MAXIMIZING SUGAR BEET YIELD, QUALITY AND WATER USE EFFICIENCY USING SOME AGRICULTURAL PRACTICES UNDER NORTH SINAI CONDITIONS

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ABSTRACT

Two field experiments in two successive seasons of 2006/2007 and 2007/2008 were conducted in the Experimental Farm of Environmental Agricultural Sciences Faculty, El-Arish, Suez Canal University, North Sinai Governorate. This study focuses on the effect of three irrigation intervals (every 5, 8 and 11 days), three plant densities (20, 28 and 46 thousand plants fed^{-1}, which resulted from three hill spacings namely 35, 25 and 20 cm, respectively) and four nitrogen fertilizer rates (60, 80, 100 and 120 kg N fed^{-1}) on growth, yield, juice quality and water relationships of multigerm sugar beet cultivar Farida. Soil texture was sandy clay with pH 7.44. Drip irrigation system with an average of 4100 ppm water salinity was used. The experimental unit area was 18 m^2 (6 rows; 60 cm width x 5 m length) and the sowing dates were 20th & 25th Oct. in the two respective seasons. Results showed that increasing irrigation intervals from 5 to 11 days sharply reduced top fresh weight and consumptive use, while, irrigation every 8 days was superior in root and sugar yields as well as water use efficiency (wu) in both seasons. However, 11- day treatment gave the highest sucrose percentage in both seasons and maximum purity percentage in the first season only. There were insignificant effects of plant density on juice purity, but the highest plant density (46 000 plants fed^{-1}) gave the maximum root fresh weight and sugar yield as well as WUE (kg sugar m^{-3} water) as compared with the lowest densities. Increasing nitrogen fertilizer rates from 60 up to 120 kg N fed^{-1} substantialy improved most of the studied growth criteria and root yield as well as WUE. Meanwhile, adding 100 kg N fed^{-1} gave the optimum sugar yield and CU. The highest sucrose and purity percentage were gained with the lowest nitrogen fertilizer rate (60 kg N fed^{-1}).

Irrigating sugar beet every 8 days with plant density of 46,000 plant/ fed and applying nitrogen fertilizer at the rate of 100 kg N fed^{-1} could be recommended for maximum root and sugar yields as well as the most effective use of irrigation water under newly reclaimed soils of North Sinai Governorate.

Key words: consumptive use (CU) and juice quality , growth criteria , irrigation intervals , nitrogen fertilizer rates , plant density, root and sugar yields,Sugar beet, water use efficiency (WUE).

1. INTRODUCTION

Sugar beet has got importance as a source for sugar production in Egypt. It has been introduced to minimize the gap between sugar production and its consumption. Suagr beet is a vital crop as a source of high energy and as an important source of feed for livstock. It is a winter crop tolerates poor and saline soil. Therefore, it could be economically grown in the newly reclaimed areas with sandy soils as in North Sinai region and enhances soil conditions for the benefit of the following crops. So, reclaiming poor and saline sandy soil and producing sugar out of it, is considered a target for minimizing the shortage of sugar production. Under newly reclaimed sandy soil conditions, improvement of sugar beet production can be achieved through standardization of irrigation interval, plant density and nitrogen fertilizer rate.

Sugar beet could be efficiently grown under a wide range of irrigation levels, where it is readily adapted to limited irrigation because plants utilize deep stored soil water and recover quickly following water stress (Winter, 1980).

Dunham (1993) showed that sugar beet is adversely affected by waterlogging. Meanwhile, he concluded that there are two reasons for the slowing of leaves enlargement and the storage process in roots as stress develop : lower turgor potential resulting in slower cell expansion and smaller stomatal conductance resulting in less carbon dioxide uptake for dry matter production. Increasing soil moisture depletion from 40 to 80 % decreased sharply root yield from 32.16 to 16.81 ton fed[-1] and root weight from 804 to 453 g/plant (Sorour, 1995). The maximum values of water use efficiency either as root or sugar per m^3 water were recorded when sugar beet plants were irrigated when soil moisture reached 60 % (Besheit *et al.,*1996) and 65 % field capacity (Mohamed *et al.,* 2000). , Khater (1999) stated that sucrose percentage of sugar beet roots increased with increasing irrigation intervals. On the other hand, irrigation intervals had no significant effect on sucrose percentage (Azzazy, 1998). Also, Shams EL- Din (2000) indicated that soil moisture depth of 30 cm produced the highest sugar beet yield, meanwhile, sucrose percentage and sugar yield was not siginficantly affected by different levels of water applied. Otherwise, Fabeiro *et al.* (2003) reported that maximum water use efficiency (170.55 kg root/ha/mm) was gained from the lowest volume of received water (6500 m^3/ha). However, EL-Maghraby *et al.* (2008) recorded that irrigation every 4 weeks gave the highest root and sugar yields as well as juice purity percentage when compraed with irrigation every 6 and/or 8 weeks. They added that significant increases were found in total soluble solids and sucrose percentages by increasing irrigation intervals up to 6 weeks. Thus, improvement of sugar beet production and quality can be achieved through optimizing irrigation intervals.

