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INCREASING OF WATER USE EFFICIENCY FOR MAIZE CROP (*ZEA-MAIZE*) UNDER LAND LEVELLING AND WATER APPLIED METHODS

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ABSTRACT

Field experiments were conducted at the farm of El-Karada Agricultural Research Station, Kafer El-Sheikh. Governorate. Water management and Irrigation System Research Institute National Water Research Center Egypt during 2007 and 2008 seasons. The experiment was arranged in strip-plot design with four replicates. The main – plot represented land levelling method use LASER leveling : 1) slope of zero cm /100m length (L_1) and 2) 10 cm /100m length (L_2) – while, the sub-plot treatments represented water applied methods. e.g.) Continuous flow irrigation, (I_1); 2) Alternative irrigation (I_2) and 3) surge irrigation with different cycle ratios, as follows : surge irrigation cycle at 10/10(I_3) ; 10/6(I_4) and 10/3(I_5)). Results indicated that under zero % slope method received more amount of water, water consumptive use efficiency, field water efficiency, crop water use efficiency than the 0.1% slope method. While, grain yield (kg/fed) and water distribution efficiency % was opposite. Also, data revealed that, alternative irrigation gave the highest values of water consumptive use (cu). Crop water use efficiency (CWUE), field water use efficiency (FWUE) and grain yield (kg/fed). While, water distribution efficiency was opposite. Where, its values were 33.90 (cm/fed), 0.995 kg/m^3, 1.85 kg/m^3, and 3342 kg/fed and 92.49% respectively. On the other side, the surge cycle ration received more

amount of water and increase water consumptive use water distribution efficiency, while, the lowest values of grain yield. Where the best treatment with surge cycle ratio at 10/10 and at 10/3 was opposite. It can be summarized that alternative irrigation decreased amount of water irrigation applied 35% and 30% than continuous flow and surge irrigation. Slope zero, produced the highest yield and water use efficiency

INTRODUCTION

Maize is a very important grain and fodder crop in all over the world. It ranks the third after wheat and rice in Egypt. Recently, the demand for grain food is continuously increasing. The objective of irrigation management should be shifted from obtaining maximum grain yield per cultivated area to maximum grain yield per unit of water. Steynberg et al. (1989) demonstrated that maize plant was more sensitive to drought during the reproductive phase than during vegclative phase. In Egypt maize consumed 17 % of the yearly amount of water required for the main field crops, while its cultivated area represented only 19% of the whole cropped area El-Mowelhi, et al (1995).

Many farmers were done about the effect of land slopes. El-saadawy and Abd-ElLatif (1998) indicated that under the 0.1% slope the infiltration opportunity more better than the traditional methods and the infiltration rate was very high with the traditional methods were 2821.51 , 2588.46 and 2293.79 m^3/fed, respectively for three different of border lengths (100 ; 75 and 50) at 0.1% slope. The water use efficiency (WUE) were 14.83, 15.92 and 17.57 kg/m^3 for the three lengths 100.75 and 50 m respectively at 0.1 % slope. Doorknobd and Pruit (1977) recommended that land slops should be ranged between 0.05 and 0.2% depending on furrow stream size, longer borders may require some land slopes to obtain efficient irrigation. Dedrick (1981) reported that length of a basin (unit area) is dependent on the infiltration characteristics of the soil, the resistance to flow the desired distribution uniformity, the net depth of application, and unit flow rate.

A primary aim for good irrigation management is to minimize deep percolation of water (infiltration exceeding the irrigation requirements). Deep percolation losses depend directly on irrigation system performance, which in turn, depends mainly on how evenly water infiltrates a cross the field . Eid et al (1999) showed that surge flow system seemed to be better than continuous irrigation, because it caused less run off, less deep percolation surge irrigation is used to allow further advance of water to reduce water losses and increasing water use efficiency. Matter (2001) studied the effect of surge furrow irrigation, compared with continuous irrigation on water management at different plouphing methods. He found that, surge flow treatments required less time to complete the advance phase than with those continuous flow treatments at different plouphing treatment . Varlev et al (1995) found that surge irrigation required 20-25% less water than continuous irrigation, whereas, deep percolation decreased from 12-15% to 6-8%, while run losses reduced from 25-30% to 10-12% by using surge irrigation**.** Osman et al. (1996) stated that surge flow irrigation gave better results; whereas, water advance time and amount of water applied were less than those of continuous one. Surface flooding irrigation by furrows is the most widely used irrigation method in clay

Yonts et al (1991) mentioned that surge irrigation reduced advance inflow time an average of 20% compared with continuous irrigation.

