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Evaluation of the response of maize to silicon additives under the influence of salt stress

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***Abstract*---**A factorial field experiment was carried out in one of the agricultural fields of Dar Al Salam sub-district in Diyala governorate during the autumn season of 2020, to reduce the role of calcium silicate in reducing the effect of salt stress on the growth and yield of maize. The experiment included two factors, the first factor: four levels of salinity for irrigation water W1, W2, W3 and W4 (1.3, 2, 4, 6) dsm^{-1} and Factor II: Three levels of calcium silicate S0, S1, and S2 (0, 75, 150) kg h^{-1}. The transactions were distributed according to a randomized complete block design (R.C.B.D) using a split-plot design system, with three replications. The seeds of yellow corn variety (Corn) of Spanish origin were planted on 29/7/2020 after preparing the experimental ground. Fertilizers were added following the fertilizer recommendation. The most important results obtained showed that Silicon addition treatment of 75 kg h^{-1} S1 gave the highest significant increase in dry weight, which amounted to 420.5 gm plant^{-1}, compared with treatment S0 and S2, with an increase of 19.8 and 15.7%, respectively. The same treatment gave the highest K: Na value, which reached 7.97, higher of each of S0 and S2 with an increase of 44.8 and 23.7%, respectively. The same treatment also gave the lowest concentration of sodium, as the percentage of sodium was 0.50% compared with treatment S0 and with a percentage of 46%, respectively, compared with treatment S0 and S2. Silicon addition treatment of 75 kg h^{-1} S1 gave the highest significant increase in dry weight, which amounted to 420.5 gm plant^{-1}, compared with treatment S0 and S2, with an increase of 19.8 and 15.7%, respectively. The same treatment gave the highest potassium value, which reached 3.22%, higher of each of S0 and S2 with an increase of 11.3and 11.4%, respectively. The same treatment gave the highest nitrogen value, which reached 2.74%, higher of each of S0 and S2

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with an increase of 9.1 and 10.0%, respectively. There were also no significant differences in the concentration of chloride in the plant due to the addition of silicon. The results of the interaction between the addition of calcium silicate and the salinity of the irrigation water showed that the best treatment was W1S1 for dry weight, as the rate of dry weight was 480.0 gm5 plant^{-1},

***Keywords*---**maize, silicon, salt stress**.**

Introduction

The global drought has led to the use of alternative sources of irrigation water, especially under the conditions of arid and semi-arid regions, including Iraq, which suffers from an acute shortage of water resources as a result of wrong water policies and fluctuating rainfall. In recent years, there has been a need to use sewage water of higher salinity than soil salinity and of poor quality as an alternative source for irrigating various field crops (Jung and Sun, 2001). In order to ration fresh water and benefit from it in other fields, many researchers resorted to using other alternatives of irrigation water to compensate for the shortage by adopting a water quality in which water (wells and drains) was used by mixing it with river water (Al-Ammari, 2016). The quality of irrigation water has a fundamental and important role in determining the productivity of soils. Soils with high productivity decrease in productivity over time and may become unproductive as a result of the accumulation of salts transferred with irrigation water in the form of dissolved ions. The most important basic ions are calcium, magnesium, potassium, sodium, chloride, sulfates, carbonates, bicarbonates and a small amount of Boron and this content of salt affects the physical and chemical properties and the vital activity of soil organisms, which is negatively reflected on all indicators of growth and plant productivity, according to the type of crop (Hussain et al., 2016). Irrigation water varies in its ionic content in terms of quality and quantity, followed by a variation in the chemical and salt content. Because of these differences, criteria have been developed to classify the quality of irrigation water, and among these criteria are: the concentration of salts and their ionic composition, so there must be methods to coexist with this water deficit and these methods Using low quality water, including sewage water, ground water, sewage and industrial water, to achieve sustainable agricultural development. Many studies have been conducted on the use of saline water in crop irrigation and trying to coexist with the problem of salinity by adding chemical fertilizers, adding organic materials, spraying nutrients, growth regulators and osmotic regulators on agricultural crops, as it had an active role in the growth and yield of agricultural crops exposed to salt stress conditions and from This fertilizer is calcium silicate (Souza et al., 2020) which works to reduce osmotic stress (Khan et al., 2019). Therefore, this study aims to evaluate the addition of different levels of silicon in reducing the damages of salt stress on the growth and yield of maize.

Materials and Methods

Potassium determination
Potassium was measured using a flame photometer, according to the method (Al-Sahhaf, 1989).

Sodium determination
Sodium was measured using a flame photometer, according to the method (Al-Sahhaf, 1989).

