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WATER REQUIREMENTS OF SOME CROPS IN NORTH SINAI GOVERNORATE:
1- EFFECT OF IRRIGATION INTERVALS AND PLANT DENSITY ON ACTUAL EVAPOTRANSPIRATION , WATER USE EFFICIENCY AND YIELD OF SUGAR BEET PLANTS.

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ABSTRACT

This study was carried out at the Experimental Farm of the Faculty of Environmental Agricultural Sciences, Suez Canal University in El-Arish, during two successive seasons, 2004/2005 and 2005/2006. The experiment aimed to study the effect of irrigation intervals and distances between drip irrigation laterals on sugar beet (*Beta vulgaris L. cv.* PL12). The experiment was assigned for cultivating sugar beet plants. The experiment included 9 treatments for the interaction between 3, 5 and 7 days irrigation intervals and 40, 50 and 60 cm distances between drip lateral lines. Each treatment plot consisted of 3 lateral lines, each was 10 m long. The treatments plot area was either 12, 15 or 18 m^2. Seeds of sugar beet plants were sown on the 1st of October in 2 successive seasons, 2004/2005 and 2005/2006, at the rate of 3 $kg.fed^{-1}$. Actual evapotranspiration and fresh and dry yield of roots and top weights increased with decreasing irrigation intervals. However, they were increased with increasing the distance between irrigation lines in both seasons. The water use efficiency increased with increasing irrigation intervals, while it was decreased with increasing the distance between irrigation lines. The highest sugar yield was obtained when sugar beet was irrigated every 5 days, while the highest sugar beet was obtained for 60 cm distance between irrigation lines in both seasons. The highest value of actual evapotranspiration was obtained at 3 days irrigation intervals with 60 cm distance between irrigation lines. The irrigation every 3 days with 60 cm distance between irrigation lines gave the highest yield, while the irrigation every 7 days with 40 cm distance between irrigation lines gave the highest water use efficiency.

Keywords: Water requirement - Drip irrigation - Irrigation intervals - Sugar beet - North Sinai

INTRODUCTION

Water resources in Egypt have become limited in view of the necessisity to reclaim new lands; i.e. horizontal agriculture expansion. In such new reclaimed lands, which are located in arid and semi-arid regions, the limiting factor for maximizing the benefit of cultivation is water. Sugar beet (*Beta vulgaris,* L) is a crop with increasing importance in Egypt. The expansion in its production helps to fill the gab in the local sugar requirements particularly as it consumes less amount of water than sugar cane. It is the major second crop after rice in the new reclaimed area in North

Delta. Sugar beet is an important winter crop in North Delta because of its tolerance to salinity and drought, beside its productivity makes it a good cash crop.

Emara (1990) found that all yield components were significantly affected by irrigation intervals. The largest values of sugar beet yield was obtained for irrigating sugar beet every 14 days, while the lowest values were obtained for irrigating every 28 days. Gaber *et al.* (1986) studied the effect of 10, 15, and 20 days irrigating sugar beet intervals on sugar production. They stated that sugar content was not affected with irrigation intervals in two seasons although root yield significantly decreased with increasing irrigation intervals. On the other hand, Azzazy (1998) found that irrigating sugar beet plants cultivated in shandaweel in Egypt every 14-days produced significantly higher top yield than irrigating every 7-days. On the contrary, Massoud and Botros (1999) cultivated sugar beet plants on loamy soil. They pointed out that different available soil moisture depletions (25, 50 and 75 %) had insignificant effect on top yield (16.999, 16.915, 16.901 ton.fed^{-1}., respectively). Tognetti, *et al.* (2003) stated that sugar beet above-ground dry-mass generally increased as the applied water increased.

Ibrahim *et al.* (1993) revealed that increasing irrigation intervals (2, 3 and 4 weeks) had insignificant increase of sugar beet root yield as they were 20.456, 20.690 and 18.527 ton.fed^{-1}., respectively. Azzazy (1998) mentioned that increasing irrigation intervals from 7 to 14 days had insignificant decrease in sugar beet root yield as they were 19.51 and 18.72 ton. fed^{-1}., respectively. Ibrahim *et al.* (1995) studied the interaction between irrigation depth and intervals on water relations and yield of sugar beet. Irrigation depths were 4, 6 and 8 cm. of water, while irrigation intervals were 7, 14 and 21 days. They reported that maximum root and sugar yields were 25.12 ton.fed^{-1}, and 4.0 ton.fed^{-1}. for 6 cm. of irrigation water applied every 14 days. Rinaldi and Venella (2006) found for sugar beet that the optimal irrigation regime produced higher root yield, although it gave the lowest sucrose yield than other irrigation treatments. Kiziloglu *et al.* (2006) reported that sugar beet deficit irrigation treatments significantly decreased root, leaf and total sugar yield compared with unstressed treatment.

