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Research Paper

Effect of Ethrel and Silicon on Popcorn (*Zea mays ssp. everta*) yield under Deficit Irrigation at vegetative growth stage

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Abstract

A field experiment was carried out in private field (Abu-Gharaq ,10 km west of Hilla city) during the autumn season of 2015 in silt clay loam soil, to study the effect of ethrel and silicon on popcorn yield at deficit irrigation. Split- split- plot arrangement in randomized complete block design with three replications was used, in which irrigation treatments a1 and a2 (full irrigation and deficit irrigation at the 8-leaf stage, respectively) operated the main plot , while ethrel levels: b0, B1 and b2 (without spray, 0.75 and 1.5 ml.L-1 ,respectively) operated sub-plots and silicon levels : c0 ,c1 and c2 (without spray, 0.1 and 0.01 mM, respectively) operated sub-sub-plots. Popcorn seed (surur var.) was planting in 24/7/2015 on ridges 75 cm apart and 20 cm between hills. The results showed that deficit irrigation reduced significantly of ear row number, grain number per row, 300 grain weight, grain yield ,and HI%). Spraying of b1 (Ethrel at 0.75 ml.L-1) was superior significantly in ear row number, grain number per row , total grain yield ,and HI%). On the other hand, Spray c1 (Silicon at 0.1 mM) was superior significantly in ear number per plant , row number per ear , grain number per row, the weight of 300 grain , total grain yield ,and HI%. The interaction between the factors had significant effect in most studied characteristics.

Keywords: maize, ethrel, silicon, deficit irrigation.

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1. Introduction

Drought, as many other environmental stresses, has adverse effects on crop yield and drought stress is a serious abiotic factor limiting cereal crop production [1] . Maize is reported to be relatively tolerant to water stress during its vegetative growth phase, very sensitive during tasseling, sulking and pollination and moderately sensitive during grain filling [2]. Thus if a crop is exposed to limit soil water, slowing the rate of soil water extraction should increase the amount of available water remaining in the soil, and one way to slow the rate of soil water extraction would be to reduce the size of the evaporative surface or leaf area index[3]. Plant growth regulators (such as ethrel) have been used as anti-lodging agents in maize fields under optimum conditions [4,5and 6]. Then, plant growth retardants have been used to reduce water use in early season crop by reducing LAI, resulting in extended water availability for critical reproductive to increase grain yield under drought stress [7 and 8]. Some studies confirm that, ethrel can induce modifications in crop growth and development, which improving water use efficiency in maize under severe water stress conditions [9]. Silicon, is the second most abundant element in the earth's crust. It has been demonstrated that silicon cause an increase in plant defense systems against abiotic and biotic stresses[10] , including water stress [11]. Many studies had clearly shown that leaves transpiration of some plants had been reduced by the application of silicon [12]. This was explained by a well-thickened layer of silica gel associated with the cellulose in the epidermal cell walls, [13] and formation of a cuticle –silica double layer, maintaining a high leaf water potential [14], which may help to reduce water loss, while epidermal cell wall with less silica gel allow water to escape at an accelerated rate [15]. The objective of the present study was to study the alleviation

effect of ethrel and silicon on popcorn yield under deficit irrigation at vegetative growth stage.

2. MATERIALS AND METHODS

A field experiment was carried out in private field (Abu-Gharaq ,10km west of Hilla city, Iraq) during the autumn season of 2015 in silt clay loam soil (Table 1). Factorial experiment in split-split plot arrangement at randomized complete block design with three replications was used. The main plot consist of two irrigation levels a0 and a1 (full irrigation and deficit irrigation applied at 8-leaf stage, respectively) , sub-plot consist of three ethrel treatments b0 , b1 and b2 (without spray , 0.75 and 1.5 ml.L^{-1}), applied at the 6-leaf stage, and the sub-sub plot consist of three silicon treatments c0 , c1 and c2 (without spray, 0.1 and 0.01 mM), applied at the 6-leaf stage. Popcorn (surur var.) seed was planted at 23 July 2004 on ridges 70 cm apart and 25 cm between hills. The experimental unit contained 4 ridges and 3 m long. Nitrogen and phosphate were applied as urea and ammonium phosphate at the rate of 400 and 250 kg.ha^{-1} , respectively. Half of the nitrogen fertilizer (urea) was top dressed at the 6-leaf stage. The plots were regularly hand weeded. The plots were irrigated by flooding irrigation systems . The deficit irrigation applied at the 8-leaf stage by cutting one irrigation. At maturity the data were added and analyzed by Gen-Stat software and the means were compared by using Least Significant Difference ($LSD_{0.05}$).

