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SUGAR BEET PRODUCTIVITY AS AFFECTED BY SOIL MOISTURE DEPLETION LEVELS AND POTASSIUM FERTILIZATION

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ABSTRACT: Two field experiments were conducted at Sakha Agricultural Research Station Kafr El-Sheikh, Governorate during the two successive seasons 1999/2000 and 2000/2001 to investigate the effect of irrigation after 40-45%, 60-65% and 80-85% depletion of available soil moisture, and three potassium levels (0, 24 and 48 kg K_2O/fed.) on sugar beet yield and its water relations. A split plot design with four replications was used. Irrigation treatments occupied the main plots, while potassium levels arranged in sub-plots. Results obtained showed that:

Increasing soil moisture depletion from 40-45% to 80-85% significantly decreased root diameter (2.60%), root weight/plant (5.05%), top yield/fed. (4.58%), root yield/fed. (3.56%) and sugar yield/fed. (2.66%). On the contrary, root length, total soluble solids and sucrose percentage were increased by 2.36, 1.16 and 1.32%, respectively. Irrigation treatments and potassium fertilization had no significant effect on purity percentage. Increasing potassium levels from zero to 48 kg K_2O/fed. significantly increased all studied traits.

Seasonal water consumptive use values were 60.90, 55.43 and 46.28 cm for irrigation after the depletion of 40-45%, 60-65% and 80-85% in available water, respectively. Water use efficiency values for both root or sugar yields increased as soil moisture depletion increased. Most of the water consumed was removed from the upper soil layer (0-15 cm) of soil profile. Seasonal water use and water uptake by roots were slightly increased, while water use efficiency for both root or sugar yields significantly increased as potassium levels increased up to 48 kg K_2O/fed. The calculated value of 0.81 and 0.88 for crop coefficient (Kc) can be used in order to calculate the water consumptive use of sugar beet in North Delta area as estimated by the aid of Penman and radiation methods. The sugar yield was highly significant and positive as associated with root yield/fed. and water consumptive use, while it was significantly negative to water use efficiency.

Key words: Sugar beet, soil moisture depletion, water consumptive use, potassium, water use efficiency, crop coefficient.

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).

Water and potassium fertilization are among the most important factors affecting sugar beet production. Gaber *et al.* (1986) found that increasing irrigation intervals from 15 to 30 days significantly decreased both root and top yields. They added that sugar content was not affected with irrigation intervals. 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). Semaika and Rady (1988) indicated that the highest values of fresh weight, length and diameter roots were obtained when plants subjected to 40% ASMD. Ibrahim *et al.* (1993) found that prolonging irrigation intervals from 14 to 28 days caused a significant reduction in root yield. Also, they found that seasonal water use values were 58.06, 55.04 and 49.86 cm for the 14, 21 and 28 days intervals, respectively. The water use efficiency of 8.66 kg for sugar beet root could be obtained from each cubic meter of water consumed. 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, irrigated at field capacity minus 5% gave the highest water use efficiency for both root and sugar yields. El-Zayat (2000) concluded that irrigated 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 by increasing the available soil moisture content in the root zone. He added 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 by increasing soil moisture depletion up to 75%. Shehata *et al.* (2000) found that under severe water stress (25% of the maximum available water) diameter, fresh weight of roots were decreased comparing with 100% of available water. However, a gradual increase in root length, total soluble solids and sucrose percentage by increasing water stress levels. On the contrary, 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 were increased root, top and sugar yields/fed. Also, they noticed that K significantly increased the sucrose content but juice purity was decreased. 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. 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 by increasing K-rates. 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 different soil moisture levels and potassium fertilizer 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 1999/2000 and 2000/2001. The soil of the experimental sites was clayey in texture. Water table level using observation well was 130 cm. EC and pH of the soil in the saturated soil paste were 2.60 dS/m and 8.10, respectively. The level of available K was 290 ppm (Black *et al.*, 1985).

