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EFFECT OF REGULATED DEFICIT IRRIGATION AND BORON RATES ON SUGAR BEET PRODUCTIVITY IN NEWLY RECLAIMED SOILS

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ABSTRACT: ***A field experiment was conducted at Km 71 West Nubaria, Alex./ Cairo desert Road, El-Behiera Government, Egypt, during two successive winter seasons, 2017/18 and 2018/ 19. The objective was to study the effect of five regulated deficit irrigation treatments [I_1 = No stress at all physiological stages, I_2 = skip irrigation at the beginning of development stage (60 days from sowing), I_3 = skip irrigation during development stage (90 days from sowing), I_4 = skip irrigation at mid season (120 days from sowing) and I_5 = skip irrigation at late season (150 days from sowing)], and four rates of boron fertilizer applied as boric acid,[B_1 = Without B (control), B_2 = 0.5 kg B/fed, B_3 = 0.75 kg B/fed, and B_4 = 1.0 kg B/ fed] on sugar beet yield and quality, amounts of applied irrigation water and water utilization efficiency. The results showed that irrigation treatments and boron rates had a significant effect on root, shoot and sugar yields. The obtained results indicated that the reductions in root yield were 9.55, 6.43, 5.58 and 0.84 t/fed, while for sugar yields were 1.89, 1.34, 1.22 and 0.10 t/fed for I_2, I_3, I_4 and I_5, respectively compared to no stress treatment. The results showed that the combined effect of irrigation treatment I_1 (no stress at all stages) and boron fertilizer rate B_2 (0.5 kg B/fed) gave the highest average values of root yield (35.041 t/fed) and sugar yield (6.315 t/fed) over the two seasons. On the other hand the average amount of applied irrigation values were 2145, 1929, 1822, 1858 and 1895 m^3/fed for the I_1, I_2, I_3, I_4 and I_5 irrigation treatments, respectively. Likewise, the highest average water utilization efficiency for sugar beet root and sugar yields of 16.523 kg root/m^3 water applied and 2.951 kg sugar/m^3 water applied were obtained with the irrigation treatment I_5 (skip irrigation at late season stage) and boron fertilizer B_3 (0.75 kg B/ fed) over two seasons. It could be maintained herein that the no stress irrigation water I_1, with 0.75 kg B/fed treatment achieved the highest yield of sugar beet (root and sugar) of the availability of sufficient irrigation water. Otherwise it is suggested to follow the irrigation treatment I_5 (no irrigation at late season) and applying boron fertilizer at rate of 0.75 kg B/fed obtain high sugar beet yields.***

Key words: ***Sugar beet – water stress – Boron – sugar yield – Water utilization***

INTRODUCTION

Sugar beet (Beta vulgaris L.) is one of the important winter crops in Egypt. It is well adapted to Egyptian environment especially in the newly reclaimed calcareous and sandy soils. The crop has essential position in winter crop rotation, not only in fertile soils but also in poor sandy, saline-alkaline and calcareous soils. Also, it consumes less water than sugar cane. Water use efficiency for producing one kilogram of sugar needs about 1.4 and 4.0 m^3 water by sugar beet and sugar cane, respectively (Quda, 2001). The need for water by different plant species depend on how much moisture stress, they are able to tolerate at any particular stage of growth. English (1990) stated that, controlled deficit irrigation proved to be an efficient tool for further research. Under water shortage conditions, this technique relates the drought stress on the plant at a given phonological stage to possible decreases in the production or quality of the crop harvested. Doorenbos and Pruitt (1975) described the physiological stages of sugar beet as: initial (25-30 days), crop development (35-60 days), mid- season (50-70 days), late season (30-50 days), and ripening (till harvesting). Yonts *et al.* (1999) showed that limited irrigation under furrow or sprinkler systems resulted in decrease in root and sugar yields by 3.8 t/ha and 0.6 t/ha, respectively compared to the full irrigation treatment. Emara *et al.* (2000) showed that the average seasonal water applied for sugar beet was ranged between 2720 to 1699 m^3/ fed. (64.8- 40.4 cm) depending upon stress status. Ibrahim *et al.* (2002) showed that the highest values of sugar beet root yield (34.95 and 30.20 t/fed) and sugar yield (5.00 and 3.18 t/ fed) were obtained under drought period of 6 weeks before harvesting in the first and second seasons, respectively in clay soil.

