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Maize productivity and crop - water relations as affected by irrigation levels and compost rates.

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ABSTRACT

A field experiment was conducted during 2014 and 2015 growing seasons at Al-Arish Agric. Res. Station, Al-Arish Governorate, Egypt. This trial aimed to investigate the effect of irrigation levels i.e. 1800, 2100 and 2400 m^3fed^{-1} as interacted with compost rates i.e. without compost supplying , 2 and 4 $tonfed^{-1}$ on maize growth, yield, yield components and some crop -water relationships. A split-plot design with four replicates was adopted. The most important results could be summarized as follows:-

1- Most of the studied maize growth parameters, grain and stover yields, grain yield attributes and chlorophyllous pigments as well N, P and K contents were significantly affected due to the adopted irrigation water levels in 2014 and 2015 seasons. Increasing irrigation water level from 1800 to 2100 or 2400 m^3fed^{-1}, resulted in gradual increases in all of the abovementioned parameters, as well as ET_c and WUE values.
2- Likely, the adopted compost rates exerted significant effects to alter all of the investigated parameters e.g. growth, grain yield and yield attributes and chemical constituents as well. The highest compost rate (4 $tonfed^{-1}$) exhibited the highest figures of the abovementioned characters besides ETc and WUE, comparable with 2 $tonfed^{-1}$ rate and without compost addition, in 2014 and 2015 seasons.
3- The interaction of the highest irrigation water level e.g. 2400 m^3fed^{-1} and supplying the compost at 4 $tonfed^{-1}$rate resulted in the highest values the investigated growth, grain and stover yields and yield attributes parameters ,chemical constituents as well as ET_c and WUE in 2014 and 2015 seasons. So, it is recommended to apply such interaction to obtain both acceptable maize yield and water utilization figures under Al-Arish conditions.

Keywords: *maize yield, irrigation water level, compost rate, growth parameters, yield and yield components, water use, water use efficiency*

INTRODUCTION

Maize (*Zea Mays* L.) is one of the most important summer cereal crops grown in Egypt. Maize grain is used for both human and poultry consumption. Therefore, increasing maize production is very important issue. Adequate supply of irrigation water and optimum N fertilizer are two main factors affecting directly the growth and productivity of maize plants. It is well known that fertility of light and sandy soils is related to addition of the organic matter.

Regarding the effect of irrigation on maize crop - water relations in arid and semi- arid regions, the daily evapotranspiration rates of maize often exceed 10 $mmday^{-1}$ for significant time periods (Howell *et al.*1995). Furthermore, NeSmith and Ritchie (1992) reported that the reductions in maize yield exceeded 90 % due to water deficit during flowering and pollination stages. The high water requirement of maize with the sensitivity to water stress indicates that limited or deficit irrigation is difficult to implement successfully without causing yield reductions, particularly in light-textured soils. In addition, maize is an efficient user of water in terms of total dry matter production and among cereals it is potentially the highest yielding grain crop. For maximum production a medium maturity grain crop requires between 500 and 800 mm of water depending on climate (FAO Water Development and Management Unit, 2015). Furthermore, El-Hendawy et al. (2008a) stated that In order to improve the WUE and grain yield for drip-irrigated maize in sandy soils, it is recommended that irrigation frequency should be once every 2 or 3 days at the investigated nitrogen levels of 380 kg N ha regardless of maize varieties. On response of maize crop to irrigation rate and frequency, El-Tantawy *et al.* (2007) showed that growth and yield attributes were increased with increasing irrigation water (IW): C.P.E ratio. The highest ET_C and WUE resulted from irrigation at 1.2 C.P.E. In connection, El-Hendawy *et al.* (2008b) on sandy soil at Ismalia, Egypt, found that corn yield, yield components, and IWUE increased with increasing irrigation rates e.g. irrigating at 1.00 ET level, comparable with 0.8 and 0.6 ET levels. Moreover, Payero et al. (2009) reported that under sub surface drip irrigation, water stress can affect growth, development and physiological processes of maize plants and reduce biomass yield. In connection, Farre, I. and J.M. Faci (2009) found that average grain yield of treatments with deficit irrigation around flowering was significantly lower than that of the well-irrigated treatments. El-Hendawy and Schmidhalter (2010) studied the frequency and rate for drip-irrigated maize (1.00, 0.80, and 0.60 of the estimated ET rates) grown on sandy soil and reported that yield variables and water use efficiencies (WUEs) were increased with increasing irrigation frequency and rate. Sharaan *et al. (*2002) found that maize crop coefficient (K_C) values were 0.74, 0.91, 1.11 and 0.27 for June, July, August and September, respectively. Whereas, Abdel-Maksoud *et al.* (2008) stated that the K_C values were 0.53, 0.74, 0.99, 0.71 and 0.62 for the abovementioned months, respectively

