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THE EFFECT OF DROUGHT STRESS CONDITION COMBINED WITH KAOLIN SPRAYING APPLICATION ON GROWTH AND YIELD PARAMETERS OF MAIZE (*ZEA MAYS*)

Ebtessam A. Youssef [a] and Ali Mohamed Ali Hozayen[b]

[a]Water Relations and Field Irrigation Department, National Research Centre, Dokki, Giza, Egypt.

[b]Agricultural Food Processing unit, Desert Research Centre, Al-Maturah, Cairo, Egypt.

Email : dr.ebtessamyoussef@yahoo.com

Abstract

This experimental study was conducted out through two successive seasons 2017 and 2018 seasons on maize cultivar Giza10 (*Zea mays*). The main goal of this experimental study was improve maize growth and yield under different levels of water stress(100, 80 and 60% of evapotranspiration ETc) by spraying application with different concentrations of kaolin (0, 2.5 and 5%) as anti-transpiration agent under drip irrigation system. The data showed that, Maize crop could gained commercial growth and yield parameters under drought stress reached to 60 % of ETc by spraying application with 5% concentration of kaolin, thus saving 40% of water irrigation.

***Key words*: **Maize, water stress, drought stress, kaolin, anti-transpiration, drip irrigation.

Introduction

Maize is one of the principle crop cultivated worldwide with a production and accessed 7,100 million tons forecast in 2017 (http://faostat3.fao.org,) and plays essential role and utilized in human and animal feeding in Egypt and grown in the humid tropics and sub/tropical region (Harris *et al.,* 2007). All over the world, 5 percent of corn can be used for seed purposes to sow next crop, 25 percent for human utilization and industrial purposes, while 67 percent is utilized for livestock feed. Therefore, maize occupies the second rank after wheat and equivalent to rice.

Abiotic environmental conditions are critical elements towards restricting the crop efficiency and can adverse effect on yield capability of maize plant such as drought stress. However, maize plants are highly oversensitive to water deficiency conditions (Lobell *et al.,* 2011; Zafar-ul-Hye *et al.,* 2014, Ghazi, 2017). Drought stress decreases agricultural production and reduces the availability and productivity efficiency in semi/arid and rain/fed areas. Drought stress has a negative effect on ion uptake, photosynthesis, food metabolism, respiration, transport, stem expansion, root propagation, ionic imbalance and disturbances in solute accumulation, depression of enzymatic activities, alteration in metabolic activities or interaction of all these factors as a physiological and biochemical processes that the seriousness of harm relies upon the exposed to drought and varied growth stages. It is considered a standout and amongst prevalent ecological stresses (Farooq *et al.,* 2009; Farahvash *et al.,* 2011 and Ghazi, 2017).

Kaolin is a clay mineral with the chemical composition $Al_2Si_2O_5(OH)_4$. It is a layered silicate mineral, with one tetrahedral sheet of silica (SiO_4) linked through oxygen atoms to one octahedral sheet of alumina (AlO_6) octahedra. Rocks that are rich in kaolinite are known as kaolin or china clay (https://en.wikipedia.org/wiki/Kaolinite). It is a technique that claim to reduce water use by plant is the reflectance type of antitranspirants as kaolin, which are natural white materials form a coating film on the leaves, it increase the leaf reflectance by reflecting the radiation and increase the vapour pressure gradient and thus reduce transpiration (Glenn *et al.,* 2002 and Creamer *et al.,* 2005 and Kamal, 2013).

Kaolin is as an effective natural antitranspirant and was reported to mitigate the negative effects of water deficiency and environmental stresses, such as heat stress and sunburn damage as well as suppress diseases and protect crops from insect pests (Kahn and Damicone, 2008 and Kamal, 2013).

Thus, the main goal of this study was to improved maize growth and yield parameters under drought stress condition by using kaolin as an anti-transpiration agent via drip irrigation.

Materials and Methods

This experimental study was conducted through two successive seasons 2017 and 2018 seasons on maize

Giza 10 (*Zea mays*). This study aimed to improve maize growth and yield under different levels of drought stress (100, 80 and 60% of evapotranspiration ETc) by spraying application with different concentrations of kaolin (0, 2.5 and 5%) as anti-transpiration agent via drip irrigation system. The maize plants grown in sandy loam soil under water stress condition at Belbeis region – El Sharkia Governorate, Egypt.

