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Effect of Silicon and Saline Irrigation Water on Productivity of Two Wheat Cultivars at South Sinai, Egypt

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TWO field experiments were conducted at Ras-Sudr Research Station, South Sinai Governorate during two successive seasons, 2011/2012 and 2012/2013, to study the effect of three levels of silicon as $KAlSi_3O_8$ incorporated to the soil at (100, 200 and 300 kg/ fed) compared by control (without silicon) on two wheat cultivars Sakha 94 (salt-tolerant) and Gimeza 10,(salt-sensitive). Both cultivars were irrigated from two wells different in salinity levels (4236 and 4748 ppm, moderate level) and (7001 and 7360 ppm high level) in the first and second seasons, respectively.

Obtained results showed that increasing irrigation water salinity from (4236 up to 7001 ppm) in the first season and from (4748 to 7360 ppm) in second season, decreased the grain yield and its components in Sakha 94 and Gimeza 10. Gimeza 10 was superior to Sakha 94 in all yield criteria in the two growing seasons except protein yield was superior in Sakha 94. The highest level of silicon (300 kg $KAlSi_3O_8$ /fed) had the superiority effect in decreasing the soil salinity hazard and consequently increased significantly all yield criteria of the two cultivars.

The effect of second order interaction indicated that incorporated soil by silicon (300 kg/fed) planted with Gimeza 10 which irrigated by (4236 and 4748 ppm) produced the highest grain yield and yield components in both seasons. However, the highest protein yield has been resulted in Gimeza 10 treated with silicon (300 kg/fed). Grain yield were significantly improved in Gimeza 10, than Sakha 94, with application of silicon (300 kg/fed).

Potassium content was significantly increased in grain wheat cultivars due to soil application of silicon under saline soil conditions. Sodium content was higher in grain wheat, cv. Sakha, 94, under saline soil condition; however Si application significantly reduced Na content in grain, while it significantly increased in K: Na ratio. High K and low Na contents in grain wheat cultivars may be one of the possible mechanisms of increasing salinity tolerance by silicon application.

In general, the current research suggested that Si application not only increased the quantity, but also enhanced the quality of wheat cultivars grown under salt stress conditions. Therefore, silicon at the

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rate of 300kg/fed and Gimeza 10, which irrigated with moderate level of salinity (4236 ppm) encourage the farmers to use of silicon to give promising grain yield.

Keywords: Saline irrigation water, Silicon, Wheat cultivars, Potassium, Sodium, Yield, Yield components.

The new goals of the Egyptian agricultural policy are to increase wheat production through the expansion of the cultivated wheat area by high production cultivars in the newly reclaimed land to offset the gap between the production and consumption (Abd El-Monem, 2010). The most new reclaimed soils in Egypt are subjected to salinity stress such as Ras-Sudr in South Sinai. The rainfall or the existing fresh water in this region is limited, so, irrigation in this region depends mostly on wells. Also, the soil of Ras-Sudr is saline and highly calcareous (Hendawey, 2009).

Soil salinity is a major problem in agriculture. The major constraints for plant growth and productivity are ion toxicity with excessive uptake of mainly Cl^- and Na^+ as well nutrients imbalance caused by disturbed uptake of essential mineral nutrients (Hellal *et al.,* 2012). Living with salinity is the only way of sustaining agricultural production in the salt affected soil (Al-Rawahy *et al.,* 2011). So that, it is important to find the best management to alleviate salt hazard.

Wheat is adversely affected by salinity stress (Zhu, 2003). Yield losses up to 45% have been reported due to salinity stress in wheat (Qureshi and Barrett-Lennard, 1998). To ensure food security and sustainable economy, there is dire need to find ways to improve salinity tolerance of wheat. Various chemical, physical and biological strategies are adapted for economic crop production on such soils (Ashraf and Harris, 2004). Of all these strategies, exogenous application of nutrients has gained a considerable ground as a shotgun approach to ameliorate the adverse effects of salt stress (Grattan and Grieve, 1999). For example, exogenous application of K ameliorated adverse effects of salt stress in wheat (Akram *et al*., 2007), Ca in bean (Awada *et al*., 1995) and N in *Phaseolus vulgaris* (Wagenet *et al*., 1983).

Furthermore, some non-essential mineral nutrients may also counteract adverse effects of salt stress. For example, silicon is a non-essential element for plant growth (Tahir *et al*., 2006), however, various studies have demonstrated that Si application significantly increased plant growth under normal (Agurie *et al*., 1992) and stress conditions including biotic and abiotic stresses as salt stress (Ma, 2004). A number of possible mechanisms are proposed through which Si may increase salinity tolerance in wheat (Ali *et al.*, 2012), *e.g.,* improving water status (Romero *et al*., 2006), increased photosynthetic activity and ultra structure of leaf organelles (Shu and Liu, 2001), stimulation of antioxidant system (Zhu *et al*., 2004) and alleviation of specific ion effect (Rafiq *et al*., 1992) by reducing Na uptake (Gong *et al*., 2003 and Liang *et al*., 2003). Si content in soils varies greatly and ranges from 1 to 45% by dry weight (Sommer *et al.,* 2006). The agricultural benefits of silicon amendments on a soil ecosystem are well established. Keeping all beneficial mechanisms of Si in salinity tolerance of wheat plants, the present study was conducted to evaluate yield and yield components and protein yield of two wheat cultivars; Gimeza 10, (salt-sensitive) and Sakha 94, (salt-tolerant), grown under saline soil conditions with different levels of Si and irrigated by two salinity levels of wells.

Material and Methods

Two field experiments were conducted at Ras-Sudr Agricultural Experimental Station of Desert Research Center, South Sinai Governorate, Egypt, during 2011/2012 and 2012 /2013 seasons to study the effect of three different levels of silicon incorporated to the soil compared to control (without silicon) on two cultivars; Gimeza 10 (salt-sensitive) and Sakha 94 (salt-tolerant) belonging to wheat (*Triticum aestivum* L.) grown on highly calcareous soil and irrigated from two wells. Physical and chemical analyses of soil before planting are presented in Tables 1a and 1b.

