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Impact of Genotypic Variation and Arginine Spraying on Sorghum Growth and Productivity

Sinan. A. Abas[1], Zeyad A. Abdulhamed[2], Baraa H. Saleh[3], and Nihad M. Abood[4*]

[1, 2] ***Department of Field Crop – College of Agriculture- University Of Anbar, Iraq***
[3] ***Coolege of Education for pure science, University Of Anbar, Iraq***
[4] ***Center of Desert studies, University Of Anbar, Iraq***
[*] *Corresponding author: E-mail*: Ag.nihad.mohammed@uoanbar.edu.iq

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ABSTRACT

A field experiment was conducted at the Agricultural Research Station of Anbar University, College of Agriculture during the spring and autumn seasons of 2021. The aim of the experiment was to investigate the effect of four concentrations of arginine on the growth and yield of three sorghum cultivars: Inqath, Babel, and Giza 113. A split-plot design was used with three replicates, where the main plots were assigned to four arginine concentrations (0, 100, 200, and 300 mg L^{-1}), and the subplots were assigned to three sorghum cultivars. The cultivar Inqath excelled significantly in leaf area, number of grains, and grain yield, with the highest average grain yield of 4.03 and 4.52 tons ha^{-1} for the spring and autumn seasons, respectively. On the other hand, the cultivar Giza 113 recorded the lowest average 3.31 and 3.94 tons ha^{-1}. Regarding ariginine concentrations, the 300 mg L^{-1} treatment excelled in the studied traits, recording the highest average yield of 4.51 and 4.98 tons ha^{-1}. Additionally, the interaction between the two factors of the study was significant for most of the studied traits.

تأثير الصنف والتغذية الورقية بألارجنين في صفات النمو والحاصل للذرة البيضاء

سنان عبدالله عباس[1] زياد عبد الجبار عبد الحميد[2] براء حميد صالح[3] نهاد محمد عبود[4]
[1، 2، 3] قسم المحاصيل الحقلية ، كلية الزراعة ، جامعة الانبار
[4] مركز دراسات الصحراء ، جامعة الانبار

الخلاصة

نفذت تجربة حقلية في محطة ابحاث كلية الزراعة جامعة الانبار، للعروتين الربيعية والخريفية لعام 2021. بهدف دراسة تأثير اربعة تراكيز من الارجنين في نمو وحاصل ثلاثة اصناف من الذرة البيضاء هي انقاذ وبابل وجيزة 113. استعمل ترتيب الالواح المنشقة split plot بتصميم R.C.B.D وبثلاثة مكررات، اذ تضمنت الالواح الرئيسة main plot تراكيز الارجنين (0 و 100 و 200 و 300) ملغم لتر$^{-1}$. فيما سجلت الاصناف في الالواح الثانوية. تفوق الصنف انقاذ معنيا في صفات المساحة الورقية وعدد الحبوب وحاصل الحبوب وسجل أعلى متوسط لصفة حاصل الحبوب بلغ 4.03 و 4.52 طن ه-1 للعروتين الربيعية والخريفية بالتتابع, فيما سجل الصنف جيزة 113 اقل متوسط بلغ 3.31 و 3.94 طن ه-1 و. اما تراكيز الارجنين فقد تفوق التركيز 300 ملغم لتر-1 في الصفات المدروسة وسجل أعلى متوسط لحاصل الحبوب بلغ 4.51 و 4.98 طن ه-1 . كذلك كان التداخل بين عاملي الدراسة معنويا في اغلب الصفات المدروسة.