Table 1: Some physical and chemical characteristics of the farm soil

physical cha.	Value and unity		chemical Cha.	Value and unity
Salt	475 g. kg^{-1}		Soil pH	7.3
Clay	357 g. kg^{-1}		Nitrogen	20 mg. kg^{-1}
Sand	168 g. kg^{-1}		Phosphorus	33 mg. kg^{-1}
Soil texture	Silt Clay Loam		Potassium	143 mg. kg^{-1}
			Ec	4.1 $dS.m^{-1}$

3. RESULTS AND DISCUSSION

Table 2 showed that ethrel had no significant effect on ear number.plant-1, while spraying of silicon led to increase earn number.plant-1, and c1 gave the highest average (1.14) while c0 gave the lowest average number (1.06). This is due to Silicon functions such as stimulation of photosynthesis, enhancement of tissue strength, and reduction of plant transpiration rate [12], which largely attributed to the reduction in transpiration rate from stomata rather than cuticle [11] , and its role in increasing water use efficiency for maize drought resistance in dry areas [16], and [17] by a combination of silica with cellulose in the epidermal cells of leaf blade, above this a layer of silica and then on the outside a very thin cuticle, which attributed great significance to this double layer (i.e,. a cuticle layer plus a layer of silica) in limiting unnecessary water loss through the epidermis[18], that caused improvement in plant growth which reflected in increasing ear number. This result was consistent with [19] and [20]. The interaction between irrigation treatments and silicon concentrations caused a significant effect , and the combination of a1c0 gave the lowest average of 1.02, which was not significantly different from the combination a0c0 while a0c1 gave the highest average number of ears (1.16) which is not differ significantly from a1c1 which gave 1.13.

Table 2: effect of deficit irrigation, ethrel and silicon on ear number.plant-1

Irrigation (A)	Ethrel (B)	Silicon (C)			Irrigation x Ethrel
		c 0) 0)	C1 (0.01)	C2 (0.1)	
Full Irrigation (a0)	b0 (0)	1.10	1.16	1.16	1.14
	b1 (0.75(	1.10	1.06	1.06	1.07
	b2 (1.5(	1.10	1.06	1.06	1.07
Deficit Irrigation (a1)	b0 (0)	1.00	1.10	1.10	1.06
	b1 (0.75(	1.03	1.06	1.06	1.05
	b2 (1.5(	1.03	1.06	1.06	1.05
	Mean of Si	1.06	1.07	1.14	
	L S D 0.05	Si= NS interaction= NS			0.05

Irrigation x Silicon					Mean of A		
	a0	1.07	1.08	1.16		a0	1.10
	a1	1.02	1.06	1.13		a1	1.07
L S D 0.05		0.07			NS		
Ethrel x Silicon	b0	1.05	1.13	1.13	Mean of Ethrel	b0	1.10
	b1	1.06	1.06	1.06		b1	1.06
	b2	1.06	1.06	1.06		b2	1.06
L S D 0.05		NS			NS		

