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Assessment of Reference and Actual Evapotranspiration, and Yield of Maize Using Different Levels of Irrigation and Filter Mud Cake

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Abstract

Two experiments were conducted at Water Studies and Research Complex (WSRC), Station, National Water Research Center, Toshka – Abu Simbel, during two growing seasons of 2018 and 2019 to compare available reference evapotranspiration (ET_o) equations (Hargreaves- Samani (HS), Makkink (MK), Priestley–Taylor (PT) and Turc (TC)) to the FAO-56 method to determine suitable alternatives for use in Toshka region, and to evaluation effects of drought stress and filter mud cake on physiological traits of two maize hybrids, three regulated deficit irrigation levels of available water content depletion (AWCD) I_1, 13 %, I_2, 25% and I_3, 50% AWCD were combined with three levels of filter mud cake (FMC) F_1: 4 kg m^2 , F_2 : 2 kg m^2 and F_3 : 0 kg.

The data revealed that the individual influence of used 13% AWCD and FMC 4 kg m^2, caused increases of the plant height (m), leaf area (cm^2), no. grains/cob, grain yield (ton/fed.) and water use efficiency (WUE) (Kg/m^3).

The data also, revealed that the average seasonal values of the actual evapotranspiration (Eta) decreased as the percentage of soil moisture depletion increased (more available water extracted) . The Eta values were 1012.5, 853.1 and 712.7mm at 13, 25 and 50% AWCD, respectively.

The data also, revealed that the grain yield in the first season (2017/2018) were 1.70, 1.32 and 0.77 ton/fed. While in the second season (2018/2019) were 1.85, 1.53 and 0.75 ton/fed for 13, 25 and 50% AWCD, respectively.

The data revealed that increased regime treatment from 13 to 50% AWCD decreased WUE by maize plants from (0.45 to 0.29 kg/m^3) and (0.48 to 0.27 kg/m^3)in 2017/2018 and 2018/2019, respectively.

The results showed that the Hargreaves - Samani (HS) equation is suitable for estimating ETo for the studied area.

Keywords: *Reference evapotranspiration, Hargreaves equation, Toshka region.*

1. Introduction

Estimating the water requirements of a crops is one of the essential data for cultivating (Thamer *et al.,* 2019). The water requirements of the crop depend on several factors, climatic conditions, crop type , variety and the soil texture (Hassan *et al.,* 2019). Irrigation technology is a water management technique that increases the effectiveness of water use as it is used in field practices or by changing management schemes to minimize evaporation losses. One of the aims of irrigation technology is to increase the efficiency of water use by reducing the irrigation water with the least effect in the final product (Hassan *et al*., 2019).

Allen *et al*., 1998 defined reference evapotranspiration ETo as: "the rate of evapotranspiration from a hypothetical reference crop with proposing a crop height of 0.12 m, a fixed surface resistance of 70 sec/m and albedo of 0.23, that closely resembling the evapotranspiration from an extensive surface of the green grass of uniform height, actively growing, well-watered, and completely shading the ground".

Many models have been developed to estimate reference evapotranspiration based on meteorological data for various climates. These models are categorized into three groups: 1) combination methods including Penman (1948) 2) radiation methods including Makkink (1957), Turc (1961) and Priestley and Taylor (1972), 3) temperature methods such as Thornthwaite (1948) and (Hargreaves-Samani 1985), Researchers from many parts of the world have compared available reference ET equations to the FAO-56 method to determine suitable alternatives for use in their regions (Shahidian *et al.*, 2012).

The Penman family of models is generally considered among the most accurate ET models in virtually any climate (Qiu *et al.* 2002). The FAO version of the Penman-Monteith model (hereafter referred to as 56PM) is so accurate that it is recommended as the sole method of calculating ETo, if data are available (Allen *et al.* 1998). The major limitation to the Penman family of models is that they require many meteorological inputs, thereby limiting their utility in data-sparse areas (Dingman 1994). The models being examined, however, generally require data that are more readily available such as temperature and relative humidity, these elements can be measured by local farmers or derived from historical data.

HS model intended to be computationally simple and applicable to a variety of climates using only commonly available meteorological data (Hargreaves and Samani 1985). It was later adopted for used by the FAO for areas where air temperature alone is the only available variable (Allen *et et al.* 1998). Allen *et al.* (1998) noted that HS tends to over predict in areas of high humidity.

