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EFFECT OF IRRIGATION SYSTEM AND WATER STRESS ON SUGAR BEET YIELD AND WATER SAVING

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ABSTRACT

Two field experiments were carried out at Agriculture Secondary School Farm in Kafr El Sheikh Governorate, in the two successive seasons, 1999-2000 and 2000-2001, to study the effect of two irrigation systems, i.e. furrow and bed systems and three water stress levels (50, 65 and 80% depletion of available soil moisture content) on sugar beet yield, water saving and water use efficiency .A split plot design with four replicates was used in this study. The obtained data showed that, Irrigation system not affected the sugar beet root yield, while the water stress treatments have highly significant effect. Also the same trend was obtained on sucrose percentage .The highest values of water applied were recorded with the furrow irrigation system and 50% depletion of available soil moisture content. While the lowest value was recorded with bed irrigation system and 80% depletion of available soil moisture content. The average values of water saving were 20.04 and 34.99% under bed irrigation system treatment and 80% depletion of available soil moisture content respectively. The averages seasonal water consumptive use of sugar beet plant were 2044.35 and 1773.36 m^3/ fed. under furrow and bed irrigation systems, respectively. On the other hand, these values were 2216.55, 1952 and 1558.05 m^3/fed. under water stress of 50,65 and 80% depletion of available soil moisture content. Treatments of bed irrigation system and water stress of 80% depletion of available soil moisture content achieved the highest value of water use efficiency. Data of soil moisture extraction revealed that sugar beet plant roots under moisted soil condition extracted a large amount of water from the surface soil layer (30 cm depth) and a little amount of water from deep soil layer (45-60cm), while the plant roots penetrated soil profile and tend to extend for more depth under dried soil conditions to obtain its need of water from deeper layer. Modified Penman equation can be used with the value of 0.78 for crop coefficient to calculate the evapotranspiration of sugar beet plant grown in the North Nile Delta.

INTRODUCTION

Sugar beet has become one of the major winter field crops in Egypt due to its high income to the farmers. Sugar beet can be irrigated with about one/fourth the water utilized by sugar cane, the other source of sugar around the world. Production and water relations of sugar beet has been widely investigated by many researchers; Howeil *et al* (1987), Bailey (1990) , Emara (1990), Ibrahim *et al* (1992) and 1993 showed that irrigating every two or three weeks, especially for the second half of the growing season of the sugar beet resulted in high yield. The values of water consumptive use were 58.06, 55.04 and 49.86 cm /Fed.for the 2, 3 and 4 weeks intervals, respectively. The water use efficiency of 8.66 kg for sugar beet root could be obtained from each cubic meter of water consumed. Eid (1994) studied the effect of irrigation depths (4,6 and 8 cm) and intervals (7,14 and 21days) on sugar beet at Sakha. He found that with increasing the irrigation interval, soil moisture content decreased clearly especially when accompanied with the least water applied of 4 cm and the longest period of 21 days. Dawlatz *et al* (1995) showed that the highest sugar beet yield and sugar production were obtained from 37.8 m^2 plot area. Actual evapotranspiration (ET) values of the average two seasons were 41.51,42.26,45.01,48.19 and 50.85 cm for 25.2,37.8,50.4,58.8 and 67.2 m^2 plot area treatments respectively. Shams (2000) showed that the treatment irrigated at field capacity plus 5% recorded the highest values of water consumptive use (2479.4 and 2563.34 m^3/fed.) for the 1^{st} an 2^{nd} seasons, respectively. The lowest value of water applied was recorded by irrigation at field capacity minus 5% and soil moisture depth of 30 cm which achieved the highest value of water use efficiency.

The present investigation was initiated to study the effect of irrigation system and water stress on sugar beet yield and its water relations.

MATERIAL AND METHODS

Two field experiments were carried out in a clay soil, in agriculture secondary school farm (Kafr El-sheikh governorate, Egypt). Some physical and chemical properties of soil for the two experiments were determined according to FAO (1976) and Black (1965) and presented in Tables (1 & 2), respectively.

