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Effect of Planting Dates and Foliar Spraying with Salicylic Acid, Selenium, Chitosan and Glycine Betaine on Growth and Productivity of Garlic

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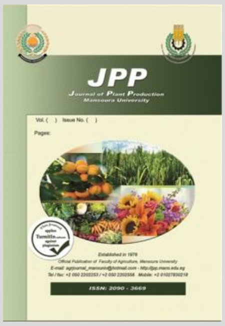

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ABSTRACT

Garlic is an economically important crop, but late planting exposes it to low-temperature stress, negatively affecting growth, yield and quality. This study aimed to enhance garlic tolerance to low temperatures and improve productivity through foliar application of stimulants under different planting dates. A field experiment was conducted on a private farm in Mit Fares village, Bani Ubaid district, Dakahlia Governorate, Egypt, using a split-plot design with three replications. The main plots were assigned to two planting dates (October 1st and November 1st), while the subplots were allocated to foliar spraying, including salicylic acid (150 mg L^{-1}), selenium (5.0 mg L^{-1}), chitosan (150 mg L^{-1}), glycine betaine (700 mg L^{-1}), and a control (tap water). Measurements were recorded at 100, 120, and 180 days after planting, covering vegetative growth parameters, photosynthetic pigments, biochemical contents, and yield attributes. Results revealed that early planting (October 1st) significantly enhanced plant growth, photosynthetic pigments accumulation, and bulb yield. Among the foliar treatments, selenium followed by salicylic acid exhibited the most positive effects, followed by glycine betaine and chitosan compared with the control treatment. Additionally, all stimulant applications under late planting resulted in a significant increase in marketable yield and bulb quality compared to the control. These results highlight the vital role of foliar stimulants in mitigating low-temperature stress and optimizing garlic productivity under different planting schedules.

Keywords: Salicylic acid, Selenium, Chitosan, Glycine betaine

INTRODUCTION

Garlic (*Allium sativum* L.) is an economically important vegetable crop widely cultivated for its culinary and medicinal uses (Papu *et al.*2014; Tesfaye and Mengesha, 2015). Its productivity and quality are highly influenced by environmental factors, particularly temperature fluctuations. Late planting often exposes garlic to low-temperature stress, which negatively affects germination, vegetative growth, and ultimately, yield and bulb quality (El-Shabasi *et al.* 2018; El-Metwaly *et al.* 2021).

To mitigate these adverse effects, the application of various stimulants has been explored as a strategy to enhance plant resilience and optimize productivity. Salicylic acid, selenium, chitosan, and glycine betaine are widely recognized for their roles in enhancing plant tolerance to abiotic stresses, including low-temperature stress. Salicylic acid acts as a signaling molecule that regulates plant defense mechanisms, improves antioxidant activity, and enhances photosynthetic efficiency, leading to better growth and yield under suboptimal conditions (Nada and Abd El-Hady, 2019; Dubey *et al.* 2023; Ali *et al.* 2024). Selenium, an essential micronutrient, plays a critical role in mitigating oxidative stress by enhancing antioxidant enzyme activity, improving nutrient uptake, and promoting cell membrane stability (Hamaiel *et al.* 2020; Doklega *et al.* 2021; Al-Salami *et al.* 2023; Amerian *et al.* 2024). Chitosan, a natural biopolymer, has been reported to stimulate plant growth by inducing defense responses, enhancing water retention, and improving nutrient assimilation, which collectively contribute to increased stress tolerance (Abd El-Hady and Abd-Elhamied, 2018; Mohamed *et al.* 2023). Glycine betaine, a well-known osmoprotectant, helps maintain cellular osmotic balance, stabilizes proteins and membranes, and improves photosynthetic performance under environmental stress (Sapt *et al.* 2019). The combined or individual application of these stimulants can effectively mitigate the adverse effects of low temperatures on garlic plants, leading to enhanced vegetative growth, higher yield, and improved bulb quality.

Therefore, this study aims to evaluate the effects of different planting dates and foliar applications of stimulants on garlic growth, yield and quality. The findings will contribute to developing effective strategies for optimizing garlic production under varying climatic conditions, ensuring higher productivity and improved bulb quality.

MATERIALS AND METHODS

Experimental Site and Design

A field experiment was conducted during the growing seasons of 2023/2024 and 2024/2025 at a private farm in Mit Fares village, Bani Ubaid district, Dakahlia Governorate, Egypt. The experimental site is characterized by a typical clay loam soil with good drainage, as its content of available N, P and K was 42.2, 7.05 and 201.3 $mgkg^{-1}$, respectively. The analysis of initial soil was done as described by Dane and Topp (2020) and Sparks *et al.* (2020). The experiment followed a split-plot design with three replications. The main plots were assigned to two planting dates: October 1st and November 1st, while the subplots were allocated to foliar applications of salicylic acid (150 mg L^{-1}), selenium as sodium selenate (Na_2SeO_4) (5.0 mg Se L^{-1}), chitosan (150 mg L^{-1}), glycine betaine (700 mg L^{-1}) and a control (tap water). All materials were purchased from the commercial market in

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Egypt. Each experimental plot covered an area of 15 m^2 (3 × 5 m), with a row spacing of 25 cm and a clove spacing of 10 cm within rows.

Climatic Conditions

The climatic conditions during the growing season showed a notable temperature decline in November compared to October, exposing the late-planted garlic to low-temperature stress, which could affect plant growth and bulb development. The average temperature in both studied season in October was 29°C during the day and 17°C at night, while in November, it dropped to 23°C during the day and 14°C at night. These lower temperatures in November may have delayed physiological processes, potentially impacting vegetative growth and final bulb formation.

