



Effect of Foliar Application of Glutamine on Growth, Physiological Characteristics and Protein Content of Different Sorghum [*Sorghum bicolor* (L.) Moench] Varieties

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ABSTRACT

Background: Glutamic acid plays an important role by increasing the plant's resistance to climate change and tolerance to unfavourable conditions such as high temperature, water stress, salinity and snow. It also acts as a strong chelating agent for trace elements and environmentally friendly fertilisers.

Methods: An experiment was conducted in plastic pots during the spring 2023 season in Kirkuk governorate, Iraq, to evaluate the effects of sorghum plant varieties (Rabih, Khair and Inkhath) under different doses of foliar application of glutamine (0, 40, 80 and 100 mg L⁻¹) on growth, physiological characteristics and protein percent in grains. This experiment was designed using a completely randomized design (CRD) with three replications.

Result: The Inkhath variety significantly required fewer days to reach 50% flowering: 62.10 days. Also, it was significantly superior in plant height, leaf chlorophyll content, plant leaf number and flag leaf area, reaching 115.23 cm, 55.50 SPAD, 10.59 leaves plant⁻¹ and 368.82 cm², respectively. The concentration of 100 mg L⁻¹ glutamic acid was significantly the earliest at 50% flowering with the highest plant height, leaf chlorophyll content, leaf number, flag leaf area and grain protein percentage, reaching 58.31 days, 116.22 cm, 56.53 SPAD, 10.44 leaves plant⁻¹, 391.68 cm² and 14.36%, respectively. The interaction between Inkhath variety and spraying with 100 mg glutamic acid was significantly the earliest in 50% flowering with the highest means in plant height, leaf chlorophyll content, plant leaf number and flag leaf area, reaching 55.60 days, 121.67 cm, 58.00 SPAD, 11.06 leaves plant⁻¹ and 450.06 cm², respectively, as well as the interaction between Rabih variety with 100 mg glutamic acid was significantly recorded highest grain protein percentage 14.88 %. The Inkhath sorghum variety showed a high response to a high spraying rate of 100 mg L⁻¹ glutamic acid, which improved growth, physiological traits and grain protein percentage.

Key words: Glutamine, Organic stimulants, Physiological indices, Sorghum plant, Varieties.

INTRODUCTION

Sorghum plants belonging to the Poaceae family, in terms of cultivated area and production, ranked fifth among cereal crops worldwide after wheat, barley, rice and maize (Al-Atwi, 2023; Mufumbo *et al.*, 2023). It is grown in tropical and subtropical regions (FAO, 2021). Sorghum grains serve as an important source of food for both humans and livestock. In many regions, sorghum flour is blended with wheat flour at proportions of up to 50% for the preparation of various food products. In developed countries, particularly United States, approximately 90% of sorghum production is utilized in the food processing industry, including the manufacture of starch and other value-added products. Sorghum grains are nutritionally rich, containing approximately 12% protein, 70% carbohydrates and 3% fat and are also a good source of B-complex vitamins (Rana, 2013). It is also commonly used in preparing poultry feed because it contains a high amount of protein (Maaruf and Raheem, 2024; Li *et al.*, 2025). It also contributes to meeting the need for green fodder in summer in Iraq (Hadi, 2020). This plant is also characterized by its tolerance to environmental conditions that are not suitable for its growth, such as drought, high temperatures and soil salinity

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(Saleh *et al.*, 2026; Zakka *et al.*, 2026). It has recently been used in the production of biofuel, where it now ranks second after corn (Abood *et al.*, 2017; Al-Bayaty and Raheem, 2026).

In industry, it is used as a basic material in the manufacture of dyes and candles (Sharif *et al.*, 2024).

Amino acids play an important role in stimulating photosynthesis in plants by acting as mediators in the Krebs cycle, through which complex sugars are oxidised into simple compounds, resulting in carbon dioxide and water and generating energy in the form of ATP (Jaff and Medan, 2024). Glutamic acid plays an important role by entering into the storage of the chlorophyll molecule and working to increase the rate of photosynthesis in the plant and increase the biomass of the vegetative part and the root, as well as increase the resistance of the plant to climate changes and increase tolerance to unfavourable conditions such as high temperature, water stress, salinity and snow (Kumar *et al.*, 2026). It also works as a strong chelating material for trace elements.