Boron is, by far, the most important trace element needed by sugar beet because the yield and quality of roots is very depressed without an adequate supply of it (Cooke and Scott, 1993; and Allen *et al.* 2007). Adequate boron (B) nutrition is critical for high yields and quality of crops. Boron increases the rate of transport of sugars (which are produced by photosynthesis in mature plant leaves) to actively growing parts and in developing fruits. Hellal *et al.* (2009) showed that all boron doses (0, 25, 50 and 100 ppm) as boric acid foliar spray found to give a significant increase in the shoot and root yields of sugar beet as compared to the untreated plants. Application of 50 ppm B was the best for achieving maximum fresh shoot and root yields as compared to other boron treatments. Positive effect of Boron may be due to its role in cell elongation and turgidity, while in case of boron deficiency plant leaves were reported to be smaller, stiff and thick (Brown and Hu, 1996).

This work was carried out to investigate the effect of five regulated deficit irrigation treatments and four boron fertilizer rates on sugar beet yield, quality, amounts of applied water and water utilization efficiency in the newly reclaimed loamy sand soils of West Nubaria region.

MATERIALS AND METHODS

A field experiment was carried out during the two winter seasons of 2017/18 and 2018/19 at km 71 West Nubaria, Alexandria/Cairo Desert Road, El-Behiera Government, Egypt. Soil samples were collected before sowing from two depths of 0-30 and 30-60 cm to determine soil physical (particle sizes, textural class, and bulk density) and chemical (EC, pH, cations and anions) properties (Page *et al.,* 1982), and some soil hydro-physical (field capacity, wilting point, and available soil moisture) parameters. The values of analysis are given in Tables 1 and 2.

Experimental design and tested variables:

The experiment was laid out in a split plot design with three replicates. The main plots were assigned to the deficit irrigation treatments, while four boron rates as boric acid (H_3BO_3, 17%) were randomly distributed in the sub-plots. The tested treatments were as follows:

Table (1): Some chemical and physical properties of soil at the experimental site.

Soil depth (cm)	EC (dS/m)	pH	Chemical parameters						
			Cations (meq/L)				Anions (meq/L)		
			Ca	Mg	Na	K	HCO_3	Cl	SO_4
0-30	1.14	7.35	3.10	2.30	4.65	1.20	2.72	7.09	0.98
30- 60	1.04	7.15	3.20	2.40	4.55	1.30	2.70	7.29	0.80

Soil depth (cm)	Physical parameters				
	Sand (%)	Silt (%)	Clay (%)	Textural class	Bulk density (g/cm^3)
0-30	87.41	6.87	5.72	loamy Sand	1.43
30-60	86.29	7.93	5.78	loamy Sand	1.59

Table (2): Field capacity (FC), Wilting point (WP), and available soil moisture (ASM) values of the soil at experimental site.

Soil depth (cm)	FC (%)	WP (%)	ASM (%)
0-30	17.60	9.56	8.04
30-60	15.65	8.51	7.14
Average	16.63	9.04	7.59

Deficit irrigation (main plots):

I_1 = No stress at all physiological stages.

I_2 = No irrigation at the beginning of development stage (60 days from sowing).

I_3 = No irrigation at the development stage (90 days from sowing).

I_4 = No irrigation at mid season (120 days from sowing).

I_5 = No irrigation at late season (150 days from sowing).

Boron rates (sub-plots):

B_1 = without (control)

B_2 = 0.5 kg B/fed

B_3 = 0.75 kg B/fed

B_4 = 1.0 kg B/fed

Solutions were prepared for use by dissolving appropriate amount of (H_3BO_3) in 400 L of deionized water and were sprayed in two equal doses after 50 and 70 days from sowing.