TABLE 1a. Physical analysis of Ras- Sudr soil (2011/2012 and 2012/2013 seasons).

Seasons	Soil depth (cm)	Sand %	Silt %	Clay %	Soil texture
2011/2012	15-30	74.4	18.7	6.9	Sandy loam
2012/2013	15-30	68.5	28.6	2.9	Sandy loam

TABLE 1b. Chemical analysis of Ras- Sudr soil (2011/2012 and 2012/2013 seasons) before sowing.

Seasons	pH	EC ds/m	Soluble cations (me/L)				Soluble anions (me/L)			
			Na^+	K^+	Ca^{++}	Mg^{++}	$CO3^{--}$	$HCO3^-$	Cl^-	$SO4^{--}$
2011/2012	7.94	6.27	18.00	1.60	30.00	22.50	0.00	1.25	60.11	10.74
2012/2013	7.93	6.29	21.35	1.79	22.63	21.17	0.00	4.80	44.25	17.89

Split- split plot design with four replications was used for each experiment. Main plots consisted of the two salinity levels from two different wells (4236 and 7001 ppm), while sub plots were devoted to the two cultivars (Sakha 94 and Gimeza 10) and silicon levels were applied to soil and arranged in sub-sub plots at 100, 200 and 300 kg/fed, of potassium silicate ($KAlSi_3O_8$), compared to control. Silicon was used as $KAlSi_3O_8$, obtained from El-Ahram Company for Mining and Natural Fertilizers. The chemical analysis of the water of the two wells in the two growing seasons is presented in Tables 2a and 2b. Data in Table 3 shows the chemical composition of $KAlSi_3O_8$ material as a source of silicon. Si of the experimental soil (mg/kg soil) of Ras- Sudr soil after harvest in the two growing seasons was determined according to Snyder (2001) (Table 4).

TABLE 2a. Chemical analysis of the two wells at Ras-Sudr in 2011/2012.

Salinity levels	EC ds/m	TDS p.p.m.	P^H	Cations (meq /L)				Anions (meq/L)		
				Ca^{++}	Mg^{++}	Na^+	K^+	$HCO3^-$	CL^-	$SO4^=$
Well No. 1	6.62	4246	7.29	16.29	22.13	30.74	0.35	1.50	30.51	37.50
Well No. 2	10.94	7001	7.67	16.03	17.27	67.09	0.49	1.40	60.29	38.58

TABLE 2b. Chemical analysis of the two wells at Ras-Sudr in 2012/2013.

Salinity levels	EC ds/m	TDS ppm	P^H	Cations (meq /L)				Anions (meq/L)		
				Ca++	Mg++	Na+	K+	$HCO3^-$	CL^-	$SO4^=$
Well No. 1	7.42	4748	7.48	17.78	14.20	45.27	0.44	1.38	39.88	36.43
Well No. 2	11.50	7360	7.92	16.31	17.80	82.22	0.48	1.48	63.17	38.16

TABLE 3. The chemical composition of silicon as $KAlSi_3O_8$ by weight percent %.

Component	SiO_2	Al_2O_3	K_2O	Na_2O	CaO	FeO	Fe_2O_3	MgO	TiO_2	P_2O_5	MnO
%	72.04	14.42	4.12	3.69	1.82	1.68	1.22	0.71	0.30	0.12	0.05

TABLE 4. Silicon content of Ras- Sudr soil (mg/kg soil) after harvest in the two growing seasons.

Treatments	Control without (Si)		100 kg Si/fed		200 kg Si/fed		300 kg Si/fed	
Seasons	**2011/12**	**2012/13**	**2011/12**	**2012/13**	**2011/12**	**2012/13**	**2011/12**	**2012/13**
Si	9.07	9.08	19.29	19.26	22.94	22.98	31.29	31.25

The area of each plot is 2x3m= 6m^2, which contains 4 rows (3 m length, 50cm width). Grains were sown in November, 20, 2011 in the first season and November, 24, 2012 in the second season with seeding rates of 80 kg/fed, for the two seasons.

Grains of the two wheat cultivars (Sakha 94 and Gimeza 10) were obtained from Agricultural Research Center. The recommended cultural practices of growing wheat plants were applied. At harvest, after 160 days randomized ten plants selected from each plot to determine: plant height (cm), spike length (cm), number of spikelets / spike, weight of 1000 grains (gm), biological yield (kg /fed), grain yield (kg /fed) and straw yield (kg/fed). In addition, samples were chosen for the protein analysis. The percentage of nitrogen and protein (N X6.25) values were calculated as described by A.O.A.C. (1980) and elements: Na and K were determined using flame emissive spectrometry (Page, 1982). All obtained data were statistically analyzed by using analysis of variances according to Snedecor and Cochran (1982) and means were grouped by LSD test at the 5% probability level.

Results and Discussion

A.1- Wheat Yield and Its Components

Effect of saline irrigation water

Yield and yield components represented by; plant height (cm), spike length (cm), number of spikelets / spike, weight of 1000 grains (g) (Tables 5a and 5b) and biological yield (kg /fed), grain yield (kg /fed), straw yield (kg /fed) and protein yield (kg/fed) (Fig. 1) as affected by saline irrigation water decreased significantly by increasing salinity from TDS 4236 to 7001 ppm. These results were more pronounced in the first season. Decreases in the aforementioned characters were increased with increasing the levels of irrigation salinity due to increasing the soil salinity. These confirmed previously in the results obtained by (Bekheta *et al*., 2009). The plant height was not significantly affected by both soil salinity, these may be due to the effects of salinity should be much more closely associated with metabolic/nutritional changes within the growing tissues of leaves than in whole or non growing leaf tissues. The obvious results agree with those obtained by (Abd El-Monem, 2010).

