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Impact of Planting Dates on Irrigation Requirements and Water Productivity of Maize in Egypt Delta

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Abstract: Future water supply in Egypt largely will depend on the severity of impacts from climate change which are still uncertainty. However, it is clear that water will be the most critical constraint to agriculture. Field experiments were carried out during summer seasons of 2007 and 2008 in Zanklon Water Research Station, Sharkia, Governorate, Egypt, to study the effect of planting dates (5 planting dates) and three irrigation regimes (60, 80 and 100% of Etc) on yield, water productivity, applied water and actual evapotranspiration in order to select the most appropriate planting date to adopt with climate change. The obtained results indicated that, the interaction effect between planting dates and irrigation levels was significant on grain yield per hectare. Grain yield was decreased by 15.2, 10.2, 11.4 and 23.5% for D1, D2, D4 and D5 planting dates respectively. For irrigation regimes, the obtained data showed that, applying 60 and 80% of the ETc significantly reduced grain yield by 11 and 24.4%. The highest grain yield per hectare was obtained from planting date on June 11 (D3) and irrigation level of 100% of the ETc (I1). The obtained data indicated that the highest value of water productivity (WP) was achieved from D3 followed by D4 while the lowest value was obtained from D1. With respect to irrigation levels, the highest value of WP was achieved at I1 followed by I2 while the lowest value was obtained at I3. Actual evapotranspiration (ETc) values were reduced by (21.9, 17.0, 11.1 and 5.6)% for D1, D2, D3 and D4 respectively comparing to D5. With respect to irrigation levels, the ETc values were gradually increased as the available soil moisture increased at the root zone while exposing plants to soil water deficit decreased the ETc. Applied water (AW) was 824, 788, 758, 723 and 685 mm for planting dates treatments D1, D2, D3, D4 and D5 respectively. These results revealed that using D3 treatment resulted in water saving about 9 and 4% with respect to planting at D1 and D2 respectively. Multiple regression analysis was used to estimate grain yield, applied water and actual evapotranspiration under different climate conditions, the obtained results showed significant correlation between grain yield, applied water and actual evapotranspiration and climate factors (max and min temperature, relative humidity, wined speed and sunshine duration). A prediction model was determined for grain yield (Y), applied water (AW) and actual evapotranspiration (ETc) as function of the previous parameters.

Key words: Climate factors · Planting date · Applied water · Water productivity · Irrigation regime · Evapotranspiration

INTRODUCTION

In Egypt, water is considered a scarce natural resource for crop production. The water demand for agriculture is about 85% of the total available water. With the rapid population increase, serious water shortage will be accrue and critical constrains will face the agricultural development [1]. The great challenge for the coming decades will therefore be the task of increasing food production with less water especially in arid and semiarid areas [2].

Maize is the world's third most important crop after rice and wheat. About 50 % of maize production is grown in developing countries such in Egypt, i.e. in Sub-Saharan

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Africa, where maize is a staple food for an estimated 50 % of the population and provides 50 % of the basic calories. Production and water relations of maize have been widely investigated by many researchers. Several investigators indicated that, planting dates has a marked effect on maize yield. Planting dates as well as amount of water in each irrigation are the most important factors that play a great role in maize production. The most proper planting date realize optimum season length and grain yield as a result of suitable climate conditions prevailing through the growth stages of maize.

Climate change may have negative future impacts on water and food security. Hence, several studies worldwide have been investigated to evaluate the impacts of climate change on water availability and on agriculture production. There is a significant concern about the impacts of climate change and its variability on agricultural production worldwide. First, issues of food security figure prominently in the list of human activities and ecosystem services under threat of dangerous anthropogenic interference on Earth's climate [3].

Bishr and Shalaby [4] found that, the maize grain yield per hectare in Eastern Delta to be lower at October, November and December, while the highest yields were obtained from 1st May to 1st July plantings. Romison and Dele Ahinleye [5] mentioned that yield and yield components were higher by sowing dates in early than in late planting dates. El-Ashmoony [6] concluded that early planting date (20 May) gave higher yield than the other planting dates. Abdel-Aziz, [7] reported that, grain yield reached the maximum values with planting on Jun 20 then it decreased significantly as planting date delayed. Khedr *et al*. [8] found that planting on mid May lengthened silking period and increased plant height, whereas mid June produced the highest means of grain yield. Salem [9] found that, medium planting date in June 5th gave higher grain yield and greatest values from most ear characters than the other two d ates (5th May and 5th July). El-Marsfawy [10], Ibrahim *et al*. [11], El-Shafeei, [12] and El-Sabagh *et al*. [13] reported that, the growth characters of grain yield of maize were increased by increasing the available soil moisture.

Khalifa [14] found that the temperature effects decreased with increasing soil water content. Tubiello *et al*. [15] described that warmer temperatures accelerated plant phenology and reduced dry matter accumulation by 20%. They also found that maize growing cycle was shortened by 16 days and actual evapotranspiration was reduced by 70 mm. Norwood [16] stated that, earlier planting decreased both maize yield and water use efficiency. The highest yields and water use efficiency achieved with the late planting date combined with later maturing hybrids and higher plant populations.