The aim of this present study is to improve the furrow irrigation system using the surge flow irrigation for maize cultivated in order to save water and to increase water use efficiency.

MATERIALS AND METHODS

Two field experiments were conducted at the farm of El-Karada Water Management Research Station-Kafr El-Sheikh Governorate. Water management and Irrigation System Research Institute National Water Research Center, Egypt during 2007 and 2008 seasons. The physical and chemical properties of soil for the two experiments were determined according to Klute (1986) and weaterman (1990) and persesented in Tables (1 and 2). Maize crop was sown on June 5 and 7 and was harvested on October 25 and 29 in 2007 and 2008 seasons, respectively. The experiment was arranged in strip-plot design with four replicates. The main plot represented land leveling system use LASER levelling . Slope of zero cm /100 m length and 10 cm / 100 m length. while the sub-plot treatments represented water applied methods. e.g. Continuous flow; (I_1) alternative irrigation (I_2) and surge irrigation with different cycle ratios, as follows : (I_3)surge irrigation (10 min on and 10 off) , (I_4) surge irrigation (10 min on and 6 min off) and (I_5) surge irrigation (10 min on and 3 min off).

Table (1) : Some physical properties of experimental soil at different depths.

Physical properties						Soil moisture content		
Soil depth cm	**Sand %**	**Fined sand %**	**Silt %**	**Clay %**	**Soil texture**	**Bulk density g/cm**	**Field capacity %**	**Permanent withing point (PwP)%**
0-20	1.60	14.40	19.50	64.50	Clay	1.11	50.62	28.07
20-40	1.80	14.90	17.10	66.20	Clay	1.28	46.11	26.12
40-60	1.80	13.20	16.00	69.00	Clay	1.33	45.20	31.00

Table (2) : Chemical properties of the experimental soil sites.

Soil depth cm	PH 1-2.5	Ec mmhos cm at 25 c	Soluble Kation meg 100 g				Soluble Anion meg 100 g				
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO^{3}--	HCO^{3}-	Cl-	So^{4}--	$CaCO^{3}$ %
0-20	8.10	2.10	5.64	5.00	9.00	0.36	-	3.40	11.0	6.76	
20-40	8.10	2.10	4.73	4.00	12.0	0.37	-	6.10	13.0	2.07	
40-60	8.30	2.65	5.0	6.40	13.0	0.34	-	5.10	13.0	8.54	

Soil samples were collected before and two days after each irrigation from three layers (20 cm) each to determine soil moisture content, at field capacity and soil bulk density were determined according to Michael (1978) and Vomocil (1957) respectively. Which presented in Table soil at Kafer El-sheikh Governorate Egypt.

Maize grains (310 hypried) a rate of 20 kg /fed was used a recommended phosphorus fertilizer was added to all plots during the preparation in the rate of 15 kg p_2 D_5/fed and nitrogen fertilizer was applied in the form of urea (48.5 N %) at the rate of 150 kg/fed. Two meter length from the fifth inner row in each sub-plats were taken to determine the grain yield. The grain yield was harvested when the grain moisture content about 15%) then converted to estimate grain yield in ton /fed.

Soil water relations:

1- Applied water (Wa):

Discharge measurements were made by using a fixed crested weir using its Empirical equation according to (Masoud, 1967) as follows:

$$Q = C\ L\ H^{3/2} \text{ ....(1)}$$

Where:

Q = Discharge in m^3/min;
L = Length of the crest in m;
H = Water head in m and
C = Discharge coefficient.

2- Water consumptive use :

Soil moisture content was determined before and after irrigation to calculate water consumptive use accordion to **lesraelsson and Hansen (1979).**

$$Cu = \frac{\Theta 2 - \Theta 1}{100} \times \mathbf{B\ d} \times \mathbf{D} \times A \text{ ....(2)}$$

Where:

Cu = Water consumptive use in eachie irrigation (cm^3).
Ө2 = Soil moisture percent after irrigation. (%),
Ө 1 = Soil moisture percent before irrigation. (%),
B d = Soil Bulk density,
D = Depth of soil layer of the soil. (m).and
A = Irrigation area (= 4200 m^2)

3- Crop water use efficiency, (CWUE)

It was calculated according to **Michael. (1978)** by the following equation: CWUE, (Kg/m^3) = $\frac{Y}{ET}$ ....(3)

Where:

Y = Grain yield (kg/fed),

ET = Evapotranspiration (m^3/fed)

4- **Field water use efficiency,** (FWUE):was calculated by **Michael (1978)** by the following equation:

$$FWUE, (Kg/m^3) = \frac{Y}{WR} \quad \text{.................................(4)}$$

Where:
Y = Grain yield (kg/fed),
WR = Total amount of water used in field (m^3/fed)

5- **Water distribution efficiency (%)** it was calculated by **Hansen et al(1980)** by the following equation:

$$DU = 100(1 - y / D) \quad \text{..........................(6)}$$

Where:

DU = Water distribution efficiency, %
Y = Average numerical absolute deviation of soil moisture
D = Average soil moisture content stored as computed at a certain time of irrigation.

Data of the two seasons were statistically analyzed according to procedures of **Snedecor and Cochran (1980) and Duncan(1954).**

RESULTS AND DISCUSSION

Total amount of applied water (m^3/fed)

Data in Table (3) indicate that increasing slope led to decrease amount of water applied. It caused to increase speed of water on soil surface and to decrease water percolation in soil layer, whereas, the amount of applied water values where 2471.04 and 2427.67 m^3/fed, at 0.0 and 0.1 % respectively.

Also, data showed that alternative surge irrigation led to decrease amount of water applied. The lowest value with surge cycle at (10/3) it in 2471.45 m^3/fed, whiles the highest value with continuous flow irrigation 's its 2785.99 m^3/fed. On the other side, there not significant different between surge irrigation at (10/10) and (10/6).

Water consumptive use (cm)

As seen in Table (4) it is evident that significant interaction between slope and surge cycle ratio in the two seasons were obtained. Increasing slope led to decrease the water consumptive use where, the highest value of CU was obtained under slope at (0.0%), while the lowest value with slope at (0.1%) it was 51.30 and 50.78 cm, respectively. Data showed that, the highest value of CU with surge cycle at (10/3) it was 56.31 cm, while CU value with alternative irrigation was apposite it was 32.9 cm.

Field water use efficiency (FWUE) and crop water use efficiency (CWUE):

Data presented in Tables (5 and 6) land slope zero % gave the highest value of FWUE (1.238 kg / m3). While the lowest value was 0.985 kg/m3 with land slope 0.1 % for alternative irrigation. Data clear that, highest value of FWUE was 1.85 kg/m^3 and lowest value was 0.985 kg/m^3 for CWUE with alternative irrigation. With the surge cycle ratio increasing time of cycle ratio led to decreased values of FWUE and CWUE interaction between water applied method with slope (0.0%) was significant.

Table (3) Total amount of water applied (m^3/fed) during 2007 and 2008 seasons.

Character	Total amount of water applied m^3/fed.							
	2007			Significant	2008			Significant
Land leveling system	Slope, %		Mean		Slope, %		Mean	
Water applied	0.0	0.1			0.1	0.1		
Continuous Irri. (I_1)	2828.54	2743.44	2785.99[a]	*	2743.68	2661.14	2702.41[a]	*
Alternative Irri. (I_2)	1838.55	1783.24	1785.24[d]	*	1783.39	1729.74	1731.74[d]	*
Surge 10/10 (I3)	2614	2588.1	2601.09[b]	*	2535.58	2510.46	2523.06[b]	*
Surge 10/6 (I4)	2591.13	2563.8	2577.47[bc]	*	2513.4	2486.89	2500.15[bc]	*
Surge 10/3 (I5)	2483	2459.9	2471.45[c]	*	2408.51	2386.1	2397.31[c]	*
Mean	2471.04	2427.67	2449.37		2396.61	2354.87	2375.74	
Significant	Ns	Ns			Ns	Ns		
L.S.D at 5%	0.67	0.67			0.65	0.65		

Mean followed by the same letter (s) are not significantly different at 5% Level according to(D MET) and Ns significant at 5% Level and not Significantly respectively.

Table (4) Water consumptive use (cm) during 2007 and 2008 seasons.

