WATER SAVING UNDER ALTERNATIVE FURROWS SURFACE IRRIGATION IN CLAY SOILS OF NORTH NILE DELTA

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ABSTRACT

Surface irrigation is the dominant method of on-farm irrigation in Egypt as well as world wide. Furrow watering is considered as one of the main types of surface irrigation. Most of the cultivated crops are grown under such type of watering. The principal advantage of furrow irrigation is the less irrigated area comparing with that under basin irrigation which equaled total cultivated acreage.

Under the present situation of water shortage that facing Egypt resulted in capita share from water for different purposes becomes less than the water poverty edge and expected more decreasing to reach the scarcity level in the few coming decades. Moreover, Egypt is the solely country in the world that its agriculture is depending mainly on irrigation, i.e. irrigated agriculture due to the high arid condition of the country.

For clay soils, the horizontal movement of irrigation water is exceeding the vertical downward movement. So, in this direction, a field trial in two seasons was conducted in North Nile Delta region to find out the impact of alternative surface irrigation on beet water relations. Comparing with the traditional furrow irrigation; fixed as well as exchangeable alternative surface irrigation effects on water saving, crop water productivity and on-farm irrigation efficiencies were analyzed.

Keywords: Alternative irrigation, Crop water productivity, Water saving

INTRODUCTION

Surface irrigation is the most common executed irrigation system in Egypt as well as world wide. This wide spread implementation might be due to its low capital cost, no special technical experience regarding operation and maintenance is needed and no specific equipment are required as well as the long practical background among local farmers regarding usage of such system.

On the other hand, surface irrigation among other methods has the lowest irrigation efficiency. Deep percolation particularly in the upper part of the irrigated field as well as the less-uniformity of irrigation water above soil surface are the main causes of the lower efficiency of surface irrigation. In average, losses of irrigation water under this method is about 45% causing several acute problems such as leaching of nutrient elements and raising of water table. Consequently, reduction in crop yield, crop-water and/or fertilizer productivity could be predicted.

Egypt is the solely country in the world that its agricultural production is irrigated, i.e. no rain fed agriculture from the economic point of view is practiced due to the very dry condition with mean annual rainfall of less than 250 mm. Under the present situation of rapid increasing of population and the limited water supply, annual capita share from water for different purposes is decreasing to less than the water poverty edge of 1000 m^3 and is expected to be less than the water scarcity level of about 500 m^3 in the few coming decades. At this situation it is hardly to make any progress in any sector of development. Agriculture is the main sector in water consumption with about 85% from national water supply.

Therefore, tremendous efforts should be implemented to minimizing water losses in irrigated agriculture particularly under surface irrigation system. Among these ways; preparing good seedbed environment, good leveling of soil surface with proper slope using laser technique, tail water reuse, cut-back irrigation as well as alternative or one by one furrow irrigation. However, improving the performance of surface irrigation should be economical, practical or even desirable.

For the old lands of Nile Delta and its valley, the implementation of alternative furrow irrigation could be incorrigible and less expensive in improving surface irrigation which expressed in up-grading irrigation efficiency. Such increasing could be attributed to the fact that the horizontal movement of soil water in the prevailing clay soils of the Nile Delta is exceeded the vertical downward movement and vise versa for sand soils. Therefore by using such technique, less irrigation water is applied and those un-irrigated furrows could obtain their water needs from the adjacent irrigated furrows through the horizontal movement of soil water.

Regarding the other furrow irrigation technique, Crabtree et al. (1985) stated that, small yield losses were recorded for sugar beet under alternative furrow irrigation (AFI) comparing with every furrow irrigation (EFI) but irrigation water use decreased by 30 to 50%. Moreover, Benjamin et al. (1994) found that for the clay loam soil the water content differences between EFI and AFI were smaller than for the loamy sand. The lower hydraulic conductivity and subsequently longer irrigation time allowed more water to move laterally under the ridge to beneath the non irrigated furrow. In other words, AFI in a clay loam soil allowed more lateral flow and the soil water content was more uniform than in loamy sand because of excessive water drainage directly beneath the irrigated furrow.

