EFFECT OF IRRIGATION INTERVALS AND NITROGEN FERTILIZATION ON THE PRODUCTIVITY OF SUGAR BEET CROP

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ABSTRACT

The present study was conducted on clay soil at Sakha Agricultural Research Station, Agricultural Research Center in 2000/2001 and 2001/2002 seasons to study the effect of three irrigation intervals (3,4 and 5 weeks) and three nitrogen fertilizer rates (90, 110 and 130 kg N/fed.) on sugar beet yield and some water relations of sugar beet, cv. Top. Split-split plot design with four replicates was used. Irrigation intervals occupied the main plots, while the nitrogen fertilizer rates were replicated in the subplots.

The results revealed that irrigation intervals of three weeks significantly produced the highest top, roots and sugar yields to be 7.72, 23.51 and 3.95 ton/fed. in 2000/2001 and 7.49, 22.57 and 3.72 ton/fed. in 2001/2002 respectively. By prolonging irrigation intervals from three to four and five weeks significantly increased root length. On the other hand, sucrose percent was not affected by irrigation intervals.

Increasing nitrogen rates from 90 kg to 110 and 130 kg N/fed. significantly increased root length, root diameter and top yield. While root yield, sucrose percent and sugar yield were not significantly affected by adding nitrogen rates in the two seasons.

Mean values of water consumptive use were 2688.3, 2188.6 and 1958.0 m^3/fed. for irrigation every three, four and five weeks, respectively.

The highest water use efficiency for root and sugar yields resulted from irrigation every five weeks to be 9.85 and 1.66 kg root, and sugar yield per m^3 of water consumed, over both seasons.

Sugar beet plants extracted about 80% of its water needs from the soil surface layer (30 cm).

INTRODUCTION

Increasing sugar production from land unite area is considered one of the important national target in Egypt to minimize sugar gab between production and consumption. Great efforts are being done to increase sugar production by proper utilization of the irrigation water and increase the efficiency of added nitrogen fertilizers. Sugar beet yield and its quality is not only depended on mineral nutrition but is also affected by environmental factors such as water. Irrigation of sugar beet every 4 weeks in Kafr El-Sheikh Governorate resulted in a significant increase of root yield in comparison with irrigation interval of 2 weeks (Khalifa and Ibrahim, 1995). The average values of water consumptive use were 2504.7, 2014.34 and 1801.16 m^3/fed. for irrigation every 3, 4 and 5 weeks. Abd El-Wahab *et al.* (1996) showed that root diameter and top yield were increased as irrigation amount increased from 1575 to 2625 m^3/fed. Ibrahim *et al.* (1993) showed that each 2-3 weeks irrigation intervals, resulted in high yields to be 20.57 ton/fed., while the yield was 18.527 ton/fed. for irrigation intervals of 4 weeks. The average water use efficiency ranged from 9.80 to 10.84 kg for sugar beet root and ranged from 1.65 to 1.97 kg for sugar yield which could be obtained from every cubic meter of water consumed (Saied, 2000).

The response of root yield and other characters of sugar beet crop to nitrogen fertilizer was detected by many workers. Eassawy (1994) found that root, top and sugar yields were significantly increased by single dose application of nitrogen at sowing or half of nitrogen at sowing and a half before the first irrigation. Sucrose content tended to be decreased by increasing nitrogen rates (Sharif and Eghbal, 1994 and Besheit *et al.*, 1995). Application of nitrogen fertilizers up to 60 kg N/fed. produced the highest root and sugar yield. While, further increase up to 90 kg N/fed. slightly reduced these yields (Edris *et al.*, 1992). Nemeat Alla (2001) indicated that increasing nitrogen rates from 90 to 140 kg N/fed. significantly increased top and root yields per fed. On the other hand, sugar percentage and sugar yield were decreased. He also found that no significant effect was detected on root length and root diameter due to nitrogen application rates.

Therefore, the aim of this investigation was to study the effect of irrigation intervals and nitrogen fertilization on sugar beet yield and its components, water consumptive use, water use efficiency and soil moisture extraction pattern.

