Response of Sugar Beet (*Beta vulgaris*, L) to Irrigation Regime, Nitrogen Rate and Micronutrients Application

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ABSTRACT

The sugar beet (*Beta vulgaris*, L) cultivar "Farida" was grown on a clay soil at Water Management Research Station at El-Karada, Kafrelshiekh, Egypt, in 2007/2008 and 2008/2009 seasons, to determine the effect of three irrigation regimes (at 40, 55, 70% depletion of available soil moisture, DAM), two nitrogen rates (75 and 90 kg N/feddan) and four micronutrients treatments (through seed soaking (SS), foliar spraying (FS), (SS+FS) and control) on growth, yields, quality and water relations. Solution of micronutrients contained 2 g from each of Zn SO4 (26% Zn), Mn SO4 (24% Mn), Fe SO4 (20% Fe) and boric acid per liter.

Abundance of the available soil moisture significantly increased dry weight/plant, leaf area index (LAI), root diameter, top yield, crop growth rate (CGR) and water consumptive use (WU). The inverse was true in root/top ratio, root length and concentration of gross sugar in roots. Increasing soil moisture level improved juice purity by decreasing impurities (K, Na and α-amino-N) in roots. The plants irrigated at 55% DAM produced the highest net assimilation rate (NAR) and water efficiency use for roots (WUER) and white sugar (WUES) production compared to those irrigated at 40 or 70% DAM.

Increasing nitrogen rate from 75 and 90 kg N/feddan significantly increased dry weight, LAI, CGR, root length, root weight, top yield, root yield, concentration of α-amino-N% and Na + K in roots, loss sugar%, sugar yield and WU. The inverse was true in root/top ratio, gross sugar%, white sugar % and juice purity %. Nitrogen rate had slightly effect on WUER and WUES.

Application of micronutrients through seed soaking and foliar spraying (SS+FS) produced the greatest dry weight, root/top ratio, LAI, CGR, root length, root diameter, root weight, top yield, root yield, gross sugar%, white sugar % and juice purity %, sugar yield, WUER and WUES. SS was at par SS+FS in most these traits. FS increased concentration of α-amino-N% and Na + K in roots and the most of mentioned traits compared with control.

All interactions had a significant effect on root and white sugar yields/feddan. The maximum root and white sugar yields and the best WUER and WUES were achieved from plants irrigated at 55% DAM and received 90 kg N/feddan along with SS+FS

It can be concluded that the irrigation at 55% DAM along with 90 kg N/feddan and SS+FS or SS was the recommended treatment for optimum root and extractable white sugar yield per unit area with less water consumptive use at Kafrelshiekh Governorate.

INTRODUCTION

The great challenge for the coming decade will therefore, be the task of increasing food production with less water particularly in areas with limited water. Increasing agricultural productivity by making the most effective use of the available water resources or more crop per drop is a major challenge. Water regime is an option that may increase water use efficiency. Mahmoodi *et al* (2008) found that the optimum soil water content for root yield of sugar beet is 70% of field capacity with 78.5 t/ha. The minimum root yield (52.5 t/ha) was observed at 90% of field capacity. Irrigation at 30, 50 and 70% of field capacity had same effect on sugar content while sugar content decreased at 90% field capacity. When the available soil water content was at 70% of field capacity, maximum root yield and quality was observed. Fabeiro *et al*.(2003) reported that Moderate water consumption rates (6898 m^3 ha^{-1}) achieved high yields (up to 117.64 t ha^{-1}). Excessive irrigation does not increase yield and when nearly 500 mm water is used, maximum water use efficiency is 7.2 kg m^{-3} (Koksal *et al.*, 2011).Water deficit decreased root yield but increased sugar, potassium and amino N amount and total irrigation increased sugar amount in sugar beet (Almani *et al*.,1997).

Nitrogen plays an important role in sugar beet production. It affects root yield and sucrose content, the two constituents of sugar yield (Draycott, 1993). Nitrogen deficiency can reduce both root and sucrose yields but high sucrose content and juice purity (Vamerali *et al*., 1999). High levels of nitrogen stimulate vegetative growth and consequently increase fresh root weight but reduce the technical quality of the roots (Draycott, 1993; Oliveira *et al*., 1993 and Marinkovic *et al.*, 2010). Fresh root and sugar yields and non-sugar impurities (K, Na and α-amino N) were positively related to increase N rate but sucrose content was reduced by increasing N rate (Tsialtas and Maslaris, 2005 and Marinkovic *et al.*, 2010).

Sugar beet response to the use of various micronutrients has been the focus of several studies. As would be expected, the importance of specific micronutrient for sugar beet production is often related

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to soil characteristics. The Egyptian soil is thought to be deficient in micronutrients as a result of many reasons such as intensive cropping, low percentage of soil organic matter and alkaline conditions of soil which decreased the availability of cation trace elements such as Mn, Zn and Fe (El-Fouly, 1983). El-Fouly *et al.* (2005) reported that spraying with micronutrients Fe, Mn, Zn and B significantly increased sugar beet root yield and content of sugar. Shaban and Negm (2008) found that foliar spraying with the combination of Zn and B increased significantly roots, shoot and sugar yield over the control. Moustafa and Omran (2006) found that foliar spray with B increased root diameter, fresh and dry weight of roots and tops, root and sugar yield, sucrose % and K as impurity. This study was proposed to evaluate the effects of irrigation regimes, nitrogen rate and micronutrients application on growth, yield, quality and some water relations of sugar beet.

MATERIALS AND METHODS

Two field experiments were conducted on a clay soil at Water Management Research Station at El-Karada, Kafrelshiekh, Egypt, during 2007/2008 and 2008/2009 seasons, to study the effect of irrigation regime, nitrogen rate and micronutrients on growth, yield, quality and some water relations of sugar beet cultivar "Farida". The preceding crop was cotton in both seasons.

Representative soil samples were taken from each site at the depth of 0-30 cm from the soil surface. Samples were air-dried then ground to pass through a two mm sieve and well mixed. The procedure of soil analysis followed the methods of Black *et al.* (1965). Results of chemical analysis in both seasons are shown in Table 1.The soil bulk density, field capacity and wilting point were determined in the experimental sites and given in Table 2. Climatic conditions; temperature, relative humidity and rainfall at El-Karada station from sowing to harvest are presented in Table 3.

The experimental field was fertilized with 31 kg P_2O_5/feddan in the form of superphosphate fertilizer (15.5 % P_2O_5) and 24 kg K_2O/feddan in the form of potassium sulphate (48%K_2O) during soil preparation.

A split-split plot design with four replications was used. The main plots were assigned to three irrigation regimes, the sub-plots to two nitrogen rates and the sub-sub-plots to application of micronutrients. The three irrigation regimes were applied at 40, 55 and 70% depletion of available moisture in soil (DAM).

Table 1. Chemical analysis of the experimental soil (0-30 cm) in 2007/8 and 2008/9 seasons

Season	pH* (1:2.5)	EC** (ds/m)	Ca CO_3 (%)	OM (%)	Available (ppm) N	Available (ppm) P	Available (ppm) K	DTPA extract (ppm) Zn	DTPA extract (ppm) Mn	DTPA extract (ppm) Fe
2007/8	7.9	2.63	3.33	1.25	22.84	13.07	345	0.71	3.29	4.92
2008/9	8.2	2.54	3.09	1.51	21.10	16.46	319	0.63	4.60	6.34

*pH derermined in soil suspension 1:2.5
** Ec determined in soil paste extract

Table 2. Field capacity, wilting point and bulk density of soils of the experimental field in 2007/8 and 2008/9 seasons

Soil depth	Field capacity %		Wilting point %		Bulk density (g/cm^3)	
(cm)	2007/8	2008/9	2007/8	2008/9	2007/8	2008/9
0 – 20	44.21	43.76	24.06	23.82	1.10	1.05
20 – 40	39.68	39.03	21.25	21.60	1.22	1.15
40 – 60	35.83	36.42	19.51	19.83	1.33	1.30
Mean	39.91	39.74	21.61	21.75	1.22	1.17