Sorour (1995) indicated that sugar yield ton.fed^{-1}. was significantly increased as plant density increased. Leilah *et al.* (2005) studied the effect of planting dates, plant populations, nitrogen fertilizer levels and times of its application and their interactions on sugar beet productivity. Plant population markedly affected all studied characters. The highest root and sugar yields ton/ha. were obtained with sowing sugar beet on both sides of ridges, 70 cm width and 25 cm between plants, hence plant density was 114240 ha^{-1}. Ibrahim *et al.* (1993) found for North Delta in Egypt that the duration of irrigating sugar beet every three weeks gave maximum WUE (8.95 kg.m^{-3}) compared with irrigation every two weeks or four weeks intervals although plant root dry weight was insignificantly different from the higher or lower irrigation treatments. Kiziloglu *et al.* (2006) studied the effect of deficit irrigation, 0, 20, 40, 60, 80, and 100% (non-irrigated) on root, leaf and total sugar yield and water use efficiency of sugar beet (Beta vulgaris L.) under semi-arid and cool climatic conditions in Turkey. They reported that the highest water use efficiency was obtained for the non-irrigated treatment (91.84 $kg.ha^{-1}mm^{-1}$). This work aimed to study the effect of irrigation intervals and distances between drip irrigation laterals on yield, yield components well as the water use efficiency of sugar beet plants under the conditions of North Sinai, Egypt.

MATERIALS AND METHODS

Field experiment was carried out at the Experimental Farm of the Faculty of Environmental Agricultural Sciences, Suez Canal University in El-Arish, during two successive seasons, 2004/2005 and 2005/2006. The experiment aimed to study the effect of irrigation intervals and distances between drip irrigation laterals on sugar beet (Beta vulgaris L. cv. LP12) yields and their components.

The determined soil moisture saturation percentage, field capacity, wilting point and available water are given in Table 1a.The initial mechanical and chemical properties of the soil used in the experiments are given in Table 1b. The chemical properties of the irrigation water for both seasons are given in Table 1c.

Table 1a : Soil moisture constants for the investigated soil.

Depth (cm.)	Saturation percentage		Field capacity		Wilting point		Available water	
	% $g.g^{-1}$	Soil moisture ($mm.15cm^{-1}$)	% $g.g^{-1}$	Soil moisture ($mm.15cm^{-1}$)	% gg^{-1}	Soil moisture ($mm.15cm^{-1}$)	% $g.g^{-1}$	Soil moisture ($mm.15cm^{-1}$)
0-15	29.77	73.68	11.90	29.45	5.17	12.80	6.73	16.65
15-30	30.22	75.25	11.89	29.61	5.06	12.60	6.83	17.01
30-45	36.46	80.39	13.67	30.14	5.14	11.33	8.53	18.81
45-60	28.75	62.96	11.18	24.48	5.84	12.79	5.34	11.69
60-75	26.43	52.73	10.88	21.71	5.68	11.33	5.20	10.38

Soil parameters determined before conducting the experiments were:

1. Particles size distribution was determined using the international A.C.A. Pippete method (Piper, 1950).
2. Bulk density was determined using J.R.H. Coutts cylinder (Piper, 1950).
3. Calcium carbonate was determined as CaCO3 % by means of Collin's calcimeter (Jackson, 1967).
4. Soil pH value was determined in 1:2.5 soil water suspension.
5. Water holding capacity, field capacity and wilting point They were determined by the weighing method using the pressure cocker and pressure membrane method (Richard, 1954).

The soil water extract for the 1:5 soil water ratio was chemically analyzed for:

a) Electrical conductivity (E.C), conductimetrically using Radiometer compenhagen N.V. type CDM 2d, Jackson (1967).
b) Carbonate and bicarbonate, titremetrically using H2SO4 and phenophthalein and bromocresol green as indicators.
c) Chloride following Mohr's method, Richard (1954).
d) Soluble sulfate was taken by the difference between the summation of soluble cations and anions.

e)Soluble potassium and sodium, by the flame photometer, Richard (1954).
f)Calcium and magnesium, by the versenate method using ammonium purpurate as an indicator for Ca++ and Eriochrome black T for Ca++ plus Mg++, Jackson (1967).

Soil moisture was determined by the weighing method after and before irrigation, Richard (1954). Air temperature and relative humidity were recorded from the meterological station at El-Arish, North Sinai Governorate.

Table 1b : Initial soil mechanical and chemical properties.

Soil properties	Season									
	2004-2005					2005-2006				
	Soil depth (cm.)									
	0-15	15-30	30-45	45-60	60-75	0-15	15-30	30-45	45-60	60-75
Mechanical properties										
Coarse sand %	63.00	59.00	46.00	44.00	46.00	63.22	60.10	45.00	44.30	45.0
Fine sand %	21.82	18.80	21.30	23.30	21.80	20.80	19.80	20.30	24.30	21.80
Silt %	7.00	13.50	21.49	17.50	20.00	7.06	12.50	24.50	18.20	21.00
Clay %	8.18	8.70	11.21	15.20	12.20	8.92	7.60	10.20	13.2	12.20
Soil texture	Loamy sand		Sandy loam			Loamy sand		Sandy loam		
Bulk density (Mgm.m-3)	1650	1660	1470	1460	1330	1650	1660	1470	1460	1330
Chemical properties (soluble ions in (1:5) soil water extract)										
Ca++ (meq.l-1)	4.5	3.0	4.4	5.4	4.5	5.01	3.91	4.6	5.85	4.6
Mg++ (meq.l-1)	3.91	4.0	4.18	3.6	3.3	3.93	4.12	4.20	3.72	3.35
Na+ (meq.l-1)	1.75	2.45	2.90	3.05	2.65	3.25	2.91	3.30	3.61	2.89
K+ (meq.l-1)	0.34	0.25	0.42	0.65	0.35	0.31	0.26	0.30	0.52	0.36
CO3-- (meq.l-1)	-	-	-	-	-	-	-	-	-	-
HCO3- (meq.l-1)	4.0	4.0	7.0	5.7	4.87	4.6	4.4	6.98	5.8	4.68
Cl- (meq.l-1)	5.0	4.25	3.5	4.5	4.32	6.1	5.30	3.96	5.32	4.68
SO4-- (meq.l-1)	1.5	1.45	1.4	2.50	1.61	1.8	1.5	1.46	2.58	1.71
EC(dS m-1) in (1:5) soil water extract)	1.05	0.97	1.19	1.27	1.08	1.25	1.02	1.3	1.37	1.19
pH in (1:2.5) soil water suspension extract)	8.0	8.13	8.06	8.19	8.25	8.1	8.0	8.12	8.05	8.09
Organic matter %	0.185	0.153	0.136	0.123	0.119	0.190	0.171	0.154	0.142	0.129
CaCO3 %	14.39	22.58	22.65	22.60	21.85	14.32	22.48	22.75	22.80	21.95

