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Effect of different water deficit and foliar spray of zinc and silicon treatments of chemical composition of maize

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A B S T R A C T

Field experiments were carried out for two consecutive seasons at the Experimental Shandaweel Agricultural Research Station, Sohag Governorate, Upper Egypt, during the growing seasons of 2013 and 2014, to study the effect of irrigation intervals and foliar spray of zinc and silicon treatments on chemical composition of maize. Results indicated that scheduling at every 10 days produced the N% , Crude protein%, Cu%, P%, K%, Zn%, Si%, Mn% and Fe% and foliar spray of zinc and silicon treatments produced the highest chemical composition of maize crop. The best N%, Crude protein%, Cu% and Mn were obtained from zinc + silicon treatments followed by zinc, silicon treatments. In contrast, untreated treatments produced the lowest values. It can be concluded that the scheduling at every 10 days and application of foliar spray of zinc + silicon treatments as the effective one could be recommended for scheduling irrigation at every 10 days with application of foliar spray of zinc, silicon or zinc +silicon treatments of maize crop at Shandaweel Agricultural Research Station, Sohag Governorate, Upper Egypt to obtain the best results from chemical composition of maize.

1. Introduction

Recently, there is a great interest in scientific research that focuses on environmental and agricultural uses of functionalized organic and inorganic compounds.[1-18] Maize is one of the main cultivated cereals all around the world. It is the third most important crop worldwide following wheat and rice. It is one of the important crops principally during the summer season in Egypt (1.724.000 fed. for white maize and 415.245 fed. for yellow maize). Egypt produces about 58 million tons of white maize and 1.3 million tons of yellow maize annually.[19]

Egypt's prosperity still depends largely on the agricultural sector and its productivity. Egypt has a fixed share from the Nile water (55.5 billion cubic meters). Capita share from water is less than 1000 cubic meter/year which is the water poverty limit. In Egypt agriculture consumes more than 80% from the water reserves. Proper irrigation management leads to maximizing net return, minimizing irrigation costs, maximizing yield, optimally distributing a limited water supply and minimizing groundwater pollution. Irrigation scheduling is the decision of when and how much water to apply to a field.[20]

The level of zinc nutrition may affect plant water relations and alter stomatal conductance.[21] Zinc deficiency may limit the ability of the crop to use the moisture reserves in the soil.[22] Zinc deficiency affects the absorption of water and nutrients from soil and thus resulting in growth and yield reduction in the plant.[23] Silicon is one of different elements that farmers can use to induce drought tolerance in plants.[24] In this way drought might be proposed that silicon nutrition assists water uptake and its transportation to stem and leaves. Silicon application improves the water relation in plants.[25] Reported that

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silica-cuticle double layer formed on leaf epidermis is liable for this improved water potential.[26] Hence, suggesting an induction of drought tolerance by Si due to reducing transpiration loss of water under moisture stress condition.

2. Results and Discussion

2.1 Chemical characteristics of maize grains

2.1.1 Effect of irrigation water regimes Nitrogen content (%), Crude protein content % and Copper content (ppm)

The results presented in **Table 1** clearly indicated that decreasing irrigation water supply significantly decreased nitrogen content (%), Crude protein content % and Copper content (ppm) in both growing seasons. Irrigation at every 10, 15 and 20 days increased nitrogen content (%) by about 30%, 15.7% and 6.6% in the 2013 season and by 29.2%, 15.6% and 6.9% in the 2014 season as compared to irrigation scheduling at every 25 days respectively. Similarly, Crude protein content % at every 10, 15 and 20 days irrigation treatments increased by 8.7%, 4.6 and 2.1%% in the 2013 season and by 8.9%, 4.2% and 2% in the second season as compared to irrigation scheduling at every 25 days respectively. Also, the same treatments increased Copper content (ppm) by 58.1%, 36.4% and 15.3% in 2013 season and 57.4%, 36.1% and 15.3% by in the second season as compared to irrigation scheduling at every 25 days respectively Explained this promoting effect of available water on nitrogen content (%), crude protein content % and Copper content (ppm) uptake that, crop uptake depends predominantly on diffusion; diffusion can only occur if soil moisture content is adequate to maintain water films between the root and the soil particles.[27-29]

