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RESEARCH ARTICLE

Effect of zinc and potassium humate spraying on growth and yield of tomato (*Solanum lycopersicum* L.)

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Abstract

This study was carried out in a greenhouse associated to the College of Technical Agriculture in Al-Musayyab (32°36′59″ N, 44°22′25″ E) during the 2024 -2025 growing season. The objective was to assess how commercial potassium humate fertilizer (PowHumus WSG 85) at five levels (0, 10, 15, 20 and 25 mL L^{-1}) and zinc spray at three levels (0, 10 and 20 g L^{-1}) interacted to enhance *S. lycopersicum* L. plant growth and productivity. The experiment was laid out in a randomized complete block design (RCBD) with three repetitions, using a drip irrigation system. Seedlings (40 days old) were transplanted at 40 cm spacing. Two foliar spraying were applied: the first 20 days after transplanting and the second, 20 days later. Measurements included: plant height, total number of leaves, number of flower cluster, number of flowers, number of fruits, fruit weight and total yield per plant. The best results were obtained by the combination with the maximum concentration of potassium humate (25 mL L^{-1}) and zinc (20 g L^{-1}), which produced notable changes. The following values were attained: 36.3 leaves, 8.03 panicles, 67.2 flowers, 23.8 fruits, 83.4 g of fruit weight, 84.2 cm of plant height and 1984.9 gm $plant^{-1}$ for total yield. Based on these results, it is possible to enhance the vegetative growth, flowering and production of tomatoes cultivated in protected environments by utilizing the combination of zinc and potassium humate. Future studies across varieties and environments are recommended to validate these results and assess economic feasibility before large-scale adoption in sustainable fertilization programs.

Keywords: foliar application; humic acid fertilizer; protected cultivation; sustainable agriculture; tomato yield; zinc spraying

Introduction

Zinc is essential micronutrient that is necessary for the growth and development of all plant species. It supports the structure and activity of enzymes such as catalase, peroxidase and cytochrome oxidase, which drive anabolic, catabolic and redox reactions (1). Zinc is also vital for chlorophyll formation through its role in cytochromes and phytosterols; besides, it influences nucleic acid function and plant-protein biosynthesis. In addition, zinc activates numerous enzymes important for overall plant health and promotes tryptophan production-the precursor of indole acetic acid (IAA), which regulates cell elongation and division. Deficiency results in severe stunting of tomato plants, with symptoms including short stems, upward-curled leaflets and mottled spotting (2, 3).

Because of the high lime component, the majority of soils in central Iraq have an alkaline tendency. This renders certain nutrients inaccessible and hinders their absorption by plant roots (4). Therefore, when the soil lacks readily available zinc, plants cannot absorb enough of this nutrient to satisfy their essential requirements (5, 6). Small doses of organic fertilizers including humic acids have been employed recently to enhance soil qualities, feed plants, quicken growth and boost output. The most prevalent kind of humic material is humates, which are complex compounds produced by the breakdown of organic materials (7).

Humic acids have a positive effect on how well plants absorb nutrients by making components, especially micronutrients, more accessible and transferable. Humic acids' amine group makes it easier for negatively charged phosphate ions to adsorb, which increases the ions' availability to plants (8). Additionally, humic acids increase auxin (IAA) activity, which is crucial for supporting root and plant development by inhibiting the enzyme indole-3-acetic acid oxidase (IAA oxidase). By binding to sodium, humic acids also increase the soil's ability to retain elements, allowing plants to withstand high quantities of that element while guarding against toxicity and osmotic issues (9). It is advantageous to add humic acids to the soil or plant because they fill it with nutrients and greatly improve the plant's resistance to heat and drought. Additionally, it promotes better and more root growth (10).

Improvement in plant growth metrics, such as the dry weight of the vegetative and root systems, fruit weight, fruit yield per plant and the percentage of total soluble solids in tomato juice was observed following the application of humic acid to the soil and foliar spraying at a concentration of 20 mL L^{-1} administered multiple times (11). They also found that when potassium humate was added to the soil or sprayed at a rate of 20 mL L^{-1}, three separate applications were made and the pepper plants produced the maximum fruit weight, early yield and overall yield. Potassium humate application to tomato plants produced significantly better results than the 20 mL L^{-1} treatment (12). Potassium humate resulted in the highest averages for plant height, leaf number, flower number, fruit weight, fruit count and total fruit yield (13).