Cultural practices:

The area of experimental plot was 21 m^2 (1/200 fed). Each plot included six ridges, 0.5 meter apart and 7.0 meters in length. During land preparation, calcium super phosphate (15.5% P_2O_5) at the rate of 100 kg/fed, potassium sulfate (48% K_2O) at the rate of 50 kg/fed were incorporated into the soil. Nitrogen fertilizer in the form of Urea (46% N) as side dressing at the rate of 100 kg N/fed, was applied in two equal doses, half after thinning (before the first irrigation) and the other half before the second irrigation.

Sugar beet balls were hand sown, 3- 5 balls par hill on one side of the ridge on the 13th and 21st of September and plants were harvested after 6 months at 2017/18 and 2018/19 seasons, respectively. Plants were thinned at the fourth leaf growth stage to obtain one plant/hill. The common agricultural practices for growing sugar beet according to the recommendations of Ministry of Agriculture were followed, except for the studied factors. At the harvest time the plants were uprooted and topped, then the following data were collected:

A- Sugar beet yield and its components:

I- Yield parameters:

1- Root yield (t/fed).

2- Shoot yield (t/fed).

3- Sugar yield (t/fed). It was calculate as follows:

$$Sugar\ yield = Root\ yield\ \left(\frac{t}{fed}\right)\ X\ sucrose\ (\%)$$

II- Quality characters:

1- Sucrose percentage.
2- Total soluble solids (TSS, %). It was measured in fresh roots juice by using Hand Refractometer according to Me Ginnis (1982).
3- Purity percentage.

B- Soil water relations:

1- Potential crop evapotranspiration (ET_p):

Potential crop evapotranspiration (ET_p) values for the two growing seasons were calculated by using the weather data from weather station established at Nubaria Research Station, using CROPWAT model (Smith, 1991) based on FAO, Penman- Monteith method. The equation is given as:

$$ETo = \frac{0.408\,\Delta\,(Rn - G) + \gamma\,[900/(T+273)]\,U_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,U_2)}$$

where:

Rn = net radiation (MJ $m^{-2}d^{-1}$)

G = soil heat flux (MJ $m^{-2}d^{-1}$)

Δ = slope of vapor pressure and temperature curve (kPa $^oC^{-1}$)

Γ = psychrometric constant (kPa $°C^{-1}$)

U_2 = wind speed at 2 m height (ms^{-1})

e_s-e_a = vapor pressure deficit (kPa)

T = mean daily air temperature at 2 m height (°C)

The crop evapotranspiration (ETc) values were calculated according to following equation:

$$ETc = ETp\ X\ Kc$$

where:

ET_c = Crop evapotranspiration (mm/day).

ET_p= Potential evapotranspiration (mm/day).

K_c = Crop coefficient. The values for sugar beet crop are presented in Table 3.

2- Amount of applied irrigation water (AIW):

The amount of applied irrigation water was measured by a flow meter and was calculated according to the following equation:

$$AIW = \frac{ETc}{Ea\ (1 - LR)}$$

where:

AIW = Applied irrigation water depth (mm/day).

E_a = Irrigation efficiency (70% for surface irrigation system under experimental conditions).

LR = Leaching requirements (10% of applied irrigation water).

3- Water utilization efficiency (WUE - kg/ m^3):

Water utilization efficiency values were calculated according to Doorenbos and Pruitt (1975) as follows:

1- WUE for roots yield (kg/m^3) =

$$\frac{Roots\ \ yields\ \ in\ \ Kg\,/\,fed}{Water\ \ applied\ \ in\ \ m3\,/\,fed}$$

2- WUE for sugar yield (kg/m^3) =

$$\frac{Sugar\ \ yields\ \ in\ \ Kg\,/\,fed}{Water\ \ applied\ \ in\ \ m3\,/\,fed}$$

Statistical analysis:

Data of the two seasons were combined and analyzed by “MSTAT” computer software package and a least significant difference (L.S.D) method was used to test the differences between treatments. Means at 5% probability level were compared. Statistical analysis was done according to Steel and Torrie (1981).

