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WATER SAVING USING GATED PIPES UNDER SOME EFFECTIVE IRRIGATION MANAGEMENT PRACTICES AT NORTH NILE DELTA.

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ABSTRACT

A field experiment was conducted during the two summer growing seasons 2009 and 2010 at the Demonstration Field for Modern Irrigation Systems at Sakha Agricultural Research Station. The main objective of this study was to find out some practical effective ways regarding saving water particularly under the present status of water shortage facing Egypt.

Gated pipes as improved surface irrigation technique was used for irrigating maize and the studied irrigation practices were; traditional irrigation or every furrow irrigation (EFI-Trt.A), cut-off irrigation (Trt.B), in addition two techniques of alternative furrow irrigation either fixed (FAI-Trt.C) or nonfixed alternate furrow irrigation (EAI-Trt.D). Moreover, two methods regarding computation of irrigation water should be applied; Ibrahim (Trt.E) and Penman-Monteith (Trt.F).

Obtained findings indicated that some suitable techniques could be practiced regarding water saving without significant reduction in marketable grain yield. The mean values of maize grain yield can be ranked as; 3.6, 3.4=3.4, 3.3=3.3 and 2.8 $ton.fed^{-1}$ obtained under treatments; E, B, D, A, C and F, respectively. While the highest water saving of nearly 12% equaled 353 $m^3.fed^{-1}$ or about 880 million m^3 at the national level (2.5 million feddan, 1 fed= 0.42 ha) could be obtained by; using gated pipes as improved surface irrigation, laser land leveling and executing either cut-off or alternate irrigation techniques.

Moreover, accurate computation of irrigation water should be applied without excess or less than the actual water needs for the growing plants and depending on the availability of climate elements. In this direction, either Ibrahim equation that mainly depending upon pan evaporation and suitable for the studied area or the FAO Penman-Monteith equation could be used in computing irrigation water.
Keywords: water saving, gated pipes, irrigation management.

INTRODUCTION

Egypt is located in the very dry region which characterized with annual rainfall less than 250 mm. The mean national rainfall is bout 20mm which is not enough for watering any crop. Therefore, no rain fed agriculture from economical point of view is implemented except in some areas at the coastal zone and Sainai Peninsula with annual rainfall of about 150mm.

So, in this regard Egypt is the solely country world wide that almost all agricultural land are under irrigation i.e. irrigated agriculture. Main source of fresh water supply is The River Nile with its water resources outside the Egypt's boundary as it is the tail country of the river. At present, capita share from water for different purposes is less than the water poverty edge of 1000

m^3 with continuously decreasing and is expecting to reach the scarcity level of less than 500 m^3 particularly under the annual growth in population. At this situation of water shortage, it is difficult to make any progress in any sector of development. Moreover, Egypt is one of the countries that likely to the adverse impacts of climate change resulting in decreasing water supply and increasing crop water needs (El-Gendy, A.M., 2011).

Agriculture is the main sector in water consumption with its water allocation of about 80-85% from total water supply.

Surface or gravity irrigation is the conventional method of watering executed in Egypt. Several obstacles or limitations are associated with this method such as; excess or over irrigation applied, less uniformity of irrigation water over soil surface, leaching of plant nutrients and raising up of water table with its destructive effects on soil properties resulting in decreasing crop yield (El-Gendy, A.M., 2011).

Therefore, improved surface irrigation becomes essential. In this direction, using the gated pipes technique is an effective way in improving surface irrigation. Gated pipe is an aluminum or PVC pipe, 6 inch diameter with orifice gates distributed along the pipe with 75 cm spacing. Gated pipes are connected with a water pump to convey and distribute irrigation water to the head of the irrigated fields which are under surface irrigation method of furrows or basins. Technology of the gated pipes (GP) flood irrigation as mentioned by BLUE WATER® Technologies INC can be listed as follows:

- Quick and easy to install.
- Designed for use in PVC or Aluminum pipe.
- Superior service and longevity.
- Manufactured to minimize environmental effects.
- Ultra violet (UV) inhibitor is added to help protect against the sun's ultra-violet radiation.
- Performance tested for extended durability.

Jayasudha and Chandrasekhar (1996) reported that gated pipes have many advantages as; many different crops can be grown in consequence without major changes in design, layout or operating procedures, high application efficiency for field or horticulture crops, efficiently used by inexperienced workers, easily to be automated, leaching is easy and save 10% of cultivated lands.

Jibin and Foroud (2007) pointed out that gated pipes system provides more uniform water distribution and reduces the irrigation water quota and conserve energy without affecting the crop yields. However, the gated pipes irrigation technique is easy to understand, and the system is movable and convenient to operate. This is very important for the system acceptance. Abou El-Soud (2009) came almost to the same findings.

