



Effect of Silicon and Absciscic Acid Spray on Growth, Yield and Quality of Sunflower under Different Irrigation Periods

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ABSTRACT

Background: During autumn season of 2022, a field experiment was conducted at College of Agricultural Engineering Sciences, University of Baghdad to investigate the effect of silicon and abscisic acid spraying on sunflowers under various water stress conditions on growth, yield and quality of sunflower in Calcareous Soil.

Methods: The experiment involved three levels of water stress, with irrigation scheduled every 2, 4 and 6 days. Additionally, three concentrations of silicon 0, 2 and 4 mg L⁻¹ and three concentrations of abscisic acid 0, 0.5, 1 mg L⁻¹ was considered. The experimental design employed a randomized complete block design (RCBD) with a split-split plot arrangement with three replicates.

Result: Results showed a significant effect of irrigation every 2 days exhibited superior performance, leading to peroxidase activity achieved 15.8 mg protein⁻¹, catalase activity of 10.98 mg protein⁻¹, abscisic acid concentration of 0.462 µg ml⁻¹, silicon concentrations of 0.283%. The application of 4 mg L⁻¹ of silicon proved to be superior, resulting in peroxidase activity of 20.35 mg protein⁻¹, catalase activity of 18.58 mg protein⁻¹, abscisic acid concentration of 0.473 µg ml⁻¹, proline concentration of 12.46 µg g⁻¹, silicon concentrations of 0.246 % and seed yield of 6.064 Mg ha⁻¹. The use of 1 mg L⁻¹ of abscisic acid achieved superiority, yielding peroxidase activity of 20.12 mg protein⁻¹, catalase activity of 19.05 mg protein⁻¹, abscisic acid of 0.508 µg ml⁻¹, proline concentration of 14 µg g⁻¹, silicon at 0.271 % and seed yield of 6.136 mg ha⁻¹.

Key words: Absciscic acid, Drought stress, Silicon, Sunflower.

INTRODUCTION

Silicon is one of the most abundant nutrients in the Earth's crust and is found mainly in an inert state with a small portion in a dissolved state. Due to agricultural practices, large amounts of it have been removed from the soil (Shi *et al.*, 2016; Sapre and Dinesh, 2016; Sinky, 2023; Truong *et al.*, 2024). Although silicon is not considered essential nutrients for plants growth, some studies have shown that it constitutes 0.1-10% of dry matter production in some plants (Epstien, 2009; Verma *et al.*, 2021 and Ebeed *et al.*, 2023). The addition of silicon on the plants played a role in reducing the effect of water stress by reducing the production of reactive oxygen species (ROS) through the promotion of enzymatic antioxidants and converting hydrogen peroxide (H₂O₂) to water (Al-Aloosy *et al.*, 2018; Saleem and Joody, 2019).

Absciscic acid is one of the essential plant hormones, serving not only as an internal signal within the plant but also as a stress hormone. It plays a fundamental role in regulating plant growth by inhibiting the release of ethylene, which is considered a growth inhibitor. It plays a crucial role during water stress and some researchers have referred to it as the "stress hormone" due to its rapid accumulation during stress conditions (Hussain *et al.*, 2012; Majeed *et al.*, 2019 and Hong-Tao *et al.*, 2023). Al-Sahuki (2013) pointed out that ABA acts as an anti-transparent, generated in response to severe drought, leading to various changes in cell functions, such as stomata closure and that fully irrigated plants have their stomata wide open and any reduction in stomata openings

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leads to reduce water loss to a great extent (AL-Jeboori *et al.*, 2017; Qadir *et al.*, 2019 and Hussain *et al.*, 2021). Studies indicate that improving plant tolerance to water stress, a process controlled by ABA, is important in reducing the rate of transpiration in leaves (Hussain *et al.*, 2012 and Mustafa, 2017). ABA is the hormone that responds most to environmental stresses and is even involved in the direct response to water stress (Vlot *et al.*, 2009 and Naser *et al.*, 2020). Bakht *et al.* (2010) indicated that water stress during the vegetative growth stages leads to reducing the ability of cells to swell and elongate and reducing their size, thus reducing the leaf area depending on the level of water stress.

Water stress is a type of abiotic environmental stresses that occurs when the soil moisture content decreases due to insufficient rainfall or when water loss exceeds

absorption through roots water uptake, leading to changes in the plants natural environment directly (a decrease in the water potential of the soil). Additionally, it results in physiological and biochemical changes in the plant's functions (Hashim and Ahmed, 2017; Abdulameer and Ahmed, 2019).

