Effect of Foliar Application of Glutamic Acid on Yield Traits and Their Components in Six Triticale Genotypes.

Ahmed Abdullah ALhalbosi1 Bushra Sh. J. ALobaidy2

Department of Filed Crops- College of Agriculture, Anbar University

)https://orcid.org/0009-0003-7187-9091)1

)https://orcid.org/0000-0002-0296-9718)2

)Email: ahm23g3006@uoanbar.edu.iq) 1 (ag.bushra.shaker@uoanbar.edu.iq)2

Abstract

A field experiment was conducted during the 2024–2025 winter season at the research station affiliated with the College of Agriculture – University of Anbar to study the effect of foliar application of glutamic acid at three concentrations (0, 250, and 500 mg•L^{-1}) on yield traits and their components in six triticale Varieties (Sara, Rizan, Al-Muhand, Admiral, Amal-7, and Farah). The results revealed that the genotype Rizan outperformed in the number of spikes (467.78 spikes•m^{-2}), grain yield (6.273 tons•ha^{-1}), and biological yield (28.467 tons•ha^{-1}). In contrast, the genotype Admiral achieved the highest values for 1000-grain weight (57.889 g) and harvest index (35.06%), while Al-Muhand recorded the highest number of grains per spike (77.17 grains•$spike^{-1}$). Regarding the effect of glutamic acid concentrations, 500 mg•L^{-1} was the most effective in enhancing spike number, grain number, grain yield, and biological yield. Meanwhile, the 250 mg•L^{-1} concentration was superior in improving 1000-grain weight. However, the harvest index gradually decreased with increasing acid concentration. Although some varities excelled in individual traits such as grain weight or grains per spike, the genotype Rizan at 500 mg•L^{-1} exhibited the best integration of yield components, leading to the highest grain yield overall .

Introduction

Triticale is a cereal crop belonging to the Poaceae , developed through scientific efforts aimed at hybridizing two cereal species: wheat (Triticum aestivum L.) as the maternal parent and rye (Secale cereale L.) as the paternal parent. The chromosome number in the resulting hybrid was doubled to produce a crop that combines the favorable traits of both parents. Triticale inherited the high productivity and disease resistance of wheat, along with the strength, robustness, and adaptability of rye to unfavorable environmental conditions such as poor soils and low drainage capacity. Triticale surpasses wheat morphologically in terms of plant size, spike length, and protein content .

It also contains a higher level of the amino acid lysine—up to 4% more than wheat [1]. According to [2]statistics, the global cultivated area of triticale is approximately 3.6 million hectares, with a total production of over 13.8 million tons and an average yield of 3835.7 kg•ha^{-1} across 45 countries. Despite these figures, triticale cultivation remains limited in Iraq, primarily due to farmers' limited awareness of its economic and physiological importance. Triticale is considered dual-purpose, as it can be used both for grain

ISSN 2072-3857

production and green fodder, owing to its vigorous growth, high tillering capacity, large leaf area, and elevated dry matter content.

Crop productivity depends mainly on the interaction between the plant's genetic makeup and surrounding environmental conditions, in addition to the role of growth-stimulating factors. Among these, bioactive compounds such as glutamic acid have demonstrated significant potential in enhancing the plant's physiological processes. Glutamic acid is one of the essential amino acids and plays a critical role in vegetative tissue formation and metabolic regulation. It also improves nutrient uptake and, when applied foliarly, positively influences growth rate, maintains nutrient balance within plant tissues, and stimulates the synthesis of proline—enhancing the plant's tolerance to environmental stress [3]. Based on the above, this study aims to evaluate the effect of glutamic acid on several physiological and biological traits in various triticale genotypes, with the goal of identifying the most effective concentrations for improving the crop's performance under local environmental conditions. The study focuses on assessing growth indicators such as chlorophyll index, leaf area, crop growth rate, and net photosynthesis, in order to determine the optimal concentration and variety combination for maximizing productivity .

