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EVAPORATION PAN AS AN EFFECTIVE METHOD FOR IRRIGATION SCHEDULING FOR SUGAR BEET IN THE NORTH NILE DELTA REGION

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ABSTRACT

The increasing needs of water for agricultural and non agricultural activities in Egypt require that the available water resource, be used efficiently and carefully. Proper irrigation scheduling makes it possible to use water prudently. Field experiments were carried out at Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt, during two successive seasons of 2009 /2010 and 2010/ 2011. 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 metres above mean sea level. These experiments aim to evaluate the irrigation scheduling using pan evaporation for sugar beet under different planting methods as procedures to optimize the irrigation water productivity and sugar beet yield. The experiment was arranged in a split plot design with four replicates. The main plots were randomly assigned to the planting methods (furrows and beds), while the sub plots were I_1 (1.2), I_2 (1.0) and I_3 (0.8) of cumulated pan evaporation (CPE).

Results showed that irrigation scheduling at 0.8 of CPE significantly increased roots and sugar yield by about 22.7% and 38.2%, respectively. Root length increased by about 7.6 and 17.2%, compared to irrigation at 1.0 and 1.2 of CPE, whereas root diameter decreased by about 12.3 and 12.8%, respectively. Irrigation at 1.2 of CPE resulted in high amounts of irrigation water applied, 3150 m^3 /fed distributed on 10 irrigations, followed by irrigation at 1.0 of CPE, 2830 m^3/fed distributed on 8 irrigations, and irrigation at 0.8 of CPE, 2370 m^3/fed distributed on 6 irrigations. The highest amount of consumptive water use, 2560 m^3/fed, was obtained under irrigation with 1.2 of CPE. While the lowest one, 1709 m^3/fed, was obtained from irrigation at 0.8 of CPE. Irrigation at 0.8 of CPE (I_3) increased the water productivity of root and sugar yield by about 43% and 65%, respectively, compared to irrigation at 1.2 CPE.

The bed planting method had the minimum values of water applied and water consumptive use compared to the furrow planting one traditional method, like local farmers practices for all irrigation treatments. Using the bed planting method instead of the furrow planting one, saved water by about 743 m^3/fed (25.7%) with irrigation at 0.8 of CPE. The highest values of roots yield, 23.56 ton/fed, and of sugar yield, 3.95 t/fed, had been obtained with the bed planting method, compared to the furrow planting method which had the lowest values 22.03 and 3.52 ton/fed, respectively, for roots and sugar yield.

Therefore, as a result of irrigation scheduling at 0.8 of CPE with planting in beds is an effective method for sugar beet to maximize yield, yield quality and productivity of the irrigation water under the condition of the studied area, in north Nile delta region.

Keywords: Irrigation scheduling, Evaporation pan, Sugar beet planting in beds, water productivity.

INTRODUCTION

Like many countries of the world, water resources of Egypt are diminishing quantitatively and qualitatively. Egypt is the solely country in the world that its agricultural production repents depends upon irrigation; 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. Agriculture is the main sector in water consumption with more than 85% from total national water supply However, water productivity (WP) is very low. The main reason for low productivity is the over irrigation by the farmers. Farmers normally over irrigate the fields due to lack of proper knowledge about irrigation scheduling; and with the intention that more water will produce more yield. However, more applications of water may result in low WP and low net income. (Ashraf *et al*., 2001).

Irrigation scheduling is the decision of when and how much water to apply to a field. Its purpose is to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level. It saves water and energy, (Jensen 1980). It has been described as the primary tool to improve water use efficiency, increase crop yields, increase the availability of water resources, and provoke a positive effect on the quality of soil and groundwater, (FAO, 1996).

The increasing needs of water for agricultural and nonagricultural activities require that the available water resources, for both surface and groundwater be used efficiently and carefully. Proper irrigation scheduling makes it possible to use water prudently. The technique of using pan evaporation for irrigation scheduling has been extensively tested by many researchers in Egypt (Khalil, 1996; Ashraf *et al*., 2002; Khalil *et al*., 2006) and it was proven to save up to 20% of the applied irrigation water by farmers. Therefore, under Egyptian conditions, extension agricultural is recommending scheduling irrigation using pan evaporation technique to the farmers as a way to conserve irrigation water. In spite of the difficult for a common farmer to maintain and to read exact level in the pan, evaporation pan can be attached with a farm to make it simple for a common farmer to design irrigation scheduling.

