

Effect of Spraying Organic Acids and Sugar Alcohols (Sorbitol) on the Growth and Flowering of Zinnia plant *Zinnia elegans* L.

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Abstract

The experiment was conducted in the field belonging to the Horticultural Structures Unit of the Department of Horticulture and Landscape Engineering / College of Agriculture / Tikrit University during the 2025 growing season to investigate the effect of spraying amino acids and sugar alcohol (sorbitol) on the growth and flowering of zinnia plants. The study included two factors: the first was spraying amino acids at four concentrations (0, 2, 4, 6 ml L⁻¹), and the second was spraying sugar alcohol at three levels (0, 3, 6 ml L⁻¹). The experiment was carried out using a Randomized Complete Block Design (RCBD) with three replications, with 4 pots per experimental unit. The main results can be summarized as follows: The amino acid spray treatment at a concentration of 6 ml L⁻¹ achieved a significant superiority in the traits of plant height (38.27 cm), number of branches (17.44 branches plant⁻¹), number of leaves (340.11 leaves plant⁻¹), and dry weight of the vegetative shoot (10.93 g). Spraying with sugar alcohol (sorbitol) at a concentration of 6 ml L⁻¹ led to a significant increase in plant height (32.39 cm), individual leaf area (15.99 cm²), and total chlorophyll content (33.53 SPAD). The 6 ml L⁻¹ concentration also achieved a significant increase in plant spread (31.33 cm). The binary interaction between amino acids and sorbitol at concentrations of 6 and 6 ml L⁻¹ recorded the highest values for increasing floral production (19.00 inflorescences plant⁻¹). The vase life of the inflorescences improved markedly, reaching a significant value of 13.818 days with the 6 ml L⁻¹ amino acid treatment, and reaching 14.33 days when interacting with sorbitol at a concentration of 3 ml L⁻¹. Most vegetative traits, including plant height (43.08 cm), plant spread (34.66 cm), and individual leaf area (18.25 cm²), showed significant superiority when sprayed with amino acids and sorbitol at concentrations of 6 and 6 ml L⁻¹.

Keywords: Zinnia plant, Amino acids, Sugar alcohols, Sorbitol

Introduction

landscaping and cut flower production due to its diverse colors and floral shapes, ease of cultivation, and tolerance to various environmental conditions (1). Zinnia plants are characterized by diverse phenotypic traits, with heights ranging from dwarf varieties to tall varieties that may exceed 100 cm. They also possess single or double, multi-layered inflorescences in various colors including white, yellow, orange, red, and purple. They are warm-climate plants that prefer high light intensity, growing optimally at moderate to high

Zinnia elegans is a summer annual ornamental plant belonging to the Asteraceae family. It is believed to be native to regions stretching from Mexico and Central America to the southern United States, where it grows wild in warm and semi-arid environments. The genus name Zinnia honors the German botanist Johann Gottfried Zinn in recognition of his scientific contributions to botany. This genus includes approximately 20 species of annual and perennial plants. Zinnia elegans is the most widespread and commonly used species in

shown that certain amino acids, such as glutamic acid and arginine, play an important role in regulating physiological processes. Glutamic acid contributes to regulating stomatal opening and closing and improving photosynthetic efficiency, while arginine is involved in the synthesis of polyamines and plant hormones related to growth, flowering, and stress tolerance. Additionally, amino acids serve as a ready source of reduced nitrogen, which reduces the energy consumed by the plant in biological reduction processes and increases the efficiency of building proteins and important metabolites (6; 22). Sugar alcohols, or Polyols, are carbohydrate compounds resulting from the reduction of monosaccharides. They occur naturally in many plants and play an important role in regulating osmotic pressure and protecting plant cells from various stress conditions such as drought, salinity, and high temperatures. These compounds are characterized by rapid absorption and transport within the plant via the phloem, as well as high solubility and ease of penetration through the cuticle layer and stomata, which has made them modern foliar nutrients used to improve the efficiency of nutrient uptake and increase the effectiveness of foliar spraying (7; 8). Given the importance of this plant as an annual species used as a flowering pot plant under the climatic conditions of Salah al-Din Governorate, this study aimed to:

1. Find stimulating alternatives for the development of ornamental plants by treating them with amino acids and sugar alcohols to improve growth and flower quality.
2. Determine the effect of these factors and their interaction on increasing the growth and floral density of ornamental plants.

temperatures, and are relatively tolerant to drought and high temperatures provided regular irrigation is available. Zinnias are widely used in landscaping, flower beds, and as cut flowers. Furthermore, dwarf varieties can be grown in pots and on balconies, which has given them significant economic and landscaping importance in the ornamental plant industry (20; 2). The cut flower sector has witnessed significant development in recent decades due to the increasing global demand for ornamental plants, as flowers have become an important part of international agricultural trade. Western European countries and the United States are among the largest consumer markets for cut flowers, while the Netherlands leads the world in production and export due to advanced production and agricultural marketing techniques. Zinnia holds particular importance among summer ornamental plants due to its aesthetic and productive qualities, making it a preferred plant for both flower producers and hobbyists alike (3; 4). Recent studies indicate that the use of biostimulants, including amino acids and sugar alcohols, has become an important trend in improving the growth of flowering plants, enhancing their productivity, and mitigating the effects of environmental stresses, due to their role in promoting physiological and vital processes within the plant in a safe and environmentally friendly manner. Amino acids are essential organic compounds in the building of proteins, nucleic acids, enzymes, and plant hormones. They also play a role in improving nutrient uptake, increasing chlorophyll content, and stimulating cell division and elongation, which positively reflects on the vegetative and floral growth of plants (5; 21). Recent research has also

Materials and Methods

Experiment Location

seedlings were transplanted on 12/4/2025 into plastic pots with a height of 25 cm and a diameter of 25 cm. One seedling was planted per pot, with the seedling at a height of (8 cm) having four true leaves. The growing medium used consisted of peat moss and mixed soil in a 2:1 volume ratio. The seedlings were then distributed among the experimental units in the field. Physical and chemical analyses of the growing medium used were conducted* [Table (1)].

The experiment was conducted in the wooden shade house belonging to the Horticultural Structures Unit of the Department of Horticulture and Landscape Engineering / College of Agriculture / Tikrit University, during the 2025 growing season, from 20/2/2025 to 29/8/2025, on *Zinnia elegans* plants.

Cultivation and Maintenance Operations: Seeds of the hybrid zinnia plant were obtained from the Syngenta company and sown in plastic trays on 4/3/2025 inside the greenhouse. The

Table (1): Physical and chemical properties of the growing medium used in the experiment.

Unit	Value	Property
		Physical Properties
%	[Value]	Sand
%	[Value]	Silt
%	[Value]	Clay
-	[e.g., Sandy Loam]	Texture Class
		Chemical Properties
-	[Value]	pH
dS m ⁻¹	[Value]	EC
%	[Value]	Organic Matter
%	[Value]	Total Nitrogen

needed, and fertilizing the plants by adding a balanced NPK fertilizer 20-20-20 at a rate of 1 g L⁻¹, with a single addition during the season. The fungicide Topsin was used at 2 g L⁻¹ added with irrigation water as a preventive measure on a monthly basis.

The analyses were conducted in the laboratory of the Department of Soil and Water Resources / College of Agriculture / Tikrit University.