Irmak *et al.* (2003b) showed that the Turc model designed in western Europe (Jensen *et al.* 1990), performs well in warm, humid climates such as those found in North Carolina (Amatya *et al.* 1995), India (George *et al.* 2002), and Florida (Irmak *et al.* 2003b).

The PT model was designed to be used in humid areas where surfaces were usually wet (Priestley and Taylor 1972).

Panchanathan *et al.* (1987) reported that the cob length, girth of cob and number of grains per cob significantly increased with an increased in moisture regime of 533 mm as compared with 351 mm.

Pressmud as bio compost used to maintain soil fertility and enhance crop production because it is rich in sugar and contains appreciable amount of essential plant nutrients viz., organic carbon, nitrogen, phosphorus, potassium, calcium and magnesium along with traces of micronutrients viz., Zn, Fe, Cu and Mn (Banulekha 2007).

The experiments were designed with the following objectives:

1- Study effect of irrigation water levels on water use efficiency (WUE) and production of maize crop

2- Study effect of filter mude cake (FMC) on WUE and production of maize crop

3- Compare available reference ET equations (Hargreaves, Makkink, Priestley–Taylor and Turc) to the FAO-56 method to determine suitable alternatives for use in Toshka region.

2. Materials and Methods

The study was carried out at the experimental farm of the Water Studies and Research Center, Toshka, Abu simbel City, Egypt, which is located at 22°, 24`.11` N longitude of 31°, 35`.43` E longitude. The altitude of the area is 188m above sea level. The selected soil is a sandy texture soil. Nitrogen, phosphorus and potassium fertilizers were added according to the ministry of agriculture recommended doses. Nitrogen in the form of ammonium sulphate (20.6% N) was added at 600kg/fed at eight equal doses, the first one was ten days after planting and the last was at flowering time. Phosphorus fertilizer in the form of super phosphate (12.5% P_2O_5) was added at the rate of 200 kg/fed before planting. Potassium fertilization in the form of potassium sulphate (50% K_2O) was added at 50kg/fed. Soil analysis was done using the standard method described by Klute (1986). The chemical and physical properties of the soil are shown in Table 1(a and b). The experiment was set up with 3 irrigation levels (I_1) 13%, (I_2) 25%, and (I_3) 50% of available water content depletion, with 3 filter mud cake levels 4 (F_1), 2 (F_2) and 0.0Kg m^2 (F_3) in a completely randomized block design with three replicates. Composition of filter mud cake used in the experiment is given in the Table 2.. The net plot size was 5 m × 2.2 m (11m^2) with three rows in each plot having 70 cm and 20 cm distance between and within rows, respectively. with 19000 plants fed^{-1} plant population. Soil field capacity (FC) and permanent wilting point (PWP) were determined using the pressure cooker and pressure membrane apparatus by determining the soil moisture in saturated undisturbed and disturbed soil samples at 0.33 and 15 bars (Shawky 1967). The available water (AW) was calculated from the differences in water content at field capacity and permanent wilting point as follows:

AWC=FC–PWP (1)

The Water use efficiency (WUE) values were calculated as follows (Viets, 1965):

WUE (kg/m³) = Grains yield (kg/fed.) / Actual evapotranspiration (m³ /fed.) (2)

Leaf area was measured using the formula suggested by Mckee (1964).

Leaf area (cm²)= Leaf length (cm) × leaf width (cm) ×0.74 (3)

Harvest of maize was 90 days after planting. At harvest ten plants were chosen randomly from each plot to estimate the maize characters as follows: plant height (m), leaf area (cm^2), number of grains per cob , 100 grains weight (g) and grains yield (Ton / fed).

