



Zinnia (*Zinnia Elegans* L.) Response to Foliar Spray of Triaccontanol and Zinc Sulfate

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Abstract:

The experimental study was conducted during the spring season of 2023 in Ghosn Nursery for Flower Production in Diyala Governorate to study the impact of foliar spraying with Triaccontanol and Zinc on the growth and flowering of zinnia plants. The experiment was designed according to randomized complete block design (RCBD) as a factorial experiment (4×4). The first stage in the experiment included planting seeds in cork plates containing peat moss; one seed was planted in each eye. The findings of this study can be concluded that foliar spraying with triaccontanol and Zinc sulfate (ZnSO₄) has significant superiority in all studied traits. The concentration of 18 mgL⁻¹ and 3 g L⁻¹ of triaccontanol and Zinc sulfate concentration respectively, was superior in all studied traits. This pioneering investigation explores applying zinc sulfate (ZnSO₄) as a targeted supplement, optimizing Zinnia growth and flowering. In addition to focusing specifically on the accompanying effect of triaccontanol and ZnSO₄ doses and holistically evaluating Zinnia performance.

Keywords: Flowering; Plant growth; Triaccontanol; Zinc sulfate; Zinnia plant.

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1. Introduction

Plants are sessile and subjected to several biotic (insects, diseases, etc.) and abiotic (drought, temperature, flooding, salt, heavy metals, etc.) environmental stresses (Balyan and Pandey, 2024). Physiological, morphological, biochemical, and molecular adaptations to various environmental stressors cause changes in the growth and metabolism of plants (Ali et al., 2025). The overall economic productivity, quantity, and quality of a wide range of crop plants are significantly limited by a number of environmental stress variables that affect the global agricultural framework (Yuan et al., 2024).

Zinnia elegans L. Annual summer flowers, English plant name youth and old age, the genus name Zinnia is taken from the name of the physician and botanist Gottfried Zinn. In contrast, the species name elegans means (charming or beautiful) (Tulub and Burda, 2023), Zinnia belongs to

the asteraceae family, which is one of the largest families in the plant kingdom, as many plants of this family are used in important medical treatments because they are a rich source of many phytochemicals and biological activity (Erilmez and Oz, 2023). They have been used in the manufacture of pharmaceutical treatments (Samy et al., 2022; Jaison et al., 2023). Dwarf zinnias are sensitive to salinity as high soil salinity affects leaf sodium and chloride concentrations, low potassium by about 15% and 25%, and low leaf chlorophyll content (Bandurska et al., 2023).

Triaccontanol (TRIA) is a natural plant growth regulator (fatty alcohol), which can replace synthetic growth regulators, which are harmful to human health and the environment. It is a straight chain of 30 carbon atoms with the molecular formula $\text{CH}_3(\text{CH}_2)_{28}\text{CH}_2\text{OH}$, and its chemical formula is $\text{C}_{30}\text{H}_{62}\text{O}$. Triaccontanol is a long-chain primary fatty alcohol with 30 carbon atoms, it has a molecular weight of 438.8192 g/mol, and a melting point of 86.5°C (Naeem et al., 2012). It serves to improve plant quality and productivity and is a natural plant growth regulator found in plant wax (Bandurska et al., 2023). Triaccontanol has been shown to have significant benefits for nitrogen fixation, photosynthesis, protein synthesis, plant growth, flowering, and enzyme activity (Islam & Mohammad, 2020; Cantaro-Segura & Huaranga-Joaquín, 2021; Colautti et al., 2023; Sarwar et al., 2022). Triaccontanol has a concentration-dependent impact; for instance, spraying plants with it enhances plant water stress, while low doses in the soil reduce plant salt stress (Verma et al., 2022). The effect of triaccontanol with high concentrations of elements, such as lead, significantly limits the plant stress and also leads to a major beneficial effect on plant seeds since treatment of plant seeds with Triaccontanol improves the plant resistance to environmental stresses which resulting in increased biomass and photosynthetic rate (Ahmed et al., 2022).