Since light interception by the crop canopy is an important factor for photosynthesis, the plant density in the field plays a determinate role in dry matter production, thus affecting crop yield. In this concern, increasing hill spacings from 15 to 20 or 25 cm increased significantly roots, tops and sugar yields (ton/fed) but no significant effect was found on sucrose and purity percentages (Yousif, 2001 and EL-sayed, 2006). On the other hand, Taleghani *et al.* (2004) in Iran, indicated that the highest sugar yield (8.17 ton/ha) and lowest water consumption (12000 m^3/ha) were obtained with row spacing of 50 x 40 cm as compared with 60 x 40 cm treatment under surface irrigation system.

However, under Alexandria conditions, the lowest plant density (20,000 plants/fed) produced the highest root yield per feddan, total soluble solids percentage and the lowest sugar yield as compared with the highest plant density (46,000 plants/fed) (EL-Maghraby *et al.*, 2008). They added that no significant effect of plant densities on sucrose and purity percentages. Therefore, planting sugar beet on suitable plant density according to environmental conditions of the region is helpful in maximizing sugar beet yield and quality.

Fertilization is among the vital factors affecting growth, yield and quality of sugar beet especially nitrogen. Over the past 20 years, progress was made towards optimizing the use of nitrogen through better understanding of crop requirement under varying conditoins of soil and climate. This is because of nitrogen pronounced effect on growth and physiological processes of sugar beet. Also, nitrogen is referred as a balance wheel of sugar beet nutrition due to the fact that the efficiency of other nutrients is based on it. As the newly reclaimed sandy soils are poor and suffered from low content of nitrogen, therfore, yields were drastically reduced. In this respect, increasing nitrogen rates from 90 to 120 kg n/fed. improved root and top weight per plant as well as root and sugar yields (EL-Kassed *et al.*, 1993; EL-Maghraby *et al.,*1998; Basha, 1999; Ouda *et al.*, 1999; and EL-Shafai, 2000). Also, nitrogen improves accumulating and translocating dry matter from tops to roots, so, determining water use efficiency (WUE) will reflect the optimum benefit of every meter of water and scarce water especially in new reclaimed soils. In this concern, Koszanski and Roy (1995) in Poland, found that increasing nitrogen rate from 0 to 180 kg N fed[-1] increased WUE. However, EL-Zayat (2000) reported that WUE increased from 11.81 to 12.83 kg root/m^3 when nitrogen rate increased from 70 to 90 kg N fed[-1]. Also, the highest values of yield components, root and sugar yields were obtained with increasing nitrogen rates up to 100 kg N/fed. (Ibrahim *et al.,*2005); 125 kg N/fed. (EL-Geddawy *et al.,* 2006); 120 kg N/fed. (EL-Geddawy *et al.,* 2008) and 150 kg N/fed. (Seadh, 2008).

Therefore, this study was undertaken to find out the optimal irrigation interval with suitable plant density and nitrogen fertilizer rate to achieve the best productivity and quality of sugar beet under sandy soil conditions of the

newly reclaimed area in North Sinai Governorate.

2. MATERIALS AND METHODS

Two field experiments were carried out at the Experimental Farm of Faculty of Environmental Agricultural Sciences, El-Arish, Suez Canal University, North Sinai Governorate in the two successive growing winter seasons of 2006/2008 in order to study the effect of three irrigation intervals (every 5, 8 and 11 days), three planting densities (20, 28, and 46 thousand plants fed^{-1}, which resulted from three hill spacings namely 35, 25 and 15 cm, respectively) and four nitrogen fertilizer rates (60, 80, 100 and 120 kg N fed^{-1}) on growth, yield and quality of multigerm sugar beet cultivar Farida. Sowing took place on the 20th and 25th of October in the two respective seasons. Drip irrigation system was used with water salinity ranged between 3500 and 4600 ppm. Irrigation was carried out every two days through the first month then the three studied intervals for 2 hours/irrigation were applied till 15 days before harvest. The mechanical and chemical analysis of the soil at the experimental site is presented in Table 1.

Each experiment included 36 treatments distributed in a split-split plot design with four replications. Irrigation intervals occupied the main plots, while, the sub plots were assigned randomly for three plant densities and the nitrogen fertilzer rates were arranged in the sub-sub plots. The experimental unit area was 18 m^2 (6 rows with 60 cm width and 5 m length). The outer two rows were considered as band. The central rows were kept to determine growth, yield and quality. The expermintal field was prepared through ploughing and calcium super phosphate (15.5% P$_2$O$_5$) was applied at the rate of 100 kg fed^{-1}. Potassium sulphate (48% K$_2$O) was added at the rate of 50 kg fed^{-1} after thining. Nitrogen fertilizer rates were applied in the form of ammonium nitrate (33.5% N) at the fourth studied rates by side dressing in two equal doses the 1st dose after thinning and the 2nd one 20 days later. Plants were thinned at the age of 35 days from planting to obtain one plant/hill. Plants were kept free from weeds, which were manually controlled by hand hoeing three times. The commen agricultural practices for growing sugar beet were followed according to the recommendations of Ministry of Agriculture and Land Reclamation, Egypt.