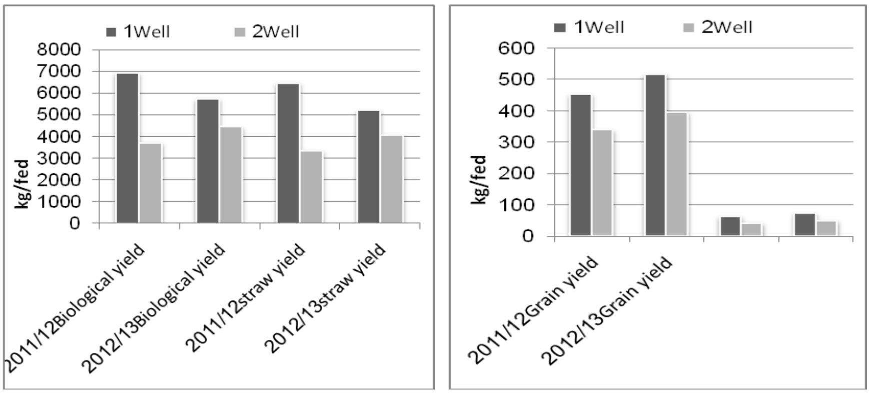

Fig.1. Effect of saline irrigation water on yield in the first and second seasons (2011/2012 and 2012/2013).

Effect of two wheat cultivars

Data presented in Tables 5a and 5b and Fig. 2, showed that cultivar Gimeza 10 was superior significantly than sakha 94 cultivar in all characters under studied in both seasons. From data it's clear that the two wheat cultivars having contrasting behaviors against salinity Gimeza 10 (salt-sensitive) and sakha 94 (salt-tolerant). This may be due to the increase in plant height, No. of grain /spike and 1000-grains weight which their output caused an increase in grain yield/fed, however, Protein yield was decreased in Gimeza 10. The differences in the grain yield of the two growing seasons were due to the salinity of wells increased in the second season than the first one as shown in Tables 2a and 2b. The difference in electric conductivity, in the two growing seasons led to the reduction in yield in the second season than the first one.

TABLE 5a. Main effect of saline irrigation water, cultivars and silicon on yield components in the first season (2011/2012) .

Characters / Treatments	Plant height (cm)	Spike length (cm)	No. of spikelets/ spike	1000-grains weight (g)
Saline irrigation water				
4236 ppm	69.98	10.07	16.33	45.44
7001 ppm	65.81	9.09	13.36	40.44
LSD at 5%	0.3177	0.1588	0.5559	1.7137
Cultivars				
Sakha 94	60.71	7.11	13.82	32.96
Gimeza 10	75.08	12.06	15.88	53.16
LSD at 5%	1.0591	0.6272	0.2420	1.1566
Silicon				
Control	56.15	8.94	13.64	29.61
100KgSi/fed	69.46	9.33	14.64	42.99
200KgSi/fed	72.48	9.86	15.25	47.65
300KgSi/fed	73.49	10.2	15.86	52.00
LSD at 5%	0.5921	0.1932	0.2147	1.2592

TABLE 5b. Main effect of saline irrigation water, cultivars and silicon on yield components in the first season (2012/2013).

Characters / Treatments	Plant height (cm)	Spike length (cm)	No. of spikelets/ spike	1000-grains weight (g)
Saline irrigation water				
4748 ppm	66.19	9.93	17.06	38.59
7360 ppm	63.91	8.94	13.43	35.51
LSD at 5%	n.s	n.s	1.2706	n.s
Cultivars				
Sakha 94	58.93	6.76	14.12	30.50
Gimeza 10	71.93	12.11	16.37	43.61
LSD at 5%	0.4252	0.5922	0.0850	3.2449
Silicon				
Control	56.30	8.78	13.81	29.41
100kg Si/fed	64.65	9.10	15.41	35.29
200kg Si/fed	68.55	9.69	15.71	40.56
300kg Si/fed	70.70	10.18	16.04	42.95
LSD at 5%	0.8247	0.1161	0.1483	1.3691

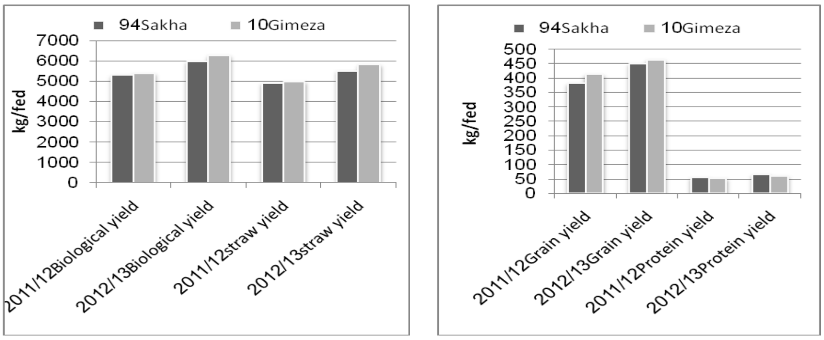

Fig. 2. Effect of wheat cultivars on yield in both seasons (2011/2012 and 2012/2013) .

Effect of silicon

Data in Tables 5a and 5b and Fig. 3 among all the silicon levels, 200 and 300 kg Si/fed, showed better results and increased significantly all characters under study; plant height (cm), spike length (cm), number of spikelets / spike, weight of 1000 grains (g), biological yield (kg /fed), grain yield (kg /fed), straw yield (kg/fed) and protein yield (kg/fed), in comparison to lower levels (100 kg / fed), except the biological yield remained unaffected by Si application in the second season. The improvement of the yield characters were more pronounced at the third level of Si (300 kg/fed) when grown under saline environments than the other Si treatments as well as control. These results are confirmed with Rafiq *et al.* (1992), Mukkram *et al.* (2006), Ali *et al.* (2009) and Saeed *et al.* (2009). They found that plant height and grain yield for wheat cultivars increased significantly with more silicon levels. This may be due to Si being able to increase resistance of plants against salinity stress which is a major yield limiting factor in arid and semiarid areas. Increase in grain yield was more pronounced in saline environments indicating beneficial effects of Si application in alleviating salinity stress (Epstein, 2001 and Al-Aghabary *et al*., 2004).