Materials and Methods

A field experiment was conducted during the 2024–2025 winter season at the Second Research Station of the College of Agriculture – University of Anbar, located in the Al-Hamidiyah area (longitude 40° E, latitude 33° N), on silty loam textured soil. The experiment was laid out using a Randomized Complete Block Design (RCBD) in a split-plot arrangement with three replications. Glutamic acid concentrations were assigned to the main plots, while triticale were assigned to the subplots, facilitating ease of foliar application and treatment implementation. The study aimed to evaluate the foliar application of glutamic acid on growth and yield indicators of six triticale (Triticale) varieties : Sara, Rizan, Al-Muhand, Admiral, Amal 7, and Farah. Three concentrations of glutamic acid were tested: 0, 250, and 500 mg•L^{-1}. The total number of experimental units was 54 (6 genotypes × 3 concentrations × 3 replications), each with a plot area of 2.5 × 1.5 m^2. Seeds were sown on November 15, 2024, at a seeding rate of 160 kg•ha^{-1}, with rows spaced 25 cm apart. Di-ammonium phosphate (DAP) fertilizer was applied before sowing at a rate of 100 kg•ha^{-1}, and urea fertilizer was added in two equal splits: the first at the tillering stage, and the second 30 days later, at a total rate of 200 kg•ha^{-1}.

Studies traits

.1Number of Spikes per Square Meter

-1000 .2Grain Weight (g(

.3Number of Grains per Spike

.4Grain Yield (tons•ha^{-1}(

.5Biological Yield (tons•ha^{-1}(

.6Harvest Index(%)

Statistical Analysis:

The collected data were subjected to analysis of variance using Genstat software, and treatment means were compared using Least Significant Difference (LSD) at the 5% probability level. [4.[

Results and Discussion

.1Number of Spikes per Square Meter

The results in Table (1) revealed significant differences among the triticale genotypes tested in this study. The genotype Rizan recorded the highest number of spikes (467.78 spikes•m^{-2}) when treated with 500 mg•L^{-1} glutamic acid, followed by Sara, indicating a strong genetic potential and growth response

ISSN 2072-3857

to the applied treatment. In contrast, the genotype Admiral recorded the lowest mean (374.22 spikes•m^{-2}). This variation is attributed to Genotypic variation among genotypes, particularly in their tillering capacity, which directly influences the number of spikes per unit area [5]. These findings align with those reported by [6] and [7]who demonstrated that varities vary in their ability to produce tillers depend on their genetic characteristics, and that superior spike number performance is often linked to the plant's physiological capacity to produce fertile tillers.

Regarding the effect of glutamic acid concentrations, the application of 500 mg•L^{-1} resulted in the highest average spike number (444.28 spikes•m^{-2}), compared to 410.00 and 389.22 spikes•m^{-2} for 250 mg•L^{-1} and 0 mg•L^{-1}, respectively. This improvement is likely due to glutamic acid's role in enhancing nutrient availability and uptake during the plant's developmental stages, which positively influences the formation of fertile branches bearing spikes. The increase in spike number is closely tied to the increased number of productive tillers per unit area. These results are consistent with findings by [8] and [9], who reported that foliar applications of amino acids significantly improve plant productivity traits.

As for the interaction between varieties and glutamic acid concentrations, the genotypes showed similar directional responses to increasing concentrations but varied in the magnitude of their response. For example, the interaction between Rizan and 500 mg•L^{-1} yielded the highest performance with an average of 491.00 spikes•m^{-2}, followed by Sara at the same concentration with 473.67 spikes•m^{-2}, indicating a high physiological response to foliar application in these genotypes. In contrast, the Admiral × control (0 mg•L^{-1}) interaction recorded the lowest value at 338.33 spikes•m^{-2} .

Table 1. Effect of glutamic acid on six triticale Varieties in number of spike.m2

average	triticale Varieties						concentrations of glutamic acid
	Rizan	Al-Muhand	Farah	Amal 7	Admiral	Sara	
389.22	448.33	360.00	368.00	393.00	338.33	427.67	0
410.00	464.00	364.33	395.33	413.00	382.33	441.00	250
444.28	491.00	404.67	440.00	454.33	402.00	473.67	500
	467.78	376.33	401.11	420.11	374.22	447.44	average
con. of glutamic acid		varieties x con. of glutamic acid			varieties		LSD 5%
3.112		6.523			3.885		

-1000 .2Grain Weight (g(

The results in Table (2) showed significant differences among genotypes and glutamic acid concentrations, as well as in the interaction between both factors. The Admiral genotype significantly outperformed others, recording the highest 1000-grain weight with a mean of 57.889 g, while Al-Muhand recorded the lowest mean of 46.011 g. This variation is

attributed to genetic differences, especially in traits related to grain filling efficiency and the plant's ability to allocate photosynthesis to developing grains. The duration of the grain filling period and the pattern of assimilate distribution within the grain are also critical factors influencing this trait, as noted by [10[