All maize plants under this study received the same applied agricultural practices except those of the experimental treatments. The experimental design was split plot arrangement of complete randomized block design (factorial experiment-split plot design) with three replicates and 10.50 m^2 (3.00×3.50 m) for each replicate area. The main plot contained 100, 80, 60 % of ETc and the sub-plot comprised three kaolin concentrations (0, 2.5 and 5%). Maize seeds were sown manually in mid-April with 15 kg per feddan. Kaolin treatments were applied twice with the required rates at mid-May and mid-June. The experiment remained until the end of mid-August, but irrigation stopped at the end of July.

The tested irrigation levels are based on different rates of irrigation water i.e. 2855, 2285 and 1713 m^3 /fed./season, which resulted from the FAO – Penman - Moteith equation using meteorological data of the region as in the following tables:

Table 1: Reference crop evapotranspiration rate (ETo) calculated with CROPWAT V.8.00computer program from meteorological data under Sharkia Governorate conditions using FAO – Penman - Moteith equation (Average of two years2017&2018).

Meteorological factor	April	May	June	July	August
Min Temp °C	12.00	15.50	18.60	20.20	20.40
Max Temp °C	27.60	31.40	34.00	34.40	34.20
Humidity %	55.00	50.00	52.00	59.00	64.00
Wind km/day	168.00	163.00	151.00	124.00	96.00
Sun hours	9.80	11.00	12.60	12.30	11.40
Rad MJ/m²/day	23.20	26.20	28.90	28.10	25.90
ETc mm/day	4.82	5.92	6.62	6.30	5.61
ETc (100%)	4.82	5.92	6.62	6.3	5.61
ETc (80%)	3.86	4.74	5.30	5.04	4.49
ETc (60%)	2.89	3.55	3.97	3.78	3.37

Water requirements = Kc × ETo Kc = crop coefficient

Table 2 : The first irrigation level of total water requirement (W. R.) was calculated by theoretical irrigation rate(m^3/ feddan/ season) from mid-April to mid-August according to the monthly data as shown in the following table.

Water requirements (W.R)	April	May	June	July	August
ETc (100%)	4.82	5.92	6.62	6.30	5.61
crop coefficient	0.40	0.80	1.15	1.15	0.75
W.R (mm/m^2/day)	1.93	4.74	7.61	7.25	4.21
W.R (m^3/fed./day)	8.10	19.89	31.97	30.43	17.67
W.R (m3/ fed. Month)	242.93	596.74	959.24	912.87	530.15

ETc=2855m^3/ feddan/ season

Table 3 : The second irrigation level of total water requirement (W. R.) was calculated by theoretical irrigation rate (m^3/ feddan/ season) from mid-April to mid-August according to the monthly data as shown in the following table.

Water requirements (W.R)	April	May	June	July	August
ETc (80%)	3.86	4.74	5.30	5.04	4.49
crop coefficient	0.40	0.80	1.15	1.15	0.75
W.R (mm/m^2/day)	1.54	3.79	6.10	5.80	3.37
W.R (m^3/fed./day)	6.48	15.93	25.60	24.34	14.14
W.R (m3/ fed. Month)	194.54	477.79	767.97	730.30	424.31

ETc=2285m^3/ feddan/ season

Table 4: The third irrigation level of total water requirement (W. R.) was calculated by theoretical irrigation rate (m^3/ feddan/ season) from half of mid-April to mid-August according to the monthly data as shown in the following table.

Water requirements (W.R)	April	May	June	July	August
ETc (60%)	2.89	3.55	3.97	3.78	3.37
crop coefficient	0.4	0.8	1.15	1.15	0.75
W.R (mm/m^2/day)	1.16	2.84	4.57	4.35	2.53
W.R (m^3/fed./day)	4.86	11.93	19.18	18.26	10.62
W.R (m3/ fed. Month)	145.66	357.84	575.25	547.72	318.47

ETc=1713m^3/ feddan/ season

Table 5: Chemical constituents of the used irrigation water.

pH	TDS ppm	Soluble cations meq /L				Soluble anions meq /L			Boron (ppm)
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCo_3^{-}	Cl^{-}	SO_4^{--}	
7.12	300	0.10	0.70	0.64	3.25	0.10	0.06	4.53	0.02

Table 6 : Chemical constituents of (1:5) soil: water extract of the soil under experimental site.