The objective of the herein work is a trial to improving the performance of surface irrigation through alternative irrigation technique. Several effects of applying this method on; saving irrigation water, water distribution efficiency, and yield as well as crop water productivity for sugar beet were considered.

Meaningfully, more crop per drop of water

MATERIALS AND METHODS

A field trial was conducted during the two successive growing seasons 2001/02 and 2002/03 at Sakha Agricultural Research Station, Kafr EL-Shiekh Governorate. The site represents the circumstances and conditions of Middle North Nile Delta region and allocated at 31-07' N Latitude, 30-57'E Longitude with an elevation of about 6 meters above mean sea level. Soil of the experimental field is clayey in texture as shown in Table (1). All agricultural practices were the same as executing in the area except the tested.

Table (1): Soil particle distribution and soil water constants for the experimental field

Soil depth (cm)	Soil particle distribution			Textural class	F.C. (%)	Db (kg/m^3)	W.P (%)	A.W (%)
	Sand (%)	Silt (%)	Clay (%)					
0-15	14.2	32.7	53.1	Clay	48.00	1.03	26.21	21.79
15-30	20.5	35.0	44.5	Clay	43.10	1.40	22.00	21.10
30-45	20.0	41.1	38.9	Clay loam	40.35	1.43	21.05	19.30
45-60	21.8	41.8	36.4	Clay loam	38.10	1.46	20.14	17.97

Alternative furrow irrigation (AFI) treatments which were as follows:

- A, traditional irrigation or so-called every furrow irrigation (EFI) i.e. during the growing season watering all cultivated furrows at each irrigation.
- B, alternative irrigation one by one fixed (1/1F) i.e. during the growing season irrigating one furrow and kept the other adjacent one without watering.
- C, alternative irrigation one by one exchangeable (1/1 Ex) i.e. during the growing season the irrigated furrow in irrigation event will be un-irrigated in the next watering and vise versa for the following irrigation and so-on.

It should be notified that the stated treatments were implemented after the first three common irrigations; sowing, Life and the following one at which fertilizer doses were applied.

Each treatment was shaped in a strip included 4 ridges 60 cm apart and 70 m long occupying an area of 168 m^2 i.e.1/25 fed. (1 fed = 0.42 ha). Irrigation intervals were the same as local farmers irrigating their fields.

DATA COLLECTIONS

1- Water Parameters

Irrigation water was controlled and measured by a fixed rectangular weir, 30 cm base width with discharge 0.01654 m^3/sec at 10 cm as effective head.

a) Water applied (Wa):

Water applied (Wa) was calculated as, Giriapa (1983):

$$Wa = Iw + Re + S \quad (1)$$

where:

Iw = irrigation water applied
Re = effective rainfall
S = amount of soil moisture contributing to consumptive use either from stored moisture in root zone and / or that from shallow water table.
Value of S was neglected due to the long duration of the growing season.

b) Crop consumptive use (Cu):

Consumptive use of the growing crop (Cu) or so called crop evapotranspiration (Etc) based on soil moisture depletion (S.M.D.) in the effective root zone defined as direct method of Cu computation was calculated as Doorenbos et al. (1979) described:

$$Cu = (F.c - W1)/100 * Db * d \quad (2)$$

where:

Cu = consumptive use, cm.
Fc = field capacity for each soil layer, %.
W1 = soil moisture before irrigation, %.
Db = bulk density of the specified soil layer, kg/m^3, and
d = depth of each soil layer, 15 cm.

2- Irrigation Efficiencies

a) Crop Water Productivity (CWP):

$$CWP = Y/Wa \quad (3)$$

b) Water use Efficiency (WUE):

$$WUE = Y/Cu \quad (4)$$

c) Consumptive use efficiency (Ecu):

$$Cu/Wa * 100 \quad (5)$$

where:

Y = root or sugar yield

3- Yield (ton/fed)

The yield of the two central furrows was weighed and computed as:

a) Root yield (ton/fed.).
b) Sugar yield (ton/fed.) obtained by multiplying root yield by sucrose percentage.

