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EFFECTS OF AVAILABLE SOIL MOISTURE DEPLETION LEVELS AND SOME FOLIAR – SPRAYED ORGANIC ACIDS ADDITIONS ON YIELD AND SOME CROP WATER RELATIONS OF DRIP-IRRIGATED MAIZE

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ABSTRACT

A field experiment was conducted at El- Areish Agricultural Research Station, North Sinai Governorate, Egypt, during 2010 and 2011 summer seasons to study the effect of available soil moisture depletion levels and foliar spray with some organic acids on grain yield, yield components, nutrient contents in grains and some crop-water relations for drip – irrigated maize (SC-10 Hybrid) .Three irrigation regimes i.e. irrigation at 75, 60 and 45% of available soil moisture depletion(ASMD) as interacted with citric, salicylic and ascorbic acids besides the control, applied as foliar spray, at 35 and 50 days after sowing in the concentration of 1g/L. The adopted treatments were assessed in split plot design with four replicates.

The main obtained results were as follows:-

1. The maize grain yield significantly affected due to the adopted irrigation treatments in both seasons and irrigation at 45% ASMD regime resulted in higher grain yield and yield components values. On the contrary, the lowest values were obtained from irrigation at 75% ASMD regime.
2. Foliar spray with the tested organic acids significantly affected grain yield and most yield components in the two seasons of study and higher values were resulted from foliar - sprayed ascorbic acid.
3. Interaction of the adopted treatments significantly did not influence grain yield and yield components attributes in the two seasons of study.
4. The tested irrigation treatments insignificantly affected N, P, and K grains contents, however, higher values were noticed due to irrigation at 45% ASMD regime. Foliar spray with ascorbic acid resulted in the highest grains N and P figures. In addition, interaction of the adopted treatments insignificantly altered grains N, P and K contents, however, higher values of grains N and P contents were noticed due to interaction of irrigation at 45% ASMD and foliar spray of ascorbic acid.

5- Seasonal evapotranspiration (ETc) values as a function of assessed treatments were 54.82 and 55.45 cm in 2010 and 2011 seasons, respectively. Irrigation at 45% ASMD resulted in the highest ETc values, while, the lowest ones were obtained due to irrigation at 75% ASMD regime. Foliar spray with the tested organic acids slightly reduced ETc values, comparable with the control. Interaction of irrigation at 45% ASMD and no-foliar spray with organic acids (control) gave the highest ET_c values which comprised 55.38 and 56.06 cm in 2010 and 2011 seasons, whereas the lowest ones were detected from irrigation at 75% ASMD and foliar application of ascorbic acid in 2010 season and with irrigation at 75% ASMD and foliar spray with citric acid in 2011 season (35.55 and 37.17cm, respectively).

6- The calculated crop coefficients were 0.22, 0.43, 1.14, 1.02 and 0.34 for May, June, July, August and September (Mean of two seasons).

7- The highest water use efficiency values resulted from irrigating maize at 75% ASMD which reached 1.57 and 1.37 kg grains m^{-3} water consumed, while irrigation at 45% ASMD gave the lowest values which comprised 1.44 and 1.31 grains m^{-3} water consumed in the two seasons, respectively. The tested organic acids resulted in higher WUE values, comparable with the control, and ascorbic acid gave the highest values which comprised 1.90 and 1.67 kg grains m^{-3} water consumed in the two seasons, respectively. Higher WUE could be achieved due to irrigating maize plants at 75% ASMD as interacted with foliar spray of ascorbic acid . Under the trial conditions and on achieving higher water productivity and reasonable maize grain yield as well, its advisable to irrigate maize crop at 60% ASMD regime with foliar spray of citric, salicylic or ascorbic acids.

Keywords*:* soil moisture depletion; foliar spray of organic acids; maize crop – water relations; water use efficiency; crop coefficient

INTRODUCTION

With the continued and rapid increase in world population, it has become of vital importance to obtain higher yield per unit of both land and available irrigation water. Calcareous soils are one of the most important factors that limited the nutrients' availability and agricultural production. Calcareous soils which are defined as having significant quantities of free excess lime $CaCO_3$ and represent the dominant soil type in many arid and semiarid climates affecting over 600 million ha of soils worldwide (Leytem and Mikkelsen 2005). The excess of calcium carbonate posses serious problems in plant nutrition, it mainly influences the pH of soil. The high pH levels from 8.0–8.4 result in relative unavailability of plant nutrients (Hakan *et al*. 2008).

In Egypt, maize (*Zea mays* L.) is major cereal summer crop, and it has a special importance because national production is not enough to meet the increase of local demands. One of the important factors to increase crop production is the successful irrigation water management.

Productivity response to water stress is different for each crop and is expected to be vary with the climate. Sufficient water must be presented in an active crop root zone for germination, evapotranspiration, nutrient root absorption, root growth and soil microbiological and chemical processes that aid in the decomposition of organic matter and mineralization of nutrients. Growing competition for scarce water resources, particularly in arid and semi-arid regions, has led to apply modified techniques for maximizing water-use efficiency and improving crop yields and quality, (Kumar *et al*., 2007; Bekele and Tilahun, 2007; Yasser *et al*., 2009).

