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SILICON MANAGEMENT AND SUSTAINABLE WHEAT PROUDUCTION UNDER RAIN – FED SOIL

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ABSTRACT

Silicon is known to effectively enhance the resistance to drought mainly and stimulating the growth and development of many plant species. Two field experiments were carried out on a private farm at Sidi Barrani, Marsa Matrouh Governorate during two successive seasons of (2011/2012 and 2012/2013). To evaluate the effect of organic matter and different sources of silicate , i.e calcium silicate (Ca-Sil), sodium silicate (Na-Sil) , magnesium silicate (Mn-Sil) and potassium silicate (K-Sil) as foliar spray on role of silicate in water stress tolerance, growth, yield, yield components and chemical composition of wheat plants under rain-fed conditions. This scientific aspect represents a new strategy technique for understanding the best usage of such materials under rain-fed conditions. The obtained results indicated that, macronutrients and Si contents of wheat plant at 70 days from cultivation follows the following order Potassium Silicate (K-Sil) > Calcium Silicate (Ca-Sil) > magnensium Silicate (Mg Sil) > Sodium Silicate (Na Sil) . Generally, spraying silicate solution achieved significant increases in wheat yield and its components as well as N, P & K contents of grain and straw compared to the control (without addition any silicate), except for the weight of 1000 grains in both growing seasons. Potassium silicate gave the highest significant response for most plant parameters in both seasons followed by CaSil, MgSil and NaSil. Meanwhile, all yield components significantly responded to the application of compost in both successive seasons.

In most cases, the interaction effect between the factors under study was insignificant on wheat yield and its components as well as macronutrients content of grains and straw in both growing seasons.
Keywords: Organic matter – Silicon – wheat plant

INTRODUCTION

Wheat *(Triticum aestivum L.)* is an important source of staple food and thus the most important crop in food security prospective. In the Mediterranean basin, wheat is cultivated on a large scale under rain-fed conditions, where water deficit is the principal abiotic factor affecting crop nutrition and yield in arid and semiarid areas and considered as one of the major limitations to the agricultural productivity worldwide (Farooq *et al.,* 2009). The management of plant nutrients is very useful to develop plant tolerance to drought. Better plant nutrition can effectively alleviate the adverse effects of drought by a number of mechanisms (Waraich *et al.,* 2011).

Silicon (Si) has received little attention from plant nutrition scientists, most likely because it is not included in the group of elements considered as essential to plant growth. Notwithstanding, beneficial effects of Si have been demonstrated for many plant species, especially when these plants are submitted to some type of stress, whether biotic or abiotic (Datnoff *et al.,* 2001a).

Si fertilizer is applied to crops in several countries for increased productivity and sustainable production (Ma *et al.,* 2001). Its properties include the beneficial effect on the ionic balance in plants, reducing toxic effects of manganese and iron excessive amounts, as well as reinforcement of cell walls (Marscher *et al.,* 1990). This element is also known for its stimulation of plant resistance to fungal diseases (Gillman *et al.,* 2003), insects (Reynolds et. al., 2009), and resistance to unfavorable environmental conditions, among others, too low temperature or water deficit. One of the mechanisms for supporting plants under water stress conditions is decreased transpiration resulting in reduction in water loss, but silicon also partakes in osmoregulation, maintaining water status and adequate supply of nutrients (Sacala, 2009). The external presence of silicon from the application of potassium silicate to the leaves probably inhibited the infection by the pathogen. (Gil Rodrigues *et al.,* 2011).

Silicon is applied in the form of silicates, e.g. potassium silicate and sodium silicate as drenches or foliar applications, and it can be also added to medium mixtures, e.g. in the form of rice husk ash (Kamenidou *et al.,* 2010) .Si is translocated to the shoot via the xylem. Chemically, salicylic acid polymerizes to form silica gel ($SiO_2\_nH_2O$) when the concentration of salicylic acid exceeds 2 mM. However, the concentration of Si in the xylem sap is usually much higher than 2 mM in rice and wheat, even though the major form of Si in the xylem has been identified as monomeric silicic acid in these plant species (Casey 2004).

There is strong demand to improve the knowledge of the relationship between Si and other nutrients and role of Si in alleviating water stress under Egyptian conditions, characterized by high temperature, high evapotranspiration, and shortage in irrigation water. So, the aim of our work was to study the effect of various sprayed Si sources and compost on yield and chemical composition of wheat plants under rain-fed conditions .

MATERIALS AND METHODS

Two field experiments were conducted in seasons 2011/2012 and 2012/2013 on authenticated private farm at Sidi Barrani (northern coast), Marsa Matrouh Governorate to study the effectiveness of different rates, of organic matter and different sources of silicate as a foliar spray on yield, its components and macronutrient contents of wheat plants. Representative soil surface (0-30 cm) samples were collected from the experimental site in each season to determine some physical and chemical properties. The chemical properties of the soil were determined according to Rebecca (2004) as well as Particle size distribution which was carried out according to the International Pipette method, using Na-hexamethaphosphate as a dispersing agent (Day, 1965). Results are shown in Table (1). Chemical analysis of compost is presented in Table (2).