4-Yield Quality

a) Sucrose percentage.
b) Purity percentage.
c) Alkaline coefficient (AC) percentage.

The quality parameters were determined at Delta Sugar Company Limited, Kafr EL-Sheikh Governorate.

Yield data were subjected to statistical analysis according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

1- Water applied (Wa):

As shown in Table 2, the traditional treatment A (EFI) received the highest seasonal water applied 2327.0 m^3/fed or 55.4 cm. This amount consists of 47.6 cm as irrigation water (IW) and 7.8 cm as rainfall (RF). Comparing with the EFI treatment, water applied was 57.7 and 56.9% for the alternative treatments; B (1/1F) and C (1/1E) respectively. So in this direction, average of saving irrigation water was about 900 m^3/fed or 80 million m3 for beet cultivated area in Kafr EL-Sheikh Governorate, the core district in sugar beet production in Egypt.

2- Crop consumptive use (Cu):

The highest value of seasonal Cu 2213.4 m^3/fed or 52.7 cm (Table 3) was obtained under traditional irrigation EFI of watering all cultivated furrows (Trt. A), whereas the lowest value 1507.0 m^3/fed or 35.9 cm was resulted under 1/1 Ex alternative furrow irrigation (Trt. C).

The average values of seasonal Cu rate were in the same trend, they were 2.6, 1.9 and 1.8 mm/day for treatments A, B and C, respectively.

This finding might be attributed to the sufficient soil moisture in the effective root zone resulted from the traditional EFI treatment A which received regular watering during the growing season.

On the other hand, the growing plants under the conditions of the alternative furrow irrigation treatments B and C subjected to moisture stress resulted from the un-irrigated furrows according to the nature of such technique. This finding is fairly in the same direction with that obtained by Emara (2000).

Table (2): Seasonal Water applied, (Wa) irrigation water (IW) and rainfall (Rf) (m^3/fed) as affected by alternative irrigation in the two growing seasons 2001/2002 and 2002/2003

Treatments	Parameters								
	Wa (m^3/fed)			IW (m^3/fed)			Rf (m^3/fed)		
	1st	2nd	Av.	1st	2nd	Av.	1st	2nd	Av.
A (control)	2532.3	2121.00	2326.95	2087.19	1911.00	1999.10	445.20	210.00	327.60
B (1/1fixed)	1507.25	1176.00	1341.63	1062.05	966.00	1014.03	445.20	210.00	327.60
C (1/1exchange)	1491.26	1157.49	1324.38	1046.06	947.49	996.78	445.20	210.00	327.60

Table (3): Consumptive use (m^3/fed.) and its rate (mm/day) as affected by alternative irrigation in the two growing seasons 2001/2002 and 2002/2003

Treatments	Parameters					
	Root yield (ton/fed)			Sugar yield (ton/fed)		
	1st	2nd	Av.	1st	2nd	Av.
A (EFI)	2285.2	2141.6	2213.4	2.7	2.5	2.6
B (1/1F)	1649.6	1535.3	1592.4	2.0	1.8	1.9
C (1/1E)	1582.4	1431.6	1507.0	1.9	1.7	1.8

3- Irrigation efficiencies:

a) Crop water productivity (CWP, kg/m^3):

It is cleared that by increasing applied irrigation water, a decreasing in CWP would be obtained and vise versa as shown in Table 4. In this regard, the mean values of CWP are 11.6, 19.5 and 18.6 kg root/m^3 water applied for treatments; A (EFI), B (1/1F) and C (1/1E). Meaningfully, the lowest value 11.6 was obtained from the local traditional irrigation received the highest amount of applied irrigation water.

Regarding sugar yield, same trend was cleared. Treatment B (1/1F) resulting the highest value 3.4 kg/m^3 water applied, whereas the lowest 1.9 kg/m^3 was obtained from treatment A.