2.1. Data collected :

At harvest, *i.e.,* 200 days from planting ten guarded plants were chosen randomly from the inner rows of each sub-sub plot to determine the following characters:

2.1.1. Yield attributes
2.1.1.1. Top fresh weight (kg/plant)
2.1.1.2. Root fresh weight (kg/plant)

2.1.2. Juice quality:
2.1.2.1. Total soluble solides (TSS %) of fresh roots was determined by using hand refractometer.
2.1.2.2. Sucrose percentage was determined by using Sacharometer according to the method described by Carruthers and Oldfield (1960).
2.1.2.3. Juice purity percentage was determined as by multiplying sucrose percentage x 100 then divided on TSS percentage

2.1.3. Root and sugar yields
2.1.3.1. Root yield (ton fed^{-1}): yield as kg per plot was determined and then converted to ton per feddan
2.1.3.2. Sugar yield (ton fed^{-1}) : root yield (ton/fed) was multiplying by sucrose percentage to determined sugar yield (ton/fed).

2.1.4. Crop-water relationship
2.1.4.1. Soil samples were taken immediately before irrigation and 24 hours later and oven dried at 105° C to calculate water consumptive use (WCU) of sugar beet as mm depth according to the following equation of Israelsen and Hansen (1962) :

$$CU = [(Q2 – Q1)/100] \times D \times Db$$

Where:

CU = water consumptive use in mm

Q2 = Soil moisture percent after irrigation by weight.

Q1 = Soil moisture percent before irrigation by weight.

D = Root depth in mm

Db = Bulk density in g/cm^3

Water consumptive use (CU) of sugar beet as m^3 fed^{-1} was calculated as follows :

$$CU (m^3 fed^{-1}) = CU (mm) \times 4.2$$

2.1.4.2. Water use efficiency (WUE) was calculated as kg roots or sugar per m^3 of water consumed according to Vites (1965).

2.2. Statistical analysis:

Data collected were subjected to the proper statistical analysis of variance of split-split plot design according to the procedures outlined by Snedecor and Cochran (1990). The mean values

Table (1): Mechanical and chemical analyese of the soil for the experimental site

Mechanical analysis (%)		Chemical analysis (mg L^{-1}) (1:5)					
		Parameters		Soluble Cations		Soluble Anions	
Sand (%)	73	Organic matter (%)	0.62	Ca^{++}	5.3	H CO3^{-1}	6.2
Silt (%)	21	Ca CO3 (%)	6.11	Mg^{++}	3.2	CL^{-}	15.11
Clay (%)	6	pH (1:2:5)	7.32	K^{+}	0.21	SO4^{--}	1.84
Texture	Sandy loam	EC (m mhos/cm 1:5)	6.56	Na^{+}	14.8		

Table (2): Some yield attributes of sugar beet as affected by irrigation intervals in 2006/2007 and 2007/2008 seasons

Irrigation intervals (day)	Top fresh weight (kg/plant)		Root fresh weight (kg/plant)	
Season	2006/2007	2007/2008	2006/2007	2007/2008
5	0.633 a	1.064 a	0.920 b	1.212b
8	0.592 b	0.863bc	1.211 a	1.406a
11	0.515 c	0.707 c	0.823 c	1.033c
F-test	**	*	**	**

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means with the same letters are not significantly different at 5 % level.

Table (3): Some yield attributes of sugar beet as affected by plant densities in 2006/2007 and 2007/2008 seasons

Plant densities (1000plantsfed^{-1})	Top fresh weight (kg/plant)		Root fresh weight (kg/plant)	
season	2006/2007	2007/2008	2006/2007	2007/2008
46	0.513 c	0.510 c	0.885 b	0.886 b
28	0.586 b	0.570 b	1.225 a	1.461 a
20	0.642 a	0.662 a	0.833 c	0.813 c
F-test	**	**	**	**

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means with the same letters are not significantly different at 5 % level.

Table (4): Some yield attributes of sugar beet as affected by Nitrogen fertilizer rates in 2006/2007 and 2007/2008 seasons

N-fertililizer rates (kgN fed^{-1})	Top fresh weight (kg/plant)		Root fresh weight (kg/plant)	
Season	2006/2007	2007/2008	2006/2007	2007/2008
60	0.301 d	0.286 d	0.772 d	0.752 d
80	0.345 c	0.341 c	0.789 c	0.770 c
100	0.432 b	0.435 b	0.832 b	0.855 b
120	0.552 a	0.583 a	0.853 a	0.869 a
F-test	**	**	**	**

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means with the same letters are not significantly different at 5 % level.

were compared using Duncan's multiple range test according to Duncan (1990). All statistical analysis were performed by using analysis of variance techneque of (MSTAT) Computer software package.

3. RESULTS AND DISCUSSION
3.1. Yield attributes:
3.1.1. Effect of irrigation intervals:

Response of sugar beet yield attributes to different irrigation intervals is shown in Table 2. Remarkable reduction was obtained in top fresh weight per plant in both seasons in response to increasing irrigation intervals. These increases amounted to 6.93 and 22.91 % in 2006/2007 season for 5-day treatment as compared with 8 and 11-day was, respectively. Similar trend was observed in the 2007/2008 season, where, the highest top fresh weight (1.064 kg/plant) was optained when plants irrigated every 5 days. The superiority of root fresh weights (1.211 and 1.406 kg/plant) were achieved with 8- days interval in the 1st and 2nd seasons, respectively. The increase in root elongation may be attributed to the increase of abscisic acid concentration in root which clearly promotes elongation under drought conditions and is reflected on dry matter accumulation. Similar results were obtained by Sorour, (1995); Besheit *et al.* (1996); Mohamed *et al.* (2000) and El-Maghraby, *et al.* (2008).