Effective on-farm irrigation management package becomes a must particularly under the water shortage status facing Egypt. Several ways under the umbrella of effective irrigation management such as; cut-off, alternate irrigation techniques as well as computing precisely irrigation water should be applied based on the climatic elements are executed in this study. Both cut-off and alternate irrigation are suitable at the clayey soils of Nile Delta characterized with high front advancement and horizontal movement of irrigation water comparing with the vertical downward movement (El-Gendy, A.M., 2011).

Graterol *et al* (1993) as well Hua and Zhong (2000) stated that for the same amount of irrigation water applied, water use efficiency and irrigation water use efficiency were greater in alternate furrow irrigation comparing with conventional furrow irrigation. Kheira (2009) stated that water logging, salinization, and low application efficiency are the main problems inherent with surface irrigation in the Nile valley. Replacing or improving the surface irrigation method with precise irrigation systems became the main interest of the decision makers and policy planners in Egypt.

Ibrahim and Emara (2009) stated that alternative furrow irrigation is one applicable technique in improving surface irrigation particularly in clay soils via; saving irrigation water, increasing the contribution from water table to crop water needs as well as the same sugar yield could be obtained. Such advantages lead to lowering water table, improving the aeration in the effective root zone which resulted in enhancing the drainage conditions of the cultivated area.

Furthermore, Ibrahim and Emara (2010) revealed that irrigation till 90% furrow length resulted in the following pronounced advantages:

1. Highest yield for both root and sugar with corresponding values of 28.7 and 4.8 ton fed^{-1} or 68.8 and 11.5 ton ha^{-1} (1ha=2.38fed).
2. Highest field water use or so-called water utilization efficiency (W.UT.E) as well as water use efficiency (W.U.E) for both root and sugar beet yield. The corresponding values were 10.8 and 1.8 $kg.m^{-3}$.
3. Saving irrigation water amounted with about 300 $m^3 fed^{-1}$ or 24 million m^3 for Kafr El-Sheikh Governorate. In other words saving water at the national beet cultivated area of about 240,000 feddan is 72 million m^3.

So, the main target of the present study is:

"More crops per drop or increasing yield per less"

Specific goals were; increasing water saving, optimizing water productivity using gated pipes as improved surface furrow irrigation. These goals were evaluated under different on-farm irrigation management techniques including; cut-off irrigation, alternate furrow irrigation as well precisely computation of irrigation water should be applied. Thus evaluation was done comparing with the conventional surface irrigation i.e. watering till the tail end of the irrigated furrows.

MATERIALS AND METHODS

Location:

Two field experiments were conducted during the two successive summer growing seasons of 2009 and 2010 at the Demonstration Modern Irrigation Systems Field, Sakha Agricultural Research Station, Kafr EL-Sheikh Governorate. The location is situated at 31º-7' N Latitude, 30º-57' E Longitude with an elevation of about 6 meters above mean sea level and represents the circumstances and conditions of Middle North Nile Delta region.

Climatic conditions:

Climatological elements during the two growing seasons were recorded as monthly averages from Sakha Agro-meteorological Station. Parameters of; air temperature (Tº, Cº), relative humidity (RH, %), wind speed at two meter height (U_2, m.sec-¹) and pan evaporation (Ep,mm.day^{-1}) are listed in Table (1)

Table 1: Climate elements; air temperature (T, Cº), relative humidity (RH, %), wind speed at 2 meter height (U_2, m.sec^{-1}) and pan evaporation (Ep, mm.day^{-1}) during the two growing seasons, 2009 and 2010.

Month	2009				2010			
	T, Cº	RH, %	U_2, m.sec-1	Ep, mm.day^{-1}	T, Cº	RH, %	U_2 m.sec^{-1}	Ep, mm.day^{-1}
June	26.2	62.5	1.32	8.1	26.3	61.3	1.22	8.0
July	27.4	67.5	1.13	7.5	26.8	67.2	1.22	7.5
August	26.6	68.5	0.92	7.0	28.5	70.1	1.09	7.0
Sept.	25.7	61.4	0.96	6.3	26.3	65.4	1.02	5.5

Some soil physical and chemical properties:

For the site of the field trial, soil samples were collected before sowing at depths; 0-15, 15-30, 30-45 and 45-60 cm. Samples were air dried and ground to pass through 2-mm sieve, for different determinations of soil chemical and physical properties as follows:

- Particle size distribution was determined according to the Pipette method (Pipere, 1950).

1- Soil salinity and soluble ions were determined in the soil paste extract (Jackson, 1967).

2- pH was measured in soil-water suspension; 1:2.5.

Soil physical and chemical properties are presented in Table 2 (a &b).

Table 2: Particle size distribution (a), chemical analysis (b),

a- Mechanical composition.