Depth (cm)	PH	TDS ppm	$Ca_2(CO)_3$ %	Soluble cations meq /100 g soil				Soluble anions meq /100 g soil				Major elements (ppm)			Minor elements (ppm)			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCo_3^{-}	Cl^{-}	SO_4^{--}	N	P	K	Fe	Mn	Zn	Cu
0-60	8.33	326	2.90	0.20	0.06	3.84	1.00	-	0.05	0.30	4.75	30.0	7.50	150.0	0.15	0.24	0.18	0.11

- TDS = total dissolved salts

Table 7 : Soil physical properties of the soil under experimental site.

Depth	Particle size distribution (%)				Moisture content (%)			
(cm)	Coarse sand	Fine sand	Silt	Clay	Saturation point (S.P.)	Field capacity (F. C.)	Available water (Av. W.)	Wilting point (W.P.)
0 - 60	43.20	19.50	24.00	13.30	28.60	14.30	7.15	7.15

The tested treatments were evaluated through the following parameters:

Growth and yield parameters : After 70 day from planting leaf of flag fresh and dry weight (g) were determined and recorded. In addition, plant height (cm), cob length(cm), number of grains per cob, 100-grains weight(g), grain yield ton per feddan, cob yield ton per feddan and straw yield ton per feddan were determined and recorded at the end of every experimental season (harvest time).

Proline Content : The proline content of fresh leaves (μ moles/g fresh weight) was determined following the method adopted by Bates *et al.*, 1973.

Leaf Chemical Composition : The dried leaves were finely grinded and digested using micro-Kjeldahl unit. The percentage of nitrogen content was determined according to Naguib, 1969. Phosphorus percentage was determined according to AOAC, 1985. Potassium percentage was determined according to Brown and Lilliland, 1964.

Seed Quality Characters : Composition of crude protein and crude oil of maize were determined using the standard methods, as described in Association of Official Analytical Chemists (AOAC, 1985). Seed samples of plots were grounded to pass through a sieve of 0.8 mm diameter. Ground seed samples were analyzed by Kjeldahl method to determine the total nitrogen. Crude protein content was calculated by multiplying total nitrogen value with a coefficient of 6.25. Crude oil percentage was determined by the Soxhlet extraction technique. Total carbohydrates content was estimated spectrophotometrically at 630 n.m. by the method of Hedge and Hofreiter (1962).

Statistical Analysis : The experimental design was split plot arrangement of complete randomized block design (factorial experiment -split plot design) with three replicates and 10.5 m^2(3X3.5) for each replicate area. The main plot contained 100, 80, 60% of ETc and the sub-plot comprised three kaolin concentrations (0, 2.5 and 5%).The data obtained were statistically analyzed using the analysis of variance method as reported by Snedecor and Cochran, 1980. The differences between means were differentiated by using Duncan's range test (Duncan, 1955).

Results

Plant height, leaf flag fresh weight and leaf flag dry weight

The data in Table (8) showed that, water irrigation levels and kaolin concentrations had a great effect on plant height, leaf flag fresh and dry weight in both seasons.

Water stress 60% ETc of water irrigation decreased plant height, leaf flag fresh and dry weight, which were 203.03 cm, 11.32 g and 3.00 g, respectively compared to 100% ETc water irrigation in the first season. In addition, spraying kaolin 5% attained the highest values, which reached to 216.90cm, 12.69 g and 3.40 g for plant height, leaf flag fresh and dry weight, respectively compared to kaolin 0%.Moreover, spraying kaolin5% combined with 100 % ETc of water irrigation gained the heights value 224.41 cm, 13.68 g and 3.58 g for plant height, leaf flag fresh and dry weight, respectively. Also, kaolin5% with 60 % ETc of water irrigation attained 210.80 cm, 12.34 g and 3.25 g for plant height, leaf flag fresh and dry weight, respectively. Those values were statistically over than kaolin0% with 100 % ETc of water irrigation. The second season get the same trend to the first season for plant height, leaf flag fresh and dry weight.

