J. Agric. Sci. Mansoura Univ., 33 (1): 857 - 870, 2008

EEFECT OF IRRIGATION AT DIFFERENT SOIL MOISTURE DEPLETION LEVELS AND RATES OF POTASSIUM FERTILIZATION ON PRODUCTIVITY AND WATER USE EFFICIENCY OF SUGAR BEET

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ABSTRACT

Two field experiments were conducted at Sakha Agricultural Research Station, Kafr El-Sheikh governorate during the two successive seasons 2005/2006 and 2006/2007 to study the effect of irrigation after 40%, 60% and 80% depletion of available soil moisture (ASMD), and three potassium rates i.e. 0, 24 and 48 kg K_2O/fed. on sugar beet yield and water use efficiencies. A split plot design with four replications was used. Irrigation treatments occupied the main plots, while potassium rates arranged in sub-plots.

Results showed that increasing soil moisture depletion from 40% to 80% significantly decreased root diameter by 2.9%, root weight/plant by 6.8%, top yield/fed. by 4.6%, root yield/fed. by 4.1% and sugar yield/fed. by 10.0% . On the other hand, root length, total soluble solids and sucrose percentage were increased by 16.1%, 1.2% and 1.20%%, respectively. Increasing potassium application up to 48 kg K_2O/fed. significantly increased root length, root diameter , root weight/plant, fresh top and root yields/fed. by 2.2%, 3.0%, 1.7%, 4.5% and 6.3%, respectively, compared to the control treatment.

Seasonal water consumptive use values were 61.0 cm, 56.19 cm and 46.38 cm for irrigation after depletion of 40%, 60% and 80% of available water, respectively. In addition increasing K-rates up to 48 kg K_2O/fed. slightly increased seasonal water use.

Seasonal irrigation water applied values were 68.28 cm (2867.8 m^3/fed.), distributed on eight irrigations, 62.08 cm (2607.4 m^3/fed.), distributed on seven irrigations and 55.07 cm (2312.9 m^3/fed.), distributed on six irrigations, for irrigation after 40%, 60%, and 80% of available soil moisture depletion, respectively.

Water use efficiencies values for both root or sugar yields increased as soil moisture depletion increased. While water use efficiencies for both root or sugar yields significantly increased as potassium rate increased up to 48 kg K_2O/fed.

The mean percentage values of water extracted from the upper 30 cm soil layer were 76.36, 71.78 and 65.18% when sugar beet plants irrigated at 40%, 60% and 80% of ASMD, respectively,

A linear slop indicated that each one cm of water applied increased the productivity of root and sugar yields by 74 and 15.7 kg/fed. In addition irrigation water applied is strongly positively correlated with roots yield and negatively to water use efficiencies.

Therefore, when water is becoming a limited factor, irrigation at 80% of ASMD could be applied for saving 17.8% of irrigation water against 4.1% and 3.4% reduction in the root and sugar compared to irrigation at 40% of ASMD.

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is considered to be the second source for sugar production in Egypt. The importance of this crop comes from its ability to grow in the new reclaimed lands. Sugar beet is also adapted to a wide range of climatic conditions. It is tolerant to soil salinity and soil water stress (Hills *et al.,* 1990). Increasing sugar production from land unit area is considered one of the important national targets in Egypt to minimize sugar gab between production and consumption. Great efforts are being done to increase sugar production by proper utilization of the irrigation water and increase the efficiency of added potassium fertilization. So, water and potassium fertilization are among the most important factors affecting sugar beet production. El-Sabbagh *et al.* (2003) revealed that increasing soil moisture depletion from 40-45% to 80-85% of available soil moisture deletion levels significantly decreased root diameter, root weight/plant, top yield/fed., root yield and sugar yield. They also found that seasonal water consumptive use values were 60.90 cm, 55.43 cm and 46.28 cm for irrigation at the depletion of 40-45%, 60-65%, and 80-85% of available soil water content, respectively. El-Zayat (2000) concluded that irrigating sugar beet plants at 75% soil moisture depletion significantly decreased root diameter, top, root and sugar yields/fed. However, root length and gross sugar content significantly decreased with increasing the available soil moisture content in the root zone. He added also that juice purity percentage was not affected by irrigation treatments. Mean seasonal consumptive use values were 61.96, 56.17 and 40.12 cm for the 33, 55 and 75% soil moisture depletion, respectively. Water use efficiency for root or white sugar production were increased with increasing soil moisture depletion up to 75%. Semaika and Rady (1988) indicated that the highest values of fresh weight, length and diameter of roots were obtained when plants were subjected to 40% ASMD. Abou-Ahmed (2003) found that irrigation intervals of three weeks significantly produced the highest top, roots, and sugar yields to be 7.61, 23.04 and 3.84 t/fed., respectively. However, by prolonging irrigation intervals from three to four and five weeks significantly increased root length. Brown *et al.* (1987) reported that when sugar beet was exposed to both early and late drought stress, it had a higher sugar content in the root, although there was a reduction in growth of sugar beet and its productivity (root and sugar yields). Saif *et al.* (1997) indicated that the highest root, top and sugar yields as well as juice quality and sucrose percentage were attained by irrigation every 21 days. Shams El-Din (2000) observed that the highest sugar beet yield was obtained with irrigation at field capacity to a depth of 30 cm. Also, he found that the highest value of seasonal consumptive use was 60.03 cm gained from watering at field capacity plus 5%. On the other hand, irrigation at field capacity minus 5% gave the highest water use efficiency for both root and sugar yields. Shehata *et al.* (2000) found that under severe water stress (25% of the maximum available water) diameter, fresh weight of roots was decreased comparing with 100% of available water. However, a gradual increase in root length, total soluble solids and sucrose percentage were obtained by increasing water stress levels. On the other hand, either purity percentage or sugar yield was lowered by drought.