Xiong Wei *et al*. [17] studied the effect of climate change on water availability and cereal production in China. They found that water availability will be reduced due to the combined effects of higher crop water requirements (due to climate change) and increasing demand for non-agricultural use of water (due to socio-economic development). Without adaptation, per capita cereal production falls in all cases, by up to 40 % of the current baseline. And climate change leading to decreases in total production by 18 %.

Matarira [18] reported that, the Global Climate Models (GCMs) and dynamic crop growth models were used to assess the potential effects of climate change on agriculture in Zimbabwe. These effects were estimated for maize. Its growth is increasingly coming under stress due to high temperature and low rainfall conditions. Projected climate change causes simulated maize yields to decrease dramatically under dry-land conditions in some regions (in some cases up to 30 %), even under full irrigation conditions. The reduction in modeled maize yields is primarily attributed to temperature increases that shorten the crop growth period, particularly the grain-filling period, thereby causing dramatic negative effects on yields. There are several potential adaptation strategies that may be used to offset the negative impacts of climate change on maize yields. These include switching to drought-tolerant maize varieties and appropriate irrigation management practices.

If the climate becomes hotter and drier, however, maize production will decrease by approximately 10-20 % over the next 50 years and specialty crops grown in specific environmentally favorable areas may be at risk [19]. Various planting dates were tested to evaluate the climate change effects on Maize. Maize production shows a considerable amount of variation under climate change conditions. Maize planted late will not give good yields, thus making maize production a less viable activity under climate change conditions [20].

Based on a range of several current climate models, the mean annual global surface temperature is projected to increase by 1.4 to 5.8°C over the period of 1990 to 2100 [21] with changes in the spatial and temporal patterns of precipitation Southworth, *et al*. [22] and Raisanen, [23]. Semi-arid areas already suffering from limited availability of water under current conditions are likely to be most sensitive to climate change, while sub-humid areas may be less adversely affected [24, 25].

Eid *et al*. [26] indicated that, the calculated water use for maize was 688 mm while the total applied water was 106 mm with an application efficiency of 65 %. Abou El-Azem *et al*. [27] found that, water requirements for maize was 842 mm, water consumptive use 540 mm and water productivity was 0.73 $kg.m^{-3}$ when seven irrigations were given excluding the planting irrigation. Khedr *et al*. [28] reported that water consumptive use of maize was 666 mm at Sakha. El-Refaie and Khater [29] found that the water requirements of maize was 786 mm. Khalil *et al*. [30] reported that the evaporation pan coefficient which be recommended for scheduling irrigation of maize was 1.0 and the seasonal water consumptive use values were 460 and 491 mm in the first and second seasons respectively. They added that, the best interaction between irrigation regime, nitrogen and potassium levels (1.0 accumulative evaporation pan 30 $kgN.ha^{-1}$ and 120 $K_2O.ha^{-1}$ which gave the maximum grain yield).

Abdel-Aziz *et al*. [31] indicated that the values of water consumptive use by maize ranged from 547 to 747 mm. El-Garhi *et al*. [32] reported that, the water consumptive use values were 637, 669, 706 and 750 mm for 0.8, 1.0, 1.2 and 1.4 (irrigation water: cumulative pan effective for maize grown in Middle Egypt).

The aim of this investigation is to study the effect of planting date and irrigation regime on consumptive water use, applied water and yield of maize crop in Egypt Delta to find out the most suitable planting date under changing different climate factors. In addition to evaluate the adaptation possibilities with introducing alternative managements and perceptions to the water resources decision makers.

MATERIALS AND METHODS

Two field experiments were conducted during two successive summer seasons 2007 and 2008 in clay soil at Water Management Research Station, of Water Management and Irrigation Systems Research Institute in Sharkia Governorate, Egypt. This site is located at 30°-35 N. latitude and 30°-57 E. longitudes with an elevation of 7 m above msl. The location represents the conditions and circumstances of Nile Delta region. Soil samples were collected to determine some soil physical and chemical properties of the experimental site. The average values of these measurements at different soil depths are presented in Table 1. Meteorological data of the experimental site are presented in Fig. 1.