The trail was carried out in plots with area of 18.0 m2 (3 x 6m). Split plot design with three replicates was used. The organic material (compost) at the rate of 0, 2, 4 tone/ Feddan was arranged in the main plots, whereas foliar applications of different sources of silicate (calcium, sodium, magnesium and potassium silicate) were randomly assigned in sub plots. The organic materials (compost) were thoroughly mixed with 0–30 cm of the surface soil layer before sowing.Silicate solution at the rate of 250 mgL^{-1} were foliar applied in three sprays, after 30, 45 and 60 days from planting, using the following silicate sources:

1-Potassium silicate (K-Sil): Genl formula; K_2SiO_3 potassium metasilicate; SiO2.K2O weight ratio varies with grade as 2.1 :1 to 2.5 :1 soluble in water.

2-Magnesium silicate (Mg-Sil): The molecule formula (mgSio3) is typically written MgO.xSiO2 where x denotes the average molar ratio of SiO2 to MgO. The molar ratio of MgO to SiO2 is approximately 2:5 slightly soluble in dilute mineral acids.

3-Calcium Silicate (Ca-Sil): Ca2SiO4 (dicalcium silicate) ; sometimes formulated 2CaO.SiO2-CaSiO3(Calcium metasilicate,CaO.SiO2) , insoluble in water and ethanol but it forms a gel with mineral acids. It is slightly soluble in HCl.

4-Sodium Silicate (Na-Sil): Formula varies from Na2SiO3 (Na2O.3.75 SiO2) to Na4SiO4 (2Na2).SiO2) and with various proportion of water , soluble in water.

Superphosphate (15% P_2O_5) and potassium sulphate (48% K_2O) were applied during land preparation for planting at rates 30 kg P_2O_5 and 24 kg K_2O/ fed, respectively. Nitrogen fertilizer was applied in three equal portions, (30, 45 and 60 days from sowing) in form of ammonium sulphate (20.5 % N) at a rate of 60 kg N /fed.

Wheat grains (variety Giza 168) were planted in the Second week of November and rain-fed irrigated system and harvested after 150 days (16th and 21th of May 2012 & 2013, respectively). Plant sample were also collected from each plot at 70 days from sowing of each growing season to determine nitrite, nitrate, silicon and percentages of P and K. At harvest, plant height (cm), spike length (cm), spike number / m2, kernels number / spike, kernels weight / spike (g) and weight of 1000 grains (g) were estimated at harvesting in ten plants taken randomly from each treatment. Grain and straw yields (ton/ fed) were also measured and recorded.

Plant samples were dried at 70 ºC; ground, digested with the acid mixture. Silicon was estimated by the colorimetric molybdenum blue method (Elliot and Snyder, 1991). Total nitrogen, phosphorus and potassium were determined according to the method described by Faithfull (2002). All data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the using MSTATC computer software package according to Gomez and Gomez (1984). Least Significant Difference (LSD) method was used to test the differences between treatment means at 5% level of significance.

Table (1): Physical and chemical properties of the experimental soil.

Season	Particle size distribution (%)				*Sp*	Ece (dSm^{-1})	pH (1:2.5)	$CaCO_3$ %	*Caution meI/*				Anions *meI/*			Available macro nutrients mg\kg		
	Coarse sand	Fine sand	Silt	*Clay*					Ca^{+2}	Mg^{+2}	Na+	K^{+}	HCO^{-}_{3}	Cl^{-}	SO^{--}_{4}	N	P	K
2011	20.7	60.57	00.24	20.11	23	73.5	24.8	62.27	70.6	50.12	80.1	80.35	88.15	52.33	40.7	35.11	10.4	90.22
2012	40.6	20.52	60.27	80.13	24	90.5	37.8	28.31	30.5	80.13	60.1	40.37	13.14	77.35	20.8	65.10	70.3	30.21

Table (2): Some chemical analysis of the compost used .

Season	Parameters												
	EC_e (dSm^{-1})	pH (1:10)	O . C	O.M	C/N	%			(mg\kg)				
						N	P	K	Fe	Mn	Zn	Cu	Pb
2011	1.58	6.3	27.22	64.46	16.70	1.63	1.17	1.66	522	218	204	261	10.12
2012	1.67	6.6	28.62	49.04	15.81	1.81	1.22	1.79	563	242	226	283	10.58

Table (3): Some Average metrological data of the investigated area (2006-2012).