2.1.2 Effect of foliar spray of zinc and silicon treatments on Nitrogen content (%), Crude protein content % and Copper content (ppm)

The results in **Table 1** clearly showed that foliar spray of zinc, silicon and zinc + silicon significantly increased Nitrogen content (%), Crude protein content % and Copper content (ppm) by 2.1% 4.6 and 8.7%, in 2013 season and by 2% , 4.2% and 8.9% in the second season, 2.1 % , 4.6 % and 8.7% in 2013 season and by 2.08% , 4.2 % and 8.9 % in the second season and 5.5%, 2.5 % and 11.9% in 2013 season and by 5.7%, 2.5% and 11.8 % in the second season as compared to untreated treatments. Zinc affects the synthesis of protein in plants hence is considered to be the most critical micronutrient and spraying of zinc promotes growth and nutrient concentration. Plants take more elements because of better-developed root systems.[30] This is due to the positive effect of Si on photosynthetic activities and thus the concentration of macro-elements.[31]

Results in **Table 2** of clarify the interaction effect between irrigation intervals and foliar spray of zinc and silicon treatments on maize Nitrogen content (%), Crude protein content % and Copper content (ppm). The effect of interaction on this characteristic was significant in the two studied seasons. The data showed that increasing water availability through irrigation increased the effect of foliar spray of zinc and silicon treatments. The maximum Nitrogen content (%), Crude protein content % and Copper content (ppm) was produced by irrigation at every 10 days with foliar spray of zinc + silicon being (1.583 and 1.607%) , (9.89 and 10.04%) and (61.40 and 61.83ppm) in the first and second season, respectively. This might be attributed to the effect of available water on the transport process in higher plants.

Table 1. Means of Nitrogen content (%), Crude protein content % and Copper content (ppm) of maize crop as effected by irrigation scheduling and foliar spray of zinc and silicon treatments for two growing seasons of 2013and 2014.

Treatments	Nitrogen content (%)		Crude protein content %		Copper content (ppm)	
	2013	2014	2013	2014	2013	2014
Irrigation scheduling (I)						
I_1	1.458	1.479	9.11	9.24	58.19	47.15
I_2	1.298	1.323	8.11	8.26	50.20	45.81
I_3	1.196	1.223	7.47	7.64	42.45	50.00
I_4	1.121	1.144	7.00	7.15	36.80	44.68
L.S.D. $_{(0.05)}$	*0.008*	*0.017*	*0.04*	*0.10*	*0.15*	*0.13*
foliar spray of zinc and silicon treatments(f)						
F_1	1.247	1.271	7.79	7.94	58.69	47.74
F_2	1.278	1.298	7.98	8.11	50.76	46.31
F_3	1.328	1.356	8.30	8.47	42.99	50.52
Untreated	1.221	1.245	7.63	7.78	37.28	45.15
L.S.D. $_{(0.05)}$	*0.006*	*0.008*	*0.03*	*0.05*	*0.12*	*0.14*
Interactions						
IF	*0.01*	*0.01*	*0.07*	*0.10*	*0.29*	*0.29*

N.S = not significant

Table 2. Nitrogen content (%), Crude protein content % and Copper content (ppm) as affected by the interaction between by irrigation scheduling and foliar spray of zinc and silicon treatments for two growing seasons of 2013and 2014.