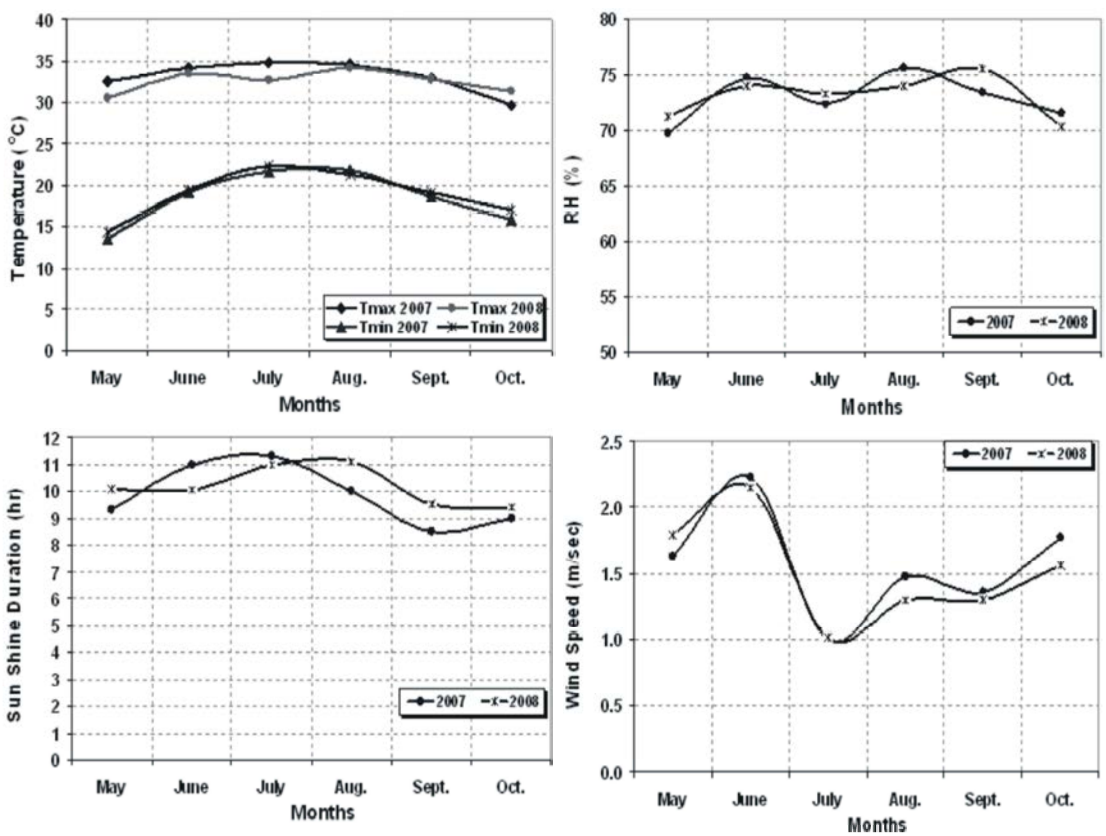

Fig. 1: Metrological data of Zankalon Water Research Station for the growing seasons 2007 and 2008.

Table 1: Some oil physical and chemical properties of the experimental site

Depth (cm)	Sand %	Silt %	Clay %	Texture	Bulk density (g cm^{-3})	Field capacity (%)	Wilting point (%)	Available water (%)	E.C (dS m^{-1})	pH
0-15	25.80	29.69	44.51	Clay	1.25	43.51	23.55	19.96	1.40	8.1
15-30	25.12	31.38	43.50		1.27	40.50	21.06	19.44	1.22	8.0
30-45	26.00	32.20	41.80		1.35	37.12	17.59	19.53	1.25	8.0
45-60	26.70	33.00	40.30		1.41	36.27	16.64	19.64	1.05	8.0
Average	25.91	31.57	42.50		1.32	39.35	19.71	19.64	1.23	8.03

The experiments were performed to study the effect of climate factors (represented in planting dates) and irrigation levels on growth, yield and some yield attributes as well as some water relations of TWC-323 maize cultivar. The normal cultural treatments for growing maize were practiced as recommended. All plots received the same level of NPK during the field preparation, calcium superphosphate (15.5 % P_2O_5) was added at rate of 239 kg.ha^{-1} and potassium as potassium sulfate form (48 % K2O) at a rate of 119 kg.ha^{-1} were applied on one dose at the field preparation. Nitrogen fertilizer was given urea (46% N) at a rate of 285 kg ha^{-1} in three equal portions, i.e. before the first, second and the third irrigations.

The experiments were laid out in a split-plot design with four replications. The planting dates were arranged in the main plots, while the sub plots were assigned for irrigation treatments. The net area of each plot was 150 m^2 with a 1.5 m distance apart between plots and it constitutes of 15 ridges. The distance between rows was 80 cm and the distance between in the row plants was 22 cm to attain the population density of 57140 plants ha^{-1} during the two growing seasons.

Planting Dates: To represent the effect of different climate factors on maize yield and water relations, different planting dates were evaluated with intervals of 15 days, these dates are: D1: May 10, D2: May 25, D3: June 11, D4: June 26 and D5: July 11.

Irrigation Levels: Water amount for irrigation levels was calculated based on actual evapotranspiration (ETc) rate during every growing season. Calculations of reference evapotranspiration (ETo) were determined according to the meteorological data at the experimental site using modified Penman-Monteith equation [33], then the crop coefficient (Kc) was obtained from FAO-56 [2] consequently the ETc was calculated as following:

$$ET_C = K_C \, x \, ET_O \qquad (1)$$

Three irrigation levels were applied; 100 % (I1), 80 % (I2) and 60 % (I3) of ETc.

Growth, Yield and Some Yield Attributions: At harvesting, random samples of ten plants were selected from each sub-plot in order to measure the plant height and yield characteristics:

- Plant height (cm)
- Ear height (cm)
- Ear diameter (cm)
- Ear length (cm)
- Grain weight per ear (g)
- 100-kernel weight (g)
- Grain yield (ton.ha^{-1})

Water Relations

Irrigation Applied Water: The irrigation water used for the experiments had the typical water quality for the region with EC of 0.4 dS m^{-1}. Improved surface irrigation was used and the amount of irrigation water applied for each treatment during growing seasons were measured by calibrated flowmeter for each irrigation. Irrigation water was transmitted to each plot through polyethylene pipes of 6 inches diameter and there was a valve in front of each plot. Consequently controlling distribution of irrigation water for each plot was achieved. Sowing irrigation was given an equal amount for all treatments until soil saturation. First irrigation was started after 21 days from planting according to treatments of planting dates then the irrigation intervals were determined based on Class A pan.