Month	Temp. mean max. (°C)	Temp. mean min. (°C)	Temp. average (°C)	Night time (°C)	Relative humidity (%)	Wind speed 2m (m/ sec)	Rain fall (mm)	Possible sunshine duration (hr)
January	18.4	10.0	13.9	12.5	67	3.7	26.1	10.3
February	19.2	10.2	14.4	12.8	62	4.3	12.1	11.0
March	21.0	11.7	16.2	14.3	62	4. 1	3.1	11.9
April	23.1	14.0	18.4	16.5	65	4.0	0.5	12.8
May	24.3	15.5	20.0	17.9	63	3.4	0.3	13.0
June	28.5	20.1	24.5	22.4	69	3.7	0.0	14.0
July	29.8	22.2	26.2	24.5	72	4.1	0.0	13.9
August	30.4	22.6	26.8	25.0	72	3.5	0.0	13.2
September	29.8	21.4	25.8	24.0	65	3.4	0.2	12.2
October	27.6	18.5	23.0	21.1	63	3.3	2.6	11.4
November	23.4	14.2	18.6	16.7	65	3.2	8.2	10.5
December	17.1	9.7	13.1	11.7	53	3.2	11.0	8.4

RESULTS AND DISCUSSION

- **Macronutrients and Si concentration in wheat plant after 70 days from planting.**

Available data in Tables (4 a & 4 b) reveal obviously that NO_2 – N, NO_3 – N , K, and Si concentration of wheat plant at 70 days were significantly increased by the sprayed silicate while P was not significantly affected. In both seasons, potassium silicate gave highly significant values for the most parameters under study compared to other treatments. The highest values were recorded in NO_2 – N (2.93mgKg^{-1}), NO_3 – N (7.12 mgKg^{-1}), K (1.67%), P(0.44%), and Si (6.71 mgKg^{-1}) at 70 days when applied with organic manure at 4 ton/fed. On the other hand, results reveal that the lowest values of NO_2 – N (2.86 mgKg^{-1}), NO_3 – N (6.72 mgKg^{-1}), K (1.52) P (0.38%), and Si (6.02 mgKg^{-1}) were recorded when sodium silicate sprayed. These results agreed with those obtained by (Kurdali and Al-Chammaa 2013). Also, Buck *et al.,* 2008 noted that applications of Si to water stressed plants resulted in significant increments of fertilizer nitrogen, potassium uptake and its use efficiency.

Although the ranges of Si sufficiently concentration in wheat are not determined to date , the contents observed in treatments can be considered appropriate , according to the range of 5.1 – 16.9 mgKg^{-1} established by Korndorfer et al. (2004) for leaves + stems. This shows that wheat is a Si – accumulating crop (Ma , 2004). Datnoff et al. (2005) noticed that cereals remove 100 to 300 Kg Si ha^{-1} which is much more removed than other macronutrients.

Data tabulated in Tables (4 a & 4 b) also reveal that the interaction between application of compost and Si foliar treatment showed non-significant effect on NO_2^-- N , NO_3^-- N , K , P and Si. The maximum average values of the two successive seasons for these parameters were 3.2 mgkg^{-1} , 6.92 mgKg^{-1}, 1.09 % , 1.03 % and 7.42% in case of compost application (4 ton/fed) + K-silicate .While the small record for these constituents was gained when using compost application (2 ton/fed) + Na-silicate.

Table (4 a): NO2-- N , NO3-- N , phosphorus , potassium and silicon concentrations in the wheat leaves sprayed by different sources of silicon at 70 days from cultivation.

Silicon / O.F	Season (1)						Season (2)					
	Cont.	**Na-Sil**	**Ca-Sil**	**K- Sil**	**Mg- Sil**	**Mean**	***Cont.***	**Na-Sil**	**Ca-Sil**	**K-Sil**	**Mg-Sil**	**Mean**
NO_2^-N mgKg^{-1}												
Cont.	2.37	2.48	2.55	2.67	2.55	2.52	2.61	2.79	2.84	3.05	2.82	2.82
2 tonne/Fed	2.68	2.73	2.84	2.13	2.80	2.64	3.03	3.11	3.26	3.38	3.20	3.20
4 tonne / Fed	2.75	2.86	2.91	2.93	2.88	2.87	3.16	3.31	3.35	3.46	3.35	3.33
Mean	2.60	2.69	2.77	2.58	2.68	2.74	2.93	3.07	3.15	3.30	3.12	3.11
LSD 5%	OF= 0.15		S= 0.2		O.F*S=NS		OF= 0.17		S= 0.22		O.F*S=NS	
NO3-- N mgKg-1												
Cont.	5.78	6.09	6.25	6.53	6.21	6.17	5.37	5.68	5.87	6.26	5.79	5.79
2 tonne/Fed	6.42	6.58	6.77	6.60	6.70	6.61	5.91	6.08	6.24	6.45	6.22	6.18
4 tonne / Fed	6.63	6.72	6.96	7.12	6.91	6.87	6.05	6.27	6.48	6.71	6.49	6.40
Mean	6.28	6.46	6.66	6.75	6.61	6.55	5.78	6.01	6.20	6.47	6.17	6.13
LSD 5%	OF= 0.20		S= 0.05		O.F*S=NS		OF= 0.15		S= 0.19		O.F*S=NS	
K %												
Cont.	1.29	1.37	1.43	1.49	1.42	1.4	0.31	0.36	0.40	0.46	0.39	0.38
2 tonne/Fed	1.37	1.42	1.56	1.51	1.47	1.47	0.37	0.4	0.44	0.48	0.42	0.42
4 tonne / Fed	1.41	1.52	1.57	1.67	1.56	1.55	0.39	0.43	0.46	0.51	0.43	0.44
Mean	1.36	1.44	1.52	1.56	1.48	1.47	0.36	0.40	0.43	0.48	0.41	0.42
LSD 5%	OF= 0.04		S= 0.05		O.F*S=NS		OF= 0.03		S= 0.04		O.F*S=NS	