Cob length, number of grains per cob and 100-grains weight

Values given in Table (9) at the first season showed that, decreasing water irrigation to 60% ETc decreased cob length, number of grains per cob and 100-grains weight, which were 14.68 cm, 409.42 and 27.32 g, respectively compared to 100 ETc (control).Regarding, spraying kaolin 5% reached to 19.34 cm, 454.03 and 29.73 g for cob length, number of grains per cob and 100-grains weight, respectively compared to kaolin 0%.At the same time, spraying kaolin 5% with 100% ETc of irrigation water gained the heights values for cob length, number of grains per cob and 100-grains weight, which was 20.74 cm, 480.22 and 30.83 g, respectively. In addition, using spraying kaolin 5% with 60% ETc of irrigation water gained 17.96 cm, 433.62 and 28.77 g, respectively, which were statistically over than to spraying kaolin 0% with 100% ETc of irrigation water. Similarly, the cob length, number of grains per cob and 100-grains weight get the same trend in the second season.

Grain, cob and straw yield ton per feddan

The data in Table (10) revealed that, the grain, cob and straw yield ton per feddan decreased to 2.47, 0.43 and 4.10 ton per feddan by using 60% ETc of irrigation water, respectively compared to 100% ETc of irrigation water in the first season. Moreover, spraying kaolin 5% reached to 3.12, 0.48 and 4.43 ton per feddan, respectively compared to kaolin 0%. Additionally, spraying kaolin 5% with 100% ETc of irrigation water gained the heights values, which were 3.47, 0.50 and 4.57 ton per feddan, respectively. Also, using spraying kaolin 5% with 60% ETc of irrigation water gained 2.83, 0.46 and 4.31 ton per feddan, respectively, which were statistically over than spraying kaolin 0% with 100% ETc of irrigation water (control). The second season get the same trend to the first season.

Chemical composition and proline leaf contents

Regarding Table (11), leaves chemical composition have affected by 60%ETc, which reached to 2.080, 0.238 and 1.70 % compared to 100%ETc, which reached to 2.519, 0.274 and 2.12 % for N, P, and K, respectively. In addition, leaves chemical composition have affected by kaolin 5% application, which reached to 2.503, 0.274 and 2.16 % N, P, and K, respectively. It is clear that spraying kaolin 5% with 100% ETc of irrigation water attained the heights value for N, P, and K, which were 2.770, 0.294 and 2.31 %, respectively. Also, using spraying kaolin 5% with 60% ETc of irrigation water gained 2.334, 0.261, and 2.03 %, which were statistically over than to (control) spraying kaolin 0% with 100% ETc of irrigation water, which were 2.187, 0.252 and 1.87 % for N, P and K, respectively. This was true in both seasons.

On the opposite direction, proline leaf content increased with decreasing irrigation water level from 100% ETc to 60% ETc of water irrigation, it is interesting to mentioned that, decreasing water irrigation quantity increased proline content. proline content get high value with 60%ETc reached to 161.23 µ g / moles of leaf fresh compared to49.08 µ g / moles of leaf fresh for100% ETc for respectively in the first season. In addition, proline contents get low values with kaolin 5% application, which reached to 84.51µ g / moles of leaf fresh. Thus, spraying kaolin 5% with 100% ETc of irrigation water attained the lowest values for proline content, which was25.36µ g / moles of leaf fresh. This was true in both seasons.

Seed quality characters

Data in Table (12) revealed that, seed quality characters have affected by 60%ETc, which reached to 77.49 % compared to 100%ETc, which reached to 79.84 % for total carbohydrates, respectively.