Although the sorghum plant is widely cultivated in Iraq as green fodder for animals, the crop is not at the required level due to the use of non-modern varieties and genotypes, primitive agricultural techniques and lack of farmers' familiarity with modern fertilizers produced in the world. So this study was conducted to test modern varieties of sorghum and use of materials other than fertilizers that known as environmental pollutants, as well as the use of environmentally friendly and safe fertilizer technology.

MATERIALS AND METHODS

This study was conducted during spring agricultural season of 2023 in Kirkuk governorate, Iraq. The soil taken from the River basin was air-dried and placed in plastic pots with a diameter of 0.3 m and a height of 0.4 m, amounting to 15 kg of soil per pot, after being sieved through a 2 mm sieve. After the soil in pots was watered, there was a long day left to get rid of the voids. Experiment was conducted in factorial completely randomized block design with three replications. Treatments comprised of three varieties of sorghum (Rabih, Khair and Inkhath) as one factor and four glutamic acid concentrations (0, 40, 80 and 100 mg L⁻¹) Foliar spray of glutamine was done at four weeks after planting and four weeks after the first spray.

The data were collected on the no. days to 50% flowering based on the appearance of 50% of the anthers in the plant inflorescence. Plant height (cm) was measured from the soil surface to the end of the inflorescence. Total chlorophyll content was measured using a SPAD 502 chlorophyll meter at the 75% flowering stage on 5 leaves per plant. No. Leaves plant⁻¹ were counted for each plant. Flag leaf area (cm²) was measured when plants reached the 50% flowering stage according to Liang *et al.* (1973): length × maximum width × 0.75. Protein percentage in grains (%) was calculated as nitrogen percentage × 6.25 (Bremner and Mulvaney, 1982). The collected data was analyzed using the Minitab statistical software program (Minitab V-16.1, 2010) for analysis of variance and Duncan's test at a probability level of 0.05 was used to compare treatment means.

RESULTS AND DISCUSSION

No. of days to 50% flowering (Day)

It is clear from the results of Table (1) that the varieties recorded significant effect on day to 50% flowering. Rabih variety recorded the longest days to reach this stages compared to Inkhath variety. The genetic differences among the varieties may have resulted differences in flowering times. The early variety may be more profitable than late varieties and requires higher collection temperatures to reach the flowering stage (Al-Aatwi, 2023). Similar results were observed by Raheem and Ali (2025) and Ahmadifauzan *et al.* (2026). It is also evident from Table 1 that foliar spray of 100 mg L⁻¹ glutamic acid reduced the time to 50% flowering as compared to control. This might have happened due to Amino acids regulate the date of flowering by increasing the efficiency of photosynthesis and plant physiological responses and reducing inhibitory activity, causing the plant to transition from vegetative growth to flowering (Al-Fahad and AL-Janabi, 2025). The significant effect on days to 50% flowering was shown by the interaction effect between sorghum varieties and glutamic acid concentrations. The interaction between Rabih variety and control treatment recorded the longest days to reach this stage.

Plant height (cm)

The results in Table 2 clearly show that the Inkhath variety plants were significantly taller than the other varieties' plants. The variation among sorghum varieties in plant height is attributed to their genetic nature and their different responses to environmental conditions reflected in vegetative growth, including plant height. These results are in line with previous findings which reported that varieties significantly affect plant height (Abas *et al.*, 2025; Mouhamad and Fadhil, 2025; Taha *et al.*, 2025). It is also evident from Table 2 that foliar spray of 100 mg L⁻¹ glutamic

Table 1: No. of days to 50% flowering (Day) as affected by varieties, glutamic acid and interaction.

Varieties	Glutamic acid (mg L ⁻¹)				Average
	0	40	80	100	
Rabih	76.00a	73.33ab	69.33c	60.00e	69.66a
Khair	70.00bc	64.60cd	64.40d	57.33f	64.08b
Inkhath	72.00b	60.74e	60.33e	55.60g	62.11c
Average	72.66a	65.55b	64.68bc	58.31c	

Table 2: Plant height (cm) as affected by varieties, glutamic acid and interaction.

Varieties	Glutamic acid (mg L ⁻¹)				Average
	0	40	80	100	
Rabih	103.00e	106.33d	110.33cd	116.67b	109.08b
Khair	101.67fcd	104.33c	104.67c	110.33c	105.25c
Inkhath	110.93c	112.67bc	115.67b	121.67a	115.23a
Average	105.20c	107.75bc	110.22b	116.22a	

acid resulted in the tallest plants compared to the control. This might have been attributed to amino acids producing several plant hormones, including auxins (IAA), which increase apical dominance and stimulate the elongation of plant cells, increasing vegetative growth, stimulating cell division and accelerating stem elongation (Abd Al-Aziz, 2010). Turfan and Turan (2023) reported a similar effect of glutamic acid in increasing garlic (*Allium sativum* L.) plants. Plant height was significantly affected by the interaction between sorghum varieties and glutamic acid concentrations; the Inkhath variety, sprayed with 100 mg L⁻¹ glutamic acid, had the tallest plants.

