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Water Requirements and Irrigation Scheduling Maize Crop by Empirical Equations Using Lysemters

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ABSTRACT

A lysimeters experiment was designed to study how to manage irrigation scheduling using different empirical equations compared to traditional irrigation method. Design of experiment was random block with three replicates. The experiment was repeated in two successive seasons (2016 and 2017) using maize crop. Four irrigation treatments were used as $T_1$for traditional, T_2 by Belany - Criddle equation, T_3 by Radiation equation and T_4 by penman equation. All irrigation treatments were inserted by 70% of soil water depletion. The results showed that T_3 had the highest values of water productivity (0.89 kg/m^3) and productivity of irrigation (0.63 kg/m^3) as an overall average of the two seasons. Data revealed also that T_1 had the highest overall mean values applied water and water consumptive use (3862.47 m^3/fed &2826.02 m^3/fed). The results indicated that the highest values for grain yield was recorded by irrigation treatment T_3 with values of 2013.90 and 1925.53 kg/fed as well as 16.33 and 18.37cm for ear length in the first and second season, respectively. Also, 100 grain weight and plant height had the highest values by treatment T_3 as compared to treatment T_1, T_2 and T_4. Under the condition of this study recommends that, the farmers under the experimental area who cultivate maize crop should irrigate every 11 days to maximize the productivity for crop and both of water productivity and productivity of irrigation water.

INTORDUCTION

Maize (*Zea mays, L*) is the 2nd essential summer crop in Egypt after rice. Cultivated area of maize is about 2215000 Fadden in 2016 with 7177000 ton of grain production (Statistical Yearbook Agriculture, 2017). Because of water scarcity and the progressively decrease of annual capita of water in Egypt (water poverty), it is essential to develop new technologies not only to acquire more water but also to perform new strategies for irrigation scheduling to decrease water use and to raise water use efficiency (WUE) in many places of the world, especially in Egypt (Sepaskhah *et al.*, 2007). Crops water requirements and irrigation scheduling for crops are rely on weather conditions in a site. Applied water amount for crop is linked with the calculation of reference evapotranspiration (ET_o), (Ouda *et al.,* 2015). A lysimeter experiment plot was conducted to study how the irrigation intervals could affect plant-water relation and their consequences on crop production. Bhat *et al.* (2017) showed that the irrigation management model (CROPWAT Model) can estimate the crop water requirements. Calculated evapotranspiration and crop water requirements permit the development of recommendation for improving irrigation management, the planning of irrigation schedules under different water supply condition and yields drop under various conditions. Therefore, maize crop was cultivated in two successive seasons (2016 & 2017). Scheduling of irrigation was managed using three emperical equations: Blaney- criddle, Radiation and Penman equations compared with traditional irrigation and evaluate their effects on yield, yield attributes and some water relations.

MATERIALS AND METHODS

An experiment with lysimeters (80 cm in diameter and 200 cm in height), was conducted during the two successive seasons of summer 2016 and 2017 for maize crop in Agricultural Research Station, Sakha, Kafr EL-Sheikh Governorate. The site is existed at 31° - 07′ N latitude, `30°-57′ E longitude with 6 meters elevation above mean sea level. The soil properties are shown in Table (1). Four irrigation treatments with 3 replicates were performed as following:

T_1: irrigation by traditional practice as performed by farmers

T_2: irrigation by 70% depletion of available water using Belany - Criddle equation.

T_3: irrigation by 70% depletion of available water using radiation equation.

T_4: irrigation by 70% depletion of available water using Penman equation.

Table 1. Some soil physical properties in the lysemeters.

Soil depth (cm)	Particle size distribution (%)			Texture class	FC (%)	WP (%)	Bulk density (g/cm^3)
	Sand	Silt	Clay				
0 – 30	30.25	44.5	25.25	Loam	27	13.5	1.07
30 – 60	28.25	45.75	26.00	Loam	27	13.5	1.07
Mean	29.25	45.125	25.625	Loam	27	13.5	1.07

The daily meteorological data were obtained from Amber program mobile for weather (www. amberweather. com) during the two seasons (2016 and 2017) to calculate ET_0.

Maize grains, cultivar triple cross (360), were sown in 16th May 2016 in the 1st season and in 2nd May 2017 in the 2nd season. Harvesting was in 20th September 2016 and in 6th September 2017, respectively. Seven corn grains were sown in 20 cm apart at each lysemeter.

Super phosphate and potassium fertilizer were added in 200 and 45 kg/fed as (15.5%P_20_5) and Potassium sulphate (48% K_2O), respectively. 90 kg N/Fed (as urea 46.5%N) was added in three doses after planting of maize. The first dose was before planting as activator dose, the second dose was before the first irrigation (EL-Mohaya irrgation) and the third does was before the second irrigation.

