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INFLUENCE OF EXOGENOUSLY APPLIED AMINO ACIDS ON SOME GROWTH TRAITS AND YIELDS OF THREE WHEAT CULTIVARS (TRITICUM AESTIVUM L.)

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Abstract

This field study examined the effect of various exogenously applied concentrations of amino acids on some local wheat varieties. The investigation was conducted using a randomized complete block design (RCBD) with three replicates in a split-plot arrangement. The main plots contained amino acid concentrations of 0, 3.0, and 6.0 ml L^{-1} together with the Iba 99, Al- Rasheed, and Abu Ghraib-3 wheat cultivars in the subplots. The Al-Rasheed cultivar recorded the highest plant height, flag leaf area, spike length and 1000-grain weight with mean values of 111.06 cm^2, 44.10 cm^2, 14.50 cm^2, and 45.00 g, respectively. The Abu Ghraib-3 cultivar had the highest mean number of spikes, grain numbers, grain yield and harvest index at 538.6 spikes m^{-2}, 53.68 grains $spike^{-1}$, 6.170 ton ha^{-1}, and 35.22%, respectively. Amino acid concentrations significantly affected all growth and yield traits with the 3.0 ml L^{-1} concentration offering the highest mean value for plant height at 104.69 cm and 513.7 spikes m^{-2}, with the quantity of grains in each spike at 49.98 grains $spike^{-1}$, total grain yield of 6.023 tons ha^{-1}, and a harvest index of 42.00%. The 6 ml L^{-1} concentration provided the highest average for flag leaf area, spike length, and 1000-grain weight at 41.89 cm^2, 12.30 cm, and 42.00 g., respectively. There was a significant interaction effect between the Al-Rasheed cultivar at the 3 ml L^{-1} amino acid concentration in plant height and between the Abu

Ghraib-3 cultivar in the number of spikes and harvest index. Also, there was an interaction between the Abu Ghraib-3 cultivar at the 6 ml L^{-1} amino acid concentration and number of seeds per spike.

Keywords: Amino acids, Growth traits, Yield, Cultivars, Wheat.

تأثير الاضافة الخارجية للأحماض الأمينية في بعض صفات النمو والحاصل لثلاثة أصناف من الحنطة (*Triticum aestivum* L.)

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الخلاصة

أجريت تجربة حقلية لدراسة تأثير إضافة تراكيز مختلفة من الأحماض الأمينية رشا على بعض أصناف الحنطة المحلية. تم تنفيذ الدراسة باستخدام تصميم القطاعات العشوائية الكاملة (RCBD) بثلاثة مكررات في ترتيب الالواح المنشقة حيث احتوت الالواح الرئيسية على تراكيز مختلفة من الأحماض الأمينية (0، 3.0، و6.0) مل لتر$^{-1}$. في حين اشتملت الالواح الثانوية على ثلاثة أصناف من الحنطة (إباء 99، الرشيد وأبو غريب 3). سجل صنف الرشيد أعلى قيم لمتوسط ارتفاع النبات، مساحة ورقة العلم، طول السنبلة، ووزن 1000 حبة وكانت القيم (111.06 سم، 44.10 سم^{2}، 14.50 سم و45.00 غم) بالتتابع. بينما أعطى الصنف أبو غريب-3 أعلى متوسط لكل من عدد السنابل في المتر المربع، عدد الحبوب في السنبلة الواحدة، حاصل الحبوب الكلي ودليل الحصاد وبلغت القيم (538.6 سنبلة م$^{-2}$، 53.68 حبة سنبلة$^{-1}$، 6.17 طن هـ$^{-1}$ و35.22%) بالتتابع. أثرت تراكيز الأحماض الأمينية معنويا على جميع صفات النمو والحاصل، نلاحظ ان التركيز 3.0 مل لتر$^{-1}$ سجل اعلى متوسط لكل من: ارتفاع النبات بلغ 104.69 سم، عدد السنابل في المتر المربع 513.7 سنبلة م$^{-2}$، عدد الحبوب في السنبلة الواحدة 49.98 حبة سنبلة$^{-1}$، حاصل الحبوب الكلي 6.023 طن هـ$^{-1}$، ودليل الحصاد 42.00%. بينما التركيز 6 مل لتر$^{-1}$ أعطى أعلى متوسط لكل من مساحة ورقة العلم، طول السنبلة ووزن 1000 حبة (41.89 سم^{2}، 12.30 سم و42.00 غم) بالتتابع. كان هناك تأثير للتداخل المعنوي بين صنف الرشيد والتركيز 3 مل لتر$^{-1}$ من الأحماض الأمينية في ارتفاع النبات وبين الصنف أبو غريب-3 ونفس التركيز في عدد السنابل/ م ودليل الحصاد، كما وجد تداخل بين الصنف أبو غريب والتركيز 6 مل لتر$^{-1}$ في عدد الحبوب بالسنبلة.