A split-plot design with four replications was followed. The main plots were occupied to irrigation treatments; i.e., 40-45, 60-65 and 80-85% depletion in available water. 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 took place in November 12 and 10 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 the 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 at random from each plot for subsequent measurements as follows:

1. Root length (cm).
2. Root diameter (cm).
3. Root weight (gm).
4. Total soluble solids (TSS%) was determined by using hand refractometer.
5. Sucrose percentage was determined by using saccharometer according to LeDocte (1927).
6. Purity of juice percentage was calculated according to the following equation.

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

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

7. Sugar yield, was calculated according the following equation:

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

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 was determined in the field (Garcia, 1978). 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 (1).

Table (1): Soil moisture constants of the experimental site.

Soil depth (cm)	Field capacity (%)	Wilting point %	Bulk density (g/cm^3)	Available soil water (%)
0-15	46.72	25.39	1.10	21.33
15-30	40.68	22.11	1.16	18.57
30-45	37.30	20.27	1.27	17.03
45-60	35.10	19.08	1.35	16.02
Mean	39.95	21.71	1.22	18.24

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. Water use efficiency (WUE):

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).

3. Soil moisture extraction pattern (SMEP):

It was calculated according to the following equation, (Israelson and Hansen, 1962).

$$SMEP = CU\ (layer) \times 100/CU\ (seasonal)$$

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).

4. Reference evapotranspiration (ET_o):

Meteorological data of Sakha station which were observed during the study are given in Table (2).

Four methods were used in calculating reference evapotranspiration (ET_o) i.e. modified Penman, radiation, modified Blaney-Criddle and Class A pan evaporation (Doorenbos and Pruitt, 1977).

a. Penman method:

$$ET_o = C[W. R_n + (1-w). f(u). (e_a-e_d)]$$

Where:

ET_o = reference evapotranspiration (mm/day).

C = adjustment factor to compensate the effect of day and night weather conditions.

W = temperature related weighting factor.

R_n = net radiation in equivalent evaporation (mm/day)

f(u) = wind related function.

(e_a-e_d) = the difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar.

Table (2): Meteorological data of Sakha Agricultural Research Station during the period of study.

Seasons	Months	Air temperature °C			Relative humidity %			Wind speed km/day	Pan evaporation mm/day
		Max.	Min.	Mean	Max.	Min.	Mean		
1999/2000	Nov.	26.5	13.3	19.9	79.0	50.0	64.5	73.5	2.84
	Dec.	17.5	9.5	13.5	70.3	46.4	58.4	106.4	2.36
	Jan.	16.5	5.8	11.2	68.0	44.5	56.3	79.0	2.11
	Feb.	19.6	6.7	13.2	74.5	48.4	61.5	98.0	2.70
	March	21.0	8.0	14.5	72.0	44.0	58.0	106.0	3.40
	April	24.5	12.0	18.3	74.0	41.9	58.0	114.5	4.88
	May	28.5	14.8	21.7	69.0	41.5	55.3	134.0	5.66
2000/2001	Nov.	23.0	11.5	17.3	91.0	44.0	67.5	77.0	2.60
	Dec.	19.1	7.8	13.5	93.0	47.0	70.0	88.0	2.48
	Jan.	17.6	5.2	11.4	92.0	44.0	68.0	102.4	2.27
	Feb.	18.2	4.8	11.5	92.0	36.0	64.0	119.5	2.74
	March	23.8	9.7	16.8	95.0	39.0	67.0	115.0	3.76
	April	25.2	12.4	18.8	89.0	30.0	59.0	170.6	5.85
	May	28.2	14.7	21.4	91.0	31.0	61.0	171.8	6.15

b. Radiation method:

$$ET_o = a + b.\ W.RS$$

Where:

- ET_o = reference evapotranspiration in mm/day
- a,b = two coefficient which depend on mean relative humidity (RH mean) and wind speed (U_2).
- W = weighting factor which depends on mean air temperature and altitude.
- R_S = solar radiation in equivalent evaporation in mm/day.

c. Blaney-Criddle method:

$$ET_o = a + b[P\ (0.46\ T + 8.13)].$$

Where:

- ET_o = reference evapotranspiration in mm/day.
- a,b = two coefficient which depend on minimum relative humidity (RH min), sunshine hours and day time wind speed.
- P = mean daily percentage of total annual day time hours for given month and latitude.
- T = mean daily temperature in °C.

d. Class A pan evaporation method:

$$ET_o = K.\ pan.\ E.\ pan$$

Where:

- ET_o = reference evapotranspiration in mm/day.
- K. pan = pan coefficient which depends on type of pan, conditions of humidity, wind speed and pan environmental conditions.
- E. pan = pan evaporation in mm/day and represents the mean daily value of the period considered.