Table 1.a. Some of the chemical properties of the studied soil before cultivation

Soil depth (cm)	CaCO3 (%)	O.M* (%)	pH in Soil paste	ECe * (dS/m) in Soil paste	Soluble ions (meq/l)						
					Anions			Cations			
					Cl^-	CO_3^{-2}+ HCO_3	$SO4^{-2}$	Na^+	K^+	Ca^{+2}	Mg^{+2}
0-20	7.08	0.18	6.24	1.50	7.2	0.5	7.2	6.9	0.1	6	1.9
20-40	6.25	0.15	6.49	1.05	4.8	0.6	4.7	4.6	0.1	4.3	1.1
40-60	5.83	Nil	6.44	0.98	5.7	0.6	3.4	5.4	0.1	3.3	0.9

O.M= Organic matter, ECe = Electrical conductivity in soil paste

Table 1.b. Some of the physical properties of the studied soil before cultivation

Soil depth (cm)	Particle size distribution (%)			Tex. class	S.P.* (%)	F.C* (%)	W.P* (%)	A.W* (%)	BD* (g/cm^3)
	Sand	Silt	Clay						
0-20	85.76	3.24	11.00	Sand	25.8	12.5	6.0	6.5	1.65
20-40	88.19	3.84	7.97	Sand	25.2	11.5	5.6	5.9	1.62
40-60	89.43	4.03	6.54	Sand	24.5	10.9	4.3	6.6	1.57

S.P= Saturation percent, F.C= Field capacity, W.P = Wilting point, A.W= Available water, B.D= Bulk density

Table 2. Composition of filter mud cake (FMC) used in the experiment

pH* (1:10)	EC (dS/m) (1:10) extract	O.M (%)	O.C (%)	Total N (%)	Total P (%)	Total K (%)	C:N ratio	WHC (g water/g compost)	Moisture (%)
7.50	1.60	26.25	14.58	0.97	1.98	1.08	1:15	2.7	28

*Suspension ratio of component to water

All statistical calculations were performed using F-variance test, statistical significance was indicated at 5% of probability (SAS., 1993). The metrological data were collected from the experimental farm of the WSRC Weather Station. The weather data included daily values of the following parameters: relative humidity(RH), solar radiation (SR), maximum (T_{max}) and minimum (T_{min}), air temperature and wind speed (Ws). Table 3 shows the average weather data.

Table 3. Average weather data in Toshka (average seven years)

Years	RH (%)	SR(watt/m^2/day)	T_{max} (ºC)	T_{min} (ºC)	Ws (m/sec)
2008	24.14	224.71	35.39	18.83	2.77
2009	23.31	224.02	35.49	18.27	2.51
2010	23.32	224.36	37.11	19.83	2.51
2011	24.15	221.77	34.64	17.77	2.57
2012	24.21	226.59	35.31	18.51	2.69
2015	24.52	224.96	34.64	19.22	3.35
2016	24.90	225.01	35.28	19.38	3.15
Average	23.94	224.40	35.43	18.74	2.73

Once the meteorological data from the WSRC was edited and quality controlled, it was used to calculate the ET_o using AB@ITC the version 1.0. It is freely available on http://www2.webng.com/bahirdarab/.

2.1 ET_0 Estimation Methods:

2.1.1 FAO-56 Method (PM):

FAO-56 PM method for estimating reference evapotranspiration on a daily time scale is written as:

(4)

$$ET_0 = \frac{0.408\,\Delta\,(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where ET_o= reference evapotranspiration (mm day^{-1}), R_n = net radiation (MJ m^{-2} day^{-1}), G = soil heat flux (MJ m^{-2} day^{-1}), T mean = average air temperature (°C), u_2 = wind speed at 2m height (ms^{-1}), e_s = saturation vapor pressure (kPa), e_a = actual vapor pressure (kPa), Δ = slope of vapor pressure curve (kPa °C^{-1}), and γ = psychrometric constant (kPa °C^{-1}).

2.1.2 Hargreaves- Samani Method (HS):

The HS method estimates ET_o based on maximum and minimum air temperature, and is written as:

$$ET_0 = 0.408 \times 0.0023 \times (Tmean + 17.8) \times (Tmax - Tmin)^{0.5} \times Ra \quad \textbf{(5)}$$

Where ET_o = reference evapotranspiration (mm day^{-1}), T_{mean}= mean air temperature (°C), T_{max} = maximum air temperature (°C), T_{min} = minimum air temperature (°C), R_a = extraterrestrial radiation (MJ m^{-2} day^{-1}), and 0.408 is a factor to convert MJ m^{-2} day^{-1} to mm day^{-1},

2.1.3 Priestley-Taylor Method (PT):

The PT model is a shortened version of the original Penman (1948) model and is defined as follows according to Jensen *et al.* (1990):

$$ET_o = 1.26 \frac{\Delta}{\Delta + \gamma} (Rn - G) \quad \textbf{(6)}$$

Where ET_o is the reference evapotranspiration (mm day^{-1}) and all other terms are identical to those defined previously.

