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EFFECT OF IRRIGATION INTERVALS, FURROW IRRIGATION SYSTEM AND NITROGEN FERTILIZER LEVELS ON SUGAR BEET YIELD AND ITS WATER RELATIONS AT NORTH DELTA

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ABSTRACT

Field experiments were conducted in 1997/98 and 1998/99 growing seasons at Sakha Agric. Res. Station in a clayey non saline-non alkaline soil to study the effects of three irrigation intervals (3, 4 and 5 weeks), two furrow irrigation system (irrigating every furrow and every other furrow alternative) and two nitrogen fertilizer levels (75% and 100% of nitrogen recommended dose) on sugar beet yield and water relations. Split-split plot design with four replicates was used. Irrigation intervals occupied the main plots, while furrow irrigation systems were replaced the sub plots and the nitrogen fertilizer levels were the sub-sub plots. Results revealed that irrigation intervals of 3 weeks, alternative furrow irrigation and application of recommended nitrogen rate were the best combination for sugar beet yield, average root weight, sucrose percentage and sugar yield. The results also indicated that the irrigation intervals of 3 weeks under every furrow irrigation received the highest amount of irrigation water and consumed more water than the other treatments. Concerning the water use efficiency, data clearly showed that the irrigation intervals of 5 weeks and irrigation of every other furrow achieved the highest values of water use efficiency. While the irrigation intervals of 3 weeks and irrigation of every furrow achieved the lowest values of water use efficiency. At the same time sugar beet roots extracted about 80% of its water needs from the upper soil layer (30 cm).

INTRODUCTION

Sugar beet (*Beta vulgaris*, L.) plays a prominent role for sugar production. Recently sugar beet has attracted the attention in Egypt for sugar production. The government encourages beet growers to increase the cultivated areas as well as the raise of its productivity. This could be achieved through proper water management and optimizing the amount of nitrogen fertilizer. Tremendous efforts should be implemented to overcome the shortage of water that facing Egypt at present. Different ways to achieve the effective irrigation management; some of those are the adoption of the furrow irrigation system as well as irrigation intervals. The irrigation of alternative furrows is particularly well suited for use of limited water on fine textured soils. The technique involves applying water to every second or third furrow. Alternatively, one could simply increase the spacing of furrows. Irrigation of alternate furrows has been studied extensively in Texas, Oklahoma, California and Nebraska since 1963 (Musick and Dusek, 1974; Stone *et al.,* 1982; Grimes *et al.,* 1968 and Fischbach and Mulliner, 1972). The results of these studies reported that smaller irrigations have been achieved with alternate furrow irrigation about one third of irrigation water was saved and irrigation

time was shorten thereby requiring less labor. Also, Benjamin *et al*. (1994) and Brian *et al*. (1999) tested the alternate furrow irrigation as a good method to increase water use efficiency, increase the crop yield and decrease the chemical leaching. These studies were focussed on the role of irrigation intervals as well as its impact on the production of crops. Gaber *et al*. (1986); Attia and Sultan (1987) and Ibrahim *et al*. (1993) studied the effect of irrigation intervals on sugar beet production. They found that increasing the irrigation interval decreased significantly the root yield and the values of water consumptive use were 58.06, 55.04 and 49.86 cm for the 2, 3 and 4 weeks intervals, respectively. The response of root yield and other characters of sugar beet to nitrogen as soil fertilizer was reported by many workers. Sucrose content tended to decrease by increasing nitrogen rates (Sharif and Eghbal, 1994 and Besheit *et al.,* 1995). Several investigators have reported that root and sugar yield were the highest with 60 k N/fed. Further increase up to 90 kg N/fed slightly reduced these yields (Edris *et al.,* 1992; Sharif and Eghbal 1994 and Besheit *et al*., 1995). Therefore, the aim of this investigation was to study the effect of alternate furrow irrigation, irrigation intervals and nitrogen fertilizer levels on production of sugar beet, its consumptive use, amount of water applied, water use efficiency and soil moisture extraction pattern.