Table 3. Mean monthly of temperature, relative humidity and rainfall during 2007/8 and 2008/9 seasons

Month	Mean of air temperature (^oc)		Mean of relative humidity (%)		Total rainfall (mm)	
	2007/8	2008/9	2007/8	2008/9	2007/8	2008/9
November	17	17.0	65.1	67.5	28	-
December	20.6	14.5	64.85	65.3	-	6
January	9.7	13.4	66.0	65.0	12	35
February	11.7	15.2	68.2	70.0	13	45
March	15.4	14.5	65.0	62.1	-	-
April	18.1	19.0	58.0	62.5	-	-
May	19.5	20.7	56.5	58.8	-	-

The two nitrogen rates were 75 and 90 kg N/feddan. Solution of micronutrients mixture were applied through seed soaking (SS), foliar spraying (FS) and SS+FS as well as control (untreated). Solution of micronutrients was containing 2 g from each of Zn SO_4 (26% Zn), Mn SO_4 (24% Mn), Fe SO_4 (20% Fe) and boric acid per liter. Seed was soaked in solution of micronutrients for 24 hours, and then dried at air room temperature for 24 hours. Foliar spraying with solution of micronutrients mixture was done twice; at 80 and 100 days after sowing.

The plot size was 44.1 m^2 (6.3 X 7 m). Each plot included seven ridges 90 cm apart and 7 m long. To avoid the effect of lateral movement of irrigation water, the main plots were isolated by levees of 1.5 m wide. Sowing took place on 15 September 2007 and 20 September 2008. Seeds of multigerm sugar beet cultivar “Farida” were sown in hills 20 cm apart on both sides of the ridge at the rate of 3-4 seeds per hill. All plots were irrigated immediately after sowing. Light irrigation was given after 8 days from sowing to ensure high seed emergence. Thirty five days after sowing, the plants were thinned to one plant per hill. The nitrogen fertilizer in the form of urea (46 % N) was applied as split into two equal doses, half before the second irrigation after thinning and the remaining half after 15 days later before the third irrigation. Irrigation treatments started after the third irrigation. Other cultural practices were done as usual.

Actual need for irrigation was determined by drying the soil samples for 24 hours to 110 ^oC and the percentage of moisture was expressed on an oven dry weight basis. Soil samples were obtained at each 20 cm soil depth to 60 cm before and after every irrigation to calculate water consumptive use (WCU) of sugar beet plant from sowing to harvest according to Israelsen and Hansen (1962) equation as follows:

$$WCU = \frac{\theta_2 - \theta_1}{100} \times B.d \times D \times 4200$$

Where:

WCU = Amount of water consumptive use (m^3/feddan).

θ_2 = Soil moisture content % after irrigation.

θ_1 = Soil moisture content % before the next irrigation.

B.d = Bulk density (g/cm^3).

D = Depth of soil layer (m).

Water use efficiency was calculated as the ratio of root or white sugar yields (kg/m^3) according to Doorenbos and Pruitt (1979) as follows:

$$WUE = \frac{\text{Yield (kg/ feddan)}}{\text{water consumpitive use} (m^3 / \text{feddan})}$$

The number of germinated hills was counted at 30 days after sowing for two ridges in each plot before plant thinning, and the percentage of emerged hills was calculated.

In each plot, 2 ridges were devoted for plant growth sampling and 5 ridges for determining root and top yields at harvest. Five guarded plants were randomly taken from each plot at 136, 151 and 165 days after sowing (DAS) to determine leaf area and dry weight of root and top per plant. The different plant fractions were oven dried to a constant weight at 70 ^oC. For leaf area measurements, the disk method was used. The growth attributes, viz. leaf area index (LAI) crop growth rate (CGR) and net assimilation rate (NAR) were computed according to the flowing formulas (Watson, 1952):

LAI= leaf area per plant/ unit ground area occupied by one plant

CGR= $W_2 - W_1/t_2\text{-}t_1$

RGR= $(\log_e W_2 - \log_e W_1)/(t_2\text{-}t_1)$

NAR= $(W_2 - W_1)(\log_e A_2 - \log_e A_1)/(A_2\text{-}A_1)(t_2\text{-}t_1)$

Where: W_1, A_1 and W_2, A_2, refer to dry weight and leaf area at t_1 and t_2, respectively in weeks.

At harvest (190 days after sowing), the central area of 18.9 m^2 of the devoted ridges for yield determination were harvested to obtained root and top yields. Ten guarded plants were taken at random and were screened for root and top yields / plant, root diameter and root length.

Sugar and other chemical content in roots were determined in Delta Company of Sugar by means of an automatic sugar polarimeter according to Le Docte as described by Mc Ginnus (1971). Corrected sugar content (white sugar) of beet was calculated by linking the beet non-sugars K, Na and α-amino-N (expressed as milliequivalents/100g of beet) as described by Harvey and Dutton (1993) as follows:

Z_B = Pol - [0.343(K+Na) +0.094 N_{BI}+0.29].

Where:

Z_B = corrected sugar content (% beet)

N_{BI}= α-amino-N determined by the “blue number” method.

Juice purity percentage (QZ) was calculated as following in the Delta Company:

$$QZ = \frac{Z_B}{Pol}$$

The obtained data were subjected to analysis of variance according to Gomez and Gomez (1984). Treatment means were compared by Duncan's Multiple Range Test (Duncan, 1955). All statistical analysis was performed using analysis of variance technique by means of "MSTATC" computer software package.

RESULTS AND DISCUSSION

1. Effect of seed soaking on germination:

The percentage of germinated hills at 30 days after sowing (DAS) as affected by seed soaking in 2007/8 and 2008/9 are presented in Fig. 1. Soaking seeds in micronutrients solution significantly enhanced seed emergence compared with untreated seed (dry seed) at 30 DAS in the two seasons. Seed soaking resulted in a substantial increase in hill germination by 4.1 and 5.8 % than untreated seeds in the first and second seasons, respectively. This may be due to leaching of inhibitors substances from the fruits by soaking seed in micronutrients solution, hence improving crop emergence, plant vigor and growth attributes. These results are in harmony with those of El-Hindi *et al*. (1990) who found that soaking sugar beet seeds in water for 24 hours increased emergence percentages. Sorour *et al*. (2009) reported that mechanical or manual plantings with soaked seed increased number of germinated hills per m^2 than planting with dry seed.

2. Growth:

Means of dry weight, LAI, CGR and NAR of sugar beet as affected by irrigation regime, nitrogen rate and micronutrients in 2007/2008 and 2008/2009 seasons are presented in Tables 4 and 5.

2.a. Effect of irrigation regime:

The abundance of available soil moisture in the root zone resulted in a substantially increase in dry matter accumulation (g/plant) and LAI at 137, 151 and 165 days after sowing (DAS) and CGR at the two periods of 137-151 and 151-165 DAS in both seasons. Scheduling irrigation at 40% depletion of available soil moisture (DAM) produced the largest dry weight, LAI and CGR, while irrigation at 70% DAM produced the lowest ones. Certainly the sufficient soil moisture content at 40% DAM favoured cell division and elongation and thus the expansion of leaves which in turn resulted in more photosynthates available for dry matter accumulation per unite area (CGR). These results confirm the findings of Sorour (1995) and El-Zayat (2000). On the contrary, root/top ratio and NAR was significantly influenced by irrigation regime in favour of plants irrigated at 55 and 70% DAM compared with those irrigated at 40% DAM. Abundance of available soil moisture content pushed the plants towards the top growth that in turn may have decreased the efficiency of assimilates translocation from tops to roots and in turn decrease root/top ratio (Sorour, 1995). Such reduction in NAR obtained from high soil moisture level may be attributed to very large leaf area which led to increase mutual-shading and transpiration and in turn caused a reduction in rate of assimilation per unit of leaf area (NAR). Sorour (1995) and El-Zayat (2000) reported similar conclusions.