Sunflower crop (*Helianthus annuus* L.), part of the Asteraceae family, is one of the world's leading oil-producing crops. It has grown recently due to global oil shortages, making it the second-highest oil producer after soybeans due to its 12% oil content and high saturated fatty acids (>33%) which makes it a top choice among vegetable oils. Additionally, sunflower seeds are rich in protein (42-93%) (AL-Tameemi *et al.*, 2019; Jasim and Al-Tameemi, 2023).

The aim is to study the effect of silicon and absciscic acid spraying on sunflowers under various water stress conditions on growth, yield and quality of sunflower in Calcareous Soil.

MATERIALS AND METHODS

A field experiment was conducted during the autumn season of 2022 in the fields of the College of Agricultural Engineering Sciences, University of Baghdad, Jadiriya-Iraq

in silty loam soil, was subjected to a randomized complete block design (RCBD) with three replications in a split-split plot arrangement. The main plots were assigned to different irrigation periods 2, 4 and 6 days symbolized as W_1 , W_2 and W_3 . Subplots were designated for the application of various concentrations of Silicon 0, 2 and 4 mg L⁻¹, symbolized as S_1 , S_2 and S_3 , while sub-sub plots contained treatments with different concentrations of absciscic acid 0, 0.5 and 1 mg L⁻¹ symbolized as ABA_1 , ABA_2 and ABA_3 . Both absciscic acid and Silicon were applied at three distinct growth stages. Soil samples were randomly collected from the 0-30 cm depth, air-dried, crushed and sieved through 2 mm diameter sieve for subsequent physical, chemical and fertility analysis (Table 1). Sunflower seeds (Master) were sown in 2 × 2 m plots, fertilized with 160 kg N ha⁻¹, 40 kg P ha⁻¹ and 70 kg K ha⁻¹ using Urea (46% N), superphosphate (21% P) and potassium sulfate (41% K), respectively. Manual weeding was performed during the experiment.

RESULTS AND DISCUSSION

Peroxidase activity

The results in Table (2) indicate that the third irrigation level W_3 significantly effect in peroxidase activity in the leaves achieved 33.4 mg protien⁻¹ compared to W_1 . It is also

Table 1: Physical, chemical and fertility properties of the soil.

pH	EC	O.M	CaCO ₃	CEC	N	P	K	Soil texture
	ds.m ⁻¹	%	%	c mol.c.kg ⁻¹		mg kg ⁻¹ soil		
7.12	2.05	1.35	19.78	16.3	77.08	15.74	289.52	Si L

Table 2: Effect of silicon, absciscic acid spray and different irrigation periods on peroxidase activity (mg protien⁻¹).

		W_1	W_2	W_3	S * ABA
S_1	ABA_1	14.00	25.20	66.30	35.16
	ABA_2	17.50	24.90	34.70	25.70
	ABA_3	13.60	22.30	30.10	22.00
S_2	ABA_1	18.20	21.90	33.10	24.40
	ABA_2	14.60	22.80	30.70	22.70
	ABA_3	15.90	20.90	23.70	20.10
S_3	ABA_1	19.30	19.10	29.20	22.50
	ABA_2	15.40	17.80	27.80	20.30
	ABA_3	14.30	14.90	25.40	18.20
LSD _{0.05}			10.25		8.65
					Average
W*S	S_1	15.03	24.13	43.70	27.62
	S_2	16.23	21.86	29.16	22.35
	S_3	16.33	17.26	27.46	20.35
LSD _{0.05}			8.01		8.65
					Average
W* ABA	ABA_1	17.16	22.06	42.86	27.36
	ABA_2	15.83	21.83	31.06	22.91
	ABA_3	14.60	19.36	26.40	20.12
LSD _{0.05}			7.87		4.55
Average	15.8		21.0	33.4	
LSD _{0.05}			3.91		

superior to concentration of silicon S_1 and achieved 27.62 mg protien⁻¹ compared to S_3 . The effect of spraying absciscic acid as ABA_1 achieved 27.36 mg protien⁻¹ compared to ABA_3 which achieved 20.12 mg protien⁻¹. The triple interaction between water irrigation levels, silicon spraying and absciscic acid had a significant effect on peroxidase activity and achieved 66.3 mg protein⁻¹ in $W_3S_1ABA_1$ compared to $W_1S_1ABA_3$.

Catalase activity

Results in Table (3) indicate that the third irrigation level W_3 significantly effect in catalase activity in the leaves achieved 30.26 mg protien⁻¹ compared to W_1 . Furthermore, it is also superior to concentration of silicon S_1 and achieved 22.57 mg protien⁻¹ compared to S_3 . The effect of spraying absciscic acid as ABA_1 achieved 23.13 mg protien⁻¹ compared to ABA_3 . The triple interaction between water irrigation levels, silicon spraying and absciscic acid had a significant effect on catalase activity in the leaves and achieved 36.90 mg protein⁻¹ in $W_3S_1ABA_1$ compared to $W_1S_3ABA_3$.