MATERIALS AND METHODS

The investigation was conduced at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, North Delta, Egypt during 2000/2001 and 2001/2002 growing seasons to study the effect of irrigation intervals and nitrogen fertilization rate on yield, yield components and some water relation of sugar beet. The experimental design was split plot with four replications. Plot was 42 m^2 containing 10 ridges 7 meters in length and 0.6 meter in width. The soil of experimental field was clayey in texture, the partial size distribution was 48.37% clay, 24.82% silt and 26.81% sand. The average EC and pH values of soil in the saturated soil paste were 2.16 dSm^{-1} and 8.17, respectively. They were determined according to the methods described by Page *et al.* (1982).

Water table was at 120 cm depth using observation well over both growing seasons. Main plots were devoted to irrigation treatments, which were irrigated every three, four and five weeks. Sub plots were allocated to nitrogen fertilizer treatments including 90, 110 and 130 kg N/fed.

Soil moisture content was gravimetrically determined on an oven-dry basis. At each sampling date, duplicate soil moisture samples were taken to a depth of 60 cm using an auger. Field capacity, permanent wilting percentage and available soil moisture were determined. The bulk density was determined using the core method to a depth of 60 cm (Klute, 1986). The average values of field capacity percentage, permanent wilting point percentage, available soil moisture and bulk density (g/cm^3) were presented in Table (1).

The experimental field was fertilized with 100 kg/fed. calcium superphosphate (15.5 kg of P_2O_5) during soil preparation.

The nitrogen fertilizer was applied in a form of urea (46.5% N) in one dose at a rate of 90, 110 and 130 kg N/fed. Nitrogen rates were applied at thinning after 35 days from planting date.

The potassium fertilizer was applied in a form of K_2SO_4 (48% K_2O) after 35 days from planting date.

Table (1): Soil moisture constant for the experimental site in the two growing seasons.

Season	Soil depth (cm)	Field capacity (%)	Bulk density (g/cm^3)	Permanent wilting point %
2000/ 2001	0-15	46.50	1.14	25.84
	15-30	42.31	1.18	22.99
	30-45	38.67	1.23	21.02
	45-60	37.71	1.34	20.49
Mean		41.30	1.22	22.59
2001/ 2002	0-15	46.70	1.13	25.30
	15-30	41.87	1.17	22.76
	30-45	39.08	1.21	21.24
	45-60	37.21	1.36	20.22
Mean		41.22	1.22	22.38

The cultivated variety of sugar beet was cv. Top. Three seeds were sown in each hill (20 cm between hills). Seeds were sown at 10 and 15 of October in 2000/2001 and 2001/2002, respectively. Plants were thinned to one plant per hill after 35 days from planting. The sugar beet was harvested on 6 and 10 May in the two seasons. Representative samples of sugar beet plants were taken at the time of harvesting to determine root and top yields as well as sugar yield constituents such as sucrose percentage, according to Le-Docte (1927). White sugar yield ton/fed. was calculated from root yield (ton/fed.) multiplied by sucrose percentage.

Recommended cultural practices of sugar beet plants were applied.

1. Water consumptive use (WCU):

Water consumptive use was calculated using the following equation (Isrealsen and Hansen, 1962):

$$Cu = \sum_{i=1}^{n} D_i \times D_{bi} \times (\theta_2 - \theta_1)/100$$

Where:

Cu = water consumptive use (cm). in the effective root zone (60 cm).

D_i = soil layer depth (15 cm).

D_{bi} = soil bulk density (g/cm^3), of the specified soil layer.

θ_1 = soil moisture %. before irrigation.

θ_2 = soil moisture %. 24 hours after irrigation.

n = number of soil layers.

