Soil and Crop-Water Relations and Productivity of Two Sugar Beet Varieties as Affected by Irrigation Rates and Soil Amendments under Drip Irrigation System

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ABSTRACT

Two consecutive growing seasons of successful field experiments 2018/19 and 2019/20 were caried out at Nubaryia Agriculture Research station (30º 54` 54`` N 29º 57` 53`` E) in calcareous soils under drip irrigation to study the effect of applied three rates of water (I) 60, 80 and 100% of potential evapotranspiration ETp (using class A pan) and two soil amendments (S) plus control treatment (without amendment) , Aquita and Potassium humate on water relation, crop coefficient and productivity of two sugarbeet varieties (V), Farida and Marathon. The statistical split-split plots design with three replicates was adopted for this study. Roots yield, gross sugar yield, amount applied irrigation water (AIW), water consumptive use (WCU), crop coefficient (Kc), productivity of irrigation water (PIW) and water productivity (WP) of the two tested sugarbeet varieties were calculated and evaluated. The results, in the two seasons, indicated that there was a significant and direct relationship between irrigation rate (I) and yield of roots and gross sugar of the two sugarbeet varieties (V). The highest values of roots crop were (30.55 tons fed^{-1}) and raw sugar (5.724 tons / feddan) obtained from the irrigation treatment of 100% of standard evapotranspiration in the first season, while it was (23.053 tons fed^{-1}) and (4.325 tons fed^{-1}). With the irrigation treatment 80% of the measured evaporation emitted in the second season. The addition soil amendment (Aquita) was more efficient than potassium humate on roots and gross sugar yields. The interactions of (I x V) was significant effect for roots and gross sugar yields in both seasons. Farida variety with 100% ETp irrigation rate recorded the highest roots and gross sugar yields in the first season, while Marathon variety with 80% rate achieved the highest ones in the second season. The (I x S) interaction was significant effect on root yields in both seasons, and the highest yield was recorded by (100 ETp irrigation rate with Aquita soil amendment) treatment. However, the (S x V) interaction was significant effect for grass sugar yield in the second season only and the highest yield was obtained by (Aquita with Farida variety) treatment. Also, the interaction of (I x S x V) was significant effect on roots and gross sugar yields in the second season only. The maximum roots were obtained by (Farida variety amended with Aquita under 100% of ETp) treatment, while the gross sugar yield was recorded by (Marathon variety amended with potassium humate under 80% of ETp) treatment. The obtained overall average values of (AIW) were 2682.31, 2173.69 and 1665.10 m^{3} fed^{-1} for 100, 80 and 60 % of ETp, respectively. Also, the overall average of water consumptive use (WCU) for the two Farida and Marathon sugarbeet varieties were (1985.05, 1597.07 and 1205.46 m^{3}) and (1956.91, 1586.14 and 1181.44 m^{3}) for 100, 80 and 60 % of ETp, respectively. Crop coefficient (Kc) was not affected by the irrigation rate and sugarbeet varieties where the seasonal average Kc values for the three stages (Initial, Mid. and Late season) of Farida and Marathon were (0.34- 0.33, 1.02 -1.01 and 0.69- 0.67), respectively.

Key words: Sugarbeet – Water Stress– Soil Amendments – Water Relations – Drip Irrigation– Sugarbeet varieties.

INTRODUCTION

In Egypt, sugarbeet (*Beta vulgaris* L) is now the first source of sugar production, producing about 1.8 million tons (67%), corresponding to 0.9 million tons (23%) for sugarcane. It is cultivated in an area of 700.000 feddan. The bulk of this area is reclaimed desert land (National Council of Sugar Crops, 2020). Water is considered an economical scare resource in many areas of the world especially in arid and semiarid regions as Arabic countries and Egypt, also, it is considered a limiting factor in agricultural expansion in all countries, all over the world. In Egypt, however, irrigation water is not sufficient for both irrigation and reclamation purposes, so drip irrigation is considered a highly efficient method of delivering water, save water, fertilizers and pesticides uniformly to most crops. The drip irrigation system designed to provide frequent low volume irrigation to crops, conserve energy and labor in addition to conserving minimizing environmental contamination. Deficit irrigating has been widely investigated as a valuable and sustainable production strategy in dry regions (Greets and Raes, 2009). In many deficits irrigation studies on sugarbeet productivity, that the irrigation at the rate of 60% evapotranspiration (ET_p) gave a highest roots, gross sugar and white sugar yields fed^{-1}. Drip irrigation sugarbeet plants with 75% irrigation water requirement (IWR) gave the heaviest