Table 1c : Chemical properties of irrigation water.

pH	EC		Soluble ions (meq.l-1)							
	dSm-1	ppm	Cations					Anions		
			Ca++	Mg++	Na+	K+	Cl-	HCO3-	CO3--	SO4--
2004/2005										
7.02	5.70	3648	20.90	17.71	18.13	0.26	46.40	2.76	-	7.84
2005/2006										
7.32	6.00	3840	21.51	19.32	18.94	0.23	48.71	2.98	-	8.31

Treatments:

The experiments were assigned for cultivating sugar beet plants. The experiment included 9 treatments for the interaction between 3, 5 and 7 days irrigation intervals and 40, 50 and 60 cm distances between drip lateral lines. Each treatment plot consisted of 3 lateral lines, each was 10 m long. The treatments plot area was either 12, 15 or 18 m2. Seeds of sugar beet plants were sown on the 1st of October in 2 successive seasons, 2004/2005 and 2005/2006, at a rate of 3 kg.fed^{-1}. Plants were thinned to 2 plants/hill on 30/10 and thinned again to 1 plant/hill on 14/11. The irrigation water was saline ground water (3648 ppm) pumped from a local well. After a 60 days pretreatment period, irrigation intervals treatments started for all plots on 30/11. For the 3 days irrigation interval treatment, it ended on 25/4. The last irrigation took place on 23/4. For the 5 days irrigation interval treatment, it ended on 23/4. The last irrigation occurred on 19/4. For the 7 days irrigation interval treatment, it ended on 25/4. The last irrigation occurred on 19/4. The periodical divisions for growth period for both crops and volumes of applied water are presented in Table 2.

The experimental design was Randomized Complete Block (RCBD) in split-plot design with three replicates. The main plots were chosen for the irrigation treatments whereas the sub-plots were chosen for the distances between drip irrigation lateral lines.

Data recorded

1. Water relationships

A) Consumptive use of water (CU.):

Consumptive use of water (CU.) was calculated using the equation given by Israelson and Hansen (1962) as follows:

$$CU. = D \times AD \times \frac{ez - ei}{100}$$

Where:

CU. = Consumptive use in cm.

D = Irrigated soil depth in cm.

AD = Bulk density, $gm.cm^{-1}$, of the chosen irrigated soil depth.

ez = Soil moisture percent after irrigation.

ei = Soil moisture percent before the next irrigation.

B) Water use efficiency (W.U.E.):

The consumed water by sugar beet plants was calculated according to **Yaron *et al.*, (1973)** as follows:

$$W.U.E. = \frac{Y}{ETa}$$

Where:

Y = Crop yield in kg/fed.,

ETa = Evapotranspiration in $m3.fed^{-1}$.

The actual evapotranspiration, ETa, is assumed to be synonymous to the calculated consumptive use of water (CU). Consequently, daily and monthly water consumptive use were calculated for specified soil depths for all treatments.

2. Crop Yield

Plants were harvested on April 29th in both seasons. The following data were recorded:

1. Fresh and dry root yield, $ton.fed^{-1}$
2. Fresh and dry top yield, $ton.fed^{-1}$
4. Sugar yield for sugar beet, $ton.fed^{-1}$
3. Statistical Analysis

2

Analysis of variance was used to test the degree of variability among the obtained data. Duncan's Multiple rang test was used for the comparison among treatment means, **Duncan, (1955)**. MSTATC program was used for the statistical analysis.

RESULTS AND DISCUSSION

1. Effect of irrigation intervals

1.1 Actual Evapotranspiration (ETa)

Water consumptions were computed from the data of soil moisture depletions; i.e. the differences between soil moisture contents before and after irrigations. They are determined gravimetrically and calculated on oven dry basis. Results given in Table 3 show that, ETa in mm for sugar beet during the two investigated seasons were affected by irrigation intervals. It obviously increased with decreasing irrigation intervals.

Table 3:Sugar beet daily, monthly averages and total actual evapotranspiration (ETa, mm) as affected by irrigation intervals during 2004/2005 and 2005/2006 seasons.