As for the effect of compost application, it is well known that soil organic matter plays a key role in the soil system and is an important regulator of numerous environmental constraints to crop productivity. Negassa et al. (2001) stated that the applied compost supplied the crop with considerable amounts of different essential macro- and micronutrients. Therefore, the integrated use of compost and low rates of inorganic fertilizers should be used to sustain maize production and productivity. Furthermore, compost addition practice plays a very active role in increasing nutrients availability and the crop yield (Baloch *et al.,* 2004; Rajput *et al.,* 2004; Ayodele and Omotoso, 2008 and Zhang *et al.,* 2009). Response of crops to apply inorganic fertilizer depends on native organic matter content in the soil or that supplied as organic fertilizers, Agboola and Omueti (1982). The plants taken up N from the soil in simple inorganic form nitrate and ammonium which are released from decomposing of complex organic compounds due to action of microorganisms via a process known as mineralization. Concerning effect of organic fertilizer on water relations, Abdou (2004); Sial *et al.* (2007)

and Mohsin *et al.* (2012) found that the most pronounced effects of the added organic amendments to either clay or sandy soils are the significant improvement in soil water retention and transmission. Mbau et al. (2015) stated that compost treated plots recorded maize grain yields representing an increase ranging from 50 to 93 % in Buyangu and 77–100 % in Ivakale above the control. Masood *et al.* (2014) in a pot experiment, found that farmyard manure (FYM) improves various soil parameters and to a large extent, the availability of water and nutrient to crops when it is applied to the soil. The authors added that plant height, root and shoot yield, and NPK uptake of maize were increased compared with the control or recommended NPK.

The aim of the present study is to investigate the effect of three compost rates and three irrigation levels and interactions in order to find out the most proper combination resulted in acceptable figures of maize yield, yield components and water productivity as well.

MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of El-Areish Agricultural Research station, North Sinai Governorate, Egypt. The farm is located at 33.82 longitude, 31.12 latitude and 4.10 m altitude above the mean sea level, during the summer seasons of 2014 and 2015.Some soil hydro-physical constants and bulk density of the experimental site are shown in Table 1. The aim of the study was to determine the effect of irrigation water level and compost rate and interaction on maize growth yield, yield components, some chemical constituents of maize and crop - water relations as well. To achieve these targets, three irrigation water levels i.e. 1800, 2100 and 2400 $m^3 fed^{-1}$ $season^{-1}$ and three compost rates i.e. without compost supplying (control), 2 and 4 ton fed^{-1} were arranged in a split- plot design with three replicates.

Table 1: Soil hydro-physical constants and bulk density of the experimental site.

Soil depth (cm)	Bulk density (gcm^{-3})		Field Capacity (%, w/w)		Wilting Point (%, w/w)		Available soil water (%, w/w)	
	2014	2015	2014	2015	2014	2015	2014	2015
·0-15	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

Samples of irrigation water and surface soil layer (00 - 30cm) were initially collected before conducting the experiment to determine particle size distribution, soil texture and some chemical characteristics according to Ryan *et al.* (1996) and data are listed in Tables 2 and 3. Concerning maize grains and stover chemical analyses, total nitrogen was determined by wet oxidation using Kjeldahl digestion and distillation procedures ,Parkinson and Allen (1975) and chlorophyll contents (mg dm^{-2}) were determined as described by Moran (1982). Phosphorous was determined calorimetrically using ammonium molybdate and ammonium metavanadate according as described by Ryan *et al.* (1996). Potassium was determined using the flame spectrophotometer method (Black, 1982).

Maize seeds (Single-Cross 10 hybrid) were sown at 15 kgfed^{-1} rate on June, 1 and 3 in 2014 and 2015 summer seasons, respectively. To ensure full germination, 60 mm of irrigation water was applied for all the sub plots at sowing with an additional irrigation of 80 mm were applied 20 days later for complete establishment of seedlings. Irrigation was executed at 4 days interval along the growing season. The tested irrigation levels were distributed on 23 irrigation events and reached to about 12, 14 and 17mm/irrigation under 1800, 2100 and 2400 m^{3}fed^{-1} levels, respectively. Irrigation time, to apply the appropriate water quantity, was determined based on dripper's number per plot and actual dripper discharge, Lh^{-1} and application efficiency as 90%. The assessed compost rates were supplied during seed bed preparation, and some of its chemical characteristics are shown in Table 4. Fertilization was managed according to the recommendation of the Ministry of Agriculture in Egypt, where superphosphate and potassium sulphate fertilizers were applied before ridging at 30 kg P_2O_5 and 48 kg K_2O fed^{-1} rates, respectively. Nitrogen fertilizer at 100 kgNfed^{-1} rate was applied in four equal portions (at 20, 35, 50, and 65 days after sowing, DAS) in the form of ammonium sulphate (20.6 %N).The adopted N fertilizer dose was thoroughly dissolved in a proper water quantity and the supernatant was injected into the irrigation system. The other common cultural practices for maize production were executed.

Table 2: Soil particle size distribution and some chemical characteristics of the experimental site.

Characters		2014	2015
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
pH (1:2.5)		8.46	7.80
$CaCO_3$ (%)		18.52	20.10
EC_e (dSm^{-1}), soil paste extract		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

Table 3: Chemical analysis of the irrigation water.

Characters		**2014**	**2015**
pH		7.3	7.2
EC_e dSm^{-1}		5.08	5.28
Soluble cations ($meqL^{-1}$)	Ca^{+2}	8.2	8.7
	Mg^{+2}	5.2	5.5
	Na^{+}	37.6	38.7
	K^{+}	0.1	0.1
Soluble anions ($meqL^{-1}$)	HCO_3^{-}	4.8	4.3
	Cl^{-}	39.7	41.6
	SO_4^{--}	6.6	7.1

Table 4: Some chemical characteristics of the used compost.