كلمات مفتاحية: احماض أمينية، صفات النمو، الحاصل، الأصناف، الحنطة.

Introduction

The *Triticum aestivum* L. is the most important and strategic food grain globally. It plays an essential role in food security for individuals and society and is a major food source for more than 35% of the world's population. It has substantial nutritional value having an excellent ratio of proteins to carbs in its grains, as well as significant amounts of vital amino acids, lipids, vitamins, and mineral substances required by the human body. The components in wheat grains have a significant impact on the final flour's chemical and physical characteristics (5 and 31). Despite Iraq being one of the original cultivators of wheat and a major producer, its average productivity remains below the required level (18) due, among others, to poor management of its fields, deterioration in soil quality, and land misuse as well as water scarcity and salinity issues. As such, there is a critical need to address these issues to increase its wheat productivity to match actual demand. (2).

One of the most important ways to achieve this goal is to use the cultivars of good quality and yield suitable for the Iraqi environment, together with proper foliar nutrition, especially with amino acids. These acids have a significant function in triggering physiological and chemical processes inside the plant as they participate in the construction of proteins and carbohydrate production by creating chlorophyll and activating photosynthesis, and increasing the plant's resistance to environmental stresses. They contribute to the development and promotion of several enzymes and enzymatic conjugations. In addition, they regulate the process of transferring elemental ions inside the plant and reduce energy consumption required for their transport, which contributes to improving the plant's growth characteristics and yield (23 and 27). Amino acids also reduce the amount of fertilizers needed, develop root systems, and stimulate plant growth above the soil surface by increasing the absorption of nutrients by the roots (12).

The objective of this study was to determine the optimum amino acid concentration required for the cultivar and to investigate how they interacted to achieve the highest productivity per unit area.

Materials and Methods

The field experiment was conducted in the Anbar Governorate area to determine the effect of foliar application of different concentrations of amino acids on some growth and yield traits of *Triticum aestivum* L. This study was based on a randomized complete block design (RCBD) with three replicators. The study factors were distributed based on the split-plot arrangement. The first (main plot) involved foliar applications of 0, 3, and 6 ml L^{-1} concentrations of amino acids obtained from the Tecamin Max compound, a liquid fertilizer containing 20 amino acids in percentages corresponding to the plant's need, in addition to organic matter and nitrogen. The second factor (sub plot) involved the three Iba 99, Al-Rasheed, and Abu Ghraib-3 wheat cultivars.