Foliar feeding is the process of spraying nutrient solutions on the vegetative system of the plant to supply the plant with the nutrients necessary for plant growth and to treat the deficiencies in these elements. Its availability is low for plants due to its ability to form insoluble aggregates, and it is necessary for many biological processes in the plant since it plays a part in several physiological and biochemical pathways (Mubashir et al., 2023; Zhao et al., 2025). Didur & Pansyryeva (2025) performed experiments revealed, the growing season of soybean plants altered under the impact of the climate factors and the latter and in turn, had an effect on the field germination and on the yield of the plants. It has also been established that in the course of the development of the plant, over the years of study, the vegetation period of soybean varied between 110 and 118 days but had the longest vegetation period on the experimental variants, that where seeds were inoculated with BTU Bioinoculant preparation and two foliar feeding were done at phase 3, when soybean had the third leaf and the budding helprost. Since the beginning of the flowering stage, soybean plants have become more responsive to the factors under study. On the options with the foliar fertilizing with helprost soy mineral fertilizer in the background of the inoculation, with BTU Bioinoculant, the flowering period took place 28 days longer by 3 days in comparison with areas without foliar fertilizing and 6 days in comparison with the control (Didur & Pansyryeva, 2025).

Zinc is a micronutrient that plays essential roles in plants, including enhancing water use efficiency, photosynthesis, protein synthesis, reactive oxygen species regulation, antioxidant function, membrane integrity maintenance, growth regulation, and vice versa gene expression (Wang et al., 2018; Noohpisheh et al., 2021), Zinc serves as a cofactor for more than 1,000 enzymatic processes and is essential for over 2,000 transcription factors (Lignicka et al., 2021). Thus, this study aims to evaluate the effect of foliar application of Triaccontanol and Zinc sulfate on vegetative, flowering growth, flower production, and the characteristics of the zinnia plant, since there is limited information available for influencing growth, flowering, and quality of the zinnia plant due to Triaccontanol. Zinc (Zn) is an essential microelement affecting many biochemical and physiological pathways in plants (Hamzah et al., 2022; Stanton et al., 2022). Zinnias are among the most popular selections for gardens worldwide due to their cheerful blooms and resilience in various conditions (El-Nashar & Aboelsaadat, 2020; Fadhil et al., 2024).

Nikipelova et al. (2024) documented that agricultural crops suffer from zinc deficiency, as almost 60% of Ukrainian soils are depleted in this micronutrient. Hence, the evaluated content in organic fertilizers should be favourable to the soils.

This pioneering investigation explores applying zinc sulfate ($ZnSO_4$) as a targeted supplement, optimizing *Zinnia* growth and flowering. While vital for plant health, past studies failed to systematically explore zinc's dose-response relationship across critical rose developmental stages. Nor did they comprehensively assess effects on vegetative traits like chlorophyll content, nitrogen, phosphorus, and potassium concentration, along with quality reproductive yields. Focusing specifically on the accompanying effect of triacontanol and $ZnSO_4$ doses and holistically evaluating *Zinnia* performance establishes this work as a novel contribution. Overall, the targeted and extensive nature of this research aims to better understand micronutrient supplementation across the ornamental industry.

2. Materials and Methods

The experiment was conducted at Ghosn Nursery for Flower Production in Diyala in the spring of 2023. The purpose of the experiment was to determine how foliar spraying with zinc and triacontanol affected the zinnia plant's growth and flowering. It ran from January 4, 2023, until July 20, 2023. Two factors were investigated in the experiment. The first component was the application of Triacontanol to foliar at different concentrations of 0, 10, 14, and 18 $mg.L^{-1}$, represented, successively, by Tr0, Tr5, Tr10, and Tr18. After 15 and 25 days of seedling life, the plants received two spray treatments of triacontanol. Zn0, Zn1, Zn2, and Zn3 stand for 0, 1, 2, and 3 $g.L^{-1}$, respectively. *Zinnia* L. seeds were imported. The research was conducted using a factorial experiment (4×4) following the Randomized Complete Block Design (RCBD) and started with the planting of seeds in cork dishes using the *Zinnia elegans* 'Magellan' cultivar, which was supplied by the Swiss seed production company Syngenta through one of the agricultural offices in Baghdad. The first phase in the research process was planting seeds in cork dishes that contained Peat moss. One seed was sown in each eye on March 14, 2022.

Table 1. Chemical and physical characteristics of soil used for agriculture.