Table (4 b): phosphorus and Silicon contents in wheat straw sprayed by different sources of silicon under rain fed soil.

Silicon	Season (1)						Season (2)					
O.F	*Cont.*	Na-Sil	Ca-Sil	K- Sil	Mg- Sil	*mean*	*Cont.*	Na-Sil	Ca-Sil	K- Sil	Mg- Sil	*mean*
P %												
Cont.	0.28	0.31	0.33	0.37	0.32	0.32	1.22	1.28	1.36	1.44	1.36	1.33
2 tonne/Fed	0.33	0.35	0.35	0.41	0.38	0.37	1.28	1.36	1.43	1.53	1.40	1.40
4 tonne / Fed	0.36	0.38	0.41	0.44	0.40	0.40	1.37	1.48	1.51	1.62	1.47	1.44
Mean	0.32	0.35	0.37	0.41	0.37	0.36	1.29	1.37	1.43	1.53	1.41	1.41
LSD 5%	OF= 0.04		S= 0.05		O.F*S=NS		OF= 0.03		S= 0.04		O.F*S=NS	
Si (mg Kg-1)												
Cont.	0.69	4.77	4.94	5.19	4.88	4.09	0.91	5.73	5.96	6.22	5.91	4.95
2 tonne/Fed	0.92	5.58	5.87	6.12	5.84	4.87	1.02	6.67	7.09	7.28	7.01	5.81
4 tonne / Fed	0.98	6.02	6.23	6.71	6.50	5.35	1.13	7.15	7.87	8.13	7.79	6.41
Mean	0.86	5.46	5.78	6.01	5.74	4.77	1.02	6.52	6.97	7.21	6.90	5.72
LSD 5%	OF= 0.22		S= 0.29		O.F*S=NS		OF= 0.16		S= 0.21		O.F*S=NS	

Growth character and yield component:

Most of the recorded growth characters of wheat plants were significantly affected by the application of organic matter and silicate sources. The effect of foliar treatment of silicate on plant height (cm) at 70 days from cultivation is shown on table (5 a). Plant height was significantly increased by spraying different sources of Si compared with the control in the two successive seasons. The high value was obtained when wheat plant was treated with silicate with different cationic forms . This may be refer to silicon effect which promotes the growth of various higher plant species (Zhu et al. 2004). Abdalla (2011) observed that Si is involved in cell elongation and division processes as well as in hormone balance.

Concerning , the effect of foliar treatment on spike length and number of spike /m2 , the measured parameters were increased by spraying silicate solutions compared with the control (non-sprayed plant) in the two successive seasons. The values were arranged in the following order:

K- Sil > Ca- Sil > Mg Sil > Na- Sil > control as shown in table (5a). In this respect , Takatsuka & Makihara (2001) associated low spikelet fertility with low Si concentration in rice plants. As well as Hanafy et al. (2008) showed that all level of silicon significantly increased number of spikes and grains of wheat plant compared with non sprayed plant. The interaction between application of compost (2 & 4 ton/fed) and foliar treatments showed non- significant effect on plant height , spike length and number of spike / m2 as shown in table (5b). The highest values were observed with application of 4 ton compost with sprayed K-sil in the two successive seasons. While, the small record was gained when growing wheat with applied 2 ton /fed compost and spraying Na- Sil.

Concerning the evaluation of yield components the date in table (5b) revealed that Si application significantly increased the number of kernel and kernel weight compared to the control (table 5b). The K-Sil has a superiority of increasing number of kernels followed by Ca-Sil, Mg-Sil and Na-Sil. The increase was 1.9, 1.5 , 1.44 and 1.25 fold of the non- sprayed plant respectively during the two successive season. Kernel weight was followed the same trend as shown in table (5b). The mass of 1000 - grain was the only component which was decreased by Si application compared to the control. That can be explained by the fact of increasing number of kern / m2.