RESULTS AND DISCUSSION

A- Sugar beet yield and yield components:

I- Yield characters (roots, shoot and sugar yields):

The 2017/18 and 2018/19 combined analysis of the effect of irrigation treatments and boron rates on root, shoot and sugar yields (t/fed) is presented in Table 4. The results showed that irrigation treatments and boron fertilizer rates had a significant effect on root, shoot and sugar yields. The highest mean values of 27.252, 7.969, and 4.764 t/fed over the two seasons for root, shoot, and sugar yields, respectively were obtained as affected by the I_1 treatment (no stress at all physiological stages), which may be ascribed to that plants did not suffer from water stress at any stage during the growing season. The obtained data revealed that water stress during late season stage did not significantly reduce root, shoot, and sugar yields. While, the same traits were significantly reduced when the plants were subjected to water stress during beginning, development and mid-season stages as compared to no stress treatment.

The 2-year average recorded in root yields reached 9.55, 6.43, 5.58 and 0.84 t/fed, for shoot yields were 5.06, 3.97, 1.18 and 1.12 t/fed, and for sugar yields were 1.89, 1.34, 1.22 and 0.10 t/fed affected by I_2, I_3, I_4, and I_5 treatments, respectively as compared to non stress (I_1) treatment. Results indicated that, the application of I_1 (no stress) and I_5 (stress at late season stage) will not significantly affect root, shoot, and sugar yields under experimental conditions. The obtained results may be due to the effect of moisture stress on vegetative growth stage of sugar beet plants. The results agreed with those reported by Ibrahim *et al.* (2002) and Emara *et al.* (2000). Also, Wittenmayer and Schiling (1998) mentioned that, as sugar beet is subjected to water stress, the root yield decreased. Dunham (1993) found that early water stress during beginning of development stage decreased root yield more than the late stress.

In regard to the effect of boron fertilizer rates on root, shoot and sugar yields (Table 4). The results indicated that increasing boron rates 0.5, 0.75, and 1.0 kg B/fed, increased root yields by 4.449, 6.270 and 3.908 t/fed, shoot yields by 1.595, 2.176 and 1.315 t/fed, and sugar yields by 0.958, 1.207 and 0.746 t/fed, respectively as compared with the control treatment (B_1). Results indicated that, spraying sugar beet crop with 0.75 kg B/fed gave the highest values of root, shoot and sugar yields. The effect of boron application may be due to the important functions of boron in stimulating plant metabolism, development and growth (Abido, 2012). Also, sugar beet yield reduction at the high level of boron is attributed to the toxicity influence of this element (Kristek *et al.,* 2006).

Table (3): Sugar beet crop coefficient values (Allen *et al.* 1998).

Stage	Period (day)	Crop Coefficient (K_c)
Initial stage	30 - 35	0.35
Development	45 - 60	1.20
Mid-season	90 - 70	0.70
Late season	15 - 40	0.50

Table (4): The effect of the deficit irrigation and boron rates treatments on root, shoot, and sugar yields of sugar beet crop.

Treatments	Root Yield (t/ fed)	Shoot Yield (t/ fed)	Sugar Yield (t/ fed)
Irrigation			
I_1	27.252 a	7.969 a	4.764 a
I_2	17.697 b	2.909 b	2.877 b
I_3	20.825 b	4.002 b	3.422 b
I_4	21.674 b	6.790 a	3.546 b
I_5	26.417 a	6.853 a	4.660 a
$L.S.D_{0.05}$	3.592	1.424	0.625
Boron			
B_1	19.116 b	4.433 b	3.126 b
B_2	23.565 a	6.028 a	4.084 a
B_3	25.386 a	6.609 a	4.333 a
B_4	23.024 a	5.748 a	3.872 a
$L.S.D_{0.05}$	2.678	1.217	0.447
Interaction			
I x B	***	***	***

The interaction effect of deficit irrigation and boron fertilizer rates treatments on root, shoot and sugar yields (t/fed) is presented in Table (5). Results indicated that, irrigation I_1 (no stress at all stages) and boron treatment B_2 (0.5 kg B/fed) bring about the highest value of root yield (35.041 t/fed) and sugar yield (6.315 t/fed). While, the lowest values of root (10.883 t/fed) and sugar yield (1.688 t/fed) were achieved with irrigation treatment I_2 (no irrigation at beginning development stage) and boron treatment B_1 (without boron fertilizer). Also, no irrigation at late season stage (I_5) and boron fertilizer rate of 0.5 kg B/fed, achieved the highest value of shoot yield (10.207 t/fed), while the lowest value of 2.197 t/fed was obtained with irrigation I_2 (no irrigation at beginning development stage) and boron fertilizer treatment B_2 (0.5 kg B/fed).