Parameter	Value	Unit
Electrical conductivity (EC) (1:1)	2.45	Decisimens.m ⁻¹
pH (1:1)	7.12	-
Organic Matter (OM)	2.778	%
CaCO ₃	156.15	gm.kgm ⁻¹
<u>prefabricated items</u>		
Nitrogen (N)	29.90	mg.kgm ⁻¹
Phosphorus (P)	10.60	mg.kgm ⁻¹
Potassium (K)	210.7	mg.kgm ⁻¹
<u>Soil articulations</u>		
clay	111.0	gm.kgm ⁻¹
Silt	129.0	gm.kgm ⁻¹
Sand	760.0	gm.kgm ⁻¹
soil texture class		Sandy Loam

2.2 Studied Traits

2.2.1-leaf area (cm²)

The leaf area of the plant was calculated by selecting five leaves from each plant in the experimental unit using the scanner program Digimizer installed on the computer to measure the area of leaves according to the method described by Sadik et al (2011), and the total leaf area was calculated according to the following equation.

$$\text{Leafy area of the plant (cm}^2\text{)} = \text{number of leaves per plant} \times \text{average area of one leaf}$$

2.2.2-Leaves relative chlorophyll content (SPAD)

The relative chlorophyll content of leaves was estimated using a Minolta SPAD-502 as described by Van Der Berg & Perkins (2004).

2.2.3 -The percentage of nitrogen in the leaves

For this purpose, 5 leaves were taken from each experimental unit and dried in an electric oven at 65 degrees Celsius for 72 hours until the weight was stabilized in the second step; 0.2 g of the crushed sample was taken and 4 ml of concentrated sulfuric acid and 2 ml of concentrated perchloric acid were added to digest the same samples. nitrogen was calculated by the micro-kjeldahl device, following the method described by Bremner & Mulvaney (1982).

2.2.4- The percentage of phosphorus (P) in the leaves.

According to the procedure described by Jackson (1958), total phosphorus was measured using a spectrophotometer (UV) set to 882 nm and calculated using ammonium molybdate, as in the digestion method mentioned above.

2.2.5-The percentage of potassium (K) in the leaves

Potassium was measured using a flame photometer by the procedure suggested by Haynes (1980) after being approximated using the digestion method mentioned above.

2.2.6- Samples digestion

The sample was digested as previously mentioned, and Zinc was measured using an atomic absorption spectrophotometer/ method number 3500-Zn ZINC (AHPA, 2017).

2.2.7- Statistical analysis

The ANOVA test was applied through the Statistical Analysis System version 0.8 (SAS, 2003) to exhibit significant differences between all treatments under the study using Dunkin's test.

3. Results and Discussion

3.1. Leaf area (cm²)

In comparison to the control treatment, which recorded the smallest leafy area of 479.02 cm², the spraying treatment with a concentration of 18 mg L⁻¹ excelled in recording the largest leafy area of the plant, measuring 670.55 cm². The results of Table 2 demonstrated that the application of triacontanol produced a notable increase in the plant's leaf area.

The plant's leaf area increased significantly with each zinc sulfate spraying treatment, but the one with the highest concentration (3 g L⁻¹) produced the largest leaf area (665.33 cm²), while the comparison treatment produced the smallest leaf area (473.80 cm²).

The result in Table 2 showed that the interaction between the treatments of triacontanol and Zinc sulfate had a significant effect on the leaf area, and the Tr18×Zn3 treatment excelled in recording the largest leaf area of 951.10 cm², while the treatments Tr0×Zn0, Tr10×Zn0, and Tr14×Zn0 recorded the smallest leaf area of 197.03, 226.97, and 295.49 cm² in sequence.