Properties	**2014**	**2015**
pH (1:10 compost : Water suspension)	6.83	6.61
EC dSm^{-1} (1:10 compost: Water extract)	1.64	1.53
O.M., %	28.83	29.17
O.C. , %	16.72	16.92
Total N, %	0.85	0.92
C / N ratio	19.67	18.39
Available P, %	0.433	0.048
Available K, %	0.551	0.568

Harvesting was executed on September, 23 and 25, respectively in 2014 and 2015 seasons. Ten plants were chosen randomly from the two inner rows of each sub-plot and plant height (cm), ear length (cm), ear diameter (cm), and 100- grain weight (g) were recorded. In addition, stover and grain yields ($tonfed.^{-1}$) were determined based on the whole sub plot area, and sampled for determining N, P and K contents. Grain protein content was estimated via multiplying N% by 6.25. Furthermore, at 35 and 50 DAS plant height, fresh and dry weights per plant were recorded and chlorophyllous pigments content was determined as well.

Data collected for the studied variables were subjected to statistical analysis using MStat computer package to calculate F ratio according to Snedecor and Cochran (1980). The means were compared using Least Significant Difference (LSD) at 5% level according to Waller and Duncan (1969).

Crop- water relationships:

1- Monthly and seasonal evapotranspiration (ETc):

The crop water consumptive use between each two successive irrigations was calculated according to the equation given by Israelsen and Hansen (1962) as follows:

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

Where:

Cu = consumptive use or actual evapotranspiration (cm).

D = Effective root zone depth (cm).

Bd = soil bulk density (gcm^{-3}).
Q_2 = soil moisture content (%, w/w) after irrigation.
Q_1 = soil moisture content (%, w/w) before the next irrigation.

2- Reference evapotranspiration (ETo)

The reference evapotranspiration (ETo) in $mmmonth^{-1}$ was calculated using the monthly averages of El-Areish metrological data and FAO Penman-Monteith equation (Allen *et al.*, 1998) and the CROPWAT model (Smith, 1991). The agro-meteorological data and the calculated ETo values are recorded in Table 5.

Table 5: The monthly averages of agro-meteorological data and ETo for North Sinai Governorate during 2014 and 2015 growing seasons.

Month	Year	Temperature C^o			Relative Humidity (%)	Wind speed ($msec^{-1}$)	ETo ($mmday^{-1}$)
		Max	Min	Mean			
June	2014	37.0	19.8	28.4	35.7	4.2	6.34
	2015	35.3	19.0	27.1	40.4	4.2	6.30
July	2014	38.1	21.1	29.6	38.8	3.8	6.46
	2015	38.2	21.1	29.6	37.4	3.7	6.39
August	2014	38.4	21.9	30.1	41.4	3.6	6.20
	2015	39.7	23.8	31.7	40.7	4.0	6.08
September	2014	35.4	20.6	28.0	45.8	3.5	5.24
	2015	36.2	19.8	28.0	44.2	3.6	5.03

3. Crop coefficient (Kc):

Maize crop coefficient values were estimated using the equation reported by Doorenbos and Kassam (1986) as follows:

$$K_C = ET_C / ETo$$

Where:

K_C = crop coefficient.
ET_C = the measured (actual) evapotranspiration of a considered period (mm day^{-1}).
ETo = reference evapotranspiration (mm day^{-1}) referring to the same period.

4. Water Use Efficiency (WUE, kgm^{-3}): Water use efficiency was estimated according to Jensen (1983) as follows:

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

Where:

WUE = kg grains m^{-3} water consumed.
Y= Grain yield, $kgha^{-1}$ was replaced to be $kgfed^{-1}$.
CU= Seasonal water consumptive use, m^3ha^{-1} replaced to be m^3fed^{-1}.

RESULTS AND DISCUSSION

Growth, yield and yield components parameters

1-Growth parameters

The results in Table 6 reveal that most of maize growth parameters were significantly affected the adopted irrigation water rates in 2014 and 2015 seasons. It is well known that maize is very responsive crop to the amount of irrigation water applied. So, increasing irrigation water level to 2400 $m^3 fed^{-1}$ resulted in higher values of plant height, fresh weight at 35 and 50 DAS, dry weight at 35 and 50 DAS in 2014 and 2015 seasons. These results may be attributed to the proper available soil moisture in the root zone of plants during the growing season which enhancing photosy-nthesis efficiency, cell division, stem elongation and dry matter accumulation. The obtained results are in agreements with those found by El-Tantawy *et al.* 2007 and Soleimanifard et al. (2011).

Concerning the effect of compost treatments, data in Table 6 indicate that the adopted compost rates significantly affected all the studied maize growth parameters in 2014 and 2015 seasons, except plant height and fresh weights at 35 and 50 DAS in 2014 season. In general, the highest figures of the growth parameters were recorded with compost addition at 4 $tonfed^{-1}$rate and seemed to reduce as the compost rate decreased. Such findings may be due to the role of organic manures in improving the soil microbial activity in releasing nutrients required for plant growth. These results are in harmony with those obtained Belay *et al.* 2001.

With respect to the effect of interaction of irrigation water levels and compost rates, results in Table 6 show that growth parameters significantly affected in 2014 and 2015 seasons. The highest averages of growth parameters were detected under 2400 $m^3 fed^{-1}$ level as interacted with 4 tons compost fed^{-1} rate. On the contrary, the lowest averages were obtained due to interaction of 1800 m^3 fed^{-1} and applying no compost in 2014 and 2015 seasons.

Table 6: Effect of irrigation level and compost rate and interaction on growth parameters of maize in 2014 and 2015 growing seasons.