2. Water use efficiency (WUE):

Water use efficiency in kg/m^3 of water consumed by sugar beet plants was calculated as follows (Viets, 1965):

$$WUE = Y/C.U.$$

Where:

$$Y = \frac{\text{Root yield kg/fed.}}{\text{Water consumptive use m}^3}$$

$$Y = \frac{\text{White sugar yield kg/ed.}}{\text{Water consumptive use m}^3}$$

Soil moisture extraction pattern (S.M.E.P.) percentage of soil moisture extraction from a certain depth (15 cm) was calculated by the following formula:

$$S.M.E.P. = \frac{\text{Sum of extracted soil moisture from a certain depth (15 cm)}}{\text{Total sum of moisture extracted in all soil layers (60 cm)}}$$

The obtained data were statistically analysed, following the procedure outlined by Snedecor and Cochran (1980). Differences among means values ere compared using Duncan Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

I. Yield and yield components:

It is clear from data listed in Table (2) that the irrigation intervals significantly affected the root length in both seasons. Irrigation every 5 weeks increased the length to be 27.70 and 28.44 cm compared to irrigation every 3 and 4 weeks in the first and second seasons, respectively. These results showed that the roots grow longer under water deficit than excessive water status. It means that the roots are searching behind the soil water (Winter, 1980) and Abd El-Wahab *et al.* (1996).

Concerning for root diameter, irrigation intervals of 3 weeks recorded the widest root diameter to be 12.17 and 11.32 cm in the first and second seasons, respectively. These results showed a decline in root diameter by prolonging irrigation intervals from 3 to 5 weeks. Diameter of beet roots has the same trend with the availability of soil water in which has the direct effect on growth of the roots. Sorour (1995) and Attia and Sultan (1987).

Table (2): Yield and yield attributes as affected by irrigation intervals and nitrogen application rates.

Variables	Irrigation intervals			kg N/fed.			Interaction
	3 weeks	4 weeks	5 weeks	90	110	130	irrig. x N
2000/2001 season							
Root length, cm	25.53 c	27.71 b	27.70 a	25.21 c	27.67 b	28.07 a	*
Root diameter, cm	12.17 a	11.69 b	11.37 c	11.01 c	11.81 b	12.40 a	N.S
Top yield, ton/fed.	7.72 a	7.43 b	7.04 c	7.11 c	7.40 b	7.69 a	N.S
Root yield, ton/fed.	23.51 a	21.01 b	19.65 c	21.08 a	21.46 a	21.63 a	N.S
Sucrose, %	16.82 a	17.49 a	16.94 a	17.06 a	17.10 a	17.09 a	N.S
Sugar yield, t/fed.	3.95 a	3.67 b	3.33 c	3.60 a	3.67 a	3.7 a	N.S
2001/2002 season							
Root length, cm	26.31 c	27.85 b	28.44 a	26.70 c	27.78 b	28.12 a	*
Root diameter, cm	11.32 a	10.87 b	10.57 c	10.32 c	10.98 b	11.46 a	N.S
Top yield, ton/fed.	7.49 a	7.21 b	6.83 c	6.88 c	7.18 b	7.46 a	N.S
Root yield, ton/fed.	22.57 a	20.17 b	18.86 c	20.24 a	20.60 a	20.76 a	N.S
Sucrose, %	16.48 a	17.14 a	16.60 a	16.68 a	16.76 a	16.78 a	N.S
Sugar yield, t/fed.	3.72 a	3.46 b	3.13 c	3.38 a	3.45 a	3.48 a	N.S

Data in Table (2) indicated that the irrigation intervals significantly affected top and root yields in both seasons.

Sugar beet plants received irrigation every 3 weeks produced the highest top and root yields than 4 and 5 weeks. The productivity of top yield was 7.72 and 7.49 ton/fed. and the productivity of root yield was 23.51 and 22.57 ton/fed. for irrigation intervals of 3 weeks in first and second seasons, respectively.

The differences in top and root yields among irrigation intervals treatments can be largely attributed to the availability of soil water which was adequate to meet the crop water needs in the effective root zone.

The results are in agreement with those obtained by Gaber *et al.* (1986): Attia and Sultan (1987): Ibrahim *et al.* (1993) and Saied (2000).