S. lycopersicum L. are among the world's most important vegetable crops, with global production exceeding 180 million tonnes and major producers including China, India, the United States, Turkey and Egypt. They provide key nutrients such as calcium, phosphorus, iron, vitamins A, C and B, making them a vital food source (14). In Iraq, tomatoes are the leading vegetable crop and are increasingly grown in greenhouses to meet rising demand. Intensive cultivation can deplete soil nutrients; therefore, growers apply zinc, vital for enzyme activation and protein synthesis and potassium humate, which enhances soil structure and nutrient uptake, to improve plant vigor, flowering and yield while preserving fruit quality (9, 15).

Due to the limitations of previous studies, this research was conducted to evaluate the effects of zinc and the organic fertilizer potassium humate on tomato growth and productivity.

Materials and Methods

The study was conducted in the greenhouse of Al-Musayyab Technical College according to an RCBD with three replicates during the 2024-2025 agricultural season. The experiment included two treatments: the first was a zinc spray at three concentration (0, 10 and 20 g L^{-1}) and five levels of potassium humate fertilizer (0, 10, 15, 20 and 25 mL L^{-1}), which is PowHumus (WSG 85), produced by the German company D-40549. Certain specifications of the potassium humate fertilizer used in the experiment were given in Table 1.

Following sterilization, the greenhouse soil was tested to ensure uniform fertility and health across the site, confirming similar physical and chemical properties in all planting areas. The area was then systematically partitioned into five terraces, each 150 cm wide (with a 50 cm channel and a 100 cm walkway). Irrigation was applied two days before planting, after which tomato seedlings (*S. lycopersicum* L., cv. Haidari, a local Iraqi variety-well adapted to the country's climatic and soil conditions) sourced from a local private farm of 40 days old with 3-4 true leaves were transplanted on both sides of each terrace at 40 cm spacing on September 25, 2024. A total of ten plants were designated for the experimental unit. The drip irrigation system was strategically installed above the terrace walkway, positioned 10 cm from the seedling location, while a distance of 1 m was maintained at both the commencement and conclusion of the greenhouse structure. Maintenance activities such as patching, weeding, pruning and training were executed on a single stem, involving the removal of lateral branches and aged leaves in a uniform manner across all experimental units. Mineral fertilizers were administered at a rate of 2250 kg ha^{-1} of ammonium sulphate and 100 kg $dunum^{-1}$ of triple superphosphate in two applications during the vegetative and floral growth phases, in accordance with standard practices for cultivating the crop in greenhouse environments (16). Soil samples (0-30 cm) were air-dried, gently crushed and sieved to 2 mm before analysis. Soil pH was determined in a 1:2.5 soil–water suspension using a calibrated glass-electrode pH meter and electrical conductivity (EC) was measured in a 1:5 soil–water extract with a conductivity meter (ISO 10390; ISO 11265). Organic carbon was estimated by the Walkley-Black dichromate oxidation method and converted to organic matter using a factor of 1.724 (17). Organic matter (OM) content was further verified using the loss-on-ignition (LOI) method by heating air-dried soil at 550 °C for 4 hr and calculating the weight loss. The cation exchange capacity (CEC) was determined using the ammonium acetate saturation method at pH 7.0, which measures the total exchangeable cations per unit weight of soil (17). Available nitrogen (NH^{4+} and NO^{3-}) was extracted with 2 M KCl and quantified colorimetrically (17). Plant-available phosphorus was measured by the Olsen sodium bicarbonate method (0.5 M $NaHCO_3$, pH 8.5) with molybdenum blue colorimetry, while exchangeable potassium was extracted with 1 M ammonium acetate (pH 7.0) and analyzed by flame photometry (17). Available zinc and other micronutrients were determined using the DTPA extraction method (0.005 M DTPA, 0.01 M $CaCl_2$, 0.1 M triethanolamine, pH 7.3) followed by measurement with atomic absorption spectrophotometry (18).The specifications of the soil used in the experiment were provided in Table 2.

Two phases of spraying were conducted, viz., 20 days following transplanting and another 20 days following the initial spray. Early in the morning, plants were sprayed and distilled water was used as the control treatment. Four plants on average per experimental unit were used to measure the following attributes:

1. **Plant height (cm):** At the conclusion of the growing season, the height of the plant was measured from the soil surface to the terminal tip.
2. **Total number of leaves:** The main stem's fully grown leaf count was determined.
3. **Number of flower clusters:** During the growing season, the number of flower clusters that developed on the plant was determined.