Absciscic acid concentration in the leaves

Results in Table (4) indicate that the third irrigation level W_3 significantly effect in absciscic acid concentration achieved 0.607 $\mu\text{g ml}^{-1}$ compared to W_1 . Furthermore, it is also superior to concentration of silicon S_2 and gave 0.547 $\mu\text{g ml}^{-1}$ compared to S_3 . The effect of spraying absciscic acid as ABA_2 achieved 0.553 $\mu\text{g ml}^{-1}$ compared to ABA_1 . The triple interaction between water irrigation levels, silicon spraying and absciscic acid had a significant effect on absciscic acid

in the leaves and achieved 0.803 $\mu\text{g ml}^{-1}$ in $W_3S_1ABA_1$ compared to $W_2S_3ABA_2$.

Proline concentration in the leaves

Results in Table (5) indicate that the third irrigation level W_3 significantly effect in proline concentration in the leaves achieved 23.39 $\mu\text{M g}^{-1}$ compared to W_1 . Furthermore, it is also superior to concentration of silicon S_1 , as it achieved 17.73 $\mu\text{M g}^{-1}$ compared to S_3 . The effect of spraying absciscic acid as ABA_1 achieved 17.37 $\mu\text{M g}^{-1}$ compared to ABA_3 . The triple interaction between water irrigation levels, silicon spraying and absciscic acid had a significant effect on proline concentration in the leaves and achieved 35.74 $\mu\text{M g}^{-1}$ in $W_3S_1ABA_1$ compared to $W_2S_3ABA_2$.

Silicon concentrations in the leaves

Results in Table (6) indicate that the third irrigation level W_1 significantly effect in silicon concentration in the leaves achieved 0.283% compared to W_3 . Furthermore, it is also superior to concentration of silicon S_3 , as it achieved 0.246% compared to S_1 . The effect of spraying absciscic acid as ABA_3 achieved 0.271% compared to ABA_1 . The triple interaction between water irrigation levels, silicon spraying and absciscic acid had a significant effect on silicon in the leaves and achieved 0.341% in $W_1S_3ABA_3$ compared to $W_3S_1ABA_1$.

Seed yield

Results in Table (7) indicate that the third irrigation level W_1 significantly effect in seed yield achieved 6.760 mg ha⁻¹ compared to W_3 . Furthermore, it is also superior to

Table 3: Effect of silicon, absciscic acid spray and different irrigation periods on catalase activity (mg protien⁻¹).

		W_1	W_2	W_3	S * ABA
S_1	ABA_1	13.10	27.90	36.90	25.96
	ABA_2	7.60	20.80	33.20	20.53
	ABA_3	11.70	20.20	31.80	21.13
S_2	ABA_1	10.90	23.60	34.20	22.90
	ABA_2	12.50	18.70	29.80	20.33
	ABA_3	11.40	17.90	28.40	19.23
S_3	ABA_1	11.00	22.70	27.90	20.53
	ABA_2	13.20	17.10	25.30	18.53
	ABA_3	7.50	17.70	24.90	16.70
LSD _{0.05}		10.21			8.31
					Average
W*S	S_1	10.80	22.96	33.96	22.57
	S_2	11.60	20.06	30.80	20.82
	S_3	10.56	19.16	26.03	18.58
LSD _{0.05}		7.62			3.36
					Average
W* ABA	ABA_1	11.66	24.73	33.00	23.13
	ABA_2	11.10	18.86	29.43	19.79
	ABA_3	10.20	18.60	28.36	19.05
LSD _{0.05}		6.41			3.20
Average	10.98	20.73			30.26
LSD _{0.05}		2.94			

concentration of silicon S_3 , as it achieved 6.064 mg ha^{-1} compared to S_1 . The effect of spraying absciscic acid as ABA_3 achieved 6.136 mg ha^{-1} compared to ABA_1 . The triple

interaction between water irrigation levels, silicon spraying and absciscic acid had a significant effect on seed yield and achieved 7.442 mg ha^{-1} in $W_1S_3ABA_3$ compared to $W_3S_1ABA_1$.

Table 4: Effect of silicon, absciscic acid spray and different irrigation periods on Absciscic acid concentration ($\mu\text{g ml}^{-1}$).