Actual Evapotranspiration (ET_C): The actual evapotranspiration ETc was measured using gravimetric soil samples on 15 cm intervals down to 60 cm were taken at sowing before and two days after every irrigation as well as at harvest time to determine the ET_C of maize crop according to Israelsen and Hansen [34], using the following formula:

$$ET_C = DxBd\ (Q_2 - Q_1)100 \quad (2)$$

where:

ET_C : Actual evapotranspiration (mm),
D : Soil depth (cm),
B_d : Bulk density ($g.cm^{-3}$),
Q_1 : Soil moisture (%) before next irrigation,
Q_2 : Soil moisture (%) 48 hours after irrigation,

The actual evapotranspiration (ETc) values are given in Fig. 4. The reference evapotranspiration (ETo) [33] was 651 mm in 2007 and 655 mm in 2008.

Water Productivity (WP): Water productivity was calculated using the following equation:

$$WP_C = \frac{Grain\ Yield\ (kg.ha^{-1})}{Applied\ Water\ Use\ (m^3.ha^{-1})}\ kg\ m^{-3} \quad (3)$$

Regression and Correlation Coefficients: Simple correlation coefficients, means, standard deviation and standard error for maize grain yield and some of climate factors were studied and multi-liner regression was computed to study the nature of the relationship between climate factors and evapotranspiration, irrigation requirements and grain yield according to Droper and Smith [35] as following:

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + \ldots\ldots\ldots b_n X_n \quad (5)$$

where:

X_1 = Maximum temperature (°C)
X_2 = Minimum temperature (°C)
X_3 = Wind speed ($m.s^{-1}$)
X_4 = Sunshine hours (h)
X_5 = Relative humidity (%)
X_6 = Actual evapotranspiration (mm)
X_7 = Applied water (mm)
Y = Grain yield ($ton.ha^{-1}$)

Statistical Analysis: Data collected for each season were subjected to proper statistical analysis and the combined analysis of the two seasons were applied according to the method adopted Snedecor and Cochron [36]. The treatments means were compared using least significant differences (L.S.D) method.

RESULTS AND DISCUSSIONS

Growth, Yield and Some Yield Attributions

Growth Criteria: Data in Table 2 indicated that, the plant height and ear length were significantly affected by planting dates. Planting on June 11 (D3) gave higher values than the other planting dates. The increase in the plant height and ear length as a result of planting date (D3) may be attributed to more suitable environmental conditions prevailing during the growth period. This result is in agreement with those obtained by Bishr and Shalaby [4], Remison and Dele Akinleye [5] and Salem [9].

Regarding the irrigation regimes, the obtained data showed that, increasing amount of irrigation levels from 60 to 100 % of ETc significantly increased plant height and ear length. Irrigation with 100 % of ETc (I1) achieved the maximum plant and ear height. Such result may be attributed to the promoting effect of water applied on vigour and vegetative growth. Data also indicated that plant height and ear length were significantly decreased with applying 60 % of ETc (I3) such decrease may be attributed to the decrease in the activity of meristematic tissues responsible for elongation. The highest and lowest plant height and ear length values were obtained at I1 and I3 treatments respectively. These results are in agreement with the findings of El-Marsfawy [10] and Khalil *et al.* [30].

Yield Components: Combined analysis of variance during the two growing seasons indicated that, planting dates has significant influence on all characteristics of yield components. The mean values are shown in Table 2. The results indicated that, the highest mean values of ear diameter, ear length, grain weight/ear and 100-kernels weight were observed for D3 treatment (June 11) followed by D4 (June 26), D2 (May 25) and D5 (July 11) treatments respectively. However the lowest one was observed at D1 treatment (May 10). The differences between treatments D1 and D5 were insignificant for ear height, D2 and D4 for plant height and D2 and D5 for ear diameter, 100-kernel weight and grain weight per ear respectively. These results are in agreement with those obtained by Bishr and Shalaby [4], Remison and Dele Ahinleye [5] and Salem [9].

For irrigation regimes, the statistical analysis revealed that, the different irrigation treatments had significant effects on all studied treatments. The average values are presented in Table 2. Ear diameter, ear length, grain weigh.ear^{-1} and 100-kernel weight were significantly affected by irrigation treatments. Applying I3 treatment (60 % of ETc) caused a significant reduction for all studied treatments. In this respect, no significant difference were detected for plant height, 100-kernel weight and grain yield per ear between treatments I1 (100 % of ETc) and I2 (80 % of ETc). These results can be

Table 2: Effect of planting dates and irrigation levels on some yield components of maize crop (combined analysis of two summer growing seasons).