In addition, total carbohydrates content has affected by kaolin 5% application, which reached to 79.76 % compared to kaolin 0% application, which reached to 77.13 %. It is clear that spraying kaolin 5% with 100% ETc of irrigation water gained the heights value for total carbohydrates, which was 80.89%. Also, using spraying kaolin 5% with 60% ETc of irrigation water gained 79.01 %, which were statistically over than to (control) spraying kaolin 0% with 100% ETc of irrigation water, which were 78.66% for total carbohydrates. The oil content and crude protein were having the same trend. This was true in both seasons.

Table 8 : Effect of irrigation water levels and kaolin spraying with different concentrations on plant height, leaf of flag fresh and leaf of flag dry weight of maize plant.

Parameters / Treatments	Plant height (cm)		leaf flag fresh weight (g)		leaf flag dry weight (g)	
	First season (2017)					
100% ETc	217.55	A	13.06	A	3.43	A
80% ETc	206.61	B	11.79	B	3.12	B
60% ETc	203.03	B	11.32	B	3.00	C
kaolin 0 %	199.99	C	11.09	C	2.94	C
kaolin 2.5%	210.30	B	12.12	B	3.20	B
kaolin 5%	216.90	A	12.96	A	3.40	A
100% ETc × kaolin 0 % (control)	209.05	e	12.11	e	3.19	e
100% ETc × kaolin 2.5 %	219.20	b	13.39	b	3.51	b
100% ETc × kaolin 5 %	224.41	a	13.68	a	3.58	a
80% ETc × kaolin 0 %	196.75	g	10.79	h	2.87	h
80% ETc × kaolin 2.5 %	207.58	e	11.70	f	3.10	f
80% ETc × kaolin 5 %	215.49	c	12.86	c	3.38	c
60% ETc × kaolin 0 %	194.17	h	10.36	i	2.77	i
60% ETc× kaolin 2.5 %	204.12	f	11.27	g	3.00	g
60% ETc × kaolin 5 %	210.80	d	12.34	d	3.25	d
	Second season (2018)					
100% ETc	231.87	A	14.13	A	3.66	A
80% ETc	218.76	B	12.75	B	3.33	B
60% ETc	213.23	B	12.38	B	3.25	C
kaolin 0 %	209.58	C	12.15	C	3.19	C
kaolin 2.5%	222.11	B	12.98	B	3.38	B
kaolin 5%	232.17	A	14.13	A	3.66	A
100% ETc × kaolin 0 % (control)	221.38	e	13.22	e	3.44	e
100% ETc × kaolin 2.5 %	235.64	b	14.40	b	3.72	b
100% ETc × kaolin 5 %	238.59	a	14.77	a	3.82	a
80% ETc × kaolin 0 %	206.62	h	11.77	h	3.09	h
80% ETc × kaolin 2.5 %	218.11	f	12.48	f	3.26	f
80% ETc × kaolin 5 %	231.55	c	14.01	c	3.64	c
60% ETc × kaolin 0 %	200.73	i	11.48	i	3.03	i
60% ETc× kaolin 2.5 %	212.57	g	12.07	g	3.17	g
60% ETc × kaolin 5 %	226.37	d	13.60	d	3.54	d

ETc = Evapotranspiration, mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Discussion

In this respect, the present data in this experimental study declare the effect of irrigation levels on vegetative growth and yield characteristics of maize. Data indicate that irrigation with 100% ETc recorded the highest significant values of vegetative growth and yield characteristics. The exception was that proline leaves content, which showed opposite direction in the first and second seasons. The negative effects of the lowest irrigation level (60 %ETc) on vegetative growth and yield characteristics may be due to the drought stress, which affects plant growth by reducing number of leaves and leaf area, resulting in less photosynthesis (Silber, 2005).

Table 9 : Effect of irrigation water levels and kaolin spraying with different concentrations on cob length, number of grains per cob and 100- grains weight of maize plant.