Soil Preparation and Cultivation

Before planting, the soil was plowed, leveled, and prepared. Calcium superphosphate (15.5% P_2O_5) at 150 kg fed^{-1}, incorporated into the soil before planting to support root establishment. Garlic (cv. Sids 40) was sown according to the studied sowing dates. Ammonium sulphate (20.5% N) at 200 kg fed^{-1}, applied in split doses during early vegetative growth. Potassium sulphate (48% K_2O) at 100 kg fed^{-1}, applied at two stages: half at planting and the rest during bulbing initiation. Irrigation and other agronomic practices were conducted according to the recommendations of the Egyptian Ministry of Agriculture and Soil Reclamation, ensuring optimal crop management under field conditions. Foliar sprays were applied five times, starting 30 days after planting with 15 day intervals.

Measurements

Measurements were recorded at three key growth stages to evaluate the impact of planting dates and foliar stimulant applications on garlic growth, biochemical composition and yield characteristics.

At 100 Days After Planting (DAP): At this stage, vegetative growth parameters were assessed, including plant height (cm), number of leaves per plant, fresh and dry weights per plant (g), and leaf area per plant (cm^2). These measurements provided insights into early plant development and vigor. Additionally, photosynthetic pigments were analyzed to determine the efficiency of photosynthesis under different treatments. Chlorophyll a, chlorophyll b, and carotenoids (mg g^{-1} F.W.) were quantified using spectrophotometry after extraction with acetone 80% (Torres *et al.* 2014). The accumulation of these pigments reflects the plant's ability to capture light energy and sustain metabolic activities during early growth.

At 120 days after planting, (DAP): Biochemical composition and nutrient status were evaluated at this intermediate growth stage. Dry matter content (%), vitamin C (mg 100 g^{-1}), total soluble solids (TSS, %), and oil content (mg g^{-1}) were analyzed using standard procedures outlined by AOAC (2000). Additionally, pyruvate content (µmol mL^{-1}), an indicator of pungency and sulfur metabolism in garlic, was determined as described by Kerr *et al.* (2012). To assess macronutrient accumulation, clove samples were digested using a mixture of sulfuric acid and perchloric acid (Peterburgski, 1968), followed by the determination of nitrogen (N), phosphorus (P) and potassium (K) concentrations according to the methods described by Walinga *et al.* (2013).

At 180 days after planting (DAP), harvest stage: The final yield and its attributes were recorded at the harvest stage to determine the overall productivity and marketable potential of garlic under different planting dates and foliar stimulant treatments. Key parameters included average bulb weight (g), bulb diameter (cm), neck diameter (cm), bulbing ratio, number of cloves $bulb^{-1}$, total bulb yield (ton fed^{-1}), and marketable yield (ton fed^{-1}).

Statistical Analysis

Data were statistically analyzed using Duncan's Multiple Range Test (DMRT) to determine significant differences among treatments, following the methodology described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Garlic performance at 100 days after planting (growth parameters)

Table (1) illustrates the impact of sowing date and foliar applications on the growth parameters of garlic plants at 100 days after planting during the 2023/2024 and 2024/2025 seasons. The assessed growth traits include plant height (cm), number of leaves per plant, fresh weight (g $plant^{-1}$), dry weight (g $plant^{-1}$), and leaf area (cm^2 $plant^{-1}$). Data in (Table 2) shows the effects of the studied treatments on photosynthetic pigments, including chlorophyll a (mg g^{-1} F.W.), chlorophyll b (mg g^{-1} F.W.), and carotene (mg g^{-1} F.W.), under the same conditions.

Individual effect of sowing date

The results in Table 1 indicate that sowing garlic on October 1st significantly enhanced plant height, number of leaves per plant, fresh and dry weight, and leaf area compared to the November 1st sowing date. This improvement could be attributed to the more favorable climatic conditions in early October, which provide a longer vegetative growth period before temperatures decline in winter. Earlier sowing allows for better root establishment and nutrient uptake efficiency, leading to increased biomass accumulation.

Regarding photosynthetic pigments (Table 2), garlic plants sown on October 1st exhibited significantly higher chlorophyll a, chlorophyll b, and carotenoid contents than those sown on November 1st. This result suggests that early planting enhances photosynthetic efficiency, which may be due to a more extended period of active photosynthesis before cold stress occurs. The higher pigment content enhances light absorption and energy conversion, leading to improved growth and productivity.

Individual effect of foliar applications

The results show that all foliar treatments improved plant growth parameters compared to the control, with selenium producing the best results, followed by salicylic acid, glycine betaine, and chitosan. Selenium enhanced plant height, leaf number, fresh and dry weight, and leaf area (Doklega *et al.* 2021). These effects may be attributed to selenium's role in improving antioxidant defense systems, reducing oxidative stress, and enhancing water-use efficiency. Salicylic acid also significantly increased growth traits. Its role in mitigating abiotic stress, enhancing photosynthesis, and regulating plant hormones like auxins and gibberellins likely contributed to this improvement. Similarly, glycine betaine helped maintain cellular osmotic balance, reducing the adverse effects of environmental stress, leading to increased biomass accumulation.

Photosynthetic pigments (Table 2) followed a similar trend, where selenium-treated plants exhibited the highest chlorophyll and carotenoid levels. Selenium is known to enhance chlorophyll stability and prevent its degradation under stress conditions. Salicylic acid and glycine betaine treatments also increased chlorophyll content, possibly by enhancing nitrogen assimilation and protecting photosynthetic machinery from oxidative damage.