		W_1	W_2	W_3	S * ABA
S_1	ABA_1	0.325	0.433	0.803	0.520
	ABA_2	0.440	0.601	0.549	0.530
	ABA_3	0.507	0.407	0.595	0.503
S_2	ABA_1	0.392	0.465	0.577	0.478
	ABA_2	0.463	0.612	0.784	0.619
	ABA_3	0.478	0.566	0.594	0.546
S_3	ABA_1	0.459	0.383	0.459	0.433
	ABA_2	0.520	0.334	0.677	0.510
	ABA_3	0.577	0.425	0.433	0.478
$LSD_{0.05}$			0.146		0.082
					Average
W*S	S_1	0.424	0.480	0.649	0.517
	S_2	0.444	0.547	0.651	0.547
	S_3	0.518	0.380	0.523	0.473
$LSD_{0.05}$			0.072		0.036
					Average
W* ABA	ABA_1	0.392	0.427	0.613	0.477
	ABA_2	0.474	0.515	0.670	0.553
	ABA_3	0.520	0.466	0.540	0.508
$LSD_{0.05}$			0.089		0.053
Average	0.462		0.469	0.607	
$LSD_{0.05}$			0.064		

Table 5: Effect of silicon, absciscic acid spray and different irrigation periods on Proline concentration in the leaves ($\mu\text{M g}^{-1}$).

		W_1	W_2	W_3	S * ABA
S_1	ABA_1	16.38	12.92	35.74	21.68
	ABA_2	8.60	15.53	24.47	16.20
	ABA_3	8.73	18.52	18.72	15.32
S_2	ABA_1	8.40	14.02	31.69	18.03
	ABA_2	12.32	16.82	26.24	18.46
	ABA_3	13.70	10.25	22.22	15.39
S_3	ABA_1	12.01	7.62	17.56	12.39
	ABA_2	13.60	9.08	17.13	13.27
	ABA_3	10.39	8.10	16.75	11.74
$LSD_{0.05}$			7.97		4.17
					Average
W*S	S_1	11.23	15.65	17.56	17.73
	S_2	11.47	13.69	17.13	17.23
	S_3	12.00	8.26	16.75	12.46
$LSD_{0.05}$			5.71		2.36
					Average
W* ABA	ABA_1	12.26	11.52	28.33	17.37
	ABA_2	11.50	13.81	22.61	15.97
	ABA_3	10.49	12.29	19.23	14.00
$LSD_{0.05}$			5.34		2.94
Average	11.57		12.54	23.39	
$LSD_{0.05}$			3.46		

The results showed the effect of water stress, represented by irrigation every 6 days, on reduction of all growth indicators and an increase in the efficiency of antioxidant enzymes and some non-enzymatic antioxidants. When plants are exposed to water stress, the activity of peroxidase and catalase enzymes increases in response to suppressing the harmful effect of this stress (Ulusu *et al.*, 2022; Orejuela-Romero *et al.*, 2023 and Al-Rubaie and Al-Jubouri, 2023). Water stress stimulates oxidative stress, leading to an increase in free radicals such as super oxides (O_2^-) and hydrogen peroxide (H_2O_2). These radicals are known as reactive oxygen species (ROS), causing adverse effects on membrane lipids, proteins, DNA and RNA, resulting in membrane damage, disturbance in cellular metabolic processes and a decrease in chlorophyll content (Abu Jadallah, 2018; Dhahi and Baktash, 2018 and Chowdary *et al.*, 2021).

Suppression of reactive oxygen species (ROS) in plants occurs through various mechanisms, including enzymatic and non-enzymatic processes. The enzymatic mechanism for inhibit ROS in plants includes enzymes such as superoxide dismutase (SOD), catalase and peroxidase (POD). These enzymes remove the toxicity of free radicals and high regulation of their activity is necessary to keep free radicals under control (Al-Fadhly *et al.*, 2019; El-Fahdawi *et al.*, 2020; Rudenko *et al.*, 2023; Riwad and Alag, 2023). Furthermore, plant exposure to water stress contributes to an increase the proline content, acting as a protective measure against these conditions. The reason for the increase in the proline content is attributed to its

limited involvement in protein formation on the one hand, or from the increase in protein catabolism and its conversion into amino acids, including proline acid. On the other hand, water deficit increased the activity of the enzyme Pyrroline-5-Carboxylate Reducases (P5CR), which reduces Pyrroline-5-Carboxyleic acid (P5C) to proline acid (Mahmood *et al.*, 2019; Mahmood *et al.*, 2020; Wang *et al.*, 2022 and Juma *et al.*, 2024).