One of the main national strategies in agriculture is cultivating sugar beet instead of sugar cane the highest water need crop. To produce one ton of sugar from beet, it needs almost one quarter of water in comparison to that for sugar cane, (Doorenbos *et al.*1979). The traditional planting method for sugar beet at Kafr El-Sheikh Governorate, the main area in national sugar beet production, is planting in furrows. The spacing of furrows is influenced by the soil type and the cultivation practice. On clay soils, the spacing between two adjacent furrows should be 75-150 cm. On clay soils, double-ridged furrows, sometimes called beds, can also be used. Their advantage is that more plant rows are possible on each ridge, facilitating manual weeding. The ridge can be slightly rounded at the top to drain off water that would otherwise tend to pond on the ridge surface during heavy rainfall, (Wang *et al.* 1999). The method of planting in beds which tested on some field and

vegetable crops were effective in increasing the crop yield and the water use efficiency. (Anonymous, 2006) reported that the maximum water saving and highest seed cotton yield was produced by the bed (raised bed) planting method. (Raut *et al.* 2000) found that soybean seed yield with 2 rows per bed higher than with 1 row per bed, although there were more pods per plant with 1 row per bed. So far, sugar beet planting in beds not yet tested.

Therefore, the aim of the present investigation was to study the impact of the irrigation scheduling using pan evaporation under two planting methods, furrows and beds, on sugar beet yield and on the irrigation water productivity to introduce the most suitable planting method and water treatment to optimize water use and sugar beet yield.

MATERIALS AND METHODS

Experimental site

A field trial was conducted during the two successive growing seasons 2009/2010 and 2010/2011 at Sakha Agricultural Research Station, Kafr EL-Shiekh, Egypt. 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**.** Agro meteorological data of Sakha station, during the two growing seasons of study are presented in Table (1). The soil of the experimental site was clayey in texture. The average of electrical conductivity of soil salinity, in soil paste extract, over 0-60 cm depth was 3.76 dSm^{-1}.Some soil physical properties of the experimental site are presented in Table (2).

Table (1): Mean of some meteorological data for Kafr El-Sheikh area during the two growing seasons of sugar beet crop.

Month	Season 2009/2010							Season 2010/2011						
	Air Temp..C°		Relative humidity, %		wind speed , km/ day	Ep mm/day	rain, mm/month	Air Temp. C°		Relative humidity, %		wind speed , km/ day	Ep, mm/ day	rain, mm/month
	maxi.	min.	max	min				max	min	max	min			
Nov.	26.0	10.5	77.7	50.0	58	2.7	0.0	26.8	11.0	82.0	54.2	63	2.8	------
Dec.	22.2	8.8	76.5	52.0	64.0	2.1	5,8	22.0	8.3	85.0	55.7	58.3	1.8	90.0
Jan.	21.5	7.8	83.5	55.0	53.0	1.8	0.0	20.3	5.8	84.2	54.0	42.5	1.9	-------
Feb.	24.5	9.4	84.2	55.7	76.8	2.9	32	23.4	7.4	87.0	54.0	64.0	2.9	22.5
Mar-	24.3	10.0	76.3	44.0	110	4.3	0.0	21.8	6.8	86.3	49.5	77.4	3.4	14.0
Apr-	28.2	11.0	96.0	40.7	96	5.6	0.0	26.5	10.0	85.0	47.7	83.7	4.9	----
May-	29.6	14.4	72.6	39.5	96	6.9	0.0	29.0	13.0	76.7	38.0	102.0	5.9	-----

***Source: meteorological station at Sakha 31-07' N Latitude, 30-57'E Longitude, N.elevation 6 m.**

Table (2): Some soil physical analysis for the experimental site.

Depth	Particle size distribution			Texture	F.C W%	PWP W%	Bulk density Mg/m^3	Available water	
	Sand %	Silt %	Clay %					w%	mm
0- 15	15.28	18.80	65.92	Clayey	47.2	25.65	1.14	21.55	36.8
15-30	19.90	13.80	66.30	Clayey	40.5	22.01	1.15	18.45	31.8
30-45	16.59	16.92	66.49	Clayey	37.0	20.10	1.24	16.91	31.4
45-60	17.65	15.24	67.12	Clayey	34.5	18.79	1.26	15.71	29.6
Total									129.6

F.C = field cap city, PWP Permanent wilting point

Experimental design and treatments

The experimental treatments were arranged in a split plot design with four replicates.The main- plots represented planting methods; furrows and beds, while the sub-plots were assigned to irrigation scheduling, i.e., I_1 (1.2), I_2 (1.0) and I_3 (0.8) of cumulated pan evaporation (CPE). Plot area was 52.5 m^2 including 10 rows 7.5m long and 70 cm apart and planting on one side ridge for furrow planting method while it was 5 rows 7.5 m long, with 140 cm apart and planting on two sides of ridges for bed planting . All treatments had 7 plants / m^2.The main difference between bed and furrow irrigation systems is the furrow spacing. A furrow spacing figure which is larger than the top width of a furrow implies a bed between two furrows. A bed is created in order to cultivate two rows of sugar beet (i.e. on the left and right side of the bed). Plots were isolated by ditches of 1.5 m in width to avoid lateral movement of water.

