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Effect of Spraying with Some Growth Stimulants on Growth, Yield and Quality of Garlic. (seds 50 variety)

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Abstract

The field experiment was conducted on garlic (*Allium sativum* L.) cultivar seds 50 during 2022/2023 and 2023/2024 growing seasons on a private farm located in Shanasha village, Aga District, Dakahlia Governorate, Egypt A field experiment was designed in randomiz complete block design to assess the impact of varying Mono Ammonium Phosphate (MAP) at 250 ppm, Copper Gluconate ($C_{12}H_{22}CuO_{14}$) at 250 ppm, Calcium/Boron Mix (Ca/B) 250 ppm, Potassium Silicate (K_2O_3Si)250ppm and Control (without foliar application) spraying water only, to evaluate their effects on garlic growth and yield. Results showed that applying, Potassium Silicate (K_2O_3Si) 250 ppm significantly enhanced plant growth indicators, such as plant height, fresh and dry weights compared to other combined treatments. This combination also led to higher nutrient concentrations (N, P, K, B) in leaves and SPAD chlorophyll readings compared to other combined treatments. At harvest, the same combined treatment achieved the highest values for yield components and bulb quality traits such as vitamin C, pungency and dry matter. In contrast, control (without spraying) resulted in the lowest growth and yield outcomes,

Key words: Ammonium Phosphate, Copper Gluconate, Calcium/Boron, Potassium Silicate, growth stimulants.

Introduction

Garlic (Allium sativum L.) is a widely valued crop with significant economic and health benefits due to its high levels of essential nutrients, antioxidants, and sulfur-containing compounds (**Kareem *et al.* 2024**). As a staple ingredient in culinary applications and a source of medicinal compounds, garlic cultivation holds substantial agricultural importance globally. Egypt, being one of the leading producers, emphasizes the need for cultivation practices that not only enhance yield but also improve quality parameters to meet both domestic demands and export requirements (**Rizk and Deshesh, 2021; Baddour *et al.* 2024**).

Foliar applications of growth stimulants, such as potassium silicate and micronutrient compounds, have been shown to positively affect growth attributes, photosynthetic efficiency and resistance to biotic and abiotic stresses in various crops, including garlic.

Mono Ammonium Phosphate (MAP) is a widely used foliar fertilizer that provides both nitrogen and phosphorus in readily available forms, essential for root development, energy transfer, and overall plant vigor. Phosphorus, a key nutrient in MAP, plays a pivotal role in energy production through ATP and promotes strong root systems and rapid growth **(Rady *et al.* 2018).** MAP has been shown to enhance root establishment in garlic, supporting greater nutrient uptake and resilience to stress conditions. The nitrogen component in MAP contributes to protein synthesis and chlorophyll formation, which are critical for photosynthesis and vegetative growth **(Niu *et al.* 2021).**

Copper Gluconate ($C_{12}H_{22}CuO_{14}$) is an organic compound that supplies copper, a vital micronutrient for plants. Copper acts as a cofactor in enzymatic reactions related to photosynthesis, lignin synthesis, and antioxidant defense systems, all of which are crucial for plant growth and productivity **(Lešnik*et al.*2010).** In garlic, copper supplementation is especially important for enhancing stress tolerance, as it supports the development of stronger tissues and increases resistance to disease. By providing copper in a gluconate form, it becomes more bioavailable, allowing for effective absorption and utilization in plant tissues **(Gourkhede *et al.* 2019).**

Calcium/Boron Mix (Ca/B) is an effective foliar supplement that combines these two essential nutrients, each with distinct roles in plant health and quality. Calcium is crucial for cell wall structure, membrane stability, and root health, contributing to the overall structural integrity and strength of garlic bulbs **(Shaban *et al.* 2019).** Boron, on the other hand, is involved in cell wall synthesis, sugar transport, and reproductive development **(Yadav *et al*. 2019).** This mix helps prevent common physiological disorders associated with calcium or boron deficiencies, such as abnormal growth or poor structural quality in garlic bulbs **(Sidhu *et al.* 2019).**

Potassium Silicate (K_2O_3Si) serves as both a potassium source and a silicon supplement, which together contribute significantly to garlic's structural and physiological resilience (**Baddour *et al.* 2024**). Potassium enhances water regulation, enzyme activation, and nutrient transport within the plant, which are essential for the development of high-quality bulbs. Silicon, a lesser-known yet beneficial element, strengthens cell walls, improves tolerance to environmental stressors like drought, and enhances resistance to diseases. The combined effects of potassium and silicon in potassium silicate promote robust plant structure, improved photosynthetic efficiency, and an increase in both bulb yield and quality (**Kareem *et al.* 2024**).