Treatments	Plant height (cm)	Ear height (cm)	Ear diameter (cm)	Ear length (cm)	Grain weight/ear (g)	100-kernel weight (g)
Planting Date						
D_1	244.90 d	143.21 d	4.28 d	17.78 c	265.50 d	32.60 d
D_2	252.68 b	149.40 c	4.55 c	19.75 c	275.40 c	34.41 c
D_3	260.12 a	158.83 a	4.88 a	21.93 a	283.20 a	36.50 a
D4	253.20 b	154.13 b	4.66 b	20.53 b	280.50 b	35.24 b
D5	248.00 c	145.57 d	4.47 c	18.93 d	274.00 c	34.20 c
F test	**	**	**	**	**	**
Irrigation Regime						
I_1	258.68 a	157.60 a	4.86 a	22.20 a	285.60 a	37.06 a
I_2	252.26 a	150.40 b	4.53 b	19.60 b	277.60 a	35.14 a
I_3	244.40 b	142.68 c	4.31 c	17.56 c	263.96 b	31.57 b
F test	**	**	**	**	**	**
Interaction						
D x I	N.S	N.S	N.S	N.S	**	N.S

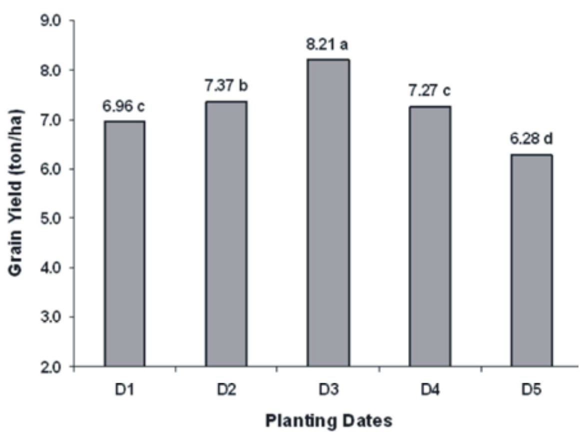

Fig. 2: Effect of planting date on grain yield of maize

attributed to the bad effects of water stress on leaf area, physiological processes, vegetative and reproductive growth and dry matter accumulation and translocation when compared with non stressed plants, [37]. These results matched with those obtained by Ainer [38], Ibrahim *et al*. [11], El-Shafeei [12], El-Sabbagh *et al.* [13] and Abou El-Azem *et al.* [27].

Grain Yield: Figure 2 illustrated that grain yield was significantly affected by planting dates as average for both seasons (combined analysis). Grain yield was increased with planting date on June 11 (D3) treatments as compared to the other dates. Grain yield was decreased by 15.2, 10.2, 11.4 and 23.5 % for D1, D2, D4 and D5 treatments respectively. The decrement in grain yield as a result of early planting dates (D1 and D2) and late planting dates (D4 and D5) treatments might be attributed to the unstable climatic conditions prevailing during the growth and development such as light intensity, temperature and diseases. Also the depression in yield of maize by planting on D1 and D5 are mainly attributed to the increase in the total number and percentage of barren stalks, borer infestation and to the decline in number of ears per plant and average of weight of ear, [9].

The effect of day and night temperature, photoperiod and water deficit on the growth stages of sorghum reveals that planting date and water use are two principle limiting factors for high crop production [39] and they showed that sorghum grain yield and its component were decreased when planting date delayed from June 24 to July 14.

In this respect, various planting dates were tested to evaluate the effect of climate factors on maize yield and water use. Maize production shows a considerable amount of variation under climate change conditions. Maize planted late will not give good yields, thus making maize production a less viable activity under different climate conditions [20].

These results can be attributed to the different climate factors affect on growth stages duration on each planting date which affects on the dry matter accumulation and translocation to reproductive organs. These results are in agreement with those obtained by Bishr and Shalaby [4], El-Aashmoony [6], Salem [9], Matarira [18], Tubiello *et al*. [15], Matarira *et al.* [20], Francisco *et al*. [40] and XiongWei *et al*. [17].

For irrigation regimes, Fig. 3 illustrated that, irrigation regime is significantly affected on the grain yield. Applying amount of water as 60 and 80 % of the Etc (I2 and I3) caused a significant reduction for grain yield by 13 and 14.9 % respectively compared to I1 (100 % of ETc). El-Naggar *et al*. [41] showed that, maize production was increased by decreasing the depletion of available soil moisture. It could be concluded that, grain yield was increased

Table 3: Effect of interaction between planting dates and irrigation levels on maize grain yield (combined analysis of two growing seasons).

	Grain weight ear^{-1} (g)					Grain yield (ton ha^{-1})				
Treatments	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5
I1	276.0	285.5	294.0	288.5	284.0	6.960	7.366	8.207	7.267	6.277
I2	267.0	281.0	287.0	280.0	273.0	6.200	6.683	7.136	6.143	5.903
I3	253.5	259.7	268.6	273.0	265.0	5.560	6.056	6.977	5.837	5.503
L.S.D at 0.05	3.9					0.29				