Seeds of sugar beet (*Beta Vulgaris* L.) were seeded in hills 20 cm in between at November 3rd, 5th in two successive seasons 2009/2010 and 2010/2011. Harvesting was done after 190 days .All agricultural practices were done as recommended by the Egyptian Ministry of Agricultural and Land Reclamation, except the two factors of study, i.e., planting methods and irrigation scheduling. The irrigation treatments were imposed after the crop foliage nearly cover the ground as recommended by (Jensen and Middleton, 1965), Eid *et al*. 1982) and Ibrahim *et al.,* 2002).

Scheduling of the irrigation:

In the present study, the daily evaporation records from class A pan type, was used. The concept of scheduling is that the available soil water (AW) theoretically equals certain ratio of the CPE,(Jensen and Middleton, 1965) and (Eid *et al.*, 1982). The irrigation scheduling by this method needs the determination of the usable soil moisture for each treatment, and the equivalent amount of the CPE that can occur while the amount of the usable moisture is being used. The usable CPE must be determined from meteorological data. This could be expressed by the following equation:

$$CPE = A.W \times MAD / K_P \quad \text{.....} \quad (1)$$

Where:

CPE = cumulative pan evaporation.

K_P = Empirical pan factor (1.2, 1.0 and 0.8 of CPE, respectively, for I_1, I_2 and I_3 treatments).

AW = Available water (mm) of the soil for the effective root zone depth.

MAD = Maximum Allowable Depletion by setting lower limit 50%.

The usable soil moisture in the soil depth from which the crop extracts appreciable amount of water could be determined by knowing the AW and the maximum allowable depletion (MAD), (James, 1988). Soil AW for the 60 cm depth was 129.6 mm, multiply this result by 50% (MAD for sugar beet) to get 64.8 mm which is the usable moisture at every irrigation. Divide the usable moisture value (64.8 mm) by the studied empirical factors (1.2, 1.0 and 0.8) to get the usable CPE for the experimental treatments I_1, I_2 and I_3, respectively, which after its accumulation can determine the time of the next irrigation. Values of the usable CPE for each treatment are reported in Table (3). They are 54.0, 64.8 and 81.0 mm for treatments of I_1, I_2 and I_3 respectively.

Table (3): CPE values for each studied treatment.

Treatments	CPE, mm
I_1 (1.2 CPE)	81.0
I_2 (1.0 CPE)	64.8
I_3 (0.8 CPE)	54.0

Irrigation management:

The irrigation in the respective treatments were applied when CPE reached approximately 54.0, 64.8 and 81.0 mm, respectively, for I_1, I_2 and I_3 treatments. The irrigation water was conveyed to the experimental field through an open channel using a centrifugal pump. The water in the channel was controlled to maintain a constant head by means of fixed bar.

The irrigation water was applied to the experimental plots until reaching the end of the plot length. This was measured and delivered by a constant rectangular weir with steel gates for each plot. The rate of discharge was 0.01654 m^3/sec at effective head of 10 cm The of water for each plot of the studied treatments was calculated by the equation;

$Q = q \times t$……(2)

Where :

Q is the volume of water delivered to the plot (m^3),

q is the discharge of the weir (m^3/ min) and

t is the time of irrigation (min).

Water applied (Wa):

Water applied was computed as follows:

$Wa = IW + Re$ …… ……. **(3)**

Where:

IW = the amount of water delivered by irrigation to the experimental plots.

Re = Effective rainfall.

Consumptive use (CU):

Water consumptive use was determined as soil moisture depletion (SMD) using the following equation, (Hansen *et al.,* 1980).

$$\textbf{Cu} = \sum_{i=1}^{1=4} D_1 \text{ x } D_{b1} \text{ x } \frac{PW_2 - PW_1}{100} \quad \text{…….. (4)}$$

CU = Water consumptive use (cm) in the effective root zone (60 cm).
D_1 = Soil layer depth (15 cm each).
D_{b1} = Soil bulk density, (Mgm^{-3}) for the given depth.
PW_1 = Soil moisture percentage before irrigation (on mass basis, %).
PW_2 = Soil moisture percentage, 48 hours after irrigation (on mass basis, %).
i = Number of soil layers each (15 cm) depth.

The summation of Cu between each two irrigations from planting up the harvest give the seasonal crop water consumptive use.

Soil moisture monitoring:

Soil samples were taken at sowing, before each irrigation, 2 days after Irrigation or rainfall, 7-10 days intervals between irrigation and at the time of harvesting, from four layers (15 cm each) for each treatment. At each sampling date, duplicate soil samples were taken and were immediately packed in tightly closed cans and transported to the laboratory, then weighed, dried in electrical furnace at 105 C° for 24 hours, then weighed again and their moisture content were calculated on dry weight basis (PW).

Crop parameters:

At harvesting (190 days from sowing) a random sample of ten plants were chosen from each plot to determine some plant parameters of sugar beet growth (root diameter and root length), as well as root weight (kg). Also, some characters of the sugar beet roots quality have been measured and calculated such as sucrose % and the purity percentage.