Table 1. Effect of sowing dates and foliar applications of stimulants on growth criteria of garlic plants at 100 days from planting (2023/24 and 2024/25)

Treatments		Plant height, cm		No. of leaves $plant^{-1}$		Fresh weight, g $plant^{-1}$		Dry weight, g $plant^{-1}$		Leaf area, cm^2 $plant^{-1}$	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Main factor: Sowing date											
November, 1st		56.10b	56.92b	4.87b	4.93b	53.16b	53.86b	13.20b	13.82b	231.73b	238.53b
October, 1st		61.31a	61.25a	6.47a	6.60a	65.47a	65.18a	14.54a	14.57a	294.20a	304.67a
LSD at 5%		0.35	0.62	0.99	1.60	0.04	0.99	0.16	0.01	1.74	9.19
Sub main factor: Foliar applications											
Control (tap water)		57.42c	57.92c	5.17b	5.17b	58.05b	58.66c	13.65b	13.78c	248.00d	249.00d
Chitosan (150 mg L^{-1})		57.68c	58.52bc	5.33b	5.67ab	58.35b	58.79c	13.73b	13.96bc	255.33cd	265.83c
Glycine betaine (700 mg L^{-1})		59.24b	59.03b	5.43ab	5.71ab	60.68a	59.99bc	13.95ab	14.28b	265.57bc	279.00bc
Salicylic acid (150 mg L^{-1})		59.52ab	59.85a	6.00ab	5.83ab	59.96a	59.99ab	14.01a	14.47a	269.33b	281.00ab
Selenium (5.0 mg L^{-1})		60.05a	60.32a	6.33a	6.50a	60.53a	60.79a	14.08a	14.55a	279.83a	286.83a
LSD at 5%		0.98	0.87	0.94	1.09	1.07	0.96	0.26	0.26	9.82	10.17
Interaction											
November, 1st	Control	55.20g	55.77e	4.33e	3.67c	52.15e	53.33d	13.01d	13.20e	215.67g	224.33g
	Chitosan	55.37fg	56.50e	4.33e	5.00bc	52.27e	53.45d	13.10d	13.48e	223.67fg	230.00fg
	Glycine	56.37efg	56.47e	4.67de	4.67c	53.55de	54.06d	13.25d	13.87d	229.67ef	242.67ef
	Salicylic	56.67ef	57.80d	5.33cde	5.00bc	53.66de	54.12d	13.31d	14.26c	238.00de	245.67e
	Selenium	56.90e	58.07d	5.67bcd	6.33ab	54.14d	54.34d	13.37d	14.28c	251.67d	250.00e
October, 1st	Control	59.63d	60.07c	6.00abc	6.67a	63.95c	63.99c	14.29c	14.37bc	280.33c	273.67d
	Chitosan	60.00cd	60.53c	6.33abc	6.33ab	64.42bc	64.13c	14.35bc	14.43bc	287.00bc	301.67c
	Glycine	61.33bc	61.17bc	6.33abc	6.67a	65.82ab	64.68bc	14.52abc	14.54abc	295.00ab	308.00bc
	Salicylic	62.37ab	61.90ab	6.67ab	6.67a	66.27a	65.85b	14.71ab	14.68ab	300.67ab	316.33ab
	Selenium	63.20a	62.57a	7.00a	6.67a	66.91a	67.24a	14.80a	14.82a	308.00a	323.67a
LSD at 5%		1.39	1.24	1.33	1.55	1.52	1.36	0.37	0.36	13.89	14.40

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 2. Effect of sowing dates and foliar applications of stimulants on photosynthetic pigments of garlic plants at 100 days from planting (2023/24 and 2024/25)

Treatments		Chlorophyll a, mg g^{-1} F.W		Chlorophyll b, mg g^{-1} F.W		Carotene, mg g^{-1} F.W	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Main factor: Sowing date							
November, 1st		1.012b	1.012b	0.791b	0.787b	0.257b	0.254b
October, 1st		1.148a	1.101a	0.855a	0.865a	0.301a	0.314a
LSD at 5%		0.002	0.011	0.012	0.010	0.001	0.001
Sub main factor: Foliar applications							
Control (tap water)		1.040d	1.037d	0.800d	0.800c	0.266c	0.269d
Chitosan (150 mg L^{-1})		1.062c	1.046cd	0.816c	0.822b	0.271c	0.275c
Glycine betaine (700 mg L^{-1})		1.092b	1.060bc	0.825bc	0.838ab	0.281b	0.289b
Salicylic acid (150 mg L^{-1})		1.100ab	1.067ab	0.834ab	0.835a	0.288a	0.295a
Selenium (5.0 mg L^{-1})		1.115a	1.078a	0.842a	0.842a	0.292a	0.298a
LSD at 5%		0.016	0.015	0.014	0.012	0.005	0.005
Interaction							
November, 1st	Control	0.977h	0.995f	0.767f	0.771e	0.242f	0.235f
	Chitosan	0.993gh	1.002ef	0.785ef	0.782de	0.249f	0.241f
	Glycine	1.017fg	1.008ef	0.792e	0.790d	0.259e	0.255e
	Salicylic	1.030ef	1.023de	0.801de	0.792d	0.267d	0.268d
	Selenium	1.046e	1.032d	0.812d	0.798d	0.267d	0.272d
October, 1st	Control	1.104d	1.078c	0.833c	0.828c	0.290c	0.302c
	Chitosan	1.131c	1.090bc	0.846bc	0.862b	0.293c	0.309bc
	Glycine	1.153bc	1.103ab	0.854ab	0.873ab	0.297c	0.314b
	Salicylic	1.169ab	1.110ab	0.867a	0.878ab	0.309b	0.322a
	Selenium	1.184a	1.123a	0.873a	0.885a	0.317a	0.325a
LSD at 5%		0.023	0.022	0.020	0.018	0.007	0.007

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Interaction effect

The interaction results reveal that the best growth parameters and highest pigment concentrations were recorded in garlic plants sown on October 1st and treated with selenium. This synergy can be explained by the extended growing season and the enhanced physiological responses induced by selenium application. Early sowing allows for prolonged photosynthetic activity, while selenium contributes to better stress tolerance and metabolic activity.