Month	Irrigation intervals (days)					
	3		5		7	
	Daily	Monthly	Daily	Monthly	Daily	Monthly
			2004-2005 season			
October	2.04	63.24	1.43	44.33	1.12	34.72
November	2.07	62.10	1.42	42.60	1.01	30.30
December	2.70	83.70	1.79	55.49	0.66	20.46
January	3.56	110.36	2.14	66.34	0.81	25.11
February *	3.87	108.33	2.22	62.16	0.98	27.44
March	6.27	194.37	4.30	133.30	1.58	48.98
April**	6.67	186.76	2.58	72.24	1.66	46.49
Total		808.957		476.46		233.50
			2005-2006 season			
October	1.87	57.97	1.62	50.22	1.08	33.48
November	1.97	59.10	1.99	59.70	0.93	27.90
December	2.74	84.94	1.91	59.21	0.66	20.46
January	4.17	129.27	2.14	66.34	0.96	29.76
February*	4.45	124.60	2.19	61.32	1.14	31.92
March	6.62	205.22	4.51	139.61	1.66	51.46
April**	6.91	193.48	2.63	73.64	1.77	49.66
Total		854.682		510.04		244.54

*** 28 days for February, and ** 28 days for April.**

Its highest total monthly values were 808.957 and 854.682 mm obtained for 3 days irrigation interval in the first and second growth seasons, respectively. The lowest ones were 233.50 and 244.54 mm obtained for 7 days irrigation interval, respectively. Consequently, the average total volumes of the two seasons for the consumed water for both seasons were 3493.642, 2071.650 and 1003.884 m3.fed^{-1}., for plants irrigated every 3, 5 and 7 days, respectively. It should be mentioned that the value of the wet surface area per feddan used for the calculation of total volumes of water was 4200 m2 due to the fact that all experimental plots surface areas were moistened during irrigation. It should also be mentioned that the total applied volumes of irrigation water for sugar beet crop for either season were 4285.239, 2727.100 and 2144.616 m3.fed^{-1}. for the 3, 5 and 7 days irrigation intervals, respectively. Percent total ETa values relative to the applied ones were 81.53, 75.97 and 46.81 for 3, 5 and 7 days irrigation intervals treatment, respectively. Hence, as the total applied irrigation water increases as the total consumed water also increases. Apparently there is a critical limit for the ratio of the depth of consumed water to the depth of applied water. In respect to the variations in daily ETa values, it generally increased from October till April. These results somewhat agree with those reported by Ibrahim, *et al.* (1995); Khalifa and Ibrahim, (1995) and Fabeiro, *et al.* (2003).

1.2. Crop Yield

In general, yield and yield components of sugar beet plants exhibited significant responses as plants were subjected to water stress by prolonging irrigation intervals (3, 5, 7 days).

1.2.1 Fresh yield

Total fresh weights of sugar beet terrestrial parts plus roots, Table 4, were 43.491, 32.573 and 26.369 ton. .fed^{-1}. for the first season as affected by irrigating every 3, 5 and 7 days; i.e. by applying 4285.239, 2727.100 and 2144.616 m3.fed^{-1}., respectively. For the second season, the fresh weights of the tops and roots were 39.383, 29.477 and 23.110 ton.fed^{-1}., respectively. The total fresh yields were divided into roots and terrestrial parts.

1.2.1.1 Root yield

Data in Table 4 show that increasing irrigation intervals from 3 to 7 days highly significantly decreased root yield for both seasons. The highest fresh roots, varied from 27.437 to 25.367, ton.fed^{-1}., obtained for irrigating the soil every 3 days, respectively. The lowest values, varied from 17.910 to 17.360 ton.fed^{-1}., obtained for the 7 days irrigation interval, respectively. These values are higher than the 13.05 ton.fed^{-1}. calculated world average according to Doorenbos and Kassam (1979). This response may be related to the production of thick roots, high crop growth rate and heavier root weight per plant. The progressive increase of sugar beet root fresh yield in response to rational irrigation compared with subjecting the crop to water stress is reported by many investigators, Cucci and Caro (1986), Anton (1991), Hilal, *et al.*, (1992), Podstawka and Ceglarek (1995), Talik and Plawinski (1995), Drashkov (1996) and Manga, *et al.*, (1998). Also, Fabeiro, *et al.*, (2003), and Tognetti, *et al.*, (2003) found similar results.

1.2.1.2 Top yield

Data in Table 4 show that, fresh top yield significantly differed among irrigation intervals treatments in the two investigated seasons. It decreased from 16.054 and 14.020 ton.fed^{-1}. obtained for the two seasons, respectively, when the soil was irrigated every 3 days to 8.0255 and 5.750 ton.fed^{-1}. when the soil was irrigated every 7 days for the two seasons, respectively. The improvement in top yield is thought to be the result of the ample supply of irrigation water. These results could be enhanced by those obtained by

Sobiech, *et al.*, (1993), Rzekanowski (1994), Gad allah, (1995), Koszanski, *et al.*, (1995a), Grzes, *et al.*, (1997) and Tognetti, *et al.*, (2003) who stated that adequate soil moisture in the root zone for fodder or sugar beet improved top fresh yield.