Soil depth, cm	Clay,%	Silt,%	Sand,%	Texture grade
0-15	59.72	23.85	16.43	Clayey
15-30	60.26	23.64	16.07	Clayey
30-45	59.60	24.42	15.98	Clayey
45-60	60.80	23.18	16.02	Clayey
Mean	60.10	23.77	16.13	

b- Chemical analysis of soil paste extract.

Soil depth, cm	Anions, m.e.L^{-1}				Cations, m.e.L^{-1}				E.C, dS. m^{-1}	pH 1:2.5
	Co_3^{--}	HCO3-	Cl-	SO4--	Ca++	Mg++	Na+	K+		
0-15	-	4.50	6.00	11.06	7.10	6.32	8.00	0.14	1.73	8.33
15-30	-	4.50	10.00	11.67	5.33	12.97	7.75	0.12	2.11	8.38
30-45	-	3.75	6.00	3.80	2.84	3.26	7.40	0.05	1.63	8.47
45-60	-	4.00	5.00	14.34	10.65	3.08	9.50	0.11	2.21	8.41
Mean									1.92	8.40

Soil moisture constants:

Field capacity (FC, %), wilting point (W.P, %) and bulk density (D_b, kg/m^3):

Field capacity on the weight basis was determined under field conditions at the experimental site and it represents the upper limit of the available water to be used by the growing plants. Permanent wilting point was determined by using a pressure membrane apparatus which equals the moisture content at a tension of 15 bars and is considered as the lower limit of the available water. Bulk density was also determined in site. Determination of F.C, W.P and D_b were done for successive soil layers, each of 15 cm till the effective root zone depth of 60cm (Hansen *et al*., 1979). Values of the three soil-water constants are tabulated in Table 3.

Table 3: Values of field capacity (F.C., %), wilting point (W.P., %), available water (A.W., %) and bulk density (D_b, Kg. m^{-3}).

Depth	F.C.%	W.P.%	A.W.%	D_d %
0-15	43.87	23.84	20.03	1.13
15-30	40.51	22.02	18.49	1.18
30-45	38.80	21.09	17.71	1.24
45-60	36.77	19.98	16.79	1.31
Mean	39.99	21.73	18.26	1.22

Field experiments:

Two field experiments were conducted during the two seasons 2009 and 2010 involved growing maize (*Zea maize L,* c.v- SC 10) as summer crop.

Dates of sowing (S) and harvesting (H) were as follows:

Season 1: S = 24/6/2009, H = 13/10/2009

Season 2: S = 10/6/2010, H = 4 /10/ 2010

All cultural practices including laser leveling were done as recommended by Agricultural Research Center (ARC), Egypt, except for the factor of study i.e. effective irrigation management for maize crop. Each treatment was shaped in a strip, 6 meter width (one gated pipe) and 70 m long occupying an area of 420 m² or 1/10 feddan (1fed.= 0.42ha). Meaningfully, each gated pipe represents one treatment.

Irrigation treatments were as follows:

Treatment A: Control, irrigation till the end of the strip as the local farmers irrigating their fields.

Treatment B: Cut-off, irrigation till the irrigation water reached about 85% from the strip length i.e. till nearly 60 meter.

Treatment C: Fixed alternative furrow irrigation (FAFI) meant during the growing season, irrigating one furrow and kept the adjacent one without watering.

Treatment D: Exchange (unfixed) alternative furrow irrigation (EAFI), meant during the growing season, the irrigated furrow will be un-irrigated in the next watering and vise versa at the following irrigations.

Treatment E: Irrigation according to Ibrahim Equation, 1981.

Treatment F: Irrigation according to FAO, Penman-Monteith Equation, 1998. It is worth mentioning that for each irrigation interval or the dates between irrigations were the same for all treatments.

Data collection:

Irrigation water (I.W):

Irrigation water was pumped from the tertiary irrigation canal (mesqa) near the control unit of The Demonstration Modern Irrigation Field, Sakha Agricultural Research Station. Then, pumped water was diverted under low pressure of about 0.3 bars to the gated pipes. Each gated pipe is 6 meter long, 6" diameter and opening (gate) spacing is 0.75 m and the discharge of each gate is 2 l sec^{-1}. Application of irrigation water was measured by water meter installed inside the control unit.

Computation of applied irrigation water:

Computation of applied irrigation water was done as follows:

For treatments A (Control) and B (Cut-off), applied irrigation water was recorded by water meter when it reached the end and 85% of the strip length, respectively. Regarding, the alternative irrigation treatments C and D, watering was stopped and measured when it reached the end of the concerning irrigated furrows as specified before.