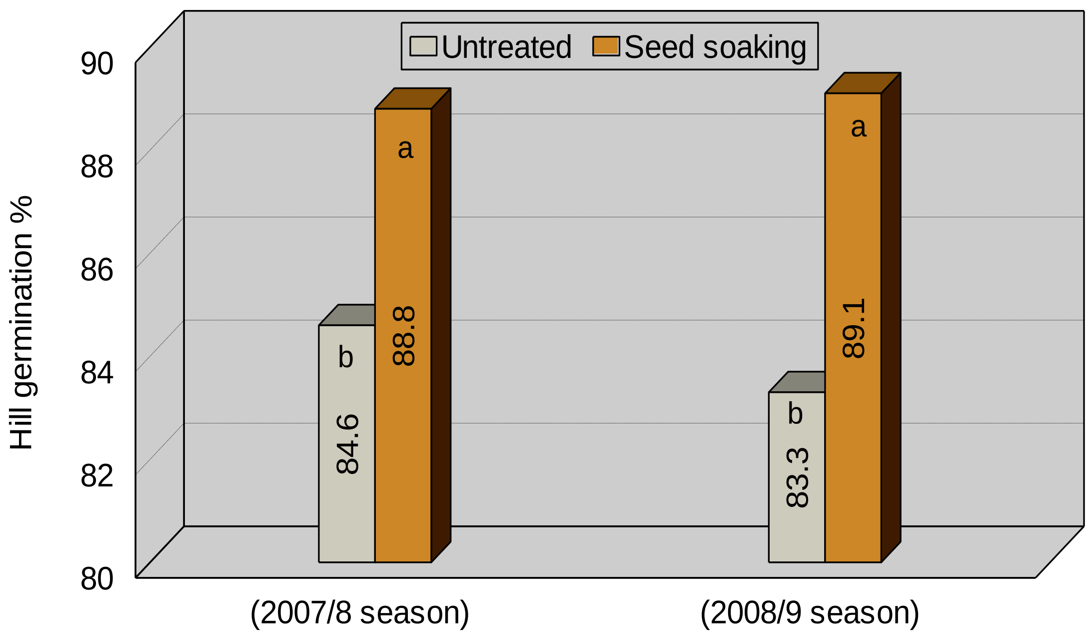

Fig. 1. The percentage of germinated hills at 30 days after sowing as affected by seed soaking in solution of micronutrients mixture in 2007/8 and 2008/9 seasons

Table 4. Dry matter accumulation and root/top ratio of sugar beet as affected by irrigation regime, nitrogen rate, micronutrient and their interactions in 2007/8 and 2008/9 seasons

Factor	2007/8 season				2008/9 season			
	Dry weight (g/plant)			Root/Top ratio	Dry weight (g/plant)			Root/Top ratio
	Days after sowing				Days after sowing			
	136	151	165	165	136	151	165	165
DAM at Irrigation (I)	**	*	*	*	**	**	**	*
40 %	192 a	233 a	305 a	1.82 b	211 a	244 a	306 a	1.98 b
55 %	173 b	211 b	286 b	2.66 a	201 a	241 a	304 b	2.41 a
70 %	147 c	176 c	235 c	2.38 a	166 c	200 c	255 c	2.29 a
Kg N/fed. (N)	*	*	*	*	**	*	**	*
75	161 b	195 b	260 b	2.42 a	176 b	209 b	262 b	2.51 a
90	181 a	218 a	290 a	2.15 b	209 a	248 a	315 a	1.94 b
Micronutrient (M)	**	**	**	NS	**	*	*	NS
Control (C)	153 c	186 c	246 c	2.4	168 c	200 c	261 c	2.32
Seed soaking (SS)	169 b	204 b	274 b	2.34	197 b	237 ab	294 a	2.25
Foliar spraying (FS)	166 b	200 b	268 b	2.18	195 b	227 b	289 a	2.16
SS + FS	194 a	236 a	313 a	2.21	211 a	251 a	310 a	2.18
Interaction								
I X N	NS	*	NS	*	NS	*	NS	*
I X M	NS	NS	*	NS	NS	NS	NS	NS
N X M	NS	NS	NS	NS	NS	NS	NS	NS
I X N X M	NS	NS	NS	NS	NS	NS	NS	NS

*, **and NS indicate P< 0.05, P< 0.01 and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's MRT.

2.b. Effect of nitrogen rate:

Beet plants received 90 kg N/ feddan were significantly superior to those received 75 kg N/ feddan in dry matter accumulation (g/plant), LAI and CGR at all sampling dates in both seasons. This reflects the important role of nitrogen in building up the photosynthetic area of beet plants and consequently accumulation of more dry matter per plant or per unites of ground area. The inverse was true in root/top ratio at 159 DAS in both seasons. Such decrease in root/top ratio may be due to the fact that with more nitrogen, top growth was favoured more than root growth. No significant differences in NAR were detected between the two nitrogen rates at all growth periods, except at the period of 151-165 DAS in the second season, where increasing nitrogen rate significantly decreased NAR. This result may be due to overlap between the large leaves of adjacent plants at higher nitrogen rate which decreased the dry matter accumulation efficiency per unit leaf area as a result of competition for light and in turn reduced NAR. Also, the result reflects the negative correlation between LAI and NAR, whereas the rate of 75 kg N/feddan produced higher NAR and lower LAI at the mentioned period. El-Zayat (2000), Attia and Abd-Motagally (2009) and Selim *et al* (2010) found that increasing nitrogen rate increased root and top dry weight and vegetative growth of sugar beet.

2.c. Effect of micronutrients:

Application of micronutrients resulted in a significant increase in dry matter accumulation (g/plant), LAI and CGR compared with control (untreated treatment) at all sampling dates, except LAI at 136 DAS in the second season. Application of micronutrients through seed soaking and foliar spraying (SS+FS) recorded the highest values of these traits. These results might be attributed to the role of micronutrients as a co-factor in the enzymatic reactions of the anabolic pathways in plant growth (Alloway 2004). There was no significant difference in root/top ratio due to micronutrients in the two seasons (Table 4). However, NAR was significantly influenced by micronutrients at the second period in both seasons, only (Table 5). The relative ranking of micronutrients treatments for NAR was inconsistent in the two seasons. Foliar spraying (FS) produced great NAR at this period in both seasons. The lowest NAR was obtained from beet plants of SS+FM treatment in both seasons. This may be attributed to the increase in mutual shading and/or the dilution effect caused by the large leaf area formed at SS+FS treatment, which in turn decreased NAR. This reflects the negative correlation between LAI and NAR. These results are in accordance with those reported by Ebrahim (1988). Sorour *et al* (2009) reported that seed soaking increased dry matter, LAI and CGR.

2.d. Effect of interaction:

The interaction between irrigation regimes and nitrogen rates had a significant effect on dry weight per plant at 151 DAS and root/top ratio at 165 DAS in the two seasons, LAI at 151 DAS in the first season and at 165 DAS in the second season as well as CGR and NAR at the period of 136-151 DAS in the first season. The interaction between irrigation regimes and micronutrients had a significant effect on dry weight per plant and LAI at 165 DAS in the first season as well as LAI at 151 DAS in the second season. However, the other interactions did not reach the level of significance for these respects.