Parameters / Treatments	Cob length (cm)		Number of grains per cob		100-grains weight (g)	
	First season (2017)					
100% ETc	18.98	A	454.74	A	29.71	A
80% ETc	15.64	B	419.80	B	27.91	B
60% ETc	14.68	C	409.42	B	27.32	B
kaolin 0 %	13.93	C	403.05	C	26.98	C
kaolin 2.5%	16.03	B	426.88	B	28.22	B
kaolin 5%	19.34	A	454.03	A	29.73	A
100% ETc × kaolin 0 % (control)	16.24	e	422.70	e	28.05	e
100% ETc × kaolin 2.5 %	19.96	b	461.30	b	30.24	b
100% ETc × kaolin 5 %	20.74	a	480.22	a	30.83	a
80% ETc × kaolin 0 %	13.10	h	398.73	g	26.64	h
80% ETc × kaolin 2.5 %	14.49	f	412.44	f	27.49	f
80% ETc × kaolin 5 %	19.33	c	448.24	c	29.58	c
60% ETc × kaolin 0 %	12.46	i	387.72	h	26.24	i
60% ETc× kaolin 2.5 %	13.63	g	406.91	f	26.95	g
60% ETc × kaolin 5 %	17.96	d	433.62	d	28.77	d
	Second season (2018)					
100% ETc	19.39	A	490.07	A	30.74	A
80% ETc	16.32	B	455.29	B	28.88	B
60% ETc	15.35	C	443.52	B	28.09	B
kaolin 0 %	14.77	C	435.49	C	27.79	C
kaolin 2.5%	16.98	B	461.11	B	29.29	B
kaolin 5%	19.31	A	492.28	A	30.63	A
100% ETc × kaolin 0 % (control)	16.73	e	465.51	e	29.37	e
100% ETc × kaolin 2.5 %	20.29	b	498.22	b	31.18	b
100% ETc × kaolin 5 %	21.14	a	506.47	a	31.67	a
80% ETc × kaolin 0 %	14.18	h	426.46	h	27.54	h
80% ETc × kaolin 2.5 %	15.63	f	449.69	f	28.63	f
80% ETc × kaolin 5 %	19.14	c	489.72	c	30.46	c
60% ETc × kaolin 0 %	13.41	i	414.51	i	26.45	i
60% ETc× kaolin 2.5 %	15.01	g	435.41	g	28.07	g
60% ETc × kaolin 5 %	17.65	d	480.63	d	29.75	d

ETc = Evapotranspiration, mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

The results are in harmony with those reported by Sultan *et al.,* 2016; Karasu *et al.,* 2015; Ertek and Kara, 2013; Bozkurt *et al.,* 2006; Cakir, 2004 they indicated that the highest values of vegetative growth and yield characteristics were obtained by using the highest irrigation amount. In addition, it is clear that foliar applications with kaolin significantly increased vegetative growth and yield characteristics especially with kaolin 5% treatment. Moreover, the lowest significant values in this respect were recorded by the kaolin 0 % treatment in both seasons. The significant responses of kaolin foliar application on vegetative growth and yield characteristics were confirmed by Karasu *et al.,* 2015; Shalata, 2013; Ezzat *et al.,* 2009 and Creamer *et al.,* 2005.

Table 10 : Effect of irrigation water levels and kaolin spraying with different concentrations on grain, cob and straw yield ton per feddan of maize plant.

Treatments / Parameters	Grain yield ton per fedaan		Cob yield ton per fedaan		Straw yield ton fedaan	
	First season (2017)					
100% ETc	3.12	A	0.48	A	4.43	A
80% ETc	2.62	B	0.44	B	4.19	B
60% ETc	2.47	B	0.43	B	4.10	C
kaolin 0 %	2.38	C	0.42	C	4.05	C
kaolin 2.5%	2.71	B	0.45	B	4.24	B
kaolin 5%	3.12	A	0.48	A	4.43	A
100% ETc × kaolin 0 % (control)	2.65	e	0.45	e	4.24	e
100% ETc × kaolin 2.5 %	3.25	b	0.48	b	4.49	b
100% ETc × kaolin 5 %	3.47	a	0.50	a	4.57	a
80% ETc × kaolin 0 %	2.30	h	0.42	h	3.99	h
80% ETc × kaolin 2.5 %	2.50	f	0.44	f	4.17	f
80% ETc × kaolin 5 %	3.06	c	0.47	c	4.42	c
60% ETc × kaolin 0 %	2.19	i	0.41	i	3.92	i
60% ETc× kaolin 2.5 %	2.39	g	0.43	g	4.07	g
60% ETc × kaolin 5 %	2.83	d	0.46	d	4.31	d
	Second season (2018)					
100% ETc	3.56	A	0.51	A	4.48	A
80% ETc	3.04	B	0.48	B	4.22	B
60% ETc	2.86	C	0.47	B	4.15	B
kaolin 0 %	2.76	C	0.46	C	4.07	C
kaolin 2.5%	3.15	B	0.49	B	4.26	B
kaolin 5%	3.56	A	0.51	A	4.52	A
100% ETc × kaolin 0 % (control)	3.18	e	0.49	e	4.27	d
100% ETc × kaolin 2.5 %	3.68	b	0.52	b	4.54	b
100% ETc × kaolin 5 %	3.83	a	0.53	a	4.64	a
80% ETc × kaolin 0 %	2.64	h	0.45	h	4.01	g
80% ETc × kaolin 2.5 %	2.98	f	0.47	f	4.15	e
80% ETc × kaolin 5 %	3.51	c	0.51	c	4.50	b
60% ETc × kaolin 0 %	2.45	i	0.44	i	3.95	h
60% ETc× kaolin 2.5 %	2.80	g	0.46	g	4.10	f
60% ETc × kaolin 5 %	3.34	d	0.50	d	4.41	c

