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Improving the Productivity and Quality of Garlic Grown under Water Deficit Stress Using Potassium Silicate as Supplementary Additives, Along with Foliar Application of Calcium and Boron

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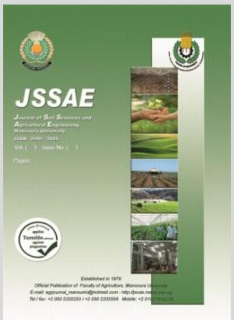

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ABSTRACT

In Egypt, garlic is of great importance in the agricultural and commercial sectors. Therefore, improving its quantitative and qualitative characteristics, especially under water deficit challenges, will have a significant positive impact on food production and the agricultural economy. So, afield experiment was carried out during two successive seasons to evaluate the effect of three irrigation requirement treatments [100,80 and 60% of Irrigation Requirements IR] as main factor, three potassium silicate rates [0.0 5.0 and 7.0 kg fed^{-1}] as sub main factor and two treatments of calcium/boron mix [applied or not] as sub sub plots on the quantitative and qualitative traits of garlic. 100% of IR achieved the highest values of most parameters *e.g.,* plant height, No. of leaves plant^{-1}, carotene, marketable bulb yield, TSS, vitamin C, followed by 80% and 60%, respectively. As the potassium, silicate rate increased the values of most traits increased, where the 7.0 kg fed^{-1} treatment led to the best results. In contrast, the calcium/boron foliar application showed no significant individual effect on some parameters such as neck diameter, vitamin C and showed a positive significant effect on other traits such as average bulb weight, bulb diameter, total and marketable bulb. As for interaction, there aren't significant difference in the effect between the combined treatment [80 % IR x potassium silicate (7.0 kg fed^{-1}) x Ca/B] and the treatment that combined 100% IR with no potassium silicate and no Ca/B application. Therefore, this approach can be incorporated into garlic cultivation, especially under water deficit conditions.

Keywords: Potassium silicate, calcium, boron, garlic

INTRODUCTION

In Egypt, garlic (*Allium sativum* .L) is of great importance in the agricultural and commercial sectors. It is a major food crop with wide medicinal and commercial uses. Therefore, improving its quantitative and qualitative characteristics will have a significant positive impact on food production and the agricultural economy (El Sayed *et al.* 2024). On the other hand, a persistent challenge currently facing the Egyptian agricultural sector is water scarcity and limited water resources. Therefore, it is necessary to study the effect of water deficit stress on garlic plant performance and work to improve its quantitative and qualitative characteristics under water-deficit conditions (Sánchez-Virosta *et al.* 2020). Furthermore, potassium silicate (K_2SiO_3) is believed to enhance plant resistance to environmental stress, including water deficit stress, and testing different levels of this can determine the best application for improving growth and productivity. The silicate fraction in the compound works to strengthen cell walls and increase their rigidity, which enhances their ability to resist environmental stress, while potassium plays a major role in regulating water movement under water stress conditions, as it regulates the absorption of water and nutrients (Pandey & Mahiwal, 2020; Baddour *et al.* 2024). Nutrients such as calcium and boron also play a key role in improving plant health and crop quality under drought stress and studying the effect of foliar sprays can help enhance garlic's resistance to water stress and improve its nutritional properties (Shaban *et al.* 2019; Yatsenko *et al.* 2020). By improving garlic's tolerance to water stress and increasing water use efficiency, greater agricultural sustainability can be achieved and the negative effects of water scarcity on agricultural production can be reduced. Finally, the aim of this study was to examine the effect of potassium silicate as supplementary additives in conjunction with foliar application of calcium and boron (Ca/B) on the productivity and quality of garlic grown under water deficit stress.

MATERIALS AND METHODS

The experimental location of this research work was Meet-Anter Village, Talkha District, Dakahlia Governorate in private farm. The experimental seasons were 2023/24 and 2024/25. In this investigation, a design of split split plot was implemented as the experimental design using three replicates. Three irrigation requirement treatments [100% of Irrigation Requirements IR (equal 1294 m^{3}fed^{-1}), 80% of IR (equal 1035.2 m^{3}fed^{-1}) and 60% of IR (equal 776.4 m^{3}fed^{-1})] were investigated as main factor, while the potassium silicate rates were represented the sub main factor [0.0 5.0 and 7.0 kg fed^{-1}], additionally two treatments of calcium/boron mix [applied or not] were arranged in the sub sub plots. The drip irrigation system was used in this investigation. Irrigation water quantities were controlled using a meter on the main irrigation pipe. The equation of FAO Penman-Monteith equation was used to calculate ET_0 (reference evapotranspiration), then multiplied by the Kc (crop coefficient) appropriate for each growth stage to obtain the

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actual plant water consumption ETc (actual plant water consumption) (Allen *et al.*1998). The quantities of water to be applied to each treatment were then determined.

Garlic cloves "cv. Balady" were obtained from agricultural research center then sown on November 3rd in both studied seasons, as the experimental area of each sub sub plot was 10 m^2 (4 lines, with 5.0 m long and 0.5 m wide), with 15 cm among the plants as planting distance on both sides of a planting row. All plots received compost before sowing two months at a rate of 6.0 ton fed^{-1}. NPK fertilizers were added as fertigation using ammonium sulphate (21% N), phosphoric acid H_3PO_4 (60%P_2O_5) and potassium sulphate (48% K_2O) at the recommended times, as the NPK fertilizers were added at rate of 90, 50 and 50 unit of N, P_2O_5 and K_2O fed^{-1} for all plots. Additionally potassium silicate was added in fertigation system as supplementary additives according to the studied treatments. The foliar application of Calcium/Boron mix was done four times with 15 days intervals, the first spraying was after 30 days from sowing. The harvest process was executed after 176 days from sowing. Table 1 illustrates the soil properties (before planting) and the studied substances characteristics. The measurements were implemented at two different stages as shown in Table 2. The statistical analysis was done for the obtained findings according to Gomez and Gomez (1984), as it was done by CoStat software (Version 6.303, CoHort, USA, 1998-2004).