Table 2. Specifications of the soil used in the experiment

Property	Unit	Value
EC	dS m^{-1}	3.4
pH	---	7.6
O.M	g kg^{-1} soil	8.9
CEC	cmol kg^{-1} soil	14.7
$CaCo_3$	g kg^{-1} soil	201
Available N		23.7
Available P	mg kg^{-1} soil	7.2
Available K		126.4
Bulk density	mg m^{-3}	1.47
Sand		458.4
Silt	g kg^{-1} soil	370.6
Clay		171
Texture		Loam

Table 1. Certain specifications of potassium humate fertilizer used in the experiment

Component	Moisture	Water solubility	Humates	Potassium	Dry matter	N	Iron
Percentage (%)	14	99.8	85	12	86	0.8	1

4. **Total number of flowers:** The plant's total number of blooms was determined.
5. **Fruit count per plant:** The fruit count per plant was determined.
6. **Fruit weight (g):** Each treatment's fruit weight was determined.
7. **Plant yield (kg):** The number of fruits per plant and the average fruit weight were determined.

The results were statistically examined (19) and the least significant difference test was used to examine mean differences at a 5 % probability level.

Results and Discussion

Plant height

Current findings showed that there were significant differences in plant height between the zinc and potassium humate spray treatments and their interaction (Table 3). In comparison to the control (no zinc spray), which produced the lowest average of 70.3 cm, the zinc spray treatment (20 g L^{-1}) worked noticeably better, providing the highest average of 76.8 cm. Regarding the potassium humate spray component, the 25 mL L^{-1} treatment worked noticeably better than the control (no humate spray), producing the greatest average of 81.6 cm as opposed to the low average of 65.3 cm. The treatment (20 g L^{-1} zinc + 25 mL L^{-1} potassium humate) produced the greatest average of 84.2 cm in terms of the interaction between the two components, greatly outperforming the control treatment (without zinc spray and without humate spray), which gave the lowest average of 62.7 cm.

Number of leaves per plant

The number of leaves per plant trait varied significantly between the zinc and potassium humate spray treatments and their interaction (Table 4). The zinc spray treatment (20 g L^{-1}) produced the highest average of 62.8 leaves per plant, which was significantly superior to the control treatment (no zinc spray), which produced the lowest average of 56.3 leaves per plant. In comparison to the control treatment (no humate spray), which generated the lowest average of 50.1 leaves per plant, the treatment (25 mL L^{-1}) produced the greatest average of 70.7 leaves per plant. Considering the interactions between the two components, with a high average of 76.3 leaves per plant, the therapy (20 g L^{-1} zinc + 25 mL L^{-1} potassium humate) was noticeably better; In contrast to the control, which produced the lowest average of 48.1 leaves per plant.

Number of flower clusters per plant

The relationship between the spray treatments of potassium humate and zinc was demonstrated in Table 5. The zinc spray treatment (20 g L^{-1}) yielded the highest average of 6.88 clusters, which was significantly superior to the control (no zinc spray), which produced the lowest average of 6.14 clusters. In comparison to the control (no humate spray), which produced the lowest average of 5.52 clusters, the potassium humate treatment at a concentration of 25 mL L^{-1} produced the greatest average of 7.53 clusters. In terms of how the two elements interacted, the treatment that produced the greatest average of 8.03 clusters (20 g L^{-1} zinc + 25 mL L^{-1} potassium humate) was noticeably better than the control treatment, which produced the lowest average of 5.27 clusters.

Number of flowers per plant

The findings in Table 6 showed that the amount of flowering per plant varies greatly depending on zinc and potassium humate treatment and how they interacted. Unlike control treatment (no zinc spray), which gave the lowest average of 52.4 flowers per plant, zinc spray treatment (20 g L^{-1}) was much better, giving the highest average of 57.5 flowers per plant. The treatment (25 mL L^{-1}) produced the highest average of 63.7 flowers per plant, which was substantially better than the control (no humate spray), which produced the lowest average of 47.7 flowers per plant. Regarding the interaction between the two factors, the treatment (20 g L^{-1} zinc + 25 mL L^{-1} potassium humate) was significantly superior, yielding the highest average of 67.2 flowers per plant, compared to the comparison control yielded the lowest average of 46.8 flowers per plant.

Number of fruits per plant

The data presented in Table 7 showed substantial differences in the number of fruits per plant feature between the zinc and potassium humate spray treatments and their interaction. The zinc spray treatment (20 g L^{-1}) generated the highest average of 19.8 fruits per plant, which was significantly superior to the control treatment (no zinc spray), which produced the lowest average of 17.4 fruits per plant. The 25 mL L^{-1} treatment generated the highest average of 22.6 fruits per plant, showing a significant improvement in the potassium humate spray factor, while the control treatment (no humate spray) produced the lowest average of 15.0 fruits per plant. The interaction between the two factors the control treatment with no zinc spray and no potassium humate application produced the lowest average of 14.3 fruits per plant.

