Surge flow irrigation for corn in clay soils

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Abstract

Field experiments were carried out during 1996 and 1997 summer seasons at Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt. These experiments aim to evaluate the furrow surge irrigation system for corn under different land levelling practices as a method to improve the efficiency of surface irrigation and water saving. The experiment was arranged in split plot design with three replicates. The main plots are assigned to land levelling practices (dead and traditional levelling), while the subplot treatments were the continuous flow irrigation and four cycle ratios of surge flow irrigation.
Obtained data showed that all tested cycle ratios of surge flow irrigation gave lower water advance times, lower amounts of applied water, higher water application efficiency and higher water distribution efficiency than that continuous flow irrigation. Advance inflow times were reduced in the case of surge flow to 21% and 20% of the time required for continuous flow under dead and traditional levelling, respectively. Amounts of applied water were reduced using surge flow irrigation by 19.1% and 16.5% of continuous flow irrigation under dead and traditional land levelling respectively. The average values of water application efficiency (WAE) varied from 68.6 to 84.2% and from 53.8 to 73.4% for surge flow irrigation under dead and traditional land levelling respectively. The corresponding values for continuous flow irrigation were 63.1% and 51.4%. Water distribution efficiency (WDE) increased using surge flow irrigation. The average WDE values under continuous flow irrigation were 85.4% and 77.1% for dead and traditional land levelling respectively. Corresponding values for surge flow irrigation varied from 88.0 to 94.7% and from 79.6 to 90.2%.

The results revealed also that the values of water consumptive use of corn were higher for continuous flow irrigation than that for surge flow one. The water consumptive use reduced with increasing the off-time in surge flow irrigation. The average of grain yield of corn under surge flow irrigation varied from 3.09 to 3.48 ton/fed. The corresponding value under continuous flow irrigation was 3.0 ton/fed. The dead levelling achieved higher grain yield than that traditional levelling. The average values of water utilization efficiency for continuous flow irrigation were 0.90 and 0.78 Kg/m^3 under dead and traditional land levelling, respectively. The corresponding values for surge flow treatments varied from 1.04 to 1.46 and from 0.86 to 1.14 Kg/m^3. For all the studied parameters the surge flow irrigation with cycle ratio of 0.5 (20 min. on and 20 min. off) gave the best results.

Introduction

Irrigation was initially introduced in Egypt as surface irrigation, about more than 3000 B-C. Surface irrigation is practiced as flooding the soil surface by basin or border irrigation, or running the water in small ditches of furrows. Despite the fact that, sprinkler and trickle irrigation are used to maximize the crop yield for unit water, the surface flooding irrigation is still the most widely used. This is because of the high cost of trained labor and energy required to conduct the alternative systems.

Generally, surface irrigation efficiency is around 50%. Over years, minor changes have been made to increase the efficiency of surface irrigation. Land smoothing, cutback technology and tail water reuse along with proper scheduling are used to reduce water losses and improve irrigation efficiency. The latest improved surface irrigation method is through surge flow irrigation (James, 1988). Many researches have been carried out either theoretically and/or experimentally, to study the several aspects of surge irrigation and to determine the involved mechanisms. However, in Egypt little work has been done on the field of water management and yield of field crops under surge irrigation, e.g. Ghalleb (1987), Zaghloul (1988) and Osman (1991).

The main objectives of the present study are:

1. To evaluate the furrow surge irrigation system of corn under different land levelling practices in heavy clay soils of Kafr El-Sheikh Governorate. 2. To improve efficiency of the surface irrigation and water saving. 3. To define the best surge flow furrow irrigation practices for corn crop owing to optimize the water utilization efficiency.

Material and Methods

Field experiments were carried out at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, during the two successive summer seasons of 1996 and 1997. The station is situated at 31^{o}C-07 N latitude, 30^{o}C-75 E longitude. It has elevation of about 6 meters above sea level. It represents conditions and circumstances of middle northern part of the Nile Delta. The experimental site located near to the main open drain and was served by tile drainage established since 1989. The tile drainage system consists of subsurface, 10 cm inner diameter, PVC pipes spaced 20 m apart and buried at 1.65 m depth.