Potassium plays an important role in physiological processes in the plant such as translocation of sugars and carbohydrates. Many investigators proved that sugar beet yield and quality are greatly affected by applied levels of potassium fertilizer. Basha (1994) observed that increasing rate of K from

25 to 100 kg K_2O/fed. significantly increased root length and diameter, top, root and sugar yields/fed., sucrose and purity percentages. El-Essawy (1996) reported that increasing K rate from zero to 48 kg K_2O/fed. significantly increased length, diameter, root weight/plant, root, top and sugar yields/fed. He added that sucrose and purity percentages were not significantly affected by the applied levels of K fertilizer. Selim and El-Ghinbihi (1999) found that increasing K increased root, top and sugar yields/fed. Also, they noticed that K significantly increased the sucrose content but juice purity was decreased. Khalifa *et al.* (2000) showed that increasing K-rates up to 45 kg K_2/fed. significantly increased root length and diameter, root and shoot yields/fed. On the contrary, purity percentage was slightly decreased with increasing K-rates. El-Shafai (2000) indicated that increasing K-level from zero to 48 kg K_2O/fed. positively increased root fresh weight/plant, sugar yield and sucrose percentage. Root yield insignificantly increased as K-level increased up to 48 K_2O/fed. Purity percentage was not significantly affected by K-levels. Khalil *et al.* (2001) indicated that potassium fertilization showed slight increase in sucrose, total soluble solids and purity.

The aim of the current work is to investigate the effect of irrigation at different soil moisture levels and potassium fertilizer rates on the productivity, juice quality and soil-water relations of sugar beet.

MATERIALS AND METHODS

This investigation was conducted at Sakha Agricultural Research Station, Kafr El-Sheikh, Governorate during the two successive seasons 2005/2006 and 2006/2007. The soil of the experimental sites was clayey in texture. Water table level using observation well was 122 cm. The average of the electrical conductivity and pH value of the soil in the saturated soil paste were 2.33 dS/m and 8.15, respectively. The level of available K was 290 ppm, according to method of Black *et al.* (1985).

A split-plot design with four replications was followed. The main plots were occupied to irrigation treatments; i.e., 40, 60 and 80% depletion in available soil water content (ASMD). The sub-plot were assigned for three potassium rates i.e., 0, 24 and 48 kg K_2O/fed. in the form of K-sulphate (48% K_2O). Sub-plot area was 42 m^2 including 10 ridges, 7 m long and 60 cm apart. Plots were isolated by ditches of 1.5 m in width to avoid lateral movement of water. The preceding crop was maize in both seasons.

Sowing process took place on November 10^{th} and 8^{th} in the two seasons, respectively. Sugar beet seeds cv. Raspoly were planted in hills 20 cm apart on one side of ridges. Plants were thinned to one plant/hill after 40 days from sowing. Phosphatic fertilizer in the form of calcium superphosphate (15.5% P_2O_5) at rate of 30 kg P_2O_5/fed. was applied during tillage operation. Potassium fertilizer with mentioned rates and nitrogen with the recommended dose 90 kg N/fed. as urea (46.5% N) were applied just before the first irrigation after thinning. Other cultural practices were carried out as recommend.

Plants were harvested, 200 days after sowing. Ten guarded plants were taken randomly from each plot for subsequent measurements i.e. 1) root length in cm, 2) root diameter in cm, 3) root weight in gm, in addition to quality parameters i.e. 4) total soluble solids (TSS%) was determined by using hand refractometer, 5) sucrose percentage, 6) purity of juice percentage and sugar yield. Sucrose percentage was determined by using saccharometer according to LeDocte (1927), and purity of juice percentage was calculated according to the following equation.