Table 1 : some physical properties of the experiment soil .

Soil depth, cm	Particle size distribution			Soil texture	Bd, g/cm^3	FC % w/w	WP % w/w
	Clay%	Silt%	Sand%				
0-20	62.91	21.5	15.59	Clayey	1.03	44.01	24.0
20-40	56.90	25.38	17.72	Clayey	1.15	39.50	21.02
40-60	52.20	26.17	21.63	Clayey	1.20	35.70	18.50

Table 2: some chemical properties of the experiment soil .

Depth (cm)	pH (1:2.5)	Ece ds/m	Soluble cations (meq/l)				Soluble anions (meq/l)			
			Ca^{++}	Mg^{++}	Na+	K+	Cl-	Co3^{--}	Hco3$^-$	So4^{--}
0-20	8.3	2.0	5.5	5.0	9.2	0.75	6.4	-	9.0	5.05
20-40	8.3	2.10	5.8	5.30	9.4	0.75	6.9	-	9.0	5.35
40-60	8.3	2.65	6.8	5.9	15.5	0.90	12.0	-	11.0	6.10

*** SO_4=was determined by difference**

The depth of the ground water table ranged between 1.0 and 1.2 m. during the experiments .Sugar beet variety ,Ras poly, was used in all treatments. A split plot design with four replicates was conducted. The main plots were assigned to two irrigation systems (furrow and bed) and the sub plot to water stress (50, 65 and 80% depletion of available soil moisture content). Figs. 1 and 2 are show the bed and furrow shapes.

Fig (1) Diagram of the bed .

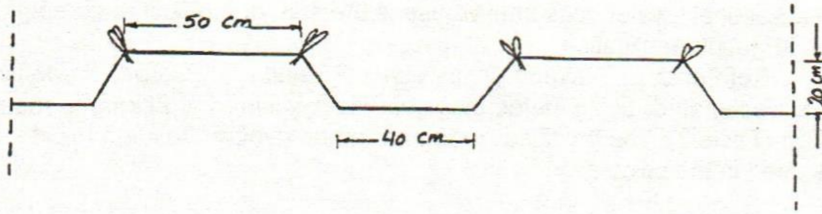
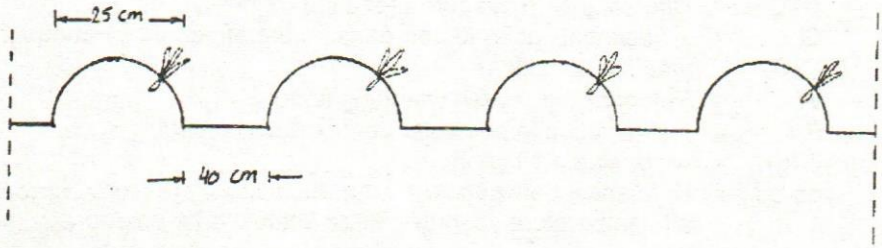


Fig (2) Diagram of the Furrow



Sugar beet was sown on the 15th and 20 of Nov. 1999 and 2000 of the growing successive seasons. Fertilizers were added at the recommended rate of Ministry of Agriculture, (70 kg N, 15kg p_2o_5 and 100kg k_2 so_4) per feddan. The data were statistically analyzed (sedeor and Cochran 1980). The following characters were studied:

Sugar beet yield :

- Root yield was recorded in ton/fed.
- Sucrose percentage was determined polarly metrically in lead acetate extract of fresh roots according to method described by le – Decote (1927).
- Amount of irrigation water applied was measured by cut-throat flume (20×90cm) and calculated as m^3/fed. (Early 1975).