Soil samples from the experimental field were collected for different soil depths, 15 cm each down to 60 cm, and analyzed for both some chemical properties and soil texture. The soil saturation extract was obtained. Total soluble salts (EC), acidity number (pH) and soluble cations and anions were determined by the methods described by Jakson (1962). The mean values are given in Table (1). In general the soil is non saline.

Table 1: Some chemical and physical analysis of experimental site.

Soil Depth	Particle size distribution			Text-Ure	Bulk density	FC w%	PWP w%	Avail-Able Water	EC	Cation c mole/kg soil				Anion c mole/kg soil			pH
	Sand	Silt	Clay		Mg/m^3			W%	dS/m	Na^+	K^+	Ca^{++}	Mg^{++}	$HCO_3^=$	Cl^-	$SO_4^=$	
0-15	15.18	18.85	65.97	Clay	1.09	47.2	25.38	21.82	1.50	0.76	0.02	0.30	0.10	0.55	0.21	0.46	8.15
15-30	19.90	13.80	66.30	Clay	1.15	40.5	21.85	18.85	1.57	0.79	0.02	0.31	0.10	0.57	0.22	0.48	8.00
30-45	16.59	16.97	66.94	Clay	1.24	39.0	21.19	17.81	1.65	0.89	0.02	0.34	0.10	0.65	0.23	0.50	8.00
45-60	12.65	15.24	67.12	Clay	1.26	38.5	20.81	17.69	2.78	1.25	0.03	0.84	0.27	0.45	0.23	1.71	7.90

The particle size distribution was determined according to the international pipette method, Black (1965). The obtained results (Table, 1) indicate that the soil is clayey in texture and the soil profile is uniform without distinct change in texture. Corn (*Zea mays* L.) as summer crop was sown in an agricultural rotation after wheat as winter crop. This rotation was repeated for two years. Sowing dates for corn were June 29, 1996 and June 30, 1997 for the first and second year, respectively. All cultural practices were the same as recommended for the area except the levelling and the irrigation treatments under study. The experiment was arranged in split plot design with three replicates. Each plot was 3.5 x 80 m= 280 m^2 = 1/15 feddan). Eight stations (S_1 to S_8) were arranged every 10 m along the furrow to measure the flow advance pattern. The treatments were as follows:

Main treatment (land levelling):
A. Dead levelling (0.0%) B.Traditional method of land levelling.
Sub treatments: five irrigation treatments were applied after sowing:
1: Represent a continuous flow irrigation (control),
2: Surge irrigation with cycle ratio of 0.8 (20 min on and 5 min off),
3: Surge irrigation with cycle ratio of 0.67 (20 min on and 10 min off),
4: Surge irrigation with cycle ratio of 0.57 (20 min on and 15 min off), and
5: Surge irrigation with cycle ratio of 0.5 (20 min on and 20 min off).
The cycle ratios were chosen according to the possible applicability. The irrigation intervals were 15 days. The amount of water in each application was added whatever number of surges needed until reaching 95% of the run length (75 m). The irrigation water was conveyed to the experimental plots through an open channel using a centrifugal pump with a water meter to measure the total volume of applied water. The inflow rate was about 5.4 L/sec.

Soil samples were taken from three selected stations along the furrow of two replicates, before and 2 days after each irrigation and immediately before harvesting from the successive soil layers 0-15, 15-30, 30-45, 45-60 cm depth. Their moisture content on the dry weight basis were determined. The advance time of the water flowing in furrow of each treatment was recorded when the water front was reached each station along the furrow. The on-off cycle time was controlled by means of stop watch. The number of surges needed until the water reached 95% of the furrow length were recorded and the irrigation time was determined.

The applied irrigation water to each experimental plot was measured using spile tubes. The effective head of water above the cross section center of irrigation spile was measured several times during irrigation and the averaged value was 6 cm. The water in the canal was controlled to maintain a constant head by means of fixed sliding type gates.

The amount of water delivered through a spile of 10 cm inner diameter was calculated by the equation:

$$q = CA\sqrt{2gh}. \quad \text{or } q = 0.0226\, D^2 h^{1/2}$$

Israelson and Hansen (1962)

Where: q = Discharge of irrigation water (L/sec),
C = Coefficient of discharge = 0.64 according to Osman 1991,
g = Gravity acceleration, 980 cm/S^2, A = Inner cross section area of irrigation spile,
h = Average effective head, cm, and D = Inside diameter of the spile tube, cm.