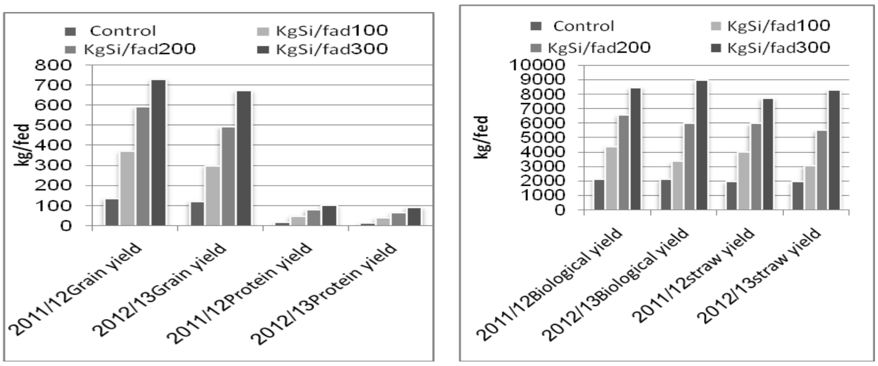

Fig. 3a. Effect of silicon on wheat yield in the first and second seasons (2011/2012 and 2012/2013).

A.2- First Order Interactions (Between Two Factors)

The interaction between wheat cultivars and silicon levels

Data in Tables 6a and 6b showed that the interaction between the two wheat cultivars and silicon levels were significant in all characters under studied except Biological yield in the second season. Concerning the effect of silicon, the highest rate of silicon application (300kg/fed) resulted in pronounced increase on the entire studied yield components compared with the control treatment, especially at the cultivar (Gimeza 10) over than (Sakha 94). These results are confirmed with Rafiq *et al.* (1992) and Levent *et al.* (2007), who reported that addition of silicon caused significant recovery from salt stress in wheat plant. A number of possible mechanisms are proposed by which Si can increase resistance of plants against salinity stress which is a major yield limiting factor in arid and semiarid areas include: stimulation of antioxidant systems in plants, complexation or co-precipitation of toxic metal ions with Si and compartment of metal ions within plants (Liang *et al.,* 2006). Increase in biological yield was more pronounced in saline environments indicating beneficial effects of Si application for alleviating salinity stress (Al-Aghabary *et al.,* 2004).

TABLE 6a. Effect of the interaction between cultivars and silicon on wheat yield and yield components (2011/2012 season).

Characters / Treatments	Plant height (cm)	Spike length (cm)	No. of spikelets/ spike	1000-grains weight (g)	Biological yield (Kg/fed)	Grain yield (Kg/fed)	Straw yield (kg/fed)	Protein yield (Kg/fed)
Sakha 94 Control	53.65	6.78	12.38	26.08	1781.23	168.10	1613.13	22.91
100KgSi/fed	61.10	7.03	13.68	32.78	3295.50	407.45	2888.05	56.68
200KgSi/fed	64.05	7.23	14.38	36.43	5218.30	585.18	4633.12	82.94
300KgSi/fed	64.05	7.40	14.85	36.58	5528.13	643.85	4884.28	97.68
Gimeza 10 Control	58.65	11.10	14.90	33.15	2411.78	104.78	2307.00	12.55
100KgSi/fed	77.83	11.63	15.0	53.20	5427.00	334.53	5092.47	41.17
200KgSi/fed	80.90	12.50	16.13	58.88	7893.00	599.98	7293.02	77.57
300KgSi/fed	82.93	13.00	16.88	67.43	9358.25	817.83	8540.42	107.28
LSD at 5%	0.8378	0.2734	1.9373	1.7818	300.7463	8.0922	252.995	1.723

TABLE 6b. Effect of the interaction between cultivars and silicon on wheat yield and yield components (2012/2013 season).

Characters / Treatments	Plant height (cm)	Spike length (cm)	No. of spikelets/ spike	1000-grains weight (g)	Grain yield (Kg/fed)	Straw yield (kg/fed)	Protein yield (Kg/fed)
Sakha 94 Control	54.08	6.38	12.48	26.53	154.20	1621.1	20.78
100KgSi/fed	57.83	6.58	14.35	28.90	325.93	1797.6	44.65
200KgSi/fed	61.68	6.85	14.65	33.30	486.20	3186.1	68.90
300KgSi/fed	62.23	7.23	15.00	33.28	561.43	3362.7	83.92
Gimeza 10 Control	58.53	11.18	15.15	32.30	91.28	2319.8	10.51
100KgSi/fed	71.48	11.63	16.48	41.68	273.40	4275.6	33.12
200KgSi/fed	75.53	12.53	16.78	47.83	501.08	5697.0	63.41
300KgSi/fed	79.18	13.13	17.08	52.63	786.25	7467.1	100.65
LSD at 5%	1.1671	0.1643	0.2099	1.9373	22.5101	215.110	2.726

(Feddan = 4200 m^2).

The interaction between saline irrigation water and silicon levels

Data in Tables 7a and 7b showed that the interaction between saline irrigation water and silicon levels were significant in all characters under studied except spike length in the first season and plant height and Biological yield in the second season which were insignificant. The application of 100 up to 300 kg Si / fed increased the yield and yield components in both seasons under two levels of saline irrigation water. These results were in agreed with those reported by Hanafy Ahmed *et al.* (2002). The best treatment in all characters under the studied was the plant irrigated by (4236 and 4748ppm) and silicon with the rate of 300 kg/fed in the both seasons. The adverse effects of salinity as regards the yield parameters were significant alleviated by Si supplement. These results are in agreement with those reported by Ali *et al.* (2009) and Abd El-Monem (2010) who found that supplementary silicon, resulted in significant increase in yield of wheat grown under saline conditions. They found that the yield decreased with increasing salinity in the absence of silicon. However, addition of Si caused significant recovery from salt stress. In the analysis of the beneficial effect of Si under saline yield condition, it is important to consider the role of Si in plant water status because the initial reduction of plant growth and yield after imposition is due to the osmotic effect of salt (Al-Aghabary *et al.,* 2004).