On the other hand, treatment E was irrigated according to Ibrahim Equation, 1981 as follows:

$$ETp = 0.1642 + 0.8\, Ep \quad \text{(1)}$$

Where:

ETp = Potential evapotranspiration, $cm.day^{-1}$

Ep = Pan evaporation, $cm.day^{-1}$

At last, treatment F irrigated according to FAO Penman and Monteith Equation as follows:

$$ETo = \frac{0.408\, \Delta\, (Rn - G) + \gamma\, [900/(T + 273)]\, U_2\, (es - ea)}{\Delta + \gamma\, (1 + 0.34\, U_2)} \quad \text{(2)}$$

The input parameters needed to calculate ETo using the CROPWAT model (Smith, 1992) are air temperature, relative humidity, sunshine hours, and wind speed.

Where:

ET0 = Reference evapotranspiration, $mm.day^{-1}$
Rn = Net radiation at the crop surface, $MJ.m^{-2}.day^{-1}$
G = Soil heat flux density, $MJ.m^{-2}.day^{-1}$
T = Mean daily air temperature, C°
U2 = Wind speed at 2 m height, $m.s^{-1}$
es = Saturation vapor pressure, kpa.
ea = Actual vapor pressure, kpa.
es-ea = Saturation vapor pressure deficit, kpa.
Δ = Slope vapor pressure curve, kpa/C°
γ = Psychometric constant, kpa.C°

Values of the stated parameters were computed either at the site (Ibrahim, 1995 and Ibrahim *et al*, 2005) or quoted from the standard Tables (FAO Irrigation Paper No.56).

Therefore, the applied irrigation water (IW) was equaled water consumed by growing crop or so-called crop evapotranspiration (Etc) which calculated as follows:

ETc = ETo × Kc…………………………………… (3)

Where:

ETc = Crop evapotranspiration, $mm.day^{-1}$

Kc = Crop coefficient of maize.

The dimensionless crop coefficient, Kc is the ratio between water consumed by the growing crop (maize) to ETo. Values of Kc were quoted from FAO Irrigation paper No. 56.

Calculation of crop water consumptive use (Cu)

Herewith is the so-called the direct method of Cu computation which meant the difference between soil moisture content after irrigation and before the next one in the effective root zone of 60cm. Such difference is the water consumed by the growing plants as transpiration (T) plus the water lost by soil surface and plant leaves as evaporation (E). The amount of Cu was calculated for the effective root zone of 60 cm as stated by Hansen *et al*., (1979):

Cu = (ϴ2- ϴ 1) ×Db × d ×A……………………(4)

Where:

Cu = Crop water consumptive use, $m^3.fed^{-1}$

ϴ2& ϴ1 = Percentage of soil moisture content on the weight basis after irrigation and before the next one, respectively.

D_b = Bulk density, $Kg.m^{-3}$.

d = Depth of effective root zone, 0.6 m.

A = Irrigated area, 1 fed. =4200 m^2 = 0, 42 ha.

Parameters of irrigation water efficiency for yield production:

Herewith efficiency of irrigation water is relating the magnitude of crop produced by water. It could be computed in several ways, one of them is "the amount of crop production given by a unit volume of water".

Crop water productivity (CWP) or so-called in other references water utilization efficiency (W.Ut.E) and water use efficiency (W.Us.E) expresses as kg crop productivity per m^3 of water applied or consumed by the growing plants. They were calculated according to Bos, (1980):

CWP = Y/I.W.…………………………………. (5)

W. Us. E = Y/C.u. …………………………… (6)

Where:

C.W.P. = Crop water productivity, $kg.m^{-3}$ water applied.

Y = Marketable crop yield, kg.

I.W = Irrigation water applied, m^3.

W. Us. E = Water use efficiency, $kg.m^{-3}$ crop water consumed.

Cu = Crop water consumed, m^3

Maize grain yield:

Marketable grain yield for maize was recorded in ton.feddan-¹ at 15.5% moisture content.

Data collected were subjected to statistical analysis according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Irrigation water (I.W, m^3/ fed.).

Data tabulated in Table (4) revealed that the conventional or traditional irrigation as the local farmers irrigating their fields in the area received the highest irrigation water (I.W, $m^3 fed^{-1}$.) exceeding all other treatments. This direction of I.W. is the same in the two growing seasons of 2009 and 2010. Meaningfully, conventional or traditional irrigation is associated with high irrigation water delivered or so-called excess water is applied with farmers in the area.

Table 4: Irrigation water (I.W, m^3 fed^{-1}.), consumptive use, (C.U, m^3 fed^{-1}.), grain yield (kg $fed.^{-1}$), water productivity (kg m^{-3} applied) and water use efficiency (W.U.E,kg m^{-3} consumed) for maize crop under different irrigation regimes (treatments) during the two seasons.