The volume of water for each strip (3.5 x 80 = 280 m^2) delivered to five furrows of 80 m length and 0.7 m apart was calculated by substituting Q in the following equation:

$$Q = q \times T \times n$$

Where: Q = Water volume m^3/strip, q = Discharge m^3/min,
T = Total time of irrigation (min) and n = Number of spile tube per each strip.
The total on-time under continuos and surge flow irrigation was calculated using a stop watch. To evaluate the flow advance rate for different treatments the approach of Christiansen *et al.,* 1966 was used as: $L = a\ t^b$
In which: L = Length of advance, t = Time of advance and a, b = Empirical constants.
Crop water consumptive use (cm) was determined as follows:

$$Cu = \sum_{i=1}^{i=4} \frac{Pw_2 - Pw_1}{100} \times D_{bi} \times D_i$$

Where: Cu = Consumptive use, cm. i = Number of soil layers,
Pw_2 and Pw_1 = Percentage of soil moisture content 48 hours after irrigation and before irrigation for the specified layer, D_i = Depth of soil layer = 15 cm, and
D_{bi} = Bulk density of the specified soil layer gm/cm^3.

Dates of harvesting of corn were Oct. 20, 1996 and Oct. 25, 1997 for the first and second season, respectively. Five plants from the central ridges at each station, were randomly chosen to determine the grain yield (ton/fed.). The water utilization efficiency as a measure to clarify variations in yield due to irrigation water was calculated according to Michael (1978) as follows:

$$WU_tE = Y/Wa$$

In which: WU_tE = Water utilization efficiency (kg/m^3),
Y = Total yield produced kg/fed., and Wa = Total applied water m^3/fed.
The collected data for grain yield were subjected to the statistical analysis according to Snedecor and Cochran (1967) and the mean values were compared by L.S.D. test and Duncan multiple range test (DMRT) according to Duncan, 1955.

Results and Discussion

1. Advance rate:

The data listed in Tables (2 and 3) revealed that the surge flow treatments had higher water advance rates, either under dead or traditional levelling, compared with the continuous flow irrigation treatments. The equations relating L and T, mean values, were: $L = 0.79\ T^{1.004}$, $L = 0.741T^{1.039}$, $L = 0.680\ T^{1.082}$, $L = 0.635\ T^{1.136}$ and $L = 0.619\ T^{1.176}$ under dead levelling, respectively for treatments A_1, A_2, A_3, A_4 and A_5. The corresponding equations for the traditional levelling were $L = 0.729T^{0.975}$, $L = 0.654T^{1.027}$, $L = 0.583T^{1.069}$, $L = 0.503T^{1.116}$ and $L = 0.527T^{1.121}$, respectively for the treatments B_1, B_2, B_3, B_4 and B_5. Also the constant (b) of the equation increased with decreasing of the cycle ratio and had relatively higher values under dead levelling than under the traditional one. This indicates that water advance rate is faster with decreasing the cycle ratio (or with increasing off-time) and under dead levelling than under the traditional levelling treatments.

The overall mean of time required for water advance to reach the end of the furrow varied from 86.3 to 66.7, with an average of 76.3 min and from 106 to 85.7, with an average of 95.2 min for surge flow treatments, under dead and traditional levelling respectively. The corresponding values for the continuous flow varied from 97.3 to 115.5 min under dead and traditional levelling, respectively. This means that the irrigation is completed faster when surge flow irrigation technique is used. Surge flow saved 21% of the time required for continuous flow to complete the irrigation, under dead levelling. The corresponding value under traditional levelling was 20%. This saving of irrigation time under surge flow was mainly because of the faster water advance rate under surge flow than under the continuous flow. The best treatment was that of 0.5 cycle ratio (20 min on and 20 min off). These results indicated that surge flow had faster advance rate with the longer off-time due to the effect of wetting and drying cycles on soil infiltration characteristics, Goldhamer *et al.* (1987). Increasing the off-time in surge flow reduces infiltration rate and results in greater advance on wetted area, Guirguis (1988). The trend of these results is in accordance with those obtained by Moustafa (1992) and Osman *et al.* (1996).