1.2.2 Dry yield

1.2.2.1 Root yield

Data presented in Table 4 show that sugar beet root dry yield per fed. for two seasons significantly differed as a result of using various irrigation intervals. A dry root yield for the first season was higher than for the second season. Their trends were similar to those observed for roots fresh yields. Increasing irrigation intervals from 3 to 7 days decreased root dry yields from 4.519 and 4.105 tons.fed^{-1}. to 3.189 and 2.765 ton.fed^{-1}. for both seasons, respectively. Such sharp reductions refer to the great reduction in dry matter accumulation. Supporting results are obtained by Hofman, *et al.*, (1992) and Kirda, *et al.*, (1999) who pointed out that rational irrigation for fodder and sugar beet enhanced root dry yield.

1.2.2.2 Top yield

Data in Table 4 show significant decrease in top yields as sugar beet irrigation intervals increased from 3 to 7 days for 2 seasons. Top yields gradually increased from 1.964 to 2.955 ton.fed^{-1}, and from 1.454 to 2.815 ton.fed^{-1}. for the first and second seasons as irrigation intervals decreased from 7 to 3 days, respectively. This response refers to the better plants growth conditions as a result of supplying the soil with the right amounts of water in the right time. In this concern, Anton (1991), Sobiech, *et al.*, (1993) from their study on fodder beet, Massoud and Botros (1999) and Fabeiro, *et al.*, (2003) on sugar beet, concluded that water stress decreased significantly crops top dry yields.

Percent relative turgidities, which are the ratio between top fresh weights minus top dry weight, to the top fresh weight were 81.59, 76.22 and 75.62 for the 3, 5 and 7 days irrigation intervals treatments, for the first seasons. They were 79.92, 77.42 and 74.71 for the same treatments, for the second season; i.e. approximately equal to the first season. It is interestingly noticed that percent turgidities calculated for plant roots were approximately 20% of the relative turgidity values for the top plant parts. They were 16.47, 17.49 and 17.41% for the previously mentioned treatments, respectively, for the first season. They were also 16.18, 15.81 and 15.93% for the second season.

1.2.3 Sugar yield

Data presented in Table 4 show significant differences in sugar yield as a result of applying various intervals in both seasons. The highest sugar yields were obtained for 5 days irrigation interval. They were 0.7 tons.fed^{-1}. higher than those obtained for the shorter irrigation interval treatment. The lowest values were obtained for the 7 days irrigation interval treatment. These results indicate that sugar production is not parallel to the state of plant turgidity. Yield results agree with those obtained by Ibrahim, *et al.*, (1993); Sorour (1995), and Emara (1996).

Table 4: Sugar beet roots and tops fresh and dry yields as well as sugar yield for plants affected by irrigation intervals during 2004/2005 and 2005/2006 seasons.

Irrigation intervals (days)	Fresh yield (ton.fed^{-1}.)		Dry yield (ton.fed^{-1}.)		Sugar yield (ton.fed^{-1}.)
	Root	Top	Root	Top	
2004/2005 season					
3	27.437 a	16.054 a	4.519 a	2.955 a	4.830 a
5	21.865 b	10.708 b	3.824 b	2.546 b	5.543 b
7	18.314 c	8.055 c	3.189 c	1.964 c	4.186 c
2005-2006 season					
3	25.367 a	14.020 a	4.105 a	2.815 a	4.647 a
5	20.820 b	8.657 b	3.292 b	1.955 b	5.385 b
7	17.360 c	5.750 c	2.765 c	1.454 c	3.945 c

***Means having the same alphabetical letter within each colum is not significantly different at the 0.05 level, according to Duncan's multiple range test.**

1.3 Water Use Efficiency (WUE)

Water use efficiency defined as the amount of dry matter produced per unit volume of water consumed by plant (Viets, 1965). Water use efficiency was calculated by dividing the fresh marketable part of crop by the volume of consumed water, m3/fed.

Data in Table 5 show, for sugar beet crop, that as irrigation intervals increased from 3 to 7 days as WUE values increased. The average values for both seasons were 7.6, 10.4 and 17.8 kg.m-3 as a result of irrigating every 3, 5 and 7 days, respectively. These values are greater than those reported by Doorenbos and Kassam (1979) which vary from 6 to 9 taking into consideration that moisture content is 80 to 85%. These results leads to conclude that the best irrigation interval for sugar beet crop is applying irrigation water every 7 days under prevailing conditions similar to those of El-Arish area. When WUE values were calculated based on average sugar production between the 2 investigated seasons and average water consumption, the results were 1.36, 2.68 and 4.05 for 3, 5 and 7 days irrigation intervals, respectively. These results are also greater than those reported by Doorenbos and Kassam (1979) which vary from 0.9 to 1.4 taking into consideration moisture content is zero percent. Consequently, it will be advised to irrigate sugar beet crop every 7 days. However, such treatment produced the least average amount of sugar 4.067 ton.fed^{-1}. and the least average root fresh yield 17.837 ton.fed^{-1}. In this respect, Emara (1990) found that water use efficiency increased by prolonging irrigation intervals up to 28 days for sugar beet. Also, the increase in water use efficiency under drought conditions was reported by many investigators, White, *et al.*, (1995); Van den Boogaard, *et al.*, (1996) and Fabeiro, *et al.*, (2003).

If agriculture strategity points towards high sugar production, it will be recommended to irrigate sugar beet crop every 5 days because average sugar production was the highest, 5.464 ton/fed. The average water consumption for this treatment was 2071.650 m3.fed^{-1}. which is approximately twice as much as the average consumed water from the 7 days irrigation treatment (1003.884 m3.fed^{-1}.).