ETc = Evapotranspiration, mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Regarding the effect of the interaction between irrigation levels and foliar applications of kaolin on the vegetative growth and yield characteristics of maize, data in our study clearly show that applying the 60% ETc combined with the foliar application of kaolin 5 % treatment had the same significant affection compared to 100% ETc combined with the foliar application of kaolin 0% treatment (control).

The pronounced promotional effect of the foliar application of kaolin under water stress conditions on vegetative growth characteristics could be related to the direct effects of kaolin on plant resistance to both biotic and abiotic stress including drought (Glenn *et al.,* 2002 and Creamer *et al.,* 2005). In addition, kaolin foliar application was reported to improve CO_2 assimilation (Glenn *et al.,* 2002). Spraying tomato plants with 5% of kaolin suspension improved water status and yield under water stress conditions (Kamal, 2013). Creamer *et al.,* 2005 and Kamal, 2013 illustrated that applications of kaolin at hot temperatures might help hot Chile pepper plants from being subjected to severe water stress. Such gains can explain the enhancement of plant growth in associated with higher plant water content in wheat grown under deficit irrigation condition.

Table 11 : Effect of irrigation water levels and kaolin spraying with different concentrations on chemical composition and proline leaf contents of maize plant.

Parameters / Treatments	N%		P%		K%		Proline (µm/F.W.g)	
	First season (2017)							
100% ETc	2.519	A	0.274	A	2.12	A	49.08	C
80% ETc	2.171	B	0.244	B	1.82	B	107.53	B
60% ETc	2.080	B	0.238	B	1.70	B	161.23	A
kaolin 0 %	1.994	C	0.233	C	1.62	C	129.56	A
kaolin 2.5%	2.272	B	0.249	B	1.87	B	103.76	B
kaolin 5%	2.503	A	0.274	A	2.16	A	84.51	C
100% ETc × kaolin 0 % (control)	2.187	e	0.252	e	1.87	e	76.63	f
100% ETc × kaolin 2.5 %	2.599	b	0.274	b	2.19	b	45.24	g
100% ETc × kaolin 5 %	2.770	a	0.294	a	2.31	a	25.36	h
80% ETc × kaolin 0 %	1.968	h	0.225	h	1.56	h	117.02	d
80% ETc × kaolin 2.5 %	2.141	f	0.241	f	1.77	f	108.95	d
80% ETc × kaolin 5 %	2.403	c	0.265	c	2.13	c	96.62	e
60% ETc × kaolin 0 %	1.828	i	0.221	i	1.42	i	195.04	a
60% ETc× kaolin 2.5 %	2.076	g	0.231	g	1.63	g	157.10	b
60% ETc × kaolin 5 %	2.334	d	0.261	d	2.03	d	131.55	c
	Second season (2018)							
100% ETc	2.662	A	0.287	A	2.22	A	45.05	C
80% ETc	2.311	B	0.258	B	1.87	B	118.08	B
60% ETc	2.178	B	0.249	B	1.75	C	178.12	A
kaolin 0 %	2.118	C	0.244	C	1.65	C	132.95	A
kaolin 2.5%	2.373	B	0.265	B	1.97	B	115.60	B
kaolin 5%	2.661	A	0.286	A	2.22	A	92.70	C
100% ETc × kaolin 0 % (control)	2.381	e	0.263	e	1.90	e	68.73	g
100% ETc × kaolin 2.5 %	2.756	b	0.295	b	2.37	b	49.53	h
100% ETc × kaolin 5 %	2.849	a	0.305	a	2.41	a	16.89	i
80% ETc × kaolin 0 %	2.033	h	0.239	h	1.59	h	137.71	d
80% ETc × kaolin 2.5 %	2.262	f	0.254	f	1.83	f	117.54	e
80% ETc × kaolin 5 %	2.638	c	0.281	c	2.20	c	98.97	f
60% ETc × kaolin 0 %	1.940	i	0.229	i	1.47	i	192.41	a
60% ETc× kaolin 2.5 %	2.100	g	0.248	g	1.71	g	179.72	b
60% ETc × kaolin 5 %	2.496	d	0.271	d	2.06	d	162.23	c