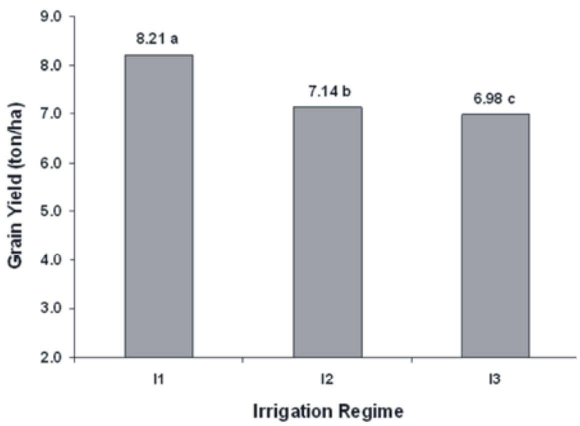

Fig. 3: Effect of irrigation regime on grain yield of maize

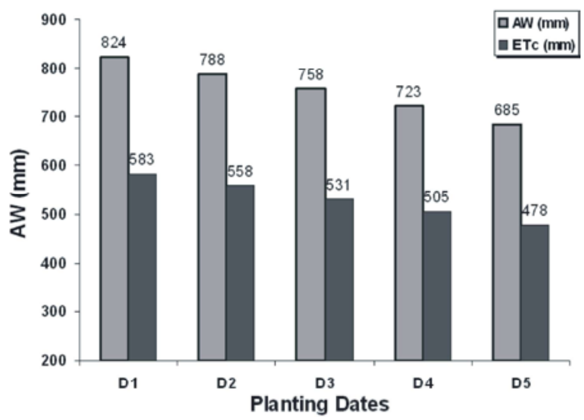

Fig. 4: Effect of planting dates on applied water (AW) and actual evapotranspiration (ETc)

with increasing available water. This increase may be attributed to the significant role of available water in affecting 100-kernel weight, [30]. These results are in agreement with those obtained by Abdel Aziz [7], Khedr *et al*. [8], El-Shafeei [12], Khedr *et al*. [28], El-Sabbagh *et al.* [13], Abou El-Azem *et al.* [27]. Generally irrigation with 100 % of the ETc and planting in June 11 (D3) gave the highest yield.

Interaction: The interaction effect of planting dates and irrigation levels was significant on grain yield per hectare. Data in Table 3 showed that the highest grain yield per hectare was obtained from planting date D3 (June 11) and irrigation level of 100 % of the ETc. whereas the lowest one was obtained from planting date of D1 (May 10) and irrigation level of 60 % of the ETc.

Water Relations

Irrigation Water Applied (IWA): IWA as affected by planting dates and irrigation levels are presented in Figure 4. The results indicated that the average of IWA values for the two growing seasons were 824, 788, 758, 723 and 685 mm for planting dates treatments D1, D2, D3, D4 and D5 respectively. These results indicate that D1 received the highest value of IWA while the D5 received the lowest value of IWA. These results revealed that using D3 treatment resulted water saving about 9 % and 4 % with respect to planting at D1 (May 10) and D2 (May 25) respectively. Similar results were reported by Salem [9] and El-Garhi *et al.* [32]. Regarding to irrigation levels (Fig. 4), the IWA values were 836, 769 and 662 mm for 100 %, 80 % and 60 % irrigation level treatments respectively. These results matched with that obtained by Eid *et al*. [26], El-Refaia and Khater [29], Khalil *et al*. [30] and El-Garhi *et al*. [32].

Actual Evapotranspiration (Etc): Actual evapotranspiration (ETc) as affected by changing the climate factors (planting dates) and irrigation levels are recorded in Fig. 4 as average of the two growing seasons. Regarding to planting dates, the ETc values were reduced by 21.9, 17.0, 11.1 and 5.6 % for D1, D2, D3 and D4 respectively compared to D5. Such reduction is mainly due to different climate factors prevailing during growth and development stages (i.e. evaporation, sunshine hours and temperature). These findings are in fully agreement with those obtained by Khedr *et al*. [8], Abdel-Aziz *et al.* [31] and El-Garhi *et al*. [32].

With respect to irrigation levels (Fig. 5), the ETc values were gradually increased as the available soil moisture increased at the root zone (i.e. irrigate maize plants with enough water increased ETc values) while exposing plants to soil water deficit caused a decrement

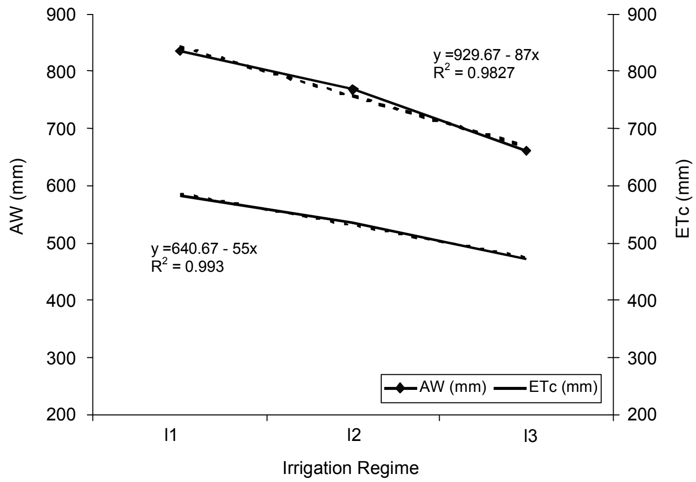

Fig. 5: Effect of irrigation regime on applied water and actual evapotranspiration

