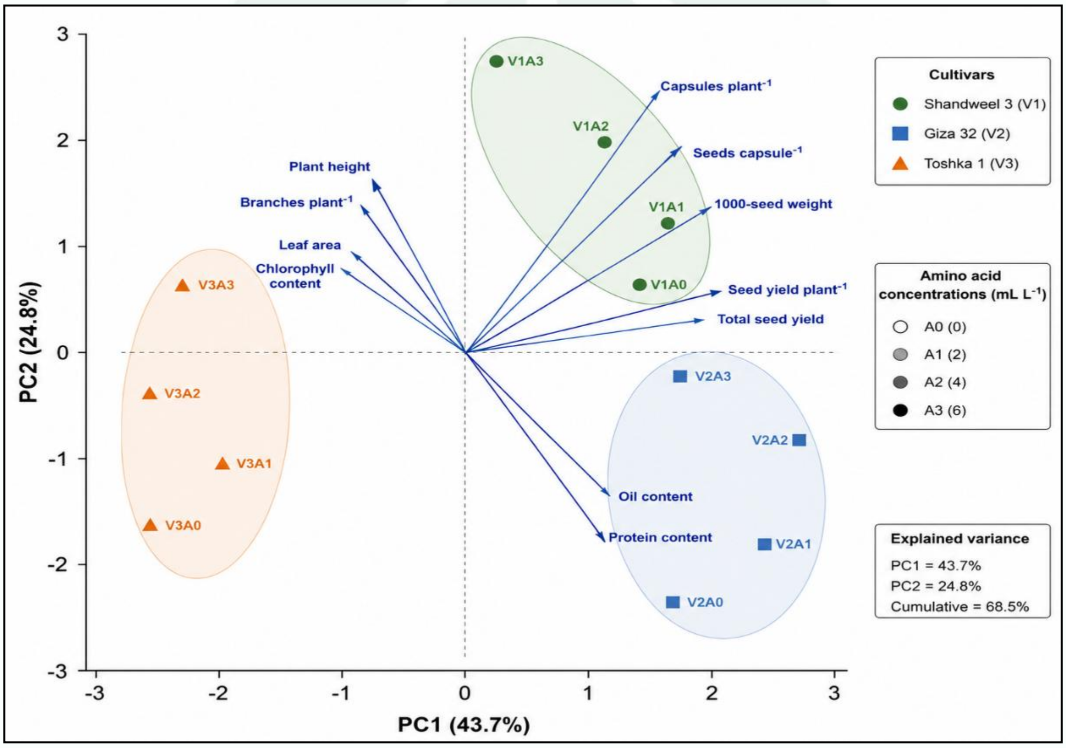

Figure 1. Principal component analysis (PCA) illustrating the relationships among growth traits, yield components, and seed quality characteristics of sesame cultivars under different amino acid concentrations.

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3.7 Effect of Amino Acid Concentrations on Total Seed Yield of Sesame Cultivars

Figure 2 indicates substantial sesame cultivars and amino acid concentration effects on total seed production. Increasing amino acid content from 0 to 6 mL L^{-1} progressively increased total seed production of all cultivars. The best production (1679 kg ha-1) was reported for Toshka 1 cultivar under the highest amino acid concentration, whereas the lowest yield (1047 kg ha-1) was obtained from untreated Giza 32 plants. In general, total seed output was significantly enhanced by the use of amino acid biostimulants irrespective of cultivar, with the highest response recorded at 6 mL L^{-1}.