Dry weight of the shoot (gm)
The dry weight of the vegetative system (leaves and stems) was measured after the physiological maturity stage, as five plants were randomly cut from the midlines of each treatment from a distance of 5 cm above the soil surface (Al-Ansari et al., 1980) and then the stems were removed from them and washed with distilled water It was well cut and cut into small pieces and then air dried for 14 days in a room, after which it was placed in perforated paper bags inside an electric oven (Oven) at a temperature between 65-70 degrees Celsius for 48 hours until reaching the stage of stability in weight (Abu Dahi, 1989).

Results and Discussion

The concentration of sodium in the plant

The results of the statistical analysis in table (1) showed that there were significant differences when adding different levels of silicon, where treatment S1 recorded the lowest average sodium concentration and amounted to (0.50)%, respectively, with a decrease of (46%) compared with the comparison treatment S0, which recorded an average of (0.73)%, and the reason was attributed That silicon reduces sodium absorption, these results are consistent with (Farooq et al., 2019). As for the levels of irrigation water, where the highest average concentration of sodium in treatment W4 was (0.96%) than the rest of the treatments W1, W2 and W3, an increase of (231.0, 92 and 37.1)%, respectively, as well as the W3 treatment, which recorded an average of (0.70)% compared to treatments W1 and W2 with an increase of (141.1 and 40%) that the increase of

Table (1) Effect of silicon additives and different levels of irrigation water and the interaction between them on the average sodium concentration in maize plant

Electrical conductivity dSm m^{-1}	Ratio of sodium in plant%			Rate of electrical conductivity
	Silicon kg h^{-1}			
	S_0	S_1	S_2	
W_1	0.36	0.24	0.26	0.2**9**
W_2	0.42	0.47	0.60	0.**50**
W_3	0.78	0.53	0.80	0.70
W_4	1.36	0.75	0.77	0.96
L.S.D $_{0.05}$	0.26			0.1**8**
Rate of silicon	0.73	0.**50**	0.61	
L.S.D $_{0.05}$	0.13			

sodium with the increase in the salinity of the irrigation water because of the increase in the concentration of sodium and this was confirmed by (Sozharajan and Natarajan, 2016 and Al-Shammari, 2021). As for the interaction between silicon and irrigation water, where treatment W4S0 recorded the highest average sodium concentration amounted to (1.36%) and treatment W1S1 recorded the lowest average sodium concentration amounted to (0.24)%. Silicon plays an important role in reducing sodium damage through several mechanisms, including the expulsion of sodium molecules into the gaps Or evenly distribute sodium within the root in addition to reducing sodium absorption (Zhao et al., 2017).

Potassium concentration in the plant

The results of the statistical analysis show the superiority of treatment S1 in the average potassium concentration, as it achieved a concentration of (3.22)% compared with treatment S0 and S2 with an increase of (11.03 and 11.4) %, respectively. These results may be attributed to the reason that silicon increases potassium absorption. It is consistent with what was found (Kaya et al., 2006; Soundararajan et al., 2017). The same table shows the superiority of treatment W1 in the average potassium, as it recorded an average of (3.20)% compared with treatment W4 (2.8)%, with an increase of (14.2)%, and it did not differ significantly from treatment W2 and W3, which recorded averages of (3.00 and 3.00)% In turn, the potassium decreased with the increase in the salinity of the irrigation water due to the competition between the monomers Na and K as a result of the increase in the concentration of Na with the increase in the salinity of the irrigation water. This is what was mentioned (Al-Shammari, 2021).

Table (2) Effect of silicon additives and different levels of irrigation water and the interaction between them on the average Potassium concentration in maize plant.

Electrical conductivity dSm m^{-1}	Ratio of Potassium in plant%			Rate of electrical conductivity
	Silicon kg h^{-1}			
	S_0	S_1	S_2	
W_1	2.83	3.35	3.24	3.20
W_2	3.04	3.20	2.90	3.00
W_3	3.12	3.19	2.78	3.00
W_4	2.70	3.15	2.63	2.8
L.S.D $_{0.05}$	0.48			0.27
Rate of silicon	2.89	3.22	2.90	
L.S.D $_{0.05}$	0.26			

As for the bilateral interaction, where the highest value was in treatment W1S1 which recorded (3.35)% and the lowest value in treatment W4S2 if it gave (2.63)% increase of silicon under conditions of saline stress. Potassium concentration increases in the vegetative total. The reason may be that silicon reduced sodium absorption. (Farooq et al., 2018) which increased potassium uptake (Soundararajan et al., 2017) and thus improved the biological processes in the plant, which was reflected in the biomass and thus increased potassium uptake in high quantities. Potassium is one of the ions that reduce the damage caused by salinity and improve interactions within the plant.