Plants sown later (November 1st) but treated with selenium or salicylic acid still performed better than untreated plants, confirming the effectiveness of these compounds in improving garlic growth under suboptimal conditions. The increased photosynthetic pigment content under these treatments further supports their role in improving photosynthetic efficiency and stress resilience. The obtained results are in harmony with those of El-Shabasi *et al.* (2018); Sapt *et al.* (2019); Al-Salami *et al.* (2023); Dubey *et al.* (2023); Mohamed *et al.* (2023).

Garlic performance at 120 days after planting (quality parameters)

Tables (3 and 4) present the effects of the studied treatments on bulb quality parameters [dry matter (%), vitamin C (mg/100g), TSS (%), pyruvate content (πmol ml⁻¹), N, P, K and oil (mg g^{-1})] of garlic plants at 120 days after planting during the 2023/2024 and 2024/2025 seasons.

Table 3. Effect of sowing dates and foliar applications of stimulants on bulb quality parameters of garlic plants at 120 days from planting (2023/24 and 2024/25)

Treatments		Dry matter, %		Vitamin C, mg 100g		TSS, %		Purvate content, πmol ml^{-1}	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Main factor: Sowing date									
November, 1st		20.71b	19.90b	13.04b	12.87b	23.35b	22.91b	9.99b	9.88b
October, 1st		22.18a	21.34a	14.29a	14.11a	24.98a	24.50a	11.11a	10.97a
LSD at 5%		0.24	0.32	0.55	0.55	0.27	0.27	0.01	0.01
Sub main factor: Foliar applications									
Control (tap water)		20.98b	20.18c	13.34c	13.16c	23.78c	23.33c	10.16c	10.08d
Chitosan (150 mg L^{-1})		21.32ab	20.42bc	13.56b	13.41b	24.03bc	23.57bc	10.46bc	10.32c
Glycine betaine (700 mg L^{-1})		21.69a	20.90ab	13.81ab	13.66b	24.29b	23.76abc	10.62abc	10.53bc
Salicylic acid (150 mg L^{-1})		21.63a	20.84a	13.83a	13.64ab	24.31ab	23.84ab	10.72ab	10.60ab
Selenium (5.0 mg L^{-1})		21.72a	20.90a	13.89a	13.70a	24.53a	24.07a	10.87a	10.71a
LSD at 5%		0.41	0.36	0.21	0.22	0.30	0.45	0.39	0.19
Interaction									
November, 1st	Control	20.08c	19.29d	12.56e	12.39c	22.89d	22.44d	9.59e	9.51g
	Chitosan	20.61bc	19.71cd	12.91d	12.78bc	23.22cd	22.83cd	9.94de	9.79f
	Glycine	20.88b	20.08bc	13.12cd	12.94b	23.33cd	22.91cd	9.93de	9.84f
	Salicylic	20.92b	20.17bc	13.30c	13.08b	23.62c	23.12c	10.15d	10.05ef
	Selenium	21.03b	20.24b	13.33c	13.16b	23.68c	23.23c	10.32cd	10.19e
October, 1st	Control	21.87a	21.07a	14.12b	13.93a	24.67b	24.22b	10.73bc	10.64d
	Chitosan	22.02a	21.13a	14.20ab	14.03a	24.84ab	24.31ab	10.98ab	10.84cd
	Glycine	22.28a	21.44a	14.34ab	14.15a	25.02ab	24.49ab	11.14ab	11.02bc
	Salicylic	22.33a	21.52a	14.35ab	14.21a	25.01ab	24.55ab	11.28ab	11.15ab
	Selenium	22.40a	21.56a	14.46a	14.24a	25.38a	24.91a	11.41a	11.22a
LSD at 5%		0.57	0.51	0.30	0.43	0.63	0.63	0.55	0.26

Means within a row followed by a different letter (s) are statistically different at a 0.05 level **TSS*= Total soluble solid**

Table 4. Effect of sowing dates and foliar applications of stimulants on bulb nutritional content and oil content of garlic plants at 120 days from planting (2023/24 and 2024/25)