Total chlorophyll content in leaves (SPAD-Reading)

The data in Table 3 show that the varieties differed significantly in leaf total chlorophyll content. Inkhath variety recorded the highest leaf chlorophyll content compared to the other varieties. Al-Bayaty and Raheem (2026) reached similar results in maize. It is also evident from Table 3 that foliar spray of 100 mg L⁻¹ glutamic acid recorded the highest leaf chlorophyll content compared to the control. Glutamic acid encourages proline synthesis, which plays an important role in osmotic regulation of the cells and the protection of pigment systems during photosynthesis (AL-Bayati and Salih, 2021). Then, lead to an increase in the total chlorophyll content of plant leaves. This leads to an increase in the plant's biological activity, as cell division and development and the effectiveness of the enzymatic system increase (Habeeb, 2022). Al-Fahad and Al-Janabi (2025) found a significant effect of amino acids on increasing total chlorophyll content of sorghum plant leaves. The interaction between varieties and foliar spray of glutamic acid significantly affected leaf chlorophyll content, with the highest SPAD reading when the Inkhath variety was sprayed with 100 mg L⁻¹ of glutamic acid.

No. of leaves plant⁻¹

The results in Table 4 confirm that the Inkhath variety recorded significantly more leaves per plant compared to other varieties. This result came from differences in effect among varieties on plant height (Table 2). These results agreed with those obtained by Ali *et al.* (2025), Begna (2025) and Kusumawardana *et al.* (2025). It is also evident from Table 4 that foliar spray of 100 mg L⁻¹ glutamic acid resulted in more leaf number compared to the control. This might have resulted in a reflection of glutamic acid's effect on plant height (Table 2). The interaction between sorghum varieties and glutamic acid concentrations significantly affected the number of plant leaves. The Inkhath variety sprayed with 100 mg L⁻¹ glutamic acid recorded a higher plant leaf number.

Flag leaf area (cm²)

The different varieties showed a significant effect on the flag leaf area of sorghum plants (Table 5). The Inkhath variety had the highest value of flag leaf area compared to the Rabih and Khair varieties. Raheem *et al.* (2023) noted

a significant impact of maize varieties on leaf area index and leaf area ratio; Ahmadifauzan *et al.* (2026) reported that sorghum varieties differed significantly in plant flag leaf area. It is also evident from Table 5 that foliar spray of 100 mg L⁻¹ glutamic acid recorded the highest flag leaf area compared to the control. Spraying the vegetative parts with glutamic acid might have led to an increase in cell division and elongation, enhancing their activity and increasing their size, which reflected positively on the flag leaf area. Abas *et al.* (2025) found that sorghum plants sprayed with an amino acid significantly increased plant leaf area compared to the control. The interaction between sorghum varieties and glutamic acid concentrations significantly affected flag leaf area; the highest value was recorded when the Inkhath variety was sprayed with 100 mg L⁻¹ of glutamic acid.

Protein percentage (%) in grains

Fig 1 shows no significant differences among varieties in their effect on the sorghum grain protein content. The values were 13.30, 13.20 and 13.34% for the varieties Rabih, Khair and Inkhath, respectively. Fig 1 shows a significant effect of glutamic acid concentrations on grain protein content. A high value was recorded for foliar spray of 100 mg L⁻¹ glutamic acid, reaching 14.36%, compared to the control,

Table 3: Leaves chlorophyll content (SPAD-Reading) as affected by varieties, glutamic acid and interaction.

Varieties	Glutamic acid (mg L ⁻¹)				Average
	0	40	80	100	
Rabih	51.16c	52.93bc	51.16c	53.39bc	52.16b
Khair	51.54c	53.01bc	51.54c	52.86bc	52.23b
Inkhath	52.00c	52.00c	54.00ab	58.00a	55.50a
Average	51.56c	54.64b	53.41b	56.53a	

Table 4: No. of leaves plant⁻¹ as affected by varieties, glutamic acid and interaction.