K: Na ratio

The results of the statistical analysis showed that there was a significant difference when adding silicon in the average ratio of K-Na, where the highest value was in treatment S1 which amounted to (7.97) compared with treatment S0, and it was significantly superior with an increase of (44.3)%, respectively. This is due to the role of silicon in reducing the toxicity of sodium ions and thus increasing K-Na. These results are consistent with what was mentioned (Adrees et al., 2015). The same table shows significant differences in the average percentage of K-Na when adding irrigation water, where the treatment W1 significantly outperformed the rest of the treatments W2, W3 and W4, and recorded the highest average of (12.03) with an increase of (80.3, 162.0 and 266.7)%, respectively.

Table (3) Effect of silicon additives and different levels of irrigation water and the interaction between them on the K:Na ratio concentration in maize plant.

Electrical conductivity dSm m^{-1}	K:Na ratio			Rate of electrical conductivity
	Silicon kg h^{-1}			
	S_0	S_1	S_2	
W_1	7.99	14.60	13.50	12.03
W_2	7.90	6.81	5.32	6.67
W_3	4.10	6.18	3.49	4.59
W_4	2.09	4.30	3.45	3.28
L.S.D $_{0.05}$	3.63			2.20
Rate of silicon	6.44	7.97	5.52	
L.S.D $_{0.05}$	1.92			

Treatment W2 recorded an average of (6.67) and it differed significantly from treatment W4 with an increase of (103.3)% respectively. These results are consistent with what was found (Sozharajan and Natarajan, 2016). As for the bilateral interaction, where treatment W1S1 recorded the highest average of (14.60) and the lowest average of treatment W4S0 reached (2.09). The reason is due to the role of silicon in reducing sodium absorption as shown in Table (15) and increasing potassium absorption as in Table (16) and these results Agree with (Parveen, 2012).

The dry weight of the shoot total gm5 plants^{-1}

The table shows the effect of silicon additions to different levels of irrigation water on the dry weight yield at the harvest stage, and it was found from the statistical analysis that there were significant differences when adding different levels of silicon compared to the control treatment. Treatment S1 achieved the highest dry weight yield by 420.5 g5 plant^{-1}) with a significant increase over treatment S0 and S2 by (19.9 and 15.6)% respectively, attributed to the reason for the superiority of S1 in the concentration of silicon and the effective role of silicon in improving biological activities and improving the photosynthesis process, which was reflected in the improvement of dry weight (Silva et al., 2021 and Rios, 2017). In addition to increasing the concentration of phosphorous for treatment S1, and phosphorous is one of the factors that cause resistance to salt stress (Bouras et al., 2021). The same table also shows that treatment W1 was significantly superior in dry weight by (448.3 gm 5 plant-1) than the rest of the treatments W3

Table (4) Effect of silicon additives and different levels of irrigation water and the interaction between them on the dry weight yield (gm5 plant^{-1}) of maize plants

Electrical conductivity dSm m^{-1}	The dry weight of the shoot total gm5 plants^{-1}			Rate of electrical conductivity
	Silicon kg h^{-1}			
	S_0	S_1	S_2	
W_1	428.3	480.0	436.7	448.3
W_2	378.3	470.0	420.0	422.8
W_3	398.3	400.3	345.0	381.2
W_4	198.3	331.7	251.7	260.6
L.S.D $_{0.05}$	65.12			41.40
Rate of silicon	363.3	420.5	350.8	
L.S.D $_{0.05}$	34.33			

and W4, with an increase of (17.7 and 72.5%, respectively, and treatment W2 was superior to (422.8 g 5 plant-1) than the rest of the treatments W3 and W4) than Treatments W3 and W4, with a significant increase of (10.9 and 62.6)%, decreased the vegetative weight with an increase in the salinity of the irrigation water. The reason is that maize loses 50% of its yield at an electrical conductivity of 4.7 dSm m^{-1}. These results are consistent with what was found (Abdul and Al-Zughaibi, 2016). As for the result of the interaction between silicon levels and irrigation water levels, the highest dry weight yield of the W1S1 treatment was 480.0 gm Plant^{-1} (with an increase of (171.6)% and a lower dry weight yield of treatment W4S0 of (198.3 gm 5 plant^{-1}) and attributed the reason to the decrease in sodium concentration and an increase in potassium concentration, which reduced the effect of salt stress. These results are consistent with what was found (Raza et al., 2019), In addition, silicon plays a role in improving biological processes, which is reflected in an increase in biomass (biomass includes shoots and grains) (Xie et al., 2015).

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