Table (5a): Plant height, Spike Length and number of spike m2 for wheat plants sprayed by different types of silicon under organic fertilizer and rain fed soil.

Silicon / O.F	Season (1)						Season (2)					
	Cont.	Na-Sil	Ca-Sil	K- Sil	Mg-Sil	*mean*	*Cont.*	Na-Sil	Ca-Sil	K- Sil	Mg-Sil	*mean*
Plant height(Cm)												
Cont.	48.20	53.00	58.60	62.40	56.80	55.8	41.20	44.50	51.70	57.60	46.30	48.26
2 tonne/Fed	52.00	59.20	61.80	66.40	58.00	59.48	44.20	49.0	60.5	64.70	53.20	54.32
4 tonne / Fed	55.47	63.20	66.80	78.40	62.40	65.17	49.0	56.10	66.4	73.7	59.87	61.01
Mean	51.89	58.47	62.40	68.93	59.07	60.15	44.8	49.87	59.53	65.33	53.13	54.53
LSD	**OF= 5.03**		**S= 6.49**		**O.F*S=NS**		**OF= 3.22**		**S= 4.15**		**O.F*S=NS**	
Spike Lenght(Cm)												
Cont.	5.30	5.70	6.20	6.80	5.90	5.98	4.82	5.10	5.85	6.20	6.65	5.52
2 tonne/Fed	5.80	6.50	6.80	7.40	6.70	6.64	5.18	5.63	6.45	6.80	6.15	6.04
4 tonne / Fed	6.10	7.0	7.30	7.60	7.10	7.02	5.65	5.49	6.80	7.22	6.51	6.33
Mean	5.73	6.40	6.77	7.27	6.57	6.55	5.22	5.41	6.37	6.74	6.10	5.97
LSD	OF= 0.34		S= 0.44		O.F*S=NS		OF= 47		S= 0.61		O.F*S=NS	
NO. of Spikes / m^2												
Cont.	167.6	177.2	196.0	207.0	192.4	188.0	160.33	167.0	187.0	199.33	181.0	179.0
2 tonne/Fed	181.80	181.80	218.0	226.20	215.60	204.7	172.33	184.0	203.67	216.0	198.0	194.80
4 tonne / Fed	195.0	213.8	239.2	245.0	233.0	225.2	183.67	198.33	221.0	239.0	217.67	211.90
Mean	181.50	190.9	217.7	226.1	213.7	206.0	172.11	183.11	204.0	218.11	198.89	195.24
LSD	OF= 12.90		S= 16.70		O.F*S=NS		OF= 5.86		S= 7.56		O.F*S=NS	

Table(5b):Kernel number/Spike, kernel weight and 1000 grains weight for wheat plants sprayed by different types of silicon under rain fed soil.

Silicon / O.F	Season (1)						Season (2)					
	Cont.	Na-Sil	Ca- Sil	K- Sil	Mg-Sil	mean	*Cont.*	Na-Sil	Ca-Sil	K- Sil	Mg-Sil	mean
Kernl . NO./Spike.												
Cont.	18.20	22.0	25.0	32.60	23.80	24.32	16.0	20.0	24.43	30.0	22.50	22.59
2 tonne/Fed	20.0	23.40	27.80	37.0	28.20	27.28	18.0	22.5	26.0	35.03	26.0	25.51
4 tonne / Fed	21.6	27.0	35.0	42.80	31.20	31.52	18.50	26.0	32.50	39.87	30.0	29.37
Mean	19.93	24.13	29.27	37.47	27.73	27.71	17.5	22.83	27.64	34.97	26.17	25.82
LSD	**OF= 2.60**		**S= 3.35**		**O.F*S=NS**		**OF= 2.26**		**S= 2.92**		**O.F*S=NS**	
Kernel Weight/Spike												
Cont.	0.64	0.75	0.89	1.05	0.83	0.83	0.68	0.79	0.91	1.13	0.88	0.88
2 tonne/Fed	0.75	0.84	0.95	1.27	0.94	0.95	0.78	0.90	1.02	1.34	0.98	1.0
4 tonne / Fed	0.78	0.98	1.19	1.41	1.12	1.10	0.83	0.96	1.29	1.51	1.19	1.16
Mean	0.72	0.86	1.01	1.24	0.96	0.69	0.76	0.88	1.07	1.33	1.02	1.01
LSD	**OF= 0.11**		**S= 0.14**		**O.F*S=NS**		**OF= 0.09**		**S= 0.12**		**O.F*S=NS**	
1000 grain Weight (g)												
Cont.	40.0	39.1	38.22	37.86	39.01	38.84	38.25	37.93	37.77	37.12	38.45	37.49
2 tonne/Fed	39.12	38.65	37.73	37.10	38.05	38.13	37.76	37.32	37.08	36.77	37.15	37.22
4 tonne / Fed	38.68	38.07	37.18	36.89	37.83	37.73	37.38	36.94	36.58	36.27	36.73	36.78
Mean	39.27	38.61	37.71	37.28	38.30	38.23	37.80	37.40	37.14	36.72	37.44	37.30
LSD	**OF= ns**		**S= ns**		**O.F*S=NS**		**OF= 1.37**		**S= 1.76**		**O.F*S=NS**	