TABLE 7a. Effect of the interaction between saline irrigation water and silicon on wheat yield and yield components (2011/2012 season).

Characters / Treatments	Plant height (cm)	No. of spikelets/ spike	1000-grains weight (g)	Biological yield (Kg/fed)	Grain yield (Kg/fed)	Straw yield (kg/fed)	Protein yield (Kg/fed)
I 1 Control	58.83	15.23	33.45	2362.75	146.23	2216.52	19.83
100KgSi/fed	71.15	15.83	45.68	4926.00	441.23	4484.77	59.34
200KgSi/fed	74.70	16.70	50.28	7567.80	709.53	6858.27	100.17
300KgSi/fed	75.23	17.58	52.38	8153.38	778.48	7374.90	116.08
I 2 Control	53.48	12.05	25.78	1830.25	126.65	1703.60	15.63
100KgSi/fed	67.78	13.45	40.30	3796.50	300.75	3495.75	38.51
200KgSi/fed	70.25	13.80	45.03	5543.50	475.63	5067.87	60.34
300KgSi/fed	71.75	14.15	51.63	6733.00	683.20	6049.80	88.88
LSD at 5%	0.8378	0.3038	1.7818	300.7463	8.0922	252.995	1.722

Which I1=saline irrigation water 4236 ppm, I2= saline irrigation water 7001 ppm in the first season while in the second season was I1= 4748 ppm and I2= 7360ppm, Tables 2a and 2b.

TABLE 7b. Effect of the interaction between saline irrigation water and silicon on wheat yield and yield components (2012/2013 season).

Characters / Treatments	Spike length (cm)	No. of spikelets/ spike	1000-grains weight (g)	Grain yield (Kg/fed)	Straw yield (kg/fed)	Protein yield (Kg/fed)
I 1 Control	9.08	15.30	32.53	134.48	2342.1	17.71
100KgSi/fed	9.43	17.30	35.98	374.35	3147.9	49.69
200KgSi/fed	10.28	17.63	42.18	592.90	4948.2	83.51
300KgSi/fed	10.93	18.00	43.70	716.08	5754.1	104.69
I 2 Control	8.48	12.33	26.30	111.00	1598.6	13.58
100KgSi/fed	8.78	13.53	34.60	224.98	2926.3	28.08
200KgSi/fed	9.10	13.80	38.95	394.38	3934.9	48.87
300KgSi/fed	9.43	14.08	42.20	631.60	5075.7	79.88
LSD at 5%	0.164	0.209	1.937	22.510	215.110	2.726

The interaction between irrigation water salinity and wheat cultivars

From analysis of variances (ANOVA Tables), the interaction between saline irrigation water and wheat cultivars were insignificantly in all characters studied in both seasons.

A.3- Second order interaction (between three factors)

The interaction between saline irrigation water, wheat cultivars and silicon levels application:

The interaction between two levels of saline irrigation water, two wheat cultivars and different silicon levels was significant in all characters under studied, plant height (cm), spike length (cm), number of spikelets / spike, weight of 1000 grains (g), biological yield (kg /fed), grain yield (kg /fed), straw yield (kg/fed) and protein yield (kg/fed), except spike length in the first season and plant height and biological yield in the second season which were insignificant. Maximum values were obtained by application of 300 kg Si/ fed, on wheat cultivar Gimeza, 10 and irrigated by low irrigation water salinity (4236 and 4748 ppm) in both seasons (Tables 8a and 8b).

TABLE 8a. Effect of the interaction between saline irrigation water, cultivars and silicon on wheat yield and yield components (2011/2012 season).

Treatments	Characters	Plant height (cm)	No. of spikelets/ spike	1000-grains weight (g)	Biological yield (Kg/fed)	Grain yield (Kg/fed	Straw yield (kg/fed)	Protein yield (Kg/fed)
4236ppm	Sakha 94 Control	56.3	13.6	27.6	1872.5	180.3	1692.2	25.32
	100KgSi/ fed	61.6	13.9	34.8	4272.5	425.2	3847.3	60.17
	200KgSi/ fed	65.5	14.8	38.7	6502.1	689.8	5812.3	99.33
	300KgSi/ fed	64.4	15.5	36.8	6112.8	640.0	5472.8	102.42
	Gimeza10 Control	61.4	16.9	39.4	2853.1	112.2	2740.9	14.34
	100KgSi/ fed	80.8	17.8	56.6	5579.5	457.3	5104.2	58.52
	200KgSi/ fed	83.9	18.7	61.9	8633.5	729.3	6104.2	102.00
	300KgSi/fed	86.1	19.7	68.0	10194.0	916.9	9277.1	129.74
7001ppm	Sakha 94 Control	51.0	11.2	24.6	1690.0	155.9	1534.1	20.50
	100KgSi/ fed	60.7	13.5	30.8	2318.5	389.7	1928.8	53.19
	200KgSi/ fed	62.7	14.0	34.2	3934.5	480.6	3453.9	66.55
	300KgSi/fed	63.8	14.2	36.4	4943.5	647.7	4295.8	92.94
	Gimeza 10 Control	55.9	12.9	26.9	1970.5	97.4	1873.1	10.75
	100KgSi/ fed	74.9	13.5	49.8	5274.5	211.8	5062.7	23.82
	200KgSi/ fed	77.9	13.6	55.9	7152.5	470.7	6681.8	54.13
	300KgSi/ fed	79.8	14.1	66.9	8522.5	718.7	7803.3	84.82
LSD at 5%		1.184	0.429	2.514	425.319	13.360	505.989	2.425

TABLE 8b. Effect of the interaction between saline irrigation water, cultivars and silicon on wheat yield and yield components (2012/2013 season).