Irrigation scheduling (I)	Foliar spray (f)	Nitrogen content (%)		Crude protein content %		Cu content (ppm)	
		2013	2014	2013	2014	2013	2014
I_1	F_1	1.403	1.420	8.76	8.87	58.10	58.96
	F_2	1.477	1.497	9.23	9.35	57.36	57.93
	F_3	1.583	1.607	9.89	10.04	61.40	61.83
	Untreated	1.370	1.393	8.56	8.70	55.90	56.03
I_2	F_1	1.287	1.310	8.04	8.18	50.20	50.93
	F_2	1.303	1.323	8.14	8.26	48.43	48.86
	F_3	1.347	1.380	8.41	8.62	55.03	55.63
	Untreated	1.253	1.277	7.83	7.98	47.16	47.63
I_3	F_1	1.183	1.143	7.39	7.56	43.33	43.60
	F_2	1.207	1.140	7.54	7.68	41.26	41.73
	F_3	1.233	1.167	7.70	7.93	45.06	45.73
	Untreated	1.160	1.127	7.25	7.39	40.16	40.90
I_4	F_1	1.247	1.271	6.95	7.14	37.00	37.46
	F_2	1.278	1.298	7.01	7.12	36.20	36.73
	F_3	1.328	1.356	7.16	7.29	38.50	38.90
	Untreated	1.221	1.245	6.87	7.04	35.50	36.03
L.S.D.$_{0.05}$		*0.01*	*0.01*	*0.07*	*0.10*	*0.29*	*0.29*

N.S = not significant

2.2.1- Effect of irrigation water regimes Phosphorous content (%), Potassium content (%) and Zinc content (ppm)

At a first glance, the data stated in **Table 3** that irrigation scheduling treatments significantly affected the values of this characteristic. Irrigation scheduling at every 10, 15 and 20 days increased Phosphorus content (%), Potassium content (%) and Zinc content (ppm) significantly except Phosphorus content (%) was insignificant in the first season. Was increased by 77.7%, 11.1% and 32.6% as compared to irrigation scheduling at every 25 days in 2013 season and by 60.7%, 16.3% and 24.1% as compared to irrigation scheduling at every 20 days in 2014 season, 17.1%, 3.5% and 2.0% as compared to irrigation scheduling at every 15 days in 2013 season and by 16.4%, 1.9% and 6.7% as compared to irrigation scheduling at every 25 days in 2014 season and 29.0%, 23.7% and 1.0% as compared to irrigation scheduling at every 25days in 2013 season and by 22.4%, 5.4% and 5.7% as compared to irrigation scheduling at every 20 days in 2014 season . Concluded that increasing N, P, K and Zn concentrations in the grains of sorghum by increasing the number of irrigations. Also, the total uptake of N, P, K and Zn by the sorghum plants increased as the number of irrigations was increased. Explained this promoting effect of available water on P uptake that crop uptake of phosphate anions depends predominantly on diffusion; diffusion can only occur if soil moisture content is adequate to maintain water films between the root and the soil particles.[29,32,33]

2.2.2 Effect of foliar spray of zinc and silicon treatments on Phosphorus content (%), Potassium content (%) and Zinc content (ppm)

Regarding the effect of zinc and silicon treatments values of Phosphorous content (%),Potassium content (%) and Zinc content (ppm), Foliar spray of zinc and silicon treatments led to insignificant except Zinc content (ppm) was a significant in two seasons increase in this characteristics characteristic increased Phosphorus content (%) by 28%, 6.5% and 6.5% in 2013 season and by 10.8%, 2.1% and 2% in the second season, as compared to unfertilized treatments, respectively, similarly, Potassium content (%) of 7.1%, 11.6% and 6 % in 2013 season as compared to unfertilized treatments . Also, the same treatments increased Zinc content (ppm) by 0.46%, 5 % and 3.2% in the second season as compared to zinc plus silicon foliar spraying respectively.[30, 34, 35]

Table 3. Means of Phosphorous content (%), Potassium content (%) and Zinc content (ppm) of maize crop as effected by irrigation scheduling and foliar spray of zinc and silicon treatments for two growing seasons of 2013and 2014.

Treatments	Phosphorous content (%)		Potassium content (%)		Zinc content (ppm)	
	2013	2014	2013	2014	2013	2014
Irrigation scheduling (I)						
I_1	0.272	0.246	0.232	0.241	30.750	31.833
I_2	0.170	0.178	0.198	0.211	29.500	27.417
I_3	0.203	0.153	0.205	0.221	24.083	26.000
I_4	0.153	0.190	0.202	0.207	24.083	27.500
L.S.D. $_{(0.05)}$	*N.S*	*0.040*	*0.009*	*0.013*	*2.030*	*3.920*
foliar spray of zinc and silicon treatments(f)						
F_1	0.233	0.205	0.211	0.217	33.083	33.167
F_2	0.194	0.189	0.220	0.227	24.917	21.833
F_3	0.190	0.188	0.209	0.216	31.500	32.917
Untreated	0.182	0.185	0.197	0.223	18.667	24.833
L.S.D. $_{(0.05)}$	*N.S*	*N.S*	*0.14*	*N.S*	*0.12*	*3.160*
Interactions						
IF	*N.S*	*0.050*	*0.029*	*N.S*	*2.480*	*N.S*