الكلمات المفتاحية: الارجنين ، اصناف الذرة البيضاء : حاصل الحبوب ، المساحة الورقية

INTRODUCTION

The risks of climate change and its impact on food security are evident to everyone. The effects of these changes have been clear in the agricultural sector; both plant and animal, through the reduction in arable land, land degradation leading to desertification, as well as reduced rainfall and increased temperatures. All these factors, in addition to other factors (wars, declining oil prices, and soil salinization), have left clear impacts on the deterioration of the agricultural sector. The importance of the sorghum crop “Sorghum bicolor (L.) Moench” lies in its ability to cope with climate changes due to its special features for adaptation to the harsh climatic conditions mentioned, as well as its various uses, making it one of the world's important food crops. It is often referred to as the "camel crop". Sorghum is capable of growing in various environments due to its physiological and morphological characteristics (Abd *et al*., 2021 and Abdulhamed *et al*., 2021). The primary use of sorghum in most producing countries is for human consumption in various forms. However, in developed countries, the use of sorghum grains as animal feed exceeds its use as human food. Its importance as feed lies in the direct use of its grains in animal nutrition, adding it to concentrates, or incorporating it into silage production and as green fodder. The crop also holds a prominent position in many countries worldwide as an alternative for biofuel production (Almodares *et al*., 2016).

The globally cultivated area for 2019/2020 was approximately 40.12 million hectares, with a production of 59.81 million tons, yielding 1.49 tons per hectare (USDA, 2020). In Iraq, the area cultivated for green fodder purposes was approximately 3,724 hectares, while for grain purposes; the cultivated area was 1,906 hectares, with an average production of 1200 kg per hectares (Agricultural Statistics Directorate, 2019). Despite the important features of the crop, its production in Iraq remains limited due to various challenges. These include farmers' reluctance to cultivate it, preferring to grow other crops such as maize and soybeans, and their lack of awareness about the importance of this crop and the good cultivars introduced to the country. Additionally, farmers rely on locally grown cultivars with low productivity. The cultivars of sorghum are quite limited in Iraq, and their seed production is low per unit area due to the predominant use of most cultivars as green fodder, leading to the extinction of their seeds. The scientific basis for any study or research involves examining the genetic composition and its suitability to environmental conditions and available nutrients, as well as addressing the issues facing the genetic composition to improve growth traits and their impact on yield, whether for fodder or grain, with maintaining high quality.

Using growth regulators at specific concentrations might improve or modifying growth traits and regulating its physiological activities, thereby increasing assimilates and their transfer to the sink (head) to enhance yield traits and its components, instead of increasing vegetative growth by increasing the period from emergence to flowering. This is due to the role of these regulators in organizing the plant's physiological processes and adjusting the balance between respiration and carbon assimilation, reflecting on the plant's traits (Al-Janabi *et al*., 2021 and Abdulhamed *et al*., 2023).

MATERIAL AND METHODS

A field experiment was conducted at the Research Station of the College of Agriculture, University of Anbar, for the spring and autumn seasons of 2021. The aim was to study the effect of four concentrations of arginine on the growth and yield of three sorghum cultivars: Inqath, Babel, and Giza 113. A split-plot arrangement in a randomized complete block design (RCBD) with three replicates was used. The main plots included arginine concentrations (0, 100, 200, and 300 mg L^{-1}) with foliar spraying carried out in two stages, four and six weeks after emergence. The subplots included the three cultivars under study.

The experimental field was prepared by plowing, smoothing, and leveling, and then it was divided into experimental units, each with an area of 9 m^2 (3 × 3 m). Each experimental unit contained four rows, with a distance of 75 cm between rows and 20 cm between plants. The field was fertilized with diammonium phosphate (DAP) fertilizer (46% P_2O_5 and 18% N) before planting at a rate of 100 kg P per hectare, mixed with the soil within each plot (Abood *et al*., 2017). Planting was conducted on 1/4/2021 for the spring season and 15/7/2021 for the autumn season, placing two to three seeds per hill. The field was irrigated immediately after planting, ensuring gentle watering to prevent seed displacement from the planting rows. Subsequent irrigations and weeding were performed as needed. The plants were thinned to one plant per hill two weeks after emergence.