II- Quality characters (sucrose, total soluble solids, and purity percentages):

The effect of irrigation and boron rates treatments on sucrose, total soluble solids (TSS) and purity percentages is presented in Table (6). The results manifested that irrigation treatments and boron fertilizers rates had a significant effect on sucrose percentage and total soluble solids (TSS, %). However, no effect of the irrigation and boron fertilizer rates treatments was observed, on purity percentage. The highest mean values of sucrose percentage (17.71%) and total

soluble solids (23.50%) were induced with the irrigation treatment I_5 (no irrigation at late season stage), while the highest mean value of purity (76.3%) was obtained from irrigation treatment I_2. The results in Table 6, revealed also that spraying sugar beet plants by 0.75 kg B/fed caused the highest values of sucrose percentage (17.14%) and total soluble solids content (22.93%). The highest value of purity percentage (75.4%) was occurred with boron fertilizer treatment B_4 (1.0 kg B/fed). These findings were in line with that found by Hellal *et al.* (2009), who stated that sucrose% increased with increasing boron doses.

Table (5): Interaction effect of deficit irrigation and boron rates treatments on root, shoot, and sugar yields of sugar beet crop.

Irrigation	Boron	Root Yield (t/ fed)	Shoot Yield (t/ fed)	Sugar Yield (t/ fed)
I_1	B_1	18.928	7.474	3.217
	B_2	35.041	6.238	6.315
	B_3	29.120	9.159	5.218
	B_4	25.918	9.005	4.304
I_2	B_1	10.883	2.759	1.688
	B_2	22.534	2.197	3.753
	B_3	18.048	4.037	2.988
	B_4	19.323	2.643	3.078
I_3	B_1	15.633	4.212	2.409
	B_2	15.113	3.348	2.303
	B_3	26.670	4.678	4.507
	B_4	25.883	3.768	4.468
I_4	B_1	25.429	5.020	4.165
	B_2	22.517	8.149	3.668
	B_3	21.785	6.941	3.360
	B_4	16.963	7.048	2.991
I_5	B_1	24.705	2.701	4.150
	B_2	22.622	10.207	4.381
	B_3	31.308	8.230	5.591
	B_4	27.034	6.275	4.518
$L.S.D_{0.05}$		4.975	2.261	0.830

Table (6): Quality characters of Sugar beet crop as affected by the deficit irrigation and boron application .

Treatments	Sucrose (%)	TSS (%)	Purity (%)
		Irrigation	
I_1	17.60 a	23.17 a	76.2 a
I_2	16.23 b	21.50 b	76.3 a
I_3	16.24 b	22.17 b	73.6 a
I_4	16.47 b	22.33 b	73.8 a
I_5	17.71 a	23.50 a	75.4 a
$L.S.D_{0.05}$	0.65	0.75	N.S.
		Boron	
B_1	16.24 b	21.73 b	74.7 a
B_2	17.12 a	22.87 a	75.3 a
B_3	17.14 a	22.93 a	74.7 a
B_4	16.89 a	22.60 a	75.4 a
$L.S.D_{0.05}$	0.59	0.75	N.S
		Interaction	
I x B	***	***	***

The interaction effect of irrigation treatments and boron fertilizers rates on sucrose, total soluble solids, and purity percentages are presented in Table 7. Results pointed out that irrigation treatment I_5 (no irrigation at late season stage) and boron fertilizer treatment B_2 (0.5 kg B/fed) scored the highest values of sucrose percentage (19.20%) and purity percentage (83.3%). While, the highest value of total soluble solids content (24.67%) was obtained from irrigation treatment (I_5) and boron fertilizer rate (B_3). The obtained results are in harmony with with those reported by Almin and Asgharipour (2012), who stated that spraying boron with concentrations of 8% (0.70 kg B/ha) and 12% (1.22 kg B/ha) significantly increased yield compared with the control. Also, sucrose concentration promoted significantly with the increase of boron concentration.