Service operations for the experiment site and all plants were carried out uniformly, which included weed removal and uprooting whenever

3.3. Study Factors and Experimental Design:

3. Spraying at a concentration of 4 ml L⁻¹. IS4

4. Spraying at a concentration of 6 ml L⁻¹. IS6

The nutrient solution used is a mixture of amino acids composed of 17 amino acids [Table (2)]. It is a brown-colored liquid. Spraying was carried out three times; the

The study included two factors:

First Factor: Spraying with the nutrient solution Isabion, denoted as IS, at four concentrations:

1. Spraying with distilled water (control). IS0

2. Spraying at a concentration of 2 ml L⁻¹. IS2

similarly for the third spray. The mixture was diluted using distilled water.

first spray was on (20/4/2025), with subsequent sprays two weeks apart for the second spray, and

Table (2): Components of the Isabion nutrient solution.

الأحماض الأمينية	
Glycine	Alanine
Proline	Glutamic acid
Hydroxy-proline	Tyrosine
Aspartic acid	Phenyl-alanine
Leucine	Iso-leucine
Methionine	Arginine
Histidine	Threonine
Serine	Lysine
Valine	

average per plant was calculated based on (24).

Individual leaf area (cm²): The area of 4 leaves from the top of fully expanded branches in different directions was measured. The sum of their areas was divided by 4 to obtain the average individual leaf area. The Digimizer program was used to measure leaf area (9) [Appendix].

Total chlorophyll in leaves (SPAD): Chlorophyll was measured in the leaves on 12/6/2021 using a SPAD-type Chlorophyllmeter directly in the field. Several readings were taken, and then the average was calculated (Xiong et al., 2015).

Fresh weight of the vegetative shoot (g): The fresh weight of the vegetative shoot of the plant was recorded using a sensitive balance.

Dry weight of the vegetative shoot (g): The vegetative shoot was taken and dried in an electric oven for 72 hours at a temperature of 65-70 °C until a constant weight was achieved. The dry weight of the sample was then taken using a sensitive balance.

Plant spread (cm): The spread was measured between the two farthest points on opposite sides of the plant in two perpendicular directions using a tape measure after the full opening of the floral inflorescences in more than

Second Factor: Spraying with the sugar alcohol sorbitol, denoted as B, at three concentrations:

1. Spraying with distilled water (control). B0
2. Spraying at a concentration of 3 ml L⁻¹. B3
3. Spraying at a concentration of 6 ml L⁻¹. B6

The sugar alcohol sorbitol 70% was used in the experiment; it is a colorless liquid. Spraying was carried out at the same times as the amino acid mixture spraying, with three sprays and 14 days between each spray. The solution was diluted using distilled water.

The experiment was conducted using a Randomized Complete Block Design (RCBD) with three replications. The number of treatments was 12, thus the number of experimental units became 36 units, with 4 seedlings per unit, bringing the total number of seedlings to 144 seedlings [Appendix (3)].

Studied Traits:

Vegetative Growth Traits:

Plant height (cm): Plant height was measured using a tape measure from the soil surface to the tip of the longest branch in the pot [Appendix (23)].

Number of leaves (leaf plant⁻¹): The total number of leaves for all plants was counted manually and periodically at the full flowering stage, and the

reading was taken (25).

5.3. Statistical Analysis:

Significant Difference (L.S.D) test at a 5% probability level for comparing treatment means (26).

Results and Discussion

Effect of Amino Acids, Sugar Alcohol, and their Interaction on Vegetative Growth Traits:

1. Plant height (cm):

second concentration (6 ml L^{-1}), reaching 32.39 cm, compared to the control treatment which reached 29.36 cm. The interaction had a highly significant effect, as the treatment IS6 B6 at concentrations of 6 and 6 ml L^{-1} was superior, reaching 43.08 cm compared to all other treatments.

one direction, and then the average

The results were statistically analyzed using the SAS program, and means were compared using the Least

Table (1) shows that the effect of spraying amino acids on plant height was significantly superior at the third concentration (6 ml L^{-1}), reaching 38.27 cm, compared to the other concentrations. Spraying with sugar alcohol also showed significant superiority in the above trait at the

Table (1): Effect of amino acids and sugar alcohol sorbitol on the trait of plant height (cm) of Zinnia plant.