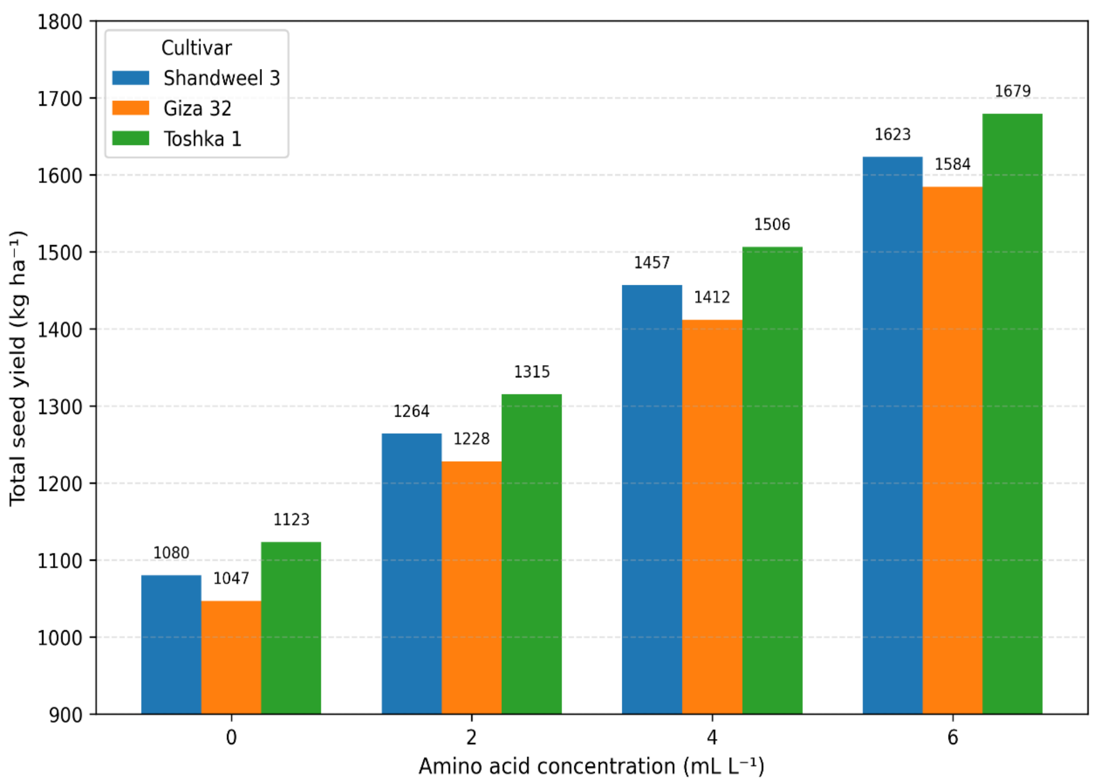

Figure 2. Effect of amino acid concentrations on total seed yield (kg ha^{-1}) of three sesame cultivars (Shandweel 3, Giza 32, and Toshka 1). Bars represent mean values obtained from three replications.

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DISCUSSION

The present study showed that the application of amino acid biostimulants to sesame cultivars significantly improved vegetative growth characteristics. This was reflected in the gradual increases in plant height, number of branches, leaf area and chlorophyll content with increasing amino acid concentration. The improved performance at 6 mL L−1 especially in Toshka 1 indicated that amino acids activated cellular metabolism and photosynthetic activity which resulted in vigorous plant growth. Viana et al. [15] found similar results, demonstrating that the application of phytostimulants increased fruit formation and chlorophyll accumulation in sesame genotypes. Likewise, El-Shazoly et al. [16] showed that algal biostimulants significantly enhanced sesame plant growth parameters and productivity. Improvements are attributed to increased photosynthetic efficiency and metabolism activity by biostimulant application.

The observed stimulatory effect of amino acids on chlorophyll content in the present study may also be due to improved nitrogen assimilation and increased metabolic activity. Physiological and transcriptomic studies revealed that genes involved in nitrogen uptake and amino acid metabolism were closely associated with the higher growth and biomass accumulation in sesame. Moreover, metabolomic analyses indicated that the accumulation of amino acids contributes to better stress adaptation and maintenance of the photosynthetic processes [7,8]. The better response of Toshka 1 than Shandweel 3 and Giza 32 indicates the existence of genotypic differences in response to amino acid biostimulants. Such variations probably reflect the genetic background and metabolic efficiency of the cultivars. Similar genotype-dependent responses were reported by Shiaa and Ajaj [12] who reported a considerable variation among sesame cultivars in oil and protein accumulation under foliar treatments. Hussain et al. [14] also reported significant effect of genotype on productivity and seed quality traits in sesame.