Ascorbic acid is an organic compound required in trace amount to maintain normal growth in higher plants (Podh, 1990). In addition, it is influences mitosis and cell growth in plants (Noctor and Foyer, 1998; Smirnoff and Wheeler, 2000) and affects nutritional cycle's activity in higher plants and plays an important role in the electron transport system (Liu *et al*. 1997). The beneficial effects of ascorbic acid upon growth and productivity have been reported on maize growth (Abdel-Wahed *et al*. 2006; El-Mergawi and Abdel-Wahed, 2007). Salicylic acid naturally occurs in plants in very low amounts and participates in the regulation of several physiological processes in plant including stomatal closure, nutrient uptake, protein synthesis, transpiration and photosynthesis (Khan *et al*., 2003, Shakirova *et al*. 2003). In addition, salicylic acid promotes some physiological processes and inhibiting others depending on its concentration, plant species, development stages and environmental conditions (Ding and Want, 2003 and Mateo *et al*., 2006). Moreover, Saeidnejad *et al*. (2012) found that salicylic acid could improve physiological properties of maize seedlings under saline conditions.

The present work was carried out to study the effects of available soil moisture depletion levels and foliar spray with citric, salicylic and ascorbic acids on maize (Single Cross-10 hybrid) grain yield, yield components, n utrients in grains and some crop- water relations under EL-Arish area circumstances.

MATERIALS AND METHODS

A field experiment was conducted during 2010 and 2011 summer seasons at El- Areish Agricultural Research Station, North Sinai Governorate, Egypt, located at lat. 31.05, long. 33.50 and 17.10m above the mean sea level. Soil bulk density and some soil moisture constants values of the experimental field are shown in Table 1. The study aimed to investigate the effect of different irrigation regimes and foliar spray with organic acids and their interaction on maize yield, yield components, N,P and K contents in grains and some crop- water relations. The adopted treatments were assessed in split-plot in randomized complete block design with four replicates. Three irrigation treatments, i.e. irrigation at 75, 60% and 45% of available soil moisture were depleted (ASMD) and such treatments were represented in the main plots. The sub plots were occupied with citric, salicylic and ascorbic acids applied as foliage – spray, besides the control treatment (water). The tested organic acids were applied at 35 and 50 days after maize sowing in the concentration of 1 Lh^{-1}. Drip irrigation system was installed in the experimental field where each experimental unit was consisted of 4 drip lines connected to a water -meter. The drip irrigation system includes a water pump connected to sand and screen filters. A 63 out diameter PVC sub- main line, connected to lateral poly ethylene lines of 16 mm out diameter. Each lateral was 25 m long and 0.8 m apart with standard 4 Lh^{-1} emitters spaced at 0.3 m apart. The actual discharge rate for emitters was found to be 3.6 Lh^{-1} due to pressure drop. Irrigation was practiced , under the adopted irrigation treatments, via calibrated tensiometers installed in each experimental unit. The proper irrigation water quantity, to refill the root zone, was applied based on the relationship of emitters number per plot, discharge and irrigation time.

Table 1. Bulk density and some soil moisture constants for the experimental site.

Soil depth (cm)	Bulk density (gcm^{-3})		Field Capacity (w/w%)		Wilting Point (w/w %)		Available soil water (w/w %)	
	2010	2011	2010	2011	2010	2011	2010	2011
00-15	1.47	1.45	11.4	10.1	5.8	5.5	5.6	4.6
15-30	1.66	1.61	10.9	10.3	5.6	5.3	5.3	5.0
30-45	1.72	1.68	9.7	9.1	4.9	4.6	4.8	4.5
45-60	1.82	1.80	9.4	9.3	4.0	3.8	5.4	5.5

Before executing the experiment, a surface soil samples, 0-30 cm depth was taken and soil particle size distribution was determined. Some soil and irrigation water chemical properties were determined according to Ryan *et al*. (1996) and data are listed in Tables 2 and 3.

According to US Salinity laboratory, 1954, the above data indicated that the soil of the experimental site is categorized as slightly saline and irrigation water is medium saline.

Table 2: Particle size distribution and some chemical analyses for the experimental site

Characters		Season 2010	Season 2011
Particle size distribution	**Coarse sand %**	12.20	10.75
	Fine sand %	53.20	51.10
	Silt %	33.88	37.40
	Clay %	0.72	0.75
	Textural class	**Sandy loam**	**Sandy loam**
	p^H (1:2.5)	8.46	7.80
	$CaCO_3$ (%)	18.52	20.10
	EC_e (dSm^{-1})*	3.20	2.84
Soluble cations ($meqL^{-1}$)	**Ca^{+2}**	3.20	4.40
	Mg^{+2}	8.70	8.10
	Na^+	11.50	14.20
	K^+	1.80	1.50
Soluble anions ($meqL^{-1}$)	**HCO_3^-**	8.60	9.80
	Cl^-	10.20	11.50
	SO_4^{--}	6.40	6.90
Macro elements (ppm)	**N**	13.45	11.90
	P	4.06	3.86
	K	28.40	26.90