Grain and straw yields as well as Biological yield

Data in table (6) showed that application of silicate significantly increased straw, grain and biological yield comparing with untreated plants, and potassium silicate recorded the highest values for yield in both seasons.

The average grain yield values in two seasons were 1.16, 0.88, 0.85 and 0.67 ton/fed while the value of straw yield were 1.90,1.49,1.37 and 1.12 ton/fed for K -Sil , Ca-Sil , Mg-Sil and Na-Sil respectively of the two successive seasons. Consequently, the biological yield was increased and followed the same trend.

The superiority of potassium silicate under rain-fed soil may be related to its content of its potassium attributed to potassium which plays an active role in the processes which ensure carbon assimilation and the transport of photosynthesis through the plant for increasing sugar, protein and growth. Potassium is important for water regulation, intake and increase water use efficiency as well as helps plants resists drought and certain diseases (Nesreen et al.,2011).

The present results warrant further studies to explore different mechanisms in plant working by which Si stimulate growth and yield, whereas there are several direct and indirect mechanism. These mechanisms include addition of silicon decrease the permeability of plasma membrane of leaf cells (Reezi *et al.,* 2009); silicon application increase leaf chlorophyll content and plant metabolism and mitigate nutrient imbalance and metal toxicity in plants (Datnoff *et al.,* 2001b) ; silicon application led to improvement in plant water status Also, Bradburry and Ahmad (1990), Rafi *et al.,* (1997), Gong *et al.,* (2003), Hattori *et al.,* (2005), Romero *et al.,* (2006) and (Mali and Aery, 2008) concluded that lower transpiration rate, greater leaf weight ratio, lower specific leaf area and significant improvement in plant biomass by silicon fed wheat plants under drought condition.

Concerning, the interaction between silicon foliar and compost application was non-significant increase in case of yield and investigated yield component as shown in table (5 a, b and 6). The maximum mean of two successive values of kernel number/spike, kernel weight/spike, weight of 1000 grain, straw yield, grain yield and biological yield were 41.29, 1.46, 36.40 , 2.08, 1.42 and 3.5 respectively. The magnitude of increase was obtained when growing wheat plant by adding 4 ton/fed compost with k-Sil as a foliar application. While the small record was gained when using 2 ton/fed compost with sprayed Na-Sil .

Generally, N,P and K concentrations under individual effect of spraying application and the interaction between compost application and foliar treatments follow one order :

K-Sil > Ca-Sil > Mg-Sil > Na-Sil . This order exactly was confirmed with yield and yield components trend. The highest values of N ,P and K average of two seasons are (0.35, 0.31 & 1.38%) in straw and (2.28, 0.63 & 0.33%) in grains respectively were produced by addition of (4 ton compost/fed+ k-Sil) . These results are in accordance with those obtained by Liang,(1999), who found that silicon could increase K adsorption and transportation in barely plants. In this respect, silicon addition may improve nutritional balance, thereby better growth performance and consequence yield production was obtained. Gharib & Hanafy (2005) noted that, silicon foliar application enhance N and K concentrations in pea shoots. Berthelsen et al.(1999) showed that silicon is playing an important role in improving P nutrition. In a field experiment, silicon significantly increase N , P and K concentrations in shoots as well as in grains (Hanafy et al.2008). Silicon application increase leaf chlorophyll content and plant mitigate nutrient imbalance and metal toxicity in plants (Datnoff et al. , 2001a). Also, silica deposition in the leaf limits transportation and hence salt accumulation (Bradbury and Ahmad 1990).

Table (6): Straw, grain & biological yield (ton/fed) of wheat plants sprayed by different sources of silicon under rain fed soil.