2. Applied irrigation water:

The number of irrigations during the whole season was seven irrigations including the sowing irrigation. The amount of the applied water to each treatments are given in Tables (4 and 5). The total amount of applied water varied according to the differences in irrigation treatments. All tested cycle ratios of surge treatments used less amount of water than that continuous one. Average volumes of applied water for continuous flow treatment (A_1) were 3402 and 3813 m^3/fed for dead and traditional levelling, respectively. The average amounts of added water by surge flow treatments A_2, A_3, A_4 and A_5 were, 3074, 2832, 2665 and 2447 m^3/fed, under dead levelling, respectively. The corresponding values under the traditional levelling were 3516, 3261, 3053 and 2883 m^3/fed for treatments B_2, B_3, B_4 and B_5, respectively. The surge flow irrigation reduced the applied water by 9.7, 16.8, 21.8 and 28.2% for the treatments A_2, A_3, A_4 and A_5, respectively under dead levelling. The corresponding reductions of the added water by surge flow under the traditional levelling were 7.8, 14.3, 20.2 and 23.9% for treatments B_2, B_3, B_4 and B_5, respectively. In other words, surge flow irrigation saves water, on average for all treatments, by about 19.1% and 16.5% of the continuous flow irrigation, under dead and traditional levelling, respectively.This means that dead levelling emphasized the saving of the applied irrigation water to corn crop. Increasing the off-time in surge flow results in greater water saving. The best treatment in saving water was that of 20 min on and 20 min off (0.5 cycle ratio). It saved water of 28.2% (959.4 m^3/fed) and 23.9% (911.4 m^3/fed) of the applied water using continuous flow irrigation under dead and traditional levelling, respectively. The trend of these results is in accordance with those obtained by Ghalleb (1987) and Osman (1991). On the other hand, data revealed that the soil under traditional method of land levelling received higher amount of irrigation water than that under dead levelling. These results are in a harmony with those obtained by El-Mowelhi *et al.* (1995).

3. Water application efficiency (WAE)

The calculated WAE values for the different irrigation treatments are illustrated in Figure (1). The surge flow had higher values of WAE compared with the continuos flow irrigation. The overall average WAE values for continuous irrigation were 63.1% and 51.4%, under dead and traditional levelling, respectively. The corresponding values for surge flow irrigation treatments varied from 68.6% to 84.2% with an average of 74.5%, and from 53.8% to 73.4%, with an average of 63.9% under dead and traditional levelling, respectively. These results indicate that WAE under surge flow irrigation exceed the continuous flow irrigation with about 11.4% and 12.5% under dead and traditional levelling, respectively.

The high efficiency of surge flow can be attributed to the surface seal that causing by the intermitted wetting and the surface hydraulic roughness of the wet advance, Guirguis (1988). It was found that WAE increase with the decrease of the cycle ratio or the increase of off-time. The best treatment was that of 0.5 cycle ratio (20 min on and 20 min off). It had the highest value of 84% and 73% as average of the two seasons, under dead and traditional levelling, respectively. These results are in close agreement with those of Osman (1991) who found that the WAE values were 60.9, 73.7, 74.4 and 77.7% for continuos flow and for surge flow of 5/5, 5/10 and 5/15 on/off min, respectively at Sakha (Kafr El-Sheikh).