Treatments		N, %		P, %		K, %		Oil, mg g^{-1}	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Main factor: Sowing date									
November, 1st		2.28b	2.20b	0.314b	0.302b	2.53b	2.47b	15.07b	14.74b
October, 1st		2.53a	2.44a	0.345a	0.331a	2.85a	2.76a	16.41a	16.07a
LSD at 5%		0.01	0.03	0.003	0.008	0.03	0.05	0.24	0.43
Sub main factor: Foliar applications									
Control (tap water)		2.31d	2.22d	0.319d	0.305d	2.56e	2.48e	15.20c	14.89c
Chitosan (150 mg L^{-1})		2.36c	2.28c	0.325c	0.312c	2.61d	2.56d	15.48b	15.12bc
Glycine betaine (700 mg L^{-1})		2.41c	2.33c	0.330bc	0.317c	2.72c	2.63c	15.87b	15.52b
Salicylic acid (150 mg L^{-1})		2.46b	2.37b	0.334b	0.321b	2.76b	2.68b	16.07a	15.76a
Selenium (5.0 mg L^{-1})		2.51a	2.42a	0.341a	0.328a	2.82a	2.74a	16.22a	15.88a
LSD at 5%		0.04	0.04	0.005	0.005	0.05	0.05	0.27	0.27
Interaction									
November, 1st	Control	2.17g	2.08h	0.303h	0.291g	2.39g	2.32g	14.53i	14.24g
	Chitosan	2.22fg	2.15g	0.310gh	0.297fg	2.46fg	2.41f	14.86hi	14.56fg
	Glycine	2.26f	2.19g	0.314fg	0.301ef	2.53f	2.48e	15.03gh	14.68f
	Salicylic	2.38e	2.26f	0.319ef	0.306e	2.61e	2.52e	15.38fg	15.06e
	Selenium	2.40de	2.31ef	0.327e	0.314d	2.67de	2.61d	15.55ef	15.17de
October, 1st	Control	2.45cd	2.35de	0.335d	0.320d	2.73cd	2.64d	15.86de	15.54cd
	Chitosan	2.50bc	2.41cd	0.341cd	0.327c	2.77c	2.72c	16.10cd	15.68c
	Glycine	2.52b	2.44bc	0.344bc	0.331bc	2.87b	2.76bc	16.45bc	16.09b
	Salicylic	2.55b	2.48ab	0.350ab	0.337ab	2.91ab	2.83ab	16.77ab	16.45ab
	Selenium	2.63a	2.53a	0.355a	0.342a	2.96a	2.87a	16.89a	16.58a
LSD at 5%		0.06	0.06	0.008	0.007	0.07	0.07	0.39	0.38

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Individual effect of sowing date

Data in Tables 3 and 4 indicate that garlic plants sown on October 1st exhibited superior bulb quality and nutritional parameters compared to those sown on November 1st. This can be attributed to the longer growing season, allowing for enhanced vegetative growth, nutrient uptake, and photosynthesis efficiency before the onset of high temperatures. The extended growth period likely contributed to higher dry matter accumulation, vitamin C content, total soluble solids (TSS), and pyruvate content. Additionally, improved nitrogen (N), phosphorus (P), and potassium (K) concentrations, along with increased oil content, suggest that early sowing allows plants to optimize resource utilization and metabolic activitiesThe delayed sowing on November 1st may have exposed plants to suboptimal environmental conditions (low temperature), shortening their growth cycle and reducing nutrient accumulation. This aligns with previous studies indicating that early planting improves garlic yield and quality by maximizing growth duration and reducing stress exposure.

Individual effect of foliar applications

Foliar applications significantly improved garlic quality and nutritional attributes. Selenium (Se) at 5.0 mg L^{-1} consistently led to the highest values in dry matter, vitamin C, TSS, pyruvate content, NPK percentage, and oil content. Selenium acts as an antioxidant, enhancing stress tolerance and enzymatic activities that promote metabolic efficiency in garlic bulbs (Doklega *et al.* 2021). Salicylic acid (SA) at 150 mg L^{-1} also showed notable improvements, as it came in the second order, likely due to its role in activating stress defense pathways, improving water retention, and enhancing nutrient assimilation. Glycine betaine (GB) at 700 mg L^{-1} demonstrated similar benefits, as it is known to enhance osmoprotection, maintain cell turgor, and improve photosynthetic efficiency under various environmental stresses. Chitosan (150 mg L^{-1}) positively influenced most quality parameters, though to a lesser extent than SA and Se. Chitosan is recognized for its role in promoting nutrient uptake, enhancing cell wall integrity, and inducing plant defense responses. The control treatment (tap water) consistently resulted in the lowest quality attributes, emphasizing the importance of all studied stimulant applications in enhancing garlic performance.

Interaction effect

The interaction between sowing dates and foliar applications indicated that garlic plants sown on October 1st and treated with selenium achieved the highest values across all measured parameters. This suggests a synergistic effect between optimal growing conditions and stimulant application. Selenium likely enhanced antioxidant defense mechanisms, while the extended growth period facilitated greater nutrient assimilation and carbohydrate accumulation in garlic bulbs. Similarly, foliar applications of salicylic acid, glycine betaine, and chitosan under early sowing conditions significantly improved bulb quality and nutrient content, emphasizing their role in enhancing stress resilience and metabolic activity.

In contrast, the lowest quality and nutrient content were observed in garlic plants sown on November 1st and treated with tap water, underscoring the combined negative impact of delayed sowing and the absence of stimulants. However, all stimulant applications under late planting conditions led to a significant improvement compared to the control. These findings align with previous research, which has demonstrated that foliar-applied stimulants can enhance plant growth, yield, and biochemical composition under various environmental conditions (Sapt *et al.* 2019; El-Metwaly *et al.* 2021; Ali *et al.* 2024; Amerian *et al.* 2024).

Garlic performance at 180 days after planting (bulb yield and its components)

Table 5 presents the effects of the studied treatments on bulb yield and its components of garlic plants at 180 days after planting during the 2023/2024 and 2024/2025 seasons.