The experiment's findings show that the foliar spraying of triacontanol on the plants had a significant effect on the vegetative growth characteristics of the *zinnia* plant, represented by the leaf area, the relative chlorophyll content in the leaves, and the percentage of potassium, nitrogen, and phosphorus in the leaves. The reason for this superiority in the vegetative growth characteristics of the plant may be attributed to the use of triacontanol. At an appropriate concentration (3mg.L⁻¹), as triacontanol has an important role in plant growth, protein synthesis, photosynthesis, nitrogen fixation, and increase the activity of enzymes in the plant, and the increase in fresh and dry weight of leaves as a result of spraying with the growth regulator triacontanol may be attributed to increased growth of By increasing the leaf area and thus increasing the surface of photosynthesis (Verma et al., 2022). And the cause of the increase in the amount of nutrients in the leaves due to spraying of triacontanol may be due to that triacontanol action increases the proportion of elements in the leaves in exchange for its physiological role in expanding and elongating and increasing the number of cells (Islam & Mohammad, 2020) it also works to increase the density and length of roots, which leads to an increase in plant absorption of the elements needed for ideal growth and thus an increase in plant height and number of branches (Hangarter et al., 1978) and an increase in permeability of membranes and the ability of the plant to absorb water and elements, as Verma et al. (2022) reported the increasing of the uptake of calcium and potassium during their study on the ability of triacontanol in improving the plant growth under stress. El-Kinany (2020) studied the influence of Triacontanol application on Pansy (*Viola wittrockiana* Gams) in growth, observing that Triacontanol produces chemical changes in the plant that increase the nitrogen content in the cell.

Table 2. Triacontanol and Zinc sulfate foliar spraying effect on the leaf area (cm²) of *Zinnia elegans* L.

Triacontanol intermediates	Zinc con. (gm.L ⁻¹)				Triacontanol concentrations (mg.L ⁻¹)
	Zn3	Zn2	Zn1	Zn0	
479.02 D	746.17 c	558.54 f	407.34 H	197.03 j	Tr0
535.57 C	865.32 b	606.02 e	456.91 G	226.97 j	Trp10
564.00 B	865.32 b	635.31 e	455.69 G	295.49 j	Tr14
670.55 A	951.1 a	700.35 d	554.14 F	431.38 gh	Tr18
	665.33 A	558.78 B	530.35 C	473.80 D	Zinc averages

Note: “Means with the same letter according to Dunkin's multiple range test ($P \leq 0.05$) does not differ significantly.

3.2. Leaves relative chlorophyll content (SPAD)

The data in Table (3) revealed that the relative chlorophyll content (RCC) in the leaves was significantly increased in all triacontanol spraying treatments, because the treatment spraying with a concentration of 18 mg L⁻¹ gave the highest relative chlorophyll content in the leaves, 50.47 SPAD degrees, while the check treatment gave the lowest relative chlorophyll content, the leaves contained 40.47 SPAD. The results indicated that all Zinc sulfate spraying treatments led to a substantial increase in the relative chlorophyll content in the leaves, and the spraying with 3 g.L⁻¹ concentration succeeded in reaching the highest relative chlorophyll content in the leaves of 47.50 SPAD, while the control treatment recorded the lowest relative chlorophyll content, were reached 39.22 SPAD in leaves.

Similarly, the interaction of the treatments of triacontanol and Zinc sulfate (ZnSO₄) significantly affected the relative chlorophyll content (RCC) in the leaves, and the treatment Tr18×Zn3 excelled in achieving the highest relative chlorophyll content in the leaves up to 60.22 SPAD compared with the treatment Tr0×Zn0, which exhibited the lowest RCC in the leaves of 35.22 SPAD.

Zinc sulfate has been singled out as a micronutrient that is of high importance during foliar application (Rossi et al., 2019). Zinc is an important catalyst in the activities of enzymes and plant growth control. The results of this research have shown that the foliar spray of zinc sulfate helps zinc-deficient plants as it improves the photosynthetic rate (Stanton et al., 2022). This synergistic action forms a basis to further research activities of enhancing the growth of *Zinnia elegans* by being very keen to the nutrient management. Experimental evidence also indicates that foliar zinc application had a significant effect on vegetative growth parameters of the zinnia, i.e. leaf area and relative chlorophyll content (Singh et al., 2025), and the foliage levels of phosphorus, nitrogen, and potassium (Irmes et al., 2023). Chlorophyll formation acts as a catalyst in numerous reactions in plant metabolism and hence leads to increased chlorophyll content in the leaves and enhances the efficiency of the photosynthesis process, which also results in increased plant height (Kamiński et al., 2024). The Amino acid tryptophan production is probably zinc's greatest function, essential for forming the plant growth hormone indole acetic acid (IAA) (Pollmann et al., 2009). This hormone promotes cell division and stimulates the activity of meristematic cells in plants, cell division and expansion in plants, and it takes part in the other activities of plant cells, and the composition of the plasma membrane, while giving massive protection against oxidation to plant cells (Sun et al., 2023). Zhao et al. (2024) used foliar spraying of Zn on sugar beet crops (*Beta vulgaris L.*) and found it had a positive effect on the leaf growth and increased Mg and Ca uptake capabilities in Mg-depleted sugar beet leaves, concomitantly raising photosynthetic pigment content, also increasing biomass and SPAD in the leaves. In addition, it improved the opening rate of the photosystem II reaction center and the function of the photosystem II reaction center, which led to higher leaf quantum yield, enhanced electron transport efficiency (Shanker et al., 2024).