Treatments \ Characters		Spike length (cm)	No. of spikelets/ spike	1000-grains weight (g)	Grain yield Kg/fed	Straw yield kg/fed	Protein yield Kg/fed
4748ppm	Sakha 94 Control	6.6	13.5	28.4	164.7	1770.3	22.80
	100KgSi/fed	6.7	15.1	29.8	371.1	1890.4	51.83
	200KgSi/fed	7.1	15.4	35.6	610.5	4159.5	88.21
	300KgSi/fed	7.5	15.9	32.2	581.4	3612.8	90.69
	Gimeza 10 Control	11.6	17.2	36.7	104.3	2913.9	12.61
	100KgSi/fed	12.2	19.6	42.2	377.6	4403.4	47.56
	200KgSi/fed	13.5	19.9	48.7	575.4	5736.8	157.64
	300KgSi/fed	14.4	20.1	55.2	850.8	7895.3	118.68
7360 ppm	Sakha 94 Control	6.2	11.5	24.7	143.7	1471.8	18.75
	100KgSi/fed	6.5	13.7	28.1	280.8	1704.7	37.47
	200KgSi/fed	6.7	13.9	31.0	361.9	2212.6	49.59
	300KgSi/fed	6.9	14.1	34.4	541.5	3112.6	77.15
	Gimeza 10 Control	10.8	13.2	27.9	78.3	1725.7	8.42
	100KgSi/fed	11.1	13.4	41.2	169.2	4147.8	18.69
	200KgSi/fed	11.6	13.7	46.9	426.8	5657.2	48.01
	300KgSi/fed	11.9	14.1	50.1	721.8	7038.8	82.62
LSD at 5%		0.2322	0.2968	2.7398	31.8241	430.220	3.855

(Feddan= 4200 m^2).

B. Chemical composition of wheat

Effect of the interaction among saline irrigation water, silicon levels application of two wheat cultivars

Data in Fig. 4a and 4b and Table 9 show that the effect of the interaction among saline irrigation water, Silicon levels application of two wheat cultivars (Sakha 94) and Gimeza 10) was significant in Na^+ (mg/g), K^+ (mg/g), protein content and (K^+/Na^+ ratio), in both seasons except potassium in the second season which was insignificant. Sodium content was higher in wheat cultivars grown under saline irrigation water; however Si application significantly reduced Na content in grain of two wheat cultivars. Potassium content was lower in grain wheat grown under high saline irrigation water (8.21 and 8.02 mg/g) than those grown in low saline irrigation water (12.92 and 12.95 mg/g) in the both season, respectively. Liang *et al.* (2007) reported a significant increase in K uptake and decrease in Na uptake under salt stress when Si was included because of increasing activity of plasma membrane H-ATPase. Potassium/Sodium ratio was lower significantly under high salinity irrigation water when Si was not applied. Increased K content and reduced Na in grains of both cultivars may be one of the possible mechanisms of increasing salinity tolerance by Si application in wheat plants.

Silicon is known also to reduce Na uptake (Matichenkov and Kosobrukhov, 2004). Silicon application enhanced K/Na selectivity ratio in wheat cultivars thus enhancing biological and grain yields. Silicon when deposited in exodermises and endodermis of roots reduced Na uptake in plants (Gong *et al.*, 2003). These results were agreed with those reported by Hanafy Ahmed *et al.* (2008). Nitrate nitrogen was accumulated in the Sakha 94 cultivar plants grown under saline conditions especially at moderately saline (4236 and 4748ppm) and strongly saline irrigation (7001 and 7360 ppm), respectively in both seasons compared to Gimeza 10. It might be due to an adaptation mechanism developed by the plants to overcome osmotic stress caused by salinity while further decrease in nitrate nitrogen might be related to the antagonistic relation between toxic Cl^- and NO^-_3, (Sharma *et al.*, 2005).

The exclusion of Na^+ ions and a higher K: Na ratio in wheat cultivars grown under saline irrigation water has been confirmed as important selection criteria for salt tolerance (Hellal *et al*., 2012). Application of Si increased significantly the contents of N, K and the K: Na ratio and decreased Na ion contents of salt - affected plants. Therefore, the results shown in (Table 8) agree with faba bean experimentations by (Hellal *et al*., 2012) which indicated that salt tolerance is associated with an enhanced K: Na discrimination trait. The ability of plant to limit Na transport into the shoot is critically importance for the maintenance of high growth rates and protection of the metabolic processes in elongation cells from the toxic effects of Na^+ (Ali *et al.*, 2012).

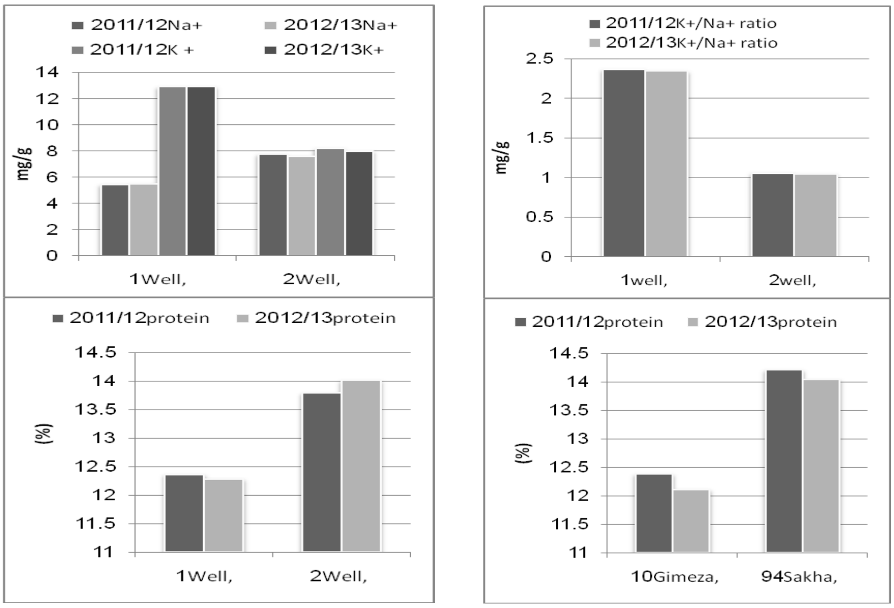

Fig. 4a. Main effect of saline irrigation water and two cultivars on chemical composition Na^+, K^+, K^+/Na^+ ratio and protein content of two wheat cultivars in the both seasons.