Yield (ton/fed):

The yield of the two central furrow or beds were harvested, weighed and computed as:

a- Root yield (ton/fed)

b- Sugar yield (ton/fed) which was computed by multiplying root yield with sucrose percentage. Sucrose percentage was estimated at Delta Sugar Company Limited, Kafr El-Sheikh.

Water productivity (WP) and productivity of the irrigation water (PIW):

It was calculated according to (Ali *et al.,* (2007), using the following equations;

WP = Y/ Cu …….…….. (5)

PIW = Y/I…… (6)

Where:

WP and PIW (kg/m^3), Y is the yield (kg/fed), Cu total water consumption of the growing season (m^3/fed.) and I is the irrigation water applied (m^3/fed).

Statistical analysis:

The obtained data were statistically analyzed by analysis of variance. according to (Gomez and Gomez, 1984) .Means of the treatment were compared by the least significant difference (LSD) at 5% level of significance which developed by (Waller and Duncan, 1979).

RESULTS AND DISCUSSION

Seasonal Water applied (Wa):

The seasonal water applied (Wa) of sugar beet consists of two items. These are irrigation (IW) and rainfall (R). The total amount of the effective rain fall was 3.78 cm and 12.6 cm for the first and second season, respectively. As reported in Table (4), watering at 1.2 of CPE (I_1) had the highest amount of irrigation water, due to frequent irrigation, followed by watering at 1.0 CPE (I_2) and 0.8 CPE (I_3). Amounts of irrigation water at 1.2 ,1.0 and 0.8 CPE were distributed on 10, 8 and 6 irrigation events including the seedling irrigation. The overall average of the amount of water applied, for the two growing seasons, are 68.2 cm (2864 m^3/fed.), 60.8 cm (2554 m^3/fed) and 57.5 cm (2417 m^3/fed). This means that treatments of 0.8 and 1.0 CPE had less amount of irrigation water applied compared to the treatment of 1.2 CPE by about 447 m^3/fed.(15.6%) and 310 m^3/fed (10.8%), respectively.

In both seasons, the bed planting method received the minimum amount of irrigation water compared to the furrow planting method. The overall average, for the two seasons, of the amount of water applied was 51.1 cm (2146 m^3/fed) and 68.8 cm (2889 m^3/fed), respectively for bed and furrow planting methods. This indicate that bed planting method saved water by about 743 m^3/fed (25.7%) compared to the furrow planting method. The trend of these results are in agreement with those of obtained for some field and vegetable crops by (Raut *et al.,* 2000), (Anonymous, 2006) and (Meleha *et al*., 2004).

Table (4): Seasonal irrigation water (IW), rainfall (R) and seasonal water applied (Wa) for sugar beet in the two growing seasons .

Treatments		Season 2009/2010				Season 2010/2011			
		IW		R	Wa	IW		R	Wa
		No	Cm	cm	cm	No	Cm	cm	cm
Bed	I_1	10	62.0		65.78	10	50.0		62.60
	I_2	8	46.0	3.78	58.22	8	39.72	12.6	57.76
	I_3	6	40.0		54.94	6	35.24		56.38
Mean			**49.33**		**59.65**		**41.65**		**58.91**
Furrow	I_1	10	78.67		71.68	10	69.70		72.88
	I_2	8	64.70	3.78	66.61	8	58.08	12.6	69.05
	I_3	6	57.49		63.98	6	46.46		65.94
Mean			**66.95**	**67.29**	**58.08**	**2.29**	**70.62**	**7.47**	

Water consumptive use (Cu):

Tabulated data in Table (5) revealed that in both seasons, sugar beet consumptive use of irrigation scheduling of 1.2 CPE (I_1) had the highest values of water consumption followed by irrigation scheduling of 1.0 CPE (I_2) and 0.8 CPE (I_3), respectively. The overall mean values of the seasonal Cu were 60.9, 47.2 and 40.7 cm, respectively for treatment of I_1, I_2 and I_3. This means that the Cu resulting from irrigation scheduling of 1.2 CPE is higher

than that of 1.0 and 0.8 CPE by 22.5% and 33.2%, respectively. It is worthy to mention that the treatment of 1.2 CPE received frequent irrigation (10 irrigation events) more than that of 1.0 and 0.8 CPE which received 8 and 6 irrigation events, respectively. These results demonstrate that water consumption increased as soil moisture was maintained high by frequent irrigation. The probable explanation of these results is that higher frequent irrigation provide chance for more consumption of water which ultimately resulted in increasing the plant transpiration and evaporation from the soil. It was noticed, in general, that seasonal Cu in the second season was relatively higher than that of the first season. This could be attributed to the less rainfall in the first season (37.8 mm) compared to that fallen in the second season (126.5mm).