5. Crop coefficient (K_c):

It was calculated as follows:

$$K_c = ET_{crop}/ET_o$$

Where:

- ET_{crop} = actual evapotranspiration in mm/day.
- ET_o = reference evapotranspiration in mm/day.

Statistical analysis:

The data were subjected to the proper statistical analysis of variance. The combined analysis was conducted for the two seasons according to Snedecor and Cochran (1980). The differences between the mean values were compared by Duncan's multiple range test (Duncan's, 1955). Also, a simple correlation coefficient among sugar yield and some traits was computed according to the method described by Snedecor and Cochran (1980).

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 reduction were 2.60. 5.05, 4.58 and 3.56% for root diameter, root weight/plant, top and root yields/fed., respectively. 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, root length was significantly enhanced deeply, when sugar beet plants were exposed to water stress. Simpson (1981) explained that lengthening the roots in the soil was to exploit the deeply stored soil moisture to avoid drought stress damage. This results are in accordance with those reported by Gaber *et al.* (1986), Saif *et al.* (1997) and El-Zayat (2000).

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 levels:					
40-45% SMD	25.87 b	10.37 a	1.049 a	7.20 a	23.59 a
60-65% SMD	26.30 a	10.23 b	1.028 b	7.08 b	23.45 a
80-85% SMD	26.48 a	10.10 c	0.996 c	6.87 c	22.75 b
K-fertilizer (kg K_2O/fed.):					
K-0	25.94 c	10.08 b	1.016 c	6.89 c	22.57 c
K-24	26.24 b	10.27 a	1.025 b	7.06 b	23.32 b
K-48	26.47 a	10.35 a	1.031 a	7.20 a	23.90 a
Interactions:					
Irrigation x years	N.S	N.S	N.S	N.S	N.S
K x years	N.S	N.S	N.S	N.S	N.S
Irrigation x K	N.S	N.S	N.S	N.S	N.S
Irrig. x K x years	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. The increment was 2.04, 2.68, 1.48, 4.50 and 5.89%, respectively, compared to the control. 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), Khalifa *et al.* (2000).

Insignificant effect were detected with any of the interactions among the two variables studied Table (3).

II. Quality parameters:

Results illustrated in Table (4) showed that total soluble solids and sucrose percentage significantly increased by increasing water stress levels. On the contrary, sugar yield was lowered by deficit irrigation. Whereas 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 results 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) and El-Zayat (2000).

Table (4): 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 levels:				
40-45% SMD	20.66 c	17.47 c	84.56 a	4.13 a
60-65% SMD	20.77 b	17.60 b	84.76 a	4.12 a
80-85% SMD	20.90 a	17.70 a	84.66 a	4.02 b
K-fertilizer (kg K_2O/fed.):				
K-0	20.69 b	17.49 c	84.52 a	3.95 c
K-24	20.78 a	17.61 b	84.71 a	4.10 b
K-48	20.86 a	17.68 a	84.75 a	4.22 a
Interactions:				
Irrigation x years	N.S	N.S	N.S	N.S
K x years	N.S	N.S	N.S	N.S
Irrigation x K	N.S	N.S	N.S	N.S
Irrig. x K x years	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 yield. These results 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 (5).

