

Effect of Benzyl Adenine and Zinc Sulfate on The Growth, Flowering and Vase Life of Zinnia Plant (*Zinnia elegans*)

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Abstract

This study was conducted to evaluate the effects of benzyl adenine and zinc sulfate on the growth, flowering, vase life of zinnia plant. The experiment was designed following a Randomized Complete Block Design (RCBD) with two factors and three replicates. The parameters of zinnia plant included growth morphology, physiological parameters, elemental composition and flowering and vase life. The growth morphology parameters studied included plant height, number of branches, number of leaves, number of internodes, shoot dry weight, and leaf area; physiological parameters included carbohydrate content, anthocyanin pigments, total chlorophyll content, and total carotene content; and elemental content parameters included nitrogen content, phosphorus content, potassium content, and zinc content also, the number of days from planting to bud emergence, the number of days from planting to anthesis, the number of flowers per plant, stem length, flower diameter, stem diameter, flower dry weight, vase life. BA at three concentrations (0, 50, and 100 mg l⁻¹), and ZnSO₄ at three levels (0, 0.50, and 0.75%) of Zinnia was studied alone and their combination. The interaction of 50 mg L⁻¹ BA with 0.50% Zn gave the earliest bud emergence.

The combination of 50 mg L⁻¹ benzyl adenine with 0.75% Zn gave the earliest flowering. The combination of 100 mg L⁻¹ BA with 0.75% Zn gave the maximum number of flowers per plant (5.11), the maximum plant height (97.28 cm), the maximum shoot dry weight (15.26 g), the maximum number of branches (9.50), and the maximum leaf area (31.35 cm²). The combination of BA with zinc gave the maximum carbohydrate content (6.14 mg.g⁻¹), the maximum anthocyanin content (232.5 mg.100 g⁻¹), the maximum nitrogen uptake (4.35%), and the maximum zinc content (0.98%).

Keywords: benzyl adenine, zinc sulfate and zinnia plant

Introduction

Zinnia is one of the most popular flowers due to its brilliance in shades of color. The colors of its blossoms vary from pink to red, bright orange, vivid yellow, white, or even smooth cream shades. This plant originates from Mexico and belongs to the Asteraceae family, counting about 20 species in total. Since Zinnias have been widely used by gardeners for many years, a great number of cultivars were bred in a

wide range of sizes and shapes, from spreading and dwarf to tall and majestic types of *Zinnia elegans*. The elegant, narrow-leaved, creeping variety is ideal for naturalizing in rock gardens, containers, and hanging baskets. Although Zinnia became popular only in the late 1800s, there are annual and perennial species available in some countries. Mostly, its annual varieties are grown as seasonal plants during summer, while in some countries, it is also grown

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commercially as a cut flower [16; 26]. For optimal development, the Zinnia plant demands balanced nutritional requirements to maintain its bright green color, tall stature, and heavy flowering with desirable size, color, and longevity [34; 26]. Nutritional imbalance in crops is one of the most important factors delaying crop productivity. The use of water-soluble fertilizer formulas in floricultural production can effectively meet the plants' demands for macro and micro-nutrient requirements by simply being in an easily assailable form [22].

Zinnia can also grow well in a garden bed, pugmarks, plastic pots, wooden boxes, and rock gardens. Zinnia may well be the easiest annual to have in a garden to grow. The leaves of Zinnia are of various kinds and have no stem, and the length may range from 5 cm to 10 cm. The seeds of Zinnia are to be planted in the nursery bed after the winter seasons in solid soil without lumps. The seeds should just be covered by 6-7mm of soil to germinate as the seeds need light to germinate. Zinnia grows well in warm climates and under seasons of reduced water [37].

Benzyl adenine (BA) and gibberellic acid treatments have also been found to encourage early flowering and augment the number of flowers in lilies [21]. [27] found that the maximum number of flowers per plant, length of flower stem, flower fresh weight, and vase life (4.333, 0.405 cm, 10.462 g, and 11.111 days, respectively) were obtained when the zinnia plant were treated by spraying BA at concentrations of 100 and 50 mg l⁻¹. The treatment of benzyl adenine increased the length of the blooming stem, size of the flower, number of flowers, and sped up blooming in case of narcissus flowers [30]. In case of croton plant, the parameters leaf weight, number of leaves, leaf surface area, and stem diameter were

also increased [15]. Furthermore, [27] also found that in case of Zinnia plant, number of leaves, number of branches, number of internodes, fresh and dry weight of shoot, leaf area in cm², and total carotene content were significantly increased at the concentration of 50 mg l⁻¹ BA, giving values of 26.741, 9.296, 12.556, 259.054, 13.829, 24.489, and 14.798 cm², respectively. However, [3] obtained that Benzyl adenine (BA at 100 mg l⁻¹) treatments significantly improved the vegetative and floral growth of the plant in terms of plant spread, height, leaf number, and branch number as well as their fresh and dry weights. These also enhanced some floral characteristics such as flowering duration, number of flowers, flower diameter, peduncle length, and peduncle diameter as well as fresh and dry flower weights and flower longevity on the plant

As with other types, nutrition plays a major role in enhancing vegetative growth and flower production in annual flowering crops. Annual flowering crops are generally responsive to nutrient application. An adequate supply of nutrients, particularly the major ones, affects not only the growth of the crop but also the yield and quality of the produce. The influence of a single nutrient, however, cannot be studied in its entirety because the effect of one nutrient is always influenced by the levels of others. It is thus necessary to study these nutrients in combination. This holds true for all essential elements, even those required in relatively small quantities, as stated by [32]. Foliar application of micronutrients directly affects crop quality and yield [14]. If applied at optimal concentrations, zinc promotes plant height, flower number, flower diameter, and flower production. But if these quantities are exceeded, there will be poor plant growth [31]. Zinc also plays a critical role in enhancing biological processes since it is

part of proteins and enzymes. Foliar spray application of micronutrients helps in reaching these micronutrients to the leaves, which act as green factories where many chemical reactions, including photosynthesis, take place to yield plant growth components [38].