On other hand, in both seasons, values of the Cu were higher under furrow planting than that under bed planting method. Mean values of Cu under planting method were 52.5 and 50.4 cm, respectively, for the growing seasons of 2009/10 and 2010/11. The corresponding values for the same two seasons under bed planting method were 49.3 and 46.0 cm, respectively. This means that the Cu values under bed planting were relatively less than that of the furrow planting by about 6.1% and 8.7% with an average of 7.4%. This finding is in the same direction with that obtained previously for sugar beet consumptive use by (Eid *et al*., 1982)

Table (5): Water consumptive use during the two growing seasons of sugar beet crop.

Treatment		Season 2009/2010			Season 2010/2011			Mean of two seasons	
		No. of irrig.	cm	M^3	No. of irrig.	cm	M^3	cm	M^3
Bed	I_1(1.2)	10	62.0	2604.0	10	56.0	2352.00	59.0	2478.0
	I_2(1.0)	8	46.0	1932.0	8	42.0	1764.00	44.0	1848.0
	I_3(0.8	6	40.0	1680.0	6	40.0	1680.00	40.0	1680.0
Mean			49.3	2072.00		46.0	1932.00	47.65	2002.0
furrow	I_1(1.2)	10	67.8	2851.8	10	57.8	2431.80	62.80	2641.8
	I_2(1.0)	8	49.9	2095.8	8	50.8	2137.80	50.35	2116.8
	I_3(0.8	6	39.9	1675.8	6	42.8	1801.80	41.35	1738.8
Mean			52.5	2207.0		50.4	2123.80	51.45	2185.8

Root length and root diameter (cm)

Mean root length and root diameter as affected by irrigation scheduling and planting method are given in Tables (6 & 7) .The obtained results showed that in both seasons, the longest roots and the smallest diameter of sugar beet were obtained under the treatment of 0.8 CPE (I_3) while the shortest and the greatest ones were recorded under treatment of 1.2 CPE (I_1). Values of root length were 40.21, 37.35 and 34.31cm, as an average of the two seasons, for treatments of I_3, I_2 and I_1, respectively. The corresponding values of root diameter, for the same treatments, were 14.3, 16.33 and 16.40 cm. This means that irrigation scheduling at 0.8 CPE increased the root length by about 7.6% and 17.2% compared to that of 1.0 and 1.2 CPE, respectively, and decreased the root diameter by about 12.3%

and 12.8% compared to irrigation scheduling at 1.0 and 1.2 CPE. This could be explained on the bases of the long irrigation period and less amount of water applied induced from the little number of watering under treatment of I_3 compared to that of I_1,(treatments of I_3 and I_1, respectively, had 6 and 10 watering during the growing season). These results are similar to those obtained by Ibrahim *et al*., (2002) found that root grow longer under moisture stress. Also, Emara, (1990) mentioned that the great root length was obtained by irrigation every 28 days, while the lowest root length was obtained by irrigation every 14 days.

Planting methods, also, had highly significant effect on length and diameter of sugar beet roots. The average values of root length, for the two seasons, were 38.51 and 36.08 cm for bed and furrow planting, respectively. The corresponding values of the root diameter were 15.88 and 15.47 cm, respectively, for the same two planting methods. This means that bed planting method increased the root length by about 6.7% and root diameter by about 2.6% compared to the furrow planting method.

Table (6): Effect of irrigation scheduling and planting methods on root length (cm) of sugar beet during seasons of 2009/2010 and 2010/2011.

Treat.	Season 2009/2010			Season 2010/2011			Mean of 2 seasons	
	bed	furrow	Mean	bed	furrow	Mean	bed	furrow
I_1 (1.2)	35.83 c	33.50 c	34.67 c	34.83 a	33.07 b	33.95	35.33	33.29
I_2 (1.0)	38.87 b	37.23 b	38.05 b	39.16 a	34.16 a	36.66	39.01	35.70
I_3 (0.8)	41.07 a	40.10 a	40.58 a	41.30 a	38.40 a	39.85	41.18	39.25
Mean	38.59	36.94	37.77	39.54	35.94	36.21	38.51	36.08

In a column means followed by common letter are not significantly different at 5% level by DMRT

Comparison :	S.E.D	L.S.D (5%)	L.S.D (1%)	S.E.D	L.S.D (5%)	L.S.D (1%)
2-1 means at each F	0.76	1.76	2.55	0.963	2.2	3,2

Table (7): Effect of irrigation scheduling and planting methods on root diameter (cm) of sugar beet during seasons of 2009/2010 and 2010/2011

Treat.	Season 2009/2010			Season 2010/2011			Mean of 2 seasons	
	bed	furrow	Mean	bed	furrow	Mean	bed	furrow
I_1 (0.8)	17.80 a	16.16 a	16.98	15.20 b	16.50 a	15.85	16.50	16.33
I_2 (1.0)	15.50 b	16.60 a	15.60	17.33 a	15.90 b	16.62	16.42	16.25
I_3 (1.2)	14.76 c	14.53 c	14.64	14.70 c	13.16 c	13.93	14.73	13.85
Mean	16.02	15.76	15.74	15.74	15.18	15.46	15.88	15.47

In a column means followed by common letter are not significantly different at 5% level by DMRT

Comparison :	S.E.D	L.S.D (5%)	L.S.D (1%)	S.E.D	L.S.D (5%)	L.S.D (1%)
2-1 means at each F	0.413	0.951	1.384	0.548	1.264	1.83

Roots and sugar yield (ton/fed).