Water consumptive use:

Water consumptive use computed as the difference in the soil moisture content after and before irrigation according to the following equation by Israel son and Hansen (1962).

$$Cu = D \times Bd \times (\theta 2 - \theta 1)/100$$

Where:

Cu = Water consumptive use m^3/fed.
D = soil depth
Bd = soil bulk density (g/cm3)
θ1 = soil moisture content before irrigation (% by weight).
θ2 = soil moisture content after irrigation or after 48 hours (% by weight).

Seasonal water consumptive use is the sum of the figures computed for each irrigation application.

- Reference evaporanspiration and Corp coefficient

It was estimated using meteorological data measured at El karada research station (Table 3). The modified Penman method (Doorenbos and Pruitt, 1977) was used in the calculation

$$ETO = C\ (w.\ Rn + (1\text{-}w)\ f\ (u)\ (ea\text{-}ed))$$

Where:

ETO = reference crop evaporanspiration (mm/day)
C = Adjustment factor to compensate the effect of day and night weather conditions.
W = Temperature related weighing factor.
Rn = Net radiation in equivalent evaporation (mm/day)
F (u) = wind related function.
ea-ed = Difference between the saturation vapor pressure of mean air temperature and the mean actual vapor pressure of the air.

Accordingly the crop coefficient kc was calculated under the prevailing condition as follows :

$$Kc = Cu\ /\ ETO$$

Table (3): Average of temperature (c°), relative humidity (%) and wind speed (km/day)

Months	1999 – 2000			2000 – 2001		
	Ave. temp., (c°)	R.H (%)	Wind speed (Km/day)	Ave. temp., (c°)	R.H (%)	Wind speed (Km/day)
Nov.	19.9	64.50	73.5	19.4	79.19	171.77
Dec.	13.5	58.35	93	15.55	65.96	144.61
Jan.	11.4	57.05	81.43	14.4	62.46	141.05
Feb.	13.15	61.45	98	12.69	43.88	142.4
Mar.	14.5	58	106	17.05	65.14	116.13
April.	18.25	57.68	114.5	18.75	54.35	170.6
May.	22.15	55.25	134	21.4	56.00	171.8

- Soil moisture extraction pattern: S.M.E.P. It was calculated according to the following equation, (Israelson and Hansen 1962).

$$S.M.E.P. = Cu.\ (layer)\ /\ Cu.\ (seasonal) \times 100$$

Where:

Cu. (layer) = sum of extracted soil moisture in each layer depth (15cm)
Cu. (seasonal) = total sum of moisture extracted from all soil depths (60 cm).

Crop water use efficiency:
It was calculated according to Michael (1978):

$$CWU.E = Y / Cu$$

Where:

CWU.E = crop water use efficiency (kg/m3)
Y = root yield (kg/fed.) .
CU = water consumptive use (m^3/fed.) .

Field water use efficiency:

The field water use efficiency was calculated as reported by Michael (1978).

$$FWUE = Y / WR$$

Where:

FWUE = field water use efficiency (kg/m^3)
Y = root yield (kg/fed.).
WR = water delivered to the field (m^3/fed.).

RESULTS AND DISCUSSION

Effect of irrigation system and water stress on sugar beet root yield and sucrose percentage:

Data presented in Table 4 showed the effect of irrigation system and water stress on sugar beet root yield and sucrose percentage. The statistical analysis of data using f test indicated that the irrigation system treatments

Table 4: Sugar beet root yield and sucrose % for the two seasons.

Treatments	Sugar beet yield, ton/fed		Sucrose %	
	1st season	2nd season	1st season	2nd season
Irrigation systems:				
A1 Furrow	23.16	23.98	17.67	17.64
A2 Bed	23.05	23.75	17.65	17.62
Mean	23.11	23.87	17.66	17.63
F. Test	N.5	N.5	N.5	N.5
L.S.D 5%	-	-	-	-
L.S.D 1%	-	-	-	-
Water stress				
B1- At depletion 50% of available soil moisture	24.23	24.98	17.81	17.82
B2- At depletion 65% of available soil moisture	23.51	24.23	17.61	17.54
B3- At depletion 80% of available soil moisture	21.59	22.40	17.57	17.48
Mean	23.11	23.87	17.66	17.63
F. Test	**	**	**	**
L.S.D 5%	0.41	0.58	0.13	0.12
L.S.D 1%	0.57	0.80	0.19	0.17
Interaction (A × B)	N.5	N.5	N.5	N.5