As for the effect of glutamic acid concentrations, the application of 250 mg•L^{-1} produced the highest overall mean 1000-grain weight (52.294 g), followed by 500 mg•L^{-1} (52.133 g), whereas the control treatment (0 mg•L^{-1}) Scored the lowest value (51.672 g). Although the differences between treatments were not statistically significant (N.S.), the general trend suggests that the moderate concentration (250 mg•L^{-1}) was more effective in enhancing grain filling. This might be due to its balanced role in stimulating metabolic processes without promoting excessive vegetative growth at the expense of grain development. The final grain weight is influenced primarily by genetic factors and secondarily by environmental and physiological conditions, including photosynthetic rate, assimilate transport efficiency, and duration of the grain filling period. Foliar application of glutamic acid at 250 mg•L^{-1} likely provided balanced conditions that supported these physiological processes—particularly in responsive varieties

like Admiral.

Regarding the interaction between varieties band concentration, the combination of Admiral and 500 mg•L^{-1} yielded the highest 1000-grain weight (60.233 g), indicating that this genotype had a high physiological efficiency in utilizing the bio-stimulant to channel assimilates toward grain formation. In contrast, the lowest value (45.633 g) was observed in the Al-Muhand × control interaction, reflecting this genotype's poor performance under untreated conditions.

These findings align with those reported by [11], who concluded that amino acids such as glutamic acid enhance nutrient absorption and protein synthesis in grains, ultimately contributing to increased grain weight .

Table 2. Effect of glutamic acid on six triticale Varieties in weight of 1000 grain (gm(

average	triticale Varieties						concentrations of glutamic acid
	Rizan	Al-Muhand	Farah	Amal 7	Admiral	Sara	
51.672	53.833	45.633	54.067	51.867	54.700	49.933	0
52.294	54.267	45.467	53.833	52.567	58.733	48.900	250
52.133	54.400	46.933	50.700	49.567	60.233	50.967	500
	54.167	46.011	52.867	51.333	57.889	49.933	Average
con. of glutamic acid		varieties x con. of glutamic acid			varieties		LSD 5%
N.S		1.0561			0.4208		

.3Number of Grains per Spike

The results in Table (3) showed significant differences among the triticale genotypes. The genotype Al-Muhand recorded the highest number of grains per spike (77.17 grains•spike^{-1}) at the 500 mg•L^{-1} concentration, indicating high pollination and

fertilization efficiency. It was followed by Sara, with an average of 74.67 grains•spike^{-1}, whereas Admiral recorded the lowest average (56.17 grains•spike^{-1}). This variation is likely due to genotypic differences that influence reproductive traits such as the efficiency of fertilization and grain set, which directly determine the final number of grains per spike. These findings are in agreement with [12] and [6], who stated that differences among wheat Varieties in this trait are associated with their ability to utilize assimilates and distribute them efficiently to reproductive organs.

Regarding the effect of glutamic acid concentrations, the concentration 500 mg•L^{-1} was the most effective in stimulating grain number, with an overall average of 67.98 grains•spike^{-1}. This was followed by 250 mg•L^{-1} (63.82 grains•spike^{-1}) and the control (0 mg•L^{-1}) with the lowest value (61.94 grains•spike^{-1}). The positive influence of glutamic acid can be attributed to its role as a precursor in chlorophyll biosynthesis, enhancing photosynthesis and thus promoting carbohydrate accumulation and improved spike fertility [13]. These results are consistent with those reported by [9[

As for the interaction between genotypes and concentrations, the combination of Al-Muhand and 500 mg•L^{-1} recorded the highest grain number (82.70 grains•spike^{-1}), while the interaction between Admiral and the control treatment (0 mg•L^{-1}) recorded the lowest value (54.30 grains•spike^{-1}.(

Table 3. Effect of glutamic acid on six triticale Varieties in number of grain per spike

average	triticale Varieties						concentrations of glutamic acid
	Rizan	Al-Muhand	Farah	Amal 7	Admiral	Sara	
61.94	58.13	73.60	55.00	58.40	54.30	72.20	0
63.82	59.40	75.20	57.80	60.30	56.50	73.70	250
67.98	63.40	82.70	59.80	66.20	57.70	78.10	500
	60.31	77.17	57.53	61.63	56.17	74.67	Average
con. of glutamic acid		varieties x con. of glutamic acid			varieties		LSD 5%
0.994		1.522			0.845		

