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 T1 for traditional, T2 by Belany - Criddle equation, T3 by Radiation equation and T4 by penman equation. All irrigation treatments were inserted by 70% of soil water depletion. The results showed that T1 had the highest values of water productivity (0.89 kg/m³) and productivity of irrigation (0.63 kg/m³) as an overall average of the two seasons. Data revealed also that T1 had the highest overall mean values applied water and water consumptive use (3862.47 m³/fed & 2826.02 m³/fed). The results indicated that the highest values for grain yield was recorded by irrigation treatment T3 with values of 2013.90 and 1925.53 kg/fed as well as 16.33 and 18.37 cm for ear length in the first and second season, respectively. Also, 100 grain weight and plant height had the highest values by treatment T1, as compared to treatment T3 and T4. 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.

INTRODUCTION

Maize (Zea mays, L) is the 2nd essential summer crop in Egypt after rice. Cultivated area of maize is about 221,5000 Fadden in 2016 with 717,7000 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 (ET0), (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 empirical 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:

T1: irrigation by traditional practice as performed by farmers

T2: irrigation by 70% depletion of available water using Belany - Criddle equation.

T3: irrigation by 70% depletion of available water using radiation equation.

T4: irrigation by 70% depletion of available water using Penman equation.

### Table 1. Some soil physical properties in the lysimeters.

<table>
<thead>
<tr>
<th>Soil depth (cm)</th>
<th>Particle size distribution (%)</th>
<th>Texture class (%)</th>
<th>FC (%)</th>
<th>WP (%)</th>
<th>Bulk density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 30</td>
<td>30.25 44.5 25.25</td>
<td>Loxam</td>
<td>27</td>
<td>13.5</td>
<td>1.07</td>
</tr>
<tr>
<td>30 - 60</td>
<td>28.25 45.75 26.00</td>
<td>Loxam</td>
<td>27</td>
<td>13.5</td>
<td>1.07</td>
</tr>
<tr>
<td>Mean</td>
<td>29.25 45.125 25.625</td>
<td>Loxam</td>
<td>27</td>
<td>13.5</td>
<td>1.07</td>
</tr>
</tbody>
</table>

The daily meteorological data were obtained from Amber program mobile for weather (www.amberweather.com) during the two seasons (2016 and 2017) to calculate ET0. 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 lysimeter.

Super phosphate and potassium fertilizer were added in 200 and 45 kg/fed as (15.5%P2O5) and Potassium sulphate (48% K2O), 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 irrigation) 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 ET0 according to Doorenbos and Pruitt (1992) as follows:
1- Blaney - Criddle method:
\[ \text{ET}_o = a + b \left( p \left( 0.46 T + 8.13 \right) \right) \text{ mm/day} \]
Where:
- \( a \) & \( b \): 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.

2- Radiation method:
\[ \text{ET}_o = C \left( W \times R_s \right) \text{ mm/day} \]
Where:
- \( C \): 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:
\[ \text{ET}_o = c \left[ W \times R_s \times \left( 1 - \frac{f(u)}{(ea_{ed})} \right) \right] \]
Where:
- \( c \): adjustment factor to compensate for the effect of day and night weather conditions
- \( W \): factor related to evapotranspiration in mm day \(^{-1}\)
- \( R_s \): net radiation in equivalent evaporation in mm day \(^{-1}\)
- \( f(u) \): wind function
- \( (ea_{ed}) \): difference between the mean actual vapor pressure of the air and the saturation vapor pressure at mean air temperature (mbar)
- \( C \): Solar radiation in equivalent evaporation in mm day \(^{-1}\).

Water consumptive use:
Water consumptive use (WCU) was calculated using the equation of Israelsen & Hansen (1962) as follow:
\[ \text{WCU} = \left( \theta_0 - \theta \right) / 100 \times B \times d \times D \times 4200 \]
Where:
- \( \text{WCU} \): Consumptive use (m3/fed)
- \( \theta_0 \): % Soil moisture content after irrigation.
- \( \theta \): % Soil moisture content before irrigation.
- B = 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).

\[ \text{W} = \text{IW} + \text{Re} \]
Where:
- \( \text{W} \): irrigation water applied amount.
- \( \text{IW} \): Irrigation water applied.
- \( \text{Re} \): 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:
\[ \text{IWP} = \frac{\text{yield, kg/fed}}{\text{applied water m3/fed}} \]
\[ \text{WP} = \frac{\text{yield, kg/fed}}{\text{Water consumptive use m3/fed}} \]