Table (5): Monthly and seasonal water consumptive use of sugar beet as affected by 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	
40-45% SMD	0	1.90	4.50	6.50	8.40	13.10	15.35	10.60	60.35
	24	1.90	4.50	6.55	8.50	13.25	15.40	10.65	60.75
	48	1.90	4.50	6.65	8.67	13.60	15.52	10.76	61.60
Mean		1.90	4.50	6:57	8.52	13.32	15.42	10.67	60.90
60-65% SMD	0	1.90	4.50	5.97	7.61	11.57	13.87	9.72	55.14
	24	1.90	4.50	6.00	7.64	11.65	13.90	9.76	55.35
	48	1.90	4.50	6.10	7.75	11.72	13.96	9.87	55.80
Mean		1.90	4.50	6.02	7.67	11.65	13.91	9.78	55.43
80-85% SMD	0	1.90	4.50	4.80	5.68	9.65	11.90	7.25	45.68
	24	1.90	4.50	4.90	5.80	9.91	11.97	7.44	46.42
	48	1.90	4.50	4.95	5.90	9.95	12.00	7.54	46.74
Mean		1.90	4.50	4.88	5.79	9.84	11.96	7.41	46.28
Overall mean		1.90	4.50	5.82	7.33	11.60	13.76	9.29	54.20
Total potassium average (cm) K-0: 53.72				K-24: 54.17			K-48: 54.71		

Amounts of seasonal water consumptive use rate increased in case of frequent irrigation as in 40-45% SMD than in case of sparsely one 80-85% SMD. 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 Ibrahim *et al.* (1993), Shams El-Din (2000) and El-Zayat (2000).

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 are in line with those reported by El-Naggar *et al.* (1996) who found an increase in water consumptive use of barely and soybean by increasing K_2O from zero to 72 kg/fed.

2. Water use efficiency (WUE):

Water use efficiency by sugar beet expressed as kg roots or sugar yield produced/m^3 of water consumed as affected by irrigation regime and potassium fertilizer is presented in Tables (6 and 7).

Table (6): Water use efficiency by sugar beet (kg root yield/m^3 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	Potassium rates (kg K_2O/fed.)			Mean
	0	24	48	
40-45% SMD	9.02	9.28	9.37	9.22 c
60-65% SMD	9.83	10.11	10.28	10.07 b
80-85% SMD	11.50	11.68	11.92	11.70 a
Mean	10.12 c	10.36 b	10.52 a	10.33

Data showed that irrigation at 80-85% soil moisture depletion achieved the highest WUE for both root and sugar yields, while it was lower under wet condition (40-45% SMD). These results could be attributed to the highly significant differences among the roots or sugar yield production as well as the differences between the water consumptive use. These results are in agreement with those obtained by Shams El-Din (2000) and El-Zayat (2000).

Table (7): Water use efficiency by sugar beet (kg sugar yield/m^3 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	Potassium rates (kg K_2O/fed.) 0	24	48	Mean
40-45% SMD	1.58	1.62	1.64	1.61 c
60-65% SMD	1.72	1.78	1.81	1.77 b
80-85% SMD	2.02	2.06	2.12	2.07 a
Mean	1.77 c	1.82 b	1.86 a	1.82

Regarding the effect of potassium, WUE for both root or sugar yields was increased by 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) who concluded that potassium supply increased WUE of corn plants.

3. 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 (8).

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 76.25, 71.74 and 65.13% when irrigated at 40-45, 60-65 and 80-85% soil moisture depletion, respectively, while the respective values were 23.75, 28.26 and 34.87% withdrawn from the lower 30-60 cm. This 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) 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 and the values were about the same

Table (8): 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
40-45% SMD	0	48.70	27.10	18.20	5.35	75.80	23.55
	24	48.96	27.29	18.32	5.49	76.25	23.81
	48	49.16	27.53	18.35	5.55	76.69	23.90
Mean		48.94	27.31	18.29	5.46	76.25	23.75
60-65% SMD	0	45.42	25.95	19.70	8.15	71.37	27.85
	24	45.68	26.15	20.12	8.27	71.83	28.39
	48	45.75	26.28	20.19	8.34	72.03	28.53
Mean		45.62	26.13	20.00	8.25	71.74	28.26
80-85% SMD	0	40.43	24.30	22.25	12.32	64.73	34.57
	24	40.66	24.56	22.42	12.50	65.22	34.92
	48	40.80	24.64	22.48	12.65	65.44	35.13
Mean		40.63	24.50	22.38	12.49	65.13	34.87

4. Reference evapotranspiration (ET_o) and crop coefficient (K_c):

Reference evapotranspiration (ET_o) values were calculated by four methods i.e. modified Penman, radiation, modified Blaney-Criddle and class A pan evaporation during the growth period of sugar beet.