Parameters	Treatments					
	A*	B*	C*	D*	E*	F*
a- 2009						
I.W., m^3 $fed.^{-1}$	2859.61 a	2578.60 a	2596.20 a	2594.56 a	2768.50 a	2499.80 a
C.U, m^3 $fed.^{-1}$	2601.48	2375.77	2150.69	2091.45	2411.22	2436.84
Rate, mm day^{-1}	5.58	6.11	5.73	5.57	5.17	5.23
Yield, kg $fed.^{-1}$	3145	3272	2985	3217	3403	2786
W.P., kg $fed.^{-1}$	1.10	1.27	1.15	1.24	1.23	1.11
W.U.E., kg $fed.^{-1}$	1.21	1.38	1.39	1.54	1.41	1.14
b-2010						
I.W., m^3 $fed.^{-1}$	3002.23 ab	2623.88 a	2544.56 ab	2559.47 ab	2918.51 a	2665.08 b
C.U., m^3 $fed.^{-1}$	2749.32	2428.08	1951.43	1999.47	2640.12	2524.62
Rate, mm day^{-1}	6.15	6.10	5.89	6.06	5.93	5.18
Yield, kg $fed.^{-1}$	3440	3626	3551	3575	3783	2883
W.P., kg $fed.^{-1}$	1.15	1.38	1.40	1.40	1.30	1.08
W.U.E., kg $fed.^{-1}$	1.25	1.49	1.82	1.79	1.43	1.14

***A: Control or conventional, irrigation till the end of the strip as the local farmers irrigating their fields.**
B: Cut-off, irrigation till the irrigation water reached about 85% from the strip length i.e. till nearly 60 meter.
C: Fixed alternative furrow irrigation (FAFI) meant during the growing season, irrigating one furrow and kept the adjacent one without watering.
D: Exchange alternative (un-fixed) furrow irrigation (EAFI), meant during the growing season, the irrigated furrow will be un-irrigated in the next watering and vise versa at the following irrigations.
E: Irrigation according to Ibrahim Equation, 1981.
F: Irrigation according to FAO, Penman-Monteith Equation, 1998.

In this direction, mean values of I.W. for the two seasons as illustrated in Fig.(1) can be ranked in descending order as; 2930.6, 2843.5, 2601.2, 2582.4, 2577.0 and 2570.4 m^3fed^{-1}. The stated values are resulted from; conventional irrigation (Trt.A), computed I.W (Trt.E, Ibrahim), cut-off irrigation (Trt.B), computed I.W. (Trt.FAO,Penman-Monteith), exchange and fixed alternate furrow irrigation (EAFI-Trt.D & FAFI-Trt.C), respectively.

Therefore, comparing with conventional irrigation, corresponding water saving resulting from different irrigation management practices are; 2.98, 11.23, 11.89, 12.07 and 12.30%, respectively.

So, by implementing some ways regarding field irrigation management as alternate irrigation, cut-off irrigation or computed irrigation water based on climatic elements at the local area. The highest percentage of saving water was obtained from the alternate irrigation technique either EFAI or FAFI with an average of 12.2% equaled 357.6 m^3 $feddan^{-1}$. While, the second percentage of water saving 11.9% equaled 348.8 m^3 $feddan^{-1}$was gained under the implementation of cut-off irrigation technique. At last, the lowest average percentage 7.4% or 217.9 m^3 $feddan^{-1}$was resulted by pre-computed irrigation water. It should be stated that the above mentioned water saving were gained under using gated pipes as improved surface irrigation accompanied with precision laser leveling of soil surface.

In general, effective on-farm irrigation management has mainly two objectives of saving water with increasing, same or slight reduction in marketable yield as obtained from conventional watering.

Hence, the recommendation of executing any way of on-farm-irrigation management is depending upon besides the two above mentioned objectives is the easiest and capability of executing by local farmers. Therefore, the ways of rationalize irrigation water from saving irrigation point of view as well the possibility of implementation can be arranged as; cut-off, alternate and computing irrigation water based on the availability of climatic elements.

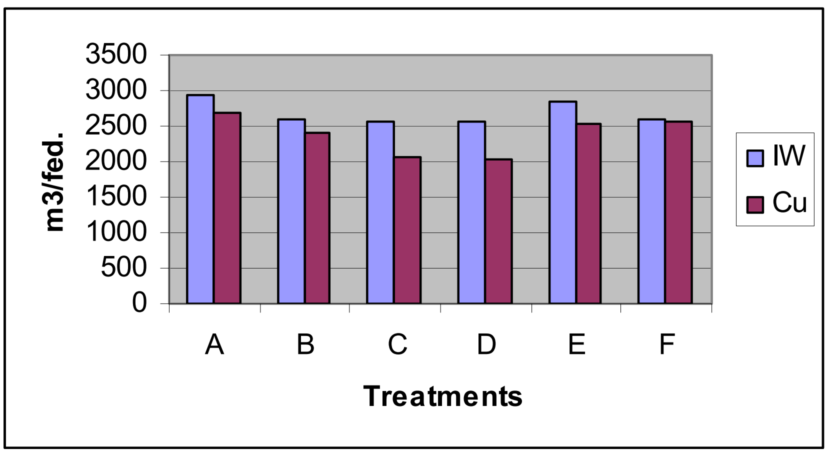

Figure 1: Mean values of maize irrigation water (IW, m^3 $fed.^{-1}$) and water consumption (C.U., m^3 $fed.^{-1}$) as affected with different irrigation management practices (treatments).