Table 5. Leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) of sugar beet as affected by irrigation regime, nitrogen rate, micronutrient and their interactions in 2007/8 and 2008/9 seasons

Factor	LAI			CGR (g/m^2/week)		NAR (g/m^2/week)	
	Days after sowing						
	136	151	165	136-151	151-165	136-151	151-165
				2007/8 season			
DAM at Irrigation (I)	**	**	**	*	**	*	*
40 %	2.71 a	4.07 a	4.66 a	224 a	413 a	66 b	92 b
55 %	2.34 b	3.15 b	3.5 b	213 a	401 a	79 a	125 a
70 %	1.64 c	2.46 c	2.74 c	162 b	331 b	80 a	127 a
Kg N/fed. (N)	*	*	*	**	*	NS	NS
75	2.13 b	3.02 b	3.41 b	191 b	361 b	77	116
90	2.32 a	3.43 a	3.85 a	208 a	402 a	74	114
Micronutrient (M)	**	*	*	*	**	NS	*
Control (C)	1.82 c	2.95 b	3.14 c	182 c	336 c	76	112 b
Seed soaking (SS)	2.36ab	3.27 b	3.63 b	195 b	385 b	73	116 ab
Foliar spraying (FS)	2.19 b	2.96 b	3.55 b	189 b	380 b	76	121 a
SS + FS	2.54 a	3.73 a	4.22 a	233 a	425 a	76	111 b
Interaction :							
I X N	NS	*	NS	*	NS	*	NS
I X M	NS	NS	*	NS	NS	NS	NS
N X M	NS	*	NS	NS	NS	NS	NS
I X N X M	NS	NS	NS	NS	NS	NS	NS
				2008/9 season			
DAM at Irrigation (I)	**	**	*	**	**	*	*
40 %	2.2 a	3.35 a	3.51 a	213 a	349 a	66 b	95 b
55 %	2.0 a	3.30 a	3.49 a	202 a	340 a	85 a	105 a
70 %	1.7 b	2.93 b	3.24 b	183 b	307 b	86 a	107 a
Kg N/fed. (N)	*	*	**	**	**	NS	*
75	1.85 b	2.97 b	3.12 b	184 b	294 b	78	115 a
90	2.09 a	3.42 a	3.71 a	215 a	372 a	80	89 b
Micronutrient (M)	NS	*	*	**	*	NS	**
Control (C)	1.85	2.90 c	3.08 c	169 c	317 c	76	108 a
Seed soaking (SS)	2.02	3.36 a	3.55ab	217 a	341 a	84	93 b
Foliar spraying (FS)	1.98	3.15 b	3.37 b	191 b	329 b	73	113 a
SS + FS	2.04	3.38 a	3.65 a	221 a	344 a	83	95 b
Interaction :							
I X N	NS	NS	*	NS	NS	NS	NS
I X M	NS	*	NS	NS	NS	NS	NS
N X M	NS	NS	NS	NS	NS	NS	NS
I X N X M	NS	NS	NS	NS	NS	NS	NS

*, ** and NS indicate $P< 0.05$, $P< 0.01$ and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's MRT.

3- Root and top yields and their components:

Means of root length, root diameter, root weight, root yield and top yield as influenced by irrigation regime, nitrogen rate and micronutrients 2007/8 and 2008/9 seasons are presented in Table 6.

3.a. Effect of irrigation regime:

There was a significant difference among irrigation regimes in root yield and its attributes in the two seasons. Beets irrigated at 70% DAM produced longer roots than those irrigated at 40% DAM. Results show that water stress enhanced deep rooting.

Table 6. Root yield, top yield and root dimensions of sugar beet as affected by irrigation regime, nitrogen rate, micronutrient and their interactions in 2007/8 and 2008/9 seasons

Factor	Root length (cm)	Root diameter (cm)	Top yield		Root yield	
			Kg/plant	t/fed.	Kg/plant	t/fed.
			2007/8 season			
DAM at Irrigation (I)	**	**	**	**	**	**
40 %	28.1 b	10.8 a	0.499 a	14.254 a	0.995 a	28.498 a
55 %	29.7 a	11.0 a	0.385 b	11.523 b	1.014 a	30.344 a
70 %	30.8 a	9.3 b	0.350 b	9.915 b	0.754 b	21.431 b
Kg N/fed. (N)	**	NS	*	*	**	**
75	28.9 b	10.3	0.370 b	10.770 b	0.879 b	25.674 b
90	30.2 a	10.4	0.453 a	13.025 a	0.963 a	27.842 a
Micronutrient (M)	**	*	*	*	**	**
Control (C)	28.0 c	9.6 b	0.315 b	10.269 b	0.819 c	24.326 c
Seed soaking (SS)	30.0 ab	10.8 a	0.430 a	12.042 a	0.948ab	27.785ab
Foliar spraying (FS)	28.9 bc	10.2 ab	0.421 a	12.224 a	0.915 b	26.322 b
SS + FS	31.3 a	10.8 a	0.479 a	13.054 a	1.001 a	28.598 a
Interaction :						
I X N	NS	NS	*	*	*	*
I X M	NS	NS	NS	NS	*	*
N X M	NS	NS	NS	NS	*	**
I X N X M	NS	NS	NS	NS	**	**
			2008/9 season			
DAM at Irrigation (I)	**	**	*	**	**	*
40 %	28.2 c	10.3 a	0.472 a	13.969 a	0.963 a	28.582 a
55 %	29.9 b	10.2 a	0.449 a	11.910 b	1.117 a	29.675 a
70 %	32.1 a	9.5 b	0.307 b	9.835 c	0.731 b	20.538 b
Kg N/fed. (N)	**	NS	**	**	*	*
75	28.6 b	9.9	0.359 b	10.860 b	0.859 b	24.958 b
90	31.6 a	10.2	0.460 a	12.949 a	1.016 a	27.572 a
Micronutrient (M)	**	NS	*	*	**	**
Control	27.5 c	9.7	0.342 b	10.359 b	0.801 c	23.593 c
Seed soaking (SS)	30.9 ab	10.1	0.426 a	11.966 a	0.994 ab	26.898ab
Foliar spraying (FS)	29.5 b	9.8	0.406 a	12.148 a	0.911b	26.136 b
SS + FS	32.4 a	10.4	0.464 a	13.145 a	1.042 a	28.433 a
Interaction :						
I X N	NS	NS	*	*	*	*
I X M	NS	NS	NS	NS	*	*
N X M	NS	NS	NS	NS	**	**
I X N X M	NS	NS	NS	NS	*	*

*, ** and NS indicate P< 0.05, P< 0.01 and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's MRT.

Such result is in harmony with that of Sorour (1995), Emara (1996), El-Zayat (2000) and Vamerali *et al* (2009). However, root diameter, root weight and root yield per feddan produced by beet plants receiving irrigation at 40 or 55% DAM were practically the same and significantly surpassed those produced by beet plants receiving irrigation at 70% DAM. Top yield per plant or per feddan was significantly increased by increasing available soil moisture.

Such increase in root yield obtained from irrigation at 40 or 55% DAM can be attributed to improved beet growth, in terms of thicker roots, higher crop growth rate and heavier root weight. Also, the abundance of soil moisture increased top yield through increasing dry matter accumulation and leaf area. These results are in accordance with those reported by Sorour (1995), Emara (1996), El-Zayat (2000) and Kenter *et al*. (2006). Mahmoodi *et al* (2008) reported that the optimum soil water content for root yield is 70% of field capacity, while the minimum root yield was observed at 90% of field capacity. El-Sarag (2009) found that increasing irrigation intervals from 5 to 11 days sharply reduced top fresh weight, while, irrigation every 8 days was superior in root yield.

3.b. Effect of nitrogen rate:

Nitrogen application exerted a significant effect on root yield, root length, root weight and top yield in favor of 90 kg N/feddan compared with 75 kg N/feddan in the two seasons. Thus, the highest nitrogen rate increased root yield through increasing LAI, dry matter accumulation, CGR, root length and root weight. However, there was no evidence for significant difference in root diameter due to nitrogen rate. The positive effect of nitrogen on root yield is supported by studies of many authors, Nemeat Alla and El-Geddawy (2001), Tsialtas and Maslaris (2005), Attia and Abd-Motagally (2009), El-Sarag (2009), Vamerali *et al* (2009), Marinkovic *et al* (2010) and Selim *et al* (2010).