Well, 1 = 4236 and 4748 ppm saline irrigation water in both seasons and **Well, 2** = 7001 and 7360 ppm saline irrigation water in both seasons

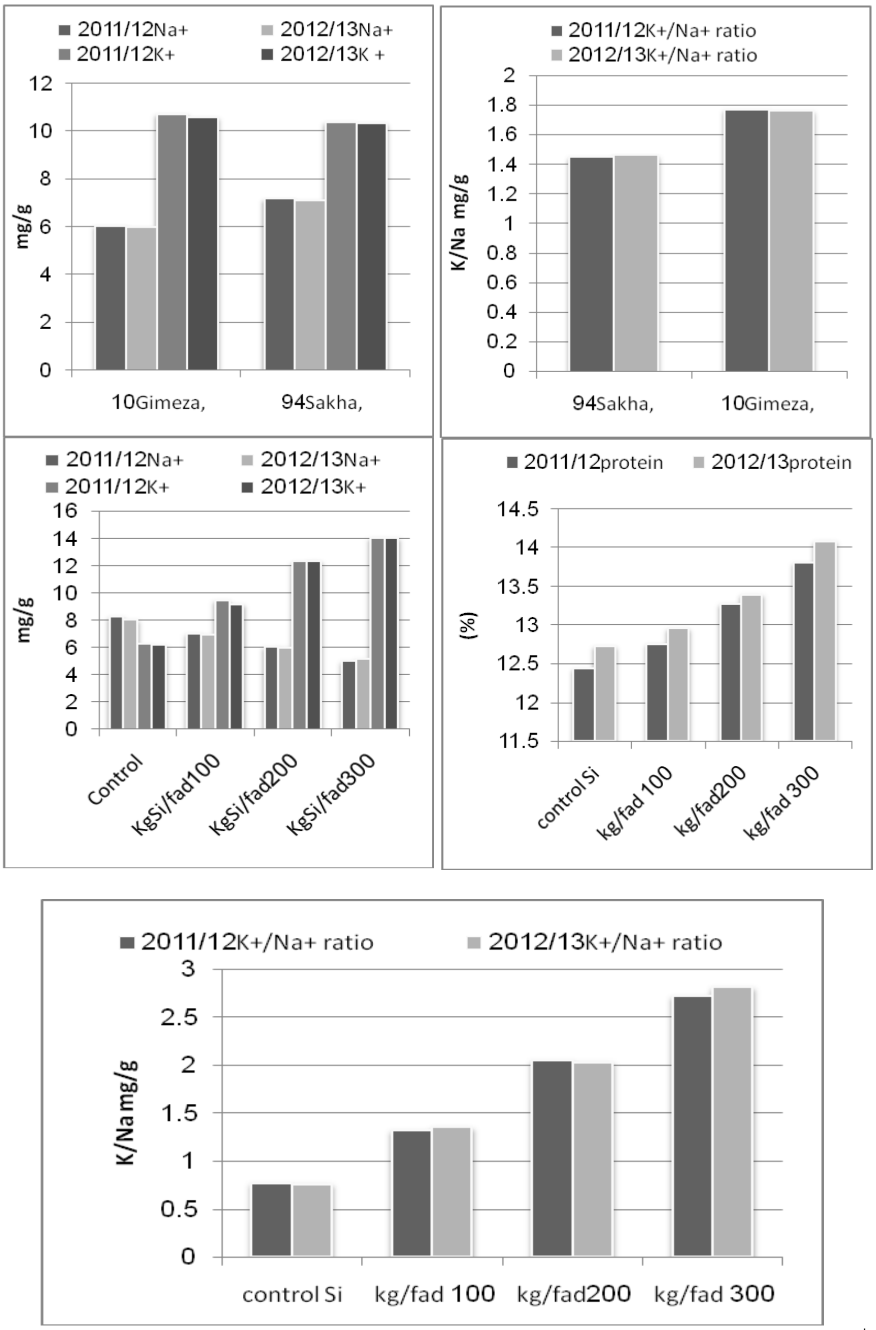

Fig. 4b. Main effect of Si application and two cultivars on chemical composition Na^+, K^+, K^+/Na^+ ratio and protein content of two wheat cultivars in the both seasons.

TABLE 9. Effect of interaction between saline irrigation water, cultivars and silicon on chemical components of two wheat cultivars grains.