Character	Water consumptive use, cm							
	2007			Significant	2008			Significant
Slope, %	Slope, %		Mean		Slope, %		Mean	
Water applied	0.0	0.1	0.1		0.0	0.1		
Continuous Irri. (I1)	52.45	51.86	52.10b	*	50.88	50.3	50.54b	*
Alternative Irri. (I2)	34.09	33.9	33.90c	*	33.07	32.69	32.88c	*
Surge 10/10 (I3)	56.52	55.86	56.29a	*	54.82	54.18	54.60a	*
Surge 10/6 (I4)	56.53	56	56.31a	*	54.82	54.32	54.62a	*
Surge 10/3 (I5)	56.91	56.3	56.31a	*	55.2	54.61	54.62a	*
Mean	51.3	50.78	51.04		49.76	49.22	49.49	
Significant	*	*			*	*		
L.S.D at 5%	0.35	0.46			0.33	0.45		

Mean followed by the same letter (s) are not significantly different at 5% Level according to(D MET) and Ns significant at 5% Level and not Significantly respectively.

Table (5) Field water use efficiency (kg/m^3) during 2007 and 2008 seasons.

Character	Field water use efficiency (kg/m3)							
	2007			Significant	2008			Significant
Slope, %	Slope, %		Mean		Slope, %		Mean	
Water applied	0.0	0.1			0.0	0.1		
Continuous Irri. (I1)	1.213	1.207	1.210ab	*	1.177	1.171	1.174b	*
Alternative Irri. (I2)	1.84	1.85	1.85a	*	1.84	1.85	1.85a	*
Surge 10/10 (I3)	1.225	1.204	1.215ab	*	1.188	1.168	1.179ab	*
Surge 10/6 (I4)	1.156	1.133	1.145b	*	1.121	1.10	1.11ab	*
Surge 10/3 (I5)	1.168	1.172	1.170b	*	1.133	1.137	1.135ab	*
Mean	1.32	1.31			1.05			
Significant	*	*			*	*		
L.S.D at 5%	0.06	0.06			0.06	0.06		

Mean followed by the same letter (s) are not significantly different at 5% Level according to(D MET) and Ns significant at 5% Level and not Significantly respectively.

Distribution efficiency %:

Table (7) illustration the increasing slope led to increase distribution efficiency, where, value it was 94.56% with slope (0.1%), while, at was 93.92% with slope (0.0%).

On the other side, increasing time of surge cycle ration led to increase "DE" value , so, the highest value recorder by surge cycle at (10/3) was 96.54%, while, the lowest value recorder by continuous irrigation it was 90.605% significant interactions were deflected between slope % and water applied system in both seasons.

Table (6) Crop water use efficiency (kg/m^3) during 2007 and 2008 seasons.

Character	Crop water use efficiency (kg/m3)							
	2007			Significant	2008			Significant
Land leveling system	Slope, %		Mean		Slope, %		Mean	
Water applied	0.0	0.1			0.0	0.1		
Continuous Irri. (I1)	1.156	1.521	1.541a	*	1.121	1.475	1.495a	*
Alternative Irri. (I2)	0.992	0.974	o.98E	*	0.992	0.979	0.995E	*
Surge 10/10 (I3)	1.344	1.325	1.336b	*	1.304	1.288	1.296b	*
Surge 10/6 (I4)	1.260	1.236	1.248c	*	1.222	1.199	1.211c	*
Surge 10/3 (I5)	1.226	1.220	1.233d	*	1.189	1.183	1.196d	*
Mean	1.2	1.24			1.17	1.22		
Significant	*	*			*	*		
L.S.D at 5%	0.02	0.02			0.02	0.02		

Mean followed by the same letter (s) are not significantly different at 5% Level according to(D MET) and Ns significant at 5% Level and not Significantly respectively.

Table (7) Distribution efficiency, % during 2007 and 2008 seasons.

Character	Distribution efficiency, %							
	2007			Significant	2008			Significant
Land leveling system / Water applied	Slope, %		Mean		Slope, %		Mean	
	0.0	0.1			0.0	0.1		
Continuous Irri. (I1)	89.9	91.31	90.61d	*	89.2	88.57	87.89d	*
Alternative Irri. (I2)	92.15	92.82	92.49c	*	92.3	90.04	89.72c	*
Surge 10/10 (I3)	95.47	95.14	95.31b	*	92.61	92.29	92.45b	*
Surge 10/6 (I4)	96.00	96.53	96.27a	*	93.12	93.63	93.38a	*
Surge 10/3 (I5)	96.08	97.00	96.54a	*	93.2	94.09	93.64a	*
Mean	93.92	94.56			91.41	91.72		
Significant	*	*			*	*		
L.S.D at 5%	0.36	0.60			0.35	0.58		

Mean followed by the same letter (s) are not significantly different at 5% Level according to(D MET) and Ns significant at 5% Level and not Significantly respectively.

Table (8) Grain yield (kg/fed) during 2007 and 2008 seasons.