II. Sucrose percentage and sugar yield:

No significant difference was detected in sucrose percentage among irrigation intervals treatments in both seasons.

Irrigation every 3 weeks produced the highest sugar yield in the two seasons (3.95 and 3.72 ton/fed., respectively). While the lowest sugar yield, in both seasons, was obtained from the treatment irrigated every 5 weeks. These results are agreeing with those obtained by Sharif and Eghbal (1994) and Saied (2000).

Concerning nitrogen rates, root length, root diameter and top yield were highly significantly affected by nitrogen rates. Increasing nitrogen rates from 90 to 110 and 130 kg N/fed. significantly increased root length, root diameter and top yield in both seasons. On the other hand, increasing nitrogen rates from 90 to 110 and 130 kg N/fed. did not significantly affect root yield, sucrose percentage and sugar yield in both seasons. It means that the recommended rate (90 kg N/fed.) is favourable than the higher rates of nitrogen fertilizer (110 and 130 kg N/fed.) which produced an insignificant increase in root yield. Similar results were obtained by Edris *et al.* (1992), Besheit *et al.* (1995) and Nemeat Alla (2001).

III. Interaction effects:

Data in Table (3) revealed that root length was significantly affected by the interaction between studied treatments (irrigation x nitrogen rates).

Table (3): Mean root length as affected by the interaction between irrigation intervals and nitrogen rates in both seasons.

Kg N/fed.	Irrigation intervals					
	2000/2001			20001/2002 season		
	3 weeks	4 weeks	5 weeks	3 weeks	4 weeks	5 weeks
90	24.11 1	26.88 efg	24.65 cde	25.32 h	27.45 cdef	27.33 def
110	25.68 h	28.21 bc	29.11 a	26.55 g	27.92 cd	28.88 ab
130	26.81 fg	28.05 cd	29.35 a	27.05 efg	28.18 bc	29.12 a

- The highest values of root length (29.35 cm and 29.12 cm) were obtained from (5 weeks x 130 kg N/fed.) in first and second seasons, respectively.

Water relations:

I. Water consumptive use:

Water consumptive use by sugar beet as function of irrigation treatments in both growing seasons are shown in Table (4).

Consumptive use of water was the highest at irrigation intervals of 3 weeks and it was found to be 2668.1 and 2708.4 m^3/fed. in both seasons, respectively. While the lowest values were obtained with irrigation intervals of 5 weeks in both seasons (1907.2 and 2008.7 m^3/fed., respectively).

Table (4): Water consumptive use (m^3/fed.) for sugar beet in the two seasons as affected by irrigation intervals and nitrogen rates.

	2000/2001 season	2001/2002 season	Mean
3 weeks	2668.1	2708.4	2688.3
4 weeks	2194.5	2182.6	2188.6
5 weeks	1907.2	2008.7	1958.0
Mean	2256.6	2299.9	

The most probable explanation for these findings is that more available soil moisture provided a chance for more vegetative growth and this in turn caused more luxuriant use of water, which ultimately resulted in increasing evapotranspiration. These results were supported by the data obtained by Gaber *et al.* (1986); Attia and Sultan (1987), Ibrahim *et al.* (1993) and Saied (2000).

II. Water use efficiency (WUE):

Results in Table (5) showed the water use efficiency in kg of beet and sugar per cubic meter of water consumed. The maximum values of water use efficiency for root and sugar yields were 9.85 and 1.66 kg/m^3 of water consumed, resulted from irrigation every 5 weeks, over both seasons. Similar results were reported by Brian *et al.* (1999).

Table (5): Water use efficiency for beet and sugar beet in kg/m^3 consumed water as affected by irrigation intervals and nitrogen rates in two seasons.