3.1.2. Effect of plant densities:

Data illustrated in Table 3 reveal that there was highly significant effect of plant densities on top and root fresh weights per plant in both seasons. The lowest plant density (20,000 plants fed^{-1}) resulted in the heaviest top fresh weight (0.642 and 0.662 kg/plant) in 2006/2007 and 2007/2008 seasons, respectively. However, moderate plant density (28,000 plants/fed) gave the maximum root fresh weight (1.225 and 1.461 kg plant^{-1}) in the two respective seasons. These results may refer to the low competition between the plants for light and nutrients under low plant densities. Similar trend was found by Yousif (2001) and Taleghani *et al.* (2004).

3.1.3. Effect of nitrogen fertilizer rates:

Results in Table 4 show a highly significant effect of nitrogen fertilizer rates on yield attributes in both seasons. Increasing nitrogen rates from 60 to 120 kg N fed^{-1} increased top fresh weight by 83.3 % in the first season and was duplicated in the second season. The same trend was found for root fresh weight, where, it increased from 0.772 and 0.752 kg/plant up to 0.853 and 0.869 kg /plant in the two respective

seasons. The differences between 100 and 120 kg N fed^{-1} on top and root fresh weight were not significant. This means that the response of sugar beet to the highest nitrogen rates (120 kg N fed^{-1}) is not economic. These results may refer to the role of nitrogen in encouraging plant uptake of the other elements and activate accumulation of carbohydrates, which are translated from leaves to developing roots, which in turn enhanced root length, diameter as well as root fresh weight per individual plant. Similar results are in coincidence with those stated by Ibrahim *et al.* (2005) and EL-Geddawy *et al.* (2008).

3.2. Juice quality

Data of juice parameters, which reflected its quality, namely Total Soluble Solids (TSS), Sucrose and purity percentages are presented in Table (5) in response to irrigation intervals, plant densities, nitrogen fertilizer rates.

3.2.1. Effect of irrigation intervals

There were significant effects of irrigation intervals on juice quality parameters in both seasons except total soluble solids (TSS) in the 1st season and purity percentage in the second season (Table 5). Irrigation intervals affected significantly at 5 % the level on TSS, where, increasing irrigation intervals from 5 to 11 days increased TSS from 18.82 to 21.33 in the 2nd season. Sucrose percentage appreciably increased corresponding to the reduction in soil moisture level. Where, the highest sucrose percentages (16.28 and 15.33 %) were obtained when sugar beet plants were irrigated every 11 days, meanwhile the lowest values (14.96 and 13.83 %) were recorded with 5-day interval in the 1st and 2nd, respectively. In concern to purity percentage, analysis of variance showed significant response at P< 0.01 to irrigation intervals in the first season only. Where, inreasing irrigation intervals from 5 to 11 days increased purity from 78.96 to 82.85 %.

3.2.2. Effect of plant densities:

Plant density had significant effect at P<0.05 on TSS in the 2nd season and sucrose percentage in the 1st season (Table 6). Moderate plant density (28,000 plants/fed.) gave the highest TSS (20.11 %). However, decreasing plant density from 46,000 to 20,000 plant fed^{-1} decreased sucrose percentage from 18.86 to 18.30 % in the first season. These reductions were by 0.58 and 2.06 % for the highest plant density as compared with the lower densities (28,000 and 20,000 plant/fed., respectively). The

Table (5): Some juice quality parameters of sugar beet as affected by irrigation intervals in 2006/2007 and 2007/2008 seasons

Parameters	TSS %		Sucrose		Juice purity %	
Intervals Irrigation (day)	2006/07	2007/08	2006/07	2007/08	2006/07	2007/08
5	18.78	18.82 c	14.96 c	13.83 c	78.96 c	73.38
8	19.50	20.23b	15.82 b	14.85 b	81.10 b	73.41
11	19.63	21.33 a	16.28 a	15.33 a	82.85 a	71.63
F-test	ns	*	**	**	**	ns

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means have the same letters

Table (6):Some juice quality parameters of sugar beet as affected by plant densities in 2006/2007 and 2007/2008 seasons.

Trait	TSS %		Sucrose percentage %		Juice purity %	
Plant densities (1000 plants/fed.)	2006/07	2007/08	2006/07	2007/08	2006/07	2007/08
46	20.05	19.82 b	18.86 a	19.07	93.96	96.15
28	20.46	20.11 a	18.75 b	18.88	91.77	93.84
20	20.15	19.02 b	18.30 c	19.01	90.76	94.34
F-test	ns	*	*	ns	ns	ns

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means have the same letters are not significantly different at 5 % level.

Table (7): Some juice quality parameters of sugar beet as affected by nitrogen fertilizer rates in 2006/2007 and 2007/2008 seasons:

Parameters	TSS %		Sucrose percentage %		Juice purity %	
Nitrogen fertilizer rates (N kg fed[-1])	2006/07	2007/08	2006/07	2007/08	2006/07	2007/08
60	19.41 d	20.33 d	18.09 a	18.22 a	93.16 a	85.36 a
80	20.22 c	21.41 c	17.25 c	17.80 bc	85.23 b	83.03 b
100	22.01 b	23.32 b	17.84 bc	17.29 c	80.93 c	74.05 c
120	25.35 a	25.50 a	16.30 d	16.75 d	64.30 d	65.66 d
F-test	*	*	**	**	**	**

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means have the same letters are not significantly different at 5 % level.