***Soil paste**

Table 3. Some chemical characteristics of the used irrigation water

Characters		Season 2010	Season 2011
	p^H	7.3	7.2
	EC_w dSm^{-1}	5.08	5.28
Soluble cations (meq/L)	Ca^{+2}	8.2	8.7
	Mg^{+2}	5.2	5.5
	Na^{+}	37.6	38.7
	K^{+}	0.1	0.1
Soluble anions (meq/L)	HCO_3^-	4.8	4.3
	Cl^-	39.7	41.6
	SO_4^{-2}	6.6	7.1

Maize seeds (SC 10 hybrid at the rate of 15kg fed^{-1}) were sown on 26^{th} and 30^{th} of May and harvested on 20^{th} and 25^{th} of September in 2010 and 2011 seasons, respectively. Fertilization was carried out according to the recommendation of the Ministry of Agriculture in Egypt as follow :- superphosphate and potassium sulphate were applied during seedbed preparation at rates 30 kg P_2O_5 and 48 kg K_2O fed^{-1}., respectively. Nitrogen fertilizer was applied in four equal portions, (at 20, 35, 50 and 65 days after sowing) in the form of ammonium sulphate (20.6 %N) at 100 kg N fed^{-1} rate of. The other usual cultural practices adopted for maize production were done. Nitrogen content in grains was determined using micro Kjeldahl as described by Black, 1982. Phosphorous was determined calorimetrically using ammonium molybdate and ammonium metavanadate according to the procedure outlined by Ryan *et al*.(1996). Potassium was determined flame spectrophotometerically (Black, 1982).

At harvesting time ten plants were chosen randomly from the two inner rows of each sub-plot and following data were measured: Plant height (cm), stem diameter (cm), ear length and ear width (cm), ear weight (g), grains weight/ plant (g), 100- grain weight (g) and grains N, P and K contents as well. Grain yield was determined based on the entire plot area and expressed as ton fed^{-1}.

The data collected were subjected to statistical analysis using M stat computer package to calculate F ratio according to Senedecor and Cochran 1980. The means were compared using Least Significant Difference (LSD) at 5% level according to Waller and Duncan, 1969.

Reference evapotranspiration (ET_o) and some crop- water relationships:

Reference evapotranspiration (ET_o)

The reference evapotranspiration (ET_o) in mm $month^{-1}$ was calculated using the monthly average of El-Areish metrological data (Table 4) and the procedures of the FAO Penman Monteith equation (Allen *et al*.1998) and the CROPWAT model (Smith, 1991).

Table 4 : Agroclimatological data for Al-Arish Governorate (average 1999-2006)

Month	Temperature (C °)		Wind speed ($msec^{-1}$)	Relative humidity%	Rainfall (mm)	E pan (mm)
	maximum	Minimum				
May	27.7	15.6	2.5	79	0.6	6.3
June	30.1	19.1	2.4	81	0.0	6.9
July	32.4	21.7	2.4	83	0.0	6.9
August	32.4	22.2	2.3	82	0.0	6.4
September	31.3	20.5	2.4	81	0.0	5.8

Monthly and seasonal evapotranspiration (ET_c):

The crop water consumptive use between two successive irrigations and at harvest as well, in 15 cm increment system to 60 cm depth of the soil profile, was calculated according to Israelsen and Hansen (1962) and expressed as:

$$Cu = \frac{D.Bd.[Q2 - Q1]}{100}$$

Where:

Cu = Actual evapotranspiration(cm).

D = Effective root zone depth (cm).

Bd = Bulk density of soil (gcm^{-3}).

Q2 = Soil moisture content (%, by weight) after irrigation.

Q1 = Soil moisture content (%, by weight) before the next irrigation.

Crop Coefficient (Kc):

The Crop coefficients (Kc) are used with ETo to estimate specific crop evapotranspiration rates. The crop coefficient is a dimensionless number (usually between 0.1 and 1.2) that is multiplied by the ETo value to arrive at a crop ET (ETc) estimate. The resulting ETc can be used to help irrigation planning, design, and management. The Crop coefficients (Kc) is estimated as follows :

$$Kc = \frac{ETc}{ETo}$$

Where:

Kc = Crop coefficient.

ETc = The measured (actual) evapotranspition of a considered period ($mmday^{-1}$).

ET_o = Reference evapotranspiration ($mmday^{-1}$) referring to the same period.

Water Use Efficiency (WUE)

In the present trial, water use efficiency was estimated as kgs grain yield per m^3 water consumed according to Jensen (1983) as follows:

$$WUE = \frac{Y}{ETc}$$

Where:

Y = grain yield in $kgha^{-1}$ and ET_c= water consumptive use (m^3ha^{-1})