In a study carried out by [44], it was shown that leaf application of ZnSO_4 affects vegetative and physiological parameters of *Pelargonium odoratissimum* significantly, and it had a maximum effect at a concentration of 2000 mg l^{-1} . Zinc sulfate acts as a growth enhancer and helps in increasing plant height, chlorophyll content, and carotenoids. According to [43], there were significant effects of foliar treatment with zinc sulfate and salinity concentration on the physiological parameters studied for (*Lavandula stoechas*), with maximum values for root fresh weight, chlorophyll b, anthocyanin pigments, and Zn concentration recorded for $2000 \text{ mg l}^{-1}\text{Zn}$. [28] investigated the effects of Zn and BA concentrations on *Zinnia* plant, finding that *Zinnia* plant generally showed superior vegetative growth and higher carotene content, especially with 50 mg l^{-1} BA and 0.50% Zn. The aim of this study is to evaluate the effects of foliar micronutrient and benzyl adenine treatments on the growth performance, flowering characteristics, chemical composition, and post-harvest quality of *Zinnia elegans* plants, with the goal of identifying optimal treatment strategies to enhance overall plant health, aesthetic appeal, and shelf life.

Materials and Method

The experiments were performed in the greenhouse of the Department of Horticulture in the College of Agriculture Engineering Sciences, University of Duhok, Kurdistan Region-Iraq, as of April 21, 2024.

The experimental layout was arranged in a factorial Randomized Complete Block

Design (RCBD), with two factors, which include Benzyl adenine (BA) at three concentrations (0, 50, and 100 mg l^{-1}), and Zinc sulfate (ZnSO_4) at three levels (0, 0.50, and 0.75%), and their interaction. The experiment consisted of 27 units ($3 \times 3 \times 3$), having four plants for each treatment, which altogether accounted for 108 plants. Seeds of the varieties of *Zinnia elegans* were imported from Pagano Costantino in Italy. To start with, seeds were germinated using peat moss. When seedlings attained four leaves, they were planted in 24 cm pots prepared using a mixture of river soil and peat moss in a 2:1 ratio. This is based on their volume. These plants are planted in a greenhouse.

Different concentrations of BA and Zn were applied three times at an interval of 15 days during the stages of growth of the plant. Data gathered covered a number of parameters, which were listed as follows: **Growth characters:** Plant height (cm), Leaves number per plant, Branches number per plant, Internodes number per plant, Shoot dry weight, and Leaf area (cm^2). **Chemical characters:** Nitrogen percent, Phosphorus percent, Potassium percent, Zinc percent, Carbohydrate, Anthocyanin, Chlorophyll (mg.g^{-1}) and Carotenoid (mg.g^{-1}). **Flowering characters:** Number of days from planting to flower bud emergence, Number of days from planting to anthesis, Number of flower plant⁻¹, Flower diameter (cm), Flower stem length (cm), Flower stem diameter (cm), Flower fresh weight (g), Flower dry weight (g), and Vase life (days).

Statistical Analysis

The experiment was carried out using a completely randomized design. Each treatment comprised three replicates and four plants for each replication. Collected data were subjected to analysis of variance (ANOVA) and the mean values were

assessed by Duncan Test at $P \leq 0.05$ using program (SAS).

Results

Vegetative growth parameters:

Plant height (cm):

Based on the data presented in table 1, the optimal concentration of BA (Benzyl adenine) for the promotion of plant height is at a concentration of 100 mg l^{-1} , where the average plant height is 93.02 cm. This indicates that the absence of BA may be the most beneficial for the maximization of plant height. If we consider the effect of zinc (Zn) on plant height, the highest mean effect on plant height is at 0.75 % zinc application, where the average plant height is at 93.26 cm. This indicates that the higher the concentration of zinc, the better the plant growth. The interaction between BA and Zn reveals that the combination of 50 mg L^{-1} BA with 0.75% Zn resulted in 97.28 cm in the most considerable increase in plant stature, suggesting a synergistic effect where minimal BA paired with maximum zinc concentration optimizes plant growth. These findings highlight the importance of balancing both growth regulators and

micronutrients to achieve optimal plant development.

Branches number per plant:

From the data provided in Table 1, the most significant values for branches per plant are observed at various concentrations of BA and Zn. In the case of BA, the highest number of branches (8.57) is observed when the concentration is 100 mg l^{-1} , which indicates that this concentration significantly promotes branching compared to other concentrations and control. In the case of Zn, the highest number of branches (8.19) is observed when the concentration is 0.75 %, which indicated that Zn positively affects branching in the plant. The interaction between BA and Zn also significantly affects branching in the plant, as indicated by the fact that the highest value of 9.50 branches per plant is observed when the concentration of BA and Zn is the highest 100 mg l^{-1} and 0.75%. This indicates that the combination of the two nutrients optimizes branching in the plant. This indicates that the use of BA and Zn on the leaves significantly affects the complexity of zinnia plant structure.

Table (1): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

BA Mg l ⁻¹	plant height (cm)			Mean effect of BA	BA Mg l ⁻¹	branches number.		Mean effect of BA	
	Zn%					Plant ⁻¹			
	0.0	0.50	0.75			0.0	0.50		0.75
0	77.61 ^c	93.47 ^{ab}	88.83 ^a _b	86.63 ^b	0	5.52 ^c	6.94 ^{bc}	7.28 ^{bc}	6.57 ^b
50	87.48 ^b	94.29 ^{ab}	97.28 ^a	91.88 ^a	50	8.28 ^{ab}	7.56 ^b	7.78 ^{ab}	7.87 ^a
100	90.88 ^{ab}	91.09 ^{ab}	93.66 ^a _b	93.02 ^a	100	7.44 ^b	8.78 ^{ab}	9.50 ^a	8.57 ^a
Mean effect of Zn	85.32 ^b	92.95 ^a	93.26 ^a		Mean effect of Zn	7.07 ^b	7.76 ^{ab}	8.19 ^a	

Leaves number per plant:

According to the information shown in Table 2, it is very clear that the highest and statistically significant value of the number of leaves per plant corresponds to the highest levels of BA and Zn. Individually, BA at a concentration of 100 mg l⁻¹ shows a positive effect on the growth of Zinnia plants, with an increased mean leaf count of 26.26 leaves per plant, significantly higher than that of the other concentrations, 0 mg l⁻¹ and 50 mg l⁻¹. The same applies to Zn, where the highest concentration of 0.50

% shows an increased mean leaf count of 26.33 leaves per plant, showing a positive effect of zinc supplementation. The combined effect of BA and Zn shows a positive effect, with the combined treatment of 100 mg l⁻¹ BA and 0.50 % Zn showing the highest leaf count reaching 30.78 leaves per plant. This shows that the combined effect of these two factors optimally promotes the growth of zinnia plants, with the highest leaf count occurring at the highest levels of BA and Zn.