Table (8): Averages of root and sugar yields of sugar beet as affected by irrigation intervals in 2006/2007 and 2007/2008 seasons

Yield	Root yield (ton fed[-1])		Sugar yield (ton fed[-1])	
Irrigation intervals (day)	2006/2007	2007/2008	2006/2007	2007/0208
5	32.21a	33.62 a	4.81 a	4.65b
8	29.85 b	32.45 a	4.73 b	4.82 a
11	24.36 c	26.01 c	3.96 c	3.92 c
F-test	**	*	**	**

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means have the same letters are not significantly different at 5 % level.

Table (9): Averages of root and sugar yields of sugar beet as affected by plant densities in 2006/2007 and 2007/2008 seasons

Yield	Root yield (ton fed[-1])		Sugar yield (ton fed[-1])	
Plant densities (1000 plants/fed.)	2006/2007	2007/2008	2006/2007	2007/2008
46	35.98 a	35.14 ab	6.73 a	6.71 a
28	30.88 b	35.47 a	5.76 b	6.64 b
20	15.16 c	15.18 c	2.78 c	2.82 c
F-test	**	**	**	**

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means with the same letters are not significantly different at 5 % level.

reduction in sucrose percentage may refer to that widenenig plant spacing may increase root weight and there is a negative correlation between root weight and its sucrose content.

3.2.3. Effect of nitrogen fertilizer rates:

A significant response at P≤ 0.05 of total solube solids (TSS) percentage to nitrogen fertilizer rates was observed in both seasons (Table 7). Where, increasing nitrogen fertilizer rates from 60 up to 120 kg N fed^{-1} increased TSS percentage from 19.41 and 20.33 % up to 25.35 and 25.50 % in the 1st and 2nd seasons, respectively. However, increasing nitrogen fertilizer rates depressed root sucrose percentage in both seasons Table (7). The highest sucrose percentages (18.09 and 18.22 %) were achieved when sugar beet was fertilized at the rate of 60 kg N fed^{-1} in 2006/2007 and 2007/2008 seasons, respectively. This decrease in root sucrose content in response to increasing nitrogen fertilizer rates may be due to excessive amounts of nitrogen which stimulate beet plants to transfer more photosynthates to the top and resulted in a decrease in root content of sucrose. In other words, this reduction in root sucrose percentage as a result of applying nitrogen fertilization is due to nitrogen role in increasing root dimensions and tissue water content as well as non-sucrose substances such as proteins and alpha amino acids, hence decreasing root sucrose content.

In contrast, applying 60 kg N fed^{-1} gave the highest purity percentages (93.16 and 91.85 %) in the two respective seasons, followed by 80 kg N fed^{-1} treatment. It could be concluded that increasing nitrogen fertilizer rates tended to reduce purity percentage. The drop in juice purity of sugar beet in response to nitrogen fertilization may be due to the increases of amino compound concentrations caused by excessive uptake of nitrate late in the season.

In this concern, Follet (1991) found that the increases in cation concentrations are associated with the decreases in the sucrose percentage, associated with an increase in water content (low dry content) in fresh sugar beet roots and caused dillution in sucrose cocentration. However, the non-sucrose constituents that decrease sucrose crystallization may include carbonate, chloride, amino acids, betaine, glutamic acid and sulphate. Therefore, not only sucrose percentage but also juice purity are expected to increase as the sum of cations decrease.

3.3. Root and sugar yields

3.3.1. Effect of irrigation intervals

Data presented in Table (8) show that root and sugar yields were significantly affected by irrigation intervals in both seasons. Increasing soil moisture stress (irrigation every 11 days) reduced sharply root yield (24.46 ton fed^{-1}) as compared with non– stressed plants (irrigation every 5 days; 32.21 ton fed^{-1}) in the first season. This was true in the second season, where, 5-day treatment increased root yield by 3.6 and 29.3 % as compared by 8 and 11-day treatment were produced by irrigating sugar beet plants every 5 days in both respective seasons. However, 5 and 11 - day treatments resulted in a significant reduction in root yield and they were by 4.5, respectively. Also, the highest sugar yields (4.81 and 4.82 ton fed^{-1}) were reported with irrigation every 5 days in the 1st and 8 days in 2nd season, respectively. Irrigation at close intervals might help in solublization and absorption of mineral nutrients from the soil to plant system which led to increase in total dry weight per plant and resulted in heavier root and sugar yield. These results are in accordance with those reported by Dunham (1993); Sorour, (1995); Besheit, *et al.* (1996) and EL-Maghraby *et al.* (2008).

3.3.2. Effect of plant densities:

Analysis of variance showed that plant densities had highly significant effects on sugar beet yield in both seasons (Table 9). Decreasing plant densities from 46,000 plant fed^{-1} to 20,000 plant fed^{-1} decreased root yield from 35.98 to 15.16 ton fed^{-1} in the first season. Moderate plant density (28,000 plants fed-1) gave the maximum root yield (35.47 ton fed^{-1}) in the 2nd season. However, decreasing plant density from 46 to 20 thousands plants/fed -1 decreased sugar yield from 6.73 and 6.71 to 2.78 and 2.82 ton fed^{-1} in the two respective seasons. These results may refer to the increasing of plants number per unit area which resulted in more yield of roots and sugar. These results are in the same line of those obtained by Yousif (2001) and EL-Maghraby *et al.* (2008).