Table 5: Sugar beet crop water use efficiency, WUE, for plants affected by irrigation intervals during 2004/2005 and 2005/2006 seasons.

Irrigation intervals (days)	Fresh yield ($kg.fed^{-1}$)	Total consumed water ($m3.fed^{-1}$)	Water use efficiency ($kg.m^{-3}$)	Fresh yield ($kg.fed^{-1}$)	Total consumed water ($m3.fed^{-1}$)	Water use Efficiency ($kg.m^{-3}$)
	2004/2005 season			2005/2006 season		
3	27437	3397	8.07	25367	3589	7.06
5	21865	2001	10.92	20820	2092	9.95
7	18314	981	18.66	17360	1027	16.90

2. Effect of plant density

2.1. Actual evapotranspiration (ETa)

Results presented in Table 6 show that, sugar beet actual evapotranspirations (ETa, mm) during the two investigated seasons increased as the distance between lateral irrigation lines increased. The averages for the highest daily values between the two seasons were found for March, were 3.91, 4.16 and 4.41 mm for the 40, 50 and 60 cm distances between lateral lines. The averages for the lowest daily values were found for November for the 40 and 50 cm between lateral lines, 1.31 and 1.48 mm and for October for the 60 cm between lateral lines, 1.66 mm. As for the average for the total ETa between the 2 investigated seasons were 477.99, 519.54 and 561.30 mm for the above mentioned distances between irrigation lines, respectively. These trends are thought to be not directly related to the increase in vaporation from the soil areas between plants, became plants vigours were almost equal for all treatments. Hence, narrow distance between lines decreased ETa. These results somewhat agree with those reported by Sorour (1995).

Table 6: Sugar beet averages daily, monthly and total actual evapotranspiration (ETa, mm) as affected by the distance between lines during 2004/2005 and 2005/2006 seasons.

Month	distance between lines (cm.)					
	40		50		60	
	Daily	Monthly	Daily	Monthly	Daily	Monthly
			2004/2005 season			
October	1.38	42.78	1.53	47.33	1.68	52.18
November	1.34	40.30	1.46	43.80	1.69	50.80
December	1.55	48.05	1.74	54.04	1.86	57.56
January	1.94	60.24	2.20	68.10	2.37	73.37
February *	2.20	61.51	2.35	65.71	2.53	70.93
March	3.86	119.76	4.02	124.52	4.27	132.37
April**	3.45	96.76	3.56	99.77	3.89	109.01
Total		469.150		503.263		546.223
			2005/2006 season			
October	1.40	43.40	1.52	47.12	1.64	50.84
November	1.27	38.00	1.50	45.00	1.73	51.80
December	1.56	48.46	1.82	56.52	1.92	59.42
January	2.26	70.06	2.40	74.30	2.62	81.12
February*	2.36	65.99	2.59	72.43	2.83	79.33
March	3.95	122.55	4.29	132.99	4.54	140.84
April**	3.51	98.37	3.77	105.47	4.03	112.93
Total		486.837		533.823		576.283

*** 28 days for February, and ** 28 days for April.**

2.2 Crop Yield

2.2.1 Root fresh and dry yields

Data given in Table 7 show that cultivating sugar beet at 40, 50 and 60 cm distances between irrigation lines significantly increased roots fresh and dry weights for the 2 investigated seasons. The highest fresh root yields varied from 24.086 to 23.017 ton.fed^{-1}. for the first and second seasons, respectively, when irrigation lines were 60 cm. apart. The lowest values varied from 20.939 to 19.417 ton.fed^{-1}. for the first and second seasons, respectively, when irrigation lines were 40 cm. apart. Roots average fresh weights between the 2 seasons were 20.178, 21.852 and 23.552 ton.fed^{-1}. for 40, 50 and 60 cm distances between irrigation lines, respectively. The obtained values for sugar beet relative turgidities were 83.81, 83.49 and 83.13%, respectively, and for the tops were 78.88, 77.95 and 78.21%, respectively, indicating that plants vigour were almost equal as concluded from actual ETa values. Data obtained for average roots dry weights were 3.267, 3.607 and 3.973 ton.fed^{-1}. for the previously mentioned distances of irrigation lines, respectively. This obtained trend is similar to that obtained for average roots fresh weights. These results agree with those obtained by Stanacev (1970) and Basha (1998).

2.2.2 Top fresh and dry yields

Data given in Table 7 show that, top fresh and dry yields were significantly increased as the distance between irrigation lines in both seasons increased. The average top fresh and dry weights were 8.939, 10.576 and 12.047 ton.fed^{-1}. and 1.888, 2.332 and 2.625 ton/fed. for 40, 50 and 60 cm distances between irrigation lines, respectively. These results are in agreement with those reported by Assey *et al.* (1992). It was interestingly found that sugar beet average roots fresh weights were 2.26, 2.07 and 1.96 times tops average fresh weights when irrigation lines were 40, 50 and 60 cm apart, respectively. Also, averages roots dry weight were 1.73, 1.55 and 1.51 times tops dry weights, respectively. Consequently, this crop is sensitive to irrigation water regime and to the degree of soil particles coherence.

Table 7: Sugar beet roots and tops fresh and dry yields and sugar yield as affected by the distances between irrigation lines during 2004/2005 and 2005/2006 seasons.

