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Physiological Traits and Growth Indicators Response of Triticale to Glutamic Acid Application Under Anbar Conditions.

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Abstract

This study investigated the performance of various triticale cultivars and the impact of glutamic acid application on key physiological traits. We found significant differences among cultivars in nearly all measured parameters, underscoring the importance of genetic selection. Notably, Sara consistently excelled in vegetative growth, including plant height and flag leaf area, while Rizan demonstrated superior stomatal conductance, tillering capacity, and relative growth rate. Exogenous application of glutamic acid consistently improved plant performance across multiple traits. Specifically, a concentration of 500 mg L^{-1} generally enhanced stomatal conductance, plant height, and tiller number, while 250 mg L^{-1} was optimal for boosting relative growth rate and net photosynthesis. This underscores the importance of glutamic acid as an advantageous biostimulant. The study indicated strong connections between genetics and environment. The ideal reaction to glutamic acid was frequently particular to the cultivar. Sara and Rizan exhibited significant synergistic advantages from glutamic acid, frequently attaining optimal performance at certain dosages. Conversely, several cultivars demonstrated no enhancement or deterioration without optimum glutamic acid. In conclusion, to get the most out of triticale, you need to do two things: choose genetically better cultivars like Sara and Rizan and use glutamic acid at levels that are right for each cultivar and attribute you want. You need to use this focused method to get the most performance out of triticale in your area.

Keyword: ***Triticale, Physiological Traits, Glutamic Acid, Growth Indicators***

I. INTRODUCTION

Triticale, a hybrid cereal (× Triticosecale Wittmack) of the Poaceae family, resulted from the intergeneric hybridization of wheat (Triticum aestivum L.) as the maternal progenitor and rye (Secale cereale L.) as the paternal progenitor. This hexaploid crop, resulting from chromosomal doubling, effectively merges wheat's high yield and disease resistance with the robustness, resilience, and tolerance to adverse environmental circumstances (e.g., infertile or poorly drained soils) derived from rye. Morphologically, triticale demonstrates enhanced traits relative to wheat, such as increased plant height, prolonged spike length, and higher protein content. Significantly, its lysine level may exceed wheat's by up to 4% (Glamočlija et al. , 2018)

Statistics reveal (FAO,2023) a planted area of over 3.6 million hectares, producing over 13.8 million tons, with an average yield of 3835.7 kg ha^{-1} across 45 nations. Despite its established benefits, triticale cultivation in Iraq remains limited, primarily due to insufficient awareness among farmers regarding its economic and physiological advantages.

Triticale's dual-purpose utility, serving as both a grain and green fodder crop, is attributed to its vigorous growth, prolific tillering, expansive flag leaf area, and high dry matter accumulation. Agricultural crop productivity is intrinsically governed by the intricate interplay between genotypic expression and prevailing environmental conditions, augmented by growth-promoting factors. Bioactive compounds, such as glutamic acid, have demonstrated significant efficacy in

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enhancing plant physiological processes. Glutamic acid is a crucial amino acid essential for the development of vegetative tissue, regulation of metabolism, and nutritional absorption in the body. Administering glutamic acid to plant leaves positively affects growth rates, maintains cellular nutritional equilibrium, and enhances proline production, augmenting plants' resilience to environmental stress (Steeve, 2008)

(Kara and Şener, 2021) Turkish researchers examined five triticale cultivars (Karma2000, Tatlicok97, Alperbey, Miknham2002, and Umranhanim) across two seasons. The vegetative growth parameters of the several cultivars exhibited significant variation. The Miknham2002 cultivar consistently exhibited the greatest height, averaging 105 cm in the first season and 103.1 cm in the second. Miknham2002 documented the largest spike length in the initial season at 9.83 cm, although Alperbey reported the longest average spike length in the subsequent season at 10.87 cm.Complementary findings by (Rashid and Alwahid, 2023) underscored significant varietal differences in growth parameters. The cultivar Amal demonstrated superior plant height (100.13 cm) and flag leaf area (52.92 cm^2), whereas Al-Mohannad registered the lowest values for plant height (95.61 cm) and flag leaf area (37.76 cm^2). In a field experiment conducted in Kirkuk Governorate, (Al-Rawi, 2024) evaluated four triticale cultivars (Sara, Rizan, Admiral, Al-Mohannad), observing significant varietal differences in vegetative growth characteristics. Admiral and Al-Mohannad exhibited earlier heading, reaching 50% heading in 91.83 and 92.58 days, respectively. Conversely, Rizan showed delayed heading, averaging 102.92 days. No significant differences in plant height were observed among these four cultivars.