The land was prepared and divided into three blocks covering 4 sq meters measuring 2x2 meters each. Each experimental unit contained eight 2-meter-long rows separated 20 cm apart, and each block was 1 meter apart. A total of 140 kg ha^{-1}

of seeds were used (19). The planting was carried out on 11/25/2019. Direct irrigation was applied based on field capacity and the moisture of the soil. For nitrogen supply, 200 kg ha^{-1} of urea fertilizer (46% nitrogen) was used, and added in three batches for the cultivation, elongation, and lining stages. The phosphate fertilizer DAP (46% P_2O_5) was added by mixing it with 100 kg ha^{-1} of field soil (16). The first batch of amino acids was sprayed when the plants' primary stems sprouted three leaves (ZGS:13) and the second batch applied when they started to flower (ZGS:60) (32), according to (12). The different treatments were sprayed on the plants in the early mornings until the leaves were completely wet. The experiment area was manually cleared of weeds. The plants in the experimental units were harvested when each cultivar reached full maturity. The following traits were studied:

- Plant height (cm): Based on an average for five random plants involving the distance between the plant's base and tip of the spike of the main branch except the awns.
- Flag leaf area (cm^2): Calculated at the flowering stage as an average of five plants based on the following equation:

Flag leaf area (cm^2) = leaf length × maximum width × 0.95 (30).

- Length of spike (cm): Based on the average of five spikes taken from the midlines of each experimental unit at physiological maturity and measured from the base of the spike to the extremity of the terminal spike without awns.
- Spike number m^2: Calculated for groups of plants harvested from $1m^2$ area of the midlines.
- Grain number/spike: Calculated as an average of 10 randomly selected spikes.
- 1000-grain weight (g): 1000 grains were randomly selected from the harvested spikes of each experimental unit and weighed.
- Grain yield (ton ha^{-1}): Based on the grain weight (g) for each trial unit's 1 m^2 harvested area. The weight was then converted to ton Ha^{-1}.
- Harvest index (%)**:** Calculated based on the equation proposed by (28):

$$Harvest\ index\ (HI) = \frac{\text{grain yield}}{biological\ yield} \times 100$$

Statistical Analysis: The data was analyzed by GenStat (version 14.0). The averages were compared based on the least significant difference test (LSD) at the 5% level.

Results and Discussion

Plant height (cm): The results indicated significant increases in the cultivars' amino acids and their interactions with plant height (Table 1). The Al-Rasheed cultivar showed the highest average for this trait at 111.06 cm, followed by Abu Ghraib-3 (97.27 cm) and Iba 99 (94.23 cm). The differences in plant height were due to their varied genetic natures and the extent to which they responded to surrounding environmental conditions. These results agree with those obtained by (6 and 17). Also, the 3 ml L^{-1} concentration produced the highest mean for plant height at 104.69 cm while the control had the lowest at 97.06 cm. This could be due to the critical role of amino acids in promoting physiological and biochemical processes such as protein and carbohydrate production through chlorophyll and boosting the process of carbon construction. This enhances plant growth as well as its participation in building and stimulating the action of many enzymes and enzymatic conjugations (23 and 26).

The overlap of cultivars and amino acids had a considerable impact on this characteristic as seen in the Al-Rasheed cultivar which had the highest mean plant height of 117.27 cm at the 3 ml L^{-1} concentration.

Table 1: Influence of cultivars, amino acids, and their interaction in plant height (cm).

Cultivars (V)	Concentrations of amino acid ml L^{-1} (A)			Mean
	0	3	6	
Iba 99	91.57	96.60	94.53	**94.23**
Al-Rasheed	105.40	117.27	110.50	**111.06**
Abu Ghraib-3	94.20	100.00	97.40	**97.27**
Mean	97.06	104.69	100.81	
LSD (0.05)	**V= 1.164**	**A= 0.821**	**VXA=1.730**	

Flag leaf area (cm^2): Table 2 shows the significant effect on flag leaf area of amino acid levels on the cultivars although there was none for the interactions between them. The Al-Rasheed cultivar had the highest mean value for this trait at 44.10 cm^2, followed by Abu Ghraib-3 (36.60 cm^2) and 36.27 cm^2 for Iba 99. These differences may be due to the genetic variations between them, as noted by (3 and 7). Also, flag leaf area increased in line with amino acid levels with the maximum mean of 41.89 cm^2 achieved at the 6 ml L^{-1} concentration while the comparison treatment gave the lowest mean at 36.04 cm^2.