Irrigation level (m^3 fed^{-1})	Compost rate ($tonfed^{-1}$)	Plant height (cm)	Fresh Weight 35 DAS ($gplant^{-1}$)	Fresh Weight 50 DAS ($gplant^{-1}$)	Dry Weight 35 DAS ($gplant^{-1}$)	dry Weight 50 DAS ($gplant^{-1}$)
2014 season						
1800 (I_1)	Zero, c1	168.9	191.8	368.7	45.77	125.0
	2 ton, C_2	177.4	202.5	414.6	47.42	130.6
	4 ton, C_3	190.6	209.9	468.2	48.13	137.1
Mean		179.0	201.4	417.2	47.11	130.9
2100 (I_2)	Zero, c1	175.2	217.5	387.4	49.62	125.1
	2 ton, C_2	184.9	233.2	422.7	51.06	131.9
	4 ton, C_3	197.1	244.1	479.8	51.29	145.7
Mean		185.7	231.6	430.0	50.66	134.7
2400 (I_3)	Zero, c1	182.2	248.3	402.1	55.79	127.6
	2 ton, C_2	190.4	259.8	439.7	56.05	138.6
	4 ton, C_3	200.9	267.7	493.2	55.77	152.7
Mean		191.1	258.6	445.0	55.87	139.7
Compost mean						
Zero ton, C_1		175.4	219.2	386.1	50.39	125.9
2 ton, C_2		184.2	231.8	425.7	51.51	133.7
4 ton, C_3		196.2	240.6	480.4	51.73	145.2
L.S.D at 0.05						
I		16.38	13.03	N.S	0.91	2.70
C		N.S	N.S	14.68	NS	2.25
I x C		10.60	30.37	25.43	4.35	3.91
2015 season						
1800 (I_1)	Zero, c1	157.9	171.6	319.7	43.2	122.0
	2 ton, C_2	165.8	179.5	371.1	44.57	138.2
	4 ton, C_3	175.7	192..1	438.1	46.89	159.8
Mean		166.5	181.1	376.3	44.89	140.0
2100 (I_2)	Zero, c1	164.5	193.4	344.1	47.23	125.0
	2 ton, C_2	175.1	204.7	393.2	48.95	141.2
	4 ton, C_3	183.4	215.8	464.6	49.78	158.4
Mean		174.4	204.6	400.0	48.65	141.5
2400 (I_3)	Zero, c1	169.6	218.6	368.4	53.51	129.5
	2 ton, C_2	178.3	221.4	418.0	51.60	142.3
	4 ton, C_3	191.1	232.9	470.9	53.26	153.5
Mean		179.7	224.3	419.1	52.79	141.8
Compost mean						
Zero ton, C_1		164.0	194.5	344.1	47.98	125.5
2 ton, C_2		173.1	201.9	394.1	48.37	140.61
4 ton, C_3		183.4	213.6	457.9	49.98	157.3
L.S.D at 0.05						
I		N.S	12.12	12.16	2.49	5.53
C		8.29	6.35	10.96	4.00	5.38
I x C		14.37	11.01	18.98	6.91	4.03

2- Grain and stover yields and yield components

The results in Table 7 reveal that the averages of yield and its components were significantly affected due to the adopted irrigation water levels in 2014 and 2015 seasons.

Table 7: Effect of irrigation level and compost rate and interaction on yield and yield components of maize in 2014 and 2015 growing seasons.

Irrigation level (m^3 fed^{-1})	Compost rate ($tonfed^{-1}$)	Ear length (cm)	Ear diameter (cm)	100- grain weight (g)	Stover yield ($tonfed^{-1}$)	Grain yield ($tonfed^{-1}$)
2014 season						
1800 (I_1)	Zero, c1	14.63	4.12	21.38	6.84	2.13
	2 ton, C_2	15.85	4.78	22.74	7.32	2.35
	4 ton, C_3	17.15	5.18	23.57	9.01	2.82
Mean		15.88	4.69	22.56	7.72	2.47
2100 (I_2)	Zero, c1	15.72	4.73	22.25	7.84	2.39
	2 ton, C_2	17.32	5.55	23.15	9.49	2.80
	4 ton, C_3	19.28	6.12	25.29	10.87	3.30
Mean		17.44	5.47	23.56	8.40	2.83
2400 (I_3)	Zero, c1	17.85	5.37	25.87	9.32	2.76
	2 ton, C_2	18.22	6.10	27.63	9.82	3.23
	4 ton, C_3	20.68	6.42	31.71	12.80	3.58
Mean		18.92	5.96	28.40	10.65	3.19
Compost mean						
Zero ton, C_1		16.07	4.74	23.17	8.00	2.43
2 ton, C_2		17.13	5.48	24.51	8.88	2.79
4 ton, C_3		19.04	5.91	26.86	10.89	3.23
L.S.D at 0.05						
I		0.47	0.78	1.11	0.51	0.07
C		1.05	087	0.89	0.23	0.06
I x C		1.82	1.52	1.54	0.04	0.11
2015 season						
1800 (I_1)	Zero, c1	13.38	4.00	20.61	5.51	1.99
	2 ton, C_2	14.21	4.55	21.78	6.37	2.19
	4 ton, C_3	15.56	5.13	22.51	7.40	2.57
Mean		14.38	4.56	21.63	6.43	2.25
2100 (I_2)	Zero, c1	15.88	4.57	21.18	7.21	2.27
	2 ton, C_2	15.36	4.93	22.58	7.49	2.65
	4 ton, C_3	17.40	5.37	24.52	8.73	2.91
Mean		16.21	4.96	22.76	7.81	2.61
2400 (I_3)	Zero, c1	16.79	5.03	24.35	7.51	2.54
	2 ton, C_2	16.20	5.25	26.86	9.35	3.06
	4 ton, C_3	18.13	5.77	28.88	10.44	3.37
Mean		17.04	5.35	26.70	9.10	2.99
Compost mean						
Zero ton, C_1		15.35	4.53	22.05	6.74	2.27
2 ton, C_2		15.26	4.91	23.74	7.74	2.63
4 ton, C_3		17.03	5.42	25.30	8.86	2.95
L.S.D at 0.05						
I		1.89	1.09	2.20	0.44	0.07
C		N.S	0.63	N.S	0.34	0.01
I x C		4.42	1.09	4.60	0.58	0.02