N.S = not significant

The interaction effect of irrigation intervals and foliar sprays of zinc and silicon treatments was significant on maize Phosphorus content (%) in the second season the maximum Phosphorus content (%)was produced by irrigation at every 10 days with foliar spray of zinc being (0.310),Potassium content (%)in the first season the maximum Potassium content (%)was produced by irrigation at every 10 days with foliar spray of zinc being (0.257) and Zinc content (ppm) in the first season the maximum Zinc content (ppm) was produced by irrigation at every 10 days with foliar spray of zinc being (37.000) is shown in **Table 4**.

Table 4. Phosphorous content (%), Potassium content (%) and Zinc content (ppm) as affected by the interaction between by irrigation scheduling and foliar spray of zinc and silicon treatments for two growing seasons of 2013 and 2014.

Irrigation scheduling (I)	Foliar spray (f)	Phosphorous content (%)		Potassium content (%)		Zinc content (ppm)	
		2013	2014	2013	2014	2013	2014
I_1	F_1	0.283	0.310	0.257	0.240	37.000	36.000
	F_2	0.293	0.283	0.253	0.263	30.000	27.000
	F_3	0.293	0.207	0.220	0.243	33.333	35.000
	Untreated	0.217	0.183	0.197	0.220	22.667	29.333
I_2	F_1	0.170	0.193	0.210	0.197	34.333	34.667
	F_2	0.177	0.180	0.203	0.223	31.667	24.000
	F_3	0.177	0.163	0.193	0.197	34.000	31.333
	Untreated	0.157	0.173	0.187	0.230	18.000	19.667
I_3	F_1	0.353	0.173	0.187	0.207	30.333	32.333
	F_2	0.170	0.160	0.230	0.217	18.333	18.333
	F_3	0.163	0.140	0.213	0.227	30.333	32.333
	Untreated	0.127	0.140	0.190	0.233	17.333	21.000
I_4	F_1	0.123	0.143	0.190	0.223	30.667	29.667
	F_2	0.137	0.133	0.193	0.203	19.667	18.000
	F_3	0.127	0.240	0.210	0.197	28.333	33.000
	Untreated	0.227	0.243	0.213	0.207	16.667	29.333
L.S.D.$_{0.05}$		*N.S*	*0.050*	*0.029*	*N.S*	*2.480*	*N.S*

N.S = not significant

2.3.1 Effect of irrigation water regimes Silicon content %, Manganese content (ppm)and Iron content (ppm)

The data stated in **Table 5** that the average values of Silicon content %, Manganese content (ppm)and Iron content (ppm) of irrigation scheduling at every 10, 15 and 20 days significantly increased Silicon content % by 92.5 %, 79 % in 2013 season and by71 %, 37.8 % by in the second season, as compared to irrigation scheduling at every 25 days respectively. In similar behavior increased Manganese content (ppm) by 32%, 12.9% and 3.2% in 2013 season and by 34.1%, 15.63% and 5.2% in the second season, as compared to irrigation scheduling at 25 days, respectively. Also, Iron content (ppm) by 22.9%, 12.6% and 6.9% in the second season, as compared to irrigation scheduling at every 25 days respectively. Explained this promoting effect of available water on elements uptake that, crop uptake of elements depends on predominantly on diffusion; diffusion can only occur if soil moisture content is adequate to maintain water films between the root and the soil particles.[29,36,37]

Table 5. Means of Silicon content %, Manganese content (ppm) and Iron content (ppm) of maize crop as effected by irrigation scheduling and foliar spray of zinc and silicon treatments for two growing seasons of 2013 and 2014.