Table 1. The soil properties (before planting) and the studied substances characteristics

Characteristics	Values
Initial soil (It was taken at depth of 30 cm and analyzed as described by Tandon, 2005)	
Characteristics	Values
EC, dSm^{-1}	2.15
pH	8.0
OM, %	1.34
K, ppm	199.0
N, ppm	39.6
P, ppm	11.2
Sand,%	25.0
Clay ,%	50.0
Silt,%	25.0
Textural class	Clay
Calcium/Boron mix (It was bought from the Egyptian commercial market)	
Characteristics	Values
Ca	18%
B	3%
N	12%
Potassium silicate (K_2SiO_3) (It was bought from the Egyptian commercial market)	
Characteristics	Values
K_2O	12%
SiO_2	25%

Table 2. The studied measurements at two different stages

Measurement Time	Trait Measured	Method of Measurement	Reference
At a period of 95 days	Plant height (cm)	Manually measured using traditional method	—
	Number of leaves $plant^{-1}$		
	Fresh weight (g $plant^{-1}$)		
	Dry weight (g $plant^{-1}$)		
	Leaf area (cm^2 $plant^{-1}$)		
	Chlorophyll a, b and carotene	Spectrophotometric method	Picazo *et al.* (2013)
	Leaf nitrogen (N) content	Micro-Kjeldahl method after digestion with H_2SO_4:$HClO_4$ (1:1)	Peterburgski,(1968); Walinga *et al.*(2013)
	Leaf phosphorus (P) content	Olsen method after digestion with H_2SO_4:$HClO_4$ (1:1)	
	Leaf potassium (K) content	Flame photometer after digestion with H_2SO_4:$HClO_4$ (1:1)	
	Malondialdehyde (MDA, μmol g^{-1} F.W.)	Spectrophotometric method	Valenzuela, (1991)
	Peroxidase POD and Catalase CAT, (unit mg^{-1} protein)	Spectrophotometric method	Elavarthi & Martin, (2010)
At a period of 180 days	Total bulb yield (ton fed^{-1})	Manually measured using traditional method	—
	Marketable bulb yield (ton fed^{-1})	Manually measured using traditional method	
	Bulb weight (g)	Manually measured using traditional method	
	Bulb diameter (cm)	Manually measured using traditional method	
	Neck diameter (cm)	Manually measured using traditional method	
	Bulbing ratio	(Bulb diameter / Neck diameter)	
	Number of cloves $bulb^{-1}$	Manually counted	
	Carbohydrate content (%)	Standard laboratory method	AOAC, (2000)
	Total soluble solids (TSS, %)	Standard laboratory method	
	Vitamin C content (mg 100 g^{-1})	Standard laboratory method	
	Dry matter content (%)	Standard laboratory method	
	Pungency (pyruvic acid content, πmol ml^{-1})	Standard laboratory method	

RESULTS AND DISCUSSION

1.First Evaluation Stage (95 Days from Planting)

Table 3 presents the effects of irrigation regimes, potassium silicate levels and calcium/boron foliar application on the vegetative growth characteristics of garlic plants *i.e*, plant height (cm), No. of leaves $plant^{-1}$, fresh weight (g $plant^{-1}$), dry weight(g $plant^{-1}$), leaf area (cm^2 $plant^{-1}$) at 95 days after planting during the 2023/24 and 2024/25 seasons. Table 4 shows the effect of the studied treatments under the same conditions on photosynthetic pigments (chlorophyll a &b and carotene, mg g^{-1}), while Table 5 illustrates the effect of the studied treatments under the same conditions on the chemical constituents in leaf (N, P and K, %). Table 6 displays the effect of the studied treatments under the same conditions on enzymatic antioxidants (peroxidase POD and catalase CAT, unit mg^{-1} protein) as well as malondialdehyde (MDA, μmol g^{-1} F.W.) as an indicator of oxidation. The data are shown for individual factors as well as their bilateral and trilateral interactions, along with statistical significance levels and LSD values.

Individual effect

The irrigation regime (IR) had a highly significant effect on all measured growth traits, photosynthetic pigments and leaf chemical content under both investigated seasons. Full irrigation at 100% of the garlic water requirement consistently achieved the highest values across all parameters (plant height, No. of leaves plant^{-1}, fresh and dry weights, leaf area, chlorophyll a &b , carotene, N, P and K, followed by 80% and 60%, respectively. This trend indicates the detrimental impact of water deficit on garlic performance development. On the other hand, the observed trends in oxidative stress markers reflect the direct influence of water availability on the garlic plant's defensive capacity (Table 6).

Under full irrigation (100% IR), garlic plants showed significantly higher activities of antioxidant enzymes such as peroxidase (POD) and catalase (CAT), along with reduced levels of malondialdehyde (MDA), a key indicator of lipid peroxidation. This suggests that optimal water supply supports cellular integrity by enhancing enzymatic scavenging of reactive oxygen species, thereby limiting oxidative damage. Conversely, under severe water deficit (60% IR), the marked reduction in POD and CAT activities, coupled with a pronounced increase in MDA content, indicates the onset of oxidative stress due to insufficient ROS detoxification.

This oxidative burden is likely a result of impaired physiological functions, including disrupted photosynthesis and nutrient imbalances, which compromise the plant's ability to maintain redox homeostasis. The superior performance of garlic plants under full irrigation can be attributed to enhanced physiological functioning supported by adequate water availability. Sufficient irrigation improves root activity and nutrient transport, which in turn promotes higher levels of chlorophyll a, chlorophyll b, and carotenoids, key pigments involved in capturing light energy for photosynthesis.

This enhanced photosynthetic efficiency likely contributed to increased biomass accumulation and leaf expansion. Furthermore, the improved nutrient status observed under optimal irrigation, particularly the elevated concentrations of nitrogen, phosphorus, and potassium in the leaves, played a fundamental role in supporting growth. Nitrogen is central to chlorophyll synthesis and enzymatic activity, phosphorus is essential for energy transfer and root development, and potassium regulates osmotic balance and stomatal function. The synchronized increase in these macronutrients aligns with the observed improvements in vegetative traits such as plant height, leaf number, and total leaf area.