Maize plants were harvested after 127 days from planting. Five plants were randomly taken from each lysimeter. The following parameters: plant height (cm), ear length (cm), 100-grain weight (g) and grain yield/Fed (kg) were measured.

Applied Irrigation water (A.I.W):

Soil moisture content was gravimetrically determined from 0-30 depth and 30- 60 cm. Soil samples of every irrigations were taken periodically until it reached the desirable level of soil moisture. The required for each irrigation quantity was determined on the basis of raising the soil moisture content to its field capacity plus 10 % as leaching requirements. Three methods: Blany - Criddle method, radiation method and Penman equation were used to calculate ET_0 according to Doorenbos and Pruitt (1992) as follows:

1- Blaney - Criddle method:

$$ET_0 = a + b\{p(0.46T + 8.13)\}\ \text{mm/day}$$

Where:

ET_0 : Reference crop evapotranspiration (mm.day^{-1})

a & b : Two coefficients it depended on minimum relative humidity (RH) , sun shine hours ratio (n/N), day time and wind speed.

P = Mean daily percentage of total annual day time hours, it was received from especial table for a given month and latitude.

T =Mean daily temperature °c.

2-Radiation method:

$$ET_0 = C(W * R_S)\ \text{mm/day}$$

Where:

ET_o: Reference crop evapotranspiration (mm.day^{-1})

C: factor depends on mean humidity, day time and wind conditions

W: factor related to temperature and altitude

R_s: Solar radiation in equivalent evaporation in mm.day^{-1}.

3- Penman method:

$$ET_O = c\,[W.R_n + (1-w).f(u).(ea-ed)]$$

Where:

ET_O = reference crop evapotranspiration in mm.day^{-1}

W = factor related to altitude and temperature

R_n = net radiation in equivalent evaporation in mm.day^{-1}

f(u) = wind related function

(ea-ed) = difference between the mean actual vapor pressure of the air and the saturation vapor pressure at mean air temperature (mbar)

C = adjustment factor to compensate for the effect of day and night weather conditions

Water consumptive use:

Water consumptive use (WCU) was calculated using the equation of Israelsen & Hansen (1962) as follow:

$$WCU = (\theta_2 - \theta_1)/100 \times B.d \times D \times 4200$$

Where:

WCU = Consumptive use (m3/fed)

θ_2 = % Soil moisture content after irrigation.

θ_1 = %Soil moisture content before irrigation.

B.d = Bulk density (Mg.m^{-3}).

D = Soil layer depth (m).

Water efficiencies:

Water productivity for applied water (IWP):

It is defined as the weight of economical crop production per applied irrigation water as cubic meter.

Amount of irrigation applied water (m3/fed):

was computed according to Giriappa (1983) .

$$Wa = IW + Re$$

Where:

Wa = irrigation water applied amount.

IW = Irrigation water applied.

Re = Effective rainfall.

Irrigation water efficiencies:

Irrigation water productivity for applied water (IWP) and water productivity for water consumptive use (WP) were calculated according to El-Bably *et al.* (2015) as follows:

$$IWP = \frac{yield, kg/fed.}{applied\ water\ m3/fed.}$$

$$WP = \frac{yield, kg/fed.}{\text{Water consumptive use (m3/fed)}}$$

Statistical analysis:

Analysis of variance (ANOVA) was evaluated according to Gomez & Gomez (1984). Duncan's Multiple Range Test was used to compare between means (Duncan, 1955). CoStat software for windows (version 6.3) was use to analyze data.

RESULTS AND DISCUSSION

1- Effect of irrigation intervals on yield and some yield attributes for maize crop:

The plant height, 100 grain weight, ear length and grain yield are shown in Table (2). T_3 recorded the highest values for most of yield and yield component properties in the first and second seasons. Grain yield recorded (2013.90 kg /fed & 1925.53 kg /fed.) for first and second seasons, respectively. Also, ear length showed the same trend with values of 16.33 and 18.37 cm for first and second seasons. Statistical analysis displayed highly significant differences between T_3 and other treatments in two growing seasons (2016, 2017). These results may be attributed to the less or close irrigation intervals as compared to other irrigation ones.

The results declared that weight of 100 grain (g) was significantly affected by irrigation treatments, whereby the highest value was found by treatment T_3 in the two alternative growing seasons, (42.83 and 40.77g). Increasing the values of 100 grain weight under treatment T_3 as compared to T_2 and T_4 as a resulted of additional water stress by lasted ones. It is also to note that is by treatment T_1 (traditional one) with unregularly irrigation intervals, which may cause unsuitable plant-water relationship and consequently a small ears with few numbers and small grain weight.

Table 2. Yield and some yield attributes of maize crop as affect by irrigation intervals.