Table 3 showed that spraying ethrel led to increase rows number per ear and b1 gave the highest average (13.8 rows), while b0 gave the lowest average (13.3 row). This result is consistent with the findings of [3] . Spray of silicon led to increase rows number and c1 gave the highest average (13.9 rows) compared to c0, (13.1 rows). This is due to the role of silicon in increasing nutrients in plant tissue, as well as to the efficient use of water and the proportion of chlorophyll which reflected positively on this trait. This results were agreement with [21]. Deficit irrigation gave the lowest average (13.4 rows) compared to full irrigation (a0) which gave (13.8 rows). This is due to the reduction in vegetative growth and the process of photosynthesis which reflected negatively in reducing rows number [22] . This results was agreed with [23] and [24] . The interaction between the irrigation and ethrel had a significant effect and a0b0 gave the highest rows (14.0), while a1b0 gave the lowest rows (12.7) and a1b1 was superior (13.86) as compared to a1b0. These results were consistent with the findings of[5], that ethrel lead to increase rows number. The interaction between irrigation and silicon had a significant effect and a0c1 gave the highest average (13.91 rows), while a1c0 gave the lowest average (12.62 rows). The combination of a1c1 gave (13.86 rows) which was superior compared to a1c0. This is consistent with [25] and [20].

Table 3: effect of deficit irrigation ,ethrel and silicon on rows no.ear-1

Irrigation (A)	Ethrel (B)	Silicon (C)			Irrigation x Ethrel		
		c 0) 0)	C1 (0.01)	C2 (0.1)			
Full Irrigation (a0)	b0 (0)	13.80	14.06	14.06	13.97		
	b1 (0.75(	13.20	13.80	13.80	13.60		
	b2 (1.5(	13.53	13.73	13.86	13.71		
Deficit Irrigation (a1)	b0 (0)	11.86	12.93	13.33	12.71		
	b1 (0.75(	13.26	14.06	14.26	13.86		
	b2 (1.5(	12.73	13.86	14.00	13.53		
	Mean of Si	13.06	13.74	13.88			
	L S D 0.05	Si=0.13	interaction=NS		0.25		
Irrigation x Silicon	a0	13.51	13.86	13.91	Mean of A	a0	13.76
	a1	12.62	13.62	13.86		a1	13.37
L S D 0.05		0.18			0.19		
Ethrel x Silicon	b0	12.83	13.50	13.70	Mean of Ethrel	b0	13.34
	b1	13.40	13.90	14.06		b1	13.78
	b2	12.96	13.83	13.90		b2	13.56
L S D 0.05		NS			0.20		

Table (4) showed that ethrel led to increase grain number per row and b1 gave the highest average (38.55), while b0 gave the lowest average (37.82). These results were consistent with the findings of [26] and [27] . Also, spraying silicon led to increase grain number per row and c1 gave the highest average (38.53), compared to c0, which gave (37.56). This is consistent with [28] and [19]. Deficit irrigation (a1) gave the lowest average (39.47) compared to full irrigation (a0) which gave 47.01. This may be due to the water tension that might have a negative impact in determining the number of the origins of the grain as well as the negative effect on photosynthesis and then causing abort fertilized grain [29]. This was consistent with [23]. The interactions between irrigation and ethrel had a significant effect and a0b0 gave the highest average (40.07) , while a1b0 gave the lowest average (35.57). The combination a1b1 reduced the harmful impact and gave 37.24. These findings are consistent with [5] . The interaction between irrigation and silicon had a significant effect and a0c1 gave the highest average (39.93) compared to a1c0 which gave 35.37 , on the other hand, a1c1 reduced the harmful impact and gave (37.13). This is consistent with [20].