Results depicted in Table (9) revealed that estimation of (ET_o) by Blaney-Criddle and class A pan methods were lower than those obtained by Penman and radiation methods. This results may be attributed to the number of climatic factors included in Blaney-Criddle and pan methods are less than in the other methods.

Table (9):Monthly reference evapotranspiration (ET_o) mm/day and crop coefficient (K_c) of sugar beet (average of the two growing seasons).

Months	Actual evapotrans-piration (ET_C) mm/day	Reference evapotranspiration (ET_o) mm/day				Average of all methods mm/day	Crop coefficient (K_c)				Average of all methods mm/day
		Penman	Radiation	Blaney Criddle	Class A pan		Penman	Radiation	Blaney Criddle	Class A pan	
Nov.	1.06	2.82	2.73	2.61	2.08	2.56	0.38	0.39	0.41	0.51	0.43
Dec.	1.45	2.24	1.99	1.76	1.82	1.95	0.66	0.73	0.83	0.80	0.76
Jan.	2.12	2.18	2.01	1.64	1.64	1.87	0.98	1.05	1.30	1.30	1.16
Feb.	3.04	2.90	2.65	1.94	2.05	2.39	1.05	1.15	1.57	1.49	1.32
Mar.	4.30	3.97	3.69	2.77	2.69	3.28	1.08	1.17	1.56	1.61	1.36
Apr.	5.14	5.32	4.70	4.22	4.03	4.57	0.97	1.09	1.22	1.29	1.14
May	3.44	6.49	5.71	5.26	4.43	5.47	0.54	0.61	0.66	0.78	0.65
Total		25.92	23.48	20.20	18.74	22.09	5.66	6.19	7.55	7.78	6.82
Mean		3.70	3.35	2.89	2.68	3.16	0.81	0.88	1.08	1.11	0.97
Percent deviation from the mean		+17.09	+6.01	-8.54	-15.19						
Seasonal (K_c) FAO value							0.80	0.80	0.80	0.80	0.80
Percent deviation from FAO value							+1.25	+10.0	+35.0	+38.75	+21.25

The percentage deviations of (ET_o) from the average values were +17.09, +6.01, -8.54 and -15.19 for modified Penman, radiation, Blaney-Criddle and class A pan, respectively. Based upon deviation values it can be concluded that the most suitable methods for calculating (ET_o) for Sakha region are radiation and Penman methods. These methods have a reasonable deviation of 6.01 and 17.09% than average values. Similar results were obtained by El-Naggar (1980) who found that (ET_o) value derived from class A pan measurements are less than values of Penman equation.

Crop coefficient (K_c) represents the relationship between reference evapotranspiration (ET_o) and actual evapotranspiration (ET_c) of sugar beet that drived from the treatment which irrigated at 40-45% SMD. Values of crop coefficient (K_c) are shown in Table (9).

Results indicated that the lowest (K_c) value was obtained at the initial stage for all methods, then increased gradually and reached its maximum at March, and then declined to reach lower value at ripening. The average values of seasonal crop coefficient (K_c) for sugar beet over the two growing seasons were 0.81, 0.88, 1.08 and 1.11 for Penman, radiation, Blaney-Criddle and class A pan methods, respectively. It is clearly that (K_c) values for Penman and radiation methods were lower than those obtained by Blaney-Criddle and the class A pan methods. This is mainly due to lower estimated value of reference evapotranspiration (ET_o) obtained by the last two methods.

Comparing the seasonal values of (K_c) for sugar beet estimated by the previous methods with that recommended by FAO (Doorenbos *et al.,* 1979), which equal 0.80 for the areas have the meteorological conditions such as that of North Delta region (low wind < 5 m/sec. and high humidity). The percentage deviation were +1.25, +10.0, + 35.0 and + 38.75% for Penman, radiation, Blaney-Criddle and class A pan, respectively. It could be concluded that the calculated values of 0.81 and 0.88 for (K_c) could be used in calculating the consumptive use of sugar beet in North Delta as estimated by the aid of Penman and radiation methods.

IV.Simple correlation coefficients (r):

The relationships between sugar yield ton/fed. and some traits of sugar beet are presented in Table (10).