The significant increases in capsule number, seeds per capsule and thousand-seed weight in the present study suggest that amino acid application enhanced

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assimilate production and translocation leading to improved reproductive efficiency. These results are consistent with Sajid et al. [17] who found that application of growth promoting compounds significantly increased seed number, thousand-seed weight and oil content of sesame. Similar improvements in productivity and quality traits were also reported by Zarei et al. [18] who showed that foliar biostimulants improved seed yield and oil accumulation under different environmental conditions. The increase in seed yield obtained in the present study confirms the positive role of biostimulants in improving sesame productivity . Similar observations were reported by Nourzadeh et al. [19] who found significant increase in seed yield and water-use efficiency of sesame by biofertilizers treatments. Also, Lima et al. [20] reported that biological stimulants improved physiological performance and increased thousand-seed weight and productivity of sesame cultivars especially under stress conditions.

The enhancement of nitrogen use efficiency and amino acid metabolism in the current report may also account for higher productivity. Using transcriptomic studies, genes participating in N-uptake, nitrate transport, and amino acid biosynthesis were reported to be significantly correlated with sesame growth and total biomass gain . Wang et al. reported that there were high nitrogen utilization efficiency-related genes associated with nitrogen assimilation and amino acid metabolism. These mechanisms might explain the recorded enhanced growth and yield of the amino acid-treated plants in this study [7].

The enhanced growth and productivity can also be attributed to the ability of amino acid biostimulants to modulate the rhizosphere ecology and stimulate beneficial microorganisms. Previous studies showed that amino acid fertilizers develop beneficial microbial communities and increase nutrient availability, resulting in improved plant performance and soil health. Indirect effects like such may have contributed to the higher productivity observed in the present study [9]. Amino acids not only enhance plant growth but also confer protection against oxidative stress by activation of antioxidant defense systems. Earlier

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transcriptomic and metabolomic investigations in sesame suggested that proline, arginine and other amino acids were accumulated under stress and contributed in scavenging of reactive oxygen species . Higher antioxidant activity has been associated with better stress tolerance and productivity in oilseed crops. Therefore, the positive results obtained in the present study could be due, at least in part, to improved physiological stability and reduced oxidative damage [8,10]. The use of amino acid biostimulants also significantly improved the seed quality traits. The highest oil and protein contents were obtained at the highest amino acid concentration especially in Toshka 1. These results are consistent with the findings of Zarei et al. who observed that biostimulant treatments increased oil percentage and protein accumulation in sesame under stress conditions. Similarly, Song et al. reported that amino acid composition and protein metabolism are closely related to oil biosynthesis and seed quality in sesame [18,21]. The increase in protein content in the present study may be attributed to the essential role of amino acids as precursors for protein biosynthesis and their involvement in nitrogen assimilation pathways. Also, photosynthetic efficiency is increased, providing sufficient assimilates for the synthesis of proteins and oils. Previous studies showed that amino acid-based biostimulants increased the overall protein production and improved the efficiency of nutrient uptake to improve seed quality and nutritional value [3].

Growth parameters, yield components and seed quality attributes were positively correlated with principal component analysis. The same findings were also reported by Raj et al who reported that productivity related parameters were closely correlated and explained the greatest contributors to total variability among treatments. Higher degree of positive correlations between physiological and yield-related traits suggest synchronized regulation by the biostimulant on growth and productivity processes [13]. ConclusionsThe data of the current study demonstrate that amino acid biostimulation is an economic-friendly agronomic technique to enhance sesame productivity with seed quality. Several mechanisms

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are involved, as indicated by recent reviews showing that amino acids enhance photosynthesis, nutrient absorption and mineral uptake; antioxidant capacity; and promote tolerance to stress conditions. This synergism makes amino acid biostimulants good candidates in sustainable agriculture, as well as climate resilient crop production [3,4].

Conclusion

Foliar application of amino acid biostimulants significantly improved the growth parameters, yield components, seed yield and seed quality of sesame cultivars. When amino acid concentration was increased up to 6 mL L-1, maximum values of most of examined features were obtained. Toshka 1 as a best cultivar among the examined cultivars, it exhibited the best performance and the highest reaction to amino acid administration. Therefore, the foliar spray of amino acids at 6 mL L-1 may be an economical and ecologically friendly strategy to improve the production and seed quality of sesame under the environmental conditions of Iraq.

Conflict of Interest

The authors declare no conflict of interest.

Funding

This research received no external funding.

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