Table 4: effect of deficit irrigation ,ethrel and silicon on grain no.row-1

Irrigation (A)	Ethrel (B)	Silicon (C)			Irrigation x Ethrel		
		c 0) 0)	C1(0.01)	C2 (0.1)			
Full Irrigation (a0)	b0 (0)	40.03	40.06	40.13	40.07		
	b1 (0.75 (	39.40	40.00	39.80	39.73		
	B2 (1.5 (	39.80	39.93	39.86	39.86		
Deficit Irrigation (a1)	b0 (0)	34.40	36.06	36.26	35.57		
	b1 (0.75 (	36.13	37.66	37.93	37.24		
	B2 (1.5 (	35.60	37.20	37.20	36.66		
	Mean of Si	37.56	38.48	38.53			
	L S D 0.05	Si= 0.13	interaction=NS		0.20		
Irrigation x Silicon	a0	39.74	40.00	39.93	Mean of A	a0	39.89
	a1	35.37	36.97	37.13		a1	36.49
L S D 0.05		0.18			0.20		
Ethrel x Silicon	b0	37.21	38.06	38.20	Mean of Ethrel	b0	37.82
	b1	37.96	38.80	38.90		b1	38.55
	b2	37.50	38.60	38.50		b2	38.2
L S D 0.05		NS			0.15		

Table (5) showed that ethrel had no significant effect on the average weight of 300 grains, while spraying silicon led to increase the average weight of 300 grains and c1 gave the highest average (48.9 g), while c0 gave the lowest average weight of 300 grains (46.4 g). This is due to several hypotheses that Si : improved photosynthetic activity, increased enzyme activity, and increased soluble substances concentration in the xylem, resulting in alleviate water stress [30]. These results were consistent with the findings of [31] and [32]. Deficit irrigation (a1) decrease the weight of 300 grains (45.0 g) as compared to a0 which gave (50.9 g). These findings are consistent with [23] , [24] and [19]. The combination of a0c1 gave the highest average weight of 300 grain (51.9 g) while the a1c0 gave the lowest average weight (43.3 g), and a1c1 was best by reducing the harmful effect of deficit irrigation and gave (46.0 g). These findings were consistent with [25], and [32].

Table 25: Effect of deficit irrigation ,ethrel and silicon on 300 grain weight

Irrigation (A)	Ethrel (B)	Silicon (C)			Irrigation x Ethrel		
		c 0) 0)	C1(0.01)	C2 (0.1)			
Full Irrigation (a0)	b0 (0)	50.0	51.8	52.5	51.5		
	b1 (0.75 (	49.4	51.2	51.4	50.7		
	b2 (1.5 (	49.0	51.1	51.8	50.6		
Deficit Irrigation (a1)	b0 (0)	42.7	45.0	45.7	44.4		
	b1 (0.75 (	43.3	45.9	46.1	45.1		
	b2 (1.5 (	43.8	46.4	46.1	45.4		
	Mean of Si	46.4	48.6	48.9			
	L S D 0.05	Si=0.15	interaction=NS		NS		
Irrigation x Silicon	a0	46.4	51.4	51.9	Mean of A	a0	50.9
	a1	46.4	45.7	46.0		a1	44.9
L S D 0.05		0.37			0.49		
Ethrel x Silicon	b0	46.4	48.4	49.1	Mean of Ethrel	b0	48.0
	b1	47.4	48.5	48.7		b1	47.9
	b2	46.1	48.8	48.9		b2	48.0
L S D 0.05		NS			NS		

Table (6) showed that ethrel had no significant effect on grain yield, while silicon spray led to increase grain yield and c1 gave the highest average rate of 5.08 t.ha^{-1} compared to c0 which gave the lowest average (4.36 t.ha^{-1}). This was attributed to the role of silicon in increasing growth, which reflected positively on yield components (number of rows , number of grain per , 300 grain weight) as shown in tables 3,4 and 5). These findings were consistent with [19] and [20] . Deficit water (a1) caused negative impact and gave the lowest average (4.15 t.ha^{-1}) as compared to full irrigation (a0) which gave 5.47 t.ha^{-1}. This is because the negative impact in decreasing the number of rows and number of grains per row (tables 3 and 4). These findings were consistent with [33], [34] and [35]. The interaction between irrigation and ethrel had a significant effect and a0b0 gave the highest average (5.868 t.ha^{-1}), while a1b0 gave the lowest average (3.839 t.ha^{-1}), and a1b1 reduced the harmful of water stress and giving (4.412 t. ha^{-1}). This is due to the role of ethrel in raising number of rows , number of grains per row(Table 3 and 4). These findings were consistent with[5] and [19]. The interaction between irrigation and silicon had a significant effect , and a0c1 gave the highest average 5.639 t.ha^{-1} compared to a1c0 which gave 3.517 t. ha^{-1} , while a1c1 was superior by reducing the harmful effect of water stress and gave 4.533 t.ha^{-1}. This is due to the silicon deposition in the skin layer, leading to reduce water evaporation out of the leaves, which reflected positively on the yield components (number of rows , number of grain per row and grain weight), (tables 3, 4 and 5). These findings are consistent with [21] and [32].