2.1.4 Makkink Method (MK):

The MK model was designed in 1957 to estimate potential evapotranspiration. This model was modified from the Penman model (1948) by disregarding aerodynamic components and replacing net radiation with solar radiation:

$$ET_o = 0.61 \frac{\Delta}{\Delta + \gamma} \frac{Rs}{2.45} - 0.12 \quad \textbf{(7)}$$

Where ET_o is the reference crop evapotranspiration (mm day^{-1}); and R_s is solar radiation (MJm^{-2}day^{-1}); and **Δ** and **γ** are the same variables defined previously.

2.1.5 Turc method (TC):

The TC model (1961) was developed in Western Europe. It has been used to some extent in the United States (e.g. (Amatya *et al.,* 1995)).

$$ET = 0.013\left(\frac{Ta}{15 + Ta}\right)(Rs + 50)$$

for $hn > 50$ **(8)**

$$ET = 0.013\left(\frac{Ta}{15 + Ta}\right)(Rs + 50)\left(1 + \frac{50 - hn}{70}\right) \text{ mm/day} \quad \textbf{(9)}$$

Where ET is the reference crop evapotranspiration (mm day^{-1}); Ta = air temperature in ^{0}C; *hn* = relative humidity in % and R_s is solar radiation ($MJm^{-2}day^{-1}$).

2.2 Models Performance Assessment

Evaluating a model performance is done using both statistical criteria (quantitative) and (qualitative). The combined approach is useful in making comparative evaluations of model performance between alternative or competing models (Loague and Green, 1991). Quantitative and qualitative approaches were used to evaluate the performance of the different models discussed in this manuscript. The qualitative approach consisted of representing the observed and estimated data graphically and quantitatively by the (R^2) and other summary and difference measures. The mean bias error (MBE) and the root mean square error (RMSE) are both error measures used to represent the average differences between predicted (Pi) and observed (Oi) values (Jacovides and Kontoyiannis, 1995). Coefficient of determination (R^2) is used to express relationship between observed and predicted values. R^2 ranges from 0 to 1. An $R^2 = 1$ represents an optimal model. Generally, $R^2 > 0.5$ is acceptable (Moriasi *et al.* 2007). The best model was selected first based on the lowest RMSE and MBE then the highest R^2 value. The mathematical formulas are described as:

$$MBE = \frac{1}{n}\sum_{i=1}^{n}(p_i - o_i) \quad \textbf{(10)}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(p_i - o_i)} \quad \textbf{(11)}$$

$$R^2 = \left(\frac{\sum_{i=1}^{n}(o_i - \bar{o})(P_i - \bar{P})}{\sqrt{\sum_{i=1}^{n}(o_i - \bar{o})^2}\sqrt{\sum_{i=1}^{n}(P_i - \bar{P})^2}}\right)^2 \quad \textbf{(12)}$$

Where: O_i is observed data, P_I is the predicted data by empirical model and *n* is the total number of observed data points. Low values of RMSE and MBE are indications of good model performance (Djaman *et al.* 2018).

3 Results and Discussion

3.1 Effect of irrigation levels on some growth attributes

3.1.1 Plant height

Irrigation levels showed significant effect on plant height in the both seasons (Table 4). It was reported by various researchers that various plant growth attributes were reduced under different water stress conditions (Rashwan *et al.,* 2016). Alam (1985) pointed out that shoot elongation was reduced by water stress during vegetative period in maize.

3.1.2 Leaf area (LA)

Irrigation levels did not significantly affect the LA in the first season (Table 4). In the second season irrigation levels affected significantly the LA. Pandey *et al.* (2000) reported in maize that increasing moisture stress resulted in progressively less leaf area and plant height. The water stress significantly reduced leaf area due to the reduced cell division. Water stress may reduce turgor pressure and hence cell expansion, resulting in approximately the same dry mass being contained within a smaller leaf area, thus raising density (Rascio *et al.* 1990).