3.c. Effect of micronutrients:

Micronutrients significantly affected root yield and all yield attributes in both seasons, except root diameter in the second seasons. The early supply of micronutrients through seed soaking enabled beet plants to deepen (in both seasons) and thicken (in the first season) its roots compared with control. Application of micronutrients resulted in a significant increase in top and root yields compared with control (untreated) in both seasons. The beets of seed soaking and foliar-micronutrients (SS+FS) produced the greatest root and top yields in the two seasons. The beets of SS were statistically at par with those of SS+FS in root and top yields. This indicates that seed soaking method was found to more effective in these respects than the foliar application. This may be due to the considerable increase in early growth which was reflected in higher root yield and its components,i.e. root length, diameter and weight. Nemeat Alla and El-Geddawy (2001) found that foliar spraying twice with micronutrients mixture significantly increased root length, root diameter, top yield and root yield. Shaban and Negm (2008) reported that combination of Zn and B increased significantly root and shoot yields over the control. Sorour *et al* (2009) reported that seed soaking increased root yield.

3.d. Effect of interaction:

Root yield were significantly affected by all interactions in both seasons. The interaction irrigation regimes × nitrogen rate had a significant effect on top yield in the two seasons. Means of root yield /feddan as influenced by the first and the second order interactions are presnted in table 7.

Irrigation regime × nitrogen rate interaction (IxN): The highest root yield per feddan was obtained from beets irrigated at 55% DAM and fertilized by 90 kg N/feddan, while the lowest one was obtained from those irrigated at 70% DAM and fertilized by 75 kg N/feddan in the two seasons.

Irrigation regime × micronutrients interaction (IxM): The combination of irrigation at 55% DAM and SS+FS or SS recorded the highest root yield without significant difference between them. However, the low irrigation regime × untreated (C) recorded the lowest in both seasons.

Nitrogen rate × micronutrients interaction (NxM): It is clear that beets received 90 kg N/feddan along with SS+FS or SS produced the greatest root yield, while those received 75 kg N/feddan without micronutrients produced the lowest one in both seasons.

Irrigation regime × nitrogen rate × micronutrients interaction (IxNxM): The combination of medium irrigation regime × high N rate × SS+FS produced the maximum root yield in both seasons. Application of SS or FS separately along with medium irrigation regime and high N rate was statistically at par with the mention combination in root yield. The combination of low irrigation regime × low N rate × without micronutrients produced the lowest root yield in both seasons.

4- Sugar yield and root quality:

The soluble non-sugars, potassium, sodium and α-amino nitrogen in the roots are regarded as impurities because they interfere with sugar extraction. Means of these impurities, gross sugar %, extractable white sugar %, loss sugar %, juice purity % and white sugar yield per feddan as affected by irrigation regime, nitrogen rate and micronutrients in 2007/8 and 2008/9 seasons are presented in Table 8.

4.a. Effect of irrigation regime :

Irrigation regimes had a significant effect on sugar yield and all root juice quality in the two seasons. Data show that water stress significantly increased total sugar content, impurities (K+ Na and α-amino-N), white sugar % and losses sugar %. Beet pants irrigated at 70% DAM recorded the highest values of these traits. Irrigation at 55% DAM was statically at par with at 70% DAM in white sugar % in both seasons. It may be that some impurities found in roots of stressed plants resulted from osmotic adjustment in sugar beet in response to soil drying (Browen *et al.*, 1987). On the contrary, juice purity % and white sugar yield/feddan were significantly decreased by water stress. Although, water stress increased the concentration of gross sugar in roots, it decreased juice purity %. This might be due to increasing impurities in the roots of stressed plants, which causes troubles during juice purification and crystallization and in turn decreased purity. Sorour (1995) found Irrigation improved sugar beet quality by reducing the K, Na and N contents. Such increase in white sugar yield (obtained from the plants irrigated at 55% DAM) may be attributed to increase root yield and white sugar extraction %. These results agree with those obtained by Sorour (1995), El-Zayat (2000), Vamerali *et al* (2009) and El-Sarag (2009). In this connection, Mahmoodi *et al* (2008) reported that irrigation at 30, 50 and 70% of field capacity had same effect on sugar content while sugar content decreased at 90% field capacity. They added that irrigation at 70% of field capacity produced the maximum root quality.

4.b. Effect of nitrogen rate:

There was a substantial difference in all traits between the two nitrogen rates in both seasons, except loss sugar% in the second season. The concentration of K + Na and α-amino-N in roots and losses sugar % were significantly increased by increasing nitrogen rate. Thus, total sugar content, extraction of white sugar and juice purity were decreased as nitrogen rate increased in both seasons. White sugar yield was significantly increased by increasing nitrogen rate from 70 to 90 kg N/feddan. This may be due to increase root yield. The findings are in agreement with those of Nemeat Alla and El-Geddawy (2001), Tsialtas and Maslaris (2005), Attia

Table 7. Root yield (t/fed.) of sugar beet as affected by the interactions among irrigation regime, nitrogen rate and micronutrient in 2007/8 and 20089/9 seasons

Irrigation (I) DAM	Micro-element (M)	2007/8 season			2008/9 season		
		Kg N/fed. (N)		Mean	Kg N/fed. (N)		Mean
		75	90		75	90	
		I x N-Mean		I-Mean	I x N-Mean		I-Mean
40%		27.37 b	29.62 ab	28.498 a	27.24 c	29.92 ab	28.58 a
55%		28.84 b	31.84 a	30.344 a	28.19 bc	31.16 a	29.68 a
70%		20.80 c	22.06 c	21.431 b	19.44 d	21.63 d	20.54 b
		N x M-mean		M-mean	N x M-mean		M-mean
	C	23.55 d	25.11 cd	24.33 c	22.56 e	24.63 de	23.59 c
	SS	26.62 bc	28.95 ab	27.79 ab	25.47 cd	28.32 ab	26.90 ab
	FS	25.23 cd	27.42 bc	26.32 b	24.81 de	27.46 bc	26.14 b
	SS+FS	27.3 bc	29.90 a	28.60 a	26.99 bcd	29.88 a	28.43 a
		I x N x M-Mean		IxM-Mean	I x N x M-Mean		IxM-Mean
40%	C	25.95 e-h	27.52 c-g	26.74 c	25.04 efg	26.58 c-f	25.81 d
	SS	28.63 c-f	30.33 a-e	29.48 bc	27.95 b-f	31.20 abc	29.58 abc
	FS	26.87 d-g	29.10 b-e	27.98 c	26.89 c-f	29.74 a-d	28.31 bcd
	SS+FS	28.05 c-f	31.54 a-d	29.79 bc	29.09 b-e	32.16 ab	30.63 ab
55%	C	26.12 e-h	28.7 c-f	27.41 c	25.29 d-g	27.97 b-f	26.63 cd
	SS	29.67 a-e	33.51 ab	31.59 ab	28.86 b-e	31.95 ab	30.41 ab
	FS	27.88 c-f	31.24 a-d	29.56 bc	27.99 b-f	30.88 abc	29.44 abc
	SS+FS	31.71 abc	33.94 a	32.82 a	30.60 abc	33.84 a	32.22 a
70%	C	18.57 j	19.10 j	18.83 e	17.35 i	19.32 hi	18.33 f
	SS	21.57 hij	23.01 g-j	22.29 d	19.60 hi	21.82 ghi	20.71 ef
	FS	20.93 ij	21.92 hij	21.42 de	19.56 hi	21.76 ghi	20.66 ef
	SS+FS	22.15 hij	24.21 f-i	23.18 d	21.26 ghi	23.64 fgh	22.45 e

Table 8. Sugar yield and root quality of sugar beet as affected by irrigation regime, nitrogen rate, micronutrient and their interactions in 2007/8 and 2008/9 seasons