Data presented in Tables (8 & 9) showed that sugar beet yield of roots and sugar had influenced significantly by irrigation scheduling and the planting methods. Total roots yield varied between 20.4 and 25.04 ton/fed, and sugar yield varied from 3.14 to 4.34 ton/fed, as an overall average for the

two seasons. The highest roots and sugar yield were achieved with irrigation scheduling of 0.8 CPE (I_3) followed by treatment of (I_2), whereas the least ones were recorded for irrigation scheduling of 1.2 CPE (I_1). This means that the great irrigation intervals induced from the irrigation scheduling at 0.8 CPE, due to the low watering number (6 irrigation events only during the growing season), increased roots and sugar yield compared to the treatment of 1.2 CPE which had relatively short irrigation intervals induced from the relative great watering number (10 irrigation events during the growing season).These results indicate that irrigation scheduling at 0.8 CPE increased sugar beet roots yield by about 22.7% and 9.2%, and yield of sugar by about 9.6% and 12.2% compared to irrigation scheduling at 1.2and 1.0 CPE, respectively.

On other hand, as shown in Tables (8 & 9), the bed planting method had significantly higher roots and sugar yield than the furrow planting, in both seasons. The overall average values obtained of roots and sugar yield for bed planting were 23.56 and 3.95 ton/fed, respectively. The corresponding values for the furrow planting method were 22.03 and 3.52 ton/fed, respectively for roots and sugar yield. This indicate that the bed planting method increased sugar beet roots and sugar yield by about 6.9% and 12.2%, respectively, compared to the furrow planting one. In addition, the highest yield of both beet roots (25.89 ton/fed) and sugar (4.68 ton/fed) were obtained by irrigation scheduling at 0.8 CPE with bed planting method.

Table (8): Effect of planting method and irrigation scheduling on root yield (ton/fed) during the two growing season 2009/2010 and 2010/2011

Treat.	Season 2009/2010			Season 2010/2011			Mean of 2 seasons	
	bed	furrow	Mean	bed	furrow	Mean	bed	furrow
I_1 (1.2)	22.630 c	19.260 c	20.945 c	20.73 b	19.06 b	19.90 c	21.68	19.133
I_2 (1.0)	24.814 b	23.043 b	23.928 b	23.20 b	22.78 a	21.98 b	23.12	22.780
I_3 (0.8)	26.526 a	24.880 a	25.703 a	25.27 a	23.50 a	24.38 a	25.89	24.190
Mean	24.650	22.394		22.25	21.92		23.56	22.030

In a column means followed by common letter are not significantly different at 5% level by DMRT

Comparison :	**S.E.D**	**L.S.D (5%)**	**L.S.D (1%)**	**S.E.D**	**L.S.D (5%)**	**L.S.D (1%)**
2-1 means at each F	**0.579**	**1.33**	**1.94**	**0.466**	**1.075**	**1.564**

Table (9): Effect of planting method and irrigation scheduling on sugar yield (ton/fed) during the two growing season 2009/2010 and 2010/2011

Treat.	Season 2009/2010			Season 2010/2011			Mean of 2 seasons	
	bed	furrow	Mean	bed	furrow	Mean	bed	furrow
I_1 (1.2)	3.21 b	2.77 c	2.99 c	3.70 b	2.90 c	3.30	3.46	2.83
I_2 (1.0)	3.66 b	3.78 b	3.72 b	4.24 a	3.76 b	4.00	3.95	3.77
I_3 (0.8)	4.5 a	3.80 b	4.15 a	4.85 a	4.18 a	4.52	4.68	3.99
Mean	3.64	3.45	3.54	4.25	3.60	3.93	3.95	3.52

In a column means followed by common letter are not significantly different at 5% level by DMRT

Comparison :	**S.E.D**	**L.S.D (5%)**	**L.S.D (1%)**	**S.E.D**	**L.S.D (5%)**	**L.S.D (1%)**
2-1 means at each F						

The lowest yield was obtained by irrigation scheduling at 1.2 CPE with furrow planting method. Therefore, irrigation scheduling at 0.8 CPE with planting in beds method could be considered as an effective method for sugar beet to maximize yield and yield quality in north Nile delta region. These results are supported by those published by several authors concerning the irrigation management for sugar beet yield, Ibrahim *et al*.,(1995) , Emara *et al*.,(2000) and Eid and Ibrahim (2010).