Juice purity % = sucrose % x 100 /T.S.S. %

Sugar yield, was calculated according the following equation:

Sugar yield (ton/fed.) = root fresh weight yield (ton/fed.) x sucrose %.

The five guarded ridges from the middle of each plot were harvested to determine both top and root fresh weight yields/fed.

Data were subjected to the combined analysis as described by Snedecor and Cochran (1980). The treatment means were compared according to Duncan's multiple range test (Duncan, 1955).

Sakha meteorological station data, during 2005/06 and 2006/07 seasons, were recorded. Meteorological data including air temperature, relative humidity, and rainfall distribution are presented in Table 1.

Table (1): Sakha meteorological data of Agricultural Research station during 2005/06 and 2006/07 seasons.

Seasons	2005/06							2006/07						
	Air temperature °C			Relative humidity (%)			Rainfall (mm)	Air temperature °C			Relative humidity (%)			Rainfall (mm)
Month	Max.	Min.	Mean	Max.	Min.	Mean		Max.	Min.	Mean	Max.	Min.	Mean	
Nov.	24.2	10.6	17.4	77.3	56.0	66.7	8.3	23.5	8.9	16.2	77.0	58.6	67.8	3.2
Dec.	20.0	7.0	13.5	86.5	60.0	73.3	8.8	19.7	4.5	12.1	82.0	62.2	72.1	10.0
Jan.	18.8	5.1	12.0	86.0	61.0	73.5	7.6	18.7	4.1	11.4	87.0	58.5	72.8	17.5
Feb.	22.0	6.0	13.0	93.4	66.0	79.7	18.0	21.6	5.6	13.6	95.4	67.6	81.5	44.1
Mar.	22.6	7.0	14.8	80.0	51.2	65.6	2.1	22.0	5.8	13.9	79.2	51.7	65.5	9.0
Apr.	27.0	9.5	18.3	81.0	47.0	64.0	24.8	25.3	7.5	16.4	80.5	49.5	65.0	11.4
May	28.5	11.6	20.1	79.3	45.0	62.2	0.0	28.3	11.1	19.7	78.9	45.1	62.0	0.0

Soil-water relations:

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depths of 15 cm down to a depth of 60 cm. Soil samples were also collected just before each irrigation, 48 hours after irrigation and at harvest time. Irrigation water was applied when the moisture content reached the desired available soil moisture in each treatment. Field capacity, Permanent wilting point and bulk density were executed according to Black *et al.* (1985) to a depth of 60 cm. Available soil moisture was calculated by subtracting wilting point from field capacity. The average values are presented in Table (2).

Table (2): Soil moisture constants for soil of the experimental site.

Soil depth (cm)	Field capacity (%)	Wilting point (%)	Bulk density (g/cm^3)	Available soil water %
0-15	46.61	25.72	1.10	20.89
15-30	40.17	23.91	1.16	16.26
30-45	37.15	22.33	1.21	14.82
45-60	35.14	21.43	1.30	13.71

III. Soil-water relations:

1. Water consumptive use (WCU):

Water consumptive use was calculated using the following equation (Hansen *et al.,* 1979).

CU = $\sum_{i=1}^{i=4} Di \times D_{bi} \times PW_2 - PW_1 / 100$

Where:

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

D_i = soil layer depth = 15 cm.

D_{bi} = soil bulk density, (g/cm^3) for this depth.

PW_1 = soil moisture percentage before irrigation.

PW_2 = Soil moisture percentage, 48 hours after irrigation.

i = Number of soil layer (15 cm).

2. Irrigation water applied (IWA):

Submerged flow orifice with fixed dimension was used to measure the amount of water applied, as the following equation (Michael, 1978).

Q = CA $\sqrt{2gh}$

Where:

Q = discharge through orifice, (1/sec).

C = coefficient of discharge, (0.61).

A = cross-sectional area of the orifice, cm^2.

g = acceleration due to gravity, cm/sec.^{2} (981 cm/sec.^{2}).

h = pressure head, causing discharge through the orifice, cm.

3. Crop water use efficiency (CWUE):

It was calculated according to Michael (1978).

WUE = Y/CU

Where:

Y = root yield or sugar yield (kg).

CU = seasonal water consumptive use (m^3).

4. **Field water use efficiency (FWUE):** was calculated according to Jensen (1983).

FWUE = $\frac{Y}{IWR}$

Where:

Y = root yield in kg

IWR = seasonal irrigation water applied in cm.