The highest average values of grain yields (3.19 and 2.99 $tfed^{-1}$) were obtained with 2400 m^3fed^{-1} of irrigation water in 2014 and 2015 seasons, respectively. Reducing the irrigation level to be 2100 or 1800 m^3fed^{-1} induced reductions in grain yield reached to 11.29 and 22.57% in 2014 season and 17.04 and 20.56% in 2015 season, respectively, comparable with 2400 m^3fed^{-1}level.The stover yield and yield attributes under study exhibited similar trends, where the highest figures of ear length, ear diameter and 100- grain weight were obtained under 2400 m^3fed^{-1}level, respectively, in 2014 and 2015 seasons comparable with 1800 and 2100 m^3fed^{-1} levels. The obtained results are in agreement with those found by El-Tantawy *et al.* (2007), El-Hendawy *et al.* (2008), Payero et al. (2009) and Farre and Faci (2009).

Data in Table 7 reveal that the averages of grain and stover yields and yield components were significantly differed due to the investigated compost rates in 2014 and 2015 seasons, except ear length and 100-grain weight in 2015 season. Supplying compost at 4 $tonfed^{-1}$ resulted in the highest values of grain yield (3.23 and 2.95 $tonfed^{-1}$in 2014 and 2015 seasons, respectively. Reducing compost rate exhibited lower grain yield values amounted to (13.62 and 24.77%) and (10.85 and 23.05%) due to supplying the compost at 2 $tonfed^{-1}$ rate and without compost addition, respectively, compared with 4 $tonfed^{-1}$ rate in 2014 and 2015 seasons. The yield attributes and stover yield exhibited similar trends, where the highest values in 2014 and 2015 seasons were attained with 4 $tonfed^{-1}$ rate and tended to reduction with reducing the compost rate. The improved values of grain and stover yields and yield attributes as well are attributed to the favorite effects of compost addition on soil water holding capacity, Abdou (2004) and soil edaphic conditions, Baloch *et al.,* 2004; Rajput *et al.,* 2004; Ayodele and Omotoso, 2008 ; Zhang *et al.,* 2009 and Mbau et al. (2015).

The results in Table 7 indicate that averages of maize yield and its components were significantly affected by the interaction of the adopted irrigation water levels and compost rates in 2014 and 2015 seasons. The highest averages of yield and yield components were observed from interaction of irrigation at 2400 m^3fed^{-1} level and applying compost at 4 $tonfed^{-1}$rate, whereas, the lowest ones were obtained from irrigation at 1800 m^3fed^{-1} level as interacted with without compost.

3-Some chemical constituents

Contents of chlorophyllous pigments, N, P and K% in stover and N, P, K and protein% in grains were significantly influenced due to the adopted irrigation water levels in 2014 and 2015 seasons, except K and P% in grains in 2014 season and K% in stover and P% in grains in 2015 season. Data in Table 8 illustrate that 2400 m^3fed^{-1} level resulted in the highest values of the investigated chemical constituents which tended to reduction as the irrigation water level decreased and such trend was true in 2014 and 2015 seasons. These results may be attributed to that the soil moisture in the root zone was more available under the highest irrigation water level that helps increased nutrients absorption which consequently enhanced the growth, yield and chemical constituents of maize plants. These results are in agreement with those obtained by Ibrahim and Hala (2007).

Table 8: Effect of irrigation level and compost rate and interaction on some chemical constituents of maize in 2014 and 2015 growing seasons.