Distance between lines (cm.)	Fresh yield (ton.fed^{-1}.) Root	Fresh yield (ton.fed^{-1}.) Top	Dry yield (ton.fed^{-1}.) Root	Dry yield (ton.fed^{-1}.) Top	Sugar yield (ton. .fed^{-1}.)
2004/2005 season					
40	20.939 b	10.128 c	3.558 b	2.135 c	4.683 b
50	22.591 ab	11.525 b	3.820 ab	2.516 b	4.853 ab
60	24.086 a	13.043 a	4.152 a	2.813 a	5.023 a
2005/2006 season					
40	19.417 b	7.750 c	2.975 b	1.641 c	4.395 b
50	21.113 ab	9.627 b	3.394 ab	2.147 b	4.689 ab
60	23.017 a	11.050 a	3.793 a	2.436 a	4.894 a

***Means having the same alphabetical letter within each colum is not significantly different at the 0.05 level, according to Duncan's multiple range test.**

2.2.3. Sugar yields

Data presented in Table 7 show that sugar beet sugar production was significantly affected by varying the distances between irrigation lines in both seasons. The average values were 4.959, 4.771 and 4.539 $ton.fed^{-1}$. for the 60, 50 and 40 cm distances between irrigation lines, respectively. Hence, increasing the distance between irrigation lines increased sugar yield. These results may be related to the trends obtained for average roots fresh or dry weights; i.e. growth status. These results agree with those obtained by Leilah *et al.* (2005).

2.3 Water Use Efficiency (WUE)

Data presented in Table 8 show that, water use efficiency values were approximately similar for the 40, 50 and 60 cm distances between irrigation lines. They were about 10 kg of fresh sugar roots per one cubic meter of consumed water. However, it should be noted that average WUE value obtained for 3, 5 and 7 days irrigation intervals points to irrigate sugar beet crop every 7 days because the obtained values were 7.6, 10.4 and 17.8 kg fresh roots per one cubic meter of consumed water. Hence, if it is necessary to conserve irrigation water during sugar beet production, then irrigation lines should be 40 cm apart and plants to be irrigated every 7 days, otherwise, irrigation lines could be 50 cm apart and plants should be irrigated every 5 days because sugar production is very well for such irrigation interval.

Table 8: Sugar beet crop averages water use efficiency for plants affected by the distance between irrigation lines.

Distance between lines or rows (cm.)	Average fresh yields ($ton. .fed^{-1}$)	Volume of consumed Water ($m3.fed^{-1}$.)	Water use efficiency ($kg.m^{-3}$)
40	20.178	2007.56	10.05
50	21.852	2177.87	10.03
60	23.552	2357.25	9.99

3. Effect of interaction between irrigation intervals and plant density

3.1. Actual evapotranspiration (ETa)

The effect of interaction between irrigation intervals and distances between irrigation lines on ETa are presented in Table 9. ETa values were more influenced by irrigation intervals than by the distances between irrigation lines. Generally, abundant irrigation water increased ETa at any distance between irrigation lines. The average values between both seasons for the total consumed water of the 3, 5 and 7 days irrigation intervals during all growth periods were 831.824, 484.275 and 239.00 mm, respectively. Opposite to this decreasing trend, the average values between both seasons for the total consumed water of the 40, 50 and 60 cm distances between irrigation lines were 478.267, 515.408 and 559.928 mm, respectively. The highest average ETa values between seasons for sugar beet was 879.73mm for irrigation every 3 days when irrigation lines were 60 cm apart. The least average depth of consumed water was 209.965 mm. when sugar beet was irrigated every 7 days and irrigation lines were 40 cm apart.

3.2. Crop Yield and Water Use Efficiency

The effect of interactions between irrigation intervals and distances between irrigation lines on the average values between the 2 investigated seasons for roots fresh, dry, tops fresh and dry weights in $ton.fed^{-1}$. as well as roots sugar production in ton/fed. were significantly affected, Table 10 all values for the forementioned parameters increased as the distance between irrigation lines increased.

9-10

Contrary to this trend, all values increased as irrigation intervals decreased, consequently the number of irrigation increased. An exception for the last trend was obtained for sugar production as their values were the highest ones when irrigation intervals were 5 days. The largest values for roots fresh or dry weights were obtained for sugar beet irrigated every 3 days and the distance between irrigation lines was 60 cm; 28.905 and 4.853 ton.fed^{-1}., respectively. The least amounts of produced roots fresh and dry weights were obtained for sugar beet irrigated every 7 days and irrigation lines were 40 cm apart; 16.449 and 2.812 ton.fed^{-1}., respectively.

The data presented in Table 10 indicate that sugar beet cultivated in environmental conditions similar to El-Arish area should be irrigated every 5 days and the distance between irrigation lines should be 60 cm apart. The reason for this recommendation is that this cultivation procedure produced 5.667 ton.fed^{-1}. sugar from 22.304 ton.fed^{-1}. fresh roots which consumed 2219.889 m3 water although sugar water use efficiency was only not the best; i.e. 2.55 kg.m^{-3} water. Apparently the second best choice of cultivating sugar beet is irrigating the plants every 3 days and the distance between irrigation lines should be 60 cm because roots fresh weight exhibited the highest value, 28.905 ton.fed^{-1}., yet this amount produced 4.846 ton.fed^{-1}. sugar beside it consumed 3694.866 m3 water, i.e. 66% more water consumed than the 5 days irrigation interval treatment and cultivating the plants 60 cm apart.