The increase in absciscic acid (ABA) concentration is due to a direct relationship between leaf ABA content and water deficiency as confirmed by Al-Fatlwai (2013); Cao *et al.* (2020) and Hwaidi (2023), who indicated that absciscic acid is a plant hormone formed in response to various environmental stresses and acts to close plant stomata as an indicator of increased external stresses, especially drought on the plant. Silicon role in alleviating drought stress, enhancing plant growth and development, increasing photosynthesis activity, reducing transpiration, as well as improving plant growth, water and nutrients absorption, carbon metabolism and stomata regulation (Mahmood *et al.*, 2020 and Rawaa and Wafaa, 2024). Additionally, silicon contributes to improving scavenging process and getting rid of free radicals by regulating the effectiveness of antioxidant enzymes (Cooke and Carey, 2023; Vieira-Filho and Monteiro, 2022; Mir *et al.*, 2022; Irfan *et al.*, 2023 and Ahmed and Al-Tameemi, 2023).

The results also showed the role of spraying with absciscic acid in resisting water stress through its role in increasing the activity of antioxidant enzymes such as peroxidase and catalase, reducing the transpiration rate

Table 6: Effect of silicon, absciscic acid spray and different irrigation periods on Silicon concentrations in the leaves.

		W ₁	W ₂	W ₃	S * ABA
S ₁	ABA ₁	0.157	0.196	0.134	0.162
	ABA ₂	0.297	0.191	0.278	0.255
	ABA ₃	0.337	0.282	0.197	0.272
S ₂	ABA ₁	0.231	0.243	0.143	0.205
	ABA ₂	0.298	0.268	0.203	0.256
	ABA ₃	0.326	0.227	0.223	0.259
S ₃	ABA ₁	0.225	0.203	0.120	0.183
	ABA ₂	0.333	0.251	0.228	0.271
	ABA ₃	0.341	0.262	0.247	0.283
LSD _{0.05}		0.091			0.052
					Average
W*S	S ₁	0.264	0.223	0.203	0.230
	S ₂	0.285	0.246	0.189	0.240
	S ₃	0.300	0.239	0.198	0.246
LSD _{0.05}		0.044			0.024
					Average
W* ABA	ABA ₁	0.204	0.214	0.132	0.184
	ABA ₂	0.309	0.237	0.236	0.261
	ABA ₃	0.335	0.257	0.222	0.271
LSD _{0.05}		0.049			0.033
Average		0.283	0.236	0.197	
LSD _{0.05}		0.036			

Table 7: Effect of silicon and absciscic acid spray and different irrigation periods on seed yield (mg ha⁻¹).

		W ₁	W ₂	W ₃	S * ABA
S ₁	ABA ₁	6.427	5.409	4.031	5.289
	ABA ₂	7.013	5.796	4.536	5.781
	ABA ₃	7.371	5.867	4.959	6.065
S ₂	ABA ₁	6.261	5.545	4.785	5.530
	ABA ₂	7.118	5.981	5.069	6.056
	ABA ₃	6.583	5.837	5.236	5.885
S ₃	ABA ₁	6.457	5.623	5.304	5.794
	ABA ₂	6.176	6.014	5.641	5.943
	ABA ₃	7.442	6.128	5.802	6.457
LSD _{0.05}					0.613
		0.830			Average
W*S	S ₁	6.937	5.690	4.508	5.711
	S ₂	6.654	5.787	5.030	5.823
	S ₃	6.691	5.921	5.582	6.064
LSD _{0.05}					0.425
		0.496			Average
W* ABA	ABA ₁	6.381	5.525	4.706	5.538
	ABA ₂	6.769	5.930	5.082	5.927
	ABA ₃	7.132	5.944	5.332	6.136
LSD _{0.05}					0.363
Average	6.760	5.800		5.040	
LSD _{0.05}		0.352			

through partial stomata closure, increasing root growth rate and thereby maintaining plant water content, These mechanisms contributes to reducing the effect of water stress, enhancing seed yield and improving water use efficiency (Aslam *et al.*, 2022; Li *et al.*, 2022; Jiang *et al.*, 2022 and Al-Mashhadany and Al-Amery, 2023).

CONCLUSION

The beneficial effects of silicon and absciscic acid Spray on growth, yield and quality of sunflower under different Irrigation Periods in calcareous soil. Irrigation every 2 days significantly enhanced physiological parameters and seed yield. The highest concentrations of silicon 4 mg L⁻¹ and absciscic acid at 1 mg L⁻¹ resulted in superior peroxidase and catalase activities, absciscic acid and proline in the leaves, increased silicon and improved seed yield.

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Conflict of interest

The authors declare that they have no conflict of interest.

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