Irrigation level ($m^3\ fed^{-1}$)	Compost rate ($tonfed^{-1}$)	Ch a in leaves (50DAS)	Ch b in leaves (50DAS)	Ch a+b in leaves (50DAS)	Stover			Grains			
					N (%)	P (%)	K (%)	N (%)	P (%)	K %	Protein (%)
2014 season											
1800 (I_1)	Zero, 1	2.455	0.783	3.238	0.23	0.20	1.12	1.59	0.33	0.29	9.24
	2 ton, c_2	2.845	0.923	3.768	0.26	0.21	1.23	1.73	0.36	0.31	9.88
	4 ton, c_3	3.352	1.043	4.395	0.28	0.23	1.27	1.78	0.40	0.33	10.26
Mean		2.884	0.916	3.800	0.26	0.21	1.21	1.70	0.36	0.31	9.79
2100 (I_2)	Zero,c1	2.581	0.875	3.456	0.25	0.23	1.23	1.64	0.36	0.30	9.77
	2 ton,c_2	3.111	1.088	3.866	0.29	0.23	1.35	1.75	0.40	0.32	10.24
	4 ton,c_3	3.720	10126	4.846	0.30	0.27	1.36	1.80	0.43	0.35	10.78
Mean		3.137	1.030	4.056	0.28	0.24	1.31	1.73	0.40	0.32	10.26
2400 (I_3)	Zero, c1	2.581	0.875	3.456	0.25	0.23	1.23	1.64	0.36	0.30	9.77
	2 ton, c_2	3.111	1.088	3.866	0.29	0.23	1.35	1.75	0.40	0.32	10.24
	4 ton, c_3	3.720	10126	4.846	0.30	0.27	1.36	1.80	0.43	0.35	10.78
Mean		3.227	1.156	4.332	0.32	0.26	1.38	1.78	0.42	0.38	10.37
Compost mean											
Zero ton, C_1		2.563	0.925	3.489	0.25	0.23	1.23	1.64	0.36	0.32	9.62
2 ton, C_2		3.049	1.062	3.999	0.29	0.23	1.32	1.75	0.39	0.34	10.16
4 ton, C_3		3.636	1.114	4.700	0.30	0.26	1.36	1.82	0.43	0.36	10.64
L.S.D at 0.05											
I		0.143	0.082	0.202	0.04	0.04	0.07	0.01	N.S	N.S	0.22
C		0.097	0.045	0.125	0.45	0.03	0.08	0.08	0.04	N.S	0.27
I x C		N.S	0.080	N.S	0.80	N.S	0.14	0.06	0.05	N.S	NS
2015 season											
1800 (I_1)	Zero, c1	2.333	0.746	3.903	0.21	0.18	1.08	1.57	0.31	0.27	9.03
	2 ton, c_2	2.728	0.893	4.217	0.25	0.21	1.18	1.69	0.35	0.30	9.72
	4 ton, c_3	3.132	0.968	0.027	0.26	0.22	1.23	1.74	0.38	0.31	10.01
Mean		2.731	0.869	3.600	0.24	0.20	1.16	1.67	0.35	0.29	9.585
2100 (I_2)	Zero, c1	2.428	0.810	3.907	0.24	0.20	1.17	1.66	0.34	0.29	9.545
	2 ton, c_2	2.917	0.996	4.486	0.27	0.22	1.30	1.73	0.38	0.34	9.95
	4 ton, c_3	3.488	1.071	0.044	0.28	0.25	1.32	1.79	0.42	0.34	10.29
Mean		2.944	0.959	3.903	0.26	0.22	1.26	1.73	0.38	0.32	9.929
2400 (I_3)	Zero, c1	2.571	1.094	3.621	0.26	0.22	1.29	1.71	0.37	0.33	9.83
	2 ton, c_2	3.071	1.117	4.100	0.30	0.23	1.34	1.69	0.41	0.35	9.72
	4 ton, c_3	3.672	1.127	3.238	0.32	0.26	1.39	1.85	0.45	0.39	10.64
Mean		3.105	1.113	4.217	0.29	0.24	1.34	1.75	0.41	0.35	10.06
Compost mean											
Zero ton, C_1		2.444	0.883	3.327	0.24	0.20	1.18	1.65	0.34	0.30	9.468
2 ton, C_2		2.905	1.002	3.907	0.27	0.22	1.27	1.70	0.38	0.33	9.795
4 ton, C_3		3.431	1.055	4.486	0.29	0.24	1.31	1.79	0.42	0.35	10.31
L.S.D at 0.05											
I		0.735	0.071	0.109	N.S	0.12	NS	0.04	NS	0.04	0.24
C		0.108	0.080	0.134	N.S	0.03	0.07	0.05	0.03	0.03	0.28
I x C		N.S	N.S	N.S	N.S	0.06	0.13	NS	0.06	0.56	0.31

Regarding the effect of the assessed compost rates, significant influences were exerted to alter the chemical constituents under study in 2014 and 2015 seasons, except K% in grains in 2014 season and N% in stover in 2015 season. Data in Table 8 indicate that the highest values of the studied chemical were obtained due to supplying 4 ton of compost fed^{-1} in 2014 and 2015 seasons. Whereas, without addition compost produced the lowest values in 2014 and 2015 seasons. These results may be due to the potency of compost (organic matter) in stimulating amino acids building and growth hormones as well, which in turn gave positive action on genetic factors that control the various metabolic processes. The obtained results are in agreement with those reported by Masood et al. (2014) who stated that increasing levels of FYM, NPK uptake of maize were increased compared with the control or recommended NPK.

The results in Table 8 show that the interaction of irrigation water levels and compost rates in 2014 were significant to influence chlorophyll b, N% and K% in stover, N and P% in grains, whereas, in 2015 the interaction was significant to affect P and K% in stover, P, K and protein% in grains. The highest values were mostly resulted from 2400 m^3fed^{-1} of irrigation water level as interacted with 4 $tonfed^{-1}$ compost rate in 2014 and 2015. Whereas, the lowest values of chemical constituents were attained due to interaction of 1800 m^3fed^{-1} level and without compost addition, and such trend was true in the two seasons of study.

I- Crop water relations

1-Seasonal evapotranspiration (ET_a)

The results in Table 9 indicate that seasonal ET_a of maize as a function of the adopted irrigation water levels and compost rates were 44.3 and 42.6 cm in 2014 and 2015 seasons, respectively. The seasonal ET_C values were increased, as irrigation water level increased. Increasing irrigation water level from 1800 to 2100 or 2400 m^3fed^{-1} caused an increase in seasonal ET_a reached to 6.47 and 12.23% and 5.68 and 10.37%, respectively, in 2014 and 2015 season comparable with 1800 m^3fed^{-1} level. These results may be referred to that decreasing the irrigation water level $season^{-1}$ decreased the available soil moisture in the root zone of plants which in turn reduce the transpiration from plant canopy and the evaporation from the soil surface as well. These results are in agreement with those reported by Sharaan *et al.* (2002) and El-Tantawy *et al.* (2007).