The obtained findings are in the same line with that obtained by Hua and Zhong (2000), Jibin and Foroud(2007) and Abou El-Soud (2009).

Water consumptive use (C.U, m^3 feddan^{-1}).

Values of seasonal C.U in the two seasons for different treatments which computed depending upon soil moisture depletion in the effective root zone of 60 cm are tabulated in Table (4). Also, the corresponding values of rate of C.U are listed in the same table.

While, mean values of C.U for the two seasons are illustrated in Fig (1). The general trend of seasonal C.U values is with that found regarding I.W. The highest computed C.U value 2695.4 m^3 feddan^{-1} (64.2cm) is found under the conventional irrigation. While, the lowest value 2041.9 m^3feddan^{-1} (48.6 cm) was obtained under the cut-off irrigation technique. Other techniques or treatments have values in-between.

Maize grain yield (Ton.fed^{-1}).

Values of maize grain yield as influenced by different irrigation regimes for the two growing seasons are tabulated in Tale (4). Regarding the first season 2009, no significant difference was obtained among different treatments. The values are 3.145, 3.272, 2.985, 3.217, 3.403 and 2.786 ton feddan^{-1} (1 fed. = 0.42 ha.). The stated values are for treatments; A(traditional irrigation), B (cut-off irrigation), C (fixed furrow alternate irrigation- FAFI), D (exchange alternate furrow irrigation-EAFI), E (Ibrahim method) and F (FAO Penman- Monteith method).

For the second season (2010), the corresponding values are; 3.440, 3.626, 3.551, 3.575, 3.783 and 2.893 ton feddan^{-1}.

The mean values for the two seasons as illustrated in Fig.(2) can be ranked as; 3.593 (Trt.E= Ibrahim method), 3.449 (Trt.B= cut-off), 3.396(Trt.D= EAI), 3.293 (Trt.A= control), 3.268 (Trt.C= FAI) and 2.835 ton fed^{-1}. (Trt.F= FAO Penman-Monteith method).

This finding is favorable, since there is no difference in the obtained marketable maize grain yield between different irrigation regimes; some tools regarding effective management of maize irrigation are raised-up. Among these ways are: cut-off, alternate furrow irrigation techniques. In addition, precisely amount of irrigation water should be applied as practiced by Ibrahim Equation which is created under Middle North Nile Delta region and it took the first rank in this study regarding maize grain yield. Moreover, FAO Penman-Monteith Equation is another method in computing irrigation water as this method is executed in worldwide.

In general, the yield of the second season (2010). This finding could be attributed to the high stand and healthy plants of second season. While, the yields of alternate irrigation (Trts. C and D) were higher in second season due to good aeration in the effective root zone.

Such promised results particularly with cut-off and alternate furrow irrigation techniques should be executed in the clayey soils instead of the traditional irrigation at which irrigation water should be reached the tail end of the irrigating furrows. This is a result of the prevailing phenomena for the clayey soils of the pronounced advancement of wetting front of irrigation water as well its high horizontal movement comparing with sandy soils. Moreover, the amount of irrigation water should be precisely determined by either Ibrahim method which evaluated in the North Nile Delta as well the world wide practical method of FAO Penman-Monteith.

In this direction, these ways are highly attractive to be implemented especially under the present situation of water shortage that facing Egypt. Limitations to get positive findings from such implementations are the un-wide use of the laser leveling technique which considered as the bench mark regarding surface irrigation improvement as well the availability of climatic elements as pan evaporation (Ep) for Ibrahim method, and air temperature, relative humidity, wind speed and solar radiation for FAO Penman-Monteith.

Another point should be taking into consideration before chosen which way should be recommended is the amount of applied irrigation water with more interest on crop water productivity.