Silicon	Season (1)						Season (2)					
O.F	*Cont.*	Na-Sil	Ca- Sil	K- Sil	Mg- Sil	Mean	*Cont.*	Na-Sil	Ca- Sil	K- Sil	Mg- Sil	mean
							Straw yield					
Cont.	0.64	0.92	1.27	1.64	1.16	1.12	0.79	0.97	1.30	1.80	1.17	1.2
2 tonne/Fed	0.92	1.11	1.48	1.87	1.37	1.35	0.94	1.15	1.51	1.87	1.41	1.37
4 tonne / Fed	1.07	1.28	1.66	2.06	1.55	1.52	1.16	1.31	1.69	2.11	1.57	1.57
Mean	0.88	1.10	1.47	1.86	1.36	1.33	0.96	1.14	1.50	1.93	1.38	1.38
LSD	**OF= 0.65**		**S= 06**		**O.F*S=NS**		**OF= 0.05**		**S= 0.07**		**O.F*S=NS**	
							Grain yield					
Cont.	0.42	0.51	0.68	0.87	0.62	0.62	0.43	0.53	0.71	0.91	0.68	0.65
2 tonne/Fed	0.54	0.65	0.81	1.15	0.79	0.79	0.57	0.67	0.84	1.18	0.82	0.81
4 tonne / Fed	0.60	0.81	1.10	1.40	1.07	1.07	0.61	0.83	1.12	1.43	1.09	1.02
Mean	0.52	0.66	0.86	1..14	0.83	0.83	0.54	0.67	0.89	1.17	0.86	0.83
LSD	**OF= 0.02**		**S= 0.02**		**O.F*S=NS**		**OF= 0.04**		**S= 0.04**		**O.F*S=NS**	
							Biological yield					
Cont.	1.06	1.42	1.96	2.51	1.78	1.75	1.22	1.50	2.0	2.71	1.85	1.86
2 tonne/Fed	1.46	1.76	2.29	3.01	2.16	2.14	1.51	1.80	2.35	3.06	2.23	2.19
4 tonne / Fed	1.67	2.10	2.76	3.46	2.61	2.52	1.77	2.14	2.80	3.53	2.66	2.58
Mean	1.40	1.76	2.34	3.0	2.19	2.13	1.50	1.81	2.38	3.10	2.25	2.21
LSD	**OF= 0.05**		**S= 0.07**		**O.F*S=NS**		**OF= 0.08**		**S= 0.10**		**O.F*S=NS**	

N, P, & K concentration in straw and grains:

Table (7): Nitrogen, phosphorus and potassium concentrations (%) in the wheat straw sprayed by different sources of silicon under rain fed soil.

Silicon	Season (1)						Season (2)					
O.F	*Cont.*	Na-Sil	Ca-Sil	K- Sil	Mg-Sil	mean	*Cont.*	Na-Sil	Ca-Sil	K- Sil	Mg-Sil	mean
							N					
Cont.	0.21	0.23	0.25	0.28	0.25	0.24	0.23	0.26	0.28	0.31	0.27	0.27
2 tonne/Fed	0.23	0.26	0.28	0.30	0.28	0.27	0.25	0.27	0.31	0.33	0.29	0.29
4 tonne / Fed	0.27	0.29	0.30	0.34	0.30	0.30	0.26	0.29	0.33	0.36	0.30	0.31
Mean	0.29	0.26	0.28	0.31	0.28	0.27	0.25	0.27	0.31	0.33	0.29	0.29
LSD	**OF= 0.03**		**S= 0.04**		**O.F*S=NS**		**OF= 0.03**		**S= 0.04**		**O.F*S=NS**	
							P					
Cont.	0.18	0.20	0.21	0.23	0.20	0.20	0.18	0.23	0.25	0.28	0.25	0.24
2 tonne/Fed	0.21	0.22	0.23	0.26	0.20	0.22	0.23	0.26	0.28	0.31	0.27	0.27
4 tonne / Fed	0.23	0.25	0.27	0.30	0.26	0.26	0.24	0.28	0.28	0.32	0.28	0.28
Mean	0.21	0.22	0.24	0.26	0.22	0.23	0.22	0.26	0.27	0.30	0.27	0.26
LSD	**OF= 0.02**		**S= 0.03**		**O.F*S=NS**		**OF= 0.03**		**S= 0.04**		**O.F*S=NS**	
							K					
Cont.	1.05	1.11	1.18	1.23	1.15	1.14	1.11	1.15	1.22	1.29	1.21	1.20
2 tonne/Fed	1.09	1.18	1.27	1.30	1.22	1.21	1.13	1.20	1.30	1.38	1.26	1.25
4 tonne / Fed	1.11	1.22	1.30	1.36	1.26	1.25	1.16	1.23	1.34	1.40	1.29	1.28
Mean	1.08	1.17	1.25	1.30	1.21	1.20	1.13	1.19	1.29	1.36	1.25	1.25
LSD	**OF= 0.06**		**S=**		**O.F*S=NS**		**OF=**		**S=**		**O.F*S=NS**	

Table (8): Nitrogen, phosphorus and potassium concentrations (%) in wheat grains sprayed by different types of silicon under rain fed soil.