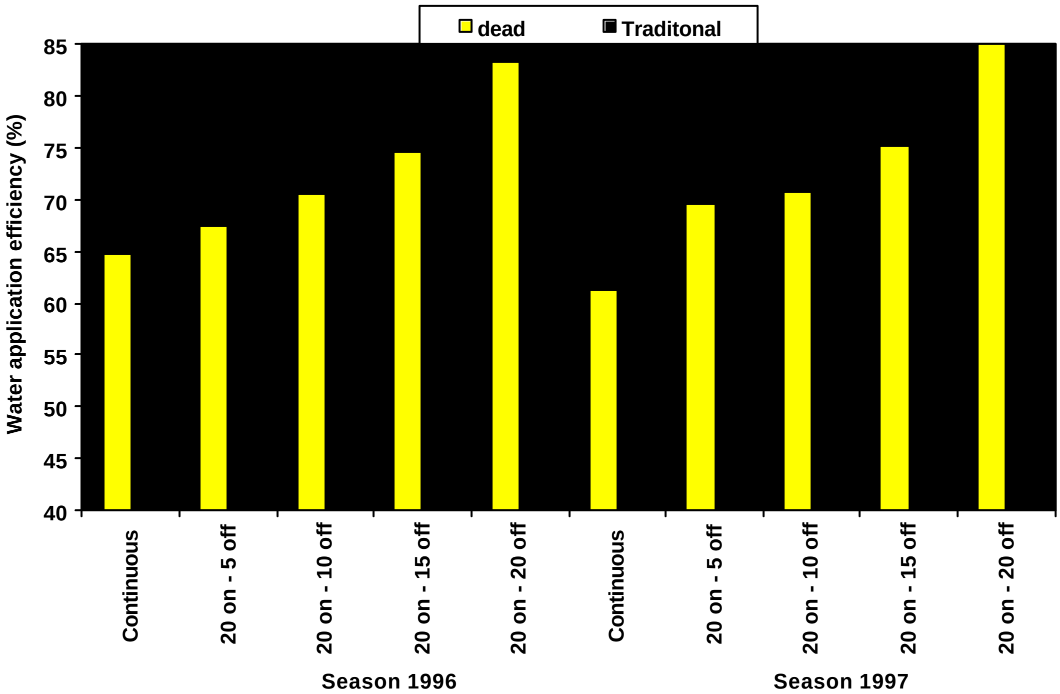

Figure 1: Values of water application efficiency (WAE) under dead and traditional levelling for furrow irrigation of corn during 1st and 2nd seasons.

4. Water distribution efficiency (WDE):

As shown in Table (6) surge flow technique recorded higher values of WDE compared with continuous flow irrigation either under dead or traditional levelling. The overall average of WDE values, for the two growing seasons, under the continuous irrigation were 85.4% and 77.1% for dead and traditional levelling, respectively. The corresponding values for the surge flow irrigation treatments varied from 88.0 to 94.7% with an average of 91.4% , and from 79.6 to 90.2% with an average of 84.9% for dead and traditional levelling, respectively. It was found that WDE values increased whenever the cycle ratio decreased or the off-time increase. The best treatment was that of 0.5 cycle ratio (20 min on and 20 min off). It had the highest values of 94.7% and 90.2% for dead and traditional levelling, respectively. The trend of these data is in agreement with those obtained by Moustafa (1992) and Evans *et al.* (1995) who mentioned that the use of surge flow was superior to continuous flow furrow irrigation for maintaining acceptable application uniformities. On the other hand, the difference between WDE values of surge flow and these of continuous flow irrigation was relatively low. It varied between 6 and 7.7%. This may be due to the nature of the clayey soils that crack severely, Pitts and Ferguson (1985).

Table (6): Values of water distribution efficiency (WDE) under different irrigation treatments for the furrow irrigation of corn.

Land Levelling	Treat.	Cycle ratio		Season 1996 Date of determination				Season 1997 Date of determination				Average of two seasons	
		On	Off	19/8	15/9	10/10	Average	13/8	7/9	28/9	Average		
Dead Levelling	A_1	Cont.	0	80.1	85.7	87.4	84.4	83.3	87.2	88.4	86.3	85.4	85.4
	A_2	20	5	83.4	86.5	92.6	87.5	85.5	89.3	91.7	88.5	88.0	
	A_3	20	10	90.0	89.2	93.8	91.0	90.6	94.0	95.0	93.2	92.1	91.4
	A_4	20	15	91.3	91.5	95.0	92.6	93.3	95.2	95.3	94.6	93.6	
	A_5	20	20	93.0	94.5	96.3	94.6	94.4	95.3	96.2	95.3	94.7	
Traditional levelling	B_1	Cont.	0	73.5	76.0	77.0	75.5	75.3	80.2	80.3	78.6	77.1	77.1
	B_2	20	5	78.4	79.3	80.5	79.4	78.6	79.8	81.0	79.8	79.6	
	B_3	20	10	80.0	83.2	87.0	83.4	83.3	84.3	86.2	84.6	84.0	85
	B_4	20	15	83.4	87.2	88.3	86.3	85.6	86.0	87.0	86.2	86.3	
	B_5	20	20	89.7	90.3	90.4	89.9	89.0	90.4	91.0	90.4	90.2	