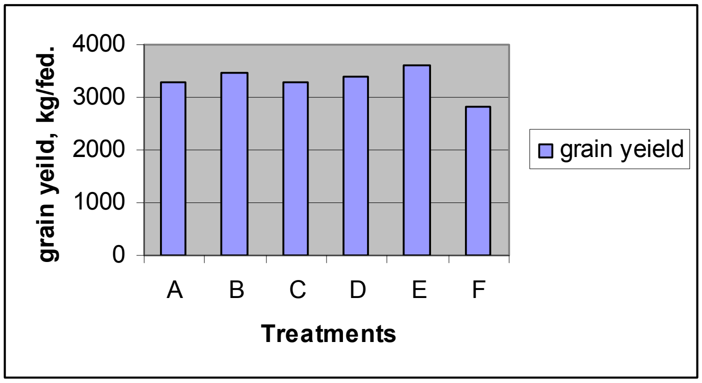

Figure 2: Mean values of maize grain yield (kg fed.$^{-1}$) as affected with different irrigation management practices (treatments).

Crop-water efficiencies:

Water productivity (W.P,kg.m^{-3}):

The water productivity parameter W.P reflects the capability of a unit of applied irrigation water in producing the marketable yield. Values of W.P for the two seasons resulting from different ways for on-farm irrigation managements are tabulated in Table (4).For almost same yield, the high amount of applied irrigation water, the less obtained water productivity. Meaningfully, marketable yield should be taking into consideration for accurate evaluation regarding such parameter and vise versa.

As illustrated in Fig. (3), mean values of W.P can be classified into two main groups; the highest value of 1.3 kg m^{-3} applied irrigation water resulting from implementation of either cut-off or alternate furrow irrigation technique. Computation of irrigation water as described by Ibrahim method came to the same value. While the lowest value 1.1 kg m^{-3} applied water resulting from either the conventional watering as well FAO Penman-Monteith. The lower value of W.P could be attributed to the highest water applied and the low obtained grain yield for the traditional and FAO Penman-Monteith irrigation methods, respectively.

These findings are in harmony with that obtained by Ibrahim and Emara (2009 & 2010).

Water use efficiency (W. U. E, kg m^{-3}):

The parameter of water use efficiency (W.U.E.) reflects the capability of unit of consumed water by the growing plants in producing the marketable yield. Values of W.U. E for the two seasons are tabulated in Table (4).For almost same yield, the high amount of consumed water, the less obtained water use efficiency. Marketable yield should be taking into consideration for accurate evaluation regarding such parameter and vise versa.

As illustrated in Fig. (3), mean values of W.U.E can be arranged in descending order as; 1.7, 1.6, 1.4=1.4, 1.2 and 1.1 kg.m^{-3} for treatments; D, C, B=E, A and F, respectively. So, implementation of either alternate furrow irrigation or cut-off irrigation techniques resulting in the high yield per unit of consumed water. Computation of irrigation water as described by Ibrahim method came to nearly same trend. While the lowest values 1.2 and 1.1 kg m^{-3} consumed water obtained from the conventional watering and FAO Penman- Monteith, respectively. The lower values of W.U. E. could be attributed to the high consumed water and the low obtained grain yield for the traditional and FAO Penman-Monteith irrigation methods, respectively.

These findings are in harmony with that obtained by Kheira (2009) and Ibrahim and Emara (2009 & 2010).

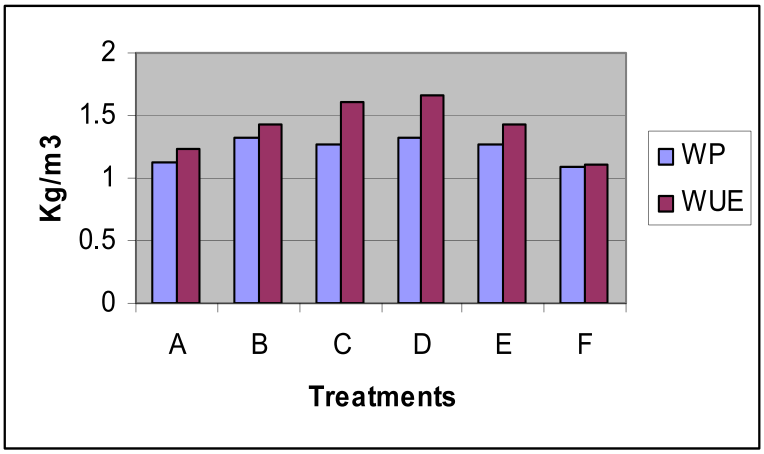

Figure 3: Mean values of water productivity (WP, Kg m^{-3}) and water use efficiency (WUE, kg m^{-3}) as affected with different irrigation management practices (treatments).

Conclusion

Under the severe water shortage facing Egypt, following are the possible technical package could be implemented:

- Precision land leveling using laser technique should widely implemented by farmers.
- Precision leveling is a main procedure in enhancing surface irrigation efficiency.

Gated pipes technique is a promised in improving surface irrigation, the convenient irrigation method in Egypt.

Several obtained advantages by using gated pipes:

- Good uniformity distribution of irrigation water.
- Low energy needed in its operation.
- Saving water.
- Gained about 10% from cultivated lands.
- By implemented cut-off or alternate furrow irrigation techniques could be gained as: high crop yield, high water saving as well high water productivity.