Table 3. Effect of the potassium silicate and Ca/B on the growth criteria of garlic plant grown under different irrigation regimes at 95days from planting during the growing seasons of 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
A: Irrigation requirement IR treatments												
100 % of IR			87.72^{a}	88.94^{a}	10.89^{a}	11.50^{a}	87.66^{a}	89.55^{a}	19.32^{a}	19.59^{a}	354.81^{a}	360.96^{a}
80% of IR			81.36^{b}	82.54^{b}	9.94^{b}	10.56^{b}	84.07^{b}	85.82^{b}	18.53^{b}	18.80^{b}	333.20^{b}	339.08^{b}
60% of IR			74.32^{c}	75.49^{c}	8.72^{c}	8.83^{c}	79.92^{c}	81.62^{c}	17.39^{c}	17.66^{c}	275.18^{c}	281.22^{c}
F. Test			**	**	**	**	**	**	**	**	**	**
LSD at 5%			0.45	0.30	0.60	0.73	0.25	0.83	0.24	0.03	3.60	3.68
B: Potassium silicate (as supplements) treatments												
Control (without)			79.50^{b}	80.66^{b}	9.50^{b}	9.72^{b}	82.61^{b}	84.31^{b}	18.16^{c}	18.43^{c}	313.56^{c}	318.56^{c}
K_1:Potassium silicate (5.0 kg fed^{-1})			80.25^{b}	81.44^{b}	9.83^{ab}	10.39^{ab}	83.61^{b}	85.35^{b}	18.37^{b}	18.64^{b}	320.28^{b}	326.55^{b}
K_2:Potassium silicate (7.0 kg fed^{-1})			83.65^{a}	84.86^{a}	10.22^{a}	10.78^{a}	85.42^{a}	87.33^{a}	18.72^{a}	18.98^{a}	329.34^{a}	336.14^{a}
F. Test			*	*	*	*	*	*	**	**	**	**
LSD at 5%			1.45	1.29	0.45	0.69	1.30	1.25	0.17	0.20	1.95	1.99
C: Calcium /boron (Ca/B) foliar applications												
Control (without)			80.91^{a}	82.09^{a}	9.74^{a}	10.15^{a}	83.63^{a}	85.41^{a}	18.36^{a}	18.63^{a}	320.19^{a}	326.17^{a}
Ca/B			81.36^{a}	82.55^{a}	9.96^{a}	10.44^{a}	84.13^{a}	85.91^{a}	18.47^{a}	18.73^{a}	321.93^{a}	328.00^{a}
F. Test			NS*	NS*	NS*	NS*	NS*	NS*	NS*	NS*	NS*	NS*
LSD at 5%			NS*	NS*	NS*	NS*	NS*	NS*	NS*	NS*	NS*	NS*
Interaction among the three factors (A×B×C)												
100 % of IR	Control	Control	86.65	88.02	10.67	11.00	86.85	88.95	19.07	19.38	352.06	357.33
		Ca/B	86.85	87.98	10.67	11.33	87.04	88.60	19.10	19.34	351.80	357.41
	K_1	Control	87.20	88.34	10.67	11.33	87.43	89.17	19.30	19.54	355.69	361.75
		Ca/B	87.74	89.20	11.00	11.67	87.54	89.57	19.37	19.71	355.46	361.84
	K_2	Control	88.89	90.03	11.00	11.67	87.98	90.04	19.44	19.71	356.72	363.49
		Ca/B	88.99	90.06	11.33	12.00	89.12	90.98	19.65	19.88	357.11	363.92
80 % of IR	Control	Control	78.04	79.20	9.33	10.00	81.99	83.63	18.15	18.42	321.15	327.29
		Ca/B	78.95	79.94	9.67	10.33	82.13	83.77	18.30	18.55	322.42	328.20
	K_1	Control	78.84	79.91	9.67	10.33	83.12	84.86	18.35	18.59	329.53	334.79
		Ca/B	79.14	80.20	10.33	10.67	83.55	85.13	18.35	18.61	329.84	335.45
	K_2	Control	86.59	88.08	10.33	11.00	86.81	88.72	19.00	19.30	348.18	354.43
		Ca/B	86.60	87.89	10.33	11.00	86.81	88.81	19.03	19.30	348.05	354.32
60 % of IR	Control	Control	73.10	74.20	8.33	7.67	78.40	80.01	17.06	17.33	266.07	270.32
		Ca/B	73.42	74.63	8.33	8.00	79.28	80.88	17.26	17.53	267.85	270.83
	K_1	Control	73.78	74.92	8.67	9.00	79.66	81.29	17.39	17.66	269.72	276.47
		Ca/B	74.83	76.07	8.67	9.33	80.39	82.10	17.43	17.72	281.43	289.01
	K_2	Control	75.14	76.14	9.00	9.33	80.45	82.05	17.48	17.73	282.63	289.70
		Ca/B	75.68	76.95	9.33	9.67	81.33	83.38	17.71	17.96	283.38	291.00
F. Test			*	*	*	*	*	*	*	*	**	**
LSD at 5%			4.65	4.03	1.19	1.38	4.12	3.77	0.38	0.39	7.99	8.14
F. Test of bilateral interaction												
A×B			*	*	*	*	*	*	*	*	**	**
A×C			*	*	*	*	*	*	*	*	*	*
B×C			*	*	*	*	*	*	*	*	*	*

Means within a row followed by a different letter (s) are statistically different at a 0.05 level **NS*= non-significant**

Table 4. Effect of the potassium silicate and Ca/B on the photosynthetic pigments in leaves of garlic plant grown under different irrigation regimes at 95 days from planting during the growing seasons of 2023/24 and 2024/25

Treatments			Chlorophyll a, mg g^{-1}		Chlorophyll b, mg g^{-1}		Carotene, mg g^{-1}	
			1st season	2nd season	1st season	2nd season	1st season	2nd season
A: Irrigation requirement IR treatments								
100 % of IR			0.977^{a}	0.995^{a}	0.723^{a}	0.737^{a}	0.345^{a}	0.353^{a}
80% of IR			0.927^{b}	0.947^{b}	0.691^{b}	0.707^{b}	0.325^{b}	0.333^{b}
60% of IR			0.868^{c}	0.890^{c}	0.630^{c}	0.646^{c}	0.286^{c}	0.293^{c}
F. Test			**	**	**	**	**	**
LSD $_{at\ 5\%}$			0.011	0.004	0.008	0.011	0.002	0.005
B: Potassium silicate (as supplements) treatments								
Control (without)			0.907^{c}	0.925^{c}	0.670^{c}	0.686^{c}	0.311^{c}	0.319^{c}
K_1: Potassium silicate (5.0 kg fed^{-1})			0.921^{b}	0.943^{b}	0.680^{b}	0.695^{b}	0.317^{b}	0.324^{b}
K_2: Potassium silicate (7.0 kg fed^{-1})			0.943^{a}	0.964^{a}	0.693^{a}	0.709^{a}	0.328^{a}	0.336^{a}
F. Test			**	**	**	**	**	**
LSD $_{at\ 5\%}$			0.006	0.007	0.004	0.006	0.002	0.002
C: Calcium /boron (Ca/B) foliar applications								
Control (without)			0.921^{a}	0.940^{b}	0.679^{a}	0.694^{b}	0.317^{b}	0.323^{b}
Ca/B			0.927^{a}	0.948^{a}	0.683^{a}	0.700^{a}	0.321^{a}	0.329^{a}
F. Test			NS*	**	NS*	**	**	**
LSD $_{at\ 5\%}$			NS*	0.006	NS*	0.004	0.002	0.002
Interaction among the three factors (A×B×C)								
100 % of IR	Control	Control	0.960	0.979	0.714	0.728	0.340	0.347
		Ca/B	0.962	0.980	0.715	0.729	0.341	0.349
	K_1	Control	0.974	0.993	0.722	0.733	0.342	0.351
		Ca/B	0.979	0.999	0.723	0.738	0.344	0.352
	K_2	Control	0.989	1.004	0.728	0.743	0.349	0.356
		Ca/B	0.994	1.015	0.732	0.748	0.353	0.361
80 % of IR	Control	Control	0.900	0.918	0.673	0.691	0.315	0.321
		Ca/B	0.905	0.925	0.678	0.695	0.319	0.327
	K_1	Control	0.917	0.942	0.684	0.698	0.322	0.328
		Ca/B	0.922	0.943	0.689	0.703	0.324	0.334
	K_2	Control	0.957	0.976	0.709	0.724	0.335	0.343
		Ca/B	0.958	0.979	0.711	0.729	0.337	0.347
60 % of IR	Control	Control	0.850	0.868	0.619	0.630	0.275	0.281
		Ca/B	0.861	0.882	0.621	0.640	0.279	0.287
	K_1	Control	0.861	0.878	0.628	0.643	0.281	0.287
		Ca/B	0.874	0.900	0.634	0.653	0.288	0.295
	K_2	Control	0.877	0.899	0.637	0.650	0.292	0.298
		Ca/B	0.884	0.911	0.642	0.661	0.303	0.311
F. Test			**	**	*	*	**	**
LSD $_{at\ 5\%}$			0.022	0.017	0.016	0.012	0.007	0.007
F. Test of bilateral interaction								
A×B			**	**	*	*	**	**
A×C			*	**	*	*	**	**
B×C			*	**	*	*	**	**