Objective of the Study

This study aims to evaluate the effects of foliar applications of specific growth stimulants on the growth, productivity, and quality of garlic. The goal is to determine the optimal combination of these treatments to enhance yield and bulb quality in garlic under the local agro-environmental conditions of Dakahlia Governorate, Egypt.

Materials and Methods

1. Experimental Site and Soil Analysis

The field experiment was conducted on garlic (Allium sativum L.) cultivar seds 50 during 2022/2023 and 2023/2024 growing seasons on a private farm located in Shanasha village, Aga District, Dakahlia Governorate, Egypt

Prior to planting garlic, soil samples were collected from a depth of 0–30 cm to analyze its physical and chemical properties. The standard analytical methods described by **Sparks *et al.* (2020) and Dane and Topp (2020)** were employed for soil analysis, and the results are presented in Table 1.

Table 1. Fundamental initial soil characteristics

Particle size distribution (%)			Texture class	Field capacity	Saturation	Organic matter	Available soil nutrients			EC, dSm^{-1}	pH
Sand	Silt	Clay					N	P	K		
					(%)		(mg kg^{-1})				
27.8	23.2	49.0	Clay	35	70	1.3	42.93	0.75	250.9	3.95	7.90

2. Plant Material

The garlic cultivar used in this experiment was Balady Sids-50, commonly known as Egyptian garlic, obtained from the Horticulture Research Institute, Agricultural Research Center, Egypt. This variety is widely grown in Egypt due to its adaptability and local demand.

3. Treatments and Experimental Design

A field experiments were designed in randomizcomplete block design with three replicates. Five treatments were used in three replicates, total of comprising 15 was used to evaluate the effect of spraying with some growth stimulants on growth, yield and quality of garlic.

Each experimental plot covered an area of 10.5 m², consisting of three rows, each 3.5 m in length and 1 m in width. Garlic cloves were planted at a spacing of 7 cm, with each row containing 150 cloves, resulting in 450 cloves per plot.

treatments: Foliar applications

- **F_1:** Control (without foliar application) spraying water only.
- **F_2:** Mono ammonium phosphate (MAP) at rate of 250 ppm.
- **F_3:** Copper gluconate ($C_{12}H_{22}CUO_{14}$) at rate of 250 ppm.
- **F_4:** Calcium/Boron mix (250 ppm), containing 18% Ca, 3% B, and 12% N.
- **F_5:** Potassium silicate(K_2O_3Si) at rate of 250 ppm, containing Si and K.

The recommended dose of potassium sulphate (50% K_2SO_4) was set at 150 kg per fed^{-1}, as per agricultural guidelines provided by the Ministry of Agriculture and Soil Reclamation (MASR).

4. Planting and Agricultural Practices

Garlic planting was conducted on October 1 in the 2022 season and on October 2 in the 2023 season. Standard agricultural practices, as recommended by MASR, were followed throughout the experiment to ensure optimal growth conditions for garlic.

5. Protocol for Applying the Treatments

Foliar treatments were applied three times throughout the garlic growth period, beginning 70 days after planting, with subsequent sprays at three-week intervals. To enhance absorption, a wetting agent (Triton B) was added at a 0.1% concentration to all spray solutions, ensuring full foliar coverage for maximum effectiveness.

6. Harvest Process

The garlic crop was harvested 200 days after planting to ensure optimal bulb maturity

7. Measurements

Data were collected at two growth stages: 150 days and 200 days post-planting.