3.1.3 Number of grains per cob

Irrigation levels affect significantly the number of grains per cob in the first season (Table 5). In the second season they did not affect significantly the number of grains per cob. Frederick *et al.* (1989) reported a decrease in maize yield due to drought stress associated with a number of barren plants, a lower number of kernels.ear^{-1} and a short grain filling period. Song-Feng *et al.* (1998) showed that water deficit led to slower pollen and filament development, reduced filament fertility and caused a reduction in grains number per ear.

3.1.4 100-grains weight (g)

Irrigation levels did not significantly affect the 100-grains weight (g) in both seasons (Table 5).

3.2 Effect of filter mud cake of some growths attributes

Filter mud cake (FMC) showed significant effect on plant height, LA and number of grains per cob in the both seasons (Table 4 and 5). FMC did not affect significantly the 100-grains weight (g) in the both seasons (Table 5). Naik and Rao (2004) reported increased in plant height was mainly due to availability of nutrient throughout the growing season.

3.3 Effect of varieties of some growth attributes

In the first season varieties did not affected significantly the plant height, number of grains per cob and100-grains weight (g) (Table 4 and 5). In the second season varieties affected significantly the plant height, number of grains per cob and100-grains weight (g) (Table 4 and 5), on the other hand varieties affect significantly the LA in the both seasons (Table 4). The hybrid differences in glucose required for synthesis of different chemical constituents at different plant organs, in carbon equivalent and in partitioning of photosynthates among the plants (Ahmed and Hassanein, 2000).

Table 4. Effect of irrigation levels, filter mud cake (FMC) and maize varieties on plant high and leaf area (LA)

Characters		Plant high (m)		Leaf area (cm^2)	
Treatment		**2018**	**2019**	**2018**	**2019**
Irrigation levels	**I_1(13% AWCD)**	182.67	187.5	457.89	494.22
	I_2 (25% AWCD)	172.78	173.89	411.56	446.28
	I_3 (50% AWCD)	167	170.94	450.33	427.06
L.S.D. 5%		6.99	7.14	*N.S.	22.2
Filter mud cake	**F_1 (4Kg)**	186.78	190.11	491.06	506.17
	F_2(2Kg)	174.11	177.28	441.89	460.17
	F_3 (control)	161.56	164.94	386.83	401.22
L.S.D. 5%		5.28	4.28	35.05	29.53
Varieties	**Fine seeds**	176.04	180.52	454.48	479.33
	Pioneer	172.26	174.37	425.37	432.37
L.S.D. 5%		N.S.	5.34	27.86	21.37

* No significant differences at 0.05 levels

*Each value represents the mean of 3 samples

3.5 Effect of irrigation levels on grain yield and water use efficiency (WUE)

Table (6) presents effects of irrigation levels on grain yield and WUE in both seasons. The I_1 increased significantly grain yield and WUE over all other irrigation levels in both the years. Similarly, I_2 treatment followed the first irrigation in both parameters in both growing seasons. The minimum WUE was observed in I_3. Overman and Martin (2002) confirmed the linear relation between grain and silage yield response to irrigation for corn. Soil water deficit reduces yield of maize and other grain crops by three main mechanisms. First, whole canopy absorption of incident Photosynthesis Active Radiation (PAR) may be reduced, either by drought induced limitation of leaf area expansion, by temporary leaf wilting or rolling during periods of severe stress, or by early leaf senescence. Second, drought stress reduces the efficiency with which absorbed PAR is used by the crop to produce new dry matter. Third, drought stress may limit grain yield of maize by reducing the harvest index (Earl and Davis, 2003).