.4Grain Yield (tons•ha^{-1}(

The results in Table (4) showed significant differences among varieties in grain yield. The Rizan genotype recorded the highest mean yield of 6.273 tons•ha^{-1}, followed by Sara with 6.190 tons•ha^{-1}, while Admiral recorded the lowest mean of 5.737 tons•ha^{-1}. The superior yield in Rizan is attributed primarily to its higher spike number (Table 1), which directly contributed to increased grain production per unit area. Although Admiral achieved the highest 1000-grain weight (57.889 g), it scored the lowest values for both spike number (374.22 spikes•m^{-2}) and grain number per spike (56.17), resulting in a lower overall grain yield. This observation highlights that improving a single component such as

grain weight is not sufficient to maximize yield unless supported by sufficient spike and grain numbers. This interdependence was also reflected in the harvest index, where Admiral had the highest value (35.06%) due to its heavier grains relative to biological yield, while Rizan —despite its superior grain yield—showed a lower harvest index (22.26%) due to a greater investment in vegetative biomass. These findings suggest that maximizing grain yield requires a balance among all yield components, not merely focusing on grain size. These results are consistent with those reported by [14], [15], and [16], who emphasized the genotypic variation in yield traits among wheat cultivars. In terms of glutamic acid concentrations, the 500 mg•L^{-1} treatment produced the highest average grain yield (6.192 tons•ha^{-1}), followed by 250 mg•L^{-1} (5.991 tons•ha^{-1}), whereas the control (0 mg•L^{-1}) recorded the lowest (5.819 tons•ha^{-1}). The increases in spike number, grain number per spike, and 1000-grain weight at 500 mg•L^{-1} were directly reflected in yield improvement. This can be explained by the role of glutamic acid in stimulating enzyme activity related to protein and carbohydrate biosynthesis and dry matter accumulation, all of which are fundamental to increasing grain yield per unit area. These findings are in line with those of [17]and Abd [11.[

Regarding the interaction between Varieties and concentrations, the combination of Rizan× 500 mg•L^{-1} produced the highest yield (6.510 tons•ha^{-1}), followed by Sara × 500 mg•L^{-1} (6.413 tons•ha^{-1}), indicating a strong response of these genotypes to foliar application. Conversely, the Admiral × control interaction recorded the lowest yield (5.600 tons•ha^{-1}(

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Table 4. Effect of glutamic acid on six triticale Varieties in yield (tan.ha1(

average	triticale Varieties						concentrations of glutamic acid
	Rizan	Al-Muhand	Farah	Amal 7	Admiral	Sara	
5.819	6.040	5.737	5.763	5.803	5.600	5.970	0
5.991	6.270	5.830	5.890	5.987	5.780	6.187	250
6.192	6.510	6.030	6.140	6.230	5.830	6.413	500
	6.273	5.866	5.931	6.007	5.737	6.190	Average
con. of glutamic acid		varieties x con. of glutamic acid			varieties		LSD 5%
0.0734		0.0835			0.0379		

.5Biological Yield (tons•ha^{-1}(

The results presented in Table (5) showed significant differences among varieties in biological yield. The genotype Rizan recorded the highest biological yield (28.467 tons•ha^{-1}), while Admiral recorded the lowest mean (16.667 tons•ha^{-1}). The superiority of Rizan in biological yield may be attributed to the positive relationship between grain yield

ISSN 2072-3857

and total biomass. Biological yield is an indicator of the total dry matter produced per unit area, and its increase reflects the genotype's ability to accumulate assimilates efficiently. The results highlight the influence of genetic factors, where changes in environmental conditions directly affect dry matter production. The Rizan variety e was also characterized by a high number of tillers per unit area, which contributed significantly to its superior biomass. These findings are in agreement with those reported by [18], [19], [20], and [21], who documented genetic variation in biological yield among different wheat cultivars.

As for the effect of glutamic acid concentrations, the 500 mg•L^{-1} treatment recorded the highest average biological yield (25.133 tons•ha^{-1}), followed by 250 mg•L^{-1} (21.611 tons•ha^{-1}), while the control had the lowest value (19.289 tons•ha^{-1}). The observed increase in traits such as tiller number, flag leaf area, plant height, spike length, and grain yield components at 500 mg•L^{-1} was positively reflected in the total biological yield. These results are consistent with [11], who found that glutamic acid improves vegetative growth and biomass accumulation.