Means within a row followed by a different letter (s) are statistically different at a 0.05 level **NS*= non-significant**

Table 5. Effect of the potassium silicate and Ca/B on the chemical constituents in leaves of garlic plant grown under different irrigation regimes at 95 days from planting during the growing seasons of 2023/24 and 2024/25

Treatments			N,%		P,%		K,%	
			1st season	2nd season	1st season	2nd season	1st season	2nd season
A: Irrigation requirement IR treatments								
100 % of IR			3.67^{a}	3.79^{a}	0.372^{a}	0.377^{a}	3.02^{a}	3.08^{a}
80% of IR			3.45^{b}	3.56^{b}	0.351^{b}	0.356^{b}	2.87^{b}	2.93^{ab}
60% of IR			3.12^{c}	3.23^{a}	0.316^{c}	0.321^{c}	2.44^{c}	2.49^{b}
F. Test			**	**	**	**	**	**
LSD $_{at\ 5\%}$			0.04	0.04	0.002	0.005	0.007	0.03
B: Potassium silicate (as supplements) treatments								
Control (without)			3.32^{c}	3.43^{c}	0.339^{c}	0.344^{c}	2.70^{c}	2.75^{a}
K_1:Potassium silicate (5.0 kg fed^{-1})			3.41^{b}	3.51^{b}	0.347^{b}	0.352^{b}	2.78^{b}	2.83^{b}
K_2:Potassium silicate (7.0 kg fed^{-1})			3.51^{a}	3.63^{a}	0.353^{a}	0.358^{a}	2.86^{a}	2.92^{c}
F. Test			**	**	**	**	**	**
LSD $_{at\ 5\%}$			0.03	0.04	0.002	0.003	0.03	0.03
C: Calcium /boron (Ca/B) foliar applications								
Control (without)			3.40^{b}	3.51^{b}	0.344^{b}	0.350^{b}	2.76^{b}	2.82^{b}
Ca/B			3.43^{a}	3.55^{a}	0.348^{a}	0.353^{a}	2.79^{a}	2.85^{a}
F. Test			**	**	**	**	**	**
LSD $_{at\ 5\%}$			0.02	0.02	0.002	0.002	0.02	0.02
Interaction among the three factors (A×B×C)								
100 % of IR	Control	Control	3.60	3.72	0.364	0.369	2.98	3.03
		Ca/B	3.61	3.72	0.368	0.373	2.99	3.05
	K_1	Control	3.66	3.77	0.371	0.376	3.02	3.08
		Ca/B	3.66	3.77	0.373	0.379	3.03	3.09
	K_2	Control	3.75	3.86	0.375	0.380	3.06	3.12
		Ca/B	3.76	3.90	0.379	0.384	3.07	3.13
80 % of IR	Control	Control	3.30	3.42	0.342	0.347	2.77	2.83
		Ca/B	3.37	3.47	0.344	0.349	2.81	2.87
	K_1	Control	3.40	3.50	0.349	0.354	2.84	2.90
		Ca/B	3.49	3.59	0.353	0.358	2.88	2.94
	K_2	Control	3.55	3.67	0.357	0.363	2.95	3.01
		Ca/B	3.58	3.70	0.359	0.364	2.98	3.03
60 % of IR	Control	Control	3.01	3.10	0.306	0.311	2.30	2.36
		Ca/B	3.06	3.18	0.312	0.317	2.33	2.38
	K_1	Control	3.10	3.22	0.315	0.320	2.43	2.48
		Ca/B	3.14	3.25	0.319	0.324	2.46	2.51
	K_2	Control	3.20	3.30	0.322	0.327	2.52	2.57
		Ca/B	3.22	3.35	0.324	0.329	2.59	2.64
F. Test			**	**	**	**	**	**
LSD $_{at\ 5\%}$			0.07	0.06	0.006	0.007	0.06	0.07
F. Test of bilateral interaction								
A×B			**	**	**	**	**	**
A×C			**	**	**	**	**	**
B×C			**	**	**	**	**	**

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

Table 6. Effect of the potassium silicate and Ca/B on the oxidation indicators in leaves of garlic plant grown under different irrigation regimes at 95 days from planting during the growing seasons of 2023/24 and 2024/25