Table 5. Effect of sowing dates and foliar applications of stimulants on bulb yield parameters of garlic plants at 180 days from planting (harvest stage) (2023/24 and 2024/25)

Treatments		Average bulb weight, g		Bulb diameter, cm		Neck diameter, cm		Bulbing ratio	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Main factor: Sowing date									
November, 1st		35.51b	34.88b	3.13b	3.17b	0.88a	0.84a	0.28a	0.26a
October, 1st		39.44a	38.80a	3.50a	3.55a	0.78b	0.75b	0.22b	0.21b
LSD at 5%		0.50	1.49	0.06	0.01	0.02	0.03	0.01	0.01
Sub main factor: Foliar applications									
Control (tap water)		36.62bc	35.86b	3.15c	3.20d	0.87a	0.83a	0.28a	0.26a
Chitosan (150 mg L^{-1})		36.56c	36.04b	3.24c	3.28c	0.85ab	0.82ab	0.26a	0.25a
Glycine betaine (700 mg L^{-1})		37.46b	36.41b	3.33b	3.37b	0.83bc	0.79b	0.25b	0.24b
Salicylic acid (150 mg L^{-1})		38.38a	38.17a	3.41a	3.47a	0.82cd	0.79bc	0.24c	0.23bc
Selenium (5.0 mg L^{-1})		38.65a	38.00a	3.45a	3.49a	0.78d	0.76c	0.23c	0.22c
LSD at 5%		0.60	0.45	0.05	0.05	0.03	0.03	0.01	0.01
Interaction									
November, 1st	Control	34.95f	35.22d	3.02g	3.07g	0.92a	0.87a	0.30a	0.28a
	Chitosan	35.02f	33.54e	3.07fg	3.11fg	0.90ab	0.86a	0.29ab	0.28a
	Glycine	35.26ef	33.83e	3.11ef	3.15f	0.88abc	0.84ab	0.28abc	0.27ab
	Salicylic	36.06de	36.33c	3.18de	3.23e	0.87bc	0.83ab	0.27bcd	0.26abc
	Selenium	36.26d	35.49d	3.21d	3.25e	0.84cd	0.80bc	0.26cbe	0.25bc
October, 1st	Control	38.29c	36.49c	3.29c	3.33d	0.82d	0.78cd	0.25de	0.23cd
	Chitosan	38.09bc	38.54b	3.35c	3.40c	0.80de	0.77cd	0.24ef	0.23cd
	Glycine	39.10b	38.46b	3.54b	3.59b	0.77ef	0.75de	0.22fg	0.21de
	Salicylic	40.70a	40.01a	3.65a	3.70a	0.74f	0.74de	0.20g	0.20e
	Selenium	41.04a	40.50a	3.69a	3.74a	0.73f	0.72e	0.20g	0.19e
LSD at 5%		0.85	0.65	0.07	0.07	0.05	0.04	0.01	0.03

Means within a row followed by a different letter (s) are statistically different at a 0.05 level **N.S*= no significant**

Table 5. Cont.

Treatments		No. of cloves bulb^{-1}		Total bulb yield, ton fed^{-1}		Marketable yield, ton fed^{-1}	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Main factor: Sowing date							
November, 1st		16.07b	15.73b	5.68b	5.58b	4.67b	4.68b
October, 1st		18.33a	18.00a	6.31a	6.21a	5.23a	5.18a
LSD at 5%		1.03	0.57	0.07	0.24	0.06	0.20
Sub main factor: Foliar applications							
Control (tap water)		16.33c	16.00d	5.86bc	5.74b	4.71e	4.75c
Chitosan (150 mg L^{-1})		16.83bc	16.50cd	5.85c	5.77b	4.83d	4.82c
Glycine betaine (700 mg L^{-1})		17.29abc	17.00bc	5.99b	5.83b	4.99c	4.98b
Salicylic acid (150 mg L^{-1})		17.67ab	17.33ab	6.14a	6.11a	5.08b	5.05a
Selenium (5.0 mg L^{-1})		18.00a	17.67a	6.18a	6.08a	5.19a	5.10a
LSD at 5%		1.16	0.72	0.10	0.07	0.10	0.08
Interaction							
November, 1st	Control	15.00e	14.67g	5.59f	5.64d	4.40h	4.49f
	Chitosan	15.67de	15.33fg	5.60f	5.37e	4.52h	4.55f
	Glycine	16.00de	15.67efg	5.64ef	5.41e	4.68g	4.70e
	Salicylic	16.67cd	16.33def	5.77de	5.81c	4.81fg	4.82d
	Selenium	17.00bcd	16.67cde	5.80d	5.68d	4.94ef	4.86d
October, 1st	Control	17.67abc	17.33bcd	6.13bc	5.84c	5.02de	5.00c
	Chitosan	18.00abc	17.67abc	6.09c	6.17b	5.13cd	5.08c
	Glycine	18.33ab	18.00ab	6.26b	6.15b	5.23bc	5.20b
	Salicylic	18.67a	18.33ab	6.51a	6.40a	5.34ab	5.28ab
	Selenium	19.00a	18.67a	6.56a	6.48a	5.43a	5.34a
LSD at 5%		1.63	1.01	0.14	0.10	0.13	0.11

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Individual effect of sowing date

Sowing date significantly influenced garlic bulb yield and its components. Garlic sown on October 1st exhibited superior performance compared to the November 1st sowing. The earlier planting resulted in increased average bulb weight, bulb diameter, number of cloves per bulb, total bulb yield, and marketable yield. The observed improvement with the early sowing date can be attributed to prolonged vegetative growth and enhanced photosynthetic efficiency. Longer exposure to favorable climatic conditions allows for better nutrient absorption and carbohydrate accumulation, leading to larger and heavier bulbs. Moreover, early sowing aligns with optimal temperature and humidity levels, reducing stress during critical growth stages and favoring efficient bulbing and clove differentiation. Conversely, delayed sowing (November 1st) led to a significant reduction in yield parameters. Shorter growth duration and increased exposure to temperature fluctuations and moisture stress might have restricted vegetative growth and nutrient assimilation, ultimately reducing bulb size and weight.