The positive effect of amino acids on metabolic processes improves the supply of food of those elements leading to accelerated cell division and expansion (20). Further, amino acids provide nitrogen, the most critical nutrient for achieving the vegetative growth of plants of which the leaves form an important part. All this contributed to the improvement in this trait.

Table 2: Influence of cultivars, amino acids, and their interaction in flag leaf area (cm^2).

Cultivars (V)	Concentrations of amino acid ml L^{-1} (A)			Mean
	0	3	6	
Iba 99	33.67	35.76	39.39	**36.27**
Al-Rasheed	39.27	45.64	47.38	**44.10**
Abu Ghraib-3	35.18	35.71	38.90	**36.60**
Mean	36.04	39.04	41.89	
LSD (0.05)	**V= 1.952**	**A= 2.303**	**V×A= ns**	

Spike length (cm): The results shown in Table 3 indicate the significant effect of cultivars on spike length with the Al-Rasheed cultivar having the highest mean value at 14.50 cm which was 48.41 and 50.57% greater than the Abu Ghraib-3 and Iba 99 cultivars, respectively. This superiority of the Al-Rasheed cultivar in spike length can be attributed to its wider flag leaf area (Table 2) which increased photosynthesis rates and the transfer of its byproducts to various plant sections. This result is similar to (9 and 11) who reported that spike length varied greatly depending on wheat types. Also, Table 3 shows that the 6 ml L^{-1} amino acid concentration produced the highest spike length mean at 12.30 cm, significantly different from the 3 ml L^{-1} concentration 10.90 cm, while the comparator treatment had the lowest mean at 10.70 cm.

The advantage of high amino acid concentration for spike length could be explained by its low height (Table 1) and broad flag leaf area (Table 2), which facilitates exploitation of processed foodstuffs during photosynthesis in the growth and elongation of the spike instead of the stem, as well as the role of amino acids in enhancing plant growth. This result agrees with those reported by (13 and 25). Finally, there was no substantial interaction between cultivars and amino acid levels.

Table 3: Influence of cultivars, amino acids, and their interaction for spike length (cm).

Cultivars (V)	Concentrations of amino acid ml L^{-1} (A)			Mean
	0	3	6	
Iba 99	8.60	9.00	9.00	**9.63**
Al-Rasheed	13.80	14.20	15.50	**14.50**
Abu Ghraib-3	9.70	9.50	10.10	**9.77**
Mean	10.70	10.90	12.30	
LSD (0.05)	**V= 0.865**		**A= 0.231**	**V×A= ns**

Spike numbers $m^{2:}$ As seen in Table 4, there was a significant impact on the cultivars of amino acid levels, and their interactions in terms of spikes per square meter. Abu Ghraib-3 had the highest mean value for this trait at 538.6 spikes m^2, substantially better than Iba 99 (408.4) while Al-Rasheed recorded the lowest mean at 375 spikes m^{-2}. The variations in the genetic nature of the cultivars as well as the ability to produce tillers may be the cause of the discrepancies in this trait. This finding is consistent with that of (1 and 14).

Also, the table shows that amino acid concentrations significantly affected the number of spikes per square meter with the 3 ml L^{-1} level having the maximum mean value of 513.7 spikes m^2. This differed significantly from the 6 ml L^{-1} concentration 421.3 and the comparison treatment which had the lowest figure for this trait at 387.0 spikes m^2.

The higher number of spikes per unit area from amino acid spraying may be due to their active involvement in producing nutrients such as nitrogen, phosphorus, and potassium more readily as reflected in the higher number of tillers holding the spikes (21). The interaction between the Abu Ghraib-3 cultivar and 3 ml L^{-1} amino acid concentration produced the best mean for this trait at 555.3 spikes m^2.

Table 4: Influence of cultivars, amino acids, and their interactions in the number of spikes m^2.