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roots and white sugar yields fed^{-1}. (El-Kady, 2015 and Masri *et al*., 2015). Also, drip irrigation at 60% of IWR gave the best roots yield and good quality of sugarbeet crop (El-Darder *et al*., 2017). Also, Maareg *et al*. (2018) found that the highest roots and sugar yields fed^{-1}. values were recorded with 75 and 100% of IWR rates, without significant difference between them, while irrigation rate of 75% of IWR significantly exceeded 100% of IWR rate, in water use efficiency (WUE). However, Zoghdan *et al*. (2019) reported that the highest values of water saving irrigation application efficiency and consumptive use efficiency were recorded with 70% IWR of furrow length, while, the highest values of roots and sugar yields, productivity of irrigation water (PIW) and water productivity (WP) were recorded with cut off irrigation at 80% of furrow length, while the lowest values of PIW and WP were recorded with the full irrigation treatment. Other studies founded that increasing amount of irrigation water up to 100% ETp fed^{-1}. significantly increased sugarbeet roots, gross sugar, white sugar yields and decreased (WUE) values under drip irrigation (Osman *et al*., 2005 and El-Kholi, 2017). Due to the high cost of chemical fertilizers and the resulting risks and environmental pollution, organic fertilizers such as farm- yard manure and compost were used, because they contain most of micro and macronutrients. Organic fertilizers as organic amendments have the capacity to improve soil structure and fertility. In some organic amendment studies on sugarbeet productivity, Maareg *et al*. (1999) indicated that the application of organic compost significantly increased roots and sugar yields. The effect of different manure sources as soil amendments on roots and sugar yields due to the improvement in soil physical and chemical properties as a result of application with these materials (Abdel-Nasser and Hussein, 2001). Also, Marinkovic *et al*. (2004) they reported that the application of organic fertilizer increased the sugarbeet yields, and Maareg *et al*. (2008) found that the roots and sugar yields significantly increased by increasing different animal manures levels addition. Also, Margo *et al*. (2015) showed that with addition of organic compost increased markedly yields of sugarbeet yields. On the other side, El-Gamal (2016) concluded that application of humic acid increased roots and gross sugar yields of sugarbeet. In study on tolerance of four sugarbeet varieties to soil water depletion levels, Hamed and Emara (2019) found that 25% water depletion recorded the best growth and yields, but the highest WUE resulted from 75% water depletion treatment.

In addition, the effects of climate change and the growing demand for agricultural products and food represent major obstacles to the sustainable and fair use of water. Therefore, it is becoming increasingly important to use soil amendments, deficit irrigation and high production varieties for saving and optimum utilization water and hence the objective of this work was to study the effect of three rates of irrigation water and two soil amendments on applied irrigation water, water consumptive use, crop coefficient, productivity of irrigation water and water productivity of two sugarbeet varieties under drip irrigation system in calcareous soil at Nubaryia area.