MATERIALS AND METHODS

This study was conducted at Sakha Agriculture Research Station Farm, during 1997/98 and 1998/99 seasons. The soil of the two experimental sites were clayey in texture and non saline-non alkaline soils. The experimental design was split-split plot with four replications. The main plots were devoted to three irrigation intervals, i.e. 3, 4 and 5 weeks, while the sub-plots were assigned to the irrigation methods (irrigation of every furrow and alternative furrows irrigation). The nitrogen fertilizer levels were allocated in the sub-sub plots, i.e. 75 and 100% of nitrogen recommended dose which equals 52.5 and 70 kg N/fed., respectively.

Sugar beet, variety (TOP) was obtained from the Delta Sugar Company at Kafr El-Sheikh Governorate.

Seed balls were sown by hand in hills 20 cm apart at the rate of 3-5 seed-balls per hill at the third week of October. Plants were thinned twice and the latter one was done to obtain a single plant/hill. Calcium super phosphate (15.5% P_2O_5) was applied during tillage operation at a rate of 100 kg/fed. while potassium sulphate (48% K_2O) at a rate of 50 kg/fed. was applied before the second watering.

Nitrogen fertilization in the form of urea (46% N) was applied in two equal doses before the first and second waterings.

Studied characters:

At maturity, five plants were taken at random from each plot and the following characteristics were recorded:

1. Root fresh weight (g).

2. Root yield of each plot was estimated in kilograms and converted to record root yield in ton/fed.
3. Sucrose percentage; was determined polarimetrically on lead acetate extract of fresh macerated roots according to the method described by Le-Docte (1927).

All data were statistically analyzed according to Snedecor and Cochran (1967).

Water measurements:

1. Water consumptive use: was calculated according to the following equations described by Israelsen and Hansen, (1962).

$$\text{Cu: } \sum_{i=1}^{i=n} \frac{\theta_2 - \theta_1}{100} \text{ x Bd x } \frac{60}{100} \text{ x } 4200$$

Where:

Cu : Water consumptive use (m^3/fed.).
n : Number of irrigations
θ_2 : Soil moisture content (%) after irrigation.
θ_1 ; Soil moisture content (%) before the next irrigation.
Bd : Bulk density (g/cm^3).

2. Amount of irrigation water applied was measured by cut-throat flume (20 x 90 cm) and calculated as m^3/fed. (Early, 1975).
3. Water use efficiency (W.U.E.):
Water use efficiency was calculated in kg/m^3 according to Abd El-Rasool *et al*. (1971) by the following formula:

$$\text{W.U.E.} = \frac{\text{Yield (kg / fed.)}}{\text{Water consumptive use (m}^3\text{ / fed.)}} \text{ x } 100$$

4. Soil moisture extraction patterns: The percentage of soil moisture extraction pattern was calculated according to the following formula:

$$\frac{(\theta_2 - \theta_1) \text{ for each depth}}{(\theta_2 - \theta_1) \text{ for all depths}}$$

RESULTS AND DISCUSSION

Beet yield, average of the beet root weight/plant, sucrose percentage and sugar yield of the different treatments are shown in Tables (1 and 2).

Beet yield and average of the beet root:

It is clear from data listed in Table (1) that the irrigation intervals affected significantly the beet yield and average of the beet root weight/plant in both seasons. Irrigation interval of 3 weeks gave the highest yield (23.6 and 22.47 ton/fed.) for the first and second seasons, respectively, followed by irrigation interval of 4 weeks (22.16 and 20.79 ton/fed.) for the first and second season, respectively. The lowest sugar beet yield was obtained from irrigation interval of 5 weeks (20.95 and 18.9 ton/fed.) for the first and second seasons, respectively. Concerning the effect of irrigation intervals on root weight per plant in kg, the data reveal that the average root weight took the

same trend as sugar beet yield. Meaningful, irrigation intervals of 3 weeks surpassed the other irrigation intervals in increasing the root weight per plant. The differences in yield between irrigation intervals treatments can be largely attributed to the amount of irrigation water which was enough to meet the crop water need. Moreover, prolonging irrigation interval to 5 weeks resulted in the lowest yield. These results are in agreement with those obtained by Gaber *et al*. (1986); Attia and Sultan (1987) and Ibrahim *et al*. (1993). On the other side, data in Table (1) showed that the furrow irrigation system affected significantly the beet yield and average root weight/plant during the course of study. Alternative furrow irrigation yielded more than irrigation every furrows by about 7.4 and 11.3% for the first and second season respectively. Alternative furrow irrigation surpassed all furrow irrigation in increasing the average root weight per plant in the two seasons of study. The positive effect of alternative furrow irrigation may be due to that this method which increased water use efficiency, increase yield and decreased nutrients leaching. These results are in harmony with those obtained by Benjamin *et al*. (1994) and Brian *et al*. (1999).