Table (2): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

Characteristics on maize plants											
BA Mgl ⁻¹		leaves number. Plant ⁻¹			Mean effect of BA	BA Mgl ⁻¹		internodes		Number.	Mean effect of BA
		Zn%						Plant ⁻¹			
								Zn%			
		0.0	0.50	0.75		0.0	0.50	0.75			
0		14.89 ^e	21.11 ^{b-e}	22.67 ^{bcd}	19.56 ^b	0	6.94 ^d	9.28 ^{bcd}	9.72 ^{bcd}	8.65 ^b	
50		16.56 ^{de}	27.11 ^a	24.78 ^{abc}	22.82 ^a	50	8.50 ^{cd}	12.28 ^{abc}	12.56 ^a	11.11 ^a	
100		18.11 ^{cde}	30.78 ^a	29.89 ^a	26.26 ^a	100	8.89 ^{bc}	14.39 ^a	14.11 ^a	12.46 ^a	
Mean effect of Zn		16.52 ^b	26.33 ^a	25.78 ^a		Mean effect of Zn	8.11 ^b	11.98 ^a	12.13 ^a		

Internodes number per plant:

Table 2 shows that the maximum statistically significant value of the internodes per plant is found when the BA concentration is 100 mg l⁻¹, where the mean value is 12.46 internodes, to show significance. Likewise, in the case of Zn treatment, the maximum value is found when the concentration of Zn is 100%, where the mean value is 12.13 internodes, to show significance. It is found that the combination of BA and Zn concentrations shows that the maximum value of internodes per plant 14.11 is found when the concentration of BA is 100 mg l⁻¹ and Zn is 0.50%, showing a synergistic effect of BA and Zn on the plants. It is evident that both

BA and Zn, individually and in combination in higher concentrations, enhance the length of internodes in zinnia plants

Shoot Dry Weight (g):

From the data provided in Table 3, the most significant figure for shoot dry weight (g) is seen when 100 mg l⁻¹ of BA is applied, as this gives the maximum figure of 13.33 g. This shows that if a higher concentration of BA is applied, this gives a better result with regard to shoot dry weight compared to a smaller concentration of BA. With regard to Zn, it is seen from the data provided in the table that if 0.75% Zn is applied, this gives a maximum figure of 12.50 g, showing that Zn also has a positive

effect on the growth of the Zinnia plant. However, if both BA and Zn are applied, this gives a synergistic effect regarding shoot dry weight, and the maximum figure is seen when 100 mg l⁻¹ of BA and 0.50% Zn are applied, reaching 15.26 g.

leaf area (cm²):

According to the data in Table 3, it is possible to identify the most significant value of the effect of BA and Zn on the leaf area, measured in cm². Thus, the highest value of the mean effect of BA concentrations on the leaf area was recorded at a concentration of 100 mg l⁻¹, where the value of the effect was 23.71 cm², showing the greatest increase in the total area of the leaves compared to lower concentrations of

BA and the control. At the same time, the application of zinc at a level of 0.75 % revealed the most significant value of the effect, where the mean effect was equal to 25.18 cm², showing the greatest increase in the total area of the leaves. Moreover, it is interesting to note that the interaction between BA and Zn revealed a significant value of the effect reaching 31.35 cm² in BA at 100 mg l⁻¹ with spraying Zn at 0.50%, indicating that such a treatment could be used synergistically to increase the total area of the foliage, which is an important parameter for assessing the vigor and productivity of plants.

Table (3): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

characteristics on zinnia plants											
BA Mgl ⁻¹		shoot dry weight (g)			Mean effect of BA	BA Mgl ⁻¹		leaf area (cm ²)			Mean effect of BA
		Zn%						Zn%			
		0.0	0.50	0.75				0.0	0.50	0.75	
0		5.55 ^d	7.51 ^{cd}	7.98 ^{cd}	7.02 ^b	0		8.58 ^e	13.79 ^{c_d}	17.07 ^c	13.15 ^c
50		8.77 ^{bcd}	13.18 ^{abc}	14.25 ^{a_b}	12.07 ^a	50		9.25 ^{de}	25.49 ^b	27.41 ^{a_b}	20.72 ^b
100		10.05 ^{a_{-d}}	14.69 ^{ab}	15.26 ^a	13.33 ^a	100		8.72 ^e	31.35 ^a	31.06 ^a	23.71 ^a
Mean effect of Zn		8.12 ^b	11.80 ^a	12.50 ^a		Mean effect of Zn		8.85 ^b	23.54 ^a	25.18 ^a	

Chemical parameters:

Carbohydrate content (mg.g⁻¹):

From the data provided in Table 4, it is clearly evident that the highest amount of carbohydrates is obtained with the highest concentration of both BA and Zn. For instance, the application of 100 mg l⁻¹ of BA results in the highest amount of carbohydrates, reaching 5.75 mg.g⁻¹, compared with the control. Likewise, the application of Zn at a concentration of 0.75% results in the highest amount of carbohydrates, 5.91 mg.g⁻¹, compared with

the control. In the case of the combined application of both BA and Zn, it is clearly evident that both these compounds positively influence the amount of carbohydrates synthesized by the Zinnia plants. In other words, the combined application of these two compounds results in a synergistic effect and leads to the highest amount of carbohydrates, 6.14 mg.g⁻¹, obtained with the highest concentration of both 50 mg l⁻¹ BA with 0.75% Zn.