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الاحتياجات المائية لبعض المحاصيل بمحافظة شمال سيناء
1- تأثير فترات الري وكثافة النباتات على النتح-بخر الفعلي، وكفاءة استخدام المياه، والمحصول لنباتات بنجر السكر

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أجريت هذه الدراسة بالمزرعة التجريبية لكلية العلوم الزراعية البيئية بالعريش جامعة قناة السويس خلال موسمي 2005/2004 ، و2006/2005م. وتهدف هذه التجربة إلى دراسة تأثير فترات الري والمسافة بين خطوط الري بالتنقيط على بنجر السكر "صنف أل بي12". احتوت التجربة على تسع معاملات تشمل التداخل (التفاعل) بين ثلاث فترات ري (3، 5 و 7 أيام)، و ثلاث مسافات بين خطوط الري بالتنقيط (40، 50 و 60 سم). احتوت كل وحدة تجريبية على 3 خطوط ري بطول 10 م، وكانت مساحة الوحدة التجريبية لها هي 12، 15 و 18م^2 على التوالي. زرعت بذور نباتات بنجر السكر في الأول من أكتوبر في كلا الموسمين (205/2004 و 2006/2005) بمعدل 3 كجم/فدان. تزايد معدل النتح-بخر الفعلي والوزن الطازج والجاف لمحصول الجذور والعرش مع نقص فترات الري، بينما تزايدت مع زيادة المسافة بين خطوط الري في كلا الموسمين. تزايدت كفاءة استخدام المياه مع زيادة الفترة بين الريات، بينما تناقصت مع زيادة المسافة بين خطوت الري. نتج أعلى محصول سكر عند ري بنجر السكر كل 5 أيام بينما كان أعلى محصول سكر عند الزراعة على مسافة 60سم بين خطوط الري في كلا الموسمين. وجدت أعلى قيمة للنتح–بخر الفعلي عند الري كل 3 أيام مع 60سم مسافة بين خطوط الري. الري كل 3 أيام مع 60سم مسافة بين خطوط الري نتج عنها أعلى محصول، بينما الري كل 7 أيام مع 40سم مسافة بين خطوط الري نتج عنها أعلى كفاءة استخدام للمياه.

Table 9: Sugar beet average monthly and total actual evapotranspiration (ETa, mm) as affected by irrigation intervals and distance between irrigation lines.

Month	Irrigation intervals (days)											
	3				5				7			
	Distances between irrigation lines (cm)											
	40	50	60	Average	40	50	60	Average	40	50	60	Average
October	56.885	60.915	65.015	60.605	42.005	47.275	52.235	47.172	30.380	33.480	38.480	34.057
November	54.600	60.450	66.900	60.650	36.600	43.845	54.450	44.965	26.250	28.500	32.550	29.100
December	74.710	87.730	90.520	84.32	51.615	58.435	62.000	57.350	18.445	19.685	22.940	20.357
January	109.895	118.265	131.595	119.918	62.155	68.045	64.665	64.955	23.405	27.280	31.465	25.883
February	106.350	117.180	125.860	116.460	58.520	61.320	65.520	61.787	26.320	28.700	34.020	29.680
March	189.720	202.585	207.080	199.795	130.200	130.505	144.615	135.107	43.555	48.670	58.125	50.117
April	185.220	191.240	193.760	190.073	66.360	71.400	81.060	72.940	41.610	45.220	58.100	48.020
Total	777.380	838.365	879.730	831.824	447.455	480.825	524.545	484.275	209.965	231.535	275.510	239.00

Table 10: Effect of interaction between irrigation intervals and distance between irrigation lines on sugar beet averages between seasons for root and top fresh and dry yields, sugar yields, consumed water and water use efficiency.

Parameters	Irrigation intervals (days)											
	3				5				7			
	Distances between irrigation lines (cm)											
	40	50	0	Average	40	50	60	Average	40	50	60	Average
Root fresh yield (ton.fed^{-1}.)	23.951	26.371	28.905	26.409	20.154	21.571	22.304	21.342	16.449	17.616	19.446	17.837
Top fresh yield (ton.fed^{-1}.)	12.469	15.011	17.631	15.037	8.442	9.846	10.760	9.683	6.081	6.872	7.749	6.901
Root dry yield (ton.fed^{-1}.)	3.691	4.394	4.853	4.313	3.298	3.555	3.823	3.559	2.812	2.873	3.247	2.977

Top dry yield (ton.fed^{-1}.)	2.167	2.991	3.581	2.913	1.937	2.269	2.547	2.251	1.562	1.735	1.830	1.709
Sugar yield (ton.fed^{-1}.)	4.614	4.756	4.846	4.739	5.255	5.471	5.667	5.464	3.750	4.085	4.363	4.067
Consumed water (m3.fed^{-1})	3264.996	3521.133	3694.866	3493.665	1879.311	2040.060	2219.889	2046.420	881.853	972.447	1157.142	1003.800
Fresh roots water use efficiency (kg.m^{-3})	7.34	7.49	7.82	7.56	10.72	10.57	10.04	10.43	18.65	18.12	16.81	17.77
Sugar water use efficiency (kg.m^{-3})	1.41	1.35	1.31	1.36	2.80	2.68	2.55	2.68	4.25	4.20	3.77	4.05