3.3.3. Effect of nitrogen fertilizer rates:

Increasing nitrogen fertilizer rates increased significantly and gradually root yield in both seasons and sugar yield in the second season (Table 10). Application of 120 kg N fed^{-1} produced the heaviest root yield (33.15 and 35.22 ton fed^{-1}) in both respective seasons. The opposite trend was found for sugar yield in the second season, where, the highest nitrogen rate (120 kg N fed^{-1}) increased sugar yield by 21.2, 14.1 and 0.37 % as compared with the lowest rates (60, 80 and 100 kg N fed^{-1}, respectively).

The difference between 100 and 120 kg N fed^{-1} was not significant, so adding nitrogen fertilizer more than 100 kg N fed^{-1} will not be econmoic for maximizing sugar beet productivity. The increases in root yield as a result of increasing nitrogen fertilizer rates may be due to the importance of nitrogen as one of the macro-nutrient elements for plant nutrition and its role in increasing vegetative growth through enhancing leaf initiation, increment chlorophyll concetration in leaves which resulted in improving photosynthesis process. Moreover, the role of nitrogen in accumulating carbohydrates, translocated from leaves to roots which in turn enhanced root fresh weight (Table 2) and finally root and sugar yields per unit area. These results are in full agreement with those obtained by El-Kassed *et al.* (1993); El-Geddawy *et al.* (2006) and Seadh (2008).

3.4. Water relationships

Sugar beet water relationships responded significantly to all the studied factors and insignificantly to any of the possible interactions (Table 11). This may be due to the individual effect of each factor.

3.4.1. Effect of irrigation intervals

Irrigation intervals affected significantly all the studied water relations except water use efficiency of sugar yield in the second season. Increasing irrigation intervals from 5 to 11 days decreased significantly and sharply water consumptive use (CU) from 3279 and 3511 to 2123 and 2311 m^3 fed^{-1} in 1st and 2nd seasons, respectively (Table 11). However, the maximum values of water use efficiency (WUE) calculated either as root in both seasons or sugar in the first season per cubic meter of water were recorded when sugar beet plants irrigated every 8 days in both growing seasons. This result is mainly due to higher root snd sugar yields produced with this irrigation interval treatment (Table, 8). Meanwhile, it could be noticed that the lowest values of WUE (kg roots and/or kg sugar/m^3 water) were obtained by irrigation every 5-days interval in both seasons. These results could be attributed to higher water consumptive use amounted 3279 and 3511 m^3 fed^{-1} in the 1st and 2nd seasons, respectively. These results are in full agreement with those reported by Mohamed, *et al.* (2000) and Fabeiro *et al.* (2003).

3.4.2. Effect of plant density

The obtained results showed that CU values were slightly higher (2454 and 2480 m^3 fed^{-1}) when beet was cultivated at plant density of 20,000 plants fed^{-1} than those recorded by the other higher plant densities. Where, these increases were by 1.4 and 0.95 % in 1st season and by 1.97 and 0.57 % in 2nd season as compared with 46,000 and 28,000 plants fed^{-1}, respectively (Table12). This result may refer to less competition between plants at lowest plant density for absorbing water and nutrients as compared with the other studied plant denities. Concerning to WUE, the highest plant density (46,000 plants fed^{-1}) generally attained higher values of WUE (kg roots and sugar/ m^3) compared with the other lowest densities in both seasons. This result is due to higher root and sugar yields (Table 9) and lower water consumptive use with the highest plant density compared with the other lowest plant densities. Similar trend was obtained by Taleghani *et al.* (2004) under different environments.

3.4.3. Effect of nitrogen fertilizer rates

Nitrogen fertilizer rates affected significantly the consumptive use (CU) and water use efficiency (WUE) calculated either as kg root/m^3 in both seasons or kg sugar/m^3 in the second season only (Table 13). Applying 100 kg N fed^{-1} gave the maximum values of CU (3280 and 3312 m^3 fed^{-1}). These superiorities were by 4.88 and 3.18 % in 2006/2007 season and by 16.21 and 3.47 % in 2007/2008 season as compared with the two lower respective rates. However, the differences between applying 100 or 120 kg N fed^{-1} had insignificant reduction (by 2.13 and 0.94 %) in both seasons, respectively; so, more nitrogen fertilizer rates will not be economical. Also, the ability of sugar beet to use irrigation water more efficiently was achieved when the plants were fertilized at the rate of 120 kg N fed^{-1} (Table 13). This may be due to the highest root yield which was obtained with the highest nitrogen rate (Table10). However, statistical analysis showed that there was no significant effect of nitrogen fertilizer rates on WUE (kg sugar/m^3 water) in the first season. This mainly refers to the non-significant differences of sugar yield in response to different nitrogen fertilizer rates in the 1st season (Table 10). However, the maximum value of WUE (1.92 kg sugar/m^3 water) was obtained with the highest nitrogen fertilizer rate (120 kg N fed^{-1}). Similar results were recorded by Koszanski and Roy (1995) and El-Zayat (2000).

3.5. Effect of interactions

Statistical analysis showed that there were no significant effects of all first and second order interactions for the studied parmeters in both seasons except the interaction of irrigation

Table (10): Averages of root and sugar yields of sugar beet as affected by Nitrogen fertilizer rates in 2006/2007 and 2007/2008 seasons

Yield	Root yield (ton fed[-1])		Sugar yield (ton fed[-1])	
Nitrogen rate (N kg fed[-1])	2006/2007	2007/2008	2006/2007	2007/2008
60	24.82 d	26.62 d	4.48 d	4.86
80	27.65 c	29.13 c	4.76 c	5.19
100	30.33 b	32.66 b	5.41 ab	5.65
120	33.15 a	35.22 a	5.43 a	5.91
F-test	**	**	*	ns

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means with the same letters are not significantly different at 5 % level.