Anthocyanin content (mg. 100g⁻¹):

Based on the data provided in Table 4, the most notable value of anthocyanin content, which measures the intensity of the pigmentation in the zinnia plants, is seen in the presence of specific concentrations of BA and Zn. When BA is used, the highest content of anthocyanin is seen when 100 mg l^{-1} of BA is used, which has a corresponding mean value of 205.37 mg. 100g $^{-1}$, indicating a significant increase in the content compared to the control. Similarly, the highest content of anthocyanin

is seen when 0.75% Zn is used, which has a corresponding value of 192.9 mg. 100g $^{-1}$, indicating a significant increase in the content compared to the lower concentration of Zn and control. The interaction between BA and Zn, however, shows that the combination of 100 mg l^{-1} BA and 0.75% Zn have the most pronounced effect on the pigmentation, as indicated by the presence of the highest concentration of anthocyanin reaching 232.5 mg. 100g $^{-1}$ this treatment significantly compared to all treatments

Table (4): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

Characteristics on zinnia plants									
BA Mgl ⁻¹	Carbohydrate content (mg.g ⁻¹)			Mean effect of BA	BA Mgl ⁻¹ ₁	Anthocyanin content in			Mean effect of BA
	Zn%					Zn%			
	0.0	0.50	0.75			0.0	0.50	0.75	
0	4.33 ^d	4.93 ^{cd}	5.67 ^{ab}	4.98 ^b	0	118.6 ^g	131.0 ^f	131.3 ^e	134.40 _c
50	5.33 ^{bc}	5.90 ^{ab}	6.14 ^a	5.79 ^a	50	143.0 ^d	172.5 ^c	192.9 ^b	169.48 _b
100	5.48 ^{ab} _c	5.86 ^{ab}	5.93 ^{ab}	5.75 ^a	100	190.4 ^b	193.3 ^b	232.5 ^a	205.37 _a
Mean effect of Zn	5.05 ^b	5.56 ^a	5.91 ^a		Mean effect of Zn	150.65 ^c	165.68 ^b	192.93 _a	

Total chlorophyll (mg.g $^{-1}$):

Table 5 shows the impact of different concentrations of BA and zinc (Zn) on total chlorophyll of zinnia plants. Notably, the highest total chlorophyll content was recorded at a BA concentration of 50 mg l^{-1} , with a value of 33.58 mg.g $^{-1}$ which indicates a remarkable increase over lower concentrations. This indicates that a higher concentration of BA has a positive effect on chlorophyll content, which is likely to boost photosynthesis. In the case of Zn, the optimal concentration was 0.50%, which led to a total chlorophyll of 34.67 mg.g $^{-1}$, indicating the most effective supplementation for zinc absorption. When analyzing the combined effect of BA and Zn, the combination of 50 mg/l BA and

0.50% zinc concentration produced the most optimal results reaching 43.30 mg.g $^{-1}$, indicating a synergistic effect that promotes plant growth and chlorophyll production. Taken together, these results clearly indicate that both BA and zinc concentration, individually and collectively, make a significant contribution to boosting chlorophyll production and promoting healthy plant growth.

Total carotene (mg.g $^{-1}$):

As such, in line with the data presented in Table 5 provided with the most notable and statistically significant effects were those related to the influence of the benzyl adenine (BA) concentration and zinc (Zn) on the total carotene content when considered individually at certain levels of

treatment. In the case of the influence of the BA concentration on the total carotene content, the data suggest that the increase in the BA concentration from 0 to 100 mg.l⁻¹ results in a certain increase in the total carotene levels, with the greatest mean effect of 14.33 mg.g⁻¹ being recorded when the plants were sprayed with 100 mg.l⁻¹ of BA. This, therefore, suggests a positive effect of benzyl adenine on the biosynthesis of carotene in the plants. In the case of the application of zinc, the data suggest that the application of Zn at a concentration of 0.75

% results in the greatest total carotene content, with a mean of 14.13 mg.g⁻¹, suggesting a positive effect of high levels of zinc on the biosynthesis of carotene in the plants. In the case of the combined application of BA and Zn, the data suggest that the combined application of high levels of the two factors results in the greatest total carotene levels reached 17.52 mg.g⁻¹ when spraying the plant with 100mg.l⁻¹ BA with 0.75% Zn, suggesting the importance of these factors in the optimization of carotene biosynthesis in zinnia plants.

Table (5): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

BA Mgl ⁻¹	total chlorophyll			Mean effect of BA	BA Mgl ⁻¹	total carotene			Mean effect of BA
	Zn%					Zn%			
	0.0	0.50	0.75			0.0	0.50	0.75	
0	9.46 ^e	24.00 ^c	23.91 ^c	19.12 ^b	0	8.47 ^c	9.41 ^c	9.44 ^c	9.11 ^b
50	16.08 ^d	43.30 ^a	41.37 ^{ab}	33.58 ^a	50	9.55 ^c	14.91 ^b	15.43 ^a	13.30 ^a
100	16.41 ^d	36.69 ^d	42.21 ^{ab}	31.77 ^a	100	9.24 ^c	16.24 ^a	17.51 ^a	14.33 ^a
Mean effect of Zn	13.98 ^b	34.67 ^a	35.83 ^a		Mean effect of Zn	9.09 ^b	13.52 ^a	14.13 ^a	

Nitrogen%:

Table 6 in the effect of varying concentrations of BA and Zn on Nitrogen percent of the zinnia plants. The greatest increase in these characteristics of the plants, as observed, is at the 100 mg.l⁻¹ concentration of the BA solution, where the greatest height of the plants, 3.95 % to indicate the superior value among the plants treated with this concentration of the solution. The greatest percentage of N 3.78 % indicates the superior value among the plants treated with this concentration of the solution, is observed at the 0.75 % concentration of the Zn solution. The interaction between the effects of the two substances on the plants reveals that the BA at 100 mg.l⁻¹ with Zn at 0.75 % treatments

are the best for the plants N uptake reaching 4.35%, indicating that the plants could be better off with the two substances.