Arginine spraying was conducted at sunset to avoid high temperatures and evaporation of the solution. The plants were thoroughly wetted, and a wetting agent (3 cm^3 per 20 liters of solution) was used to increase the efficiency of the plants in absorbing the solution, according to the aforementioned concentrations. When the plants reached the 100% flowering stage, nets were installed, and the entire field was covered to prevent bird attacks. Harvesting was done when each cultivar reached full maturity. Data were statistically analyzed using the GENSTAT program through analysis of variance (ANOVA) for all studied traits according to the randomized complete block design with split plot arrangement. The Least Significant Difference (LSD) test was used to compare the means statistically at a 5% probability level (Al-Rawi and Khalaf Allah, 1980).

RESULTS AND DISCUSSION

The results indicate that there were significant differences between cultivars in the number of days from planting to physiological maturity for both seasons (Table 1). The cultivar Inqath reached physiological maturity earlier, requiring fewer days to reach this stage, with 113.25 and 116 days for spring and autumn seasons, respectively, compared to the cultivars Babel and Giza 113. The latter (Giza 113) recorded the longest duration to reach this stage, with 117.95 and 119.44 days for both seasons, respectively. The variation among sorghum cultivars in reaching this stage may be attributed to differences in their genetic composition and their response to environmental conditions. This result is consistent with other research findings that indicate significant differences among sorghum cultivars in the duration needed from planting to physiological maturity (Abood and Mirare, 2024).

The application of arginine at different concentrations had a significant effect on this trait. The 300 mg L^{-1} concentration recorded the shortest time to maturity, with 114.62 and 115.73 days for spring and autumn seasons, respectively. In contrast, the control treatment (distilled water) recorded the longest duration to reach this stage, with 118.25 and 119.77 days for both seasons, respectively. This result is consistent with other findings.

The interaction between the two study factors affected only the second season. The plants of the Inqath cultivar sprayed with the 300 mg L^{-1} concentration had the shortest average duration for this trait, at 114 days.

Table 1. Effect of Cultivar and Arginine Foliar Treatment on Number of Days from Planting to Physiological Maturity (days) of Sorghum in Spring and Autumn Seasons of 2023.

	Arginine conc. mg L^{-1}	**Cultivars**			**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Spring season	**Distilled water**	115.4	119.67	119.67	118.25
	100	113.9	117.83	118.33	116.69
	200	112.4	116.30	117.00	115.23
	300	111.3	115.73	116.83	114.62
	Cultivars mean	113.25	117.38	116.95	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		1.76	NS		1.66
		Cultivars			**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Autumn season	**Distilled water**	122.67	117.65	119.01	119.77
	100	119.00	117.33	117.76	118.03
	200	118.33	116.67	117.12	117.37
	300	114.00	116.22	115.89	115.37
	Cultivars mean	116	116.96	119.44	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		1.84	3.21		1.99

The results in Table 2 show that the Giza 113 cultivar significantly outperformed the others with the highest average plant height of 230.4 and 252.97 cm for spring and autumn seasons, respectively, compared to the Babel and Inqath cultivars, which exhibited the lowest average plant heights of 182.62 cm and 189.8 cm in the first and second seasons, respectively. The difference in plant height among the cultivars could be due to their genetic nature and their varying responses to environmental conditions, which is reflected in the differences in vegetative growth traits, including plant height. These findings are consistent with those of previous studies that have indicated significant differences in plant height among sorghum cultivars (Abood *et al*., 2017).

The increase in the concentrations of applying the amino acid arginine to the plants led to a significant increase in plant height, with the highest average plant heights of 214.43 and 229.17 cm in the first and second seasons, respectively, which was not significantly different from the result obtained at 200 mg L^{-1} in the first season. The reason for the increase in plant height with higher levels of amino acids may be attributed to their positive role in activating the division of meristematic tissues and increasing the production of the growth hormone gibberellin, which is important for cell division and elongation. Additionally, they play a role in the biosynthesis of enzymes that contribute to cell division, expansion, and plant development, which is reflected in the increased plant height (Mostafa *et al*., 2010).