Treatments			POD, unit mg^{-1} protein^{-1}		CAT, unit mg^{-1} protein^{-1}		MDA, µmol.g^{-1} F.W	
			1st season	2nd season	1st season	2nd season	1st season	2nd season
A: Irrigation requirement IR treatments								
100 % of IR			4.14^{a}	4.23^{a}	10.02^{a}	10.19^{a}	12.30^{c}	11.34^{c}
80% of IR			3.56^{b}	3.63^{b}	9.64^{b}	9.81^{b}	13.56^{b}	12.52^{b}
60% of IR			2.24^{c}	2.29^{c}	8.78^{c}	8.97^{c}	14.69^{a}	13.54^{a}
F. Test			**	**	**	**	**	**
LSD at 5%			0.08	0.06	0.15	0.21	0.20	0.23
B: Potassium silicate (as supplements) treatments								
Control (without)			2.73^{c}	2.79^{c}	9.09^{c}	9.24^{c}	13.93^{a}	12.85^{a}
K_1:Potassium silicate (5.0 kg fed^{-1})			3.43^{b}	3.50^{b}	9.55^{b}	9.74^{b}	13.52^{b}	12.46^{b}
K_2:Potassium silicate (7.0 kg fed^{-1})			3.79^{a}	3.86^{a}	9.80^{a}	9.99^{a}	13.10^{c}	12.09^{c}
F. Test			**	**	**	**	**	**
LSD at 5%			0.03	0.01	0.05	0.07	0.07	0.11
C: Calcium /boron (Ca/B) foliar applications								
Control (without)			3.23^{b}	3.29^{b}	9.42^{b}	9.60^{b}	13.62^{b}	12.56^{a}
Ca/B			3.40^{a}	3.47^{a}	9.54^{a}	9.72^{a}	13.41^{a}	12.37^{b}
F. Test			**	**	**	**	**	**
LSD at 5%			0.06	0.03	0.08	0.07	0.06	0.07
Interaction among the three factors (A×B×C)								
100 % of IR	Control	Control	3.24	3.30	9.43	9.58	12.83	11.79
		Ca/B	3.44	3.52	9.56	9.72	12.63	11.66
	K_1	Control	4.32	4.41	10.10	10.24	12.42	11.45
		Ca/B	4.46	4.56	10.17	10.35	12.23	11.24
	K_2	Control	4.63	4.71	10.34	10.55	11.93	11.02
		Ca/B	4.76	4.86	10.51	10.70	11.75	10.90
80 % of IR	Control	Control	2.89	2.95	9.22	9.41	14.08	13.06
		Ca/B	3.08	3.15	9.31	9.48	13.86	12.78
	K_1	Control	3.62	3.69	9.67	9.85	13.69	12.62
		Ca/B	3.74	3.80	9.76	9.94	13.43	12.38
	K_2	Control	3.92	4.00	9.90	10.05	13.28	12.25
		Ca/B	4.13	4.22	9.97	10.12	13.03	12.01
60 % of IR	Control	Control	1.80	1.85	8.42	8.54	15.17	13.98
		Ca/B	1.92	1.96	8.59	8.68	14.99	13.83
	K_1	Control	2.10	2.14	8.75	8.96	14.79	13.63
		Ca/B	2.34	2.39	8.85	9.08	14.58	13.45
	K_2	Control	2.55	2.60	8.96	9.17	14.39	13.23
		Ca/B	2.73	2.78	9.11	9.36	14.22	13.13
F. Test			**	**	*	**	**	**
LSD at 5%			0.18	0.09	0.24	0.23	0.20	0.20
F. Test of bilateral interaction								
A×B			**	**	*	*	**	**
A×C			**	**	*	*	**	**
B×C			**	**	*	*	**	**

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

Potassium silicate applications also significantly influenced growth traits, photosynthetic pigments and leaf chemical content. The treatment with 7.0 kg fed^{-1} (K_2) was superior in enhancing plant height, No. of leaves $plant^{-1}$, fresh and dry weights, leaf area, chlorophyll a &b, carotene, N, P and K. This suggests that higher doses of potassium silicate are more effective in supporting plant vigor, likely due to the dual role of potassium and silicon. Also, it can be notecied from the data in Table 6 that potassium silicate supplementation, particularly at 7.0 kg fed^{-1} (K_2), significantly enhanced the activities of antioxidant enzymes and reduced MDA levels across irrigation treatments. This can be attributed to silicon's role in stabilizing cellular membranes, improving leaf tissue structure, and enhancing potassium-mediated metabolic processes. The dual contribution of potassium and silicon may have supported better stomatal function and improved photosynthetic efficiency, thus reducing the overproduction of ROS under stress.

In contrast, the calcium/boron foliar application showed no significant individual effect on any of the growth traits and chlorophyll (a & b) content in the 1st season only, but the calcium/boron foliar application showed a positive significant effect on chlorophyll (a & b) in the 2nd season as well as carotene and NPK in leaf during both studied season. The foliar application of calcium and boron (Ca/B), although less impactful than potassium silicate, also contributed to reinforcing the antioxidative defense system. Calcium may have involved in signaling pathways that activate antioxidant enzyme synthesis, while boron may have played a structural role in cell wall integrity and may help maintain membrane stability under stress. Generally, it can be said that, although the individual effect of Ca/B was not significant in terms of growth criteria , its interaction with irrigation and silicate treatments may have further supported cell wall stability, sugar transport, and hormonal balance, indirectly contributing to better pigment synthesis and nutrient uptake.

Interaction effect

The bilateral interactions between irrigation and potassium silicate (A×B), irrigation and Ca/B (A×C), and potassium silicate and Ca/B (B×C) were all statistically significant across all traits. These interactions indicate that the effectiveness of one factor is modulated by the presence of another. For instance, the benefits of potassium silicate were more pronounced under adequate irrigation, while the Ca/B spray showed subtle enhancements when water was limited. The three-way interaction (A×B×C) revealed that the combination of 100% irrigation, 7.0 kg fed^{-1} potassium silicate, and Ca/B spray resulted in the highest values for plant height, No. of leaves $plant^{-1}$, fresh and dry weights, leaf area, chlorophyll a &b, carotene, N, P and K in both seasons. Conversely, the lowest values of these parameters were observed in the treatment that combined 60% irrigation with no potassium silicate and no Ca/B application. Additionally, it can be noticed that there aren't significant difference in the effect between the combined treatment of 80 % IR x K_2 x Ca/B and the treatment that combined 100% irrigation with no potassium silicate and no Ca/B application. As for the oxidation damage, Table 6 illustrate that the Ca/B effect was particularly evident when applied alongside potassium silicate under moderate to severe water stress. Taken together, the reductions in oxidative damage observed in the treated plants are consistent with improvements in photosynthetic pigment content (chlorophyll a, b, and carotenoids) and leaf nutrient levels (N, P, and K). These enhancements likely reflect a systemic physiological improvement that reduced oxidative stress by maintaining metabolic balance and promoting more efficient stress adaptation mechanisms. The obtained results are in harmony with those of Shaban *et al.* (2019); Pandey & Mahiwal, (2020); Sánchez-Virosta *et al*. (2020);Yatsenko *et al.* (2020); Baddour *et al.* (2024); El Sayed *et al*. (2024).