Table 26: Effect of deficit irrigation ,ethrel and silicon on 300 grain weight

Irrigation (A)	Ethrel (B)	Silicon (C)			Irrigation x Ethrel		
		c 0) 0)	C1(0.01)	C2 (0.1)			
Full Irrigation (a0)	b0 (0)	5.405	6.051	6.148	5.868		
	b1 (0.75 (	5.053	5.352	5.347	5.251		
	b2 (1.5 (	5.165	5.313	5.423	5.300		
Deficit Irrigation (a1)	b0 (0)	3.096	4.104	4.318	3.839		
	b1 (0.75 (	3.85	4.658	4.727	4.412		
	b2 (1.5 (	3.606	4.484	4.553	4.214		
	Mean of Si	4.362	4.994	5.086			
	L S D 0.05	Si= 0.122 interaction=NS			0.158		
Irrigation x Silicon	a0	5.207	5.572	5.639	Mean of A	a0	5.473
	a1	3.517	4.415	4.533		a1	4.155
L S D 0.05		0.169			0.180		
Ethrel x Silicon	b0	4.250	5.078	5.233	Mean of Ethrel	b0	4.854
	b1	4.329	4.918	4.950		b1	4.733
	b2	4.508	4.986	5.075		b2	4.856
L S D 0.05		NS			NS		

Table (7) showed that spraying ethrel had no significant effect on biological yield, while spraying silicon led to a significant increase and c1 gave the highest average of 14.958 t.ha^{-1}, while c0 gave the lowest average (13.321 t.ha^{-1}). This is due to the role of silicon in increasing the ability of the plant photosynthesis and increase manufacturing and accumulation of photosynthesis products, which reflected positively on the accumulation of dry matter in the shoots of the plant and grain yield (Table 6). The Si-alleviated effects have been associated with an increase in antioxidant defense abilities and enhanced plant tolerance to abiotic stresses [36], affecting metabolic processes including the improvement in plant water status [37], regulation of plant defense system [10], and changes in ultra- structure of leaf organelles [38]. These findings are consistent with the findings of [19] , [20] and [28]. Deficit irrigation (a1) had significant effect in reducing biological yield (12.463 t.ha^{-1}) as compared to full irrigation (a0) which gave (16.164 t.ha^{-1}). This results due to that the lack in moisture tends to Limitation in gaseous exchange because of stomatal closure restricts, which caused decrease in dry root weight and shoot growth [39] . These findings are consistent with [40] , [41] and [42]. The interaction between irrigation and ethrel had a significant effect , and a0b0 gave the highest average (17.136 t.ha^{-1}), and a1b0 gave the lowest average (11.838 t.ha^{-1}), while a1b1 gave 12.959 t.ha^{-1}). These results were consistent with the findings of [5].