(Al-Namrawi, 2021) study demonstrated that foliar application of glutamic acid at 200 mg L^{-1} significantly enhanced plant growth. This treatment notably increased tiller density to 392.80 tillers m^{-2}, compared to 371.36 tillers m^{-2} in the control. Flag leaf area also significantly improved, reaching a maximum average of 35.50 cm^2 at 200 mg L^{-1} glutamic acid, compared to 31.30 cm^2 in the control. The study also noted that the higher glutamic acid concentration (200 mg L^{-1}) extended the floral growth period to 140.08 days, relative to 139.25 days in the control.

II. Current Research Objectives

Building upon these findings, the present study aims to comprehensively evaluate the impact of glutamic acid on various growth traits across several triticale cultivars. The primary objective is to identify optimal glutamic acid concentrations that can effectively enhance the performance of this vital crop under the specific local environmental conditions prevailing in Iraq.

III. 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 genotypes 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) genotypes: 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}.

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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 (Al-Mohammadi and Fadhel., 2012)

IV. RESULTS AND DISCUSSION

A. Stomatal conductance

serves as a critical physiological indicator reflecting a plant's capacity for gas exchange with the atmosphere, specifically the uptake of carbon dioxide essential for photosynthesis and the release of water vapor through stomata. The presented findings meticulously analyze the impact of genetic variability among triticale cultivars and the application of glutamic acid on this pivotal physiological process.

Significant differences were observed in the mean stomatal conductance among cultivars, indicating inherent variations in their ability to regulate stomatal apertures. The cultivar Rizan recorded the highest mean conductance at 0.047µmol m−2 s−1, signifying superior physiological efficiency in maintaining an optimal stomatal opening for effective gas exchange. This efficiency likely contributes to enhanced photosynthetic rates and, consequently, higher productivity. Conversely, the cultivar Admiral exhibited the lowest mean conductance at 0.030µmol m−2 s−1. This suggests that Admiral may exercise greater conservatism in stomatal opening, potentially as a mechanism to mitigate water loss, albeit at the potential cost of reduced carbon dioxide assimilation.

Foliar application of glutamic acid at various concentrations significantly and positively influenced stomatal conductance. The concentration of 500 mg L−1 yielded the highest mean conductance of 0.043µmol m−2 s−1, outperforming the control treatment (no application) which registered 0.033µmol m−2 s−1. This effect can be elucidated through several physiological mechanisms. Glutamic acid is recognized for its role in the synthesis of proline and other compounds that aid plant stress responses. Glutamic acid can influence the equilibrium of plant hormones such as abscisic acid (ABA) and cytokinins, which regulate the opening and closing of stomata. Utilizing glutamic acid at appropriate concentrations facilitates the maintenance of open stomata, enhancing the plant's ability to absorb carbon dioxide and promoting photosynthesis (Dubrovna et al., 2022)

The analysis of the interaction between triticale cultivars and glutamic acid concentrations revealed substantial differences in cultivar responses. The cultivar Rizan demonstrated a notable and progressive increase in stomatal conductance with higher concentrations of glutamic acid. This indicates that Rizan possesses intrinsic physiological mechanisms enabling it to use glutamic acid more effectively for enhanced stomatal opening and gas exchange, demonstrating a robust correlation between this cultivar's genetic makeup and the stimulatory effects of glutamic acid. The enhanced reaction in Rizan may result from greater guard cell functionality or increased sensitivity of glutamic acid receptors in this specific cultivar. Conversely, the reactions of the cultivars Admiral and Sara to the administration of glutamic acid were minimal or statistically insignificant. This indicates that these cultivars may not possess the same ability to utilize glutamic acid for enhancing stomatal conductance, possibly due to differences in their absorption routes, metabolic processing, or stomatal regulatory systems that are less reactive to external glutamic acid effects. The observed physiological variability highlights the need to examine genotype-environment (GxE) interactions to comprehend and enhance crop responses fully.