This has been extended with studies into the synergistic effects of different agronomic treatments on the outcomes of plant growth. Triacontanol mixed with zinc sulfate was proven to have a polycentric effect on growth booster in *Zinnia elegans*. Hormonal reactions caused by triacontanol, along with nutritional contribution mediated by zinc sulfate, form a strong base that promotes the intensive growth of the plants of zinnia. Besides, zinc sulfate is a key factor in the foliar responses, as it provides the required micronutrients, thus increasing the rate of photosynthesis and growth in *Zinnia elegans*.

Table 3. Triacontanol and Zinc foliar spraying Effect on the relative chlorophyll content in leaves (SPAD) of *Zinnia elegans L.*

Triacontanol intermediates	Zinc con. (gm.L ⁻¹)				Triacontanol concentrations (mg L ⁻¹)
	Zn3	Zn2	Zn1	Zn0	

40.47 D	45.22 g	43.22 h	38.22 j	35.22 k	Tr0
44.38 C	50.22 d	45.88 f	43.22 h	38.22 j	Trp10
47.22 B	55.22 b	48.22 e	45.22 g	40.22 i	Tr14
50.47 A	60.22 a	53.22 c	45.22 g	43.22 h	Tr18
	47.50 A	47.63 B	42.97 C	39.22 D	Zinc averages

Note: "Means with the same letter according to Dunkin's multiple range test ($P \leq 0.05$) does not differ significantly"

3.3. Nutrients

3.3.1 Nitrogen percentage (N%) in the leaves

According to Table 4, the percentage of nitrogen (N%) in the leaves was significantly impacted by the triacontanol spraying treatments. The nitrogen percentage in the leaves increased to 2.39 % with the spraying treatment at a concentration of 18 mg L⁻¹, while the control treatment recorded the lowest percentage of nitrogen in the leaves, which reached 2.23 %.

It was found that all Zinc sulfate spraying treatments had a significant effect on the percentage of nitrogen in the leaves, and the spraying treatment with a concentration of 3 g L⁻¹ led to an increase in the percentage of nitrogen in the leaves, reaching 2.36 %, compared to the control treatment, which recorded a rate of 2.14 %.

The nitrogen percentage (N%) in the leaf was affected significantly by the interaction treatments of spraying triacontanol and ZnSO₄ (Table 4). The application of Tr18×Zn3 exhibited the highest N% in the leaves (2.58%) compared to the optimum one (2.11%) recorded with Tr0×Zn0.

Table 4. Triacontanol and Zinc sulfate foliar spraying effect on the N% in the leaves of *Zinnia elegans* L.

Triacontanol intermediates	Zinc con. (gm.L ⁻¹)				Triacontanol concentrations (mg L ⁻¹)
	Zn3	Zn2	Zn1	Zn0	
2.23 D	2.34 d	2.21 gf	2.12 hi	2.11 i	Tr0
2.28 C	2.44 bc	2.35 d	2.18 gh	2.13 hi	Trp10
2.33 B	2.50 b	2.43 c	2.27 ef	2.14 hi	Tr14
2.39 A	2.58 a	2.47 bc	2.31 de	2.19 gh	Tr18
	2.46 A	2.37 B	2.22 C	2.14 D	Zinc averages

Note: "Means with the same letter according to Dunkin's multiple range test ($P \leq 0.05$) does not differ significantly"

3.3.2 phosphorus percentage (P%) in leaves

As demonstrated by Table 5, the foliar spray treatment of triacontanol indicated a significant effect on P% in leaves. The foliar spray triacontanol treatment increased P% in leaves with 0.33 % in a concentration of 18 mg L⁻¹, compared with the control treatment, which had the lowest value of 0.21 %.