5. Soil moisture extraction pattern (SMEP):

It was calculated according to the following equation, (Hansen *et al.,* 1979).

SMEP = CU (layer) x 100/CU (seasonal)

Where:

CU (layer) = sum of extracted soil moisture in each soil layer (15 cm).

CU (seasonal) = total sum of moisture extracted in all soil layers (60 cm).

RESULTS AND DISCUSSIONS

I. Yield and its components:

Data presented in Table (3) revealed that as the soil moisture stress increased significant and gradual decrease in all studied traits of sugar beet (except for root length) were recorded. The highest reduction was 2.9%. 6.8%, 4.6% and 4.1% for root diameter, root weight/plant, top and root yields/fed., respectively, resulted from irrigation at 80% of ASMD compared with irrigation at 40% of ASMD.

At the same time, the results showed that there were no significant differences in root yield between irrigation after 40% and 60% of ASMD. The decrease in root yield and its characteristics might be due to the reduction in both metabolic products and transport of photosynthetic assimilates under the water stress condition. On the other hand, when sugar beet plants were exposed to water stress, root length was significantly enhanced deeply, Simpson (1981) explained that lengthening the roots in the soil was to exploit the deeply stored soil moisture to avoid drought stress damage. This result is in accordance with those reported by Gaber *et al.* (1986), Saif *et al.* (1997), El-Zayat (2000), Abou-Ahmed (2003) and El-Sabbagh *et al.* (2003).

Table (3): Mean values of root characteristics, fresh top and root yield of sugar beet as affected by soil moisture depletion and different rates of potassium fertilizer in the combined analysis over the two growing seasons.

Treatments	Root length(cm)	Root diameter (cm)	Fresh root/plant (kg)	Fresh top yield (ton/fed.)	Fresh root yield (ton/fed.)
Irrigation treatments:					
40% ASMD	22.45 b	9.32 a	1.058 a	7.15 a	23.72 a
60% ASMD	25.88 a	9.18 b	1.029 b	7.03 b	23.39 a
80% ASMD	26.06 a	9.05 c	0.986 c	6.82 c	22.74 b
K-fertilizer :					
Control (K-0)	24.52 b	9.03 b	1.022 c	6.84 c	22.51 c
24 kg K_2O/fed	24.82 b	9.22 a	1.031 b	7.01 b	23.42 b
48 kg K_2O/fed	25.05 a	9.30 a	1.039 a	7.15 a	23.92 a
Interactions:					
Irrigation x season	N.S	N.S	N.S	N.S	N.S
K x season	N.S	N.S	N.S	N.S	N.S
Irrigation x K	N.S	N.S	N.S	N.S	**
Irrig. x K x season	N.S	N.S	N.S	N.S	N.S

Means designated by the same letter at each cell are not significantly different at 5% level according to Duncan's multiple range test.
N.S.: indicate not significant

Regarding potassium effect, data showed that increasing potassium application up to 48 kg K_2O/fed. had significantly increased root length, root diameter , root weight/plant, fresh top and root yields/fed. by 2.2%, 3.0%, 1.7%, 4.5% and 6.3%, respectively, compared to the control treatment. This result could be attributed to the important role of potassium in physiological processes in the plant such as translocation of sugars and carbohydrates. Similar results obtained by Basha (1994) and Khalifa *et al.* (2000).

Insignificant effect was detected with any of the interactions between the two variables studied except irrigation and potassium rates on roots yield t/fed. as shown in Table 3.

Interaction between irrigation treatments and potassium rates:

It is obvious form Table 4 that the highest mean values of root yield was obtained from irrigation at 40% of ASMD that fertilized with 48 kg K_2O/fed. However, the lowest value resulted from irrigation at 80% of ASMD without potassium fertilizer.

Table (4): Interaction between irrigation treatments and potassium rates on root yield, over both growing seasons.

Irrigation	Root yield t/fed		
treatments	**40% ASMD**	**60% ASMD**	**80% ASMD**
K-fertilizer :			
Control (K-0)	22.80c	22.47c	22.27c
24 kg K_2O/fed	23.88b	23.52b	22.87
48 kg K_2O/fed	24.47a	24.00a	23.10b

II. Quality parameters:

Results illustrated in Table (5) showed that total soluble solids and sucrose percentage were significantly increased with increasing water stress levels. On the contrary, sugar yield was lowered by deficit irrigation. Purity percentage was not significantly affected by soil moisture levels. Brown *et al.* (1987) observed an increase in respiration rate during the early phases of stress as a result of hydrolysis of starch to sugar. These results are in harmony with those obtained by Roberts *et al.* (1980), Nissen *et al.* (1987), Shehata *et al.* (2000), El-Zayat (2000) and El-Sabbagh *et al.* (2003).