The interaction between the two study factors had a significant effect on this parameter for both seasons. The plants of the Giza 113 cultivar sprayed with a concentration of 300 mg L^{-1} recorded the highest average for this trait, reaching 242.2 and 270.0 cm.

Table 2. Effect of Cultivar and Arginine Foliar Treatment on Sorghum Plant Height (cm) in Spring and Autumn Seasons of 2023.

	Arginine conc. mg L^{-1}	**Cultivars**			**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Spring season	**Distilled water**	167.2	176.7	211.7	185.2
	100	176.7	188.3	231.7	198.9
	200	193.3	194.0	236.0	207.8
	300	193.3	207.8	242.2	214.43
	Cultivars mean	182.62	191.7	230.4	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		4.67	9.45		7.5
		Cultivars			**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Autumn season	**Distilled water**	183.3	178.9	226.0	196.07
	100	186.7	186.1	248.3	207.03
	200	190.0	196.7	267.6	218.1
	300	199.2	218.3	270.0	229.17
	Cultivars mean	189.8	195.0	252.97	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		7.14	10.42		6.65

Table 3 results clarify that the Inqath cultivar achieved the highest average leaf area (5163.5 and 5592.5 cm^2), significantly outperforming the other two cultivars. The Giza 113 cultivar recorded the lowest average of 4829.3 and 4911 cm² for the two seasons, respectively. The difference in leaf area among the cultivars could be attributed to their genetic composition, which affects the duration of leaf growth and expansion. This result is consistent with the findings of Abdulhamed *et al*. (2021).

The results also show that plants sprayed with arginine at a concentration of 300 mg L^{-1} significantly outperformed with the highest average leaf area of 5282.3 and 5522 cm², compared to plants sprayed with concentrations of 200 and 100 mg L^{-1} and those sprayed with distilled water only, which gave the lowest average of 4381.3 and 4821 cm² for both seasons, respectively. The superiority of the amino acid spray treatments in leaf area can be attributed to the positive role of amino acids in many physiological and biological processes, such as increasing cell division and expansion, differentiation and growth, and the efficiency of photosynthesis, which then leads to increased nutrient absorption and consequently an increase in this trait (Mohamed *et al.*, 2015). Amino acids are also a source of nitrogen, which is the most important nutrient, needed by the plant at all growth stages, including leaf growth.

The interaction between the two study factors had a significant effect on this trait for the first season only. The plants of the Inqath cultivar sprayed with a concentration of 300 mg L^{-1} recorded the highest average leaf area of 5624 cm² for the first season only, while the plants of the Babel cultivar sprayed with distilled water recorded the lowest average of 4190 cm².

Table 3. Effect of Cultivar and Arginine Foliar Treatment on Sorghum Leaf Area (cm²) in Spring and Autumn Seasons of 2023.

	Arginine conc. mg L^{-1}	**Cultivars**			**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Spring season	**Distilled water**	4388	4190	4566	4381.3
	100	5157	4541	4786	4828
	200	5485	4970	4976	5143
	300	5624	5234	4989	5282.3
	Cultivars mean	5163.5	4733.8	4829.3	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		234.6	412.5		276.8
		Cultivars			**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Autumn season	**Distilled water**	4636	5253	4576	4821
	100	4958	5312	4789	5019.6
	200	5024	5776	5066	5288.7
	300	5324	6029	5213	5522
	Cultivars mean	4985	5592	4911	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		212.4	NS		275.4

The data in table 4 show that the Inqath cultivar significantly outperformed with the highest average grains number (2309.3 and 2364.3 grains $plant^{-1}$) for the two seasons, respectively, compared to the Babel and Giza 113 cultivars, which gave the lowest average for this trait, with 1800.5 and 1662.8 grains $plant^{-1}$ for the two seasons, respectively. The reason for the superiority of the Inqath cultivar in this trait is attributed to its superiority in leaf area (Table 3), which provides a greater amount of manufactured food to go to the emerging flowers, thus reducing their abortion. This result is consistent with the findings of Abood *et al*. (2023) and Abood and Salih (2018).