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Table (1) : Effect of glutamic acid on six triticale genotypes in Stomatal Conductance

concentrations of glutamic acid	triticale genotypes						average
	Sara	Admiral	Amal 7	Farah	Al-Muhand	Rizan	
0	0.043	0.027	0.038	0.029	0.031	0.032	0.033
250	0.045	0.028	0.046	0.049	0.034	0.044	0.041
500	0.029	0.033	0.049	0.039	0.044	0.066	0.043
average	0.039	0.03	0.044	0.039	0.036	0.047	
LSD 5%	genotypes		Genotypes x con. of glutamic acid			con. of glutamic acid	
	0.0029		0.0055			0.0040	

B. Relative Growth Rate (RGR)

The evaluation of the Relative Growth Rate (RGR) in triticale reveals significant physiological variability influenced by genetic differences among cultivars, the application of glutamic acid, and their interactive effects. RGR is an essential statistic which measures a plant's efficiency in biomass accumulation over time, highlighting the effectiveness of physiological processes like photosynthesis and dry matter distribution. Cultivars exhibit significant differences in their physiological effectiveness in achieving increased RGRs. The cultivar Farah exhibited outstanding performance, achieving the highest mean relative growth rate of 0.0709 g g−1 day−1. This advantage illustrates Farah's exceptional ability to efficiently harness solar energy and convert it into dry matter, indicating improved photosynthetic efficiency and biomass accumulation in vegetative structures. These findings corroborate earlier research by (Saleh,2015) and (AbdelKarim et al., 2015).

Highlighting intrinsic genetic variability among cultivars in their ability to manifest physiological potential. The cultivar Al-Muhannad demonstrated the lowest mean relative growth rate (RGR) of 0.0563 g g−1 day−1, highlighting the differences in physiological efficiency among cultivars. In a pertinent context, foliar treatment of glutamic acid had a beneficial and considerable impact on RGR. The 250 mg L−1 concentration of glutamic acid exhibited the greatest overall mean of 0.066 g g−1 day−1, surpassing the control treatment (no application), which recorded 0.061 g g−1 day−1. This effect is attributed to the vital role of glutamic acid as a fundamental amino acid in plant metabolic pathways. It directly participates in nitrogen assimilation, serving as a precursor for the synthesis of numerous amino acids and proteins essential for growth and development. Glutamic acid is also believed to enhance photosynthetic efficiency, either by improving chlorophyll biosynthesis or by influencing the activity of key enzymes in the Calvin cycle, thereby increasing carbohydrate production and dry matter accumulation.

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Table (2): Effect of glutamic acid on six triticale genotypes in Relative Growth Rate.

concentrations of glutamic acid	triticale genotypes						average
	Sara	Admiral	Amal 7	Farah	Al-Muhand	Rizan	
0	0.0617	0.0544	0.0446	0.0746	0.0686	0.063	0.061
250	0.0672	0.0655	0.0712	0.0625	0.0548	0.0755	0.066
500	0.069	0.0714	0.0665	0.0755	0.0456	0.059	0.065
average	0.0660	0.0638	0.0608	0.0709	0.0563	0.0658	
LSD 5%	genotypes		Genotypes x con. of glutamic acid			con. of glutamic acid	
	0.0016		0.0030			0.0021	

Most interestingly, a significant interaction was observed between cultivars and glutamic acid concentrations, indicating that the response of each cultivar to the exogenous application of this amino acid is not uniform. The cultivar Rizan, in combination with the 250 mg L−1 concentration, recorded the highest mean RGR, reaching 0.0755 g g−1 day−1. This superior performance reflects a unique physiological compatibility between Rizan's genetic makeup and the mechanisms activated by glutamic acid. It is plausible that Rizan possesses a higher inherent capacity for glutamic acid uptake and processing, or that its metabolic pathways respond optimally to external supplementation of this amino acid, leading to maximized growth efficiency. In contrast, the cultivar Amal 7 with the control treatment recorded the lowest mean RGR of 0.0446 g g−1 day−1, which may suggest that this cultivar experiences physiological limitations in the absence of external support or requires a different concentration of glutamic acid to enhance its growth.