Factor	Gross sugar (%)	K+Na	α-N	White sugar	loss sugar	Juice purity	Sugar yield (t/fed.)
		(meq/100g)		(%)	(%)	(%)	
				2007/8 season			
DAM at Irrigation (I)	**	**	**	*	**	*	*
40 %	17.53 b	7.68 b	3.97 b	14.23 b	3.30 b	81.18 a	4.053 a
55 %	18.34 a	8.30 a	4.16 a	14.81 a	3.53 a	80.76ab	4.500 a
70 %	18.59 a	8.61 a	4.19 a	14.95 a	3.64 a	80.43 b	3.208 b
Kg N/fed. (N)							
75	18.22 a	8.15 b	4.07 b	14.75 a	3.47 b	80.98 a	3.786 b
90	18.08 b	8.24 a	4.15 a	14.57 b	3.51 a	80.60 b	4.055 a
Micronutrient (M)							
Control	17.84 b	8.22 b	4.08 b	14.35 c	3.49 ab	80.43 b	3.481 c
Seed soaking (SS)	18.33 a	8.04 c	4.03 b	14.90 a	3.43 b	81.32 a	4.134 a
Foliar spraying (FS)	18.15 a	8.35 a	4.21 a	14.60b	3.55 a	80.46 b	3.841 b
SS + FS	18.28 a	8.19 bc	4.11 b	14.80ab	3.48 ab	80.95 a	4.226 a
Interaction :							
I X N	NS	NS	*	*	NS	*	*
I X M	NS	NS	*	*	NS	*	**
N X M	NS	NS	*	NS	NS	NS	*
I X N X M	NS	NS	NS	NS	NS	NS	**
				2008/9 season			
DAM at Irrigation (I)	**	**	*	**	**	*	*
40 %	17.40 c	6.65 c	3.29 b	14.53 c	2.88 b	83.46 a	4.150 b
55 %	18.85 b	7.33 b	3.60 a	15.71 a	3.14 a	83.33 a	4.661 a
70 %	19.22 a	7.68 a	3.65 a	15.96 a	3.27 a	83.00 b	3.278 c
Kg N/fed. (N)							
75	18.63 a	7.15 b	3.44 b	15.57 a	3.07 b	83.55 a	3.876 b
90	18.35 b	7.29 a	3.58 a	15.22 b	3.13 a	82.97 b	4.184 a
Micronutrient (M)							
Control (C)	18.22 b	7.21 b	3.43 c	15.15 c	3.09 b	83.10bc	3.567 c
Seed soaking (SS)	18.61 a	7.03 c	3.48 bc	15.58 a	3.03 b	83.72 a	4.172ab
Foliar spraying (FS)	18.55 a	7.40 a	3.59 a	15.39 b	3.17 a	82.93 c	4.001 b
SS + FS	18.59 a	7.23 b	3.56 ab	15.46ab	3.10 ab	83.29ab	4.378 a
Interaction :							
I X N	NS	NS	*	*	NS	*	*
I X M	NS	NS	NS	*	NS	NS	*
N X M	NS	NS	*	NS	NS	NS	NS
I X N X M	NS	NS	NS	NS	NS	NS	NS

*, ** and NS indicate P< 0.05, P< 0.01 and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's MRT.

and Abd-Motagally (2009), Marinkovic *et al* (2010) and Selim *et al* (2010). Marinkovic *et al* (2010) stated that the sugar content significantly decreased, while the content of α-amino-N and sodium significantly increased with increasing N dose.

4.c. Effect of micronutrients:

Application of micronutrients as SS, FS and SS+FS resulted in a significant increase in total sugar content compared with control in both seasons. However, the soluble non-sugars, potassium + sodium and α-amino nitrogen in the roots were significantly increased by foliar spraying with micronutrients (FS) compared with control treatment. Seed soaking in micronutrients solution (SS) increased extractable white sugar % and juice purity% through improving sugar beet quality by increasing gross sugar% and reducing K+ Na and N contents and loss sugar%. Beet plants of SS or/and FS outyielded control plants in white sugar yield. The maximum white sugar yield was obtained from the treatments containing seed soaking (SS). This may be due to the considerable increase in root yield and white sugar extraction percentage. These results are in accordance with those reported by Ebrahim (1988). Shaban and Negm (2008) reported that combination of Zn and B increased significantly sugar yield over the control. Sorour *et al* (2009) reported that seed soakig increased dru matter, LAI and CGR.

4.d. Effect of interaction :

The interactions irrigation regimes × nitrogen rates for the concentration of amino-nitrogen and white sugar% in both seasons, irrigation regimes × micronutrients for white sugar% in both seasons and amino-nitrogen in the first season, nitrogen rates × micronutrients for amino-nitrogen in both seasons. The entire first and second order interactions had a significant effect on white sugar yield in both seasons (Table 9).

Irrigation regime × nitrogen rate interaction (IxN): The highest white sugar yield per feddan was obtained from beets irrigated at 55% DAM and fertilized with 90 kg N/feddan, while the lowest one was obtained from beets those irrigated at 70% DAM and fertilized by 75 kg N/feddan in the two seasons.

Irrigation regime × micronutrients interaction (IxM): The higher white sugar yield was achieved by irrigation at 55% DAM along with either SS+FS or SS in both seasons. However, the lowest one was achieved by irrigation at 70% DAM without micronutrients.

Nitrogen rate × micronutrients interaction (NxM): Data show clearly that beets received 90 kg N/feddan along with SS+FS or SS produced the greatest white sugar yield, while those received 75 kg N/feddan without micronutrients produced the lowest one in both seasons.

Irrigation regime × nitrogen rate × micronutrients interaction (IxNxM): The combination of medium irrigation regime × high N rate × SS+FS produced the maximum white sugar yield in both seasons.

Table 9. Sugar yield (t/fed.) of sugar beet as affected by the interactions among irrigation regime, nitrogen rate and micronutrient in 2007/8 and 2008/9 seasons

Irrigation (I) DAM	Micro-nutrients (M)	2007/8 season			2008/9 season		
		Kg N/fed. (N)		Mean	Kg N/fed. (N)		Mean
		75	90		75	90	
		I x N-Mean		I-Mean	I x N-Mean		I-Mean
40%		3.952 b	4.155 b	4.053 a	4.022 c	4.278 bc	4.150 b
55%		4.289 b	4.712 a	4.500 a	4.484 b	4.838 a	4.661 a
70%		3.117 c	3.299 c	3.208 b	3.121 e	3.435 d	3.278 c
		N x M-mean		M-mean	N x M-mean		M-mean
	C	3.420 c	3.543 c	3.481 c	3.457 e	3.676 de	3.567 c
	SS	3.976 ab	4.291 a	4.134 a	4.001 bcd	4.343 ab	4.172ab
	FS	3.687 bc	3.995 ab	3.841 b	3.848 cd	4.155 bc	4.001 b
	SS+FS	4.06 ab	4.392 a	4.226 a	4.196 abc	4.561 a	4.378 a
		I x N x M-Mean		IxM-Mean	I x N x M-Mean		IxM-Mean
40%	C	3.712 c-h	3.806 c-h	3.759 def	3.652 f-j	3.772 e-i	3.712 ef
	SS	4.178 b-e	4.297 bcd	4.238 cd	4.176 c-g	4.479 b-e	4.327 cd
	FS	3.864 c-g	4.088 b-f	3.976 cde	3.967 d-h	4.240 c-f	4.104 de
	SS+FS	4.052 b-f	4.430 a-d	4.241 cd	4.294 c-f	4.620 a-d	4.457 bcd
55%	C	3.785 c-h	4.086 b-f	3.936 cde	3.973 d-h	4.257 c-f	4.115 de
	SS	4.469 abc	5.061 a	4.765 ab	4.648 a-d	5.054 ab	4.851 ab
	FS	4.122 b-e	4.634 ab	4.378 bc	4.445 b-e	4.758 abc	4.602 bc
	SS+FS	4.78 ab	5.065 a	4.923 a	4.868 abc	5.283 a	5.076 a
70%	C	2.764 i	2.736 i	2.750 h	2.744 k	3.000 jk	2.872 g
	SS	3.282 ghi	3.516 e-h	3.399 fg	3.18 ijk	3.497 g-j	3.339 f
	FS	3.073 hi	3.265 ghi	3.169 gh	3.132 ijk	3.465 hij	3.299 fg
	SS+FS	3.349 f-i	3.679 d-h	3.514 efg	3.427 hij	3.779 e-i	3.603 f

Application of SS or FS separately along with medium irrigation regime and high N rate was statistically at par with the mention combination in white sugar yield. The combination of low irrigation regime × low N rate × without micronutrients produced the lowest white sugar yield in both seasons.