5. Water consumptive use (WCU):

As shown in Table (7) the values of WCU, average of the two seasons, varied from 41.6 to 47.9 cm and from 45.4 to 51.5 cm under the surge flow irrigation treatments for dead and traditional levelling, respectively. The corresponding values for the continuous irrigation treatment were 50.1 and 53.5 cm for dead and traditional levelling, respectively. The tendence of these results are in agreement with those obtained by Musick *et al.* (1987) who showed that surge flow irrigation reduced seasonal water use during 7 irrigations by 6%. Ghalleb (1987) found that the consumptive use for the continuous flow irrigation was higher (3.36 mm/day) than those for the surge flow irrigation, 3.18 and 3.0 mm/day respectively with cycle ratios of 1/2 and 1/4. Also, the surge flow treatments A_5 and B_5 recorded the lowest values of WCU (41.6 and 45.6 cm) under the dead and traditional levelling, respectively. The continuous irrigation treatments A_1 and B_1 had the highest values of 50.1 and 53.5 cm, respectively.

6. Grain yield:

Data tabulated in Table (8) showed that the highest grain yield was obtained under the surge flow treatment of 0.5 cycle ratio (20 min and 20 min off). It had an overall average of 3.48 and 3.40 ton/fed for the first and second seasons, respectively. On the other side, the lowest grain yields of 3.05 and 2.98 ton/fed were obtained under the continuous irrigation, for 1st and 2nd seasons, respectively. This means that the increase in corn grain yield under the best treatment (0.5 cycle ratio) was 14.1% above the yield of the continuous irrigation.

Table (7): Water consumptive use (cm) of corn (season 1996 and 1997) for different treatments.

Land levelling	Treat.	Cycle		Season 1996		Season 1997		Average of two seasons	
		On	Off	Cm	m^3/fed	cm	m^3/fed	cm	m^3/fed
Dead levelling	A_1	Cont.	0	51.80	2175.6	49.3	2070.6	50.1	2104.2
	A_2	20	5	48.30	2028.6	47.6	1999.2	47.9	2011.8
	A_3	20	10	46.56	1955.5	45.3	1902.6	45.9	1927.8
	A_4	20	15	44.47	1867.7	43.2	1814.4	43.8	1839.6
	A_5	20	20	42.62	1790.0	40.6	1705.2	41.6	1747.2
Traditional levelling	B_1	Cont.	0	54.60	2293.2	52.4	2200.8	53.5	2251.2
	B_2	20	5	52.60	2209.2	50.4	2116.8	51.5	2163.0
	B_3	20	10	48.20	2024.4	47.3	1986.6	47.8	2007.6
	B_4	20	15	46.40	1948.8	45.4	1906.8	45.9	1927.8
	B_5	20	20	45.60	1915.2	45.2	1898.4	45.4	1906.8

Table (8): Grain yield (ton/fed) of corn in the two growing seasons 1996 and 1997 as affected by irrigation treatments and land levelling practices.

Cycle ratio		Season 1996			Season 1997		
On	Off	Dead Levelling	Traditional levelling	Mean	Dead Levelling	Traditional levelling	Mean
Cont.	0	3.110 CD	3.00 D	3.055 D	3.000 EF	2.960 F	2.980 D
20	5	3.260 BCD	3.040 CD	3.150 CD	3.150 CD	3.030 DEF	3.090 C
20	10	3.340 ABC	3.170 CD	3.25 BC	3.220 BC	3.110 CDE	3.165 C
20	15	3.480 AB	3.270 BCD	3.375 B	3.430 A	3.150 CD	3.290 B
20	20	3.600 A	3.360 ABC	3.480 A	3.530 A	3.270 B	3.400 A
Mean		3.358	3.218		3.266	3.104	
L.S.D. at 5% = 0.323					L.S.D. at 5% = 0.1136		