Character	Grain yield (kg/fed)							
	2007			Significant	2008			Significant
Land leveling system / Water applied	Slope, % 0.0	Slope, % 0.1	Mean		Slope, % 0.0	Slope, % 0.1	Mean	
Continuous Irri. (I1)	3431	3312	3371.5a	*	3328	3212	3270.36a	*
Alternative Irri. (I2)	3384	3300	3342a	*	3282	3201	3241.74a	*
Surge 10/10 (I3)	3201	3115	3158b	*	3104	3021	3063.26b	*
Surge 10/6 (I4)	2996	2906	2951c	*	2906	2818	2862.47c	*
Surge 10/3 (I5)	2900	2884	2892d	*	2813	2797	2805.24d	*
Mean	3182.4	3103.4			3086.93	3010.3		
Significant	*	*			*	*		
L.S.D at 5%	0.75	0.75			0.73	0.73		

Mean followed by the same letter (s) are not significantly different at 5% Level according to(D MET) and Ns significant at 5% Level and not Significantly respectively.

Grain yield (kg/fed):

Data in Table (8) showes that, significant interactions were delected between slope % and different irrigation system in the two seasons. Slope(0.0%) treatment gave the best value of grain yield, it was 3182.4 kg/fed. While , slope(0.1%) treatment was apposite it was 3103.4 kg/ fed. These increase yield with slope (0.0%) treatment due to increase amount of water applied- than in slope (0.1%) treatment.

Regarding to different irrigation systems, data clear the increasing time of surge cycle ratio led to decrease of grain yield. Continuous flow irrigation treatment gave the highest value, it was 3371.5 kg/fed. While the lowest value with surge cycle at (10/3), it was 2892 kg/fed. The interaction between slope (0.0%) treatment with continuous irrigation gave the best value, while slope(0.1%) treatment with surge cycle at (10/3) was opposite.

CONCLUSIONS

It can be concluded that alternative irrigation saved amount of irrigation water by about of 35% and 30% than continuous flow irrigation and surge cycle ratio. Land slope zero, % produced the highest yield, net profit and water use efficiency.

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الملخص العربي

زيادة كفاءة الاستهلاك المائي للذرة الشامية تحت طرق تسوية التربة وإضافة مياه الري

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أجريتْ التجارب الحقلية في بمحطة بحوث القرضا- محافظة كفر الشيخ أثناء عامي 2007- 2008 . وكانت المعاملة الرئيسية هي طرق تسوية التربة وتم استخدام التسوية بالليزر لعمل الميول المستخدمة. – {الأول الميل 0 سم /100 متر (0.0%) (L 1)) (والثاني 10 سم /100 متر (0.1 %) (L 2)} - بينما، المعاملة الثانويةِ كانت طرقِ إضافة المياه . وهـي: - 1) رَيّ تدفقِ مستمرِ 2) الرَيّ التبادلي3) الري النبضي. كالتّالي: (10 دقائق فتح ، 10 دقائق غلق (10/10) و (10 دقائق فتح ، 6 دقائق غلق (6/10) و(10 دقائق فتح ، 3 دقائق غلق (3/10).
أشارتْ النَتائِجُ بأنّ تحت الميول صفر % أعطت أكثر معدل في كميةِ الماءِ المضافة، وكفاءة الاستهلاك المائي. كفاءة الاستهلاك المائي الحقلي عن المعاملة 1.0 %. والتي أعطت كفاءة عالية في توزيعِ الماء و اعلي إنتاجية للمحصول كجم/ ف .
أيضا أعطت معاملة الرَيَّ التبادلي أقل القيم للماء المستهلك، (cu) 33.90 سم. وكفاءة الاستهلاك المائي (CWUE) 0.995 كجم /م3 ، وكفاءة الاستهلاك الحقلي (FWUE) 1.45 كجم/ م 3 وإنتاجية المحصول 3342 كجم / فدان واقل قيمة للتوزيع المائي فكانت 92.49 % .على التوالي.
وكانت أحسن معاملة في الري النبضي هي المعاملة 10/10 وأقلهم المعاملة 3/10 .
يوصي الباحث بإتباع طريقة الري التبادلي في أراضي شمال الدلتا حيث أعطت أعلي إنتاجية لمحصول الذرة بالنسبة للمعاملات المختلفة التي أجريت بالتجربة، نظراً لتوفير كميات مياه هائلة يمكن توجيهها إلي التوسع الأفقي في الأراضي الجديدة.