RESULTES AND DISCUSSION

1-Grain yield and yield components

The results in Table 5 reveal that maize grain yield was significantly affected due to the adopted available soil moisture depletion levels in 2010 and 2011 seasons. The highest grain yield e.g. 3.31 and 3.05 t fed^{-1} were obtained from irrigation at 45% available soil moisture depletion ASMD, respectively, in 2010 and 2011 seasons. On the contrary, irrigation at 75% ASMD gave the lowest grain yield which reached 2.41 and 2. 19 t fed^{-1} in 2010 and 2011 seasons, respectively. With respect to yield component attributes as affected by irrigation regimes under study, data reveal that ear length, ear diameter, ear weight $plant^{-1}$, grains weight $plant^{-1}$ and 100 – kernel weight traits were reduced significantly due to irrigating based on 75% ASMD regime, as compared with 45% one, in 2010 season. The trend was slightly differed in 2011 season where stem diameter, ear weight/plant, grains weight/plant and 100 – kernel weight traits were significantly reduced under irrigation at75% ASMD regime, comparable with 45 and 60% one .The grain yield and yield components reductions resulted from irrigating at 75% ASMD could be attributed to less available soil moisture, in the root zone, under such treatment which leads to reduction in cell division, cell elongation, photosynthesis activities and dry matter accumulation in plant and reproductive organs.. In connection, Farooq *et al*. (2009) found that the drought stress reduces leaf size, stem extension and root proliferation and disturbs plant water relations. Moreover, El-Sayed *et al*. (2010) stated that decreasing irrigation water quantity gave a negative effect on plant growth.

Regarding the effect of foliar spray with organic acids, data in Table 5 show that maize grain yield was significantly increased with the tested organic acids, as compared with the control, and such trend was true in the two seasons of study. In 2010 season the increase percentages in grain yield due to foliar spray with citric, salicylic and ascorbic acids reached 47.0, 21.20 and 61.75, respectively, comparable with control. The corresponding increase percentages in 2011 season comprised 50.26, 22.50 and 68.21, as compared with control, respectively. The favorite effects of ascorbic acid upon growth and productivity have been reported on maize growth (Abdel-Wahed *et al*., 2006; El-Mergawi and Abdel-Wahed, 2007).

Data in Table 5 indicate that the interaction effects of the adopted available soil moisture depletion levels and organic acids used as foliar spray on maize grain yield and yield components were insignificant, however, higher values of grain yield and most of the measured yield components were noticed under irrigating at 45% ASMD level as interacted with ascorbic acid applied as foliar spray in the two seasons of study.

It is worthy to mention that, under the assessed irrigation regimes, foliar spraying of ascorbic acid resulted in higher both maize grain yield and yield attributes values. In this sense, Noctor and Foyer (1998) stated that ascorbic acid significantly reduces the undesirable accumulation of sodium in the stems of salt-stressed plants and its protective effect is more related to reduce active oxygen species (AOS) damage to essential proteins and/or nucleic acids.

Table 5: Effect of available soil moisture depletion%, foliar spray with organic acids and their interaction on maize yield and yield components in 2010 and 2011 season.

Treatment		Plant height (cm)	Stem diameter (cm)	Ear ength (cm)	Ear diameter (cm)	Ear weight plant^{-1} (g)	Grains weight Plant^{-1} (g)	100-kernel weight (g)	Grain yield (ton fed^{-1})
2010 season									
Available soil moisture depletion%									
75%		181.75	2.05	18.82	5.63	148.63	120.10	25.58	2.41
60%		188.50	2.13	19.02	5.78	171.30	134.49	30.90	2.91
45%		192.25	2.19	19.21	5.91	184.57	141.96	32.44	3.31
LSD 05		NS	NS	0.21	0.17	25.70	11.35	1.07	0.10
Organic acids									
Control		201.33	1.93	19.53	5.27	134.23	112.81	28.14	2.17
Citric		182.67	2.14	18.89	5.91	178.98	137.65	29.88	3.19
Salicylic		188.67	2.08	18.97	5.75	153.30	124.73	29.35	2.63
Ascorbic		177.33	2.34	18.66	6.15	206.15	153.55	31.19	3.51
LSD 05		13.51	0.116	0.26	0.17	18.85	18.85	1.13	0.187
Interaction effects : (A S M D x Organic acids) treatments.									
ASMD 75%	**Control**	195	1.87	19.15	5.13	113.50	97.48	24.09	1.72
	Citric	178	2.08	18.71	5.79	157.80	126.76	25.97	2.71
	Salicylic	184	2.00	18.89	5.61	134.82	112.35	25.25	2.15
	Ascorbic	170	2.27	18.52	5.98	188.39	143.81	27.03	3.07
ASMD 60%	**Control**	202	1.94	19.61	5.28	140.38	116.30	29.02	2.10
	Citric	184	2.12	18.83	5.91	180.70	139.16	31.04	3.23
	Salicylic	189	2.09	18.96	5.77	156.21	127.35	30.96	2.69
	Ascorbic	179	2.39	18.68	6.15	207.90	155.15	32.58	3.61
ASMD 45%	**Control**	1.98	1.98	19.83	5.41	148.80	124.65	31.32	2.69
	Citric	2.22	2.22	19.14	6.02	198.45	147.02	32.61	3.61
	Salicylic	2.16	2.16	19.0	5.88	168.88	134.48	31.84	3.07
	Ascorbic	2.38	2.38	18.78	6.31	222.15	161.70	33.97	3.86
LSD 05		NS	NS	NS	NS	NS	NS	NS	NS
Available soil moisture depletion%		**2011 season**							
75%		173.19	1.87	18.04	5.27	137.96	113.47	23.47	2.19
60%		181.50	1.95	18.29	5.40	157.70	127.08	28.09	2.68
45%		184.75	2.01	18.39	5.52	177.82	134.50	29.60	3.05
LSD 05		NS	0.09	NS	NS	23.36	15.53	1.22	0.16
Organic acids									
Control		192.00	1.80	18.68	4.91	128.96	108.85	26.01	1.95
Citric		176.00	1.97	18.08	5.56	171.54	129.93	27.29	2.93
Salicylic		178.92	1.91	18.25	5.38	142.25	117.77	26.54	2.39
Ascorbic		172.33	2.10	17.95	5.74	188.55	143.51	28.37	3.28
LSD 05		15.38	0.17	N.S.	0.43	23.22	20.01	01.05	0.13
Interaction effects : (A S M D x Organic acids) treatments.									
ASMD 75%	**Control**	187.00	1.72	18.41	4.77	107.88	93.48	22.38	1.55
	Citric	172.00	1.90	17.91	5.48	145.50	119.40	23.80	2.48
	Salicylic	167.75	1.83	18.12	5.24	124.00	105.45	23.06	1.89
	Ascorbic	166.00	2.02	17.72	5.59	174.45	135.55	24.63	2.84
ASMD 60%	**Control**	192.00	1.80	18.70	4.93	133.35	113.94	26.74	1.89
	Citric	177.00	1.98	18.12	5.57	167.80	131.75	28.34	3.003
	Salicylic	183.00	1.92	18.32	5.34	144.95	120.80	27.58	2.44
	Ascorbic	174.00	2.11	18.01	5.75	184.70	141.82	29.69	3.40
ASMD 45%	**Control**	197.00	1.88	18.92	5.04	145.65	119.12	28.91	2.39
	Citric	179.00	2.03	18.21	5.62	201.33	138.65	29.74	3.32
	Salicylic	186.00	1.98	18.31	5.55	157.81	127.07	28.97	2.86
	Ascorbic	177.00	2.16	18.12	5.89	206.50	153.15	30.78	3.61
LSD 05		NS	NS	NS	NS	NS	NS	NS	NS