Cultivars (V)	Concentrations of amino acid ml L^{-1} (A)			Mean
	0	3	6	
Iba 99	386.5	462.2	376.5	**408.4**
Al-Rasheed	266.5	523.5	333.0	**375.0**
Abu Ghraib-3	506.0	555.3	554.5	**538.6**
Mean	387.0	513.7	421.3	
LSD (0.05)	**V= 32.14**	**A= 73.46**	**V×A=75.82**	

Number of grains per spike: As evident from Table 5, the Abu Ghraib-3 cultivar's mean value for grain numbers was superior at 53.68 grains $spike^{-1}$ followed by Al-

Rasheed 47.39 while the Iba 99 registered the lowest mean value for this characteristic at 43.48 grains spike^{-1}. These variation in the cultivars may be due to their genetic nature. Similar results were found by (6 and 24) who mentioned the statistically significant variations in the quantity of grains in spikes among the cultivars. Table 5 also shows that the 3 ml.L^{-1} amino acid concentration produced the highest average value of 49.98 grains spike^{-1}, though not significantly different from the 49.82 grains spike^{-1} for the 6 ml L^{-1} concentration. The non-spraying treatment had the lowest average for this attribute at 44.74 grains spike^{-1}.

The benefits of amino acids in stimulating biological processes within plants may have led to this result as their participation proteins and carbohydrates are formed by generating chlorophyll and activating photosynthetic metabolites. This leads to an increase in the amount of processed food going to the developing spike which increases their fertility and reduces their abortion, thereby raising the number of grains in each spike (23). The quantity of grains per spike was significantly impacted by the interaction between cultivars and amino acid concentrations. The Abu Ghraib-3 responded best to the interaction with the 6 ml L^{-1} concentration registering the highest value for this trait at 56.10 grains spike^{-1}.

Table 5: Influence of cultivars, amino acids, and their interactions in the number of grains spike^{-1}.

Cultivars (V)	**Concentrations of amino acid ml L^{-1} (A)**			**Mean**
	0	**3**	**6**	
Iba 99	40.67	46.77	43.00	**43.48**
Al-Rasheed	42.00	49.80	50.37	**47.39**
Abu Ghraib-3	51.57	53.37	56.10	**53.68**
Mean	44.74	49.98	49.82	
LSD (0.05)	**V=2.073**	**A= 5.034**	**V×A=5.131**	

1000 grain weights (g): Table 6 shows that the cultivars have a significant impact on 1000-grain weights. The Al-Rasheed cultivar had the highest average for this characteristic at 45.00 g while the Abu Ghraib-3 had the lowest at 34.83 g. The reason for the former's superiority in 1000 grain weight may be attributed to the low mean number of grains in the spike (Table 5). This resulted in a lack of competition for foodstuffs among grains at the time of their emergence, causing them to grow in size and then weight. This was also noted by (8 and 29). Also, the 1000-grain weights increased significantly with higher amino acid concentrations, with the 6 ml L^{-1} concentration producing the highest mean weight at 42.00 g. The comparative therapy produced the lowest mean of 39.33 g. This could be due to the superior 6ml L^{-1} concentration in the flag leaf area as seen in Table 2. The photosynthesis process becomes more efficient and the results of this are transferred from the source (leaves) to the sink (grains) leading to fullness of the grain and its heavier weight (15). The photosynthesis and product transfer rates are noted to be related to grain weight. The overlap of the study factors had no significant influence on the 1000-grain weights.

Table 6: Influence of cultivars, amino acids, and their interactions in the weight of 1000 grains (gm).