Table (11): Some water relationships of sugar beet as affected by irrigation intervals in 2006/2007 and 2007/2008 seasons

Water relatioships	CU (m^3 fed[-1])		WUE (kg root m^{-3} water)		WUE (kg sugar m^{-3} water)	
Irrigation intervals (day)	2006/2007	2007/2008	2006/2007	2007/2008	2006/2007	2007/2008
5	3279 a	3511 a	9.84 c	9.58 c	1.45 c	1.34
8	2343 b	2555 b	12.75 a	12.76 a	2.03 a	1.89
11	2123 c	2311 c	11.46 b	11.28 b	1.88 b	1.71
F-test	**	**	**	**	**	ns

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means with the same letters are not significantly different at 5 % level.

Table (12): Some water relationships of sugar beet as affected by plant densities in 2006/2007 and 2007/2008 seasons

Water relationships	CU (m^3 fed[-1])		WUE (kg root m^{-3} water)		WUE (kg sugar m^{-3} water)	
Plant densities (1000 plant/ fed)	2006/2007	2007/2008	2006/2007	2007/2008	2006/2007	2007/2008
46	2420 c	2432 c	14.85 a	14.44 a	2.75 a	2.76 a
28	2431 b	2466 b	12.69 b	14.38 ab	2.34 b	2.70 a
20	2454 a	2480 a	6.17 c	6.11 c	1.15 c	1.11 c
F-test	**	**	**	**	**	**

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means with the same letters are not significantly different at 5 % level.

Table (13): Some water relationships of sugar beet as affected by nitrogen fertilizer rates in 2006/2007 and 2007/2008 seasons

Water relationships	CU (m^3 fed[-1])		WUE (kg root m^{-3} water)		WUE (kg sugar m^{-3} water)	
Nitrogen fertilizer rates (N kg fed[-1])	2006/2007	2007/2008	2006/2007	2007/2008	2006/2007	2007/2008
60	3120 d	2850 d	7.88 d	9.34 d	1.45	1.72 b
80	3179 c	3201 c	8.66 c	9.11 c	1.46	1.63 d
100	3280 a	3312 a	9.26 b	9.86 b	1.64	1.70 c
120	3210 b	3281 b	10.33 a	10.73 a	1.68	1.80 a
F-test	**	**	**	*	ns	**

*, ** and ns = significant at P< 0.05, 0.01 levels and not significant, respectively. Means with the same letters are not significantly different at 5 % level.

Table (14): Interaction effect between irrigation intervals and nitrogen fertilizer rates on root and sugar yields in 2006/2007 season.

Parampeters	Root yield (ton fed^{-1})				Sugar yield (ton fed^{-1})			
	Nitrogen fertilizer rates (N kg fed^{-1})							
Irrigation intervals (day)	60	80	100	120	60	80	100	120
5	27.74 ef	32.48 bc	33.65 b	37.72 a	3.76 h	4.24 g	5.83 a	5.18 c
8	27.84 ef	28.72 de	29.64 c	32.63 bc	4.86 def	4.68 ef	4.88 def	5.40 bc
11	19.31 i	22.05 h	26.81 f	25.24 g	3.42 i	3.62 hi	4.62 f	4.78 ef
F-Test	**				**			

* and ** = significant at P< 0.05 and 0.01 levels. Means with the same letters are not significantly different at P < 0.05 % level

Table (15): Interaction effect of irrigation intervals, plant densities and nitrogen fertilizer rates on root and sugar yields in 2007/2008 season.

Parampeters		Root yield (ton fed^{-1})				Sugar yield (ton fed^{-1})			
Irrigation intervals (day)	Plant densities (1000 plants/fed)	Nitrogen fertilizer rates (N kg fed^{-1})							
		60	80	100	120	60	80	100	120
5	46	38.75 ij	41.45 h	46.47 c	44.77 e	3.32 j	3.61 h	3.80 e	3.94 d
	28	38.88 i	41.70 gh	43.73f	45.28 d	3.30 j	3.51 i	3.77 f	3.91 d
	20	18.65 uv	21.11 s	22.83 rs	25.68 p	1.30 rs	1.52 r	1.71q	2.01 n
8	46	37.91k	43.42 f	44.98 de	49.32ab	3.24 k	3.82 e	4.01 c	4.39 a
	28	38.18 jk	44.02 ef	45.91 d	49.65 a	3.21 k	3.76 f	3.92 d	4.33 b
	20	18.42 uv	23.24 qr	25.21 p	27.80 op	1.23 t	1.74 q	1.94 p	2.20 o
11	46	30.98 n	34.93 lm	40.96 hi	44.88 de	2.59 m	2.69 kl	3.32 ij	3.69 g
	28	34.49 lm	35.46 l	41.84 gh	45.58 d	2.54 n	2.63 kl	3.24 j	3.63 h
	20	18.07 v	18.93 tuv	21.43 s	23.67 qr	0.91 u	1.03 st	1.28 s	1.51 r
F-Test		**				**			

* and ** = significant at P< 0.05 and 0.01 levels. Means with the same letters are not significantly different at P < 0.05 % level

intervals and nitrogen fertilizer rates on root and sugar yields in the 1st season and the second order interaction on root and sugar yields in the 2nd seasons. This may be due to the individual effect of each factor.