8.1. At 150 days post-planting

Growth parameters, including plant height (cm), number of leaves plant^{-1}, fresh weight (g plant^{-1}) and dry weight (g plant^{-1}) were measured. Leaf chemical compositions such as nitrogen (N, %), phosphorus (P, %), potassium (k%)and boron (B, mg kg^{-1}) contents in leaves were determined. Leaf samples were digested with a mixture of $HClO_4$ + H_2SO_4according to **Peterburgski, (1968)**. Nitrogen was measured by Micro-Kjeldahl, phosphorus by spectrophotometry and potassium by flame photometry as per the methods of **Walinga *et al.* (2013),** while boron was estimated using hot water extraction with a spectrophotometer as described by **Sah and Brown, (1997).** Chlorophyll content was estimated using a Minolta Chlorophyll Meter (SPAD-502). Yield components, including bulb fresh weight (g plant^{-1}), bulb dry weight (g plant^{-1}), number of cloves per bulb, bulb diameter (cm), neck diameter (cm), bulb yield (kg plot^{-1}) and bulbing ratio (neck diameter/bulb diameter) were also recorded.

8.2. At 200 days post-planting

Bulb traits like fresh and dry weights (g plant^{-1}), bulb and neck diameters (cm) and clove weight (g) were measured. Also, yield measures such as total yield (ton fed^{-1}), treated yield (ton fed^{-1}), weight loss percentage (after 200 days of planting) and bulbing ratio (neck diameter/bulb diameter) were measured.

N, P, K, and B levels in bulbs were analyzed as previously described. Vitamin C content (mg 100g^{-1}), carbohydrate percentage, total dissolved solids (TDS %), pungency (pyruvate content, µmol m^{-1}and dry matter percentage were determined following **A.O.A.C (2000)** protocols.

8.3. Storability assessment

Following curing, 2 kg of bulbs were randomly sampled from each plot in both seasons and stored in mesh bags at room temperature (24 °C ± 5 °C). Weight loss of stored bulbs was recorded monthly to the end of the storage period as described by **Rizk and Deshesh, (2021)** using the following formula:

Weight loss (%) =

[(initial weight of storage bulb – weight at sampling date) x 100] / initial weight of storage bulb.

9. Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA) as outlined by **Snedecor and Cochran (1980).** Mean comparisons were carried out using the Least Significant Difference (LSD) test to establish statistical significance among treatments.

Results and Discussion

The findings of this research work will be presented and discussed under the following headings:

3.1. Plant vegetative growth characteristics at 150 Days from Planting

3.1.1. Growth parameters

Table 2 demonstrates the impact of varying ratios of mineral different foliar supplements on garlic growth performance during the 2022/23 and 2023/24 seasons. The parameters measured include plant height (cm), the number of leaves plant^{-1}, fresh and dry weights (g plant^{-1}).

Effect of foliar supplements

Among the foliar supplements, potassium silicate (F_5) at 250 ppm showed the greatest enhancement in plant height (cm), the number of leavesplant^{-1}, fresh and dry weights (g plant^{-1}), indicating its positive role in stimulating garlic growth. Other supplements also had beneficial effects on growth but were less pronounced than potassium silicate. In other words, the sequence of foliar applications from most effective to least effective in enhancing garlic growth performance was as follows: potassium silicate ranked highest, resulting in significant improvements in plant height, fresh weight, and dry weight across both seasons. Calcium/boron followed, also showing a positive impact on plant growth parameters but to a slightly lesser extent than potassium silicate. Copper gluconate came next, contributing moderately to growth performance. Mono ammonium phosphate (MAP) was effective but ranked lower than the other foliar applications. Finally, the control (without any foliar application) showed the least impact, further confirming the role of these foliar treatments in boosting garlic growth traits. This order highlights potassium silicate and calcium/boron as particularly influential in optimizing growth performance. The effectiveness of potassium silicate could be attributed to its role in reinforcing plant cell walls and enhancing nutrient absorption, which supports better growth performance under field conditions (**Baddour *et al.* 2024; Kareem *et al.* 2024)**. The same trend was found during both studied seasons.