The results in table 4 also show that the 300 mg L^{-1} concentration achieved the highest average grains number (2207 and 2202.3 grains $plant^{-1}$), significantly outperforming the other concentrations. The 0 mg L^{-1} concentration recorded the lowest average, with 1759.7 and 1642.3 grains $plant^{-1}$ for both seasons, respectively. The positive effect of increasing the concentrations of amino acids in increasing plant height and leaf area (Tables 2 and 3) provided a greater amount of manufactured food to go to the developing grains, increasing their setting and reducing their abortion, thus increasing their number in the head. In this context, Issa (1990) indicated that the plants can only set and mature seeds that it can supply with the products of photosynthesis. This result is consistent with Al-Janabi *et al*. (2021).

The results indicate a significant interaction between the two study factors in the spring season only. The plants of the Inqath cultivar sprayed with a concentration of 300 mg L^{-1} recorded the highest average for this trait, reaching 2678 grains $head^{-1}$.

Table 4. Effect of Cultivar and Arginine Foliar Treatment on Grains number (grains $plant^{-1}$) of Sorghum in Spring and Autumn Seasons of 2023.

	Arginine conc. mg L^{-1}	**Cultivars**			**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Spring season	**Distilled water**	1948	1690	1641	1759.7
	100	2165	1776	1719	1886.7
	200	2446	1927	1878	2083.7
	300	2678	1979	1964	2207.0
	Cultivars mean	2309.3	1843	1800.5	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		60.5	138.1		113.1
			Cultivars		**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Autumn season	**Distilled water**	1925	1513	1489	1642.3
	100	2346	1664	1579	1863.0
	200	2456	1704	1695	1951.7
	300	2730	1989	1888	2202.3
	Cultivars mean	2364.3	1717.5	1662.8	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		174.0	NS		217.5

The results in table 5 indicate that the Giza 113 cultivar significantly outperformed with the highest average weight of 1000 grains for both seasons at 26.27 and 31.76 g, respectively, compared to the other cultivars. The Inqath cultivar gave the lowest average weight of 1000 grains in both seasons, with 23.75 and 25.88 g, respectively. The longer grain filling period in the Giza 113 cultivar (Table 1) contributed to providing a greater amount of manufactured food for each grain, which was reflected in the increased weight. In this context, Issa (1990) noted that seed weight is a function of the rate of photosynthesis and the translocation of its products. This result is consistent with many researchers who found significant differences between sorghum cultivars (Abdulhamed *et al*., 2017; Abood *et al*., 2021 and Ibrahim *et al*., 2024).

The results revealed a significant increase in the weight of 1000 grains with increasing concentrations of the amino acid (arginine). The 300 mg L^{-1} concentration gave the highest average weight of 1000 grains for both seasons, reaching 28.46 and 31.34 g, respectively, without a significant difference from the 200 mg L^{-1} concentration, but significantly different from the 100 mg L^{-1} concentration and the control treatment sprayed with distilled water, which gave the lowest average weight of 21.00 and 27.85 g, respectively, for both seasons. The increase in amino acid concentrations may have improved vegetative growth traits such as plant height and leaf area (Tables 2 and 3), leading to an increase in the products of photosynthesis due to increased light interception, which ultimately resulted in an increased weight of 1000 grains. The weight of 1000 grains is considered a sink where the products of photosynthesis are concentrated. This result aligns with the findings of Al-Janabi *et al*. (2021), who observed a significant increase in the weight of 1000 grains.

The interaction between cultivars and arginine concentrations had a significant effect on this trait in the second season only. The Giza 113 cultivar sprayed with a concentration of 300 mg L^{-1} recorded the highest average weight of 32.88 g, significantly different from the other treatments. In contrast, the combination of the Inqath cultivar and the 300 mg L^{-1} concentration recorded the lowest average weight of 23.56 g.

Table 5. Effect of Cultivar and Arginine Foliar Treatment on Weight of 1000 Grains (g) of Sorghum in Spring and Autumn Seasons of 2023.