The effects of the different concentrations of zinc sulfate spraying on the P% in the leaves were significant for all spraying treatments. The treatment with a concentration of 3 g L⁻¹ gave a higher percentage of phosphorus (P%) in the leaves in comparison to the control treatment, 0.36% and 0.16%, respectively.

The interaction treatment of spraying zinc sulfate and triacontanol had a significant impact on the P% in the leaves, and the application of triacontanol and zinc sulfate at Tr18×Zn3 led to an increase in the phosphorus percentage (P%) in the leaves to 0.43%, while the highest percentage was found in the leaves when the treatment Tr0×Zn0 reached 0.15%.

Table 5. Triacontanol and Zinc sulfate foliar spraying Effect on phosphorus percentage in the leaves (%) of *Zinnia elegans* L.

Triacontanol intermediates	Zinc con. (gm.L ⁻¹)				Triacontanol concentrations (mg L ⁻¹)
	Zn3	Zn2	Zn2	Zn0	
0.21 C	0.27 d-h	0.23 fgh	0.16 i	0.15 i	Tr0
0.23 C	0.33 cd	0.20 ghi	0.21 hig	0.16 hi	Tr10
0.29 B	0.43 ab	0.32 cde	0.26 efg	0.15 i	Tr14
0.33 A	0.43 a	0.36 ab	0.30 c-f	0.19 hi	Tr18
	0.36 A	0.29 B	0.24 C	0.16 D	Zinc averages

Note: "Means with the same letter according to Dunkin's multiple range test ($P \leq 0.05$) does not differ significantly"

3.3.3 Potassium percentage (K%) in the leaves

The effect of triacontanol spraying treatments was found to be significant with the potassium percentage (Table 6). The treatment of spraying with 18 mgL⁻¹ showed a high leaf potassium percentage value (2.37 %) in the leaves compared with the control treatment (1.61 %) for the leaf potassium percentage.

It was observed that all of the zinc sulphate spraying treatments had a very significant effect on the percentage of potassium in the leaves, and spraying with a concentration of 3 gm L⁻¹ gave vegetative growth to raise the percentage of potassium in the leaves to 2.13 %, accompanied by the control treated at 5 was 1.63 %.

Triacontanol and zinc sulfate spraying interactions had a notable impact on the leaves' potassium content, and the treatment Tr18×Zn3 increased the percentage of potassium in the leaves and amounted to 2.73 %, while the highest percentage was when the treatment Tr0×Zn0 reached 1.47 %.

Table 6. Triacontanol and Zinc sulfate foliar spraying Effect on the potassium percentage (%) in leaves of the Zinnia plant (*Zinnia elegans* L).

Triacontanol intermediates	Zinc con. (gm.L ⁻¹)				Triacontanol concentrations (mg L ⁻¹)
	Zn3	Zn2	Zn1	Zn0	
1.61 C	1.48 h	1.85 def	1.61 efg	1.47 h	Tr0
1.71 C	1.67 fgh	1.85 def	1.81 fgh	1.53 gh	Trp10
2.10 B	2.66 ab	2.15 cd	2.01 de	1.61 fgh	Tr14
2.37 A	2.73 a	2.37 bc	2.47 ab	1.89 def	Tr18
	2.13 A	2.05 B	1.97 B	1.63 C	Zinc averages

Note: "Means with the same letter according to Dunkin's multiple range test ($P \leq 0.05$) does not differ significantly"