Individual effect of foliar applications

Foliar applications significantly improved garlic bulb yield traits compared to the control (tap water). Among the tested treatments, selenium and salicylic acid exhibited the greatest positive effects on yield attributes, followed by glycine betaine and chitosan, with the control showing the lowest values. Selenium application resulted in notable increases in bulb weight, diameter, and overall yield, ranking first among the treatments. This improvement may be attributed to selenium's role in enhancing antioxidant activity, reducing oxidative stress, and improving nutrient uptake efficiency, collectively supporting better bulb development.

Salicylic acid, which showed no significant difference from selenium as both ranked first, may have contributed to increased garlic yield by enhancing plant resilience to environmental stress, regulating hormonal balance, and stimulating metabolic processes that promote bulb enlargement. Glycine betaine (700 mg L^{-1}) likely acted as an osmoprotectant, helping maintain cellular hydration under stress conditions, thereby improving plant vigor and promoting bulb growth. Similarly, chitosan may have contributed to higher bulb yield by enhancing plant defense mechanisms, boosting photosynthetic efficiency, and stimulating root development. Overall, foliar applications led to significant improvements compared to the control, underscoring their effectiveness in enhancing garlic yield under various environmental conditions.

Interaction effect

The interaction between sowing date and foliar applications significantly influenced bulb yield and its components. The highest values for bulb weight, diameter, total yield, and marketable yield were recorded for garlic sown on October 1st and treated with selenium or salicylic acid. These findings suggest a synergistic effect between early sowing and stimulant application, where favorable environmental conditions maximize the efficacy of foliar treatments.

The beneficial effects of selenium and salicylic acid were more pronounced under early sowing, likely due to extended growth duration and improved stress tolerance mechanisms. Similar trends were observed with glycine betaine and chitosan applications, though their effects were slightly less pronounced compared to selenium and salicylic acid.

On the other hand, garlic sown on November 1st and treated with tap water exhibited the lowest yield parameters. However, even under late sowing conditions, foliar applications significantly improved bulb yield and quality, demonstrating their potential in mitigating the adverse effects of delayed planting. The findings are in an accordance with those of Sapt *et al.* (2019); El-Metwaly *et al.* (2021); Ali *et al.* (2024); Amerian *et al.* (2024).

CONCLUSION

This study highlights the crucial role of foliar applications in enhancing garlic productivity, particularly under late planting conditions, where plants face increased environmental stress. Among the tested treatments, selenium and salicylic acid demonstrated the most significant improvements in bulb yield attributes, likely due to their roles in mitigating oxidative stress, enhancing nutrient uptake, and promoting stress tolerance. Glycine betaine and chitosan also contributed positively by improving osmotic balance, photosynthetic efficiency, and plant defense mechanisms. The findings emphasize the importance of targeted foliar applications as a practical and sustainable strategy to optimize garlic yield and quality, especially in regions where late planting is necessary due to climatic constraints. Based on these results, it is recommended to integrate selenium and salicylic acid into garlic production systems to maximize productivity and stress resilience. Further research should explore their combined effects with other stimulants to enhance long-term crop sustainability.

REFERENCES

Abd El-Hady, M. A. and A. S. Abd-Elhamied (2018). Impact of foliar, soil mineral fertilization and some activators on cucumber productivity. J. Plant Production, Mansoura Univ., 9(2): 193 -201.

Ali, K. A., Ahmed, A. T., Mohammed, M. M., & Mohammed, O. H. (2024). Effect of proline and salicylic acid on some physiological characteristics and chemical content of garlic plants Garlic Allium sativum L. Journal of Education and Scientific Studies, 8(23).

Al-Salami, M. O. G., & Alhasnawi, N. J. R. (2023, December). Effect of water stress and selenium spraying on vegetative and yield indicators of garlic *Allium sativum* L. In IOP Conference Series: Earth and Environmental Science, 1262 (5), pp. 052042. IOP Publishing.

Amerian, M., KhoramiVafa, M., Palangi, A., Gohari, G., & Ntatsi, G. (2024). The effect of different levels of urea and sodium selenate on the morphophysiological characteristics of garlic (*Allium sativum* L.). Scientia Horticulturae, 337, 113469.

AOAC (2000).″ Official Methods of Analysis‶. 18th Ed. Association of Official Analytical Chemists, Inc., Gaithersburg, MD, Method 04.

Dane, J. H., & Topp, C. G. (2020). Methods of soil analysis, Part 4: Physical methods (Vol. 20). John Wiley & Sons.

Doklega, S. M., El-Kafrawy, M. M., & Imryed, Y. (2021). Impact of gypsum soil addition and foliar application of selenium on red cabbage plants grown on sodic Soil. Plant cell biotechnology and molecular biology, 108-117.

Dubey, P. M., Pandey, B. R., Bagare, V., & Upadhyay, J. (2023). Growth, yield and quality of garilic (*Allium sativum* L.) influenced by the application of sulphur and salicylic acid. International Journal of Environment and Climate Change, 13(11), 2135-2139.

El-Metwaly, H. M. B., El-Morsy, A. H. A., & El-Basir, A. (2021). Influence of planting dates and some NK-rates on productivity and storability of garlic. Journal of Plant Production, 12(1), 19-24.

El-Shabasi, M. S. S., Osman, Y. M. M., & Rizk, S. M. (2018). Effect of planting date and some pre-planting treatments on growth and yield of garlic. Journal of Plant Production, 9(12), 1091-1096.