Table (5): Mean values of root juice quality and sugar yield of sugar beet as affected by soil moisture depletion and different rates of potassium fertilizer in the combined analysis over the two growing seasons.

Treatments	Total soluble solids (TSS%)	Sucrose (%)	Purity (%)	Sugar yield (ton/fed.)
Irrigation treatments:				
40% ASMD	20.52 c	17.35c	84.55 a	4.12 a
60% ASMD	20.59 b	17.45 b	84.75 a	4.08 ab
80% ASMD	20.74 a	17.50 a	84.38 a	3.98 b
K-fertilizer :				
Control (K-0)	20.59 b	17.40 c	84.51 a	3.92 c
24 kg K_2O/fed	20.62 a	17.43 b	84.53 a	4.08 b
48 kg K_2O/fed	20.65 a	17.47 a	84.60 a	4.18 a
Interactions:				
Irrigation x season	N.S	N.S	N.S	N.S
K x season	N.S	N.S	N.S	N.S
Irrigation x K	N.S	N.S	N.S	N.S
Irrig. x K x season	N.S	N.S	N.S	N.S

Means designated by the same letter at each cell are not significantly different at 5% level according to Duncan's multiple range test.
N.S.: indicate not significant

Increasing the applied dose of potassium from zero to 48 kg K_2O/fed. significantly increased total soluble solids, sucrose percentage and sugar yield. On the other hand, purity percentage was not significantly influenced by K-rates. The appreciable effect of increasing the applied K-levels on sugar yield could be attributed to the beneficial influence of potassium on root fresh weight/plant, sucrose %, purity % and root and sugar yields. This result coincides with that obtained by Basha (1994), and El-Shafai (2000). All the interactions failed to exert any significant effects on the studied characters.

III. Soil-water relations:

1. Water consumptive use (WCU):

Mean values of water consumptive use as affected by soil moisture levels and different rates of potassium fertilizer are presented in Table (6).

Seasonal water consumptive use was increased as a result of higher frequent irrigation due to irrigation after 40% of ASMD than irrigation after 60% and 80% of ASMD. This trend showed that the increment in water consumptive use depends on the availability of soil moisture in the root zone. Doorenbos and Pruitt (1977) gave an extensive explanation of the effect of available soil water on evapotranspiration, they stated that after irrigation or rain the water content will be reduced primarily by evapotranspiration. As the soil was dried, the rate of water transmitted through the soil will reduce. The effect of soil water content on evapotranspiration varies with crop and soil type, as well as water holding characteristics. Carter *et al.* (1980) showed that limited irrigation reduced evapotranspiration rates because of drier surface soil and partial stomatal closure, thereby decreasing the rate of water extraction from the soil reservoir by the plant. These results were supported by the data obtained by Shams El-Din (2000) and El-Zayat (2000) and El-Sabbagh *et al.* (2003).

Table (6): Monthly and seasonal water consumptive use of sugar beet as affected by available soil moisture depletion and different rates of potassium fertilizer (average the two seasons).

Irrigation treatments	Potassium fertilizer (kg K_2O/fed.)	Monthly rates (cm)							Seasonal rates (cm)
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	
40% ASMD	0	1.77	4.63	6.27	8.52	13.21	16.15	9.90	60.45
	24	1.77	4.63	6.32	8.62	13.35	16.20	9.95	60.84
	48	1.77	4.63	6.42	8.79	13.71	16.32	10.06	61.70
Mean		1.77	4.63	6.43	8.64	13.43	16.22	9.97	61.00
60% ASMD	0	1.77	4.63	5.74	7.73	11.68	14.67	9.02	55.24
	24	1.77	4.63	6.77	7.76	11.76	14.70	9.06	56.45
	48	1.77	4.63	6.87	7.87	11.81	14.76	9.17	56.88
Mean		1.90	4.63	5.79	7.79	11.76	14.71	9.08	56.19
80% ASMD	0	1.77	4.63	4.57	5.80	9.76	12.70	6.55	45.78
	24	1.77	4.63	4.67	5.92	10.02	12.77	6.74	46.52
	48	1.77	4.63	4.72	6.02	10.06	12.80	6.84	46.84
Mean		1.77	4.63	4.65	5.91	9.95	12.76	6.71	46.38
Total potassium average (cm) K-0 = 53.82 , K-24= 54.60 K-48 = 55.15									

Respecting to the effect of K-rates application, data showed a slight increase in seasonal water use as K-rates increased. Such increase in evapotranspiration rate following potassium application may be due to the enhancing effect of K-fertilizer on growth which resulted in an increase in plant canopy thereby increasing the transpiring surface and that reflected on seasonal water use. The above results were in line with those reported by El-Sabbagh *et al.* (2003) who found an increase in water consumptive use of sugar beet plants by increasing K_2O from zero to 48 kg/fed.