Table 5. Effect of irrigation levels, filter mud cake (FMC) and maize varieties on no. grains /ear and Grain index (weight as g/100 grains)

Characters		No. grains /cob		Grain index (weight as g/100 grains)	
Treatment		2018	2019	2018	2019
Irrigation levels	I_1(13% AWCD)	334.61	345.33	31.27	37.04
	I_2 (25% AWCD)	362.17	311.22	31.88	36.02
	I_3 (50% AWCD)	271.33	275.33	27.32	34.97
L.S.D. $_{5\%}$		47.03	N.S.	N.S.	N.S.
Filter mud cake	F_1 (4Kg)	331.61	354	32.46	35.99
	F_2(2Kg)	354.5	320.72	29.52	36.09
	F_3 (control)	282	257.17	28.49	35.94
L.S.D. $_{5\%}$		37.14	35.12	N.S.	N.S.
Varieties	Fine seeds	337.52	343.37	29.84	38.29
	Pioneer	307.89	277.89	30.47	33.73
L.S.D. $_{5\%}$		N.S.	20.76	N.S.	1.20

*Each value represents the mean of 3 samples

Table 6. Effect of irrigation levels, filter mud cake (FMC) and maize varieties on Grain yield and water use efficiency (WUE) of maize

Characters		Grain yield (Ton/fed)		WUE (kg /m^3)	
Treatment		2018	2019	2018	2019
Irrigation levels	I_1(13% AWCD)	1.70	1.85	0.45	0.48
	I_2 (25% AWCD)	1.32	1.53	0.41	0.47
	I_3 (50% AWCD)	0.77	0.75	0.29	0.27
L.S.D. $_{5\%}$		0.33	0.18	0.08	0.06
Filter mud cake	F_1 (4Kg)	1.58	1.71	0.51	0.53
	F_2(2Kg)	1.25	1.39	0.37	0.40
	F_3 (control)	0.97	1.03	0.26	0.28
L.S.D. $_{5\%}$		0.27	0.15	0.07	0.04
Varieties	Fine seeds	1.16	1.40	0.35	0.41
	Pioneer	1.36	1.36	0.41	0.40
L.S.D. $_{5\%}$		0.19	N.S.	0.06	N.S.

WUE= Water use efficiency

3.5 Effect of filter mud cake (FMC) on grain yield and water use efficiency (WUE)

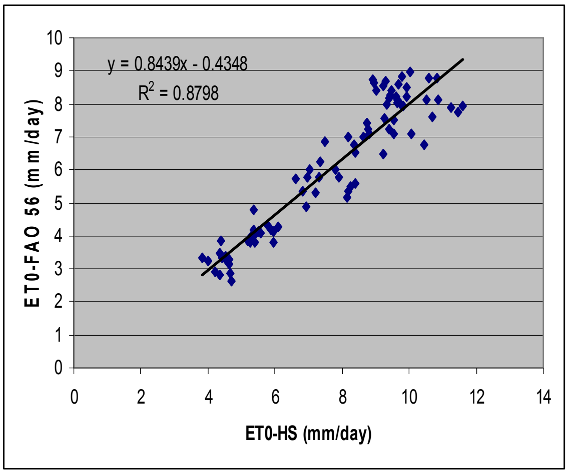
The lowest grain yield and WUE value were obtained under F_3 treatment in 2018, for both years. Ghoneim *et al.* (2002) and Yang *et al.* (2013) reported that application of FMC to agricultural fields is likely to improve soil health by adding macro and micronutrients and organic matter to soil ultimately crop productivity. In sandy soils FMC helps in improving the retention of moisture (Tisdall and Oades 1982).

Estimating evapotranspiration from the original form of the methods

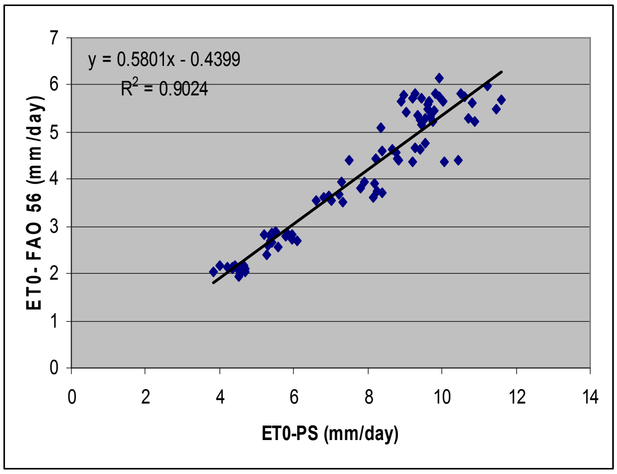
Figure 1 presents the calculated evapotranspiration from Hargreaves - Samani, Priestley - Taylor, Makkink and Turc equations versus the FAO-56 PM method for the Toshka region. The statistical parameters MBE, RMSE and PE for each method were estimated and presented in Table 7. Among the four methods, the Hargreaves method provided the best ET estimations based on the lowest error statistics MBE, RMSE and PE, Figure 1(a).