Table (1): Sugar beet yield in ton/fed. and weight of single root in kg for the two seasons as affected by different treatments.

Treatments	Beet yield		Average	Weight of the beet root		Average
	1st	2nd		1st	2nd	
Irrigation intervals						
21 days	23.6	22.47	23.04	1.76	1.57	1.67
28 days	22.16	20.79	21.48	1.16	1.2	1.18
35 days	20.95	18.9	19.93	0.89	0.83	0.86
F-test	*	*		*	*	
LSD 0.05	1.3	1.42		0.419	0.25	
LSD 0.01	-	-		-	-	
Furrow system						
Every furrow	21.44	19.61	20.53	1.15	1.09	1.12
Alternative furrow	23.03	21.83	22.43	1.39	1.31	1.35
F-test	*	*		*	*	
LSD 0.05	1.2	0.81		0.382	0.32	
LSD 0.01	-	-		-	-	
Nitrogen fertilizer level						
75%	22.21	20.51	21.36	1.19	1.10	1.15
100%	22.26	20.92	21.59	1.35	1.30	1.33
LSD 0.05	n.s	n.s		*	*	
LSD 0.01	-	-		0.275	0.18	
	-	-		-	-	

Concerning the nitrogen fertilizer levels, the data indicated that there was no significant effect on sugar beet yield in the two seasons. On the other hand, the nitrogen fertilizer levels affected significantly the average root yield per plant in the two seasons. The highest root weight per plant was obtained by the application of the recommended dose of nitrogen as compared to 75% of recommended dose treatment. The increment of root weight due to the recommended dose of nitrogen may be attributed to the role of nitrogen

fertilizer in improving root dimensions by increasing division or elongation of cells. Similar results were obtained by Edris *et al.* (1992) and Besheit *et al*. (1995).

Statistical analysis of data as shown in Table (1) revealed that there was no response of beet yield and root weight to the interaction among irrigation intervals, furrow system and nitrogen fertilizer levels. But it could be concluded that application of nitrogen recommended dose, irrigation each 3 weeks under alternative furrow irrigation maximized the root weight and sugar beet yield. In contrast, the application of 75% nitrogen recommended dose, irrigation each 5 weeks under irrigation all furrow recorded the lowest yields of both beet yield and root weight.

Sucrose percentage and sugar yield:

Sucrose percentage showed a slight negative response to the irrigation intervals in the two seasons of study, but sugar yield was increased significantly. Irrigation interval of 3 weeks gave the highest sugar yield in the 1st and 2nd seasons (4212.6 and 3992.92 kg/fed., respectively). While the lowest sugar yield in both seasons was recorded at irrigation intervals of 5 weeks (3796.14 and 3417.12 kg/fed., respectively).

With respect to the effect of furrow system, the results indicated that sucrose percentage was not affected significantly, but sugar yield was significantly affected in the two seasons of study. The highest values of sucrose percentage and sugar yield were achieved by alternative furrow irrigation due to increasing root yield.

Respecting to the nitrogen fertilizer levels, the sucrose percentage and sugar yield indicated that no significant effects of nitrogen fertilizer levels. The highest sugar yield (3892.7 kg/fed.) was obtained by applying the recommended dose of nitrogen level. While the lowest one (3848.1 kg/fed.) was found with applying 75% of nitrogen recommended dose.
Sharif and Eghbal (1994) confirmed this result. They stated that sugar yield was the highest with 60 kg N/fed. further increase to 90 kg N/fed. slightly reduced the yield.