Regarding the effect of compost rate on seasonal ET_a, data in Table 9 show that the highest ET_a values e.g. 45.9 and 44.6 cm were recorded with compost addition at 4 $tonfed^{-1}$,which are higher than those under 2 $tonfed^{-1}$ rate and without compost addition by (3.05 and 7.41%) and (4.04 and 9.19 %), respectively, in 2014 and 2015 seasons. These results are in agreement with those reported by Abdou (2004), Sial *et al.* (2007), Mohsin *et al.* (2012) and Masood et al. (2014) who found that increasing levels of organic matter, for maize crop, resulted in increased soil water content compared with the control or recommended NPK.

Data in Table 9 indicate that the highest ET_a values e.g.48.3 and 46.4cm in 2014 and 2015 seasons, respectively, resulted due to interaction of irrigation at 2400 m^3 irrigation water level and 4 $tonfed^{-1}$ of compost rate.

These results may be due to that increasing compost level to 4 ton fed^{-1} and applying 2400 m^3 water fed^{-1} increased N availability to plants and soil moisture availability which gave vigorous vegetative growth and this in turn increased transpiration from plants and evaporation from soil. On the contrary, interaction of 1800 m^{3}fed^{-1} of irrigation water level and without addition compost rate attained the lowest ET_a values which comprised 39.9 and 38.3cm, respectively, in 2014 and 2015 seasons.

Table 9: Effect of irrigation level, compost rate and interaction on seasonal evapotranspiration (ET_a, cm) of maize in 2014 and 2015 seasons.

Compost rate	Irrigation level							
	2014 season				2015 season			
	1800 m^{3}fed^{-1}	2100 m^{3}fed^{-1}	2400 m^{3}fed^{-1}	Mean	1800 m^{3}fed^{-1}	2100 m^{3}fed^{-1}	2400 m^{3}fed^{-1}	Mean
Zero compost	39.9	42.2	45.4	42.5	38.3	40.4	42.9	40.5
2 tonfed^{-1}	41.8	44.9	46.7	44.5	40.5	43.2	44.8	42.8
4 tonfed^{-1}	43.3	46.2	48.3	45.9	42.6	44.9	46.4	44.6
Mean	41.7	44.4	46.8	44.3	40.5	42.8	44.7	42.6

2- Reference evapotranspiration (ETo, mmday^{-1})

The daily ET_O rates (mmday^{-1}) during the two growing seasons of 2014 and 2015 are shown in Table 10. The daily ET_O values were estimated using the daily meteorological data of North Sinai Governorate and the procedures of FAO- Penman Monteith equation from June to September in 2014 and 2015 seasons. The results show that ET_O values were started high during June and July, then decreased gradually during August and September and such trend was true in 2014 and 2015 seasons. These results may be attributed to the changes in the weather factors from month to the other. These results are confirmed with those reported by Allen *et al.* (1998), which mentioned that the ET_O values are mainly depending on the evaporative power of the air in the around area, i.e. temperature, wind speed, relative humidity and solar radiation.

3- Crop coefficient (K_C)

The K_C reflects the influence of crop cover percentage on the ETo values during different growth stages. The K_C values were calculated from daily ET_a and daily ETo rates of the same period from planting to harvest as shown in Table 10. Data reveal that the K_C values for the highest seed yield interaction (irrigating with 2400 m^{3}fed^{-1} season^{-1} and supplying 4 ton of compost fed^{-1}) were started low during June (initial growing season). Thereafter, the K_C values increased during July (establishment and rapid vegetative growth stages) and reached its maximum values at August (maximum growth and heading stages). The K_C values decreased again during September (maturity and harvesting stages). The obtained results trend was similar in 2014 and 2015 seasons. Such findings may be referred to the high diffusive resistance of the bare soil during initial growing stage (June), which reduced by increasing the crop cover percentage until maximum vegetative growth (July) and anthesis stage (August). However, at late season (September) the transpiration decreased sharply, as most leaves became dry. These results are in the same trend with those reported by Abdou (2004).

Table 10: Reference evapotranspiration ETo (mmday^{-1}), daily ET_a (mmday^{-1}) and crop coefficient (K_C) values of maize under the highest yielding interaction (I_3C_3) in 2014 and 2015.

Month	2014 season			2015 season		
	ET_O (mmday^{-1})	ET_C (mmday^{-1})	K_C	ET_O (mmday^{-1})	ET_C (mmday^{-1})	K_C
June	6.34	2.71	0.43	6.30	2.57	0.41
July	6.46	6.19	0.96	6.39	6.02	0.94
August	6.20	4.90	0.79	6.08	4.64	0.76
September	5.24	2.77	0.55	5.03	2.77	0.46

4- Water Use Efficiency (WUE)

The WUE values expressed as, kg seeds m^{-3} of water consumed by the crop plants are presented in Table 11. The results show that the water use efficiency values, as a function (overall average) of irrigation water levels and compost rates were 1.51 and 1.45 kg seeds m^{-3} water consumed in 2014 and 2015 seasons, respectively. Irrigating at 2400 m^{3}fed^{-1} level gave the highest WUE values e.g. 1.62 and 1.59 kg seeds m^{-3} water consumed in 2014 and 2015 seasons, respectively. The WUE with 2400 m^{3}fed^{-1} level surpassed those with 2100 and 1800 m^{3}fed^{-1} by (6.79 and 14.20 %) and (8.81 and 16.98 %), respectively, in 2014 and 2015 seasons. These results may be due to the remarkable increase in grain yield more than the increase in ETa. These results are in harmony with those of Abdou (2004); El-Tantawy et al. (2007) and El-Hendawy and Schmidhalter (2010) who reported that yield variables and water use efficiencies (WUEs) were increased with increasing irrigation frequency and rate. Furthermore, water utilization efficiency for harvested yield (Ey) for grain varies between 0.8 and 1.6 kgm^{-3} (FAO Water Development and Management Unit, 2015).