Amino Acid Mean	Sugar Alcohol Sorbitol (ml L^{-1})			Amino Acids (ml L^{-1})
	$_6B$	$_3B$	B_0	
25.92	25.75	26.33	25.69	$_0IS$
27.94	28.00	28.91	26.91	$_2IS$
32.00	32.75	32.91	30.33	$_4IS$
38.27	43.08	37.25	34.50	$_6IS$
	32.39	31.35	29.36	Sorbitol Mean (B)

Amino Acids	Sugar Alcohol	Interaction	LSD 5%
1.45	1.25	2.51	

2. Number of branches (branch plant^{-1}):

branches trait, reaching 14.25 branches plant^{-1} , compared to the control treatment which reached 13.41 branches plant^{-1} . The binary interaction between the two factors, amino acids and sugar alcohol, had a highly significant effect, as the treatment IS6 B6 at concentrations of 6 and 6 ml L^{-1} was superior, reaching 18.00 branches plant^{-1} , compared to the control treatment and most other treatments.

It is evident from the results obtained in Table (2) that the effect of spraying amino acids on the trait of number of branches achieved significant superiority with the third concentration (6 ml L^{-1}), reaching 17.44 branches plant^{-1} , compared to the other concentrations. From the same table, we find that the sugar alcohol treatment at a concentration of 6 ml L^{-1} was significantly superior, giving the highest value for the number of

Table (2): Effect of amino acids and sugar alcohol sorbitol on the trait of number of branches (branch plant⁻¹) of Zinnia plant.

Amino Acid Mean	Sugar Alcohol Sorbitol (ml L ⁻¹)			Amino Acids (ml L ⁻¹)
	B ₆	B ₃	B ₀	
11.44	11.33	11.66	11.33	IS ₀
12.44	12.66	12.66	12.00	IS ₂
15.00	15.00	13.33	13.66	IS ₄
17.44	18.0	17.66	16.66	IS ₆
	14.25	13.83	13.41	Sorbitol Mean (B)

Amino Acids	Sugar Alcohol	Interaction	LSD 5%
0.82	0.71	1.43	

3. Number of leaves per plant (leaf plant⁻¹):

concentration (6 ml L⁻¹), reaching 284.91 leaves plant⁻¹, compared to the other concentrations. The binary interaction had a highly significant effect, as the treatment IS₆ B₆ at concentrations of 6 and 6 ml L⁻¹ was superior, reaching 348.33 leaves plant⁻¹, compared to the control treatment and most other treatments.

The data in Table (3) indicate that spraying with amino acids for the trait of number of leaves showed a significant difference at the third concentration (6 ml L⁻¹), reaching 340.11 leaves plant⁻¹, compared to the other concentrations. As for spraying with sugar alcohol, it was significantly superior in the above trait at the second

Table (3): Effect of amino acids and sugar alcohol sorbitol on the trait of number of leaves (leaf plant⁻¹) of Zinnia plant.

Amino Acid Mean	Sugar Alcohol Sorbitol (ml L ⁻¹)			Amino Acids (ml L ⁻¹)
	₆ B	₃ B	₀ B	
229.11	237.33	236.67	213.33	₀ IS
242.44	244.00	245.33	238.00	₂ IS
295.11	310.00	297.00	278.3	IS ₄
340.11	348.33	336.67	337.67	₆ IS
	284.91	278.91	266.83	Sorbitol Mean (B)

Amino Acids	Sugar Alcohol	Interaction	LSD 5%
12.34	10.69	21.38	

4. Individual leaf area (cm²):

using the third concentration (6 ml L⁻¹), reaching 16.70 cm², compared to the control treatment which reached 14.58 cm², and with the first

The results in Table (4) indicated that the effect of spraying amino acids on the trait of individual leaf area recorded a significant difference when

As for the binary interaction, it had a highly significant effect, as the treatment IS6 B6 at concentrations of 6 and 6 ml L⁻¹ achieved superiority, reaching 18.25 cm², compared to all treatments.

concentration which reached 14.37 cm².