These results underscore that the judicious selection of the optimal cultivar, alongside the targeted application of bioactive nutrients like glutamic acid, can significantly influence the physiological productivity of triticale.

C. Net Photosynthesis

The data in Table (3) indicate that Triticale cultivars demonstrate considerable physiological diversity in growth potential and dry matter accumulation. The cultivar Farah exhibited an exceptional Relative Growth Rate (RGR), achieving the highest mean of 0.0709 g g−1 day−1. This demonstrates its remarkable capacity to transform available resources into biomass, signifying high efficiency in photosynthesis and organic matter allocation. In contrast, the cultivar Al-Mohannad demonstrated the lowest relative growth rate at 0.0563 g g−1 day−1, underscoring the substantial impact of genetic potential on growth efficiency. Similarly, the cultivar Admiral demonstrated significantly increased net photosynthesis, achieving the highest average of 0.0013 g cm−2 day−1.

This indicates that Admiral's leaves are more efficient at producing dry matter per unit area. Conversely, the cultivar Sara recorded the lowest mean net photosynthesis at 0.0006 g cm−2 day−1, demonstrating substantial differences in carbon fixation efficiency among cultivars. These inherent variations form the basis for selecting the most suitable cultivars for cultivation. Foliar application of glutamic acid had a positive and significant effect on both physiological indicators. At a concentration of 250 mg L−1, glutamic acid recorded the highest mean for both RGR (0.066 g g−1 day−1) and net photosynthesis (0.001 g cm−2 day−1), outperforming control treatments. Glutamic acid, as an essential amino acid, is crucial for various fundamental physiological processes.

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The results indicate that administering glutamic acid at its optimal concentration may effectively improve plant physiological performance. The results highlight the importance of the su The results underscore the critical relationship between cultivars and glutamic acid concentrations, indicating that physiological responses are not only additive effects of individual components but rather a consequence of their intricate interactions. The cultivar Amal 7, when exposed to 250 mg L−1 of glutamic acid, achieved the highest net photosynthetic rate of 0.0014 g cm−2 day−1, surpassing all other treatments.

This confirms that Amal 7 responds effectively to this specific concentration of glutamic acid, hence enhancing its photosynthetic efficiency. The cultivar Admiral at 500 mg L−1 demonstrated a significant value, indicating that cultivars may differ not only in their sensitivity to glutamic acid but also in the optimal dosage that elicits their maximum physiological response. Conclusion section is mandatory and contains advantages, disadvantages, review the main part of research paper and use of research work. If author want to acknowledge someone, then acknowledgement section should include in research paper after conclusion. Appendix section (if required) appears before acknowledgement section.

Table (3): Effect of glutamic acid on six triticale genotypes in Net Photosynthesis

concentrations of glutamic acid	triticale genotypes						average
	Sara	Admiral	Amal 7	Farah	Al-Muhand	Rizan	
0	0.0006	0.0013	0.0006	0.0012	0.0012	0.0005	0.0009
250	0.0007	0.0011	0.0014	0.0008	0.0008	0.0013	0.001
500	0.0006	0.0014	0.0011	0.0011	0.0006	0.0007	0.0009
average	0.0006	0.0013	0.001	0.0011	0.0009	0.0008	
LSD 5%	genotypes		Genotypes x con. of glutamic acid			con. of glutamic acid	
	0.00010		0.00017			0.00010	

D. Plant Height (cm)

Table 4 demonstrates notable disparities in average plant height between cultivars. The cultivar Sara recorded the highest mean height at 140.61 cm, indicating that this cultivar possesses a high inherent genetic capacity for substantial vertical growth. This variation is attributed to differences in the genetic makeup of the cultivars, which dictate their response to environmental conditions and their ability to utilize resources for vertical biomass accumulation. In contrast, the cultivar Amal 7 registered the lowest mean plant height at 124.23 cm, suggesting its genetic potential for vertical growth is comparatively lower than that of Sara. Foliar application of glutamic acid significantly influenced plant height. The concentration of 500 mg L−1 recorded the highest mean height at 134.12 cm.

This concentration outperformed the 250 mg L−1 concentration, which yielded a lower mean of 131.88 cm. This suggests that glutamic acid, at its higher concentration (within the study's range), can stimulate vertical plant growth. This physiological role can be explained by glutamic acid's fundamental contribution, as an essential amino acid, to the synthesis of proteins and enzymes crucial for cell division and cell elongation—two critical processes for increasing plant height.