Table 2. The impact of foliar supplements on plant height, number of leaves/plant and leaves fresh, Dry weight of garlic plants garlic growth performance during the 2022/23 and 2023/24 seasons

Treatments	Plant height, cm		No. of leaves plant^{-1}		Fresh weight, g plant^{-1}		Dry weight, g plant^{-1}	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
F_1: Control **(**without foliar application)	116.68d	103.71e	10.08a	9.50b	89.52e	83.54e	18.11e	16.75e
F_2: MAP (250 ppm)	117.74d	105.24d	10.33a	9.67ab	93.64d	85.97d	18.44d	17.14d
F_3: Copper gluconate (250 ppm)	119.43c	106.42c	10.42a	9.83ab	96.26c	88.60c	19.21c	18.16c
F_4: Ca/B (250ppm)	121.03b	107.87b	10.67a	9.92ab	98.91b	91.25b	20.33b	18.44b
F_5: Silicate potassium (250ppm)	122.29a	109.59a	10.75a	10.08a	103.09a	94.03a	21.12a	19.21a
LSD at 5%	**1.20**	**1.06**	**NS***	**0.57**	**1.12**	**1.02**	**0.22**	**0.19**

Means within a row followed by a different letter (s) are statistically different at 5%
NS*= Non-significant

3.1.2. Chemical constituents of plant foliage in leaves and chlorophyll SPAD reading

The chemical composition [N, P, K (%), B (mgkg^{-1})] of garlic leaves and chlorophyll content, measured as SPAD readings, were analyzed across different treatments, including mineral potassium fertilizer combined with bio-fertilization and various foliar supplements. Results, presented in Table 3, reflect data collected over the 2022/23 and 2023/24 seasons.

Table 3. The impact of foliar supplements on chemical constituents in leaves of garlic and photosynthetic pigment during the 2022/23 and 2023/24 seasons

Treatments	N, %		P, %		K, %		B, mg kg^{-1}		Chlorophyll, SPAD	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
F_1: Control **(**without foliar	3.05d	3.18c	0.325c	0.337c	2.39d	2.48c	25.67c	26.07c	63.84c	62.68d
F_2: MAP (250 ppm)	3.08c	3.21c	0.330b	0.342b	2.42cd	2.52bc	25.84bc	26.23bc	64.13bc	63.72c
F_3: Copper gluconate (250	3.12b	3.25b	0.333b	0.346b	2.44c	2.54bc	26.01ab	26.39ab	65.59ab	65.00b
F_4: Ca/B (250ppm)	3.15a	3.29a	0.339a	0.353a	2.47b	2.57ab	26.14a	26.55a	66.11a	65.41b
F_5: Silicate potassium (250	3.18a	3.31a	0.342a	0.356a	2.51a	2.61a	26.28a	26.67a	67.02a	66.20a
LSD at 5%	**0.03**	**0.04**	**0.003**	**0.003**	**0.03**	**0.06**	**0.28**	**0.30**	**1.51**	**0.59**

Means within a row followed by a different letter (s) are statistically different at 5%
NS*= Non-significant

Effect of foliar supplements

Also, the same Table shows that F_5 (potassium silicate) had the most pronounced impact on nutrient concentrations and chlorophyll SPAD values, followed closely by F_4 (Ca/B) then F_3 and F_2, respectively. The control treatment (F_1) consistently resulted in the lowest values. The same trend was found during both studied seasons.

The superior effect of potassium silicate (F_5) can be explained through several scientific mechanisms: Potassium silicate not only supplies potassium, an essential macronutrient for plants, but also provides silicon, which plays a crucial role in enhancing plant health. Silicon can improve cell wall structure, leading to better stress tolerance and enhanced nutrient uptake efficiency(**Epstein,1994)**. The higher nutrient concentrations observed in F_5 can be attributed to these synergistic effects. The presence of potassium is vital for chlorophyll production, which is essential for photosynthesis. The application of potassium silicate likely contributed to increased chlorophyll SPAD readings, indicating better photosynthetic efficiency and overall plant health. This aligns with findings that potassium silicate can enhance chlorophyll content and photosynthetic activity in various crops (**Zyada and Bardisi, 2018**; **Abdel-Latif *et al.* 2019; Mohamed *et al.* 2019**; **Baddour *et al.* 2024; Kareem *et al.* 2024)**.