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 used 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). \( T_1 \) 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 \( T_1 \) 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 indicates that weight of 100 grain (g) was significantly affected by irrigation treatments, whereby the highest value was found by treatment \( T_1 \) 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 result of additional water stress by lasted ones. It is also to note that is by treatment \( T_1 \) (traditional one) with unregulary 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height, cm</th>
<th>Ear length, cm</th>
<th>100 - Grain weight, g</th>
<th>Grain yield, kg/fed</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>118.53</td>
<td>14.10</td>
<td>31.06</td>
<td>1453.47</td>
</tr>
<tr>
<td>T2</td>
<td>121.17</td>
<td>13.00</td>
<td>33.97</td>
<td>1563.40</td>
</tr>
<tr>
<td>T3</td>
<td>126.77</td>
<td>16.33</td>
<td>42.83</td>
<td>2013.90</td>
</tr>
<tr>
<td>T4</td>
<td>90.23</td>
<td>12.87</td>
<td>27.30</td>
<td>1321.47</td>
</tr>
<tr>
<td>F-test</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>T1</td>
<td>122.26</td>
<td>14.30</td>
<td>32.83</td>
<td>1452.80</td>
</tr>
<tr>
<td>T2</td>
<td>123.76</td>
<td>15.97</td>
<td>36.17</td>
<td>1553.60</td>
</tr>
<tr>
<td>T3</td>
<td>136.90</td>
<td>18.37</td>
<td>40.77</td>
<td>1925.53</td>
</tr>
<tr>
<td>T4</td>
<td>100.00</td>
<td>12.83</td>
<td>28.80</td>
<td>1353.53</td>
</tr>
<tr>
<td>F-test</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

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

Plant height was highly affected by irrigation treatment \( T_1 \) as compared to other irrigation treatments. The values by \( T_1 \) 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 90.23 cm & 100.00 cm for T4
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 T1
(traditional) showed the maximum quantity with mean
values of 3934.37 m³/fed and 3969.56 m³/fed in the first
and second season, respectively. ON the other hand, other
irrigation treatments has the lowest quantities in the order
of T4>T3>T2>T1, with mean values of 2663.48, 3009.51
and 3150.85 m³/fed. The maximum amount of irrigation
water by T1 is certainly attributed to the bulk numbers of
irrigation times as compared to irrigation treatment T4,
which has lowest number of irrigation time. These results
are in a good agreement with those introduced by Gharib

Table 3. Seasonal applied water amount of maize
(m³/fed) as affect by irrigation intervals in
the two growing seasons.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>1st season</th>
<th>2nd season</th>
<th>Mean of two seasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>3934.37a</td>
<td>3969.56a</td>
<td>3862.47a</td>
</tr>
<tr>
<td>T2</td>
<td>3060.47bc</td>
<td>2958.54c</td>
<td>3009.51c</td>
</tr>
<tr>
<td>T3</td>
<td>3299.83b</td>
<td>3007.86b</td>
<td>3150.85b</td>
</tr>
<tr>
<td>T4</td>
<td>2794.32c</td>
<td>2532.63d</td>
<td>2663.48</td>
</tr>
</tbody>
</table>

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 T1
(Traditional irrigation practice) with mean values of
2965.59 m³/fed and 2686.45 m³/fed for the first and second
cropping seasons, respectively. Meanwhile, irrigation
treatment T4 recorded the lowest values owing to the little
number of irrigation times with the longest irrigation
intervals. Mean water values by T1 were 1929.43 m³/fed
and 1697.25 m³/fed. for the first and second seasons. The
general trend of seasonal water consumptive use was in the
sequence of T1>T2>T4>T3 with the values 2826.02,
2227.42, 2093.29 and 1813.34 m³/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,
m³/fed) as affected by irrigation intervals.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>1st season</th>
<th>2nd season</th>
<th>Mean of two seasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>2965.59a</td>
<td>2686.45b</td>
<td>2826.02</td>
</tr>
<tr>
<td>T2</td>
<td>2171.36c</td>
<td>2015.22d</td>
<td>2093.29</td>
</tr>
<tr>
<td>T3</td>
<td>2388.94c</td>
<td>2065.90b</td>
<td>2227.42</td>
</tr>
<tr>
<td>T4</td>
<td>1929.43b</td>
<td>1697.25c</td>
<td>1813.34</td>
</tr>
</tbody>
</table>