Average fruit weight

Table 8 indicates that the individual effects of zinc and potassium humate sprays, as well as their combined interaction, significantly influenced the average fruit weight. The zinc spray treatment (20g L^{-1}) resulted in the highest average fruit weight of 75.5 g, which was significantly greater than that of the control (no zinc spray), which had the lowest average of 69.5 g. The potassium humate spray treatment at 25 mL L^{-1} produced an average fruit weight of 80.1 g, significantly higher than the control treatment (no humate spray), which had the lowest average of 64.8 g. Regarding the combined effect of the two factors, the treatment of 20 g L^{-1} zinc + 25 mL L^{-1} potassium humate produced the highest average fruit weight of 83.4 g, compared with the control treatment (without zinc and without potassium humate sprays, which had an average of 64.8 g).

Fruit yield

The zinc and potassium humate spray treatments, as well as their interaction in the trait of plant fruit yield, differed significantly (Table 9). In comparison to the control treatment (no zinc spray), which produced the lowest average of 1222.0 g, the zinc spray treatment (20 g L^{-1}) was noticeably better, yielding the highest average of 1511.5 g. The treatment (25 mL L^{-1}) produced the highest average of 1810.7 g for the potassium humate spray factor, which was significantly better than the control (no humate spray), which produced the lowest average of 973.9 g. The treatment that produced the highest average of 1984.9 g per plant for the interaction treatments between the two variables was 20 g L^{-1} zinc + 25 mL L^{-1} potassium humate compared to the control (without zinc spray and without humate spray), which gave the lowest average of 892.3 g.

Table 3. The effect of spraying potassium humate and zinc on the height of tomato plants

Potassium humate (mL L^{-1})	Zinc (g L^{-1}) 0	Zinc (g L^{-1}) 10	Zinc (g L^{-1}) 20	Mean
0	62.7	64.2	68.9	65.3
10	65.3	69.6	73.2	69.4
15	70.4	72.5	77.5	73.5
20	73.9	78.1	80.4	77.5
25	79.2	81.3	84.2	81.6
Mean	70.3	73.1	76.8	

Table 4. The effect of spraying potassium humate and zinc on the number of leaves

Potassium humate (mL L^{-1})	Zinc (g L^{-1})			Mean
	0	10	20	
0	48.1	49.7	52.4	50.1
10	50.7	53.1	55.8	53.2
15	55.4	58.2	61.7	58.4
20	61.7	64.8	67.9	64.8
25	65.8	70.1	76.3	70.7
Mean	56.3	59.2	62.8	
LSD 0.05	Zinc	Humate	Interaction	
	2.65	3.02	5.43	

Table 5. Effect of potassium humate and zinc spray on the number of flower clusters

Potassium humate (mL L^{-1})	Zinc (g L^{-1})			Mean
	0	10	20	
0	5.27	5.46	5.82	5.52
10	5.52	5.87	6.33	5.91
15	6.11	6.46	6.89	6.49
20	6.67	6.98	7.35	7
25	7.11	7.46	8.03	7.53
Mean	6.14	6.45	6.88	
LSD 0.05	Zinc	Humate	Interaction	
	0.32	0.51	0.78	

Table 6. Effect of potassium humate and zinc on the number of flowers per plant

Potassium humate (mL L^{-1})	Zinc (g L^{-1})			Mean
	0	10	20	
0	46.8	47.5	48.8	47.7
10	48.1	49.7	52.6	50.1
15	51.4	54.2	57.8	54.5
20	55.8	58.9	61.3	58.7
25	60.1	63.8	67.2	63.7
Mean	52.4	54.8	57.5	
LSD 0.05	Zinc	Humate	Interaction	
	2.47	3.89	6.22	

Table 7. The effect of spraying potassium humate and zinc on the number of fruits per plant

Potassium humate (mL L^{-1})	Zinc (g L^{-1})			Mean
	0	10	20	
0	14.3	14.9	15.8	15
10	45.3	16.4	17.6	16.4
15	16.9	18.5	20.1	18.5
20	18.9	20.4	21.8	20.4
25	21.5	22.4	23.8	22.6
Mean	17.4	18.5	19.8	
LSD 0.05	Zinc	Humate	Interaction	
	1.13	2.04	2.88	

Table 8. The effect of spraying potassium humate and zinc on the average fruit weight