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Moreover, glutamic acid may affect the equilibrium of plant hormones that regulate growth, including auxins and gibberellins, which are recognized for their direct influence on stem elongation. Examining the relationship between cultivars and glutamic acid concentrations underscores the significance of genotype-environment (GxE) interaction in ascertaining optimum responses. The interaction between cultivar Sara and the 500 mg L−1 concentration yielded the highest average plant height at 143.67 cm.

This confirms that Sara not only possesses high genetic potential for vertical growth but also responds optimally to higher concentrations of glutamic acid, reflecting its physiological capacity to maximize the benefits from this stimulant. In contrast, the same 500 mg L−1 concentration applied to the cultivar Amal 7 yielded the lowest mean plant height at 123.67 cm. This result suggests that Amal 7 may not possess the same physiological capacity to respond positively to high concentrations of glutamic acid as Sara, or that its genetic mechanisms differ in how they process and utilize this amino acid. This could be due to variations in response genes or metabolic pathways affected by glutamic acid.

Table (4): Effect of glutamic acid on six triticale genotypes in Plant Height (cm)

concentrations of glutamic acid	triticale genotypes						average
	Sara	Admiral	Amal 7	Farah	Al-Muhand	Rizan	
0	135.87	133.33	124.97	131.57	135.33	135.47	132.76
250	142.3	131.9	124.07	129.07	129.2	134.73	131.88
500	143.67	133.3	123.67	136.07	130.57	137.47	134.12
average	140.61	132.84	124.23	132.23	131.7	135.89	
LSD 5%	genotypes		Genotypes x con. of glutamic acid			con. of glutamic acid	
	1.351		2.212			0.832	

E. Tiller Number (m^2)

The study revealed significant differences in the mean tiller number per square meter among cultivars (Table 5), confirming that tillering capacity is a genetically determined trait. The cultivar Rizan recorded the highest tiller count, reaching 499.11 tillers m−2. This superiority is attributed to Rizan's robust genetic foundation, which confers a higher inherent tillering capacity. This increased branching may result from reduced inter-plant competition for nutrients, leading to an elevated concentration of internal hormones that break apical dominance and stimulate the growth of lateral buds, thereby increasing the overall number of tillers, a finding consistent with (Al-Younis, 1987) and (Baqir, 2018)

In contrast, the cultivar Admiral registered the lowest mean tiller number, at 399 tillers m−2, indicating that its genetic tillering capacity is lower compared to Rizan.

The amounts of glutamic acid markedly elevated the number of tillers. The 500 mg L−1 concentration exhibited the greatest mean tiller count of 472.44 m−2. This concentration exceeded the control treatment (no application), which recorded 225.61 tillers m−2. The stimulatory effect of glutamic acid is due to its function as a vital amino acid that actively facilitates essential physiological and biochemical processes in plants. It facilitates the synthesis of proteins vital for cellular growth and tissue development while contributing to carbohydrate production by promoting chlorophyll

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synthesis and stimulating photosynthesis. These essential processes supply the requisite energy and components to promote the development of lateral buds and enhance tillering (El-Gizaw et al., 2009)

The analysis of the notable interaction between cultivars and glutamic acid concentrations demonstrated diverse responses of cultivars to external stimuli. The interaction between the cultivar Rizan and the 500 mg L−1 concentration yielded the highest mean tiller count, achieving 519 tillers m−2. This likely demonstrates the distinct superiority of Rizan, which effectively utilizes elevated levels of glutamic acid to enhance its tillering capacity, signifying physiological and genetic compatibility that enables this cultivar to reach its optimal productive potential. In contrast, the control treatment utilizing the cultivar Al-Mohannad produced the lowest average tiller count at 370.33 tillers m−2. This indicates that Al-Mohannad may exhibit diminished responsiveness to glutamic acid or be adversely impacted by its deficiency, underscoring the necessity of investigating cultivar-specific interactions to enhance performance.