So, in this direction average water saving in maize irrigation is about 353 $m3.fed^{-1}$ equaled nearly one billion m^3 at the national level (2.5 million fed).

Depending upon the availability of climatic elements, Ibrahim or FAO Penman Monteith equations could be used in computing irrigation water.

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توفير مياه الري باستخدام المواسير المبوبة تحت بعض الممارسات الفعالة للري بشمال دلتا النيل

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أقيمت تجربة حقلية بالحقل الإرشادي لنظم الري الحديثة- محطة البحوث الزراعية بسخا- محافظة كفر الشيخ. والتي تمثل منطقة وسط شمال دلتا النيل وذلك خلال موسمي ٢٠٠٩،٢٠١٠ حيث تمت زراعة الذرة هجين فردي ١٠ بهدف:

تقدير الوفر في مياه الري باستخدام المواسير المبوبة وتحت حزمة من تقنيات الري علي مستوي الحقل. حيث تم تسوية الحقل تسوية دقيقة بالليزر- وكانت المعاملات الزراعية كالموصي بها من مركز البحوث الزراعية ماعدا معاملات إدارة الري والتي طبقت في شرائح بعرض ٦ متر (ماسورة مبوبة) وطول ٧٠ متر. وهذه المعاملات هي:

معاملة أ: الري التقليدي كالمتبع في المنطقة حيث يقف الري عندما تصل مياه الري الي نهاية الشريحة.

معاملة ب: (إيقاف الري Cut-offعندما تصل مياه الري الي حوالي ٨٥% من طول الشريحة-أي حوالي ٦٠ متر.

معاملة جـ: (الري التبادلي الثابت) حيث يتم ري خط وترك الخط المجاور بدون ري وذلك خلال موسم نمو الذرة.

معاملة د: (الري التبادلي المتغير) حيث يتم ري خط وترك الخط المجاور بدون ري وذلك في الريه- علي ان يتم عكس ذلك في الرية التالية.... وهكذا.

معاملة هـ: (الري حسب معاملة ابراهيم) حيث يتم حساب كمية مياه الري الواجب إضافتها بناء علي معادلة ابراهيم والتي تناسب المنطقة تحت الدراسة والتي تعتمد علي قراءات وعاء البخر

معاملة و: (الري حسب معادلة الفاو بنمان- مونتيث) والتي تعتمد اساسا علي العناصر المناخية.

وفيما يلي أهم النتائج المتحصل عليها:

- رتبت قيم الاحتياجات المائية ترتيباً تنازلياً ب: ٢٩٣٠.٦> ٢٨٤٣.٥> ٢٦٠١.٢> ٢٥٨٢.٤> ٢٥٧٧.٠> ٢٥٧٠.٤ م^3 / فدان. وكانت القيم المقابلة في الوفر في مياه الري مقارنة بالري التقليدي بـ : ٢.٩٨- ١١.٢٣- ١١.٨٩- ١٢.٠٧- ١٢.٣٠% وذلك للمعاملات السابقة.
- أعلي قيم للإستهلاك المائي تحصل عليها من معاملة الري التقليدي بـــ ٢٦٩٥.٤ م^3/فدان- واقل القيم ٢٠٤١.٩ م^3 /فدان نحصل عليها من إيقاف الري عند ٨٥% من طول خط الري.
- اعلي محصول حبوب ذرة قد تحصل عليه من الري طبقاً لمعاملة إبراهيم (٣.٦ طن/ فدان)- يليه ايقاف الري (٣.٤ طن/ فدان).
- أعلي القيم للإنتاجية المحصولية من وحدة المياه المضافة ١.٣ كجم/ م^3 ماء مضاف تحصل عليه إما من ايقاف الري عند ٨٥% من طول الشريحة أو من الري التبادلي في الخطوط.

وعليـــــه:

فإنه يمكن ترشيد الري لمحصول الذره عن طريق:

١. التسوية بالليزر هي العامل الأساسي لرفع كفاءة الري السطحي.
٢. تطبيق اي من تقنية ايقاف الري عند وصول مياه الري إلى حوالي ٨٥% من شريحة الري- أو الري التبادلي في الخطوط.مما ينتج عنه وفر في مياه الري بحوالي ٣٥٣ م^3 /فدان او مايزيد عن ٨٨٠ مليون م^3 علي المستوي القومى(٢.٥ مليون فدان).
٣. عند توفر العوامل المناخية خاصة قيم وعاء البخر او العوامل المناخية الأخري فانه يمكن حساب كميه مياه الري الواجب إضافتها باستخدام معادلة إبراهيم المناسبة لمنطقة الدلتا أو معادلة الفاو بنمان- مونتيث.

قام بتحكيم البحث

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