Water relations:

Water consumptive use:

Water consumptive use by sugar beet plants as a function of irrigation treatments for both growing seasons are shown in Table (3). For both seasons, consumptive use of water was the highest at irrigation interval of 3 weeks and it was found to be 2546.04 and 2463.55 m^3/fed. in the 1st and 2nd seasons, respectively. While the lowest values were obtained with irrigation intervals of 5 weeks in both seasons (1872.76 and 1834.56 m^3/fed. respectively).

Concerning the furrow irrigation system, data reveal that the alternative furrow irrigation consumed water less than every furrow irrigation by about 12.6 and 14.1% for the 1st and 2nd seasons, respectively. From data obtained it is obvious that the water consumptive use increased as increasing the amount of irrigation water applied.

Table (2): Sucrose percent and sugar yield in kg/fed. for the two seasons as affected by different treatments

Treatments	% sucrose		Average	Sugar yield		Average
	1st	2nd		1st	2nd	
Irrigation intervals						
21 days	17.85	17.77	17.81	4212.6	3992.92	4102.76
28 days	18.2	18.1	18.15	4033.12	376299	3898.06
35 days	18.12	18.08	18.1	3796.14	3417.12	3606.63
F-test	n.s	n.s.		*	*	
LSD 0.05	-	-		230.0	320.0	
LSD 0.01	-	-		-	-	
Furrow system						
Every furrow	17.97	17.91	17.94	3852.77	3510.28	3681.53
Alternative furrow	18.15	18.05	18.1	4179.95	3938.45	4059.2
F-test	n.s	n.s		*	*	
LSD 0.05	-	-		198.5	266.5	
LSD 0.01	-	-		-	-	
Nitrogen fertilizer level						
75%	18.06	17.97	18.02	4010.69	3685.41	3848.05
100%	18.06	17.99	18.03	4022.03	3763.27	3892.65
F-test	n.s	n.s		n.s	n.s	
LSD 0.05	-	-		-	-	
LSD 0.01	-	-		-	-	

Table (3): Water consumptive use (m^3/fed.) for sugar beet in two seasons as affected by different treatments.

Irrigation intervals	Irrigation technique		Mean	Irrigation technique		Mean
	Every furrow	Alternative furrow		Every furrow	Alternative furrow	
	1st season			2nd season		
21 days	2740.5	2351.58	2546.04	2709.46	2217.64	2463.55
28 days	2152.92	1899.66	2026.29	2131.16	1873.62	2002.39
35 days	1984.88	1760.64	1872.76	1939.56	1729.56	1834.56
Mean	2292.77	2003.96	2148.36	2260.06	1940.27	2100.17

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) and Ibrahim *et al*. (1993).

Amount of irrigation water applied:

The total amount of irrigation water applied was measured and recorded as shown in Table (4). It could has been noticed that the irrigation interval of 3 weeks under every furrow irrigation system received the highest amount of irrigation water. While the irrigation interval of 5 weeks under

alternative furrow irrigation utilized the least amount of irrigation water in the first and second seasons.

It can be seen from data that the alternative furrow irrigation saved water by 21.85 and 19.81% in the first and second season, respectively.

Table (4): Amount of water applied (m^3/fed.) for sugar beet as affected by irrigation technique in the two seasons.

Irrigation intervals	Irrigation technique		Water saving %	Irrigation technique		Water saving %
	Every furrow	Alternative furrow		Every furrow	Alternative furrow	
	1st season			2nd season		
21 days	3942.3	2978.4	24.45	3791.48	2956.5	22.02
28 days	3224.42	2561.14	20.57	3134.13	2520.64	19.57
35 days	2965.22	2356.69	20.52	2845.33	2337.78	17.84
Mean	3377.31	2632.08	21.85	3256.98	2604.97	19.81

Water use efficiency:

Results in Table (5) show the water use efficiency in kilogram of beet and sugar per cubic meter of water consumed as influenced by different treatments throughout the two seasons of investigation.

Irrigation intervals of 5 weeks under alternative furrow irrigation achieved the highest values of water use efficiency for beet yield and sugar yield in the two seasons of study. While irrigation every 3 weeks under all furrows irrigation achieved the lowest values of water use efficiency. These results are in agreement with those obtained by Brian *et al*. (1999).

Table (5): Water use efficiency for beet and sugar yield in kg/m^3 consumed water for different treatments.