	Arginine conc. mg L^{-1}	**Cultivars**			**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Spring season	**Distilled water**	20.13	21.33	21.53	21.00
	100	23.46	24.67	25.66	24.60
	200	25.77	26.23	27.82	26.61
	300	25.67	29.60	30.10	28.46
	Cultivars mean	23.75	25.45	26.27	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		2.16	NS		1.87
			Cultivars		**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Autumn season	**Distilled water**	23.56	30.12	29.85	27.85
	100	25.60	31.95	31.55	29.7
	200	26.21	32.14	32.76	30.03
	300	28.18	32.96	32.88	31.34
	Cultivars mean	25.88	31.79	31.76	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		174.0	NS		217.5

The results indicate that the Inqath cultivar recorded the highest grain yield of 4.03 and 4.52 tons ha^{-1} for spring and autumn seasons, respectively, significantly outperforming the Babel and Giza 113 cultivars in both seasons (Table 6). The Giza 113 cultivar recorded the lowest average yield of 3.31 and 3.94 tons ha^{-1} for spring and autumn seasons, respectively. The superiority of the Inqath cultivar in grain yield was attributed to its higher number of grains per head (Table 4). In this context, many researchers have found significant differences in grain yield among sorghum cultivars (Abood *et al*., 2023; and Abood and Salih, 2018).

Regarding the effect of amino acid concentrations, Table 6 shows a significant increase in grain yield with increasing concentrations of the amino acid in both seasons. The 300 mg L^{-1} concentration achieved the highest average yield for both seasons, reaching 4.51 and 4.98 tons ha^{-1}, respectively, while the control treatment recorded the lowest average grain yield of 2.67 and 3.33 tons per hectare for both seasons, respectively. The increase in the number of grains per head and the weight of 1000 grains at the 300 mg L^{-1} concentration (Tables 4 and 5) led to an increase in grain yield per unit area. This result supports the findings of Abdulhamed *et al*. (2024) who found that increasing amino acid concentrations led to an increase in yield components and consequently grain yield.

The interaction between arginine concentrations and cultivars also had a significant effect on this trait for both seasons, as shown in Table 6. The Inqath cultivar sprayed with a concentration of 300 mg L^{-1} recorded the highest average yield of 4.94 and 5.36 tons ha^{-1} for spring and autumn seasons, respectively. In contrast, the Giza 113 cultivar sprayed with distilled water recorded the lowest average yield of 2.38 and 3.17 tons ha^{-1} for spring and autumn seasons, respectively.

Table 6. Effect of Cultivar and Arginine Foliar Treatment on Weight of 1000 Grains (g) of Sorghum in Spring and Autumn Seasons of 2023.

	Arginine conc. mg L^{-1}	Cultivars			Arginine mean
		Inqath	**Babel**	**Giza 113**	
Spring season	**Distilled water**	2.78	2.84	2.38	2.67
	100	3.74	3.37	3.01	3.37
	200	4.65	4.04	4. 77	4.15
	300	4.94	4.56	4.03	4.51
	Cultivars mean	4.03	3.70	3.31	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		0.36	0.88		0.43
			Cultivars		**Arginine mean**
		Inqath	**Babel**	**Giza 113**	
Autumn season	**Distilled water**	3.53	3.31	3.17	3.33
	100	4.34	3.94	3.73	4.00
	200	4.87	4.27	4.09	4.41
	300	5.36	4.83	4.77	4.98
	Cultivars mean	4.52	4.08	3.94	
	LSD 0.05	**Cultivars**	**Interaction**		**Arginine**
		0.45	1.04		0.66

CONCLUSION

We conclude that the sorghum cultivars were significantly variation in all studied parameters. However, Inqath sorghum cultivar significantly excelled in the leaf area and number of grains, which was positively reflected in grain yield for spring and autumn seasons. Regarding ariginine concentrations, the 300 mg L^{-1} treatment improved the vegetative parameters and produced the highest yield of sorghum in seasons.

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