2. Irrigation water requirements (IWR):

Table 7 indicated that irrigating sugar beet plants at 40%ASMD resulted in the highest amount of water applied to be 68.28 cm (2867.8 m^3/fed.), distributed on eight irrigations, followed by irrigation at 60% of ASMD to be 62.08 cm (2607.4 m^3/fed.), distributed on seven irrigations and irrigation at 80% of ASMD to be 55.07 cm (2312.9 m^3/fed.), distributed on six irrigations, respectively. Planting irrigation and the first irrigation were the same for all irrigation treatments. The average of the effective rainfall was 5.8 cm over both growing seasons. It is obvious that amount of irrigation water applied was gradually increased as a result of growing up of a vegetative growth that required higher amount of irrigation water to meet its water requirements, and then it decreased again. These findings maybe attributed to growth stages, and the availability of soil water content in the root zone.

Table (7): Amounts of seasonal irrigation water applied (cm) as affected by the different irrigation treatments, as well as the amounts of effective rainfall (cm), over both seasons.

Variables	Irrigation treatments		
	40% ASMD	**60% ASMD**	**80% ASMD**
Planting irrigation	10.05 cm (422.1 m^3/fed.)	10.05 cm (422.1 m^3/fed.)	10.05 cm (422.1 m^3/fed.)
1st irrigation	7.86 cm (330.1 m^3/fed.)	7.86 cm (330.1 m^3/fed.)	7.86 cm (330.1 m^3/fed.)
2nd irrigation	8.19 cm (344.0 m^3/fed.)	8.67 cm (364.1m^3/fed.)	8.95 cm (375.9 m^3/fed.)
3rd irrigation	8.69 cm (365.0 m^3/fed.)	8.90 cm (373.8m^3/fed.)	9.24 cm (388.1m^3/fed.)
4th irrigation	9.08 cm (381.4 m^3/fed.)	9.32 cm (391.4m^3/fed.)	9.86 cm (414.1 m^3/fed.)
5th irrigation	8.42 cm (353.6 m^3/fed.)	8.80 cm (369.6 m^3/fed.)	9.11 cm (382.6 m^3/fed.)
6th irrigation	8.11 cm (340.6 m^3/fed.)	8.48 cm (356.2 m^3/fed.)	
7th irrigation	7.88 cm (331.0 m^3/fed.)		
Irrigation water applied	68.28 cm (2867.8m^3/fed.)	62.08 cm (2607.4m^3/fed.)	55.07 cm (2312.9m^3/fed.)
Effective rainfall*	5.80 cm (244.0 m^3/fed.)	5.80 cm (244.0 m^3/fed.)	5.80 cm (1559.5 m^3/fed.)
Irrigation water requirements (IWR)	74.08 cm (3111.4 m^3/fed.)	67.88 cm (2851.4 m^3/fed.)	60.87 cm (2556.9 m^3/fed.)

***Effective rainfall = incident rainfall x 0.7 (Novica, 1979)**

3. Crop water use efficiency (CWUE):

Water use efficiency by sugar beet expressed as kg roots or sugar yield produced/cm of water consumed as affected by irrigation regime and potassium fertilizer is presented in Table 8.

Data showed that irrigation after 80% of ASMD resulted in the highest CWUE for both root and sugar yields, while it was lower under 40% of ASMD. These results could be attributed to the high significant differences in the roots or sugar yield production as well as the differences between the water consumptive uses. These results are in agreement with those obtained by Shams El-Din (2000), Saied (2000), El-Zayat (2000), El-Sabbagh *et al.* (2003) and Abou Ahmed (2003).

Regarding the effect of potassium, CWUE for both root or sugar yields was increased with increasing potassium rate. This finding could be related to higher yield more than the increase in water consumed by sugar beet. The previous results are in line with those reported by Welch and Flannery (1985), and El-Sabbagh *et al.*, (2003) who concluded that potassium supply increased CWUE of sugar beet and corn plants.

Table (8): Crop water use efficiency by sugar beet in kg root and sugar yield /cm of water consumed as affected by soil moisture depletion and different rates of potassium fertilizer in the combined analysis over the two growing seasons.