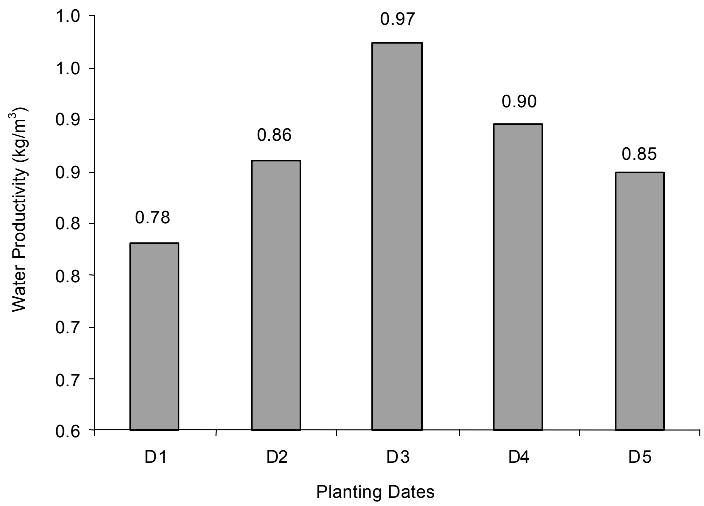

Fig. 6: Effect of planting date on water productivity of maize

in ETc. This trend is agreement with those obtained by Metwally *et al*. [42], who found that water consumptive use was increased with increasing water applied. However subjecting maize plants to water stress reduced the ETc. Talha *et al*. [43] concluded that the average values of transpiration rate was decreased with decreasing the available soil moisture level at the root zone. In this respect, Ghazy [44] stated that the irrigation treatment at 40 % depletion of available soil moisture consumed water more than other treatments which were irrigated at 85 % depletion of available soil moisture. These results are in agreement with those obtained by Eid *et al*. [26], Khalifa [14], Khedr *et al*. [28], Abou El-Azem *et al*. [27] and El-Garhi *et al*. [32].

Water Productivity (WP): Values of water productivity expressed as the grain production of maize in kg per m^3 of water consumed as affected by planting dates and irrigation levels as average of the two growing seasons are presented in Fig. 6. The obtained data indicated that the highest value of WP was achieved from D3 (June 11) followed by D4 (June 26) while the lowest value was obtained from D1 (May 10). This likely due to the early planting (treatment D1) was unsuitable for growth stages of maize plants specially temperature and sunshine hours, hence decrease grain yield, as a result of not adopted climate factors. The relative increase in WP were 19.4, 10.8, 7.5 and 10.8 % for planting dates of D1, D2, D4 and D5 respectively compared to D3 (which is recommended as the most suitable period of climate factors for maize growth). The observed trend was that WP decreases as the irrigation water applied increases.

Table 4: Simple correlation coefficients, means, standard deviation and standard error for maize grain yield and some climate factors over both seasons (2007 and 2008)

	Variables	Mean	Standard deviation	Standard error	Coefficient of variation
X_1	Maximum temperature (°C)	33.290	00.974	23.470	0.896**
X_2	Minimum temperature (°C)	19.070	01.469	0.805	0.893**
X3	Wind speed ($m.sec^{-1}$)	1.380	00.229	0.205	0420*
X_4	Sunshine duration (h)	10.060	00.570	3.000	0.914**
X_5	Relative humidity (%)	67.340	5.968	1.046	0.921**
X_6	Actual evapotranspiration (mm)	530.720	40.691	0.169	0.708**
X_7	Water applied (mm)	755.710	53.732	0.067	0.851**
Y	Grain yield ($ton.ha^{-1}$).	6.532	00.541	0.052	-

* Significant at 5% level ** Significant at 1% level

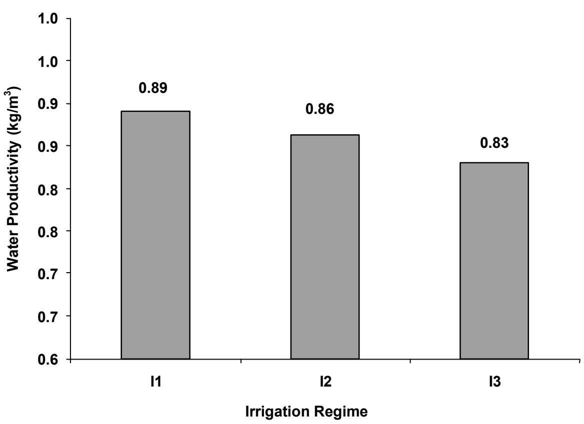

Fig. 7: Effect of irrigation regime on maize water productivity

With respect to irrigation levels, the WP values as shown in Fig. 7 indicated that the highest value of WP was achieved at I1 (100 % of ETc) followed by I2 (80 % of ETc) while the lowest value was obtained at I3 (60 % of ETc). This result might be due to high grain yield from I1 and low grain yield from I2 and I3 due to the water stress on the maize crop. It can be concluded that, I1 seemed to be better adopted and more efficient compared to I2 and I3. This result is agreement with those obtained by Norwood [16], Khalil *et al*. [30] and El-Garhi *et al*. [32].

Regression and Correlation Coefficients: Simple correlation coefficients, mean values, standard deviation and standard error for the studied variables are presented in Table 4. The results show that, yield of maize was correlated with X_2, X_6 and X_7, with high significant positively and negatively with X_1, X_3 and X_5 respectively. Similar results were obtained by Anier *et al*. [38].