2.Second Evaluation Stage (176 Days from Planting)

Table 7 indicates the influence of irrigation regimes, potassium silicate rates and Ca /B foliar application on the physical parameters of bulb [average bulb weight (g), bulb and neck diameter (cm), bulbing ratio, No. of cloves per bulb] at 178 days after planting (harvest time) during the 2023/24 and 2024/25 seasons. Table 8 illustrates the effect of the studied treatments under the same conditions on total and marketable bulb yield (ton fed^{-1}), while Table 9 shows the effect of the studied treatments under the same conditions on the quality bulb traits [carbohydrates (%), total soluble solids TSS (%), vitamin C (mg 100g), dry matter (%) and pungency(purvate content $\pi mol.ml^{-1}$)].

Individual effect

Tables 7, 8 and9 show that the irrigation treatment of 100% IR achieved the highest values of all aforementioned traits, followed by 80% and 60%, respectively. This can be explained by the role of the availability of garlic's water requirements, which was mentioned previously, in improving growth performance and the chemical content of the leaves, and this was positively reflected in the quantitative and qualitative characteristics of the crop.

On the other hand, it can be noticed from the same Tables that as the potassium silicate rate increased the values of most traits increased, where the rate of 7.0 kg fed^{-1} led to the best results. This is due to the synergistic effect of both potassium and silicate, which increased the resistance of the garlic plant to environmental stress as mentioned above, which was then reflected in productivity.

Table 7. Effect of the potassium silicate and Ca/B on the bulb yield traits of garlic plant grown under different irrigation regimes at 176 days from planting during the growing seasons of 2023/24 and 2024/25

Treatments			Average bulb weight, g		Bulb diameter, cm		Neck diameter, cm		Bulbing ratio		No. of cloves $bulb^{-1}$	
			1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
A: Irrigation requirement IR treatments												
100 % of IR			41.89a	42.62a	4.28a	4.38a	1.33a	1.36a	0.312a	0.311a	29.44a	30.00a
80% of IR			38.66b	39.21b	3.95b	4.05b	1.14b	1.16b	0.288b	0.285b	26.44b	27.33b
60% of IR			29.14c	29.56c	3.47c	3.55c	0.90c	0.92c	0.258c	0.259c	23.11c	23.56c
F. Test			**	**	**	**	**	**	**	**	**	**
LSD at 5%			0.10	0.12	0.04	0.05	0.06	0.06	0.017	0.017	0.91	1.72
B: Potassium silicate (as supplements) treatments												
Control (without)			35.52c	36.03c	3.80c	3.89c	1.07c	1.09c	0.279b	0.278b	25.33b	25.89b
K_1:Potassium silicate (5.0 kg fed^{-1})			36.33b	36.89b	3.88b	3.98b	1.11b	1.14b	0.285ab	0.286ab	26.33ab	26.72b
K_2:Potassium silicate (7.0 kg fed^{-1})			37.84a	38.46a	4.02a	4.11a	1.19a	1.21a	0.294a	0.292b	27.33a	28.28a
F. Test			**	**	**	**	**	**	*	*	*	*
LSD at 5%			0.07	0.09	0.02	0.02	0.04	0.05	0.013	0.012	1.03	0.94
C: Calcium /boron (Ca/B) foliar applications												
Control (without)			36.38b	36.92b	3.88b	3.97b	1.11a	1.13a	0.87a	0.283a	26.19a	26.74a
Ca/B			36.75a	37.33a	3.92a	4.01a	1.13a	1.16a	0.285a	0.287a	26.48a	27.19a
F. Test			**	**	**	**	NS*	NS*	NS*	NS*	NS*	NS*
LSD at 5%			0.11	0.10	0.02	0.03	NS*	NS*	NS*	NS*	NS*	NS*
Interaction among the three factors (A×B×C)												
100 % of IR	Control	Control	41.46	42.15	4.16	4.27	1.26	1.28	0.303	0.300	28.67	29.33
		Ca/B	41.52	42.15	4.21	4.29	1.29	1.31	0.307	0.310	29.00	29.67
	K_1	Control	41.59	42.26	4.25	4.36	1.31	1.34	0.310	0.310	29.67	29.67
		Ca/B	42.09	42.81	4.31	4.40	1.34	1.37	0.310	0.313	29.33	30.33
	K_2	Control	42.33	43.09	4.36	4.47	1.38	1.40	0.317	0.313	29.67	30.33
		Ca/B	42.35	43.24	4.39	4.48	1.41	1.43	0.323	0.323	30.33	30.67
80 % of IR	Control	Control	36.00	36.50	3.83	3.95	1.06	1.08	0.277	0.273	25.33	26.00
		Ca/B	37.00	37.50	3.86	3.96	1.07	1.09	0.280	0.277	25.67	27.00
	K_1	Control	37.60	38.16	3.88	3.98	1.10	1.12	0.283	0.283	26.33	27.33
		Ca/B	38.43	38.98	3.90	3.99	1.14	1.16	0.290	0.290	26.33	27.33
	K_2	Control	41.48	42.00	4.09	4.18	1.22	1.24	0.300	0.293	27.33	28.00
		Ca/B	41.45	42.14	4.14	4.24	1.23	1.25	0.300	0.293	27.67	28.33
60 % of IR	Control	Control	28.48	28.86	3.30	3.39	0.86	0.88	0.260	0.257	21.00	21.33
		Ca/B	28.62	29.01	3.42	3.50	0.87	0.89	0.250	0.253	22.33	22.00
	K_1	Control	28.88	29.27	3.45	3.53	0.89	0.91	0.260	0.260	23.33	22.67
		Ca/B	29.40	29.86	3.51	3.60	0.90	0.92	0.257	0.257	23.00	23.00
	K_2	Control	29.56	30.00	3.55	3.62	0.92	0.94	0.257	0.260	24.33	26.00
		Ca/B	29.87	30.32	3.57	3.65	0.95	0.97	0.270	0.270	24.67	26.33
F. Test			**	**	**	**	**	**	*	*	*	*
LSD at 5%			0.32	0.29	0.07	0.10	0.07	0.07	0.017	0.017	2.79	1.36
F. Test of bilateral interaction												
A×B			**	**	**	**	**	*	*	*	*	*
A×C			**	**	**	**	*	*	*	*	*	*
B×C			**	**	**	**	*	*	*	*	*	*

Means within a row followed by a different letter (s) are statistically different at a 0.05 level
NS*= non-significant

Table 8. Effect of the potassium silicate and Ca/B on the total and marketable bulb yield of garlic plant grown under different irrigation regimes at 176 days from planting during the growing seasons of 2023/24 and 2024/25