Table 7: Effect of deficit irrigation, ethrel and silicon on biological yield

Irrigation (A)	Ethrel (B)	Silicon (C)			Irrigation x Ethrel		
		c 0) 0)	C1(0.01)	C2 (0.1)			
Full irrigation (a0)	b0 (0)	16.173	17.483	17.750	17.136		
	b1 (0.75 (	14.803	15.940	15.937	15.560		
	B2 (1.5 (	15.263	15.800	16.330	15.798		
Deficit Irrigation (a1)	b0 (0)	10.870	12.047	12.597	11.838		
	b1 (0.75 (	11.513	13.540	13.823	12.959		
	B2 (1.5 (	11.300	13.167	13.310	12.592		
	Mean of Si	13.321	14.663	14.958			
	L S D 0.05	Si= 0.4327	interaction=NS		0.4342		
Irrigation x Silicon	a0	15.413	16.408	16.672	Mean of A	a0	16.164
	a1	11.228	12.918	13.243		a1	12.463
L S D 0.05		NS			0.3368		
Ethrel x Silicon	b0	14.765	13.522	15.173	Mean of ethrel	b0	14.487
	b1	14.553	13.052	14.623		b1	14.076
	b2	14.670	13.388	15.077		b2	14.378
L S D 0.05		NS			NS		

Table (8) showed that ethrel had no significant effect on the harvest index, while silicon led to increase harvest index, and c1 gave the highest average of 34.01, which was not differ significantly from c2, which gave an average of 34.05 as compared to c0, which gave 32.53. This is due to the role of silicon in increasing the accumulation of dry matter in plant shoots and grain yield (Table 7). These findings were consistent with [20] and [32] . Deficit irrigation (a1) gave the lowest average (33.22) compared to a0 which gave 33.84 and perhaps the reason for the decline in the harvest index due to the lower of economic quotient at deficit irrigation (a1) as the relationship direct correlation between economic yield and harvest index, or it due to the water tensile pulling down the speed and duration of transmission of dry matter accumulated in the grain, causing economic yield decline [40] . These results were agreed with [24] , [43] and[44]. The interaction of irrigation with ethrel had a significant effect and a0b1 gave the highest average of 34.21, while a1b0 gave the lowest average (32.27) on the other hand a1b1 gave 34.01. Ethrel spray reflected positively in raising most of yield components (number of rows , number of grains and 300 grain weight), which reflected on economic yield that is directly proportional to the harvest index [45]. These findings are consistent with the findings of [5]. The interaction between irrigation with silicon caused a significant increase in harvest index and a0c1 gave the highest average of 33.93, while a1c0 gave the lowest average (32.27) on the other hand a1c1 gave an average of 33.73 which indicate that silicon eliminate the harmful effect of water stress on this trait. These findings are consistent with [25]and [28].

Table 8: Effect of deficit irrigation ,ethrel and silicon harvest index

Irrigation (A)	Ethrel (B)	Silicon (C)			Irrigation x Ethrel		
		c 0) 0)	C1(0.01)	C2 (0.1)			
Full Irrigation (a0)	b0 (0)	33.43	34.62	34.59	34.21		
	b1 (0.75 (	34.13	33.57	33.58	33.76		
	b2 (1.5 (	33.83	33.22	33.63	33.56		
Deficit Irrigation (a1)	b0 (0)	30.47	33.27	33.06	32.27		
	b1 (0.75 (	33.44	34.20	34.40	34.01		
	b2 (1.5 (	33.90	33.21	33.05	33.38		
	Mean of Si	32.53	34.01	34.05			
	L S D 0.05	Si= 0.3138 interaction=NS			0.2573		
Irrigation x Silicon	a0	33.80	33.80	33.93	Mean of A	a0	33.84
	a1	33.67	32.27	33.73		a1	33.22
L S D 0.05		0.5625			0.1686		
Ethrel x Silicon	b0	30.95	34.33	34.45	Mean of Ethrel	b0	33.24
	b1	33.64	34.01	33.71		b1	33.78
	b2	33.01	33.81	33.89		b2	33.57
L S D 0.05		NS			NS		

4. CONCLUSION

It was concluded that spraying ethrel and or Si on maize plants before irrigation deficit was beneficial. Spraying ethrel at 0.75 ml/L and or Si at 0.1 nM/L showed a significant improve of yield and its components and effectively mitigated the adverse effects of drought stress. Si was more effective in alleviating drought stress on maize than ethrel. However, further studies are needed for a better understanding of the physiological or biochemical roles of silicic acid at molecular level.

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