Irrigation intervals	WUE for beet yield				WUE for Sugar yield			
	Every furrow		Alternative furrow		Every furrow		Alternative furrow	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
21 days	9.68	8.34	9.96	10.03	1.55	1.48	1.78	1.78
28 days	10.05	9.52	11.94	11.36	1.83	1.73	2.17	2.06
35 days	9.52	8.79	13.06	11.99	1.73	1.59	2.370	2.17
Mean	9.75	8.88	11.65	11.13	1.7	1.6	2.11	2.0

Soil moisture extraction pattern:

Data of mean values of soil moisture extraction percentage in the upper 60 cm soil depth are presented in Tables (6 and 7). The results showed that most of water extracted by sugar beet plant 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 percentages were similar for the different irrigation treatments.

Also, data showed the highest uptake of water by sugar beet plants from the surface soil layer (0-15 cm) that constituted 50.49% was obtained with irrigation intervals of 4 weeks under all furrows irrigation technique. 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.

Table (6): Soil moisture extraction patterns by sugar beet roots as affected by irrigation technique in the first season.

Irrigation	Ever furrow			Alternative furrow		
intervals	0-15	15-30	30-60	0-15	15-30	30-60
21 days	49.27	30.61	20.12	50.16	31.72	18.12
28 days	50.49	31.56	17.95	47.81	34.26	17.93
35 days	45.4	34.11	20.49	47.4	32.99	19.61
Mean	48.39	32.09	19.52	48.46	32.99	18.55

Table (7): Soil moisture extraction patterns by sugar beet roots as affected by irrigation technique in the second season.

Irrigation	Ever furrow			Alternative furrow		
intervals	0-15	15-30	30-60	0-15	15-30	30-60
21 days	49.72	31.41	18.87	47.95	33.72	18.33
28 days	50.4	31.33	18.27	48.64	31.42	19.93
35 days	47.49	34.44	18.07	48.64	34.2	17.16
Mean	49.2	32.39	18.4	48.41	33.11	18.47

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تأثير فترات الرى ، نظم الرى بالخطوط ومعدلات التسميد النيتروجينى على محصول البنجر والعلاقات المائية بمنطقة شمال الدلتا

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أجريت تجارب حقلية فى الموسمين ١٩٩٨/١٩٩٧ ، ١٩٩٩/١٩٩٨ فى محطة البحوث الزراعية بسخا فى أرض طينية ليست ملحية أو قلوية لدراسة تأثير ثلاث فترات للرى كل ٣ ، ٤ ، ٥ أسابيع ، نظامين للرى بالخطوط وهما رى كل الخطوط ، ورى خط وترك خط (نظام تبادلى) ومعدلين من التسميد النيتروجينى ٧٥% ، ١٠٠% من المعدل الموصى به فى محصول بنجر السكر على العلاقات المائية. إستخدم تصميم القطع المنشقة مرتين مع أربعة مكررات حيث مثلت فترات الرى القطع الرئيسية بينما مثلت نظم الرى فى الخطوط القطع الشقية الأولى وكانت معدلات التسميد النيتروجينى هى القطع الشقية الثانية.

وتشير النتائج أن الرى كل ٣ اسابيع تحت ظروف الرى التبادلى فى الخطوط وإضافة المعدل النيتروجينى الموصى به أعطى أعلى محصول لبنجرالسكر ، متوسط وزن الجذر لكل نبات ونسبة السكر ومحصول السكر.

كما أظهرت النتائج أن معاملة الرى كل ٣ أسابيع فى نظام رى كل الخطوط قد إستقبلت أعلى كمية من مياة الرى المضافة وقد سلكت هذه المعاملات نفس الإتجاه مع كمية المياه المستهلكة وتدل النتائج أيضا أن المعاملات التى رويت كل ٥ أسابيع فى النظام التبادلى للخطوط قد حققت أعلى القيم لكفاءة إستخدام المياه بينما الرى كل ٣ أسابيع تحت نظام رى كل الخطوط قد أعطت اقل القيم لكفاءة إستخدام مياة الرى كما إستخلصت جذور نبات بنجر السكر من الطبقة العليا بعمق ٣٠سم حوالى ٨٠% من الرطوبة الأرضية الميسرة.