B- Soil water relations:

1- Potential evapotranspiration (ET_p):

Potential evapotranspiration (ETp) values calculated by FAO Penman-Montieth methods, using CROPWAT model for the two growing seasons are presented in Table 8. The seasonal ETp values were 53.14 and 50.92 cm in 2017/18 and 2018/19 growing seasons, respectively.

2- Amount of applied irrigation water (AIW):

The depths, amounts, and mean applied irrigation water by surface irrigation system to the sugar beet crop according to the irrigation treatments during the two growing seasons are

presented in Table 9. Results indicated that the AIW values were 2166, 1927, 1828, 1933 and 1989 m^3/fed for I_1, I_2, I_3, I_4 and I_5 irrigation treatments, respectively during the first season. The values were 2123, 1932, 1816, 1784 and 1800 m^3/fed. for the same respective treatments during the second season. The overall average of amount of applied irrigation water (AIW) values were 2145, 1929, 1822, 1858 and 1895 m^3/fed for the I_1, I_2, I_3, I_4 and I_5 irrigation treatments, respectively. The applied water for I2, I_3, I_4 and I_5 irrigation treatments were 10.01, 15.02, 13.35 and 11.64%, respectively less than I_1 treatment. The obtained results cleared that amount of applied water decreased by decreasing the number of irrigations according to the selected growth stage. The obtained results agreed with those of Doorenbos and Kassam (1979), Eid *et al.* (1987) and Abdel-Nasser *et al.* (2014).

Table (7): Interaction effects of deficit irrigation and boron rates treatments on quality characters of sugar beet crop.

Irrigation	Boron	Sucrose (%)	TSS (%)	Purity (%)
I_1	B_1	17.07	22.67	75.3
	B_2	18.13	22.67	80.0
	B_3	18.67	22.67	82.3
	B_4	16.53	22.67	67.0
I_2	B_1	15.63	21.33	73.3
	B_2	16.67	22.67	75.3
	B_3	16.57	22.67	73.0
	B_4	16.03	19.33	83.3
I_3	B_1	15.37	21.67	70.7
	B_2	15.27	23.67	65.0
	B_3	16.90	21.67	78.0
	B_4	17.43	21.67	80.7
		16.33	21.33	76.7
	B_2	16.33	22.33	73.0
	B_3	15.53	23.00	67.3
	B_4	16.67	22.67	78.0
I_5	B_1	16.80	21.67	77.3
	B_2	19.20	23.00	83.3
	B_3	18.03	24.67	73.0
	B_4	16.80	24.67	68.0
L.S.D$_{0.05}$		1.09	1.40	6.2

Table (8): Potential evapotranspiration (ETp) values during the two growing seasons.

Month	2017/18		2018/19	
	ETp (mm/day)	mm/Month	ETp (mm/day)	mm/month
Sep.	4.34	73.78	4.18	37.62
Oct.	3.11	96.41	3.09	95.79
Nov.	1.95	58.50	1.92	57.60
Dec.	1.34	41.54	1.25	38.75
Jan.	1.25	38.75	2.28	70.68
Feb.	1.96	56.84	2.70	75.60
Mar.	2.86	88.66	3.81	118.11
Apr.	4.05	76.95	5.01	15.03
Total (mm)		531.43		509.18

Table (9): Depths, amounts, and means of applied water (mm & m^3/fed) of different irrigation treatments for sugar beet crop during 2017/18 and 2018/19 growing seasons.

Days from sowing	Irrigation treatments									
	I_1		I_2		I_3		I_4		I_5	
	2017/18	2018/19	2017/18	2018/19	2017/18	2018/19	2017/18	2018/19	2017/18	2018/19
Sowing	189.50	145.90	189.5	145.90	189.5	145.90	189.5	145.90	189.5	145.90
40	91.34	83.86	91.34	83.86	91.34	83.86	91.34	83.86	91.34	83.86
60	56.90	45.26	-	-	56.90	45.26	56.90	45.26	56.90	45.26
90	80.43	72.93	80.43	72.93	-	-	80.43	72.93	80.43	72.93
120	55.45	80.71	55.45	80.71	55.45	80.71	-	-	55.45	80.71
150	42.05	76.71	42.05	76.71	42.05	76.71	42.05	76.71	-	-
Total (mm)	515.67	505.37	458.77	460.11	435.24	432.44	460.22	424.66	473.62	428.66
m^3/fed	2166	2123	1927	1932	1828	1816	1933	1784	1989	1800
Mean	2145		1929		1822		1858		1895	