Regarding the interaction between gvarieties and concentrations, the highest biological yield was recorded in the Rizan× 500 mg•L^{-1} treatment (32.933 tons•ha^{-1}), while the lowest was observed in the Admiral × control treatment (13.867 tons•ha^{-1} .(

Table 5. Effect of glutamic acid on six triticale Varieties in biological yield (tan.ha1(

average	Triticale varieties						concentrations of glutamic acid
	Rizan	Al-Muhand	Farah	Amal 7	Admiral	Sara	
19.289	25.067	15.800	17.800	19.667	13.867	23.533	0
21.611	27.400	16.533	21.200	21.467	16.600	26.467	250
25.133	32.933	20.800	23.600	25.267	19.533	28.667	500
	28.467	17.711	20.867	22.133	16.667	26.222	average
con. of glutamic acid		varieties x con. of glutamic acid			varieties		LSD 5%
0.2759		0.5626			0.3337		

.6Harvest Index(%)

The results in Table (6) indicated significant differences among genotypes in terms of harvest index. The Admiral genotype recorded the highest harvest index (35.06%), while the Rizan× 500 mg•L^{-1} treatment had the lowest (19.78%). Among glutamic acid concentrations, the control (0 mg•L^{-1}) scored the highest average harvest index (31.38%), and the index decreased progressively with increasing concentration, reaching 25.29% at 500 mg•L^{-1}.

Although the harvest index is considered a physiological indicator of the plant's efficiency in converting total biomass into

ISSN 2072-3857

economic yield (i.e., grain), a higher value does not necessarily imply greater total productivity. In this study, the higher harvest index recorded in the control treatment was likely due to limited vegetative growth, which reduced total biomass and increased the relative contribution of grain yield. In contrast, the higher glutamic acid concentration promoted vigorous vegetative growth, which raised the biological yield more than the grain yield, thus reducing the harvest index proportionally.

Therefore, the decline in harvest index at 500 mg•L^{-1} does not indicate inefficiency, but rather reflects the increased vegetative component induced by the bio-stimulant, while maintaining high grain yield. This interpretation is consistent with previous findings by [22] and [23]in wheat and barley, respectively. Accordingly, the high concentration is still recommended in agronomic applications aimed at maximizing absolute grain production, while a higher harvest index under untreated conditions should not be interpreted as superior performance.

As for the interaction between genotypes and concentrations, the combination Admiral × control recorded the highest harvest index (40.48%), reflecting this genotype's inherent efficiency in allocating biomass toward grain under natural conditions. Conversely, the Rizan× 500 mg•L^{-1} interaction resulted in the lowest index (19.78%), due to the high biological yield achieved in this treatment.

Table 6. Effect of glutamic acid on six triticale Varieties in harvest index(%)

average	triticale Varieties						concentrations of glutamic acid
	Rizan	Al-Muhand	Farah	Amal 7	Admiral	Sara	
31.38	24.11	36.37	32.41	29.52	40.48	25.38	0
28.68	22.89	35.29	27.79	27.92	34.83	23.38	250
25.29	19.78	29.01	26.03	24.67	29.86	22.38	500
	22.26	33.56	28.74	27.37	35.06	23.72	average
con. of glutamic acid		varieties x con. of glutamic acid			varieties		LSD 5%
0.879		1.131			0.577		

Conclusions and Recommendations

The results of this study demonstrated that foliar application of glutamic acid at a concentration of 500 mg•L^{-1} significantly improved yield components in triticale. In particular, the genotype Rizan exhibited the highest physiological and genetic efficiency, recording the greatest values in spike number, grain yield, and biological yield, especially under the highest concentration. In contrast, the genotype Admiral excelled in 1000-grain weight and harvest index, while Al-Muhand was superior in the number of grains per spike. Although individual genotypes showed strength in specific traits such as grain weight

ISSN 2072-3857

or grain number, the Rizan variety at 500 mg•L⁻ ¹ demonstrated the best integration among yield components, making it the most productive overall. The study recommends the use of glutamic acid at 500 mg•L⁻ ¹, particularly with the Rizan variety , to enhance grain production under local environmental conditions..

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