There was highly significant effect of irrigation intervals and nitrogen fertilizer rate interaction on root and sugar yields in the first season (Table 14). Where, The maximum root yield (37.72 ton fed^{-1}) was obtained when beets were irrigated every 5 days and fertilized at the rate of 120 kg N fed^{-1}, while, the minimum one (19.31 ton fed^{-1}) was achieved from the interaction of11-days interval with 60 kg N fed^{-1}. However, irrigating beets every 5 days under nitrogen fertilizer rate of 100 kg N fed^{-1} gave the highest sugar yield (5.83 ton fed^{-1}), but the lowest one (3.42 ton fed^{-1}) was gained with 11-day inteval and 60 kg N fed^{-1} interaction.

Concerning to the second order interaction, irrigation every 8 days at moderate plant density

(28,000 plants/fed) with 120 kg N fed^{-1} treatment gave the maximum root yield (49.65 ton fed^{-1}), while, the minimum value (18.07 ton fed^{-1}) was achieved from the interaction of irrigation every 11 at 20,000 plant/fed. with nitrogen fertilizer rate of 60 kg N fed^{-1}(Table, 15). However, moderate water stress (8-days) and higest plant density (46,000 plant/fed) under the rate of 120 kg N fed^{-1} gave the optimum sugar yield (4.39 ton fed^{-1}), meanwhile, the lowest sugar yield (0.91 ton fed^{-1}) was gained from irrigation every 11 day with the lowest plant density and nitrogen fertilizer rate.

CONCLUSION

Generally, it is recommended that irrigating sugar beet plants every 8 days with plant density of 46,000 plant/fed and nitrogen fertilization at the rate of 100 kg N fed^{-1} is the best combination for the optium sugar yield and the most efficient

water use under sandy and newly reclaimed soils conditions of North Sinai Governorate.

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تعظيم الإنتاجية ، الجودة وكفاءة استخدام الماء لبنجر السكر باستخدام بعض المعاملات الزراعية تحت ظروف شمال سيناء

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ملخص

نفذت تجربتان حقليتان خلال موسمى 2006/2007 و 2007/2008 م فى المزرعة التجريبية لكلية العلوم الزراعية البيئية بالعريش, جامعة قناة السويس لدراسة تأثير ثلاث فترات رى (5و 8 و 11 يوما) ، ثلاث كثافات نباتية (46 و 28 و 20 ألف نبـات /فدان والتـى نتجت عـن مسافات الزراعـة بين الجـور 15 و 25 و 35 سم , على التوالى) و أربعـة معدلات من التسميد النيتروجينى (60 و 80 و 100 ، و 120 كجم ن / فدان) على نمو ، محصول , وصفات الجـودة ، بالإضافة الى العلاقات المائية لبنجر السكرصنف متعدد الأجنة " فريدا" . كان قوام التربة رملى طميى ورقم الحموضـة 7.32 . أستخدم نظـام الرى بـالتنقيط وكـان متوسط ملوحـة مـاء الرى 4100 جزء فى المليـون . كانت مساحة القطعـة التجريبية 18 م[2] (6 خطوط: المسافة بين الخطوط 60 سم , وطول الخط 5 م). تمت الزراعة فى 20 و 25 اكتوبر فى موسمى الزراعة الأول والثانى على التوالى. أوضحت النتائج زيادة فترات الرى من 5 الى 11 يوما اعطى انخفاضا حادا فى وزن العرش الغض والإستهلاك المائى، فى حين ان الرى كل 8 ايام اعطى افضل قيم لمحصول الجذر والسكر علاوة على كفاءة استخدام الماء فى موسمى الزراعة. بينما الرى كل 11 يوما زاد نسبة السكروز فى موسمى الزراعة, ونسبة النقاوة فى الموسم الأول فقط . كانت التأثيرات غير معنوية للكثافة النباتية على نسبة النقاوة , ولكن اعطت الكثافة العاليـة (46000 نبـات /فدان) اعلى وزن طـازج للجذر و محصول السكر و كفاءة استخدام المـاء (كجم سكر/ م[3] مـاء) عند المقارنة بالكثافة الأقل . كان لزيادة معدلات التسميد النيتروجينى من 60 الى 120 كجم ن /فدان تأثيرا محسنا للصفات الخضرية المدروسة و محصول الجذور علاوة على كفاءة استخدام المياة. أعطت معاملـة 100 كجم ن / فدان أعلى محصول للسكر ،و معدل استهلاك الماء بينما كانت أعلى نسبة سكروز ونقاوة عند اضافة أقل معدل للتسميد النيتروجينى (60 كجم ن / فدان) .

وطبقا لهذه الدراسة يمكن التوصية برى بنجر السكر كل 8 أيام, وزراعته بكثافة نباتية عالية (46000 نبـات/ فدان) واستخدام التسميد النيتروجينى بمعدل 100 كجم ن / فدان لتعظيم انتاجيـة الجذور والسكر وتحقيـق أعلـى كفاءة لأستخدام مياه الرى تحت ظروف الأراضى الرملية فى محافظة شمال سيناء.

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