Treatments	Plant height, cm	Ear length, cm	100 – Grain weight, g	Grain yield, kg/fed)
		1st season		
T1	118.53^{b}	14.10^{b}	31.06^{bc}	1453.47^{c}
T2	121.17^{a}	13.00^{b}	33.97^{b}	1563.40^{b}
T3	126.77^{ab}	16.33^{a}	42.83^{a}	2013.9^{a}
T4	90.23^{c}	12.87^{b}	27.30^{c}	1321.47^{d}
F-test	***	*	***	***
		2nd season		
T1	122.26^{b}	14.30^{c}	32.83^{c}	1452.80^{bc}
T2	123.76^{a}	15.97^{b}	36.17^{b}	1553.60^{b}
T3	136.90^{a}	18.37^{a}	40.77^{a}	1925.53^{a}
T4	100.00^{c}	12.83^{c}	28.80^{d}	1353.53^{c}
F-test	***	**	***	***

*, ** and *** indicate P<0.05, <0.01 and <0.001. Means in each column appointed by the same letter are not significantly different at 5% level by Duncan's Multiple Range Test.

Plant height was highly affected by irrigation treatmentT_3 as compared to other irrigation treatments. The values by T_3 were 126.77 and 136.90 cm in the 1st and 2nd seasons, respectively. The increasing of plant height by T_3 irrigation may be due to the optimum plant- water relationship, which resulted by such irrigation treatment and consequently more deep roots and longer plant stem. On the contrary, other irrigation treatments registered the lower values. The values were 90.23cm &100.00 cm for T_4 by the first and second seasons.

Data of plant height, 100 grain weight, ear length and grain yield are within agreement with those reported by Bhat *et al*. (2017) and Eissa *et al*. (2017), who found that slightly water stress caused a slightly significant reduction in grain yield.

2- Effect of irrigation intervals on seasonal amount of applied water:

Data in Table (3) displayed a different amount of applied water by irrigation treatments, in which T_1 (traditional) showed the maximum quantity with mean values of 3934.37 m^3/fed and 3690.56m^3/fed in the first and second season, respectively. ON the other hand, other irrigation treatments has the lowest quantities in the order of $T_4<T_2<T_3$ with mean values of 2663.48, 3009.51 and 3150.85m^3/fed. The maximum amount of irrigation water by T_1 is certainly attributed to the bulk numbers of irrigation times as compared to irrigation treatment T_4, which has lowest number of irrigation time. These results are in a good agreement with those introduced by Gharib *et al.*, (2016), Eissa *et al*., (2017) and Kumer and Jat, (2018).

Table 3. Seasonal applied water amount of maize (m^3/fed) as affect by irrigation intervals in the two growing seasons.

Treatments	1st season	2nd season	Mean of two seasons
T1	3934.37^a	3690.56^a	3862.47^a
T2	3060.47^c	2958.54^c	3009.51^c
T3	3299.83^b	3007.86^b	3150.85^b
T4	2794.32^d	2532.63^d	2663.48^d
F-test	***	***	-

***** indicate P<0.001. Means in each column appointed by the same letter are not significantly different at 5% level by Duncan's Multiple Range Test.**

3- Effect of irrigation intervals on water consumptive use:

The seasonal amount of water consumptive use was obviously affected by irrigation treatments (Table 4). The highest values were recorded under irrigation treatment T_1 (Traditional irrigation practice) with mean values of 2965.59 m^3/fed and 2686.45m^3/fed for the first and second cropping seasons, respectively. Meanwhile, irrigation treatment T_4 recorded the lowest values owing to the little number of irrigation times with the longest irrigation intervals. Mean water values by T_4 were1929.43 m^3/fed and 1697.25 m^3/fed. for the first and second seasons. The general trend of seasonal water consumptive use was in the sequence of $T_1>T_3>T_2>T_4$ with the values 2826.02, 2227.42, 2093.29 and 1813.34 m^3/fed. These results are in a good agreement with those obtained by Gharib *et al.,* (2016) and Eissa *et al* (2017).

Table 4. Seasonal amount of water consumptive use for maize crop in the two growing seasons (cm, m^3/fed) as affected by irrigation intervals.