**** and N.5 = significant at 1% and not significant**

It could be noticed that the highest sugar beet yield is gained from A1B1.

had no significant effect on the productivity of root yield. While it was affected significantly by water stress treatments. Treatment (B1) of 50% depletion of available soil moisture content achieved the highest value of sugar beet yield followed by treatment (B2) of 65% depletion of available soil moisture content. While treatment (B3) of 80% depletion of available soil moisture content recorded the lowest value.

Sucrose percentage:

The sucrose percentage ranged between 17.57 and 17.81 % in the first season, while in the second season varied between 17.48 and 17.82 %. Also the statistical analysis revealed that there is no response of sucrose percentage to the irrigation systems treatments. While there is a response to the water stress.

A mount of water applied:

The amount of irrigation water applied to sugar beet for different treatments in the two seasons are presented in Table 5 .The average total amounts for two seasons of irrigation water applied to sugar beet by furrow irrigation system were 3252.55, 2636.54 and 2121.25 m^3/fed. under water stress of 50, 65 and 80 % depletion of available soil moisture content respectively. While it was 2588.6, 2139.7 and 1676.25 m^3/fed by bed irrigation system under the previous water stress respectively. These results indicated that bed irrigation system could save water with an average of 20.41, 18.84 and 20.98 % of the applied water to sugar beet crop under water stress treatments of 50, 65 and 80 % depletion of available soil moisture content, respectively.

Table 5: Amount of water applied, water consumptive use, crop water use efficiency and field water use efficiency in studied the treatments.

Treatments		Amount of water applied, m^3/fed	Water consumptive use, m^3/fed	Crop water use efficiency, kg/fed	Field water use efficiency, kg/m
Season 1		1999-2000			
Irrigation System	Water stress				
Furrow A1	B1	3204.6	2429.8	10.03	7.61
	B2	2612.4	2028.0	11.65	9.05
	B3	2112.0	1658.0	12.96	10.17
Average		2643.0	2038.6	11.55	8.94
Bed A2	B1	2587.20	1940.50	12.10	9.31
	B2	2124.4	1880.5	12.44	10.98
	B3	1671.6	1452.7	14.94	12.98
Average		2129.4	1774.56	13.16	11.09
Season 2			2000-2001		
Furrow A1	B1	3300.50	2450.5	10.26	7.62
	B2	2660.68	2039.0	12.04	9.23
	B3	2130.50	1660.9	13.40	10.44
Average		2697.23	2050.1	11.9	9.10
Bed A2	B1	2590.0	1995.40	12.43	9.58
	B2	2150.0	1860.50	12.85	11.12
	B3	1680.90	1460.60	15.44	13.42
Average		2140.3	1772.17	13.57	11.37

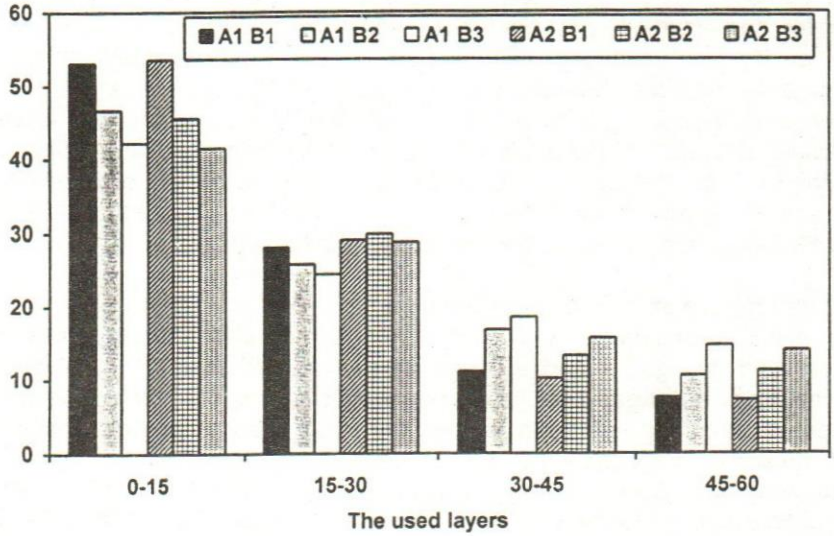
Water use efficiency:

The term water use efficiency has been widely used in irrigation crop production to describe the efficiency of irrigation with respect to crop yield. It is partially important in comparing crop production from the standpoint of water conservation and production cost. Value of crop and field water use efficiency are calculated and recorded in Table (5). Data clearly showed that the bed irrigation system treatment recorded the highest values in the two seasons. With regard to the effect of water stress on water use efficiency, results showed that the 80 % depletion of available soil moisture content (B3) achieved the highest value followed by 65% depletion of available soil moisture content (B2). While the lowest value was obtained from treatment of 50 % depletion of available soil moisture content (B1).

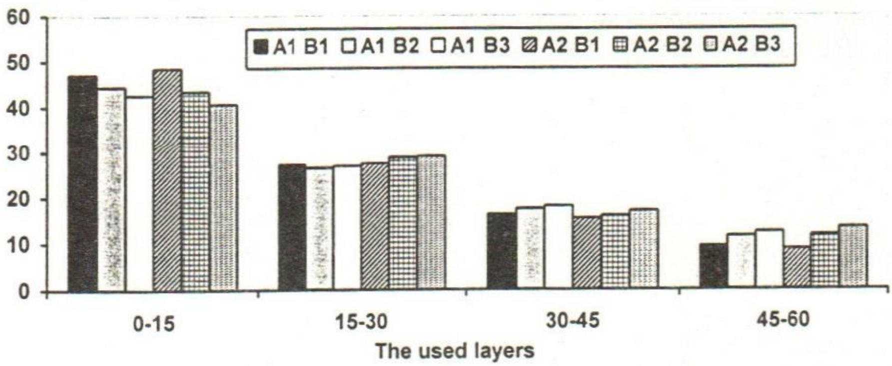
Soil moisture extraction pattern :

Data of soil moisture extraction pattern in the upper 60 cm soil depth are illustrated in figs. 3 and 4 .Data clearly showed that the most of water consumed by sugar beet was removed from the soil surface layer. The highest percentage of the moisture uptake was occurred at the surface 15 cm of the soil profile. Less water was extracted from the successive depths. Data indicated also when the soil is kept wet as adopted in 50% depletion of available soil moisture content (B1) more water is extracted from the upper 30 cm soil depth. Whereas, increasing soil moisture stress as adopted in 80% depletion of available soil moisture content (B3) plants tended to extract its water from lower depths. It can be concluded that plant roots penetrate soil profile and tend to extend for more depth under dried soil conditions to obtain their needs of water from the deeper layer. These results are in agreement with those obtained by Shams (2000).

Fig(3)Percentage of soil moisture extrated by sugar beet roots from different layres as affected by treatments in 1999-2000 season.



Fig(4)Percentage of soil moisture extracted by sugar beet roots from different layers as affected by treatments in 2000-2001 season.



Monthly water consumptive use and crop coefficient :

The average actual water consumptive use of all the treatments was calculated for each month of the growing season (Table 6). With comparing these figures to the monthly average reference evapotranspiration in the study area, the average actual crop coefficients for sugar beet were obtained. It could be noticed that crop coefficient was very low at the beginning of the growing season and then the value increased and reached its maximum in Mar, and again then declined to reach its minimum value at maturity. It can be concluded that the calculated value of 0.73 for (Kc) can be used in order to calculate the water consumptive use of sugar beet in the northern Nile Delta area by using Modified Penman equation.