MATERIALS AND METHODS

Two field experiments were conducted at the farm of Nubaryia Agricultural Research Station (30º 54` 54`` N 29º 57` 53`` E) during 2018/19 and 2019/20 growing seasons to study the effects of tree drip irrigation rates and two soil amendments on productivity, applied irrigation water, water consumptive use, crop coefficient, productivity of irrigation water and water productivity of two sugarbeet varieties in calcareous soil at Nubaryia region. The used surface drip irrigation system in the experimental farm includes an irrigation pump connected to sand and screen filters and a fertilizer injector tank. Main line is made of PVC pipe of 63 mm diameter, while drip lateral lines of 16 mm diameter are connected to the main line. Each lateral is 25 m long and 0.5 m spacing. Emitters of 4.0 Lh^{-1} manufacture discharges were spaced 30 cm apart on the lateral line. The determined values of Christiansen coefficient and emission uniformity were 94% and 92% respectively. The actual average discharge rate of emitter was 3.52 Lh^{-1}. The soil texture was sandy clay loam (60% sand, 19.1% silt and 20.9% clay) with average bulk density (BD) =1.21 g cm^{-3}, pH = 8.4, O.M. = 0.60%, $CaCO_3$ = 31.8% and EC 1.341 dSm^{-1} Black (1965). Soil field capacity (F.C) and wilting points (WP) of the soil samples were determined by pressure extractor apparatus then available soil moisture (ASM) values were calculated. The obtained results are presented in Table (1).

The experimental design was split split plot design with three replicates.

The main plots were devoted to the three irrigation rates as follows:

1- I_1: irrigation with amount of water equals 60% of potential evapotranspiration (ET_P).

2- I_2: irrigation with amount of water equals 80% ETp.

3- I_3: Irrigation with amount of water equals 100% ETp.

Table 1. Field capacity, wilting point, available water and bulk density for soil of the experimental site at Nubuyria Agric. Res. Station farm.

Soil depth (cm)	Field capacity (%)	Wilting points (%)	Available water (%)	Bulk density (g cm^{-3})
0-15	24.6	13.53	11.37	1.17
15-30	24.7	13.42	11.28	1.20
30-45	23.9	12.99	10.91	1.22
45-60	23.6	12.83	10.77	1.25
Means	24.27	13.19	11.08	1.21

The distance between each treatment and anther was 2 meter to prevent overlap between them. (ETp) determined by class A pan of experimental side.

The sub-plots included two varieties as follows:

1- Marathon (as monogerm variety).

2- Farida (as polygerm variety).

The sub- sub plots included two soil amendments as follows plus control treatment (without amendment);

(Granular soil amendments were mixed with the soil before it was placed in the experimental site. The granular soil amendments were mixed with a soil mass equivalent to the mass of the soil layer.

1- Aquita (9% Zn, 3.5 CaO, 0.6 S) added to the soil before sowing at the 4 Kg fed^{-1} rate.

2- Potassium humate (10% K_2O) added after sowing at the 4 Kg fed^{-1} rate.

Sugarbeet varieties, Farida and Marathon seeds were sown on the 11th and 17th of November and yield was harvested on the 11th and 17th of June in the first and second growing seasons, respectively, seeds were sown in hills spaced 0.30 m. a part. Hills were thinned to a single plant 30 days after planting. The experimental unit consists of six ridges, 0.5 meter apart and 3 meters in length long-during land preparation, super phosphate was added as a single rate of 30 kg P_2O_5 fed^{-1} before sowing. All treatments received 60 kg N fed^{-1} of ammonium nitrate, 33.5%N and 24 kg of k_2O fed^{-1} as potassium sulfate were added in two equal doses. The first one was applied after thinning and the second one applied four weeks later. All other recommended cultural practices for growing sugarbeet at Nubaryia area were followed. At harvest four central ridges were devoted for determining roots yield. Gross sugar percentage in juice of beet roots in each treatment was determined according to Le-Docte as described by Mc Ginnis (1982). Gross sugar yield was estimated based on the product of roots yield × gross sugar percentage.

Water relation:

I- Soil water relations:

I-1- Amount of applied irrigation water (AIW), (mm day^{-1}):

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

$$AIW = \frac{\mathrm{ETp\ x\ Kr}}{Ea(1-LR)}$$

Where;

ET_p = potential evapotranspiration (mm day^{-1}) values obtained by class A pan evaporation method Doorenbos and kassam (1979) and calculated as follows:

$ET_p = E_{pan} \times K_{pan}$

Where;

E_{pan} = measured pan evaporation daily values (mm day^{-1}).