3- Water utilization efficiency (WUE, kg/ m^3):

The effect of irrigation treatments and boron fertilizer rates on average water utilization efficiency as kg roots and sugar yields per cubic meter of applied water is presented in Table 10. Results indicated the highest WUE root and sugar yields values of 13.164 kg root/m^3 water and 2.460 kg sugar/m^3 water were obtained for irrigation treatment I_5 (no irrigation at late season stage). Also, the highest WUE root and sugar yield values of 13.164 kg root/m^3 water and 2.243 kg sugar/m^3 water were occurred due to boron fertilizer treatment B_3 (0.75 kg B/fed). The results coincided with those reported by Doorenbos and Pruitt (1975) and Osman *et al.* (2005).

The interaction effect of irrigation treatments and boron fertilizer rates on average water utilization efficiency values for root and sugar yields is presented in Table 11. The results showed that the highest WUE root and sugar yields values of 16.523 kg root/m^3 water and 2.951 kg sugar/m^3 water were obtained from irrigation treatments I_5 (no irrigation at late season stage) and boron fertilizer treatment B_3 (0.75 kg B/fed). Similar results were founed by Emara *et al.* (2000), who reported that the highest water utilization efficiency was 14 kg/m^3 which was accompanied with drought stress at late season growth stage.

Table (10): Average water utilization efficiency values for root and sugar yields as affected by deficit irrigation treatments and boron rates of sugar beet crop.

Treatments	WUE of root yield (kg/ m^3)	WUE of sugar yield (kg/ m^3)
I_1	12.709	2.222
I_2	9.258	1.491
I_3	11.429	1.878
I_4	11.665	1.909
I_5	13.942	2.460
$L.S.D_{0.05}$	1.643	0.289
B_1	9.954	1.626
B_2	12.074	2.088
B_3	13.164	2.243
B_4	12.010	2.010
$L.S.D_{0.05}$	1.337	0.225
I x B	***	***

Table (11): The interaction effect of deficit irrigation and boron fertilizer rate treatments on average water utilization efficiency values for root and sugar yields of sugar beet crop.

Irrigation	Boron	WUE of root yields (kg/m^3)	WUE of sugar yields (kg/m^3)
I_1	B_1	8.827	1.500
	B_2	16.341	2.945
	B_3	13.580	2.434
	B_4	12.087	2.008
I_2	B_1	5.640	0.875
	B_2	11.678	1.945
	B_3	9.353	1.548
	B_4	10.359	1.595
I_3	B_1	8.579	1.322
	B_2	8.294	1.264
	B_3	14.637	2.474
	B_4	14.205	2.452
	B_1	13.687	2.242
	B_2	12.119	1.975
	B_3	11.726	1.808
	B_4	9.130	1.610
I_5	B_1	13.038	2.190
	B_2	11.939	2.312
	B_3	16.523	2.951
	B_4	14.268	2.385
$L.S.D_{0.05}$		2.989	0.503

Conclusions

From the obtained results it could be concluded that:

1- Sugar beet yield and yield components were significantly reduced when the plants were subjected to water stress during beginning, development and mid season stages compared with no stress treatment.

2- The boron fertilizer rates had a significant effect on root, shoot and sugar yields.

3- The results showed that, irrigation treatment I_1 (no stress at all stages) and boron fertilizer treatment B_2 (0.5 kg B/fed) gave the highest values of root yield (35.041 t/fed) and sugar yield (6.315 t/fed).

4- Irrigation treatments and boron fertilizer rates had a significant effect on sucrose percentage and total soluble solids.

5- Average amount of applied irrigation values were 2149, 1929, 1822, 1858 and 1895 m^3/fed for I_1 (no stress at all stages), I_2 (stress at beginning development stage), I_3 (stress at development), I_4 (stress at mid-season) and I_5 (stress at late season) irrigation treatments, respectively.