Characters		Na^+ (mg/g)		K^+ (mg/g)		K^+/Na^+ ratio		% Protein content	
Treatments	Seasons	2011/ 2012	2012/ 2013	2011/ 2012	2012/ 2013	2011/ 2012	2012/ 2013	2011/ 2012	2012/ 2013
(4236 and 4748) ppm	Sakha,94 Control	5.75	5.52	6.88	6.43	1.19	1.16	13.1	13.2
	100KgSi/ fed	5.66	5.46	8.67	7.76	1.53	1.42	13.4	13.7
	200KgSi/ fed	5.08	5.17	9.29	9.49	1.82	1.83	13.7	13.9
	300KgSi/ fed	4.37	4.92	9.64	10.30	2.21	2.09	14.3	14.4
	Gimeza,10 Control	6.61	6.59	4.60	4.55	0.69	0.69	10.7	11.1
	100KgSi/ fed	6.06	6.20	6.91	6.93	1.14	1.11	11.1	11.3
	200KgSi/ fed	5.73	5.69	9.22	8.69	1.60	1.53	11.3	11.5
	300KgSi/ fed	4.43	4.53	10.54	10.03	2.38	2.21	11.5	11.8
(7001 and 7836) ppm	Sakha,94 Control	9.06	9.19	6.92	7.13	0.76	0.77	13.8	14.1
	100KgSi/ fed	6.99	6.74	11.10	10.84	1.58	1.60	14.1	14.2
	200KgSi/ fed	6.42	6.50	15.87	15.81	2.47	2.43	14.5	14.4
	300KgSi/ fed	5.18	5.06	17.52	17.08	3.38	3.37	15.6	16.1
	Gimeza,10 Control	11.74	11.01	6.72	6.78	0.57	0.61	12.1	12.7
	100KgSi/ fed	9.54	9.54	11.41	11.39	1.19	1.19	12.6	12.8
	200KgSi/ fed	7.16	7.27	15.05	15.65	2.10	2.15	13.7	13.8
	300KgSi/ fed	6.35	6.15	18.75	18.90	2.95	3.07	13.9	14.2
LSD at 5%		0.413	0.400	1.126	n.s	------	------	0.228	0.137

Conclusion

It was concluded from the current field study that using silicon is beneficial to mitigate salinity stress under a wide range of field conditions. The results of this study highlight the role of silicon in improving wheat cultivars yield under low or high saline irrigation water. We suggest that under low saline irrigation water, silicon should be treated soil by concentration 300 kg Si/fed, increased significantly grain yield/feddan to minimize the hazardous effects of salinity on yield of wheat cultivars. Si improvement in wheat yield was associated with reduced Na^+ uptake and increased K^+ uptake resulting an improved K^+/Na^+ ratio in seed cultivars; Gimeza 10, performed Sakha 94 under salinity stress. In general, silicon at the rate of 300 kg/fed and irrigated by well (4236 and 4748 ppm moderate level of salinity), encourage the farmers to use silicon to enhance the salt tolerance of wheat that is mediated via improvement in yield and yield components.

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تاثير السيليكون والرى بالمياة المالحه على انتاجية صنفيين من القمح بجنوب سيناء ـ مصر

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تم إجراء تجربتين حقليتين بمحطة مركز بحوث الصحراء براس سدر بمحافظة جنوب سيناء خلال الموسمين الزراعيين 2011/ 2012و2012 /2013 وذلك لدراسة تاثير اضافة بعض مستويات من السيلكون الى التربة بمعدلات (100-200-300 كجم/ف) مقارنة بدون اضافة السيلكون للتربة والموصى بة من شركة الاهرام للتعديين والذى يعرف بقدرتة العالية على تخفيف الاثار الضارة للملوحة على انتاجية صنفيين من القمح احداهما متحمل للملوحة (سخا 94) والاخر حساس للملوحة (جميزة 10) والتى تم ريهما من بئران مختلفان بالمحطة تصل ملوحتهما الى 4236 و7001 جزء في المليون فى الموسم الاول و 4748 حتى 7360 جزء في المليون فى الموسم الثانى وقد أوضحت النتائج المتحصل عليها الأتي :-

1. بزيادة مستويات ملوحة ماء الري تقل صفات المحصول ومكوناته لكلا الصنفين في كلا الموسمين .
2. تفوق صنف جميزة 10على صنف سخا 94 في صفات المحصول ومكوناته في كلا الموسمين وذلك لزيادة ارتفاع النبات بة ووزن المائة حبة وطول السنبلة على العكس فقد تفوق الصنف سخا 94 فى محصول البروتين وذلك فى كلا الموسميين.
3. زيادة محصول القمح ومكوناتة معنويا بزيادة اضافة السيلكون الى التربة بمعدل 100 كجم /فدان وحتى 300 كجم/فدان في كلا الموسمين.
4. كان التفاعل بين ملوحة ماء الري وصنفي القمح غير معنويا فى صفات المحصول ومكوناته وفي التركيب الكيماوى ايضا فى كلا الموسمين .
5. زاد محصول القمح صنف جميزة 10 ومكوناتة باستخدام المعدل المرتفع من السيلكون 300 كجم / فدان وأدى إلى زيادة صافى دخل محصول القمح وذلك تحت الظروف الملحية فى كلا الموسميين.
6. زادت نسبة البوتاسيوم و نسبة البوتاسيوم / الصوديوم وقلت نسبة الصوديوم فى حبوب صنف جميزة 10 عند الرى بالبئر ذات المستوى المنخفض للملوحة في كلا الموسمين على العكس من ذلك يرتفع ايون الصوديوم ومحتوى البروتين عند الرى بالتركيز المرتفع للاملاح فى صنف سخا 94 وذلك فى كلا الموسميين.
7. تزداد نسبة البوتاسيوم الى الصوديوم لصنف القمح جميزة 10 عند معاملة التربة بالتركيز المرتفع للسيلكون (300 كجم/ فدان) وعند رية بمياة البئر التى تصل نسبة الاملاح فية 4236 و 4748 جزء فى المليون وذلك فى كلا الموسميين.
8. ينصح في الاراضى المتأثرة بالأملاح كما في منطقة راس سدر بمحافظة جنوب سيناء اضافة السيليكون الى التربة بمعدل 200 كجم / ف للاصناف المتحملة للملوحة (سخا 94) وبمعدل 300 كجم /ف للاصناف الحساسة للملوحة (جميزة 10) لاعطاء محصول جيد وزيادة العائد الأقتصادى للمزارعين بالإضافة إلى تقليل التلوث من الاستخدام الزائد للأسمدة الكيماوية .