Season	WUE for sugar beet yield			WUE for sugar yield		
	2000/2001	2001/2002	Mean	2000/2001	2001/2002	Mean
3 weeks	8.81	8.33	8.57	1.48	1.37	1.43
4 weeks	9.57	9.24	9.41	1.67	1.59	1.63
5 weeks	10.30	9.39	9.85	1.75	1.56	1.66
Mean	9.56	8.99		1.63	1.51	

III. Soil moisture extraction pattern:

Data of mean values of soil moisture extraction percentage in the upper 60 cm of soil depth are presented in Table (6).

Table (6): Soil moisture extraction pattern by sugar beet plants as affected by irrigation intervals in both seasons.

Irrigation intervals	Depths (cm)				Average	
	0-15	15-30	30-45	45-60	0-30	30-60
2000/2001 seasons						
3 weeks	49.84	35.08	13.70	1.38	84.92	15.08
4 weeks	47.44	32.14	15.20	3.22	79.58	18.42
5 weeks	40.27	28.37	23.96	7.40	68.64	31.36
2001/2002 seasons						
3 weeks	48.99	34.37	14.79	1.85	83.36	16.64
4 weeks	46.21	30.87	19.77	3.15	77.08	22.92
5 weeks	40.67	27.22	22.95	9.16	67.89	32.11

The results showed that the most of water extracted by sugar beet was removed from the soil surface layer (0-30 cm). The highest percentage of the moisture uptake was occurred at the surface layer of 15 cm of the soil profile. The average moisture extraction percentage were similar for the different irrigation treatments. It can be concluded that, about 80% of the water extracted by sugar beet roots was obtained from the upper 30 cm soil layer and about 20% from the lower (30-60 cm) soil layer.

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تأثير فترات الرى والتسميد النيتروجينى على إنتاجية محصول بنجر السكر

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أقيمت تجربتان حقليتان بمحطة البحوث الزراعية بسخا فى موسمى ٢٠٠٠/٢٠٠١م ، ٢٠٠١/٢٠٠٢م لدراسة تأثير فترات الرى (٣ ، ٤ ، ٥ أسابيع) ومعدلات التسميد النيتروجينى (٩٠ ، ١١٠ ، ١٣٠ كجم نيتروجين للفدان) على إنتاجية محصول بنجر السكر وبعض العلاقات المائية على الصنف توب.

وقد استخدم نظام القطاعات المنشقة فى تصميم التجربة مع أربعة مكررات حيث كانت فترات الرى فى القطع الرئيسية بينما كانت معدلات التسميد النيتروجينى فى القطع المنشقة.

أوضحت النتائج أن الرى كل ٣ أسابيع أدى إلى زيادة معنوية فى إنتاجية محصول الجذور والسكر لتكون ٢٣,٥١ ، ٣,٩٥ طن للفدان فى الموسم الأول ، ٢٢,٥٧ ، ٣,٧٢ طن للفدان فى الموسم الثانى على التوالى.

كما أدى الرى كل ٤ أسابيع إلى زيادة معنوية فى محصول العرش ليكون ٧,٧٢ ، ٧,٤٩ طن للفدان للموسمين. كما أدت زيادة فترات الرى من ٣ إلى ٤ اسابيع ، ٥ أسابيع إلى زيادة معنوية فى طول الجذر بينما نسبة السكر لم تتأثر معنويا بفترات الرى.

أدت زيادة معدلات التسميد النيتروجينى من ٩٠ إلى ١١٠ ، ١٣٠كجم نيتروجين للفدان إلى زيادة فى طول الجذر وقطره وكذلك محصول العرش. بينما لم تتأثر إنتاجية الجذور والسكر ونسبة السكروز معنويا بمعدلات التسميد النيتروجينى فى الموسمين.

وقد سجلت أعلى كفاءة لإستخدام مياه الرى عند معاملة الرى كل ٥ أسابيع لإنتاج ٩,٨٥ كجم من الجذور ، ١,٦٦ كجم والسكر لكل متر مكعب من الماء المستهلك على مدى الموسمين.

استخلصت نباتات بنجر السكر حوالى ٨٠% من احتياجاتها المائية من طبقة التربة السطحية بعمق ٣٠سم.