Treatments			Bulb yield, ton fed^{-1}		Marketable yield, ton fed^{-1}	
			1st season	2nd season	1st season	2nd season
A: Irrigation requirement IR treatments						
100 % of IR			8.80^{a}	8.95^{a}	7.64^{a}	7.78^{a}
80% of IR			8.12^{b}	8.24^{b}	6.91^{b}	7.05^{b}
60% of IR			6.12^{c}	6.21^{c}	5.85^{c}	5.97^{c}
F. Test			**	**	**	**
LSD $_{at\ 5\%}$			0.02	0.02	0.03	0.08
B: Potassium silicate (as supplements) treatments						
Control (without)			7.46^{c}	7.57^{c}	6.49^{c}	6.62^{c}
K_1:Potassium silicate (5.0 kg fed^{-1})			7.63^{b}	7.75^{b}	6.82^{b}	6.95^{b}
K_2:Potassium silicate (7.0 kg fed^{-1})			7.95^{a}	8.08^{a}	7.08^{a}	7.23^{a}
F. Test			**	**	**	**
LSD $_{at\ 5\%}$			0.01	0.02	0.04	0.04
C: Calcium /boron (Ca/B) foliar applications						
Control (without)			7.64^{b}	7.75^{b}	6.73^{b}	6.86b
Ca/B			7.72^{a}	7.84^{a}	6.86^{a}	7.00a
F. Test			**	**	**	**
LSD $_{at\ 5\%}$			0.02	0.02	0.03	0.04
Interaction among the three factors (A×B×C)						
100 % of IR	Control	Control	8.71	8.85	7.24	7.38
		Ca/B	8.72	8.85	7.39	7.53
	K_1	Control	8.73	8.87	7.59	7.73
		Ca/B	8.84	8.99	7.74	7.91
	K_2	Control	8.89	9.05	7.86	7.99
		Ca/B	8.89	9.08	8.00	8.16
80 % of IR	Control	Control	7.56	7.67	6.46	6.60
		Ca/B	7.77	7.88	6.68	6.80
	K_1	Control	7.90	8.02	6.86	6.99
		Ca/B	8.07	8.19	7.03	7.15
	K_2	Control	8.71	8.82	7.21	7.35
		Ca/B	8.71	8.85	7.21	7.39
60 % of IR	Control	Control	5.98	6.06	5.54	5.66
		Ca/B	6.01	6.09	5.64	5.75
	K_1	Control	6.06	6.15	5.76	5.88
		Ca/B	6.18	6.27	5.92	6.01
	K_2	Control	6.21	6.30	6.03	6.19
		Ca/B	6.27	6.37	6.18	6.31
F. Test			**	**	**	**
LSD $_{at\ 5\%}$			0.07	0.06	0.08	0.12
F. Test of bilateral interaction						
A×B			**	**	**	**
A×C			**	**	**	**
B×C			**	**	**	**

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

Table 9. Effect of the potassium silicate and Ca/B on the bulb quality traits of garlic plant grown under different irrigation regimes at 176 days from planting during the growing seasons of 2023/24 and 2024/25

Treatments			Carbohydrates, %		TSS, %		Vitamin C, mg 100g		Dry matter, %		Pungency, purvate content πmol.ml^{-1}	
			1st season	2nd season	1st season	2ndseason	1st season	2ndseason	1stseason	2ndseason	1stseason	2nd season
A: Irrigation requirement IR treatments												
100 % of IR			26.80^{a}	27.36^{a}	27.92^{a}	28.30^{a}	16.63^{a}	16.87^{a}	25.91^{a}	26.46^{a}	13.40^{a}	13.69^{a}
80% of IR			24.96^{b}	25.48^{b}	26.86^{b}	27.24^{b}	15.78^{b}	16.02^{b}	24.37^{b}	24.87^{b}	12.77^{b}	13.04^{b}
60% of IR			22.98^{c}	23.44^{c}	24.73^{c}	25.11^{c}	14.55^{c}	14.77^{c}	22.42^{c}	22.90^{c}	11.16^{c}	11.39^{c}
F. Test			**	**	**	**	**	**	**	**	**	**
LSD $_{at\ 5\%}$			0.25	0.30	0.17	0.14	0.28	0.26	0.66	0.41	0.26	0.20
B: Potassium silicate (as supplements) treatments												
Control (without)			24.37^{c}	24.85^{c}	26.17^{c}	26.54^{c}	15.35^{c}	15.57^{c}	23.79^{c}	24.26^{c}	12.20^{c}	12.46^{c}
K_1:Potassium silicate (5.0 kg fed^{-1})			24.79^{b}	25.29^{b}	26.47^{b}	26.85^{b}	15.59^{b}	15.82^{b}	24.15^{b}	24.67^{b}	12.44^{b}	12.71^{b}
K_2:Potassium silicate (7.0 kg fed^{-1})			25.59^{a}	26.14^{a}	26.88^{a}	27.26^{a}	16.02^{a}	16.27^{a}	24.77^{a}	25.30^{a}	12.70^{a}	12.95^{a}
F. Test			**	**	**	**	**	**	**	**	**	**
LSD $_{at\ 5\%}$			0.26	0.15	0.30	0.15	0.14	0.08	0.13	0.12	0.09	0.13
C: Calcium /boron (Ca/B) foliar applications												
Control (without)			24.82^{b}	25.33^{b}	26.43^{b}	26.81^{b}	15.60^{a}	15.83^{a}	24.16^{a}	24.67^{a}	12.36^{b}	12.62^{b}
Ca/B			25.01^{a}	25.52^{a}	26.58^{a}	26.95^{a}	15.70^{a}	15.94^{a}	24.31^{a}	24.82^{a}	12.53^{a}	12.79^{a}
F. Test			**	**	**	**	NS*	NS*	NS*	NS*	**	**
LSD $_{at\ 5\%}$			0.12	0.15	0.08	0.11	NS*	NS*	NS*	NS*	0.10	0.07
Interaction among the three factors (A×B×C)												
100 % of IR	Control	Control	26.24	26.86	27.59	28.02	16.39	16.60	25.40	25.87	13.28	13.55
		Ca/B	26.47	26.97	27.70	28.01	16.44	16.71	25.43	25.94	13.32	13.62
	K_1	Control	26.88	27.39	27.81	28.23	16.61	16.87	25.85	26.46	13.33	13.65
		Ca/B	26.93	27.52	27.99	28.40	16.64	16.85	25.93	26.53	13.46	13.72
	K_2	Control	27.04	27.64	28.23	28.59	16.78	17.01	26.31	26.83	13.47	13.74
		Ca/B	27.25	27.78	28.23	28.57	16.90	17.16	26.56	27.11	13.56	13.84
80 % of IR	Control	Control	24.39	24.83	26.31	26.65	15.37	15.57	23.88	24.34	12.39	12.66
		Ca/B	24.42	24.90	26.48	26.87	15.50	15.71	23.96	24.45	12.58	12.83
	K_1	Control	24.52	25.03	26.69	27.01	15.65	15.89	24.05	24.51	12.61	12.87
		Ca/B	24.60	25.06	26.89	27.30	15.70	15.93	24.38	24.92	12.92	13.22
	K_2	Control	25.80	26.37	27.37	27.83	16.12	16.40	24.96	25.53	12.96	13.21
		Ca/B	26.05	26.68	27.42	27.75	16.33	16.59	24.97	25.47	13.18	13.44
60 % of IR	Control	Control	22.26	22.69	24.33	24.71	14.10	14.33	21.84	22.28	10.79	11.01
		Ca/B	22.42	22.84	24.59	24.97	14.27	14.50	22.21	22.68	10.85	11.07
	K_1	Control	22.73	23.21	24.63	24.98	14.43	14.63	22.30	22.77	11.06	11.28
		Ca/B	23.07	23.52	24.80	25.20	14.51	14.75	22.40	22.84	11.25	11.54
	K_2	Control	23.52	23.96	24.94	25.29	14.93	15.15	22.80	23.40	11.39	11.61
		Ca/B	23.86	24.42	25.12	25.51	15.04	15.28	22.99	23.43	11.63	11.86
F. Test			**	**	**	**	*	*	*	*	*	*
LSD $_{at\ 5\%}$			0.36	0.44	0.24	0.33	0.41	0.41	0.60	0.63	0.30	0.21
F. Test of bilateral interaction												
A×B			**	**	**	**	*	*	*	*	*	*
A×C			**	**	**	**	*	*	*	*	*	*
B×C			**	**	**	**	*	*	*	*	*	*