Potassium humate (mL L^{-1})	Zinc (g L^{-1})			Mean
	0	10	20	
0	62.4	64.3	67.8	64.8
10	65.1	68.9	71.9	68.6
15	69.5	72.5	75.2	72.4
20	73.4	76.2	79.1	76.2
25	77.2	79.8	83.4	80.1
Mean	69.5	72.3	75.5	
LSD 0.05	Zinc	Humate	Interaction	
	2.84	3.92	6.25	

Table 9. The effect of spraying potassium humate and zinc on the plant's fruit yield

Potassium humate (mL L-1)	Zinc (g L-1)			Mean
	0	10	20	
0	892.3	958.1	1071.2	973.9
10	996	1130	1265.4	1130.5
15	1174.6	1341.3	1511.5	1342.5
20	1387.3	1554.5	1724.4	1555.4
25	1659.8	1787.5	1984.9	1810.7
Mean	1222	1354.3	1511.5	
LSD 0.05	Zinc	Humate	Interaction	
	14.27	20.38	33.47	

During the current study, the increase in growth indicators and yield following zinc spraying for the treatment at a level of 20 g L^{-1} was reflected in higher average plant height, total number of leaves, number of flower clusters, number of flowers per plant, number of fruits per plant, fruit weight and overall fruit yield. This improvement can be attributed to the efficiency of the foliar spraying method in increasing zinc content in plants and accelerating vegetative growth, which enhanced zinc absorption by the leaves through proportionally timed doses, thereby achieving the highest averages for the studied traits (20). It also reflects the efficiency and speed of its absorption and the plant's preference for it through different methods, which achieved a significant response in tomato plant production due to its absorption, assimilation and contribution to vital processes and growth indicators such as plant height, inflorescences and increased production, which enhances the fact that the cultivated tomato variety is a high-yielding hybrid variety with a high response to added zinc fertilizers. Added zinc also plays a role in increasing the efficiency of photosynthesis and the formation of many important compounds in photosynthesis such as cytochromes and ferredoxins which leads to an increase in the studied traits. It also assists in the synthesis of proteins, carbohydrates, fats and activates the activity of several enzymes (21,22). This may be due to the response of tomato plants to zinc fertilization, which increases the rate of photosynthesis, enhances plant growth and encourages the growth of the vegetative system. Most plants require zinc because it is an essential micronutrient that plays a critical role in enzyme activation, protein synthesis and overall plant growth as well as development. It also aids in the formation of chlorophyll, although it is not a component of chlorophyll (23).

The findings of the statistical analysis showed that all of the flowering and vegetative growth indicators under study significantly increased as a result of the two factors' interaction. This could be the result of potassium and nano-zinc working together.

The role of humic acid in potassium humate fertilizer in promoting vegetative growth, as measured by the length of the plant and the total number of leaves, is responsible for the increase in tomato plant growth and quantity indicators during the present study. This increases the assimilates produced in the leaves and their transfer to the fruiting parts, which increases the yield (24).

Although potassium does not contribute to the composition of any cellular components, it is one of the essential elements for plant growth and development. Also, it plays a supporting role in many essential processes, such as the formation of proteins and amino acids. This effect is also responsible for the increase in the characteristics under current study. The physiological effects of potassium humate are comparable to those of auxins and cytokinins (9). In tomato plants (24) and cucumber plants (25), it has been found out that spraying with humic acid fertilizer led to an increase in the number of fruits, fruit weight and the total yield of the plant, which is consistent with the current study results.

We conclude from the present study that foliar application of zinc at a concentration of 20 g L^{-1} significantly enhanced all measured parameters, including plant height, number of leaves per plant, number of flower clusters, number of flowers, number of fruits, fruit weight and fruit yield per plant, compared to other zinc levels. Similarly, spraying potassium humate at 25 ML L^{-1} also markedly improved these traits, achieving the highest averages for all the above indicators.

Conclusions and Recommendations

The results of this study showed that the interaction of zinc spraying at a concentration of 20 g L^{-1} and potassium humate at a concentration of 25 mL L^{-1} effectively contributed to improving vegetative as well as flowering growth and increasing tomato yield under protected cultivation conditions. This was achieved by enhancing nutrient uptake, stimulating physiological processes and increasing plant tolerance to environmental stress. Based on these results, it is recommended that this treatment be adopted as part of integrated fertilization programs for tomatoes in greenhouses. Future studies should be conducted on different varieties and locations to verify the consistency of the effects, in addition to evaluating the economic feasibility of these agricultural inputs and assessing their impact on fruit quality.

Authors' contributions

All authors contributed equally to the writing and preparation of the manuscript. Each author was involved in the preparation of the original draft, as well as the revision and final approval of the submitted version.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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