K_{pan} = pan coefficient. K_{pan} values that depend on the relative humidity, wind speed and the site conditions (bore or cultivated). A kpan value of 0.75 was used for the experimental site.

K_r = reduction factor that depends on ground cover. A_{kr} value of 1.0 was used since crops spacing were less than 1.8 m a part James (1988).

E_a = irrigation efficiency = $K_1 \times K_2$ = 0.85

Where;

K_1 = emitter uniformity coefficient = 0.90 for the drip system at the site.

K_2: drip irrigation system efficiency = 0.94 for the drip system at the site.

L.R = Leaching requirements, the LR was dismissed as good water quality and soil.

I-2- Water consumptive use (WCU):

Water consumptive use values were calculated according to Israelson and Hansen (1962) using the following equation:

$$WCU = \sum_{i=1}^{i=4} \left(\frac{\theta_2 - \theta_1}{100}\right) \times \int \times d$$

Where: WCU = water consumptive use, cm

i = number of soil layer

Ө2 = percentage of soil moisture content after irrigation

Ө1 = percentage of soil moisture content before irrigation

d = depth of soil layer (cm)

∫ = specific gravity = soil bulk density /water density

$I = \frac{D}{ETc}$, where,

D: is the net depth of irrigation application (mm),

ETc: is the daily crop evapotranspiration (mm/day).

I-3- Crop coefficient (Kc)

Crop coefficient (Kc) for sugarbeet was calculated as follows:

$$Kc = ETa / ETp$$

Where;

ETa = Actual evapotranspiration = WCU, mm day^{-1})

ET_p = potential evapotranspiration (mm day^{-1})

II- Crop water relation

II-1-Productivity of irrigation water (PIW), (kg m^{-3}):

Productivity of irrigation water (PIW) was estimated according to (Ali *et al.*, 2007).

$$PIW = \frac{GY}{AW}$$

Where:

GY = yield kg fed^{-1} and

AW= applied water (m^3 fed^{-1}). (Irrigation water+ effective rainfall)

Note: effect rainfall = rainfall*0.7 (Novica, 1979)

The amounts of rain were calculated according to the meteorological stations and deducted from the quantities of irrigation with each irrigation

II-2- Water productivity (WP), (kg m^{-3}):

Water productivity is generally outlined as crop yield per cubic meter of water consumption. It was calculated according to (Ali *et al*., 2007).

$$WP = \frac{GY}{ET}$$

Where:

GY = yield (kg fed^{-1}) and

ET = Total water consumption of the growing season (m^3 fed^{-1}.).

Data Recorded:

The collected in the two experiments involved the following traits:

A- Yield components:

A-1- Roots yield (tons fed^{-1}).

A-2- Gross sugar yield (tons fed^{-1}).

B- Water relation:

B-1- Soil water relation:

B-1-1- Amount of applied irrigation water (AIW).

B-1-2- Water consumptive use (WCU).

B-1- 3- Crop coefficient (Kc).

B-2- Crop water relation:

B-2-1- Productivity irrigation water (PIW).

B-2-2- Water productivity (PW).

Statistical analysis:

The obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the spit plots design as described by Steel and Torrie (1960). Means were separated using the least significant difference (L.S.D) method.

RESULTS AND DISCUSSIONS

A- Yield components:

Average values of sugarbeet yield components, i.e., roots yield and gross sugar yield (tons fed^{-1}.) as affected by three irrigation rates, two soil amendments and two sugarbeet varieties during the two growing seasons are depicted in Tables (2 & 3).

A-1- Roots yield (tons fed^{-1}):

The results in Table (2) showed that there were significant differences in the roots yield fed^{-1} due to the irrigation water rates addition in both growing seasons.