Phosphor%:

From Table 6 provided, the effects of the application of BA and Zn on the various parameters of the zinnia plants, including the phosphorus percent, are outlined. It is evident that the most prominent statistically significant value is that of the application of the highest concentration of BA, that is, 100 mg.l⁻¹, where the phosphorus content is 0.10%. Individually, the application of BA is seen to positively affect the phosphorus content, with the increase in concentration corresponding to the increase in the phosphorus content. This value is similar to the foliar application of Zn, where the

application is seen to significantly affect the phosphorus content, especially when the concentration is 0.75 %, where the phosphorus content is 0.10. From the above, it is evident that the application of both BA and Zn individually positively affects the phosphorus content, with the combined

application having the most pronounced effect when used in optimal concentrations. The interaction between the effects of the two substances on the plants reveals that the BA at 100 mg l⁻¹ with Zn at 0.75 % treatments are the best for the plants P uptake reaching 0.123 %

Table (6): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

Characteristics on Zn and P plants									
BA Mg l ⁻¹	Nitrogen%			Mean effect of BA	BA Mg l ⁻¹	Phosphor%			Mean effect of BA
	Zn%					Zn%			
	0.0	0.50	0.75			0.0	0.50	0.75	
0	2.63 ^f	2.72 ^f	3.22 ^{de}	2.85 ^c	0	0.037 ^f	0.042 ^{ef}	0.057 ^d	0.05 ^c
50	3.13 ^e	3.44 ^{cd}	3.76 ^{bc}	3.44 ^b	50	0.050 ^{ef}	0.070 ^c	0.088 ^b	0.07 ^b
100	3.54 ^{cd}	3.96 ^b	4.35 ^a	3.95 ^a	100	0.079 ^{bc}	0.086 ^b	0.123 ^a	0.10 ^a
Mean effect of Zn	3.10 ^c	3.37 ^b	3.78 ^a		Mean effect of Zn	0.06 ^c	0.07 ^b	0.10 ^a	

Potassium%:

Table 7 shows the effect of the application of different concentrations of BA and Zn on the potassium content of zinnia; it is evident that the foliar application of BA at a concentration of 100 mg l⁻¹ showed a significant increase in the potassium content of the zinnia plant. The potassium content increased to 4.13%, which is higher than obtained from the application on control. Similarly, the foliar application of Zn at a concentration of 0.75% showed a significant increase in the potassium content of the Zinnia plant. The potassium content increased to 3.95%, which is higher than the potassium content obtained from the application of Zn at lower concentrations of (0.0 and 0.5 mg l⁻¹). The interaction between the applications of BA and Zn showed that the application of the two compounds at the highest concentrations showed the highest potassium content, reaching 4.40% in treatment containing 100 mg l⁻¹ BA with 0.75% Zn. This shows that the application of

the two compounds has a synergistic effect on the potassium content of the zinnia plant.

Zinc%:

Table 7 shows that the maximum significant amount of zinc exists at the 100 mg L⁻¹ concentration of BA, resulting in 0.08%. Thus, the application of BA at this concentration significantly increases the amount of zinc in zinnia plants. Regarding the application of zinc, the foliar application of Zn also significantly increases the amount of zinc in the plants, which reaches 0.07% with the spraying of Zn at 0.75% concentration. The table reveals that the average amount of zinc increases with the increase of concentration of BA and Zn. The combined effect of the application of BA and Zn reveals the synergistic effect of the combined application of the two, as the combined application of the two results in the maximum percentage of zinc, reaching 0.98% with the application of 100 mg L⁻¹ of BA and 0.75% concentration of Zn.

Table (7): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

Characteristics on Zinnia plants									
BA Mgl ⁻¹	Potassium%			Mean effect of BA	BA Mgl ⁻¹	Zinc%			Mean effect of BA
	Zn%					Zn%			
	0.0	0.50	0.75			0.0	0.50	0.75	
0	2.82 ^e	2.76 ^e	3.44 ^d	3.01 ^c	0	0.023 ^g	0.030 ^{fg}	0.045 ^{de}	0.03 ^c
50	3.23 ^d	3.74 ^c	4.01 ^{bc}	3.66 ^b	50	0.037 ^{efg}	0.054 ^{cd}	0.071 ^{bc}	0.05 ^b
100	3.93 ^{bc}	4.06 ^b	4.40 ^a	4.13 ^a	100	0.061 ^{bcd}	0.075 ^b	0.098 ^a	0.08 ^a
Mean effect of Zn	3.33 ^c	3.52 ^b	3.95 ^a		Mean effect of Zn	0.04 ^c	0.05 ^b	0.07 ^a	

Flowering parameters:**Day number from planting to flowers Bud emergence:**

As derived from the data presented in Table 8, it is evident that the application of BA at a concentration of 50 mg l⁻¹ resulted in the earliest bud emergence, as indicated by a mean of 52.10 days from planting, thereby promoting flowering significantly more than the control, which had a mean of 61.22 days. Zinc (Zn) at 0.75% concentration also resulted in earlier bud emergence, as indicated by a mean of 53.68 days, which is significantly earlier than both the control and other zinc concentrations. In relation to the interaction between BA and Zn on the day number from planting to flowers, it is evident that the interaction between 50 mg l⁻¹ of BA and 0.50% Zn resulted in the earliest bud emergence, as indicated by 48.17 days, thereby suggesting a synergistic effect that optimizes flowering. In conclusion, it is evident that the application of 50 mg l⁻¹ BA and 0.75% Zn individually resulted in promoting bud emergence, while the interaction between 50 mg l⁻¹ of BA and 0.50% Zn resulted in an enhanced effect, thereby indicating their potential as an effective agent for promoting flowering in zinnia plants.