The Hargreaves method has the RMSE of 0.05 mm/d, MBE of 1.63 mm/d and PE of 21.83%. The corresponding coefficients of determination, R^2 is 0.8798. The results suggest that the Hargreaves in their original form is relatively appropriate method among all other methods of estimating ET_o for the Toshka region. The MK, PT and TC methods consistently underestimated daily ET_o compared with the full FAO-56 method for all months This result is consistent with the findings of Jensen *et al.* (1990), who concluded that the TC approach yielded better results in comparison to other radiation based methods for humid regions. For a semiarid environment, most radiation models are not recommended to be used (Trajković and Gocić, 2010). The HS equation produced average daily ET_o estimates very near or slightly lower, in general, than those from the FAO-56 method. This result is consistent with the findings of López *et al.* (2006), who concluded that the HS performed better in semiarid and arid regions. HS uses Ra rather than Rs for radiation data. This means that HS is using the maximum possible radiation value and not taking into account atmospheric transmissivity. This would make sense with HS as it uses Ra rather than Rs for an input and is immune to any local meteorological/climatological patterns. (Hargreaves and Allen 2003).

The findings of this study can be used as a platform in the Toshka region of Egypt, for irrigation planning, design and management.



(a)



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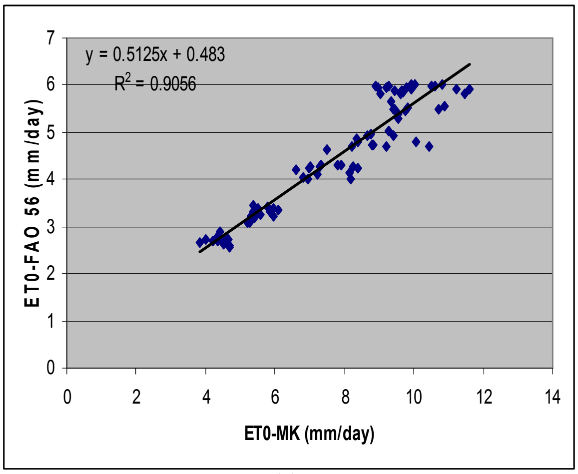

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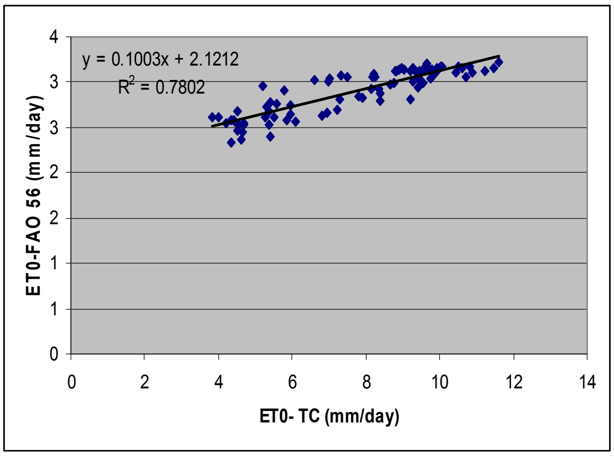

(d)

Figure 1: Estimated ET_o from original form of equations versus FAO-56 PM (a, b, c and d)

Table 7. Error values of average daily ET_o estimates on monthly basis as compared to FAO-56 method