5. Water relations:

Water consumptive use (WU) by sugar beet plants from sowing to harvest and water consumptive use efficiency for root (WUER) and for white sugar (WUES) are illustrated in Tables 10, 11 and 12.

5.a. Effect of irrigation regime :

As soil moisture regime increased water consumptive use (WU) was increased due to more improved growth and perhaps luxury consumptive of water (Sorour, 1995, El-Zayat, 2000 and El-Sarag, 2009). Water use efficiency for root or white sugar production were increased by increasing depletion of available soil moisture up to 55%, then it decreased. This could be attributed to increase of root and white sugar yields at 55% DAM. In this connection, Sorour (2009) stated that water use efficiency for root or white sugar production were increased by increasing depletion of available soil moisture up to 60%, then it decreased. El-Sarag (2009) on sandy soil found that increasing irrigation intervals from 5 to 11 days sharply reduced consumptive use, while, irrigation every 8 days was superior in water use efficiency.

5.b. Effect of nitrogen rates:

Water consumptive use was increased as nitrogen rate increased from 75 to 90 kg N/feddan. This may be attributed to the considerable increase in leaf area index at high nitrogen rate which resulted in a greater transpiration and in turn higher water consumptive use. Increasing nitrogen rate slightly increased water use efficiency for root and white sugar. Similar resultes were obtained by El-Zayat (2000).

5.c. Effect of micronutrients:

Application of micronutrients slightly increased WU in both seasons. However, it substantially increased WUER and WUES. The treatment SS+FS recorded the best values of WUER and WUES. This may be due to increase of root yield and white sugar yield at

Table 10. Seasonal consumptive use (m^3/frddan) of sugar beet as affected by irrigation regime, nitrogen rate, micronutrient and their interactions in 2007/8 and 2008/9 seasons

Irrigation (I) DAM	Micro-nutrients (M)	2007/8 season Kg N/fed. (N) 75	90	Mean	2008/9 season Kg N/fed. (N) 75	90	Mean
		I x N-Mean		I-Mean	I x N-Mean		I-Mean
40%		2277	2378	2328	2304	2418	2361
55%		2113	2202	2157	2160	2218	2189
70%		1545	1622	1584	1559	1614	1587
		N x M-mean		M-mean	N x M-mean		M-mean
	C	1959	2048	2003	1985	2060	2022
	SS	1977	2066	2021	2006	2081	2044
	FS	1972	2061	2017	2001	2076	2038
	SS+FS	2005	2095	2050	2040	2117	2078
		I x N x M-Mean		IxM-Mean	I x N x M-Mean		IxM-Mean
40%	C	2250	2350	2300	2286	2398	2342
	SS	2277	2378	2328	2299	2413	2356
	FS	2265	2366	2316	2297	2411	2354
	SS+FS	2316	2419	2367	2334	2449	2392
55%	C	2096	2185	2141	2131	2188	2160
	SS	2115	2204	2159	2166	2223	2194
	FS	2113	2202	2157	2151	2209	2180
	SS+FS	2127	2217	2172	2193	2252	2223
70%	C	1531	1608	1570	1538	1593	1565
	SS	1539	1615	1577	1553	1608	1580
	FS	1539	1616	1578	1554	1609	1581
	SS+FS	1572	1651	1611	1592	1648	1620
N-Mean		1978	2068		2008	2083	

Table 11. Water use efficiency for root yield (Kg root/m^3 water) of sugar beet as affected by irrigation regime, nitrogen rate, micronutrient and their interactions in 2007/8 and 2008/9 seasons

Irrigation (I) DAM	Micro-nutrients (M)	2007/8 season			2008/9 season		
		Kg N/fed. (N)		Mean	Kg N/fed. (N)		Mean
		75	90		75	90	
		I x N-Mean		I-Mean	I x N-Mean		I-Mean
40%		12.02	12.45	12.24	11.82	12.37	12.10
55%		13.65	14.46	14.05	13.04	14.04	13.54
70%		13.46	13.59	13.52	12.46	13.39	12.93
		N x M-mean		M-mean	N x M-mean		M-mean
	C	12.04	12.24	12.14	11.37	12.00	11.68
	SS	13.54	14.07	13.80	12.70	13.62	13.16
	FS	12.88	13.35	13.12	12.44	13.28	12.86
	SS+FS	13.70	14.34	14.02	13.26	14.17	13.71
		I x N x M-Mean		IxM-Mean	I x N x M-Mean		IxM-Mean
40%	C	11.54	11.71	11.62	10.95	11.08	11.02
	SS	12.57	12.75	12.66	12.16	12.93	12.54
	FS	11.86	12.30	12.08	11.71	12.33	12.02
	SS+FS	12.11	13.04	12.57	12.46	13.13	12.80
55%	C	12.46	13.13	12.80	11.87	12.78	12.33
	SS	14.03	15.20	14.62	13.33	14.37	13.85
	FS	13.20	14.19	13.69	13.01	13.98	13.49
	SS+FS	14.91	15.31	15.11	13.95	15.03	14.49
70%	C	12.12	11.88	12.00	11.28	12.13	11.71
	SS	14.01	14.25	14.13	12.63	13.57	13.10
	FS	13.60	13.56	13.58	12.59	13.53	13.06
	SS+FS	14.09	14.67	14.38	13.35	14.34	13.85
N-Mean		13.04	13.50		12.44	13.27	

application of micronutrients through SS+FS and in turn water use efficiency in both seasons.

5.d. Effect of interaction :

Means of WU, WUER and WUES as influenced by the first and the second order interactions are presnted in Table 10, 11 and 12.

Irrigation regime × nitrogen rate interaction (IxN): Water consumptive use (WU) was increased by increasing irrigation water regime and N rate. However, water stress resulted in increased water consumptive use efficiency for root (WUER) and sugar (WUES) at any N rate. The best water use efficiency for root and sugar were obtained from irrigation at 55% DAM along with application of 90 kg N/feddan.

Irrigation regime × micronutrients interaction (IxM): Application of micronutrients resulted in a slightly increase in WU at any irrigation rate. Abundance soil moisture increased WU at any micronutrients treatment. However, WUER and WUES were improved by application of micronutrients at the same irrigation regime. The higher WUER and WUES were achieved by irrigation at 55% DAM along with either SS+FS or SS in both seasons.

Nitrogen rate × micronutrients interaction (NxM): Application of micronutrients had slightly effect on WU at the same nitrogen rate. However, WU was increased by increasing nitrogen rate at any micronutrients treatment. Data show clearly that beets received 90 kg N/feddan along with SS+FS recorded the highest values of WUER and WUES.

Irrigation regime × nitrogen rate × micronutrients interaction (IxNxM): Data in Table 10 that abundance of soil moisture in root zone substantially increased WU at any combination of nitrogen rate and micronutrients in both seasons. The highest values of actual WU (2419 and 2449 m^3/feddan) were obtained from the combination of high irrigation regime × high N rate × SS+FS, while the lowest WU values (1531 and 1538 m^3/feddan) were obtained from low irrigation regime × low N rate × without micronutrients in the two seasons, respectively. The increase of actual water consumptive use at the combination of high irrigation regime × high N rate × SS + FS can be attributed to increase

Table 12. Water use efficiency for white sugar yield (Kg white sugar/m^3 water) of sugar beet as affected by irrigation regime, nitrogen rate, micronutrient and their interactions in 2007/8 and 2008/9 seasons