Macronutrients content in maize grain:

Data in Table 6 clear out that the adopted irrigation regimes did not exert any effect to alter maize grains N,P and K contents, however, higher values were resulted from irrigating at 45% ASMD regime and such trend was true in the two seasons of study.

Data in Table 6 reveal that effect of the tested organic acids was mostly insignificant on N, P and K contents in the two seasons of study.. In addition, higher values of both N and P contents were recorded due to foliar application of the assessed organic acids, comparable with the control, and ascorbic acid seemed to be superior in this respect. In this sense, Khan and Srivastava (1998) found that treating maize plants with ascorbic acid improved total dry matter and nitrate uptake values even with salt – induced plants. In addition, Saeidnejad *et al*. (2012) found that salicylic acid alleviated the harmful effects of salinity on maize total dry matter and shoot dry matter as well as relative water content (RWC). Data in Table 6 also clear out that K content seemed to be adversely affected, where lower K values were obtained due to foliar application of the tested organic acids, in comparison with the control.

Interaction of the adopted treatments did not affect N, P and K contents in maize grains in the two seasons of study, however, most of the higher values of N and P were recorded with 45% ASMD regime as interacted with either the control or foliar - applied ascorbic acid.

Table 6: Effect of available soil moisture depletion levels, foliar spray of organic acids and their interaction on nutrients percentage of maize grains in 2010 and 2011 seasons.

Treatments		2010 Season			2011 Season		
Available soil moisture depletion		N %	P %	K %	N %	P %	K %
75%		1.92	0.41	0.34	1.88	0.37	0.30
60%		1.97	0.45	0.37	1.91	0.39	0.33
45%		1.99	0.46	0.38	1.91	0.40	0.36
L.S.D 0.05		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Organic acids							
Control		1.90	0.40	0.40	1.83	0.34	0.36
Citric acid		1.97	0.44	0.35	1.92	0.39	0.31
Salicylic acid		1.91	0.42	0.38	1.88	0.35	0.34
Ascorbic acid		2.05	0.48	0.33	1.96	0.45	0.30
L.S.D 0.05		0.13	N.S.	N.S.	N.S.	0.09	N.S.
Interaction effects : (A S M D x Organic acids) treatments.							
75% ASMD	Control	1.88	0.38	0.38	1.85	0.32	0.33
	Citric acid	1.92	0.42	0.32	1.89	0.38	0.28
	Salicylic acid	1.89	0.39	0.35	1.86	0.34	0.31
	Ascorbic acid	1.98	0.45	0.31	1.93	0.42	0.27
60% ASMD	Control	1.91	0.41	0.40	1.87	0.35	0.36
	Citric acid	1.97	0.45	0.36	1.92	0.40	0.31
	Salicylic acid	1.92	0.43	0.38	1.88	0.35	0.34
	Ascorbic acid	2.06	0.49	0.34	1.97	0.46	0.30
45% ASMD	Control	1.92	0.42	0.41	1.78	0.35	0.38
	Citric acid	2.01	0.46	0.37	1.96	0.41	0.34
	Salicylic acid	1.93	0.44	0.40	1.91	0.36	0.37
	Ascorbic acid	2.10	0.51	0.34	1.99	0.48	0.34
L.S.D 05		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

3- Reference evapotranspiration (ET_o) and some crop - water relations:
Reference evapotranspiration (ET_o)

The reference evapotranspiration ET_o (mm month^{-1}) during maize growing seasons extended from May to September were estimated using the FAO Penman Monteith equation and the monthly average of the meteorological data of El-Areish area and the results are recorded in Table 7. Data prove that the monthly ET_o values were started low on May, then increased during June to reach the maximum values during July. Thereafter it decreased again during August to reach low values during September. These results are mainly due to the variation in weather factors from month to another. In this connection, Allen *et al*. (1996) reported that the ET_o values depended mainly on the evaporative power, i.e. air temperature, solar radiation, air relative humidity and wind speed.