Treatments	Silicon content %		Manganese content (ppm)		Iron content (ppm)	
	2013	2014	2013	2014	2013	2014
Irrigation scheduling (I)						
I_1	0.414	0.402	22.77	23.08	118.29	118.85
I_2	0.332	0.324	19.48	19.89	108.30	108.89
I_3	0.233	0.237	17.80	18.11	102.82	103.40
I_4	0.215	0.235	17.24	17.20	93.24	96.65
L.S.D. $_{(0.05)}$	*0.28*	*0.027*	*0.27*	*0.67*	*12.9*	*14.75*
foliar spray of zinc and silicon treatments(f)						
F_1	0.275	0.340	19.01	19.44	106.69	107.42
F_2	0.337	0.354	19.50	19.39	108.25	108.83
F_3	0.330	0.245	20.16	20.52	105.07	108.69
Untreated	0.253	0.259	18.62	18.93	102.64	103.04
L.S.D. $_{(0.05)}$	*0.032*	*0.022*	*0.29*	*0.64*	*N.S*	*N.S*
Interactions						
IF	*0.665*	*0.044*	*0.59*	*N.S*	*N.S*	*N.S*

N.S = not significant

2.3.2 Effect of foliar spray of zinc and silicon treatments on Silicon content %, Manganese content (ppm)and Iron content (ppm)

Results are given in **Table 6** cleared also that Silicon content % and Manganese content (ppm) significantly affected by foliar spray of zinc and silicon, Application of zinc + silicon, zinc and silicon treatments increased Silicon content % values of this characteristic significantly by 8.6%, 33.2% and 30.4% as compared to untreated treatments, respectively in 2013 season and by 38.7 %, 44.4% and 5.7% in the second season, as compared to zinc plus silicon foliar spraying respectively, and increased

Manganese content (ppm) values of this characteristic significantly by 2%, 4.7% and 8.2 % in 2013 season and by 2.6%, 2.4 % and 8.3 % in the second season as compared to unfertilized treatments, respectively. Foliar feeding of nutrients may actually promote root absorption of the elements through improving root growth and increasing nutrients uptake.[38, 30]

On maize, the interaction impact of irrigation intervals with zinc and silicon foliar sprays was significantly on Silicon content % and Manganese content (ppm) in the first season only. Silicon content %: In both seasons, irrigation at every 10 days provided the highest Silicon content % with foliar zinc +silicon spray (0.507) in the first season and the highest Silicon content % with foliar Silicon spray (0.510) in the second season and Manganese content (ppm) **Table 6** shows the maximum Manganese content (ppm) achieved by irrigation every 10 days with foliar zinc + silicon spray (24.31) in the first season.

Table 6. Silicon content % and Manganese content (ppm) as affected by the interaction between by irrigation scheduling and foliar spray of zinc and silicon treatments for two growing seasons of 2013and 2014.

Irrigation scheduling (I)	Foliar spray (f)	Silicon content %		Manganese content (ppm)	
		2013	2014	2013	2014
I_1	F_1	0.350	0.507	22.38	22.73
	F_2	0.500	0.510	22.91	23.16
	F_3	0.507	0.283	24.31	24.63
	Untreated	0.300	0.307	21.48	21.80
I_2	F_1	0.327	0.383	19.00	19.73
	F_2	0.383	0.387	19.75	19.93
	F_3	0.50	0.300	20.66	21.00
	Untreated	0.270	0.227	18.51	18.90
I_3	F_1	0.227	0.260	17.48	17.73
	F_2	0.257	0.280	18.00	18.40
	F_3	0.250	0.210	18.23	18.66
	Untreated	0.200	0.200	17.50	17.66
I_4	F_1	0.197	0.210	17.20	17.56
	F_2	0.210	0.240	17.35	16.06
	F_3	0.231	0.187	17.43	17.80
	Untreated	0.240	0.303	17.00	17.36
L.S.D.$_{0.05}$		*0.065*	*0.044*	*0.59*	*N.S*

N.S = not significant

3. Conclusion

Generally, from all previous results it can be concluded that the scheduling at every 10 days with spraying zinc, silicon or zinc +silicon treatments produced the highest chemical composition of maize under the local environment of the Shandaweel region (Upper Egypt).