Cultivars (V)	Concentrations of amino acid ml L^{-1} (A) 0	3	6	Mean
Iba 99	41.50	41.00	43.50	**42.00**
Al-Rasheed	43.00	45.50	46.50	**45.00**
Abu Ghraib-3	33.50	35.00	36.00	**34.83**
Mean	39.33	40.50	42.00	
LSD (0.05)	**V= 1.292**	**A= 2.516**	**V×A= ns**	

Grain yield (ton ha^{-1}): The cultivars and amino acid concentrations significantly affected total grain yield, whereas the interaction was non-significant for grain yield (Table 7). The highest average grain yield was achieved by the Abu Ghraib-3 cultivar (5.611 ton ha^{-1}), followed by Al-Rasheed (5.421 ton ha^{-1}) and the Iba 99 at 5.059 ton ha^{-1}. The higher number of spikes and grains per spike (Table 4 and 5) of the Abu Ghraib-3 cultivar may be the cause for its superiority in total grain yield, which is dependent on each of its components. This finding is similar to a study by (6 and 22) who indicated the existence of significant differences between wheat cultivars in this trait. Further, Table 7 shows that the 3 ml L^{-1} concentration produced the greatest mean for grain yield at 5.941 ton ha^{-1}, not much different from the 5.468 ton ha^{-1} for the 6 ml L^{-1}. The control treatment gave the lowest mean for this trait at 4.682 ton ha^{-1}. The improvement in this trait after the 3 ml L^{-1} amino acid application was due to their favorable impact on the yield's components, which included the number of spikes m2 and the quantity of grains per spike (Tables 4 and 5). It also contributed to higher grain production per unit area. There was no significant effect of cultivars and amino acid levels on overall grain yield.

Table 7: Influence of cultivars, amino acids, and their interactions in grain yield (ton ha^{-1}).

Cultivars (V)	Concentrations of amino acid ml L^{-1} (A) 0	3	6	Mean
Iba 99	4.580	5.510	5.087	**5.059**
Al-Rasheed	4.880	6.297	5.087	**5.421**
Abu Ghraib-3	4.587	6.017	6.230	**5.611**
Mean	4.682	5.941	5.468	
LSD (0.05)	**V= 0.472**	**A= 0.731**	**V×A= ns**	

Harvest index (%): The results of the harvest index are depicted in Table 8. The cultivars had a significant effect on the index with the Abu Ghraib-3 giving the highest value at 35.22% while the Iba 99 had the lowest 31.12%. The superiority of the former is due to its higher grain yield in the unit area (Table 7). This finding is similar to (4 and 10) who noted that wheat cultivars had different harvest index values due to their different efficiency in converting dry matter into grain. Also, amino acid concentrations significantly affected the harvest index with the 3 ml L^{-1} concentration having the highest value for this trait at 33.43% though not significantly different for the 6 ml L^{-1} concentration at 32.19% but highly so for the control treatment's 31.24%. This could be due to the 3 ml L^{-1} concentration's superiority for the yield components comprising number of spikes per square meter and grain number per spike (Tables 4 and 5). The harvest index was significantly impacted by the interplay of cultivars and amino acid levels. The overlap of the Abu Ghraib-3 cultivar at the 3 ml L^{-1} amino acid level produced the highest index value at 35.60% whereas the Iba 99's comparison treatment had the lowest at 29.70%.

Table 8: Influence of cultivars, amino acids, and their interactions in the harvest index (%).

Cultivars (V)	Concentrations of amino acid ml L^{-1} (A)			Mean
	0	3	6	
Iba 99	29.70	32.41	31.10	**31.12**
Al-Rasheed	33.66	32.29	32.30	**32.70**
Abu Ghraib-3	30.37	35.60	32.96	**35.22**
Mean	31.24	33.43	32.19	
LSD (0.05)	**V= 1.309**	**A= 1.884**	**V×A= 2.325**	

Conclusions

All the wheat cultivars used in this study responded to spraying with amino acid. The Abu Ghraib-3 and amino acid concentration of 3 ml L^{-1} produced the best yield for grains while the 6-ml L^{-1} application enhanced the vegetative growth trait due to the abundance of nitrogen in the amino acid and its role in improving plant growth.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

I. A. Sarhan: methodology, writing of original draft, and statistical analyses of data; S. I. Neamah review and editing. Both authors have read and agreed to the published version of the manuscript.

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