Irrigation (I) DAM	Micro-nutrients (M)	2007/8 season Kg N/fed. (N) 75	90	Mean	2008/9 season Kg N/fed. (N) 75	90	Mean
		I x N-Mean		I-Mean	I x N-Mean		I-Mean
40%		1.74	1.75	1.74	1.75	1.77	1.76
55%		2.03	2.14	2.08	2.07	2.18	2.13
70%		2.02	2.03	2.02	2.00	2.13	2.06
		N x M-mean		M-mean	N x M-mean		M-mean
	C	1.75	1.73	1.74	1.75	1.80	1.77
	SS	2.03	2.09	2.06	2.00	2.10	2.05
	FS	1.88	1.95	1.92	1.94	2.02	1.98
	SS+FS	2.04	2.12	2.08	2.07	2.17	2.12
		I x N x M-Mean		IxM-Mean	I x N x M-Mean		IxM-Mean
40%	C	1.65	1.62	1.63	1.60	1.57	1.59
	SS	1.84	1.81	1.82	1.82	1.86	1.84
	FS	1.71	1.73	1.72	1.73	1.76	1.74
	SS+FS	1.75	1.83	1.79	1.84	1.89	1.86
55%	C	1.81	1.87	1.84	1.86	1.95	1.90
	SS	2.11	2.30	2.20	2.15	2.27	2.21
	FS	1.95	2.10	2.03	2.07	2.15	2.11
	SS+FS	2.25	2.28	2.27	2.22	2.35	2.28
70%	C	1.80	1.70	1.75	1.78	1.88	1.83
	SS	2.13	2.18	2.15	2.05	2.17	2.11
	FS	2.00	2.02	2.01	2.02	2.15	2.08
	SS+FS	2.13	2.23	2.18	2.15	2.29	2.22
N-Mean		1.93	1.97		1.94	2.02	

evaporation at high available moisture; more supplying plants with sufficient moisture led to an increase in green cover and hence increase transpiration. Although, medium irrigation regime was equivalent to high irrigation regime in root and sugar yields at the combination of high N rate × SS+FS, medium regime was lower in water consumptive use and it saved 202 and 197 m^3 water consumptive use than high irrigation regime in the two seasons, respectively. Tables 11 and 12 showed that WUER and WUES were increased by increasing depletion of available soil water from 40 to 55% DAM and then it decreased at any combination of nitrogen rate and micronutrients in both seasons. The combination of medium irrigation regime × high N rate × SS+FS recorded the highest values of WUER 15.31 and 15.03 kg root/m^3 water use and WUES 2.28 and 2.35 kg whit sugar /m^3 water use in the first and second seasons, respectively. This may be due to increase root and whit sugar yields. However, the combination of high irrigation regime × low N rate × without micronutrients recorded the lowest values of WUER 11.54 and 10.95 kg root/m^3 water use in the first and second seasons, respectively. The combination of high irrigation regime × high N rate × without micronutrients recorded the lowest values of WUES 1.62 and 1.57 kg whit sugar /m^3 water use in the first and second seasons, respectively. Application of SS did not differ than SS+FS in WU, WUER, WUES, root yield and sugar yield at medium irrigation regime and high N rate.

It can be concluded from this study that the irrigation at 55% DAM along with 90 kg N/feddan and SS+FS or SS was the recommended treatment for optimum root and extractable white sugar yield per unit area with less water consumptive use at Kafrelshiekh Governorate

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الملخص العربي

إستجابة بنجر السكر لمستويات الرى ومعدلات النيتروجين وإستخدام العناصر الصغرى

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تم زراعة بنجر السكر صنف "فريدا" فى تربة طينيه بمحطة بحوث إدارة المياه- وزارة الرى بالقرضا- كفرالشيخ موسمي 2008/2007، 2009/2008، لدراسة إستجابة نمو ومحصول وجودة جذور بنجر السكر وإستهلاكة المائى لثلاث مستويات رى (الرى عند إستنفاذ 40%، 55%، 70% من الماء الميسر فى التربه حتى عمق 60سم من سطح التربه) ومعدلين من السماد النيتروجينى (75، 90كجم ن/فدان) وأربع معاملات بالعناصر الصغرى (إستخدم محلول من مخلوط العناصر الصغرى فى نقع التقاوى، الرش الورقى، نقع التقاوى+ الرش الورقى، الى جانب معاملة المقارنة). وقد إحتوى محلول العناصرعلى مخلوط من حمض البوريك وكبريتات كل من الزنك و الحديد والمنجنيز بمعدل 2جرام من كل منها.

وكانت أهم النتائج كما يلى:

أدت وفرة الرطوبه الأرضيه الميسرة فى منطقة الجذور إلى زيادة الوزن الجاف للنبات، دليل مساحة الأوراق، سمك الجذر، معدل النمو، محصول العرش، الإستهلاك المائى. وكان التأثير عكسى على نسبة الجذر إلى العرش، طول الجذر، تركيز السكر الكلى فى الجذور. وبالرغم من أن زيادة مستوى الرطوبه الأرضيه الميسرة أدت إلى نقص محتوى السكر الكلى فى الجذور، إلا أنها أدت أيضا الى تقليل محتوى عصير الجذور من المواد الغير سكريه الذائبه (البوتاسيوم، الصوديوم، النيتروجين الأمينى)، مما يؤدى إلى زيادة نقاوة العصير. حيث أن زيادة هذه المواد الغير سكريه فى الجذور يتعارض مع عملية إستخلاص السكر الأبيض وتؤدى إلى زيادة نسبة السكر المفقود فى المولاس والمنتجات الأخرى. وقد أعطت النباتات المرويه عند إستنفاذ 55% من الماء المتيسر أعلى معدل كفاءة تمثيلية، محصول جذور, نسبة سكر أبيض مستخلص، محصول سكر أبيض، كفاءة إستعماليه للماء لإنتاج الجذور أو السكر الأبيض. أدت زيادة معدل السماد النيتروجينى من 75 الى 90كجم ن/فدان إلى زيادة الوزن الجاف للنبات، دليل مساحة الأوراق، معدل النمو طول ووزن الجذر، محاصيل الجذور والعرش والسكر الأبيض للفدان، تركيز النيتروجين الأمينى والصوديوم + البوتاسيوم فى الجذور، الإستهلاك المائى. وعلى العكس، فقد أدى نقص معدل النيتروجين الى زيادة معنويه فى نسبة الجذر إلى العرش، محتوى السكر الكلى، نسبة السكر الأبيض المستخلص، نقاوة العصير. ولم يؤثر معدل النيتروجين على كفاءة الماء المستهلك فى إنتاج الجذور أو السكر الأبيض.

أدى إستخدام العناصر الصغرى فى نقع التقاوى والرش الورقى معا الى إنتاج أعلى وزن جاف للنبات، نسبة الجذر الى العرش، دليل مساحة الأوراق، معدل النمو، طول وسمك ووزن الجذر، محاصيل الجذور والعرش والسكر الأبيض للفدان، نسبة سكر كلى، نسبة سكر أبيض، نسبة نقاوة عصير، كفاءة الماء المستهلك فى إنتاج الجذور والسكر الأبيض. ولم تختلف معاملة نقع البذور معنويا عن معاملة النقع + الرش الورقى فى معظم القياسات السابق ذكرها وخاصة محصول الجذور ومحصول السكر. وقد أدى الرش الورقى بمحلول العناصر الصغرى الى زيادة تركيز كل من النيتروجين الأمينى والصوديم والبوتاسيوم فى الجذور وكذلك زيادة معظم الصفات السابق ذكرها عن معاملة المقارنة.

أثرت كل التفاعلات بين العوامل المختلفه معنويا على محصولى الجذور والسكر الأبيض للفدان. وقد تحقق أعلى محصولى جذور وسكر أبيض وأفضل كفاءة إستعماليه للماء من النباتات المرويه عند إستنفاذ 55% من الماء المتيسر بالتربه ومسمدة بمعدل 90كجم ن/فدان مع العناصر الصغر بنقع التقاوى والرش الورقى معا.

ومن نتائج هذه الدراسه يمكن التوصيه بزراعة بنجر السكر بتقاوى منقوعة فى محلول العناصر الصغرى مع الري عند أستنفاذ 55% من الماء المتيسر والتسميد بمعدل 90كجم ن/فدان مع الرش بالعناصر للحصول علي أعلي أنتاجيه بأقل إستهلاك مائى وذلك تحت ظروف محافظة كفر الشيخ.