Treatments	1st season	2nd season	Mean of two seasons
T1	2965.59^a	2686.45^a	2826.02
T2	2171.36^c	2015.22^c	2093.29
T3	2388.94^b	2065.90^b	2227.42
T4	1929.43^d	1697.25^d	1813.34
F-test	***	***	-

***** indicate P<0.001. Means in each column appointed by the same letter are not significantly different at 5% level by Duncan's Multiple Range Test.**

4-Effect of irrigation intervals on irrigation water productivity and water productivity:

Highly significant relationship between irrigation treatments and each of irrigation water productivity (IWP) as well as water productivity (WP) (Table 5). T_3 registered the highest values for both (IWP) and (WP), whileT_1 has the lowest values. The general trend for (IWP) and (WP), as related to irrigation treatments, were in the sequence of $T_3>T_2>T_4>T_1$ (IWP). Mean values for the above sequence were 0.63 kg/m^3 > 0.52 kg/m^3 >0.50 kg/m^3 > 0.38 kg/m^3, while the mean values for (WP) were 0.89 kg/m^3 > 0.75 kg/m^3 >0.72 kg/m^3 > 0.52 kg/m^3. The higher values for (IWP) or (WP) by treatment T_3 could be attributed to the optimum irrigation intervals as well as water consumptive use, whereby T_1, T_2 and T_4 treatment with lower values for (IWP) or (WP) could be due to the reverse effect of unsuitable irrigation intervals and also water consumptive. These findings are in the same agreement with this obtained by Gharib *et al*., (2016) and Eissa *et al*., (2017).

Table 5. Irrigation water productivity and water productivity as affected by irrigation intervals.

Treatment	1st season		2nd season		Mean of two seasons		1st season	2nd season
	WP, kg/m^3	IWP, kg/m^3	WP, kg/m^3	IWP, kg/m^3	WP, kg/m^3	IWP, kg/m^3	Irrigation intervals, day	
T1	0.49^d	0.36^d	`0.54^d	0.39^d	0.52	0.38	8.00^d	8.00^d
T2	0.72^b	0.51^b	0.77^b	0.52^b	0.75	0.52	11.57^b	11.57^b
T3	0.84^a	0.61^a	0.93^a	0.64^a	0.89	0.63	10.50^c	10.62^c
T4	0.68^c	0.47^c	0.76^d	0.53^c	0.72	0.50	13.50^a	13.83^a
F test	***	***	***	***	-	-	***	***

***** indicate P<0.001. Means in each column appointed by the same letter are not significantly different at 5% level by Duncan's Multiple Range Test.**

CONCLUSION

This current investigation concluded that the best treatment for all studied parameters for yield, Water productivity and productivity of irrigation water was T_3. So, this study recommends that, the farmers under the experimental area who cultivate maize crop should irrigate every 11 days to maximize the productivity for crop and both of water productivity and productivity of irrigation water.

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جدولة الرى والاحتياجات المائية لمحصول الذرة باستخدام المعادلات التجريبية تحت الليزوميترات

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أجريت تجربة ليزوميترات أسطوانية الشكل (80×200سم) في قطاعات كاملة العشوائيه بثلاث مكرارت خلال موسمى صيف 2016، 2017 علي محصول الذره بمحطة البحوث الزراعيه بسخا محافظة كفر الشيخ بهدف دراسة ادراة فترات الري والاحتياجات المائية لمحصول الذرة باستخدام المعادلات المناخيه المختلفه مقارنة بالري التقليدي. وكانت معاملات الري : الري العادي T_1 ، الري بعد استنفاذ 70% من الماء المضاف طبقا لمعادلة بلاني كريدل T_2، الري بعد استنفاذ 70% من الماء المضاف طبقا لمعادلة الاشعاع T_3 والري بعد استنفاذ 70% من الماء المضاف طبقا لمعادلة بينمان T_4. أعطت المعاملة الثالثة T_3 اعلي القيم بالنسبه لمحصول الحبوب وطول الكوز للذره وهي الري كل 11يوم خلال الموسم حيث كان محصول الحبوب 2013,90 ، 1925,53 كجم /فدان وطول الكوز16,33 ، 18,37سم خلال موسم النمو الاول والثاني علي الترتيب وكذلك سجل طول النبات ووزن 100 حبة اعلي القيم تحت معاملة الري T_3 مقارنة بمعاملات الري الاخري. وسجلت معاملة الرى T_3 أقل القيم فى الماء المضاف مقارنة بمعاملة الري التقليدى T_1 التى اعطت اعلي القيم للماء المضاف حيث كانت القيم 3934,37، 3690.56 م3/ فدان وسجلت قيم الماء المستهلك أعلى القيم حيث كانت 2965.59، 2686.45 م3/فدان خلال موسمي النمو الاول والثاني علي الترتيب. وسجلت اعلي القيم لانتاجية الوحده من الماء المضاف والمستهلك تحت معاملة الري T_3 حيث كانت 0.84 ، 0.93 كجم / م3 بالنسبه للماء المضاف 0.61، 0.64 كجم / م3 بالنسبه للماء المستهلك. تحت ظروف هذه الدراسة فانه يوصى عند زراعة الذرة رى المحصول كل 11 يوم للحصول على أعلى انتاجية من محصول الحبوب واعلى كفاءة لاستخدام وحدة المياه.