Varieties	Glutamic acid (mg L ⁻¹)				Average
	0	40	80	100	
Rabih	8.30c	9.77b	9.43b	10.20ab	9.40b
Khair	8.90bc	9.20b	9.43b	10.06ab	9.39b
Inkhath	10.03ab	10.50a	10.80a	11.06a	10.59a
Average	9.07c	9.82b	9.88b	10.44a	

Table 5: Flag leaf area (cm²) as affected by varieties, glutamic acid and interaction.

Varieties	Glutamic acid (mg L ⁻¹)				Average
	0	40	80	100	
Rabih	233.07f	287.00de	297.50de	363.50c	295.26b
Khair	258.50ef	263.70e	293.10de	359.50c	293.70b
Inkhath	305.30d	330.00cd	390.00b	450.06a	368.82a
Average	265.62d	293.00c	326.86b	391.68a	

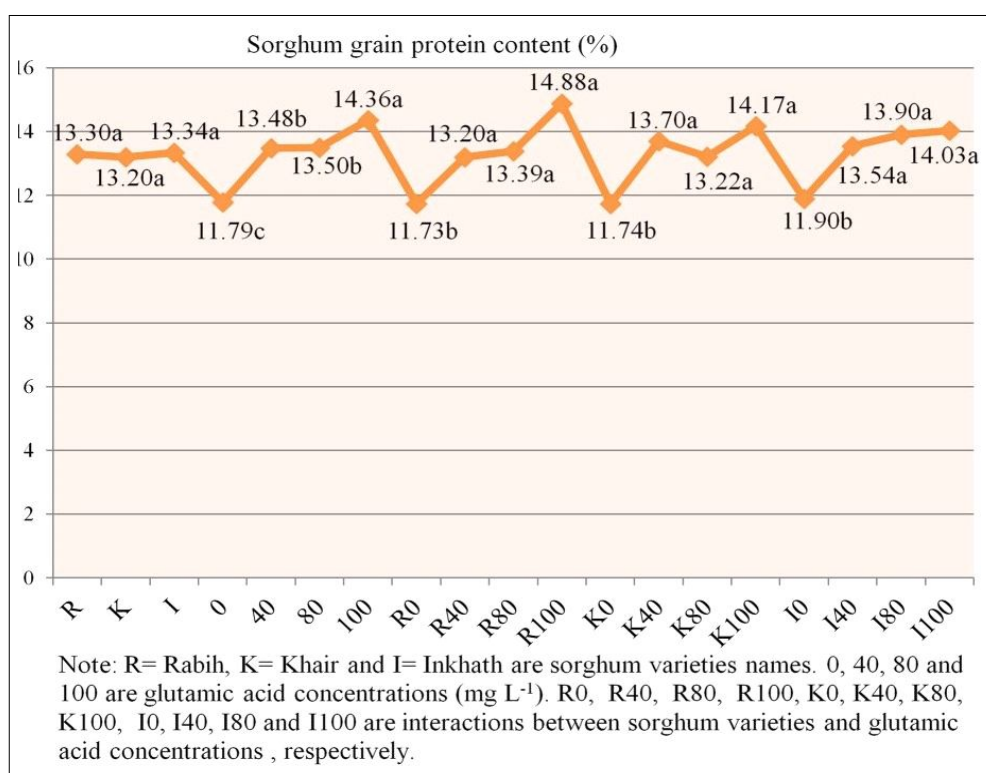


Fig 1: Grain protein content (%) as affected by varieties, glutamic acid and interaction.

which was 11.79%. Spraying amino acids on plant leaves improves physiological characteristics directly involved in nitrogen assimilation, through their ammonium (NH_4^+) contents. Amino acids and their derivatives stimulated the synthesis of chlorophyll, protein and phytohormones, as there is an increase in the percentage of protein (Noroozlo *et al.*, 2019). Islam *et al.* (2024) reported a significant effect of glutamic acid spraying on increasing grain protein percentage in maize. The interaction between sorghum varieties and concentrations of glutamic acid showed a significant effect on sorghum grain protein content. A high value of 14.03% was recorded when the Rabih variety was sprayed with 100 mg L^{-1} glutamic acid.

CONCLUSION

It concludes that the sorghum varieties varied significantly, with the Inkhath variety significantly excelling. Foliar spray of glutamic acid had a stimulating effect on growth, physiological characteristics and grain protein content at a high level of 100 mg L^{-1} . The spraying of glutamic acid, as a growth stimulant, had practical implications for sorghum crop growth, improved plant growth through higher leaf chlorophyll content and promoted grain quality *via* increasing crude protein.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

Experiment on plants, not animals.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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