Irrigation treatments	CWUE (kg root yield/cm of water consumed)			Mean
	40% SMD	60% SMD	80% SMD	
K-fertilizer :				
Control (K-0)	377.2e	406.7d	486.4b	423.4C
24 kg K_2O/fed	392.6de	416.6cd	491.5a	433.6B
48 kg K_2O/fed	396.5de	425.5c	493.1a	438.4A
Mean	388.8C	416.3B	490.3A	
	CWUE (kg sugar yield/cm of water consumed)			**Mean**
K-fertilizer :				
Control (K-0)	65.84g	70.80e	84.27b	73.64C
24 kg K_2O/fed	68.72fg	72.67d	85.23a	75.54B
48 kg K_2O/fed	69.57f	74.43c	85.65a	76.55A
Mean	68.04C	72.63B	85.05A	

Means designated by the same letter at each cell are not significantly different at 5% level according to Duncan's multiple range test.

4. Field water use efficiency (FWUE):

Data in Table 9 indicated that irrigation at 80% of ASMD increased FWUE (kg root and sugar yield/cm of water applied) compared to irrigation at 60% and 40% of ASMD, respectively. El-Sabbagh *et al.* (2003) indicated that water utilization efficiency increased with increasing in soil moisture stress. Applying potassium fertilizer at rate of 48 kg K_2O/fed. increased FWUE compared to the treatments received 24, K_2O/fed. and the control, respectively.

The interaction between irrigation and potassium rates in Tables 8 and 9 showed that higher value of water use efficiencies was obtained from irrigation at 80% of ASMD with 48 kg K_2O/fed. On the other hand, irrigation at 40% of ASMD with control treatment resulted in lower water use efficiencies.

Table (9): Field water use efficiency by sugar beet in kg root and sugar yield/cm of water applied as affected by soil moisture depletion and different rates of potassium fertilizer in the combined analysis over the two growing seasons.

Irrigation treatments	FWUE (kg root yield/cm of water applied)			Mean
	40% ASMD	60% ASMD	80% ASMD	
K-fertilizer:				
Control (K-0)	307.8h	331.0e	365.8b	334.9C
24 kg K_2O/fed	322.4g	346.4d	375.7a	348.2B
48 kg K_2O/fed	330.3f	356.5c	379.4a	355.4A
Mean	320.4C	344.6B	373.6A	
	FWUE (kg sugar yield/cm of water applied)			**Mean**
K-fertilizer:				
Control (K-0)	53.73g	57.61e	63.38b	58.24C
24 kg K_2O/fed	56.44f	60.43d	65.14a	60.67B
48 kg K_2O/fed	57.94ef	62.37c	65.91a	62.07A
Mean	56.04C	60.14B	64.81A	

Means designed by the same letter at each cell are not significantly different at 5% level according to Duncan's multiple range test.

5. Soil moisture extraction pattern (SMEP):

Data of mean values of soil moisture extraction percentage in the upper 60 cm soil depth as affected by soil moisture depletion and potassium fertilizer are presented in Table (10).

Results indicated that the highest percentage of moisture uptake was occurred at the surface layer 15 cm of the soil profile. Less water was extracted from the successive depths. The mean percentage values of water extracted from the upper 30 cm soil layer were 76.36, 71.78 and 65.18% when irrigated at 40%, 60% and 80% of ASMD, respectively, while the respective values were 23.64%, 28.22% and 34.82% withdrawn from the lower 30-60 cm.

Table (10): Percentage of water uptake by sugar beet roots from soil layers as affected by soil moisture depletion and potassium fertilizer (average the two seasons).

Irrigation treatments	K-rates kg (K_2O/fed.)	Soil depth(cm)				Average moisture extraction	
		0-15	15-30	30-45	45-60	0-30	30-60
40% ASMD	0	47.65	28.20	18.70	5.45	75.85	24.15
	24	47.91	28.49	18.82	4.78	76.40	23.60
	48	48.11	28.73	18.85	4.41	76.84	23.16
Mean		47.89	28.51	18.79	4.81	76.36	23.64
60% ASMD	0	44.37	27.02	20.2	8.41	71.39	28.61
	24	44.63	27.25	20.62	7.50	71.88	28.12
	48	44.70	27.38	20.69	7.23	72.08	27.92
Mean		44.57	27.23	20.50	7.71	71.78	28.22
80%A SMD	0	39.38	25.40	22.75	12.47	64.78	35.22
	24	39.61	25.66	22.92	11.81	65.27	34.73
	48	39.75	25.74	22.98	11.53	65.49	34.51
Mean		39.58	25.60	22.88	11.94	65.18	34.82

These findings could be attributed to the fact that most of plant roots are concentrated in the upper soil layers and those are the most effective in water extraction. The same results were found by Mitchell and Rusell (1971), and Abou Ahmed (2003) who reported that a relatively high water uptake from the top layers occurred compared to deep layers, as a result of the concentration roots in the upper layers. For potassium fertilizer, results showed that no obvious effect on the removal moisture.