This finding is in harmony with those obtained by Baily (1990), Ibrahim et al. (1992) and Emara (2000) who reported that an adverse effect was found between amount of applied irrigation water and CWP for both beet root and sugar yield.

b) Water use efficiency (WUE, kg/m^3):

This parameter is an indicator for the capability of the growing plants to converting the used water into crop yield (Table 4). For the irrigated treatments; A (EFI) and the two alternative ones of B (1/1F) and C (1/1E), average values for beet roots are 12.1, 15.1 and 16.1 kg/m^3 water used. Regarding sugar yield, the corresponding values are 2.0, 2.7 and 2.9 kg/m^3, respectively. These results are in the same direction with that found by Emara (2000).

c) Consumptive use efficiency (Ecu, %):

This parameter reflects the capacity of roots to extract the stored soil moisture between irrigation periods. The alternative treatment B (1/1F) has the highest Ecu of 122.9% (Table 4). This finding could be attributed to the contribution from water table to crop water needs (Cu). In this regard, average seasonal water applied for treatment B (IW+ RF) was 1341.6 m^3/fed, while seasonal Cu was 1592.4 m^3/fed.

Therefore, the difference -251 m^3/fed between water applied and crop consumptive use is the contribution of water table to Cu. The same finding was declared those obtained by Doorenbos et al. (1979) who stated that the consumptive efficiency increased with the increase of crop water consumption and with the decrease of water applied.

So, by implementing alternative irrigation technique, contribution from water table to crop water needs could be enhanced. This contribution amounted with about 23% and 16% under the alternative irrigation regime of treatments B (1/1F) and C (1/1E), respectively. Thus contribution resulted in:

- Lowering water table.
- Improving the aeration status into the effective root zone.
- Improving the drainage condition of the cultivated area.

Table (4): Crop water productivity (kg/m^3), Water use efficiency (kg/m^3) and Consumptive use efficiency (%) as affected by alternative irrigation in the two growing seasons 2001/2002 and 2002/2003

Treat.	Parameters														
	C.W.P. (kg/m^3)						W.U.E. (kg/m^3)						Ecu		
	Root yield			Sugar yield			Root yield			Sugar yield					
	1st	2nd	Av.	1st	2nd	Av.	1st	2nd	Av.	1st	2nd	Av.	1st	2nd	Av.
A (EFI)	10.5	12.7	11.6	1.7	2.1	1.9	11.6	12.6	12.1	1.9	2.1	2.0	90.2	101.0	95.6
B (1/1F)	16.7	22.4	19.5	2.9	3.9	3.4	14.9	16.6	15.7	2.6	2.9	2.7	111.5	134.3	122.9
C (1/1E)	16.0	21.3	18.6	2.9	3.8	3.3	15.0	17.1	16.1	2.7	3.0	2.9	106.8	124.8	115.8

4- Yield (ton/fed):

a) Root and sugar Yield, ton/fed:

As shown in Table (5), mean values of root yield are 26.7, 24.9 and 24.1 ton/fed for the traditional treatment A and the alternative treatments B and C respectively. Comparing with the highest yield of treatment A, only a slight reduction between 7-10% was resulted for the alternative treatments B and C, respectively.

This finding could be attributed to that under the 1/1 fixed alternative irrigation (Trt. B); the un-irrigated furrow depends mainly for its water needs on the side lateral movement of soil water from the adjacent irrigated furrow.

Moreover, the reduction in yield with 10% under the alternative 1/1 exchange (Trt. C) was due to the long irrigation interval. For each cultivated furrow, an irrigation was left per each two successive watering applied to the traditional treatment A. Meaningfully, irrigation interval for each furrow under the exchangeable alternative technique (1/1E) is twice comparing with that applied to the EFI traditional irrigation. Crabtree et al. (1985) came to similar conclusion.

Regarding sugar yield, same yield far all tested irrigation treatments was obtained (Table 5) with an overall mean 4.3 ton/fed (10.2 ton/ha). This finding is more encourage able to overcoming the gap between consumption and production of sugar commodity besides the saving of irrigation water.

Therefore, by implementing alternative irrigation technique, almost the same sugar yield which considered as the utmost target for growing sugar beet was obtained comparing with the traditional irrigation. The excess water delivered to the normal local irrigation, EFI (Trt. A) produced only little high root yield, while under alternative irrigation, high sucrose content was obtained.