In the first season, increasing water irrigation rate significantly increased the roots yield fed^{-1} value, and any increase in irrigation rate always followed by a significant increase in value of roots yield fed^{-1}. Raising irrigation rate from 60 to 80 and 100% of ET_p increased roots yield from 22.867 to 26.975 and 30.055 tons fed^{-1}, respectively. This means there were increases in yield of roots about 17.96% and 31.43% in cases of 80 and 100% ET_p, respectively as compared with 60% of ET_p as shown in Table (2).

Table 2. Effect of three irrigation rates, two soil amendments and two sugarbeet varieties on roots yield (tons fed^{-1}) during the two growing seasons.

Treatment	Sugarbeet varieties	First season				Second season			
		Soil amendments			Mean	Soil amendments			Mean
		Control	Potassium Humate	Aquita		Control	Potassium Humate	Aquita	
I_1	V_1	19.710	23.737	24.057	22.501	18.050	19.800	21.733	19.861
	V_2	20.937	23.903	24.857	23.232	15.833	19.667	21.900	19.133
Mean		20.323	23.820	24.457	22.867	16.942	19.733	21.817	19.497
I_2	V_1	24.473	27.500	28.270	26.748	19.433	21.300	25.283	22.005
	V_2	26.177	27.527	27.900	27.201	22.167	25.900	24.233	24.100
Mean		25.325	27.513	28.085	26.975	20.800	23.600	24.758	23.053
I_3	V_1	29.270	34.343	35.760	33.124	18.883	20.433	26.533	21.950
	V_2	24.477	28.947	27.533	26.986	18.583	24.733	25.500	22.939
Mean		26.873	31.645	31.647	30.055	18.733	22.583	26.017	22.444
V x S	V_1	24.484	28.527	29.362	27.458	18.789	20.511	24.517	21.272
	V_2	23.863	26.792	26.763	25.806	18.861	23.433	23.878	22.057
Mean		24.174	27.659	28.063	26.632	18.825	21.972	24.197	21.665
L.S.D at $_{0.05}$									
I		0.807				0.757			
V		0.915				0.412			
S		0.633				0.546			
I x V		1.585				0.714			
I x S		1.097				0.947			
V x S		0.896				0.773			
I x V x S		N.S				1.339			

* Irrigation treatments I_1= 60%, I_2= 80% and I_3= 100% ET_p

* V_1 = Farida and V_2 = Marathon S= Soil amendment

In the second season the irrigation rate of 80% ET_p (23.053tons fed^{-1}) and 100% ET_p (22.444 tons fed^{-1}) significantly increased roots yield than 60% ET_p rate (19.497 tons fed^{-1}) The increase in roots yield fed^{-1} due to adding 80 and 100% ET_p irrigation rates, reached about 19.50 and 15.12%, respectively as compared with 60% ET_p rate, without significant differences between them. Soil amendments, Aquita and potassium humate exhibited effect on roots yield of sugarbeet (tons fed^{-1}). In the first season, the roots yield with Aquita soil amendment treatment (28.063 tons fed^{-1}) was slightly higher than that recorded with soil amendment, potassium humate (27.659 tons fed^{-1}), without significant difference between them.

However, in the second season, the Aquita treatment significantly increased roots yield (24.197 tons fed^{-1}) than the potassium humate treatment (21.972 tons fed^{-1}) as shown in Table (2).

The interaction between the irrigation rates and soil amendments (I × S) was significant effect for roots yield in the two seasons. The obtained data observed that the highest roots yield values were recorded by Aquita (31.647 tons fed^{-1}) and potassium humate (31.645 tons fed^{-1}.) under 100% ETp irrigation rate in the first season and Aquita (26.017 tons fed^{-1}) only under the same rate in the second season. There was significant difference between the two sugarbeet varieties, Farida and Marathon in both seasons. Farida variety recorded the highest roots yield (27.458 tons fed^{-1}) in the first season, while Marathon variety achieved the highest roots yield (22.057 tons fed^{-1}) in the second season. The overall average of roots yields fed^{-1} was 24.365 and 23.932 tons fed^{-1} for Farida and Marathon sugarbeet varieties, respectively.