Following potassium silicate, the treatment with calcium and boron (F_4) also showed substantial positive effects on nutrient concentrations and chlorophyll values. Calcium is known to improve cell wall stability and enhance nutrient transport within the plant **(Eticha. *et al* .2017)**. Boron plays a critical role in the transport of sugars and other metabolites, which can indirectly influence chlorophyll synthesis and nutrient accumulation (**Li *et al.* 2015; Shaban *et al.* 2019;Yatsenko *et al.* 2020; Rahman *et al.* 2022).**

The foliar treatments of copper gluconate (F_3) and MAP (F_2) ranked lower than F_4 and F_5, but still contributed positively to nutrient concentrations. Copper is an essential micronutrient involved in various enzymatic processes (**Gourkhede *et al.* 2019**; **El-Sonbaty and El-Gamal, 2021; Muñoz-Fambuena, 2022)**, while MAP provides both phosphorus and nitrogen, essential for plant growth (**Rady *et al.* 2018; Niu *et al.*2021; Chakole *et al.* 2023)**. However, their impact on chlorophyll content and nutrient concentrations was less pronounced compared to the significant benefits observed with potassium silicate and the calcium/boron combination.

The control treatment (F_1), which did not receive any foliar application, consistently resulted in the lowest nutrient concentrations and chlorophyll SPAD values. This underscores the importance of foliar nutrition in enhancing plant performance and nutrient accumulation, as plants without foliar treatments are often limited in nutrient availability and physiological activity.

3.1.3. Yield and its components (150 days)

Table 4 presents the impact of various ratios of mineral potassium fertilizer and bio-fertilization, along with foliar supplements, on physical bulb traits and yield of garlic plants at 150 days after planting during the 2022/23 and 2023/24 seasons. The measured traits included bulb fresh weight (g plant^{-1}), bulb dry weight (g plant^{-1}), number of cloves per bulb, bulb diameter (cm), neck diameter (cm), bulb yield (kg plot^{-1}) and bulbing ratio.

Table 4. The impact of foliar supplements on physical bulb traits and yield of garlic plant at 150 days from planting during the 2022/23 and 2023/24 seasons

Treatments	Bulb fresh weight, g plant^{-1}		Bulb dry weight, g plant^{-1}		No. of cloves bulb^{-1}	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
F_1: Control **(**without foliar application)	52.29d	49.96d	20.56e	17.68d	31.42c	29.00d
F_2: MAP (250 ppm)	50.65e	51.28c	21.37d	17.95d	31.92bc	29.58cd
F_3: Copper gluconate (250 ppm) **COPPER GLUCONATE**	54.46c	53.71b	21.64c	18.38c	32.50b	30.17bc
F_4: Ca/B (250ppm)	56.28b	55.57a	22.17b	19.04b	33.33a	30.75b
F_5: Silicate potassium (250ppm)	57.99a	56.10a	22.68a	19.59a	33.92a	31.67a
LSD at 5%	**0.50**	**0.56**	**0.23**	**0.43**	**0.73**	**0.81**

Means within a row followed by a different letter (s) are statistically different at 5%
NS*= Non-significant

Table 4. Cont.

Treatments	Bulb diameter, cm		Neck diameter, cm		Bulb yield, Kg plot^{-1}		Bulbing ratio	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
F_1: Control **(**without foliar application)	4.97d	4.83c	0.99b	1.12d	40.43e	36.76e	0.30b	0.45a
F_2: MAP (250 ppm)	5.05cd	4.93c	1.00b	1.18c	41.55d	37.56d	0.30b	0.45a
F_3: Copper gluconate (250 ppm)	5.18bc	5.02bc	1.10a	1.19bc	42.20c	38.38c	0.31b	0.44a
COPPER GLUCONATE								
F_4: Ca/B (250ppm)	5.28ab	5.17ab	1.13a	1.24ab	43.18b	39.20b	0.32a	0.43b
F_5: Silicate potassium (250ppm)	5.45a	5.30a	1.13a	1.28a	44.30a	39.62a	0.33a	0.45a
LSD at 5%	**0.21**	**0.20**	**0.05**	**0.05**	**0.39**	**0.38**	**0.01**	**0.02**

Means within a row followed by a different letter (s) are statistically different at 5%
NS*= Non-significant

Effect of foliar supplements

Among the foliar supplements, potassium silicate (F_5) exhibited the most favorable impact on garlic bulb traits and yield, recording the maximum values of bulb fresh weight (g plant^{-1}), bulb dry weight (g plant^{-1}), number of cloves per bulb, bulb diameter (cm), neck diameter (cm), bulb yield (kg plot^{-1}) and bulbing ratioin both seasons. In contrast, the control treatment (F_1) showed the lowest performance, suggesting that the absence of foliar applications limits the potential growth and yield of garlic.