Spraying with sugar alcohol also achieved significant superiority in the same trait at the second concentration (6 ml L⁻¹), reaching 15.99 cm², compared to the control treatment which reached 14.78 cm².

Table (4): Effect of amino acids and sugar alcohol sorbitol on the trait of individual leaf area (cm²) of Zinnia plant.

Amino Acid Mean	Sugar Alcohol Sorbitol (ml L ⁻¹)			Amino Acids (ml L ⁻¹)
	₆ B	₃ B	₀ B	
14.58	14.77	15.03	13.9	₀ IS
14.37	13.44	14.89	14.78	₂ IS
15.90	17.51	15.51	14.68	₄ IS
16.70	18.25	16.10	15.75	₆ IS
	15.99	15.38	14.78	Sorbitol Mean (B)

Amino Acids	Sugar Alcohol	Interaction	LSD 5%
1.11	0.96	1.93	

5. Fresh weight of the vegetative shoot (g):

concentration (6 ml L⁻¹), compared to the control treatment which reached 44.84 g. The binary interaction also had a highly significant effect, as the treatment IS6 B6 at concentrations of 6 and 6 ml L⁻¹ was superior, reaching 57.10 g, compared to the control treatment which reached 37.83 g, and most other treatments.

It is evident from Table (5) that the effect of spraying amino acids on the trait of fresh weight of the vegetative shoot showed significant superiority at the third concentration (6 ml L⁻¹), recording 55.60 g, compared to the other concentrations. Table (7) also shows that spraying with sugar alcohol was significantly superior in the above trait, reaching 47.07 g at the second

Table (5): Effect of amino acids and sugar alcohol sorbitol on the trait of fresh weight of the vegetative shoot (g) of Zinnia plant.

Amino Acid Mean	Sugar Alcohol Sorbitol (ml L ⁻¹)			Amino Acids (ml L ⁻¹)
	₆ B	₃ B	₀ B	
39.71	40.60	40.70	37.83	₀ IS
40.98	41.03	41.26	40.66	₂ IS
47.63	49.56	47.73	45.60	₄ IS
55.90	57.10	55.33	55.26	₆ IS
	47.07	46.25	44.84	Sorbitol Mean (B)

Amino Acids	Sugar Alcohol	Interaction	LSD 5%
1.47	1.27	2.55	

6. Dry weight of the vegetative shoot (g):

the second concentration (6 ml L^{-1}), reaching 9.67 g, compared to the other concentrations. The binary interaction between amino acids and sugar alcohol shows a highly significant effect, as the treatment IS6 B6 at concentrations of 6 and 6 ml L^{-1} achieved superiority, reaching 11.43 g, over all treatments.

Table (6) indicates that the effect of spraying amino acids on the trait of dry weight of the vegetative shoot was significantly superior at the third concentration (6 ml L^{-1}), reaching 10.93 g, compared to the other concentrations. Spraying with sugar alcohol also achieved significant superiority in the same above trait at

Table (6): Effect of amino acids and sugar alcohol sorbitol on the trait of dry weight of the vegetative shoot (g) of Zinnia plant.

Amino Acid Mean	Sugar Alcohol Sorbitol (ml L^{-1})			Amino Acids (ml L^{-1})
	$_6\text{B}$	$_3\text{B}$	$_0\text{B}$	
8.31	8.53	8.50	7.90	$_0\text{IS}$
8.60	8.56	8.66	8.56	$_2\text{IS}$
9.64	10.16	9.56	9.20	$_4\text{IS}$
10.93	11.43	10.60	10.76	$_6\text{IS}$
	9.67	9.33	9.10	Sorbitol Mean (B)

Amino Acids	Sugar Alcohol	Interaction	LSD 5%
0.27	0.23	0.47	

7. Plant spread trait (cm):

(cm) at the second concentration (6 ml L^{-1}), reaching 31.33 cm, compared to the other concentrations. The interaction had a highly significant effect, as the treatment IS6 B6 at concentrations of 6 and 6 ml L^{-1} was superior, reaching 34.66 cm, compared to the control treatment which reached 25.00 cm, and most other treatments.