Table 6: Monthly water consumptive use and sugar beet crop coefficient in two seasons.

Month	1999 – 2000			2000 – 2001		
	Average Actual water consumptive use mm/day	Reference Evapotrans-piratipn, mm/day	Crop coefficient	Average Actual water consumptive use, mm/day	Reference Evapotrans-piratipn, mm/day	Crop coefficient
Nov.	0.61	3.39	0.18	0.66	2.29	0.29
Dec.	1.35	1.71	0.79	1.33	2.05	0.65
Jan.	1.69	1.87	0.90	1.70	2.38	0.71
Feb.	2.64	2.57	1.03	2.65	3.38	0.78
Mar.	4.09	3.98	1.03	4.21	3.91	1.08
April	5.09	4.41	1.15	5.27	5.91	0.89
May	2.38	6.55	0.36	2.27	6.69	0.34
Average			0.78			0.68

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تأثير طريقة الري و الإجهاد المائي علي إنتاجيه محصول بنجر السكر و توفير المياه

محمد إبراهيم مليحة

معهد بحوث أداره المياه و طرق الري- المركز القومي لبحوث المياه

تم إجراء تجربتين حقليتين في مزرعة مدرسة كفر الشيخ الثانوية الزراعية في موسمي ١٩٩٩ – ٢٠٠٠ , ٢٠٠٠ – ٢٠٠١ م لدراسة تأثير طرق الرى وهى الرى فى خطوط ومصاطب وثلاث معاملات من الإجهاد المائي وهى (٥٠ , ٦٥ , ٨٠ %) من الماء الميسر على إنتاجية محصول بنجر السكر وتوفير وكفاءة استخدام المياه . تم استخدام تصميم القطع المنشئة مرة واحدة في أربع مكررات لهذه الدراسة .

أوضحت نتائج الدراسة أن طرق الرى لم تؤثر على إنتاجية جذور محصول بنجر السكر , بينما أثرت معاملات الإجهاد المائى بمعنوية عالية على الإنتاجية . وكذلك نفس الاتجاه تم الحصول عليه فى صفة نسبة السكروز أعلى قيم من الماء المضاف للري تم الحصول عليها مع معاملة الرى في خطوط وعند ٥٠% رطوبة , بينما كانت أقل قيمة من الماء المضاف للري تم الحصول عليها مع طريقة الرى في مصاطب وعند ٨٠% رطوبة . متوسط قيم الماء الذي تم توفيره كانت ٢٠,٠٤ , ٣٤,٩٩ % مع معاملة الرى فى مصاطب و ٨٠% رطوبة علي التوالي . وكانت متوسط الاستهلاك المائي لمحصول بنجر السكر كان ٢٠٤٤,٣٥ , ١٧٧٣,٣٦ م ٣ / فدان مع طريقتى الرى في خطوط ومصاطب على التوالى .وعلى الجانب الأخر قدر متوسط الاستهلاك المائى بـ ٢٢١٦,٥٥ , ١٩٥٢ , ١٥٥٨,٠٥ م ٣ / فدان عند ٥٠ , ٦٥ , ٨٠% رطوبة على التوالى .وكانت أعلى قيمه لكفاءة استخدام المياه عند التفاعل بين طريقتي الرى في مصاطب ٨٠% رطوبة.

امتصت جذور نبات بنجر السكر أكبر كمية من المياه من الطبقات السطحية للتربة الرطوبة وأقل كمية من الطبقات تحت السطحية في حالة وجود بينما في حالة الظروف الجافة تمتد الجذور إلى تحت التربة لتحصل على احتياجاتها من المياه من الطبقات تحت السطحية هذا و يمكن استخدام المعامل ٠,٧٨ لحساب الاستهلاك المائي لبنجر السكر فى أراضى شمال الدلتا وذلك باستعمال معادلة بنمان المعدلة .