3.2. Yield and its Components at Harvest Stage (200 days)

Table 5. The impact of foliar supplements on physical bulb traits and yield of garlic plant at 200 days from planting during the 2022/23 and 2023/24 seasons

Treatments	Bulb fresh weight, g plant^{-1}		Bulb dry weight, g plant^{-1}		Bulb diameter, cm		Neck diameter, cm	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
F_1: Control **(**without foliar application)	85.95e	76.68d	24.11e	14.98e	5.56d	3.70c	1.69c	1.65c
F_2: MAP (250 ppm)	88.16d	77.54d	25.72d	16.10d	5.70c	3.78c	1.73bc	1.68c
F_3: Copper gluconate (250 ppm)	90.14c	79.54c	26.39c	17.08c	5.74c	3.90b	1.77b	1.72bc
F_4: Ca/B (250ppm)	91.55b	81.16b	27.79b	18.40b	5.82b	4.08a	1.87a	1.76b
F_5: Silicate potassium (250ppm)	92.88a	82.76a	28.40a	19.93a	5.89a	4.16a	1.95a	1.85a
LSD at 5%	**0.89**	**0.88**	**0.31**	**0.20**	**0.06**	**0.09**	**0.08**	**0.07**

Means within a row followed by a different letter (s) are statistically different at 5%
NS*= Non-significant

Table 5. Cont.

Treatments	Weight of clove, g		Yield, ton fed^{-1}		Treated yield, ton fed^{-1}		Weight loss, %		Bulbing ratio	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
F_1: Control **(**without foliar application)	1.59d	1.65d	16.17e	14.70e	9.45e	8.70e	42.21a	41.43a	0.20b	0.23a
F_2: MAP (250 ppm)	1.71c	1.76c	16.62d	15.02d	9.87d	9.19d	41.24b	39.38b	0.20b	0.23a
F_3: Copper gluconate (250 ppm)	1.75bc	1.80bc	16.88c	15.35c	10.31c	9.47c	39.27c	38.77c	0.21a	0.23a
F_4: Ca/B (250ppm)	1.79ab	1.85ab	17.27b	15.68b	10.66b	9.88b	38.63d	37.53d	0.21a	0.24a
F_5: Silicate potassium (250ppm)	1.84a	1.90a	17.72a	15.85a	11.16a	10.17a	37.43e	36.51e	0.21a	0.24a
LSD at 5%	**0.07**	**0.07**	**0.16**	**0.16**	**0.10**	**0.10**	**0.42**	**0.36**	**0.01**	**N.S**

Means within a row followed by a different letter (s) are statistically different at 5%
NS*= Non-significant

Effect of foliar supplements

In terms of foliar applications, Table 5 presents the effects of the studied treatments on garlic yield and physical bulb traits at harvest. The treatment with potassium silicate (F_5) significantly enhanced all yield components while also reducing the weight loss percentage compared to the control (F_1).

Other foliar treatments, such as calcium-boron (Ca/B) (F_4), followed by copper gluconate at 250 ppm (F3) and monoammonium phosphate (MAP) (F_2), also had positive contributions to yield; however, they were less effective than F_5. The improvement observed in these treatments indicates the importance of nutrient availability through foliar applications, which can lead to better growth performance and bulb quality in garlic.

3.3.Chemical Constituents and Quality of Bulbs at Harvest Stage (200 days)

3.3.1. Chemical constituents of bulb

The chemical composition of garlic bulbs at harvest was significantly influenced by various treatments involving mineral potassium fertilizers, bio-fertilization, and foliar supplements. The results summarized in Table 6 highlight the effects of these treatments on nitrogen (N, %), phosphorus (P, %), potassium (K, %) and boron (B, mg kg^{-1}) concentrations in the bulbs across two growing seasons (2022/23 and 2023/24).