Day number from planting to anthesis:

Based on the data shown in Table 8, it is clear that the use of BA at a concentration of 50 mg l⁻¹ led to the earliest flowering, as it took a mean of 83.20 days from planting to flowering, hence promoting flowering significantly compared to the control, which took a mean of 89.55 days. Zinc (Zn) at a concentration of 0.75% also led to the earliest flowering, as it took a mean of 83.58 days, which is significantly earlier than the control and other concentrations of zinc. Concerning the interaction between BA and Zn regarding the number of days from planting to flowering, the interaction between 50 mg l⁻¹ BA and 0.75% Zn led to the earliest flowering, as it took a mean of 78.83 days, hence suggesting a synergistic effect that optimizes flowering. In conclusion, it is clear that the use of 50 mg l⁻¹ BA and 0.75% Zn individually led to the promotion of flowering, while the interaction between 50 mg l⁻¹ of BA and 0.50% Zn led to an enhanced effect, hence indicating their potential as effective agents for promoting flowering in zinnia plants.

Table (8): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

Characteristics on maize plants									
BA Mg ^l ₁	day number from planting to flowers Bud emergence			Mean effect of BA	BA Mg ^l ₁	day number from planting to anthesis			Mean effect of BA
	Zn%					Zn%			
	0.0	0.50	0.75			0.0	0.50	0.75	
0	91.33 _a	86.28 ^a _b	91.03 _a	89.55 ^a	0	61.08 _a	63.53 ^a	59.06 _a	61.22 ^a
50	89.92 _a	79.06 ^b	78.83 _b	83.20 ^b	50	58.31 _a	48.17 ^b	49.89 _b	52.10 ^b
100	92.08 _a	92.08 ^a	79.08 _b	86.92 ^{ab}	100	62.64 _a	49.72 ^b	52.08 _b	54.82 ^b
Mean effect of Zn	90.33 _a	85.81 ^a _b	83.58 _b		Mean effect of Zn	60.68 _a	53.81 ^b	53.68 _b	

Number of flowers per plant:

On the basis of the data provided in Table 9, it was found that the maximum number of flowers per plant was recorded when 100 mg l⁻¹ BA alone was used, resulting in an average of 4.37 flowers per plant, which revealed a substantial increase over the control and other concentrations of BA. The use of zinc (Zn) alone was also beneficial, and the maximum number of flowers (4.37) was recorded at 0.75% Zn concentration, which was slightly higher than the control but not as effective as the BA treatment at 100 mg l⁻¹ concentration. Considering the combined effect of BA and Zn, it was found that the maximum flowering (5.11 flowers per plant) was recorded when 100 mg l⁻¹ BA and 0.75% Zn were used simultaneously, which revealed a synergistic effect and was more effective than individual treatments. From the above discussion, higher concentrations of BA are most effective in enhancing the number of flowers per plant, and their combined use with zinc further increases flowering, which reveals the potential use of combined foliar application for maximizing flower production in zinnia plants.

Flower stems length (cm):

From the data presented in the Table 9, it is clear that the application of BA alone at a concentration of 50 mg l⁻¹ produced the longest length of the flower stem, which was 85.01 cm, and this shows that the higher the concentration of BA, the more it promotes the elongation of the stem of the zinnia plant. When considering the application of zinc (Zn) alone, the longest length of the stem, which was 88.18 cm, was produced by the application of 0.50% Zn, which shows that a moderate level of Zn is the one that optimally promotes the growth of the stem. However, the interaction effect of the application of both BA and Zn amplifies the effect, and the longest length of the stem, which was 90.03 cm, was produced by the interaction effect of the application of 50 mg l⁻¹ of BA and 0.50% Zn, which shows that the combined effect of the application of both BA and Zn is the one that significantly promotes the growth of the stem.

Table (9): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

Characteristics on Zinnia plants										
BA Mg l ⁻¹	Number of flowers per plant			Mean effect of BA	BA Mg l ⁻¹	flower (cm)	stem	length	Mean effect of BA	
	Zn%									Zn%
	0.0	0.50	0.75							
0	2.72 ^d	3.36 ^{cd}	3.33 ^{cd}	3.14 ^b	0	81.85 ^a	87.99 _a	82.54 ^a	84.12 ^a	
50	3.19 ^{cd}	3.42 ^{cd}	4.67 ^{ab}	3.76 ^a	50	80.60 ^a	90.03 _a	84.41 ^a	85.01 ^a	
100	3.92 ^{bc}	4.08 ^{ab} _c	5.11 ^a	4.37 ^a	100	81.58 ^a	86.53 _a	83.49 ^a	83.87 ^a	
Mean effect of Zn	3.28 ^b	3.62 ^b	4.37 ^a		Mean effect of Zn	81.34 ^b	88.18 _a	83.48 ^a _b		

Flower diameter (cm):

Based on the data presented in Table 10, the application of BA alone at 100 mg/l resulted in the minimum mean flower diameter of 7.23 cm among the different concentrations and control which give the highest results reaching 7.75 cm, indicating a negative effect of BA on flower diameter. When considering zinc (Zn) alone, the treatment with 0.50% Zn concentration produced a flower diameter of 7.61 cm, which is slightly higher than other Zn levels and control which give the minimum results reaching (7.25 and 7.59) cm respectively, suggesting that Zn at this level may promote larger flowers. The overall trend indicates that Zn independently contributes to increased flower diameter, with the optimal results observed at 0.50% Zn alone reaching 7.99 cm while the lesser flower diameter was found in BA at 100 mg l⁻¹ and Zn at 0.75 % reaching 6.69 cm.