ETc = Evapotranspiration, mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Conclusion

In conclusion, the results clearly suggest that kaolin5% obviously improved maize growth and yield under drought stress reached to 60 %ETc, which could save 40% of water irrigation and gained the same yield and quality compared to the control without any reduced in them.

Table 12 : Effect of irrigation water levels and kaolin spraying with different concentrations on seed quality characters of maize plant.

Parameters / Treatments	Total carbohydrates (%)		Oil content (%)		Crude protein (%)	
	First season (2017)					
100% ETc	79.84	A	3.81	A	15.89	A
80% ETc	78.07	B	3.47	B	13.84	B
60% ETc	77.49	C	3.33	C	13.14	B
kaolin 0 %	77.13	C	3.27	C	12.69	C
kaolin 2.5%	78.52	B	3.53	B	14.12	B
kaolin 5%	79.76	A	3.81	A	16.05	A
100% ETc × kaolin 0 % (control)	78.66	e	3.61	e	14.47	e
100% ETc × kaolin 2.5 %	79.98	b	3.86	b	16.40	b
100% ETc × kaolin 5 %	80.89	a	3.96	a	16.79	a
80% ETc × kaolin 0 %	76.75	h	3.15	h	12.21	h
80% ETc × kaolin 2.5 %	78.07	f	3.48	f	13.32	f
80% ETc × kaolin 5 %	79.39	c	3.78	c	15.99	c
60% ETc × kaolin 0 %	75.97	i	3.05	i	11.40	i
60% ETc× kaolin 2.5 %	77.51	g	3.25	g	12.65	g
60% ETc × kaolin 5 %	79.01	d	3.68	d	15.37	d
	Second season (2018)					
100% ETc	82.05	A	3.96	A	16.06	A
80% ETc	79.92	B	3.61	B	13.94	B
60% ETc	79.07	B	3.50	B	13.05	B
kaolin 0 %	78.55	C	3.43	C	12.71	C
kaolin 2.5%	80.34	B	3.69	B	14.44	B
kaolin 5%	82.14	A	3.95	A	15.89	A
100% ETc × kaolin 0 % (control)	79.98	e	3.66	e	14.43	e
100% ETc × kaolin 2.5 %	82.88	b	4.02	b	16.63	b
100% ETc × kaolin 5 %	83.28	a	4.20	a	17.11	a
80% ETc × kaolin 0 %	78.28	h	3.38	h	12.24	h
80% ETc × kaolin 2.5 %	79.42	f	3.57	f	13.88	f
80% ETc × kaolin 5 %	82.05	c	3.88	c	15.70	c
60% ETc × kaolin 0 %	77.39	i	3.26	i	11.47	i
60% ETc× kaolin 2.5 %	78.72	g	3.47	g	12.82	g
60% ETc × kaolin 5 %	81.09	d	3.78	d	14.87	d

ETc = Evapotranspiration, mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

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