The increase in the percentage of potassium, phosphorus and nitrogen in the leaves may also be attributed to the action of Zinc on increasing the photosynthetic activity of the plant by regulating the work of stomata, which is necessary to maintain the structure and function of chloroplasts and thus increase the efficiency of the plant in absorbing those elements, which leads to the accumulation of elements in the plant and thus increasing its percentage in the leaves, and Zinc increases plant resistance to abiotic stress conditions as it acts as an antioxidant in the plant (Guo et al., 2022; Zuluaga et al., 2023), these outcomes align with Ahmadi et al. (2024) findings regarding the application of zinc sulfate to the Safflower Seed Yield (*Carthamus tinctorius* L.), their study demonstrated that the application of zinc sulfate can reduced the negative effects of unfavorable environmental conditions, significantly improving crop yields as well as nitrogen, phosphorus, potassium, zinc, and iron content in harvested seeds. Their findings demonstrated how foliar spraying expedites micronutrient absorption by plants, enabling quicker remediation of deficiencies compared to traditional soil-based applications. In the analysis made by Ahmad et al. (2024), stated that the supplementation of zinc improves yield with the normal agronomic conditions and also regulates drought and heat tolerance in crops that are exposed to environmental stressors. It is noteworthy that foliar applications at the early growing season seemed to have the most significant impact on end-of-season yields, presumably because they provided the critical nutritional input at the very beginning of crop development.

3.4. The number of petals (inflorescence petal⁻¹)

The results in Table 7 indicated that the treatments from triacontanol had significantly influenced the number of petals; The control treatment recorded the lowest number of inflorescence⁻¹ petals (82.63), whereas the spraying treatment with a concentration of 18 mg L⁻¹ increased the number of petals to 96.60

All spraying treatments of Zinc sulfate (ZnSO₄) were observed to be significantly effective on petals number. 3 g L⁻¹ concentration of the spraying treatment significantly increased petals number up to 100.99 petals inflorescence⁻¹ as compared with the control treatment (78.21 petals inflorescence⁻¹).

The interaction treatments between spraying triacontanol and Zinc sulfate demonstrated a significant effect on the number of petals, and the treatment Tr18×Zn3 increased the number of petals and amounted to 112.33 petals of inflorescence⁻¹, while the lowest number of petals was in the treatment Tr0×Zn0 and amounted to 71.01 petals of inflorescence⁻¹.

According to Sarwar et al. (2020), triacontanol spraying had a significant impact on the flowering growth parameters of the zinnia plant, that is, the number of inflorescences and petals, and on photosynthesis. Bhandari et al. (2021) attributed the treatment-induced increase in petal numbers in inflorescences, numbers, and diameters of inflorescences to triacontanol application that, if done at the right concentration, improved vegetative plant growth and thus enabled more synthesis and accumulation of photosynthetic materials, which ultimately increased petals and inflorescences in number and flowerpots in diameter.

Table 7. Triacontanol and Zinc sulfate foliar spraying effect on the petals number (inflorescence plant⁻¹) of *Zinnia elegans* L.

Triacontanol intermediates	Zinc con. (g.L ⁻¹)				Triacontanol concentrations (mg L ⁻¹)
	Zn3	Zn2	Zn1	Zn0	
82.63 D	91.00 d	86.51 f	82.00 g	71.01 i	Tr0
88.46 C	99.87 c	89.98 e	86.01 f	78.01 h	Trp10
91.22 B	100.76 b	91.01 d	91.22 D	81.90 g	Tr14
96.60 A	112.33 a	100.89 b	91.25 d	81.93 g	Tr18
	100.99 A	92.09 B	87.62 C	78.21 D	Zinc averages

Note: "Means with the same letter according to Dunkin's multiple range test ($P \leq 0.05$) does not differ significantly"

4. Conclusions

This experiment found that triacontanol and zinc sulfate (ZnSO₄) foliage treatments promote vegetative and reproductive growth of the species of zinnia. The foliar spraying of triacontanol on the plants had a significant effect on the vegetative growth characteristics of the zinnia plant, represented by the leaf area, the relative chlorophyll content in the leaves, and the percentage of potassium, nitrogen, and phosphorus in the leaves. Plants treated with triacontanol at a concentration of 18mg L⁻¹ had enhanced growth and flowering properties, which led to high quality infloescences. Zinc sulfate foliar application had a significant effect on growth and flowering characteristics, but the concentration that provided the most desirable results for the assessed characteristics was above 3 g/L. Therefore, it is proposed that more experiments should be carried out to explain the influence of triacontanol and zinc sulfate spraying on other ornamental species, and the application concentration, spray frequency, application number, and combined effects on growth enhancement should be considered.

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