6. Regression slopes and correlation coefficients:

A linear equation is presented in Table 11 indicated that each one cm of water applied increased the productivity of roots and sugar yield by 74 and 15.7 kg/fed. as shown in Eq. [1 and 2]. It means hat both root and sugar yields were improved with increasing water consumption. However, each one cm of water applied decreased crop water use efficiency (CWUE) by 7.8 kg root yield/cm of water consumed (Eq. [3]) and decreased field water use efficiency (FWUE) by 4.1 kg/root of water applied (Eq. [4]). Irrigation water applied is strongly positively correlated with roots and sugar yields and negatively to water use efficiencies as shown in Table 11. The positive correlation indicted that sugar yield increases when root and sugar yields and water consumptive use increase due to irrigation water applied. In this concern, Ghanem and Gomma (1985), and El-Sabbagh *et al.* (2001) found that sugar yield was positively and significantly correlated with root yield.

Table (11): Regression slopes and correlation coefficients between irrigation water applied (IWR) and root yield (RY), sugar yield (SY), crop water use efficiency (CWUE) and field water use efficiency (FWUE).

Variables	Equation	Correlation (r)
IWR	Ỳ= 18275 + 74 (RY)..[1]	0.65*
IWR	Ỳ= 2998 + 15.7 (SY)..[2]	0.67*
IWR	Ỳ= 956 – 7.8 CWUE..[3]	-0.72
IWR	Ỳ= 620 – 4.1 FWUE..[4]	-0.69

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تأثير الرى عند مستويات مختلفة من الرطوبة الأرضية والتسميد البوتاسى علىإنتاجية وكفاءة استخدام المياه لمحصول بنجر السكر بمنطقة شمال الدلتا مصر

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أجريت هذه الدراسة بمحطة البحوث الزراعية - محافظة كفرالشيخ عامى 2006/2005 و 2007/2006 لدراسة تأثير الرى عند مستويات مختلفة من الرطوبة الأرضية والتسميد البوتاسى على المحصول والجودة وكفاءة استخدام المياه لنبات بنجر السكر.

واستخدم تصميم القطع المنشقة فى أربع مكررات حيث وزعت معاملات الرى بالقطع الرئيسية وهى الرى عند فقد 40% ، 60% ، 80% من الماء الميسر بالتربة ومعاملات التسميد البوتاسى بالقطع المنشقة وهى (صفر ، 24 ، 48 ك.ج بو2 أ/فدان) وقد أوضحت النتائج ما يلى:

1- أدى الرى عند فقد 80% من الماء الميسر إلى نقص معنوى لصفة قطر ووزن الجذر ومحصول الجذور والعرش والسكر/فدان. مع وجود زيادة معنوية لصفة طول الجذر والمواد الصلبة الذائبة الكلية ونسبة السكروز.
2- أدى زيادة التسميد البوتاسى حتى 48 ك.ج بو2 أ/فدان إلى زيادة معنوية لكل الصفات تحت الدراسة.
3- لم يكن لمعاملات الرى والتسميد البوتاسى تأثير معنوى على النسبة المئوية للنقاوة.
4- أدى الرى عند فقد 40% من الماء الميسر إلى الحصول على أعلى القيم لصفة الأستهلاك المائى الموسمى. وأقل القيم لكفاءة استخدام مياه الرى.
5- وجد أن نبات بنجر السكر استهلك أكبر كمية من الماء الذى يحتاج إليه من الطبقة السطحية للتربه (صفر - 15سم).
6- أدى التسميد البوتاسى إلى زيادة طفيفة لصفة الاستهلاك المائى الموسمى. بينما كانت الزيادة معنوية بالنسبة لكفاءة استخدام مياه الرى.
7- أشار ميل خط الانحدار ان كل واحد سم من كمية مياه الرى المضافة ادى الى زيادة انتاجية محصول الجذوروالسكر بـ 74.0 و 15.7 ك ج /فدان. كما اشارت النتائج إلى وجود ارتباط عالى المعنوية وموجب بين كمية مياه الرى المضافة وكل من محصول الجذور/فدان و محصول السكر/فدان ، بينما كان الارتباط معنوى وسالب مع كفاءاءت استخدام مياه الرى.

يتبين مما سبق انه عندما يكون مياه الرى هى العامل المحدد للزراعة فان الرى عند فقد80% من الماء المسير قد يوصى به حيث ان الانخفاض فى انتاجية محصول الجذور والسكر يصل 4.1% و 3.4% مقابل توفير فى مياه الرى يصل الى 17.8% مقارنة بالرى عند فقد 40% من الماء الميسر.