Monthly and seasonal evapotranspiration (ET_c)

Regarding monthly $ET_{c,}$ data in Table 7 indicate that ET_c values started with low values during May and increased gradually during June to reach its maximum values at July, as a result of the increase in vegetative growth, which requires higher quantities of water by plants. Thereafter the values reduced again during August (Physiological maturity stage) to reach it minimum values at September (Harvesting). These results may be referred to that the monthly water consumptive use starts small because plant seedlings need less water at their initial growth stage. Therefore, soil moisture losses are mainly due to evaporation form soil surface. With the advance of plant age, the plant canopy increase and consequently both transpiration and monthly consumptive use increased. These results are in parallel with those reported by Oktem *et al*. (2003) and Ayotamuno *et al*. (2007)), who mentioned that peak water consumption of maize depends on the availability of soil moisture in the root zone and plant growth stage.

Regardless foliar application of the organic acids, ET_c values were the highest as maize was irrigated according to 45% ASMD regime, comparable with 60 and 75% ones. The increases in ET_c, due to irrigation at 45% ASMD regime, were (22.23 and 16.79%) and(49.25 and 45.12%) higher than those under 60 and 75% ASMD regimes, respectively, in 2010 and 2011 seasons. The probable explanation of such increases in ET_c values is that the frequent irrigation provides chance for more water consumption that ultimately resulted in increasing transpiration by plants and evaporation from the soil surface.

Concerning effect of foliar- sprayed organic acids, data in Table 7 show that the tested organic acids seemed to reduce seasonal ETc for maize crop, comparable with the control. The reduction values in ETc, two seasons mean, reached 2.68, 1.49 and 2.59%, with citric, salicylic and ascorbic acids, respectively, compared with the control.

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The results in Table 7 show that the seasonal ET_c of maize crop, as a function due to the interaction of the adopted treatments e.g. available soil moisture depletion levels, foliar spray with organic acids reached 54.82 and 55.45cm in 2010 and 2011 seasons, respectively. These results may be due the differences between that two seasons in weather factors and plant growth attributes and grain yield as well. Interaction of irrigation at 45% ASMD and no-foliar spray with organic acids (control) gave the highest ET_c values which comprised 55.38 and 56.06 cm in 2010 and 2011 seasons, whereas the lowest ET_c values were detected from irrigation at 75% ASMD and foliar application of ascorbic acid in 2010 season and with irrigation at 75% ASMD and foliar spray with citric acid in 2011 season (35.55 and 37.17cm, respectively).

Crop Coefficient "Kc"

Most crops do not require much water during the season as would be needed to meet the potential evapotranspiration, even though adequate soil moisture can be provided (Jensen, 1983). Thus, the term crop coefficient is used to differentiate water requirements of the crops. For determination of crop coefficient, both actual and reference evapotranspiration are measured concurrently. Results of the current study Table 8 show that crop coefficient was low at the beginning of the initial growth period, (due to relatively large diffusive resistance of the bare soil). Thereafter, crop coefficient increased as the plant canopy increased due to the increase in growth and expansion of leaves. The factors affecting crop coefficient (Kc) are mainly the prevailing weather conditions, crop characteristics, sowing date, rate of crop development and length of growing season. In the present trial, mean value of Kc was 0.22 during the initial growth period and tended to increase with time and reached the highest value in July and August (1.14 and 1.02, respectively) and such period is defined as the peak of water demand. The crop coefficient decreased again during the late season to reach lower value (0.34). It is worthy to mention that , on conserving the water resources, ETc values under 60% ASMD regime which resulted in reasonable WUE figures, were used in Kc values estimation.

Table 8: Reference evapotranspiration (ETo) and crop coefficient (Kc) calculated during months of maize growing seasons 2010 and 2011.

	Season	May	June	July	August	September
Actual ET (mm month^{-1})	**2010**	6.20	81.33	227.55	195.03	38.08
	2011	5.70	82.78	227.43	195.70	42.88
Mean		6.00	82.05	227.49	195.36	40.48
ETo (mm month^{-1})	**2010**	36.40	195.90	199.60	193.75	106.00
	2011	18.00	182.70	200.88	190.03	133.30
Mean		27.20	189.30	200.24	191.89	119.65
Kc	**FAO 56**	0.35	0.62	1.20	1.0	0.60
	Calculated	0.22	0.43	1.14	1.02	0.34

Water Use Efficiency (WUE):