6- The highest water utilization efficiency for root and sugar yields were (16.523 kg root/m^3 water applied) and (2.951 kg sugar/m^3 water applied) were obtained from irrigation treatment I_5 (no irrigation at late season stage) and boron fertilizer B_3 (0.75 kg B/ fed).

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تأثير النقص المنظم للرى ومعدلات البورون على إنتاجية بنجر السكر بالأراضى حديثة الإستصلاح

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الملخص العربى

أجريت تجربة حقلية عند الكيلو ٧١ طريق اسكندريه- القاهره الصحراوى فى منطقة غرب النوباريه- محافظة البحيره- مصر خلال موسمين متعاقبين ٢٠١٧/١٨ و ٢٠١٨/ ١٩ وكان الهدف من البحث دراسة تأثير خمس معاملات رى: حرمان ريه فى مراحل النمو المختلفه وهى: أ١= الرى فى كل مراحل النمو، أ٢= حرملن ريه فى مرحلة بداية تطور النمو (٦٠ يوم بعد الزراعه)، أ٣= حرمان ريه فى مرحلة تطور النمو (٩٠ يوم بعد الزراعه)، أ٤= حرمان ريه فى مرحلة منتصف النمو (١٢٠ يوم بعد الزراعه)، أ٥= حرمان ريه فى نهاية مرحلة النمو (١٥٠ يوم بعد الزراعه)، واستخدمت أربع معدلات لتسميد بالبورون (ب١= بدون اضافه، ب٢= ٠,٥، ب٣= ٠,٧٥ ، ب٤= ١,٠ كجم بورون/ فدان) على إنتاجية وجودة بنجر السكر وعلى كميات المياه المضافه وكفاءة إستخدام وحدة مياه الرى.

وأوضحت النتائج المتحصل عليها أن الإنخفاض فى محصول جذور بنجر السكر وصلت ٩,٥٥، ٦,٤٣، ٥,٥٨، ٠,٨٤ طن/ فدان - بينما الإنخفاض فى محصول السكر كان ١,٨٩، ١,٣٤، ١,٢٢، ٠,١٠ طن/ فدان بالمقارنه بمعاملة الرى (أ١) الرى فى كل مراحل النمو وذلك عند حرمان ريه فى مرحلة بداية النمو وتطور النمو ومنتصف النمو ونهاية مرحلة النمو على الترتيب كمتوسط للموسمين.

كما أوضحت النتائج أن معاملة الرى (أ١) الرى بدون حرمان فى كل مراحل النمو ومعدل السماد بالبورون (ب٢) ٠,٥ كجم بورون/ فدان أعطت أعلى متوسط لمحصول الجذور (٣٤,٠٤١ طن/ فدان) ومحصول السكر (٦,٣١٥ طن/ فدان) كمتوسط للموسمين. وأظهرت النتائج أن متوسط كميات المياه المضافه كانت ٢١٤٥، ١٩٢٩، ١٨٢٢، ١٨٥٨، ١٨٩٥ م٣/ فدان لمعاملات الرى أ١، أ٢، أ٣، أ٤، أ٥ على الترتيب للموسمين. كذلك أوضحت النتائج أن أعلى متوسط كفاءة إستخدام لوحدة المياه لمحصولى الجذور والسكر كانت (١٦,٥٢٣ كجم جذور/ م٣ ماء مضاف و ٢,٩٥٢ كجم سكر/ م٣ ماء مضاف) من معاملة الرى (أ٥) حرمان ريه فى نهاية مرحلة النمو مع معدل التسميد بالبورون (ب٣= ٠,٧٥ كجم بورون/ فدان) خلال الموسمين.

لذلك نوصى فى منطقة غرب النوباريه فى حالة وفرة مياه الرى من الواجب اضافة جميع الريات دون حرمان خلال موسم النمو (أ١) ويمكن استخدام معاملة الرى (أ٥) حرمان ريه فى نهاية مرحلة النمو مع اضافة معدل التسميد بالبورون (٠,٧٥ كجم بورون/ فدان) فى حالة نقص مياه الرى للحصول على أعلى محصول لبنجر السكر.

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