4. Experimental

4.1 Materials and methods

The present investigation was carried out at Shandaweel Agricultural Research Station, Sohag, Upper Egypt located at a 26º 26" latitude and 31º 68” during the growing seasons of 2013 and 2014, to study the effect of foliar spray of zinc and silicon treatments on yield, yield components and water relations for maize crop. The experiment design was split- plot design with three repetitions was used in both growing seasons. Water stress treatments were allocated to the main-plot and was randomly distributed in the sub plots. The area of each plot was 21 m^2 (3 ×7m) = 1/ 200/ fed. The soil of the experimented site was clay loam in texture (24.6% sand 38.7% silt and 36.7% clay). Phosphorus fertilizer was applied at the rate of 23.25 kg/fed of P_2O_5 in the form of mono supper phosphate (15.5% P_2O_5). Phosphorus fertilizer was added at planting time. Nitrogen fertilizer was applied at the rate of 100 kg/ fed in two equal portions in the form of urea (46.5% N). The first portion was added before the first irrigation, while the second portion was applied before the second irrigation. Potassium fertilizer was applied at the rate of 48 kg/ fed of K_2O in the form of potassium sulfate (48% K_2O) and was added into two equal doses at the same times of the nitrogen fertilizer application.

Reference evapotranspiration (ETo) values were computed using ETo_calculator_V3.2.[39]**.** The ETo data also presented in **Tables 7**.

Table 7. Meteorological data for Shandaweel Agric. Res. Station, and reference evapotranspiration (ETo) during the growth season of 2013.

Months	2013					2014				
	Temperature (ºC)		RH (%)	WS	n	Temperature (ºC)		RH (%)	WS	SR
	Max.	Min.		m/sec	(hours/day)	Max.	Min.		m/sec	(hours/day)
June	38.5	22.4	34	2.2	12.3	38	22	34	2.3	12.3
July	37.5	22.4	44	1.9	12.2	35.9	21.7	38	2	12.2
August	37.1	22.0	46	1.9	11.9	37.2	22.9	35	2	11.9
September.	35.9	20.6	47	2.3	10.8	34.4	21	43	2.5	10.8
Mean	37.2	21.8	42.7	2.0	11.8	41.1	26.0	31.5	2.2	11.8

WS= wind speed m/sec ; SR = solar radiation, MJ/m^2/day, RH =relative humidity in % ETo= evapotranspiration, mm

Chemical characteristics of maize grains

The following characteristics were recorded:

1- Nitrogen content: nitrogen content was determined using kjeldahl .[40]
2- Crude protein content (%): The crude protein was calculated by multiplying the % nitrogen concentration in maize meal by 6.25.[41] Phosphorus content, Zinc, Silicon, Iron, Manganese and Copper: phosphorus content, Zinc, Silicon, Iron, Manganese and Copper by using Inductive Coupled Plazma (ICP) Ultima (2)
3- Potassium content: potassium content was flame photometer .[40]

A. Irrigation intervals.

I_1 - Irrigation every 10 days – with total arrogations (9)
I_2 - Irrigation every 15 days – with total arrogations (7)
I_3 - Irrigation every 20 days – with total arrogations (6)
I_4 - Irrigation every 25 days – with total arrogations (5)

B. Zinc and Silicon treatments.

F_1- Zinc at a rate of 100 mg/kg on form of Zinc Sulfate 33% zinc content.
F_2- Silicon at a rate of 100 mg/kg on form of Silicone Gel.
F_3- Zinc + Silicon 100 mg/kg.
F_4- Untreated.

Zinc and Silicon treatments were applied at June 11, 2013 and repeated June 16, 2014 while, harvesting time was October 4, 2013 and October 9, 2014.

Statistical analysis:

All data were statistically analyzed according to technique of analysis of variance (ANOVA) as randomized complete block design on split- split plot design as mentioned by means of (MSTAT-C) Computer software package.[42,43]and Least significant differences (LSD) at 5% level of probability was used to compare between treatments means.

This work encourages us to make more efforts and scientific papers such as the previous ones that are useful in agriculture and other fields.[44-48]

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