It is evident from the results obtained in Table (7) that the effect of spraying amino acids on the plant spread trait was significantly superior at the third concentration (6 ml L^{-1}), reaching 32.44 cm, compared to the other concentrations. Spraying with sugar alcohol also showed significant superiority in the plant spread trait

Table (7): Effect of amino acids and sugar alcohol sorbitol on the plant spread trait (cm) of Zinnia plant.

Amino Acid Mean	Sugar Alcohol Sorbitol (ml L^{-1})			Amino Acids (ml L^{-1})
	$_6\text{B}$	$_3\text{B}$	$_0\text{B}$	
27.00	30.33	25.66	25.00	$_0\text{IS}$
29.22	30.33	29.00	28.33	$_2\text{IS}$
29.77	30.00	29.33	30.00	$_4\text{IS}$
32.44	34.66	33.00	29.66	$_6\text{IS}$
	31.33	29.25	28.25	Sorbitol Mean (B)

Amino Acids	Sugar Alcohol	Interaction	LSD 5%
1.42	1.23	2.46	

8. Total chlorophyll trait (SPAD):

chlorophyll trait, reaching 33.53 SPAD, compared to the first concentration (3 ml L⁻¹) which reached 31.55 SPAD. As for the interaction, it had a highly significant effect, as the treatment IS6 B6 at 6 and 6 ml L⁻¹ was superior, reaching 37.80 SPAD, compared to the control treatment which reached 28.63 SPAD, in addition to most other treatments.

The results in Table (8) indicated that the effect of spraying amino acids on the total chlorophyll trait recorded significant differences at the third level (6 ml L⁻¹), reaching 34.11 SPAD, compared to the control treatment which reached 30.42 SPAD and the second level (4 ml L⁻¹). Table (10) indicates that spraying with sugar alcohol at a concentration of 6 ml L⁻¹ was significantly superior in the total

Table (8): Effect of amino acids and sugar alcohol sorbitol on the total chlorophyll trait (SPAD) of Zinnia plant.

Amino Acid Mean	Sugar Alcohol Sorbitol (ml L ⁻¹)			Amino Acids (ml L ⁻¹)
	₆ B	₃ B	₀ B	
30.42	31.23	31.40	28.63	₀ IS
33.81	33.76	31.53	36.13	₂ IS
31.88	31.33	31.96	32.36	₄ IS
34.11	37.80	31.33	33.20	₆ IS
	33.53	31.55	32.58	Sorbitol Mean (B)

Amino Acids	Sugar Alcohol	Interaction	LSD 5%
1.75	1.52	3.04	
Amino Acids	Sugar Alcohol	Interaction	LSD 5%
0.07	0.06	0.12	

Discussion:

physiological and productive processes of the plant. This is due to the role of amino acids in stimulating cell division and elongation. Treating plants with amino acids leads to a set of interrelated physiological and biochemical mechanisms, as amino acids are basic building blocks for protein synthesis (10). The increased availability of amino acids leads to enhanced activity of enzymes associated with cell division and elongation processes, which directly reflects on increasing plant height and

The results showed that spraying with amino acids, sugar alcohol, and their interactions affected the traits of vegetative growth, mineral content, and floral and root growth traits. We find that amino acids significantly affected the traits of plant height, number of leaves, individual leaf area, number of branches, fresh and dry vegetative weight, plant spread diameter, and total chlorophyll [Tables (3, 4, 5, 6, 7, 8, 9, 10)]. This may be attributed to the effective role of these compounds in enhancing the