Eq.	Hargreaves			Priestley - Taylor			Makkink			Turc		
Par. Yea.	RMSE (mm/d)	MBE (mm/d)	PE (%)	RMSE (mm/d)	MBE (mm/d)	PE (%)	RMSE (mm/d)	MBE (mm/d)	PE (%)	RMSE (mm/d)	MBE (mm/d)	PE (%)
2008	0.05	1.48	20.72	0.12	3.70	48.80	0.11	3.19	41.16	0.16	4.79	59.76
2009	0.04	1.19	16.87	0.11	3.40	46.89	0.10	2.94	39.28	0.15	4.47	57.68
2010	0.04	1.27	17.07	0.11	3.53	47.49	0.10	3.08	40.21	0.16	4.63	58.52
2011	0.04	1.24	18.21	0.11	3.28	46.07	0.09	2.87	39.24	0.15	4.40	57.89
2012	0.05	1.46	20.68	0.11	3.47	47.29	0.10	3.13	41.45	0.16	4.69	59.95
2015	0.08	2.48	30.49	0.14	4.29	51.97	0.13	3.92	46.43	0.18	5.45	62.76
2016	0.08	2.29	28.76	0.14	4.19	50.71	0.13	3.83	45.57	0.18	5.34	61.57
Avg.	0.05	1.63	21.83	0.12	3.69	48.46	0.11	3.28	41.9	0.16	4.82	59.73
R^2	0.8708			0.9024			0.9056			0.7802		

RMSE = root mean square error, MBE = mean bias error, PE= percent error and R^2 = determination coefficient,

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تقييم البخر نتح المرجعي والفعلي والمحصول للذرة الشامية تحت مستويات ري مختلفة مع إضافة طينة المرشحات

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الملخص

أجريت هذه الدراسة في مزرعة تجارب الأبحاث الزراعية بمجمع الدراسات والبحوث المائية بتوشكي خلال موسمي ٢٠١٨ و ٢٠١٩ وذلك بغرض مقارنة بعض معادلات البخر نتح المرجعي وهي هاري جرفيس ، ماكنيك ، بريستلي – تايلور وترك بمعادلة بنمان مونتيث – الفاو ٥٦ للوصول إلي أنسب معادلة لظروف توشكى المناخية ذات مدخلات مناخية قليلة.

أيضا تهدف الدراسة إلي دراسة تأثير مستويات ري مختلفة وإستخدام طينة المرشحات على البخر نتح الفعلي وعلى انتاج وكفاءة استخدام المياه لمحصول الذرة الشامية. ولتحقيق هذه الأهداف تم استخدام ثلاث مستويات ري ١٣، ٢٥ و ٥٠% استنزاف من الرطوبة الأرضية المتاحة مع استخدام ثلاث مستويات من طينة المرشحات كنترول (صفر كجم)، ٢كجم/م^{٢} و ٤كجم/ م^{٢}.

وقد أوضحت النتائج أن التأثير الفردي لمستوي الري ١٣% استنزاف من الرطوبة الأرضية المتاحة وطينة المرشحات عند مستوي ٤كجم/م^{٢} كان معنويا وتسبب في زيادة طول النبات، مساحة الورقة، عدد الحبوب/ كوز، كفاءة استخدام المياه وانتاج الذرة الشامية.

كما أوضحت النتائج أن متوسط القيم السنوية للبخر نتح الفعلي قد انخفض بزيادة استنزاف الرطوبة الأرضية المتاحة وسجلت قيم البخر نتح الفعلي ١٠١٢,٥، ٨٥٣,١ و ٧١٢,٧ مم عند مستويات الري ١٣، ٢٥ و ٥٠% على الترتيب.

أوضحت النتائج أيضا أن انتاج محصول الذرة الشامية سجل في الموسم الأول (٢٠١٧/٢٠١٨) ١,٧٠، ١,٣٢ و ٠,٧٧ طن/فدان. بينما في الموسم الثاني (٢٠١٨/٢٠١٩) سجل ١,٨٥، ١,٥٣ و ٠,٧٥ طن/فدان عند مستويات الري ١٣، ٢٥ و ٥٠% على الترتيب.

وأوضحت النتائج أن زيادة الإجهاد المائي من ١٣ إلي ٥٠% استنزاف من الرطوبة الأرضية المتاحة قد أدي إلي خفض قيم كفاءة إستخدام المياه من ٠,٤٥ إلي ٠,٢٩ كجم/م^{٣} و٠,٤٨ إلي ٠,٢٧ كجم/م^{٣} في الموسم الأول والثاني على الترتيب.

أوضحت النتائج أن أنسب معادلة لتقدير البخر نتح المرجعي تحت ظروف منطقة توشكى هي معادلة هاري جرفيس– سيماني

الكلمات الدالة: *البخر نتح المرجعي ، معادلة هارجرفيس و منطقة توشكى.*