Productivity of irrigation water (PIW):

As shown in Fig (1) and (2), decreasing the irrigation scheduling from 1.2 to 0.8 CPE increased PIW of both root and sugar yield. The highest average values of PIW 11.09 and 2.8 kg/m^3 for root and sugar yield, respectively, were obtained under treatment irrigation scheduling of 0.8 CPE (I_3), while the lowest ones 6.32 and 0.96 kg/m^3, respectively were obtained under irrigation scheduling of 1.2 CPE (I_1). These results indicate that irrigation at 0.8 of CPE (I_3) increased the PIW of root and sugar yield by about 43% and 65%, respectively, compared to irrigation at 1.2 CPE (I_1).This means that the effect of irrigation scheduling was more pronounced on yield of sugar than on the roots of beet. The higher values of PIW of (I_3) than that of (I_1) is obviously due to the less amount of the applied water, (Table 4), and to the higher yield, (Tables 8&9), of treatment (I_3) than that of (I_1). These findings are in harmony with those obtained by Ibrahim and Emara (2010), Emara *et al*., (2000), and Eid and Ibrahim (2010) who reported that an adverse effect was found between amount of Wa and PIW for both root and sugar yield.

Concerning the effect of planting method on the PIW, as shown in Fig. (1) planting in beds increased PIW values of root and sugar yield compared to planting in furrow method. This is due to the increase of roots and sugar yield with the planting in beds method.

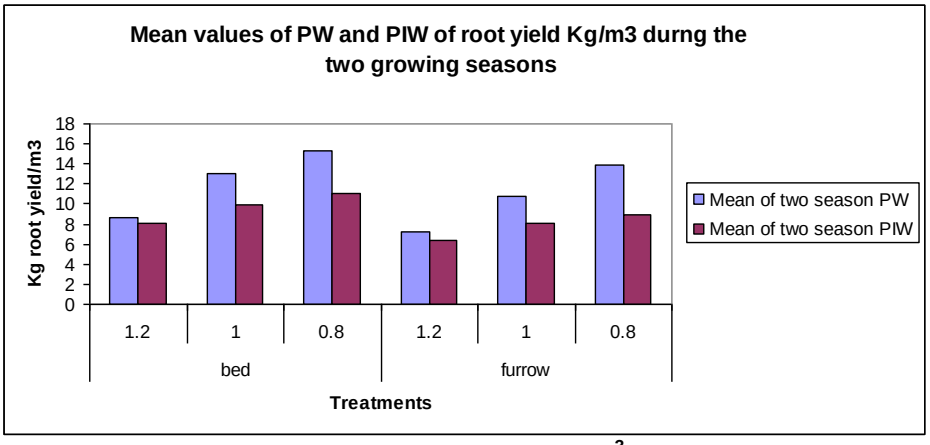

Fig. (1): Mean values of water productivity Kg/m^3 (WP) and Productivity of irrigation water Kg/m^3 (PIW) of root yield in 2009/2010 and 2010/2011 growing seasons.

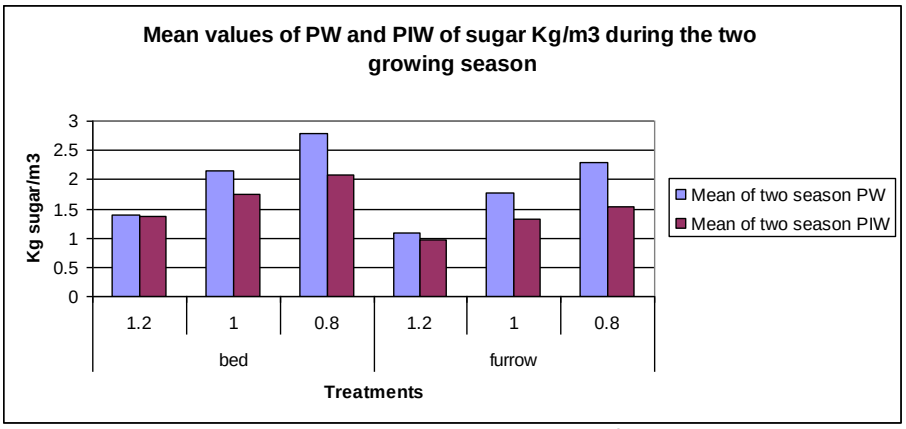

Fig. (2): Mean values of Water productivity Kg/m^3 (WP) and Productivity of irrigation water Kg/m^3 (PIW) of sugar yield in 2009/2010 and 2010/2011growing seasons.

The highest average values of PIW 9.42 and 1.71 kg/m^3 for root and sugar yield ,respectively ,were obtained under treatment of bed planting, whereas the lowest ones 7.72 and 1.26 kg/ m^3, respectively, were obtained under treatment of furrow planting. This means that bed planting method increased PIW of roots and sugar yield by about 22% and 35.7 % respectively relative to furrow planting method.