The results in Table 9 indicate that WUE overall mean, due to interaction of the adopted treatments were 1.52 and 1.34 kg grains/m^3 water consumed in 2010 and 2011 seasons, respectively. It is evident that irrigation maize at 75% ASMD gave the highest WUE values, reached 1.57 and 1.37 kgs grains/m^3 water consumed, respectively, in 2010 and 2011 seasons. Moreover, it is notable that the differences in WUE values resulted from irrigation at 60 and 75% ASMD were very small to compare. In addition, irrigation at 45% ASMD gave the lowest WUE values which comprised 1.44 and 1.31 grains/m^3 water consumed in 2010 and 2011 seasons, respectively. These findings could be attributed to higher evapotranspiration resulted from irrigation at 45% ASMD while the grain yield was not proportioned with ETc increase, whereas under irrigation at 75% ASMD the reduction in ETc was more than the grain yield decrease. The present results are in line with those reported by Ghadiri and Majidian (2003), Abdel Mawly and Zanouny (2005)and Yang *et al*. (2005)), who mentioned that the efficiency of water use had decreased as the soil moisture was maintained high by the frequent irrigation.

Table 9 :Water use efficiency (kg grains m^{-3} of water consumed) as affected by available soil moisture depletion levels and foliar application of organic acids in 2010 and 2011seasons

Variables / Organic acids	Available soil moisture depletion level						Mean	
	75%		60%		45%			
	2010	2011	2010	2011	2010	2011	2010	2011
Control	1.09	0.93	1.11	0.93	1.16	1.01	1.12	0.96
Citric acid	1.78	1.59	1.72	1.54	1.57	1.43	1.69	1.52
Salicylic acid	1.37	1.19	1.42	1.22	1.33	1.23	1.38	1.21
Ascorbic acid	2.06	1.77	1.93	1.69	1.7	1.56	1.90	1.67
Mean	1.57	1.37	1.55	1.35	1.44	1.31	1.52	1.34

Results in Table 8 indicate that foliar spray with the tested organic acids resulted in higher WUE values, comparable with the control and ascorbic acid gave the highest values which comprised 1.90 and 1.67 kg grains m^{-3} water consumed in 2010 and 2011 seasons, respectively. In connection, the beneficial effects of ascorbic acid upon growth and productivity have been reported on maize growth (Abdel-Wahed *et al*., 2006; El-Mergawi and Abdel-Wahed, 2007). The lowest WUE values i.e. 1.12 and 0.96 kg grainsm^{-3}water consumed were detected from the control treatment (without foliar- sprayed organic acids) and such findings were true in the two successive seasons.

It is obvious from the interaction data that the highest WUE values i.e. 2.06 and 1.77 kg grains m^{-3} water consumed in 2010 and 2011 seasons, respectively, can be achieved due to irrigating maize plants at 75% ASMD as interacted with foliar spray of ascorbic acid.

Conclusion

Data of the present trials prove that treating the maize plants with exogenous ascorbic acid, as foliar spray, can remarkably increase the yield and its components as well as grains macronutrients contents. The increase in plant resistance to salt-stress could be attributed to activity of the adopted organic acids e.g. ascorbic, salicylic and citric acids in exerting a favorite partial inhibition of both drought conditions and salt stress induced due to irrigating with saline water. So, based on the present data and on conserving water resource and achieving reasonable yield, its advisable to irrigate maize crop at 60% ASMD regime with foliar spray of citric, salicylic or ascorbic acids.

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تأثير الري عند استنفاذ مستويات مختلفة من الماء الميسر بالتربة والرش الورقي بالأحماض العضوية على الإنتاجية وبعض العلاقات المائية للذرة الشامية تحت نظام الري بالتنقيط

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أقيمت تجربة حقلية بمحطة البحوث الزراعية بالعريش التابعة لمركز البحوث الزراعية- بشمال سيناء مصر .خلال موسمين زراعيين متتاليين 2010 و 2011 لدراسة تأثير الري عند استنفاذ مستويات مختلفة من الماء الميسر و الرش بالأحماض العضوية على محصول الذرة الشامية (هجين فردي 10) ومكوناته والقيمة الغذائية للحبوب وبعض العلاقات المائية. تم دراسة ثلاث معاملات للري هي الري عند فقد 75% و 60% و 45% من الرطوبة الميسرة بالتربة مع 4 معاملات من الرش بالأحماض العضوية هي صفر (بدون رش أحماض عضوية)، و الثانية الرش بحمض الستريك ، الثالثة الرش بحمض السلسيلك و الرابعة بحمض الاسكوربيك (بتركيز 1جم/لتر لكل منهم) عند 35 و 50 يوم من الزراعة. وكان تصميم التجربة في قطع منشقة كامل العشوائية مع أربعة مكررات تحت نظام الري بالتنقيط.

وكانت أهم النتائج كما يلي:-

1- تأثر محصول الحبوب معنويا بمعاملات الري تحت الدراسة . أفضل محصول نتج من الري عند استنفاذ 45% من الرطوبة الميسرة بالتربة ، بينما أدي الري عند استنفاذ 75% من الرطوبة الميسرة أقل محصول للحبوب وذلك في موسمي الدراسة . كان لمعاملات الري تأثير معنوي علي معظم مكونات المحصول و أعلي قيم كانت مع الري عند استنفاذ 45% من الرطوبة الميسرة. أدي رش الأحماض العضوية تحت الدراسة الي تأثير معنوي علي محصول الحبوب و كذا مكوناته فيما عدا صفة طول الكوز في الموسم الثاني . أعطي الرش بحمض

اسكوربيك أعلي قيم لمحصول الحبوب في كلا الموسمين . التفاعل بين المعاملات تحت الدراسة لم يكن له تأثير معنوي علي محصول الحبوب ومكوناته و ذلك في موسمي الدراسة.