Flower stem diameter (cm):

The most favorable results for flower stem diameter (cm) of zinnia plants were found in Table 10 when using 100 mg l⁻¹ of BA alone, as it gave the longest mean stem length of 0.42 cm. This shows that an increased concentration of BA enhances

flower stem diameter. When looking at the application of Zn alone, the results showed that when using 0.50% Zn, the flower stem diameter was similar at approximately 0.40 cm. This shows that Zn has a positive effect on the growth of flower stem diameter. It is interesting to see that when using a combination of BA at 100 mg l⁻¹ and Zn at 0.50%, the results showed an increased flower stem diameter of 0.45 cm, which is wider than when using either of these treatments alone. This shows a synergistic effect of BA and Zn on the flower stem diameter of zinnia plants. The results show that when using a combination of BA and Zn, the flower stem diameter of zinnia plants is increased, with the flower stem diameter found when using the highest concentration of BA and a moderate concentration of Zn.

Table (10): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

characteristics on zinnia plants					characteristics on zinnia plants					
BA Mgl ⁻¹	flower		diameter	Mean effect of BA	BA Mgl ⁻¹	flower		stem	diameter	Mean effect of BA
	(cm)					(cm)				
	Zn%					Zn%				
	0.0	0.50	0.75			0.0	0.50	0.75		
0	7.94 _a	7.99 ^a	7.32 ^a	7.75 ^a	0	0.36 ^a	0.37 ^a	0.36 ^a	0.36 ^b	
50	7.07 _a	7.59 ^a	7.74 ^a	7.46 ^a	50	0.38 ^a	0.39 ^a	0.39 ^a	0.39 ^{ab}	
100	7.77 _a	7.24 ^a	6.69 ^a	7.23 ^a	100	0.44 ^a	0.45 ^a	0.36 ^a	0.42 ^a	
Mean effect of Zn	7.59 _a	7.61 ^a	7.25 ^a		Mean effect of Zn	0.39 ^a	0.40 ^a	0.37 ^a		

Flower Dry Weight (g):

Data in Table 11 show the most optimal results for flower dry weight (g) were obtained at the highest concentration of BA and Zn. This indicates that when BA was applied at 100 mg l⁻¹, it produced the highest flower dry weight of 1.54 g. This shows that the 100mg l⁻¹ concentration of BA was optimal for flower dry weight. On the other hand, when zinc was applied at 0.50 % concentration, it produced the highest flower dry weight of 1.64 g among all the concentrations of zinc. This indicates that the optimal concentration for flower dry weight was the high concentration of zinc. When the combination of BA at 100 mg l⁻¹ and Zn at 0.50% was applied, the results showed that the flower dry weight increased to 1.81 g, which was wider than when the treatments were applied separately. This shows the synergistic effect of BA and Zn on the flower stem diameter of zinnia plants.

Vase life:

From the data presented in Table 11, it is noted that the best results regarding vase life were recorded when applying BA individually at a concentration of 100 mg l⁻¹, which recorded the highest vase life, reaching 11.01 days. indicating that benzyl

adenine increases the vase life of flowers to a greater degree than zinc at a higher concentration. When comparing the results of applying Zn, it is noted that the highest vase life is recorded at a concentration of 0.75%, reaching 10.78 days, this indicates that zinc plays a significant role in increasing the vase life of flowers. Finally, regarding the combined application of BA and Zn, it is noted that this application of BA at 100 mg l⁻¹ and Zn at 0.75% record a higher vase life reaching 10.78 day the value significant increase in some treatments in vase life, indicating a synergistic effect of this application. It is noted that applying zinc at a concentration of 0.75% is the best factor for increasing vase life, whereas applying benzyl adenine individually and in combination records a positive effect on increasing vase life, especially at higher concentrations.

Table (11): Effect of foliar application of BA and Zn concentration on different characteristics on zinnia plants

characteristics on banana plants											
BA Mgl ⁻¹	flower dry weight			Mean effect of BA	of	BA Mgl ⁻¹	vase life			Mean effect of BA	
	(g)										
	Zn%										
	0.0	0.50	0.75				0.0	0.50	0.75		
0	1.49 ^{ab}	1.48 ^a _b	1.32 ^a _b	1.43 ^a		0	9.53 ^b	9.56 ^b	10.08 ^a _b	9.72 ^b	
50	1.29 ^{ab}	1.65 ^a _b	1.09 ^b	1.34 ^a		50	9.78 ^b	9.75 ^b	10.74 ^a _b	10.09 ^b	
100	1.50 ^{ab}	1.81 ^a	1.29 ^a _b	1.54 ^a		100	9.92 ^b	11.33 ^a _b	11.78 ^a	11.01 ^a	
Mean effect of Zn	1.42 ^{ab}	1.64 ^a	1.23 ^b			Mean effect of Zn	9.74 ^a	10.21 ^a	10.87 ^a		

Discussion

The results show that each increase in BA and Zn has led to an increase in morphology, physiological parameter, and elemental composition. The growth morphology parameters studied included the number of days from planting to bud emergence, the number of days from planting to anthesis, the number of flowers per plant, stem length, flower diameter, stem diameter, flower dry weight, vase life as in (tables 1,2,3,4); also, plant height, number of branches, number of leaves, number of internodes, shoot dry weight, and leaf area as in (tables 5,6,7); physiological parameters included carbohydrate content, anthocyanin pigments, total chlorophyll content, and total carotene content; and elemental composition parameters included nitrogen content, phosphorus content, potassium content, and zinc content as in (tables 8,9,10,11). revealed that spray of BA at 50 and 100 mg l⁻¹ significantly delayed the flower bud appearance as compared to control. Hence, increase in concentration of putrescine and BA delayed the bud formation in zinnia plant. It has been reported that nutritional and climatic conditions during the growing period also play a major role in determining the flowering characteristics of plants.

Increase in number of days taken to bud appearance in Lilium by foliar spray of BA at 50 mg l⁻¹ has also been reported earlier [6]. Days taken to bud appearance and color showing also determine the earliness or late flowering of any cultivar thus, both habits are helpful in regulating the availability of flowers for longer period in the flower market reported by [7]. Similar to our study, delayed flowering has been reported by the application of BA in salvia and lilium crops earlier [10].