Regarding the effect of compost addition, applying 4 tonfed^{-1} rate resulted in the highest WUE values (1.67 and 1.57 kgseedsm^{-3} water consumed), which surpassed 2 tonfed^{-1}rate and without compost supplying by (10.78 and 18.56%) and (7.00 and 15.29%), respectively, in 2014 and 2015 seasons. It is evident that compost supplying improved WUE for maize could be attributed to the resultant higher grain yield. These results are in the same line to those found by Abdou (2004) Sial *et al.* (2007) and Mohsin *et al.* (2012).

The interaction of the highest both irrigation water level (2400 m^{3}fed^{-1}) and compost rate (4 tonfed^{-1}) resulted in the highest WUE figures which comprised 1.76 and 1.73 kg seedsm^{-3} water consumed in 2014 and 2015 seasons, respectively.

Table 11: Effect of irrigation water level, compost rate and interaction on water use efficiency (kg grainsm^{-3}) consumed water of maize crop in 2014 and 2015.

Compost rate	Irrigation level							
	2014 season				2015 season			
	1800 m^3fed^{-1}	2100 m^3fed^{-1}	2400 m^3fed^{-1}	Mean	1800 m^3fed^{-1}	2100 m^3fed^{-1}	2400 m^3fed^{-1}	Mean
Zero compost	1.27	1.35	1.45	1.36	1.24	1.34	1.41	1.33
2 tonfed^{-1}	1.34	1.48	1.65	1.49	1.29	1.46	1.63	1.46
4 tonfed^{-1}	1.55	1.70	1.76	1.67	1.44	1.54	1.73	1.57
Mean	1.39	1.51	1.62	1.51	1.32	1.45	1.59	1.45

On conclusion and based on the current results, it is advisable to apply irrigation with 4200 m^{3}fed^{-1} level and supplying the compost at 4 tonfed^{-1} rate interaction to accomplish both acceptable maize yield and water utilization figures under Al-Arish conditions.

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انتاجية الذرة وبعض العلاقات المائية المتأثرة بكميات الرى ومعدلات الكمبوست

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أقيمت تجربتان حقليتان خلال الموسم الصيفي ٢٠١٤ و ٢٠١٥ فى محطة البحوث الزراعية – العريش – شمال سيناء لدراسة تأثير مستويات مياه الرى هي ١٨٠٠، ٢١٠٠ ، ٢٤٠٠ م^{3}ف$^{-1}$ بالاضافة الى ثلاث معدلات من الكمبوست هي صفر (بدون إضافه) و ٢ و ٤ طن فدان$^{-1}$ علي النمو والمحصول ومكوناته وكذلك بعض المكونات الكيميائيه والعلاقات المائية في الذرة الشامية .استخدم تصميم القطع المنشقه مرة واحده في اربعة مكررات واختبرت مستويات الري في القطع الرئيسية وتمثلت معدلات الكمبوست في القطع المنشقة وفيما يلي ملخص لأهم النتائج المتحصل عليها:

١- تأثرت معظم قياسات النمو والمحصول ومكوناته وكذلك المكونات الكيميائيه معنويا بمستويات الري ومعدلات إضافة الكمبوست تحت الدراسة في كلا الموسمين.

٢- سجلت أعلي القيم للنمو (آرتفاع النبات- الوزن الطازج والجاف عند ٣٥ ،٥٠ يوم من الزراعة) ومكونات المحصول (طول الكوز- قطر الكوز- وزن ال١٠٠ حبه) ومحصولي الحبوب والقش بالاضافة الي المكونات الكيميائية (كلوروفيل أ ، ب ، أ+ ب - % للنيتروجين والفسفور والبوتاسيوم في كلا من القش والحبوب - % للبروتين في الحبوب) والاستهلاك المائي وكفاءة استخدام المياة مع مستوي الري ٢٤٠٠ م^{3}ف$^{-1}$ و اتجهت هذه القيم للانخفاض التدريجي بنقص مستويات الري ولوحظ هذا الاتجاه في كلا الموسمين.

٣- اضافة الكمبوست بمعدل ٤ طن فدان$^{-1}$ أعطي القيم الأعلي لكل الصفات السابقة الذكر أعلاه وذلك في كلا الموسمين مقارنة بعدم الاضافة ومعدل ٢ طن فدان$^{-1}$.

٤- تفاعل مستوي الري ٢٤٠٠ م^{3} ف$^{-1}$ ومعدل ٤ طن فدان$^{-1}$ من الكمبوست أظهر القيم الأعلي من الصفات سابقة الذكر ، و كانت قيم معامل المحصول هي ٠.٤٢ ، ٠,٩٥ ، ٠,٧٨ ، ٠,٥١ لشهور يونيو - يوليو - أغسطس - سبتمبر علي الترتيب (متوسط للموسمين لهذا التفاعل). وعلية ينصح بتطبيق هذا التفاعل (تحت ظروف المنطقة التي اقيم بها البحث) للحصول علي قيم عالية من المحصول النهائي للاذرة الشامية وكذلك الاستخدام الأمثل لمياه الري.