Table (10): Simple correlation coefficient (r) between sugar yield and top yield, root yield, water use efficiency and water consumptive use (average of the two seasons).

Variables	Sugar yield ton/fed.	Top yield ton/fed.	Root yield ton/fed.	Water use efficiency	Water consumptive use
Sugar yield/fed.	—				
Top yield/fed.	0.521	1.00			
Root yield/fed.	0.910**	0.542	1.00		
Water use efficiency	-0.645*	-0.498	0.900**	1.00	
Water consumptive use	0.707**	0.522	0.931**	0.995**	1.00

*, ** significant at 0.05 and 0.01 levels of probabilities.

The data showed that sugar yield had highly significant positive correlation with each of root yield/fed. and water consumptive use, while it was significantly negative to water use efficiency. Highly significant positive correlation were found between root yield/fed. and each of water use efficiency and water consumptive use. Water use efficiency was significantly positive as correlated with water consumptive use. The positive correlation indicted that sugar yield increases when root yield and water consumptive use increase. In this concern, Ghanem and Gomma (1985) found that sugar yield was positively and significantly correlated with root length, root diameter as well as between root and top yield.

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تأثير مستويات الرطوبة الأرضية والتسميد البوتاسى على إنتاجية محصول بنجر السكر

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أجريــت هــذه الدراســة بمحطة البحوث الزراعية بسخا ــ محافظة كفرالشيخ عامى ١٩٩٩/٢٠٠٠م ، ٢٠٠٠/٢٠٠١م لدراســة تأثــير الــرى عند مستويات مختلفة من الرطوبة الأرضــية فــى منطقة امتصاص الجذور والتسميد البوتاسى على المحصول والجودة ، وبعض العلاقات المائية لنبات بنجر السكر.

واســتخدم تصــميم القطــع المنشــقة فى أربع مكررات حيث وزعت معاملات الرى بالقطع الرئيسية وهى الرى عند فقد ٤٠-٤٥% ، ٦٠-٦٥% ، ٨٠-٨٥% من الماء الميسر بالتربة ومعاملات التسميد البوتاسى بالقطع المنشقة وهى (صفر ، ٢٤ ، ٤٨ كجم بو٢ أ/فدان)

وقد أوضحت النتائج ما يلى:

١- أدى الــرى عــند فقد ٨٠-٨٥% من الماء الميسر إلى نقص معنوى لصفة قطر ووزن الجــذر ومحصــول الجــذور والعرش والسكر/فدان. مع وجود زيادة معنوية لصفة طول الجذر والمواد الصلبة الذائبة الكلية ونسبة السكروز.
٢- أدى زيــادة التسميد البوتاسى حتى ٤٨ ك.ج بو٢ أ/فدان إلى زيادة معنوية لكل الصفات تحت الدراسة.
٣- لم يكن لمعاملات الرى والتسميد البوتاسى تأثير معنوى على النسبة المئوية للنقاوة.
٤- أدى الــرى عــند فقد ٤٠-٤٥% من الماء الميسر إلى الحصول على أعلى القيم لصفة الأستهلاك المائى الموسمى. وأقل القيم لكفاءة استخدام مياه الرى.
٥- وجــد أن نــبات بــنجر السكر استهلك أكبر كمية من الماء الذى يحتاج إليه من الطبقة السطحية للتربه (صفر ــ ١٥سم).
٦- أدى التســميد البوتاســى إلى زيادة طفيفة لصفة الاستهلاك المائى الموسمى. بينما كانت الزيادة معنوية بالنسبة لكفاءة استخدام مياه الرى.
٧- يمكن استخدام قيمة معامل المحصول ٠,٨١ ، ٠,٨٨ عند حساب الاستهلاك المائى لبنجر السكر فى منطقة شمال الدلتا وذلك باستخدام طريقتى بنمان المعدلة والاشعاع.
٨- اشارت النتائج إلى وجود ارتباط عالى المعنوية وموجب لصفة محصول السكر/فدان وكل مــن محصــول الجــذور/فدان والاستهلاك المائى الموسمى ، بينما كان الارتباط معنوى وسالب مع كفاءة استخدام مياه الرى.