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). T1 registered
the highest values for both (IWP) and (WP), while T4 has
the lowest values. The general trend for (IWP) and (WP),
as related to irrigation treatments, were in the sequence of
T3>T2>T4>T1 (IWP). Mean values for the above sequence
were 0.63 kg/m³ > 0.52 kg/m³ > 0.50 kg/m³ > 0.38 kg/m³,
while the mean values for (WP) were 0.89 kg/m³ > 0.75
kg/m³ > 0.72 kg/m³ > 0.52 kg/m³. The higher values for
(IWP) or (WP) by treatment T1 could be attributed to the
optimum irrigation intervals as well as water consumptive
use, whereby T1, T2 and T4 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

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

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1st season</th>
<th>2nd season</th>
<th>Mean of two seasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP, kg/m³</td>
<td>0.49a</td>
<td>0.36b</td>
<td>0.54b</td>
</tr>
<tr>
<td>IWP, kg/m³</td>
<td>0.39b</td>
<td>0.52c</td>
<td>0.38c</td>
</tr>
<tr>
<td>T1</td>
<td>0.52</td>
<td>0.38</td>
<td>0.80</td>
</tr>
<tr>
<td>T2</td>
<td>0.75</td>
<td>0.52</td>
<td>11.57</td>
</tr>
<tr>
<td>T3</td>
<td>0.89</td>
<td>0.63</td>
<td>10.50</td>
</tr>
<tr>
<td>T4</td>
<td>0.72</td>
<td>0.50</td>
<td>13.50</td>
</tr>
<tr>
<td>Irrigation intervals, day</td>
<td>13.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-test: *** *** *** ***</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*** 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 T1.
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 الزراعة والاحتياطات المالية لمحصول الذرة باستخدام المعادلات التجريبية تحت الريوميترات

أحمد سعد الحناوي و فاطمة حسن السيد
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أجريت تجربة لزيووميترات أسطوانية الشكل (80×200 سم) في قطاعات كاملاً العطوفية ثلاث مكررات خلال موسم صيف 2016، على محصول الذرة بمحطة الجود الزراعية بسخا محافظة كفر الشيخ. حيث دراسة إثبات فترات الري والاحتياطات المالية لمحصول الذرة باستخدام المعادلات النانية مختلفة مقارنة بثري التقليدي. وكانت معمدات الري: الري العادي T1، الري يعتمد على نسبة 70% من الماء المضاعف طبقاً لśmie الامتداد T1، والري يعتمد على نسبة 70% من الماء المضاعف طبقاً ل迷信 الامتداد T1، المشار إليها بالاعتماد على المقاس الميوللي T1. T1 عُلُجت المعادلة الثالثة T1 التي عُلجت عدم القيمة بالنسبة لمحصول الذرة وطول الزهرة وهي الري كل 1 يوم خلال الموسم حيث كان محصول الذرة 1925.5 كجم/هكتار وطول الزهرة 16.37 سم/يوم وصلت نسبة أول الأمر نمو الولي T1 المقارنة بعمادولات الري الأخرى. وسجلت معادلة الري T1 البتريب وذلك سجل طول الزهرة ووزن الري 100 حبة آب القيمة تحت معادلة الري T1 للعماداة الري التقليدي T1 التي عُلُجت عدم القيمة لمحصول الذرة حيث كانت القيمة T1 في المجال المضاعف مقارنة مععمدات الري التقليدي T1 التي عُلُجت عدم القيمة لمحصول الذرة حيث كانت T1 في مجال مماثلة للمستقبلات T1 في مجال مماثلة للمستقبلات T1 حيث كانت T1 435.32 كجم/م2 بالنسبة للامتداد المضاعف T1 التي عُلُجت عدم القيمة لمحصول الذرة حيث كانت T1 0.64 كجم/م2 بالنسبة للمستقبلات. تمت تجربة هذه الدراسة بوجه يوضوي عند زراعة الذرة رقم 11 يوم للحصول على أعلى النتائج من محصول الذرة واعدة كفاءة لاستخدام وحدة المياه.