Effect of foliar supplements

Among the foliar treatments, potassium silicate (F_5) was particularly effective, significantly enhancing the concentrations of all measured nutrients compared to the control (F_1). This treatment resulted in the highest nitrogen (2.62and 2.67%), phosphorus (0.301 and 0.313%), potassium (2.41and 2.47%), and boron (21.32 and 21.67 mg kg^{-1}) levels in both seasons. Other foliar applications, such as calcium-boron (F_4) and copper gluconate (F_3), also showed positive effects, although they were not as pronounced as those from potassium silicate. The sequence of treatments can be attributed to the differential effects of various foliar applications on nutrient availability and uptake in garlic plants. The effectiveness of potassium silicate can be linked to its role in improving cell wall strength, photosynthesis efficiency, and overall plant health, which facilitates better nutrient absorption. Other foliar applications, such as calcium-boron (F_4) and copper gluconate (F_3), also showed positive effects; however, their impact was less pronounced than that of potassium silicate. This suggests that while these treatments contributed to nutrient enhancement, potassium silicate's unique properties likely played a more critical role in maximizing nutrient concentrations and supporting plant growth (**Zyada and Bardisi 2018; Kareem *et al.*2024)**.

Table 6. The impact of foliar supplements on chemical constituents of garlic bulb during the 2022/23 and 2023/24 seasons

Treatments	N, %		P, %		K, %		B, mg kg^{-1}	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
F_1: Control **(**without foliar application)	2.46e	2.52d	0.284e	0.295e	2.29d	2.34c	20.59d	20.94d
F_2: MAP (250 ppm)	2.50d	2.56cd	0.288d	0.300d	2.31d	2.36bc	20.78cd	21.09cd
F_3: Copper gluconate (250 ppm)	2.54c	2.60bc	0.293c	0.305c	2.36c	2.41ab	20.97bc	21.28bc
F_4: Ca/B (250ppm)	2.58b	2.64ab	0.296b	0.308b	2.38b	2.43a	21.12ab	21.46ab
F_5: Silicate potassium (250ppm)	2.62a	2.67a	0.301a	0.313a	2.41a	2.47a	21.32a	21.67a
LSD at 5%	**0.03**	**0.06**	**0.002**	**0.003**	**0.02**	**0.06**	**0.21**	**0.25**

Means within a row followed by a different letter (s) are statistically different at 5%
NS*= Non-significant

3.3.2.Quality of bulb

Table 7 illustrates the impact of various ratios of mineral potassium fertilizer and bio-fertilization, along with foliar supplements and their interactions on the quality traits of garlic bulbs during the 2022/23 and 2023/24 growing seasons.

Table 7. The impact of foliar supplements on bulb quality traits of garlic growth performance during the 2022/23 and 2023/24 seasons

Treatments	Vitamin C, mg 100g^{-1}		Carbohydrates, %		TDS, %		Pungency (purvate content πmol.ml^{-1})		Dry matter, %	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
F_1: Control **(**without foliar	13.45d	13.66c	21.83d	22.24d	23.62b	24.10b	10.05e	10.24c	20.71c	22.42c
F_2: MAP (250 ppm)	13.55cd	13.74c	22.06c	22.49c	23.86ab	24.34ab	10.16d	10.36bc	20.96bc	22.67bc
F_3: Copper gluconate (250	13.66bc	13.88b	22.21bc	22.70bc	23.98ab	24.45ab	10.31c	10.54ab	21.11abc	22.91abc
F_4: Ca/B (250ppm)	13.75ab	13.95b	22.34ab	22.79ab	24.16ab	24.56ab	10.47b	10.68a	21.41ab	23.15ab
F_5: Silicate potassium	13.88a	14.09a	22.53a	22.97a	24.33a	24.86a	10.56a	10.77a	21.60a	23.29a
LSD at 5%	**0.15**	**0.13**	**0.22**	**0.24**	**0.55**	**0.58**	**0.09**	**0.24**	**0.51**	**0.53**

Means within a row followed by a different letter (s) are statistically different at 5%
NS*= Non-significant

Effect of foliar supplements

Foliar supplements also had a significant impact on garlic bulb quality, with potassium silicate (F_5) proving to be the most effective treatment. This foliar application resulted in the highest levels of Vitamin C (13.88, 14.09 mg 100g^{-1}), carbohydrates (22.53, 22.97%), TDS (24.33, 24.86%), pungency (10.56, 10.77 µmol ml^{-1}) and dry matter (21.60, 23.29%) in both growing seasons, respectively. Other foliar treatments, such as calcium-boron (F_4) and copper gluconate (F_3), demonstrated beneficial effects but did not reach the efficacy of potassium silicate.