Table (5): Effect of glutamic acid on six triticale genotypes in Tiller Number (m^2)

concentrations of glutamic acid	triticale genotypes						average
	Sara	Admiral	Amal 7	Farah	Al-Muhand	Rizan	
0	459.67	370.33	436	410.33	397	480.33	425.61
250	472.33	403.33	460.33	441.33	382.67	498	443.00
500	489.67	423.33	482.67	472.33	447.67	519	472.44
average	473.89	399.00	459.67	441.33	409.11	499.11	
LSD 5%	genotypes		Genotypes x con. of glutamic acid			con. of glutamic acid	
	2.020		3.623			2.332	

F. Flag Leaf Area (cm^2)

Flag leaf area is a critically important physiological indicator in cereal crops, as this leaf significantly contributes to grain filling and ultimately determines final yield. The results demonstrate significant effects of both the genetic makeup of cultivars and the application of glutamic acid on the flag leaf area, in addition to their interaction. Cultivars exhibited significant differences in their average flag leaf area, highlighting the essential role of genetics in morphological characteristics.

The cultivar Sara significantly exceeded the other cultivars, attaining the highest average of 43.96 cm^2. This superiority is likely attributable to Sara's unique genetic composition, which facilitates the formation of a larger flag leaf, signifying its genetic efficacy in resource distribution and the development of vital plant structures. These findings correspond with (Ottman, 2000) and (El-Said and Mahdy, 2016), emphasizing that genetic variations affect a plant's susceptibility to environmental factors and contribute to growth discrepancies. Conversely, the cultivar Al-Mohannad demonstrated the smallest average flag leaf area, measuring 37.23 cm^2, indicating that its genetic potential for producing a large flag leaf is inferior to Sara's.

The findings demonstrated that applying glutamic acid at a concentration of 500 mg L−1 substantially increased the average flag leaf area to 42.36 cm^2. This mean was markedly higher than the untreated control plants, with the lowest mean of 36.18 cm^2. The beneficial impact of glutamic acid is ascribed to its essential physiological function in the plant. Glutamic acid is a fundamental amino acid that enhances the plant's ability to absorb nitrogen, a vital ingredient for

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creating proteins, nucleic acids, and chlorophyll. Enhanced nitrogen availability positively influences overall vegetative growth, increasing leaf quantity and area expansion, thereby augmenting the plant's photosynthetic capability. The analysis of the interaction reveals that cultivar responses to glutamic acid differ.

The interaction between the cultivar Sara and the 500 mg L−1 concentration yielded the highest average flag leaf area, measuring 46.23 cm². This superiority confirms that Sara possesses a high genetic predisposition for forming a large flag leaf and responds optimally to high concentrations of glutamic acid, maximizing its efficiency in this vital trait. In contrast, the control treatment with the cultivar Al-Mohannad yielded the lowest mean flag leaf area, at 32.1 cm2. This demonstrates that Al-Mohannad is negatively affected by the absence of glutamic acid and may be unable to achieve its full potential in the flag leaf area without external support.

Table (6): Effect of glutamic acid on six triticale genotypes in Flag Leaf Area (cm^2)

concentrations of glutamic acid	triticale genotypes						average
	Sara	Admiral	Amal 7	Farah	Al-Muhand	Rizan	
0	40.26	33.05	39.04	33.16	32.1	39.45	36.18
250	45.4	42.22	39.31	40.81	41.11	41.84	41.78
500	46.23	42.48	44.09	42.58	38.48	40.3	42.36
average	43.96	39.25	40.81	38.85	37.23	40.53	
LSD 5%	genotypes		Genotypes x con. of glutamic acid			con. of glutamic acid	
	1.517		3.265			2.817	

V. CONCLUSION

For top triticale performance, focus on Sara and Rizan cultivars, especially with glutamic acid.

Sara excels in overall plant vigor, height, and flag leaf area. Pair it with 500 mg L^{-1} glutamic acid for robust growth and efficient light capture.

Rizan is superior for gas exchange, tillering, and rapid growth. It responds well to 250 mg L^{-1} glutamic acid for better growth rate and tillering, and 500 mg L^{-1} for maximum tillers and stomatal efficiency.

In short, Sara is choice for strong, leafy plants, while Rizan is for abundant tillers and efficient internal processes. Both thrive with glutamic acid, but adjust the concentration based on the cultivar and the specific trait you want to boost. This targeted approach will maximize your triticale yield.

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