2- لم يكن لمعاملات الري تأثير معنوي علي ال % من الممتص بالحبوب من النتروجين والفسفور و البوتاسيوم ، و إن سجلت أعلي القيم من هذه العناصر الغذائية مع الري عند استنفاذ 45% من الرطوبة الميسرة بالتربة . أدي الرش بالأحماض العضوية (اسكوربيك و السلسيليك) إلي زيادة الممتص بالحبوب من عنصري النتروجين والفسفور ولكن مع البوتاسيوم كان السلوك مختلفا. لم يؤثر التفاعل بين المعاملات تحت الدراسة معنويا علي الممتص بالحبوب من النتروجين والفسفور و البوتاسيوم.

3- أعلي قيم للاستهلاك المائي كانت مع ري الأذرة عند استنفاذ 45% من الرطوبة الميسرة بالتربة ، بينما أدي الري عند استنفاذ 75% من الرطوبة الميسرة إلي أقل القيم ، ذلك في موسمي الدراسة. رش الأحماض العضوية تحت الدراسة أدي إلي نقص قليل في قيم الاستهلاك المائي للذرة تراوح من 1.49 إلي 2.48% مقارن بالكنترول (بدون رش أحماض عضوية). أعلي قيم للاستهلاك المائي كانت بالري عند استنفاذ 45% من الرطوبة الميسرة مع عدم رش أحماض عضوية.

4- قيم معامل المحصول (متوسط الموسمين) كانت 0.22 ، 0.43، 1.14، 1.02 ، 0.34 لشهور مايو ، يونيه ، يوليو ، أغسطس ، سبتمبر علي التوالي.

5- أعلي قيم لكفاءة استخدام مياه الري (1.57 و 1.37 كجم حبوب/م^3 ماء مستهلك) كانت مع الري عند استنفاذ 75% من الرطوبة الميسرة بينما أقل القيم (1.44 و 1.31 كجم حبوب/م^3 ماء مستهلك) كانت مع الري عند استنفاذ 45% من الرطوبة الميسرة. أدي الرش بالأحماض العضوية تحت الدراسة إلي تحسن كفاءة استخدام مياه الري.

قام بتحكيم البحث

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Table 7: Monthly and seasonal evapotranspiration ET_c as affected by available soil moisture depletion and foliar spray with organic acids and their interaction in 2010 and 2011 seasons.

Irrigation / Treatments	Organic acid	2010 season May	Jun.	Jul.	Aug.	Sep.	Seasonal water consumption (cm)	2011 season May	Jun.	Jul.	Aug.	Sep.	Seasonal water Consumption (cm)
75% ASMD	Control	0.62	5.44	14.43	13.24	3.97	37.70	0.57	5.98	14.73	13.61	4.86	39.75
	Citric acid	0.62	5.29	14.13	12.52	3.76	36.32	0.57	5.3	14.93	12.23	4.14	37.17
	Salicylic acid	0.62	5.68	14.34	12.79	3.91	37.34	0.57	5.33	14.74	12.9	4.25	37.79
	Ascorbic acid	0.62	5.36	14.04	12.16	3.37	35.55	0.57	5.89	14.14	12.86	4.63	38.09
Mean		0.62	5.44	14.24	12.68	3.75	36.73	0.57	5.63	14.64	12.90	4.47	38.21
60% ASMD	Control	0.62	7.14	16.89	16.56	3.99	45.20	0.57	7.96	17.92	17.66	4.13	48.24
	Citric acid	0.62	6.93	16.8	16.44	3.93	44.72	0.57	7.23	17.18	17.14	4.33	46.45
	Salicylic acid	0.62	6.72	17.34	16.38	3.9	44.96	0.57	7	17.84	17.4	4.58	47.39
	Ascorbic acid	0.62	6.6	17.22	16.26	3.81	44.51	0.57	7.21	17.85	17.36	4.84	47.83
Mean		0.62	6.85	17.06	16.41	3.91	44.85	0.57	7.35	17.70	17.39	4.47	47.48
45% ASMD	Control	0.62	8.32	22.92	19.66	3.86	55.38	0.57	8.25	23.1	19.98	4.16	56.06
	Citric acid	0.62	8.2	22.68	19.42	3.8	54.72	0.57	8.32	22.98	19.35	4.11	55.33
	Salicylic acid	0.62	8.26	22.83	19.57	3.86	55.14	0.57	8.39	22.61	19.57	4.32	55.46
	Ascorbic acid	0.62	7.75	22.59	19.36	3.71	54.03	0.57	8.15	22.28	19.38	4.56	54.94
Mean		0.62	8.13	22.76	19.50	3.81	54.82	0.57	8.28	22.74	19.57	4.29	55.45