spraying with sugar alcohol (sorbitol) led to a significant effect on most vegetative growth traits of zinnia plants, including plant height, number of branches, number of leaves, leaf area, fresh and dry weight, and plant spread, as well as chlorophyll content. This effect is attributed to sorbitol acting as an osmotic regulator within plant cells (15). Sugar alcohol contributes to maintaining cellular turgor pressure, which enhances cell division and elongation processes, and thus increases vegetative growth. It also plays a role in improving photosynthetic efficiency by increasing chlorophyll content, leading to increased carbohydrate synthesis. Additionally, sorbitol contributes to the transport of photosynthetic products within the plant, which positively reflects on the growth of various tissues. It also plays a role in reducing the impact of environmental stresses, allowing the plant to direct its energy towards growth rather than resistance processes (16). These results are consistent with the findings of (17), (18), (19).

Reference

- flower production report 2024. Food and Agriculture Organization of the United Nations.
- 4- **Floriculture International. (2023).** Global trends in cut flower production and trade. Floriculture International, 33(4), 14–20.
- 5- **Rouphael, Y., & Colla, G. (2020).** Biostimulants in agriculture. *Frontiers in Plant Science*, 11, 40.
- 6- **Ertani, A., Francioso, O., Tinti, A., Schiavon, M., & Nardi, S. (2021).** Evaluation of seaweed extracts and amino-acid-based biostimulants on number of branches. Amino acids contribute to stimulating the photosynthetic process through their role in the formation of chlorophyll pigment, as some of them, such as glycine and glutamic acid, enter the biosynthetic pathways of chlorophyll synthesis. Consequently, this leads to increased photosynthetic efficiency, which explains the increase in leaf area and number, as well as the increase in dry weight due to the accumulation of carbohydrate materials (11). Proline also contributes to improving tolerance to environmental stresses, thereby maintaining growth continuity and increasing biomass. Especially in rapidly dividing developing tissues, amino acids play a role in improving water balance within plant cells by regulating osmotic pressure, which increases cell turgidity and thus increases fresh weight, in addition to supporting the vital processes responsible for dry matter accumulation (27). These results are consistent with the findings of (12), (13), and (14). The results in Tables (3, 4, 5, 6, 7, 8, 9, 10) indicate that
- 1- **Benchasri, S. (2021).** Growth and flowering development of zinnia (*Zinnia elegans* Jacq.) under environmental conditions. *International Journal of Agricultural Technology*, 17(3), 1045–1056.
- 2- **Al-Abbasi, N. A., Al-Hadethi, M. E., & Hassan, R. K. (2021).** Response of zinnia plants to different environmental and nutritional treatments. *IOP Conference Series: Earth and Environmental Science*, 761(1), 012067.
- 3- **FAO. (2024).** Global floriculture market and cut