Gomez; K. A., & Gomez, A.A (1984). "Statistical Procedures for Agricultural Research". John Wiley and Sons, Inc., New York.pp:680.

Hamaiel, A. F.; M. A. M. Abd El-Hady and Kh. R. Hussien (2020). Impact of sulfur rates and some foliar applications on broccoli. J. Plant Production, Mansoura Univ., 11 (9): 835 – 839.

Kerr, D., Grahame, G., & Nakouzi, G. (2012). Assays of pyruvate dehydrogenase complex and pyruvate carboxylase activity. Mitochondrial Disorders: Biochemical and Molecular Analysis, 93-119.

Mohamed, I. H., Abdelrasheed, K. G., Abbas, H. S., & Shehata, M. N. (2023). Effect of foliar application by chitosan on five garlic genotypes in Aswan the southern Egypt. Aswan University Journal of Sciences and Technology, 3(2), 67-90.

Nada, M. M. and M. A. M. Abd El-Hady (2019). Influence of salicylic acid on cucumber plant under different irrigation levels . J. Plant Production, Mansoura Univ., 10 (2): 165-171.

Papu, S., Jaivir, S., Sweta, S., & Singh, B. R. (2014). Medicinal values of garlic (*Allium sativum* L.) in human life: an overview. Greener Journal of Agricultural Sciences, 4(6), 265-280.

Peterburgski, A. V. (1968)."Handbook of Agronomic Chemistry". Kolos Puplishing House, Moscow, (in Russian, pp. 29-86).

Sapt, W. M., Metwally, H. G., Shehata Omran, A. E., & Ragab, M. E. (2019). Effect of irrigation levels, soil conditioner and foliar application of potassium silicate or glycine betaine on vegetative growth and chemical composition of garlic. Arab Universities Journal of Agricultural Sciences, 27(3), 1947-1953.

Sparks, D. L., Page, A. L., Helmke, P. A., & Loeppert, R. H. (Eds.). (2020). Methods of soil analysis, part 3: Chemical methods (Vol. 14). John Wiley & Sons.

Tesfaye, A., & Mengesha, W. (2015). Traditional uses, phytochemistry and pharmacological properties of garlic (*Allium Sativum*) and its biological active compounds. Int. J. Sci. Res. Eng. Technol., 1, 142-148.

Torres, P. B., Chow, F., Furlan, C. M., Mandelli, F., Mercadante, A., & Santos, D. Y. A. C. D. (2014). Standardization of a protocol to extract and analyze chlorophyll a and carotenoids in Gracilaria tenuistipitata Var. Liui. Zhang and Xia (Rhodophyta). Brazilian Journal of Oceanography, 62, 57-63.

Walinga, I., Van Der Lee, J. J., Houba, V. J., Van Vark, W., & Novozamsky, I. (2013). Plant analysis manual. Springer Science & Business Media.

تأثير مواعيد الزراعة والرش الورقي بحمض السالسيلك والسيلينيوم والشيتوزان والجليسين بيتاين على النمو والإنتاجية في الثوم

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الملخص

يُعد الثوم من المحاصيل الاقتصادية المهمة، إلا أن زراعته المتأخرة تعرضه للإجهاد الناتج عن انخفاض درجات الحرارة، مما يؤثر سلبًا على النمو والمحصول والجودة. استهدفت هذه الدراسة تعزيز تحمل نباتات الثوم لدرجات الحرارة المنخفضة وتحسين إنتاجيتها من خلال الرش الورقي ببعض المحفزات تحت مواعيد زراعة مختلفة. تم تنفيذ تجربة حقلية في مزرعة خاصة بقرية ميت فارس، مركز بني عبيد، محافظة الدقهلية، مصر، باستخدام تصميم القطع المنشقة بثلاث مكررات. تم تخصيص القطع الرئيسية لموعدي الزراعة (الأول من أكتوبر والأول من نوفمبر)، بينما تم تخصيص القطع المنشقة لمعاملات الرش الورقي، والتي شملت حمض السالسيلك (١٥٠ ملجم لتر$^{-1}$)، والسيلينيوم (٥,٠ ملجم لتر$^{-1}$)، والشيتوزان (١٥٠ ملجم لتر$^{-1}$)، والجليسين بيتاين (٧٠٠ ملجم لتر$^{-1}$)، بالإضافة إلى معاملة الكنترول (ماء الصنبور). تم تسجيل القياسات عند 100 و١٢٠ و١٨٠ يومًا بعد الزراعة ، حيث شملت الصفات المتعلقة بالنمو الخضري، وصبغات البناء الضوئي، والمحتوى الكيميائي الحيوي، وصفات المحصول. أظهرت النتائج أن الزراعة المبكرة (الأول من أكتوبر) أدت إلى تحسين ملحوظ في النمو النباتي وتراكم صبغات البناء الضوئي وزيادة محصول رؤس الثوم. من بين معاملات الرش الورقي، كان للسيلينيوم التأثير الإيجابي الأكبر، يليه حمض السالسيلك، ثم الجليسين بيتاين، يليه الشيتوزان مقارنة بمعاملة الكنترول. بالإضافة إلى ذلك، أسهمت جميع معاملات المحفزات في تحسين المحصول القابل للتسويق وجودة رؤس الثوم مقارنة بمعاملة الكنترول. تؤكد هذه النتائج الدور الحيوي لتلك المحفزات الورقية في تخفيف تأثير إجهاد درجات الحرارة المنخفضة وتحسين إنتاجية الثوم تحت مواعيد الزراعة المختلفة.

الكلمات الدالة: حمض السالسيلك ،السيلينيوم ،الشيتوزان ،الجليسين بيتاين.