Table (5): Root and Sugar yields (ton/fed) as affected by alternative irrigation in the two growing seasons 2001/2002 and 2002/2003

Treatments	Characters					
	Root yield (ton/fed)			Sugar yield (ton/fed)		
	1st	2nd	Comb	1st	2nd	Comb
A (EFI)	26.462	26.900	26.681	4.253	4.408	4.331
B (1/1F)	24.494	25.196	24.846	4.20	4.44	4.22
C (1/1E)	23.749	24.443	24.096	4.238	4.335	4.286

b) Yield quality, %:

Sucrose, Purity and Alkalinity Coefficient, %:

Alternative irrigation had highly significant effect on sucrose percentage (Table 6). The mean values at the two growing seasons are arranged in descending order as: 17.9, 17.2 and 16.3% respectively for treatments C (1/1E), B (1/1F) and A (EFI). This result revealed that increasing irrigation water caused decreasing sucrose percentage. Meaningfully, sucrose percentage has the opposite trend with the amount of water applied. This finding could be attributed to that under the fairly stress condition of alternative irrigation, the rate of sugar accumulation is hastened than that of the un-stressed plants with enough soil water. Alvino (1983) and Dunham (1993) came to almost same meaning.

Regarding purity percentage, nearly same trend was observed. The highest mean value 83.4 % was resulted from the 1/1E alternative exchangeable irrigation (Trt C), while the lowest 78% resulted from the traditional irrigation (EFI) of treatment A. No significant difference among alternative treatments regarding this trait. Meaningfully, purity percentage has the opposite trend with the amount of water applied. Similar results were obtained by Emara (1999, 2000) who stated that water stress during the growing beet season not usually improved purity percentage.

Alkalinity coefficient (AC) is a parameter to determining the juice impurity percentage. Alternative irrigation has a highly significant effect on this parameter (Table 6). The mean values of AC percentage are 3.0, 3.3 and 3.2% for the EFI and the two alternative treatments 1/1F and 1/1E, respectively. This parameter is affected with the summation of Sodium (Na) and Potassium (K) as nominator and amino nitrogen (amino-N) as dominator. Therefore, by increasing the dominator, the AC percentage will be decreased and vise versa. It is worthwhile to mention that values higher than 1.8% indicated that high sugar purity is obtained and no impurities conditions is occurred which might be resulted from the high doses of fertilizers.

Table (6): Sucrose, Purity and Alkaline coefficient (Ac) percentage as affected with irrigation water regime in the two growing seasons 2001/2002 and 2002/2003

Treatments	Characters								
	Sucrose			Purity (%)			Ac (%)		
	1st	2nd	Av.	1st	2nd	Av.	1st	2nd	Av.
A (EFI)	16.10	16.39	16.25	77.60	78.39	78.00	2.93	2.96	2.95
B (1/1F)	17.13	17.22	17.17	82.44	82.51	82.47	3.25	3.27	3.26
C (1/1E)	17.85	17.85	17.85	83.35	83.48	83.41	3.19	3.22	3.20

CONCLUSION

From data obtained, the following are the main advantages raised-up under the implementation of alternative surface irrigation technique:

1. Almost same sugar yield was obtained comparing with the traditional furrow irrigation with an overall mean 4.3 ton/fed or 10.3 ton/ha.
2. Saving a pronounced amount of irrigation water amounted 1000 m^3/fed or more than 35% from water applied equaled nearly 80.0 million m^3 for the cultivated beet area in Kafr EL-Sheikh Governorate, the main area of beet production in Egypt.
3. Higher values of different irrigation efficiencies; 19.1 and 15.9 kg/m^3 as CWP and WUE for beet roots, 3.3 and 2.8 kg/m^3 regarding sugar yield, respectively. Moreover, the highest mean value of 119.3% as storage efficiency was occurred.
4. Enhancing the contribution of water table to beet water needs with an average of 19%.

RECOMMENDATION

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.

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