Silicon	Season (1)						Season (2)					
O.F	*Cont.*	Na-Sil	Ca- Sil	K- Sil	Mg- Sil	mean	*Cont.*	Na-Sil	Ca- Sil	K- Sil	Mg- Sil	mean
						N						
Cont.	1.79	1.88	1.94	2.02	1.94	1.91	1.83	1.94	1.98	2.04	1.95	1.95
2 tonne/Fed	1.90	1.96	2.06	2.16	2.03	2.02	1.91	2.03	2.04	2.23	2.06	2.06
4 tonne / Fed	1.98	2.03	2.14	2.23	2.11	2.10	1.98	2.05	2.17	2.32	2.11	2.13
Mean	1.89	1.96	2.05	2.14	2.03	2.01	1.91	2.01	2.06	2.20	2.04	2.04
LSD	**OF= 0.04**		**S= 0.05**		**O.F*S=NS**		**OF= 0.06**		**S= 0.07**		**O.F*S=NS**	
						P						
Cont.	0.48	0.50	0.53	0.56	0.53	0.52	0.51	0.52	0.53	0.58	0.52	0.53
2 tonne/Fed	0.51	0.52	0.56	0.58	0.55	0.54	0.53	0.56	0.58	0.61	0.58	0.57
4 tonne / Fed	0.53	0.55	0.59	0.61	0.57	0.57	0.57	0.58	0.60	0.64	0.58	0.59
Mean	0.51	0.52	0.56	0.58	0.55	0.55	0.54	0.55	0.57	0.61	0.56	0.57
LSD	**OF= 0.3**		**S= 0. 4**		**O.F*S=NS**		**OF= 0.04**		**S=**		**O.F*S=NS**	
						K						
Cont.	0.2	0.22	0.23	0.25	0.23	0.23	0.20	0.24	0.26	0.29	0.24	0.25
2 tonne/Fed	0.21	0.24	0.26	0.28	0.25	0.25	0.23	0.25	0.28	0.33	0.27	0.27
4 tonne / Fed	0.24	0.25	0.27	0.30	0.26	0.26	0.25	0.28	0.29	0.37	0.29	0.30
Mean	0.22	0.24	0.25	0.28	0.25	0.25	0.23	0.26	0.28	0.33	0.27	0.27
LSD	**OF= 0.03**		**S= 0.04**		**O.F*S=NS**		**OF= 0.03**		**S= 0.04**		**O.F*S=NS**	

Conclusions and future research

- Rain-fed agriculture will maintain an important role in the growth of food production in the future. However, appropriate investments and policy reforms will be required to enhance the contribution of rain-fed agriculture.
- Our preliminary studies have shown that silicon leaf application efficiently supplied Si for wheat plants. As for, leaf-supplied Si increased nutrient concentrations in leaves and grain yield of wheat combined with compost application of 4 ton/fed cropped under rain-fed conditions.
- There is now a large body of research indicating improved resistance to pests, disease, drought and other stresses on plants from the application of silica fertilizers. There is also evidence of improved nutrient uptake.
- Further work is needed to understand the genetic mechanism behind Si induced water stress tolerance in wheat.

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إدارة السليكون والإنتاجية المستدامة للقمح تحت نظام الزراعة المطرية

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أجريت تجربتان حقيلتان في مزرعة من المزارع الخاصة بسيدي براني محافظة مرسى مطروح ، خلال موسمين متتاليين (2011/2012 - 2012/2013) وكان الهدف من هذه الدراسة هو تقييم تأثير استخدام المواد العضوية ومصادر مختلفة من السيليكون (سيليكات الكالسيوم ، الصوديوم ، المغنيسيوم والبوتاسيوم) رشا على الأوراق وتأثيرة على النمو والمحصول ومكوناته والتركيب الكيميائي لنبات القمح. يمثل هذا الجانب العلمي تقنية إستراتيجية جديدة لفهم أفضل استخدام لمثل هذه المواد في ظل ظروف الزراعة المطرية. وقد أشارت النتائج إلى أن تركيزات كل من النتروجين والفوسفور والبوتاسيوم والسيليكون في نبات القمح عند 70 يوما من الزراعة إتبع الترتيب التالي K-Sil > Ca-Sil > Mg-Sil > Na-Sil. أدى استخدام الكمبوست بمعدل 4 طن بالإضافة إلى الرش بسليكات البوتاسيوم إلى حدوث أعلى زيادة في كل من ارتفاع النبات، طول السنبلة، عدد السنابل /مترمربع مقارنة بالكنترول، باستثناء وزن ال 1000 حبة في كلا الموسمين المتتاليين. وقد أخذ تركيز كل من النتروجين والفوسفور والبوتاسيوم فى كل من القش والحبوب الترتيب التالي: K-Sil > Ca-Sil > Mg-Sil > Na-Sil والذي أكد نفس اتجاه المحصول ومكوناته.