Prediction Model of Maize Yield: The multiple regression analysis was used to estimate the grain yield of maize from studied climate. These climate factors are maximum and minimum temperature, wined speed, sunshine hours and relative humidity. The other related factors are water applied and water consumptive use. The multiple regression equation was as follows:

$$Y_1 = 74.495 - 2.303 X_1 + 0.577 X_2 - 1.967 X_3 + 3.499 X_4 - 0.564 X_5 + 0.095 X_6 - 0.630 X_7 \quad R^2 = 0.929$$

where:

Y_1 = Grain yield of maize ($ton.ha^{-1}$)
X_1 = Maximum temperature (°C)
X_2 = Minimum temperature (°C)
X_3 = Wind speed ($m.s^{-1}$)
X_4 = Sunshine hours (h)
X_5 = Relative humidity (%)
X_6 = Actual evapotranspiration (mm)
X_7 = Water applied (mm)

In this respect the correlation coefficient was highly significant $(0.964)^{**}$.

The previous equation shows that the relative contribution (R^2) of all variables, affected on the grain yield of maize by 0.929. From the foregoing results it can be concluded that the previous multiple regression equation can be used as a tool to predict the grain yield of maize from the climate factors to estimate the most suitable planting date for maize production. Doorenbos *et al*. [45] concluded that the climate factors which determine maximum yield of maize are temperature, radiation and length of total growing season in addition to any specific temperature and day length requirements for crop development.

Prediction of Applied Water (AW): The multiple regression analysis was used to estimate the consumptive use from the factors study. In this model the factor study are maximum and minimum temperature, wined velocity, sunshine duration, relative humidity, water applied. The multiple regression equation was as follows:

$Y_2 = 302.166 - 8.295\, X_1 + 1.575\, X_2 + 6.253\, X_3 + 13.605\, X_4 - 1.949\, X_5 + 1.291\, X_6\; R^2 = 0.899$

where:

Y_2 = Water applied (mm)
X_1 = Maximum temperature (°C)
X_2 = Minimum temperature (°C)
X_3 = Wind speed ($m.s^{-1}$)
X_4 = Sunshine hours (h)
X_5 = Relative humidity (%)
X_6 = Actual evapotranspiration (mm)

In this respect the correlation coefficient was highly significant $(0.899)^{**}$. The previous equation shows that the relative contribution (R^2) of all variables, affected on the water applied by 0.899. From the foregoing results it can be concluded that the previous multiple regression equation we can be used as a good tool for irrigation engineers and decision makers to predict the irrigation requirements using the previous parameters.

Prediction of Actual Evapotranspiration (ET_C): The multiple regression analysis was used to estimate the consumptive use from the factors study. In this model the factor study are maximum and minimum temperature, wined velocity, sunshine duration, relative humidity, water applied.

The multiple regression equation was as follows:

$Y_3 = 242.805 + 6.561\, X_1 - 1.239\, X_2 - 1.798\, X_3 - 10.460\, X_4 + 1.603\, X_5 + 0.766\, X_7\; R^2 = 0.887$

where:

Y_2 = Actual evapotranspiration (mm)
X_1 = Maximum temperature (°C)
X_2 = Minimum temperature (°C)
X_3 = Wind speed ($m.s^{-1}$)
X_4 = Sunshine hours (h)
X_5 = sRelative humidity (%)
X_6 = Water applied (mm)

In this respect the correlation coefficient was highly significant $(0.887)^{**}$. The previous equation shows that the relative contribution (R^2) of all variables, affected on the water consumptive use by 0.887. From the foregoing results it can be concluded that the previous multiple regression equation we can be used as a good tool for irrigation engineers and decision makers to predict the actual crop evapotranspiration using the previous parameters.

CONCLUSION

This study is aims to find out the most suitable planting date under changing the different climate factors in order to recommend a suitable decision for irrigated maize production. It could be concluded that the interaction effect o f planting dates and irrigation levels was significant on grain yield per hectare. The highest grain yield per hectare was obtained from planting date in June 11 and irrigation level of 100 % of the ETc (I1).

It is recommended to grow maize on June 11 whereas the highest value of water productivity (WP) was achieved and resulted water saving which indicates that the climate factors at that date are most suitable environment for growing maize followed by June 26. It means that low temperature planting date is not suitable for maize growth while increasing temperature up to certain level could affects negatively on the maize production and consumptive water use.

Regarding to irrigation levels, it could be concluded that, decreasing soil moisture content affects negatively on maize production the highest. In water shortage situations 80 % of ETc could be used with very slightly reduction in grain yield.

Actual evapotranspiration (ETc) values were reduced and applied water (AW) was decreased with advancing the planting dates from May 10 to July 10 at the same time the ETc values were gradually increased as the available soil moisture increased at the root zone while exposing plants to soil water deficit decreased the ET_c.

The most effective climate factors which determine maximum yield of maize are temperature, radiation. Also the length of total growing season is affecting on the yield of maize. From the obtained results it can be concluded that the developed and calibrated equations can be used as a good tool for irrigation engineers and decision makers to predict the irrigation requirements using the climate parameters and predict the maize yield under different climatic conditions.

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