3.4. Weight Loss Percentage after Harvest

The results presented in Table 8 provide a comprehensive overview of the impact of different ratios of mineral potassium fertilizer and bio-fertilization treatments, along with foliar supplements, on the weight loss percentage of stored produce over time during both studied seasons.

Effect of foliar supplements

The statistical analysis of foliar supplements indicates a notable impact on reducing weight loss percentages. The control group (F_1), which did not receive any foliar applications, showed the highest weight loss, emphasizing the benefits of foliar treatments in minimizing this loss. Among the treatments, potassium silicate (F_5) proved most effective in reducing weight loss, followed by calcium-boron (F_4), copper gluconate (F_3) and monoammonium phosphate (MAP) (F_2).

Table 8. The impact of foliar supplements on weight loss percentage after two, three, four, five, six, seveneight and ninemonths of the storage periods during the 2022/23 and 2023/24 seasons

Treatments	May		June		July		August		September		October		November		December	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
F_1: Control **(**without foliar	7.67a	7.55a	3.03a	3.16a	2.19a	2.27a	1.74a	1.84a	1.03a	1.08a	0.91a	0.95a	0.87a	0.90a	0.74a	0.78a

F_2: MAP (250 ppm)	7.56ab	7.38b	2.96ab	3.09b	2.07b	2.16b	1.70b	1.78b	1.03a	1.08ab	0.90a	0.94a	0.87a	0.90a	0.74a	0.77a
F_3: Copper gluconate (250	7.46b	7.28c	2.91bc	3.03b	1.93c	2.01c	1.61c	1.69c	1.02a	1.06ab	0.90a	0.94a	0.85ab	0.88ab	0.74a	0.77a
F_4: Ca/B (250ppm)	7.17c	6.76d	2.85cd	2.96c	1.85d	1.92d	1.43d	1.50d	1.01a	1.06b	0.89a	0.94a	0.84ab	0.87b	0.73a	0.76a
F_5: Silicate potassium (250ppm	6.80d	6.60e	2.79d	2.90d	1.80e	1.87e	1.37e	1.44e	1.01a	1.05b	0.88a	0.92a	0.83b	0.86b	0.73a	0.76a
LSD at 5%	**0.16**	**0.07**	**0.07**	**0.06**	**0.02**	**0.03**	**0.03**	**0.02**	**N.S**	**0.02**	**N.S**	**N.S**	**0.03**	**0.03**	**N.S**	**N.S**

Means within a row followed by a different letter (s) are statistically different at 5%
NS*= Non-significant

These treatments were particularly beneficial during the early storage months, underscoring the role of timely foliar applications in enhancing moisture retention and maintaining produce quality throughout storage.

The efficacy of foliar treatments in reducing weight loss is linked to their role in strengthening cell walls and enhancing cellular water retention. Potassium silicate (F5), for instance, helps form stronger cell walls through silica deposition, which improves plant tissue resilience and reduces water loss during storage. Calcium-boron (F_4) contributes to cell wall stability and cell cohesion, further minimizing dehydration. Copper gluconate (F_3) plays a role in enzymatic activity and overall cellular health, indirectly supporting moisture retention. Finally **(MENG et al. 2007)**, monoammonium phosphate (MAP) (F_2) enhances cellular turgor pressure, which also aids in maintaining tissue integrity(**Liao *et al* 2015**). Generally, these foliar applications may have improved the produce's ability to retain moisture, especially in the initial storage period, reducing weight loss and preserving quality.

Conclusion

Based on the obtained results, it can be concluded that applying a potassium silicate foliar application at 250 ppm, represents the best-combined treatment for enhancing garlic growth, productivity and quality.

Generally, the findings highlight the importance of balanced potassium fertilization, in supporting garlic growth, yield and quality. Foliar applications of potassium silicate and other stimulants proved effective in further enhancing plant resilience and quality. It is recommended to consider a potassium silicate foliar application at 250 ppm. applied three times beginning 70 days after planting, with subsequent sprays at three-week interval partial substitute for mineral potassium to reduce costs and environmental impact, foliar sprays as supplementary treatments for improved storage.

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