Means within a row followed by a different letter (s) are statistically different at a 0.05 level **NS*= non-significant**

In contrast, the calcium/boron foliar application showed no significant individual effect on neck diameter (cm), bulbing ratio, No. of cloves per bulb, vitamin C (mg 100g), dry matter (%) in both studied seasons, but the calcium/boron foliar application showed a positive significant effect on average bulb weight (g), bulb diameter (cm), total and marketable bulb yield (ton fed^{-1}), carbohydrates (%), total soluble solids TSS (%) and pungency(purvate content πmol.ml^{-1}) during both studied season. The positive effect of Ca/B on garlic plant at the first evaluation stage, which was mentioned above, was positively reflected in the quantitative and qualitative characteristics of the crop at harvest time.

Interaction effect

The bilateral interactions between irrigation and potassium silicate (A×B), irrigation and Ca/B (A×C), and potassium silicate and Ca/B (B×C) were all statistically significant across all quantitative and qualitative traits. The three-way interaction (A×B×C) revealed that the combination of 100% irrigation, 7.0 kg fed^{-1} potassium silicate, and Ca/B spray resulted in the highest values all aforementioned traits. Additionally, it can be noticed that there aren't significant difference in the effect between the combined treatment of 80 % IR x K_2 x Ca/B and the treatment that combined 100% irrigation with no potassium silicate and no Ca/B application. The obtained results are in harmony with those of Pandey & Mahiwal, (2020); Sánchez-Virosta *et al*. (2020);Yatsenko *et al.* (2020); Baddour *et al.* (2024).

CONCLUSION

According to the results obtained, the combination of 100% irrigation, 7.0 kg fed^{-1} potassium silicate, and Ca/B spray resulted in the best results in terms of the quantitative and qualitative traits of garlic plant. Conversely, the lowest values of these parameters were observed in the treatment that combined 60% irrigation with no potassium silicate and no Ca/B application. Additionally, it can be noticed that there aren't significant difference in the effect between the combined treatment [80 % IR x potassium silicate (7.0 kg fed^{-1}) x Ca/B] and the treatment that combined 100% IR with no potassium silicate and no Ca/B application. Generally, it can be concluded that this approach can be incorporated into garlic cultivation, especially under water deficit conditions.

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تحسين إنتاجية وجوده الثوم النامي تحت الاجهاد المائي باستخدام سليكات البوتاسيوم كإضافات تكميلية مع الرش الورقي بالكالسيوم والبورون

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الملخص

في مصر، يُعد الثوم ذو أهمية كبيرة في القطاعين الزراعي والتجاري .ولذلك، فإن تحسين صفاته الكمية والنوعية، وخاصة في ظل تحديات العجز المائي، سيكون له تأثير إيجابي كبير على إنتاج الغذاء والاقتصاد الزراعي .لذلك، أجريت تجربة حقلية خلال موسمين متتاليين لتقييم تأثير ثلاث معاملات ري(١٠٠و ٨٠ و٦٠٪ من متطلبات الري) كعامل رئيسي، وثلاث معدلات من سيليكات البوتاسيوم (٠,٠ و٥,٠ و٧,٠ كجم فدان-١) كعامل منشق أول ومعاملتين من خليط الكالسيوم / البورون (تم الرش او لم يتم) كقطع منشقة ثانية على الصفات الكمية والنوعية للثوم .حققت المعاملة ١٠٠٪ من متطلبات الري أعلى القيم لمعظم المدلولات مثل ارتفاع النبات، وعدد الأوراق للنبات ، والكاروتين، ومحصول الرؤس القابل للتسويق، والمواد الصلبة الذائبة الكلية، وفيتامين سي، تليها معاملة ٨٠٪ من متطلبات الري و٦٠٪ من متطلبات الري على التوالي. بزيادة معدل سيليكات البوتاسيوم ارتفعت قيم معظم الصفات حيث أدى معدل ٧,٠ كجم للفدان إلى أفضل النتائج .في المقابل، لم يُظهر رش الكالسيوم/البورون الورقي أي تأثير فردي معنوي على بعض المعايير مثل قطر العنق وفيتامين سي، الا انه أظهر تأثيرًا إيجابيًا معنويًا على صفات أخرى مثل متوسط وزن الرأس وقطر الرأس والمحصول الكلي للرؤس القابل للتسويق .أما بالنسبة للتداخل، فلا يوجد فرق معنوي في التأثير بين المعاملة المشتركة [٨٠ %من متطلبات الري × سيليكات البوتاسيوم (٧,٠ كجم فدان-١)×Ca/B] والمعاملة التي جمعت ١٠٠ %من متطلبات الري بدون سيليكات البوتاسيوم وبدون إضافة Ca/B. لذلك، يمكن التوصية بدمج هذا النهج في زراعة الثوم، وخاصة في ظل ظروف العجز المائي