- the Harmful Effect of Some Heavy Metals Pollution in the Irrigation Water (B) Effect of Lead Treatments. Egyptian Academic Journal of Biological Sciences, H. Botany, 12(1): 107-122.
- 14- Hassan, S., & Al-Tamimi, A. (2024). Response of *Gypsophila paniculata* plant to foliar spraying with aspartic acid and its effect on vegetative branching density. *Journal of Rafidain Agriculture*, 52(1), 204-216.
 - 15- Patel, S., & Goyal, A. (2022). Functional properties of sugar alcohols. *International Journal of Food Sciences and Nutrition*, 73(2), 123–135.
 - 16- Stoop, J. M., Williamson, J. D., & Pharr, D. M. (2021). Mannitol metabolism in plants: A method for coping with stress. *Trends in Plant Science*, 6(11), 488–493.
 - 17- Al-Nasiri, K. (2023). Response of *Dahlia* plant to foliar spraying with mannitol in promoting vegetative growth and NPK content. *Tikrit Journal of Agricultural Sciences*, 23(4), 101-114.
 - 18- Garcia, M., Smith, J., & Lopez, A. (2023). Ornamental *Phlox* response to foliar mannitol: Effects on osmotic balance and NPK accumulation. *Scientia Horticulturae*, 295, 110820.
 - 19- Davis, R., & Moore, L. (2024). Foliar application of sorbitol improves vegetative shoot biomass and floral diameter in *Chrysanthemum*. *Scientia Horticulturae*, 312, 111840.
 - 20- Kumar, P., Singh, R., & Verma, A. (2022). plant metabolism and productivity. *Plants*, 10(5), 941.
 - 7- Sami, F., Yusuf, M., Faizan, M., Faraz, A., & Hayat, S. (2021). Role of sugars under abiotic stress. *Plant Physiology and Biochemistry*, 109, 54–61.
 - 8- Rady, M. M., Semida, W. M., & Abd El-Mageed, T. A. (2022). Polyols and sugar alcohols as innovative biostimulants for improving plant tolerance to abiotic stresses. *Agronomy*, 12(3), 761.
 - 9- Alqaisi, M. R., Mohsin, R. M., & Ahmed, T. S. (2020). Efficiency of image analysis as a direct method in spore dimensions measurement. *Plant Cell Biotechnol Mol Biol*, 21, 57-64.
 - 10- Ahmad, R., & Khan, M. A. (2010). Biochemical and chemical roles of sugar alcohols in modulating nutrient complexation and stress tolerance in plants. *Journal of Plant Nutrition and Soil Science*, 173(4), 512–521.
 - 11- Jacob, R. H., Afify, A. S., Shanab, S. M., & Shalaby, E. A. (2024). Chelated amino acids: biomass sources, preparation, properties, and biological activities. *Biomass Conversion and Biorefinery*, 14(3), 2907-2921.
 - 12- Al-Obaidi, M. K. M. (2020). Effect of amino acid tryptophan and organic fertilizer Acadain on growth and yield of three cultivars of *Gladiolus* hybrid [Master's thesis, College of Agriculture, University of Kirkuk].
 - 13- El-Shanhorey, N. A. and S. S. Ahmed (2021). Effect of Foliar Applied Tryptophan on Tuberose Plants for Decreasing

- Phytochemistry, 10(1), 2161-2165.
- 24- **Sahu, J. K., Tamrakar, S. K., Tiwari, A., and Lakpale, R. (2021).** Effect of nitrogen, phosphorus and potassium on growth and flowering of *chrysanthemum* . The Pharma Innovation Journal. 10(7): 1289-1292.
- 25- **Chawla, S. L., Patel, R. B., Dhaduk, B. K., Patil, S., and Bhatt, D. (2021).** Varietal assessment of chrysanthemum (*Dendranthema grandiflorum*) under south Gujarat agro-climatic conditions. Current Horticulture, 9(2), 64-67.
- 26- **Der, G., & Everitt, B. S. (2021).** Statistical Analysis in Simple Steps Using SAS. CRC Press.
- 27- **Alabdaly, M. M., & Abdullah, S. Kh. (2024).** Influence of potassium, sugar alcohol, and boron on growth and chemical composition of melons under protected cultivation. Anbar Journal of Agricultural Sciences .
- Performance of ornamental annual flowers under subtropical conditions. Journal of Ornamental Horticulture, 25(1), 35–44.
- 21- **Nargesi, M. M., Beiranvand, H., & Karimi, R. (2022).** Amino acids as eco-friendly biostimulants in ornamental plants: Growth, physiology and productivity responses. Scientia Horticulturae, 295, 110851.
- 22- **Bethany, R. L., Morgan, P. T., & Silva, J. A. (2025).** Amino acid biostimulants and their role in sustainable crop production under abiotic stress. Frontiers in Plant Science, 16, 145211.
- 23- **Thiripurasundari, S., Velmurugan, M., Geethanjali, S., and Thamaraiselvi, S. P. (2021).** SG. Evaluation of cut chrysanthemum (*Dendranthema grandiflorum* Tzvelev.) under open field and polyhouse in Coimbatore conditions. Journal of Pharmacognosy and