CONCLUSION

The increasing needs of water for agricultural and non agricultural activities in Egypt require that the available water resource be used efficiently and carefully. Proper irrigation scheduling makes it possible to use water**.** The obtained results of the present study concluded that irrigation scheduling at 0.8 of CPE with planting in beds is an effective method for sugar beet to maximize yield, yield quality and productivity of the irrigation water under the condition of the studied area, in north Nile delta region. Irrigation scheduling at 0.8 of CPE significantly, increased roots and sugar yield by about 22.7% and 38.2%, respectively, saved irrigation water by about 24.7% and 16.2% compared to irrigation at 1.2 and 1.0 CPE, respectively, and increased the water productivity of root and sugar yield by about 43% and 65%, respectively, compared to irrigation at 1.2 CPE.

Using the bed planting method instead of the furrow planting one, saved water by about 743 m^3/fed (25.7%) with irrigation at 0.8 of CPE and increased roots yield by about 6.9% and sugar yield by 12.2% compared to the furrow planting method. There for the bed planting method with irrigation at 0.8 of CPE for sugar beet is recommended to optimize sugar beet yield and the productivity of irrigation water.

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وعاء البخر كوسيلة فعالة فى جدولة رى البنجر فى شمال دلتا النيل

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الاحتياجات المتزايدة من المياه لاغراض الأنشطة الزراعية وغير الزراعية في مصر تحتاج إلى موارد مائية متاحة، ويمكن استخدامها بكفاءة وبعناية. وجدولة الري السليمة تجعل من الممكن استخدام المياه بحكمة. وقد أجريت تجارب حقلية في محطة بحوث سخا الزراعية، كفر الشيخ، مصر، خلال موسمين متتاليين عام 2010/2009 و 2010 /2011. الموقع يمثل الظروف وأحوال منطقة وسط شمال دلتا النيل، والتى تقع في خط العرض 07-31 N، 30-57'E خط الطول مع ارتفاع حوالي 6 أمتار فوق مستوى سطح البحر وهذه التجارب تهدف إلى تقييم جدولة الري باستخدام وعاء البخر لبنجر السكر تحت أساليب الزراعة المختلفة وأجريت هذه الدراسة لتحسين إنتاجية المياه والري والسكر لمحصول البنجر. وقد تم ترتيب هذه التجربة في تصميم القطع المنشقة مرة واحده مع أربع مكررات. وكانت المعاملات الرئيسية طريقة الزراعة (الخطوط والمصاطب)، في حين أن المعاملات تحت سطحية كانت (1.2) I_1، (1.0) I_2 و(I_3) (0.8) من البخر نتح التراكمى (CPE) وأظهرت النتائج أن المعاملة 0.8 من البخر نتح التراكمى CPE حققت زيادة كبيرة في محصول الجذور ومحصول السكر بنحو 22.7٪ و 38.2٪ على التوالي.وزيادة طول الجذر بنحو 7.6 و 17.2٪، مقارنة مع الري في 1.0 و 1.2 من البخر نتح

التراكمى CPE ، في حين أن قطر الجذرزاد بنسبة حوالي 12.3 و 12.8٪ على التوالي. أدى الري في 1.2 من البخر نتح التراكمى CPE في كميات كبيرة من مياه الري التطبيقية، 3150 م^3 / فدان موزعة في 10 الري، تليها الري في 1.0 من CPE2380م^3 /للفدان موزعة على 8 الري، والري بنسبة 0.80 من CPE، 2370 م^3/للفدان وزعت في 6 ريات.

تم الحصول على أكبر قدر من الاستهلاك المائى 2560 م^3 /للفدان تحت الري مع 1.2 من البخر نتح التراكمى CPE. في حين تم الحصول على أدنى مستوى ، 1709 م^3 /للفدان ، من0.8 من البخر نتح التراكمى CPE.

الجدولة عند 0.8 (I_3) أدت إلى زيادة في إنتاجية المياه من محصول الجذور والسكر بنسبة حوالي 43٪ و 65٪، على التوالي، مقارنة بالرى عند 1.2 من البخر نتح التراكمى CPE وكانت طريقة الزراعة على مصاطب أقل القيم فى استخدام مياه الرى وكذلك الاستهلاك المائى مقارنة مع الزراعة على خطوط لجميع المعاملات. باستخدام طريقة زرع المصاطب بدلا من الزرعة على خطوط ، وفرت حوالي 743 م^3/للفدان (25.7٪) ونتيجة لذلك، حققت معاملة الجدولة عند 0.8 من البخر نتح التراكمى CPE أعلى محصول من الجذور 23.56 طن للفدان ومحصول السكر 3.95 طن للفدان تحت ظروف الزراعة على مصاطب مقارنة بالزراعة على خطوط التى حققت 22.03 طن للفدان من الجذور و 3.52 طن للفدان من السكر.

لهذا الزراعه على مصاطب والرى عند 0.8 من البخر نتح التراكمى CPE هى الأفضل من حيث أعلى محصول وأحسن جودة وأعلى انتاجية للمياة تحت ظروف منطقة الدراسة فى شمال دلتا النيل.

قام بتحكيم البحث

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