The maximum number of sprays per plant was obtained with BA at (100 mg l⁻¹) as compared to control. Besides this, BA at 50 mg l⁻¹. Similar to our research findings, effect of BA on increase in growth characters has also been reported by [5]. The longest stem length obtained with BA at 100 mg l⁻¹ BA as compared to control. There was significant increase in the cut stem length at all levels of BA over control (Table 3). Similarly, benzyl adenine (BA) increased stem length in salvia and tuberose as reported earlier [19; 10]. Similarly, increased vase life (table 4) with the application of BA at 100 mg l⁻¹ has also been reported earlier in gerbera [11].

The improvement in vegetative growth indicators when spraying with benzyl adenine (table 4.5) may be attributed to its role in increasing cell division and elongation, which enhances plant height. These positive impacts the number of leaves, leading to an increase in the outputs of biochemical reactions and photosynthesis, ultimately promoting plant growth and branching. As a result, the fresh and dry weight of the chrysanthemum plant increases, reflecting the physiological processes within it [39; 41].

Plant height is longer by spraying with a BA (table 4) compared with the control. This increase in stem length due to the role of the BA in cell elongation and division [2]. Cytokinin leads to increase the nitrogen content on leaves which is important in the formation of protein, nucleic acid, chlorophyll, enzyme, vitamins and plant hormones. In addition to the formation of cell membrane, ATP and NADP and amides [2]. [1] reported an increase in plant height of *Dianthus caryophyllus* L. by treated with 50 mg l⁻¹ of cytokinin. [2] also agree with these results, as increased in plant height of *Chrysanthemum hortorum* Hort. by treated with BA

Shoot dry weight was increased due to spray with a BA (table 7). Cytokines stimulate the movement and accumulation of food in leaves and increase dry weight. In addition to cells weight related to wall cellulose and water in it [35]. The leaf number of Zinnia plant increased by spraying with BA. This increase is caused by the effect of cytokinin in stimulating leaf primordia and increase cell division [1]. This effect agrees with [2] in his studies on *Chrysanthemum hortorum* observed an increase in leaf number due to sprayed with 50 mg l⁻¹ of BA. [1]. Leaf area increased due to spray with a BA (table 7). Cytokinin has

an important role in the movement of dissolvent to the side of sink source. Or maybe delay senescence and consequently increase leaf number [2]. Using regulators of growth of BA, increased rate of chlorophyll in leaves of Zinnia (table 7) this agree with *Zantedeschia aethiopica* plant [42]. In order for cytokinins to affect branching or flowering, they must be absorbed by the meristem or on the stem below it. Foliar sprays may be plant should be covered, Lower stem sprays have been used to stimulate branching in Monstera and Alocasia [40].

Foliar application of zinnia plants to Zn resulted in profound effect on flowering time and floral characteristics (1,2,3,4), rendering early flowering with Zn treatment. It could be attributed to the involvement of Zn in the synthesis of plant hormones. Optimum supply of Zn exhibits proper hormonal level within plants [9], which induces early maturity and thus causes early flowering [24]. Zinc application also improves the nutritional status within plants. Nutrients, sucrose and phytohormones move in combination from leaves to shoot apical meristem to induce early flowering. In Zn fertilized plants, their flower size also increased along with spike length, whereas Zn deficient conditions caused stunted flower size. Findings of our study correspond with that of [25] who documented improved flower size in gladiolus with adequate Zn supply.

Application of Zn extended the display life of zinnia cut flowers (table 4). Since cut flowers are prone to desiccation and oxidative stress during vase life; therefore, Zn being an activator of certain enzymes, could regulate anti-oxidative activity and membrane stability in the plants under stress. This study demonstrated the reduced membrane leakage under optimal Zn supply. Zinc prefers binding with

sulfohydryl group of the membrane protein and protects the phospholipids and proteins from disulfide formation and thiol oxidation [4]. This phenomenon resulted in reduced membrane leakage, and enhanced the vase life of cut flowers

Highest leaf area at tasseling stage might be attributed to highest leaf numbers (table 6 and 7). This result also followed the trend as studied by [29] where they quoted that combined treatment of foliar spray at 2% Zn. These values also followed the result of [23].

Foliar spray of Zn significantly increased plant height of Gerbera [20], increased height of Iris plants [18]. Similar results were observed by [36] in pot marigold. The result of [12] expressed that the use of foliar application stimulates plant growth and better development of plants, leading to the increase in morphological characters such as plant height.

Data presenting that different zinc levels had a significant effect on stem diameter (cm) of zinnia plant (Table3). It may be due to zinc is an essential constituent of cell component and constituents of the various cell membranes that are also important for the maintenance of cell structure and induce cell division resulted in enhanced vegetative growth like stem diameter [17]. The improvements in these characters might be due to enhancement in vegetative growth which is likely to be responsible for more accumulation of photosynthetic materials, hence resulted in giving maximum value in these characters. These findings are very similar to the findings of [8] in chrysanthemum. Spraying different Zinc levels had a significant effect on number of branches plant⁻¹ of zinnia plant (table 6), the result is similar with the [33]. reported that, number of branches increased in anise (*Pimpinella anisum*). Foliar application of ZnSO₄ significantly

increased the number of leaves per plant in Iris, [18]. Similarly, [13] observed a significantly higher number of leaves per plant in Gerbera due to foliar application of Zn.

Conclusion

The current study has shown that the application of benzyl adenine and zinc sulfate has a significant impact on the growth, flowering, and chemical characteristics of *Zinnia elegans* L. It has also shown that the application of a combination of 50 mg L⁻¹ BA and 0.75% zinc sulfate has the earliest flowering and the highest flower yield. Benzyl adenine has a significant impact on vegetative and flowering characteristics of the crop, whereas zinc sulfate has a positive effect on vegetative growth and pigments. The synergistic effect of the two growth regulators resulted in increased plant height, leaf area, and biomass. The application of the growth regulators also increased the biochemical parameters of the crop, including carbohydrates, anthocyanin, and nitrogen content, which play a vital role in the development of the flowers. The application of benzyl adenine and zinc sulfate has shown a promising result in the cultivation of Zinnia flowers.

Conflict of Interest

Regarding this manuscript, the authors disclose no conflicts of interest.

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