Generally, surge flow irrigation had higher grain yield values than that the continuous one, either under dead or traditional levelling. The overall average of grain yield under surge flow treatments varied from 3.15 to 3.48 ton/fed and from 3.09 to 3.4 ton/fed for 1st and 2nd seasons, respectively. The corresponding values under the continuous treatment varied between 3.05 and 2.98 ton/fed for 1st and 2nd season, respectively. The dead levelling treatment achieved higher grain yield values than that the traditional levelling treatment. It had an overall average values of 3.35 and 3.26

ton/fed compared with 3.2 and 3.1 ton/fed for 1st and 2nd season, respectively. The statistical analysis showed significant differences between treatment of 20 min on/20 min off and the other treatments. While there were no significant differences between the treatments 20 on/5 off, and 20 on/10 off for the two growing seasons. The high production of corn under surge irrigation compared with continuous one may be attributed to the improvement of soil areation conditions, more uniformity water distribution along the furrow and maintenance of nutrients. These results are in agreement with Ghalleb (1987) and Osman (1991) who found that the grain yields of corn under surge irrigation were higher than under the continuous one.

7. Water utilization efficiency (WU_tE):

Values of WU_tE for the different irrigation treatments under dead and traditional levelling are presented in Table (9). The surge flow treatments had higher values of WU_tE than those of continuos flow ones. Also, WU_tE values were higher under dead levelling than that under the traditional levelling. The overall average of WU_tE values (average of two seasons) for continuous flow irrigation were 0.9 and 0.78 kg/m^3 under dead and traditional levelling, respectively. The corresponding values for surge flow treatments varied from 1.04 to 1.46, with an average of 1.25 kg/m^3 and from 0.86 to 1.14, with an average of 1.00 kg/m^3 under dead and traditional levelling, respectively. The best treatment was that of 0.5 cycle ratio, it had the highest WU_tE value of 1.46 and 1.14 kg/m^3, respectively for dead and traditional levelling. The explanation of these results, as mentioned before is that surge flow irrigation especially with dead levelling leads to higher water distribution uniformity, less water losses by deep percolation and less amount of applied water during the irrigation.

Table (9): Water utilization efficiency of corn (in kg/m^3) under different irrigation treatments.

Treatment				Season 1996			Season 1997			Average
Land levelling		Cycle ratio On	Off	Yield kg/fed	Wa m^3/fed	WU_tE Kg/m^3	Yield kg/fed	Wa m^3/fed	WU_tE kg/m^3	of two Seasons
Dead levelling	A_1	Cont.	0	3110.0	3435	0.91	3000.0	3368	0.89	0.90
	A_2	20	5	3260.0	3137	1.03	3150.0	3011	1.04	1.04
	A_3	20	10	3340.0	2952	1.13	3220.0	2713	1.18	1.15
	A_4	20	15	3480.0	2780	1.25	3430.0	2423	1.41	1.33
	A_5	20	20	3600.0	2583	1.39	3530.0	2310	1.52	1.46
Traditional levelling	B_1	Cont.	0	3000.0	4082	0.73	2960.0	3544	0.83	0.78
	B_2	20	5	3040.0	3780	0.80	3030.0	3259	0.92	0.86
	B_3	20	10	3170.0	3465	0.91	3110.0	3057	1.01	0.96
	B_4	20	15	3270.0	3288	0.99	3150.0	2818	1.11	1.05
	B_5	20	20	3360.0	3133	1..07	3270.0	2675	1.22	1.14

Wa = total amount of the applied water during the season.

The above mentioned results are similar to those obtained by Osman (1991) who found that surge irrigation leads to increase water use efficiency by 0.69 kg/m^3 at Sakha farm and by 0.9 kg/m^3 at Abis farm than that water use efficiency for continuous irrigation. Ghalleb (1987) compared continuous flow irrigation with three different surge irrigation treatments of cycle ratio of 1/2, 1/3 and 1/4. He showed that WU_tE was 0.58 kg/m^3 for continuous flow and varied between 0.79 to 1.0 kg/m^3 for surge flow irrigation.

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