The interaction between the irrigation rates and sugarbeet varieties (I × V) was significant effect for roots yield fed^{-1}. in the two growing seasons, the results revealed that the Farida variety plants irrigated with 100% ETp irrigation rate recorded the highest roots yield (33.124 tons fed^{-1}) in the first season, however, Marathon variety plants under 80% ETp rate recorded the highest yield of roots (24.1 tons fed^{-1}) in the second one.

The interaction between sugarbeet varieties and soil amendments (V × S) was significant effect for roots yield in both seasons. The highest roots yield values (29.362 and 28.572 tons fed^{-1}) were obtained by Farida variety amended with Aquita and potassium humate, respectively in the first season, while the combination of Farida variety and Aquita amendment was recorded the highest roots yield (24.517 tons fed^{-1}) in the second season.

The interaction among irrigation rates, soil amendments and sugarbeet varieties (I × V × S) was significant effect for roots yield in the second season only. In this respect, Farida variety amended with Aquita under 100% ETp irrigation rate was recorded the highest roots yield value (26.533 tons fed^{-1}) as shown in table (2).

A.2. Gross sugar yield (tons fed^{-1}):

Also, the results indicated that the gross sugar yield was significantly influenced by irrigation rates, soil amendments and sugarbeet varieties in the two growing seasons, as shown in Table (3). In the first season, irrigation rate significantly increased gross sugar yield, and any increase in the irrigation water applied was followed by a respective increment in gross sugar yield fed^{-1}.

Table 3. Effect of three irrigation rates, two soil amendments and two sugarbeet varieties on gross sugar yield (tons fed^{-1}) during the two growing seasons.

Treatment	Sugarbeet varieties	First season				Second season			
		Soil amendments			Mean	Soil amendments			Mean
		Control	Potassium Humate	Aquita		Control	Potassium Humate	Aquita	
I_1	V_1	3.453	4.415	4.368	4.079	3.158	3.719	3.913	3.597
	V_2	3.645	4.707	4.859	4.403	2.824	3.535	4.270	3.543
Mean		3.549	4.561	4.613	4.241	2.991	3.627	4.092	3.570
I_2	V_1	4.719	5.566	5.551	5.279	3.497	4.046	4.844	4.129
	V_2	4.726	5.477	5.478	5.227	3.952	5.092	4.517	4.520
Mean		4.722	5.522	5.515	5.253	3.725	4.569	4.681	4.325
I_3	V_1	5.532	6.790	6.688	6.336	3.493	3.987	4.867	4.116
	V_2	4.526	5.460	5.347	5.111	3.343	4.532	4.717	4.197
Mean		5.029	6.125	6.017	5.724	3.418	4.260	4.792	4.156
V x S	V_1	4.568	5.590	5.536	5.231	3.383	3.917	4.541	3.947
	V_2	4.299	5.214	5.228	4.914	3.373	4.386	4.501	4.087
Mean		4.433	5.402	5.382	5.073	3.378	4.152	4.521	4.017
L.S.D at $_{0.05}$									
I			0.308				0.147		
V			0.166				0.067		
S			0.172				0.119		
I x V			0.288				0.116		
I x S			N.S				0.207		
V x S			N.S				0.169		
I x V x S			N.S				0.293		

* Irrigation treatments I_1= 60%, I_2= 80% and I_3= 100% ET_p

* V_1 = Farida and V_2 = Marathon S= Soil amendment

The increase was about 23.86 and 34.97% due to adding 80 and 100% ETp irrigation rates, respectively as compared with 60 % ETp irrigation rate. In the second season, beet plants irrigated with 80% and 100% ETp irrigation rates significantly increased gross sugar yield fed^{-1} than those irrigated with 60% ETp rate. These increases were about 21.15 and 16.41 % in gross sugar yield fed^{-1} for 80 and 100% ETp irrigation rates, respectively, as compared by 60% ETp rate. There was significant difference between them. Generally, the rate of 80% ETp produced the highest gross sugar yield (4.325 tons fed^{-1}), while the rate of 60% ETp produced the lowest one (3.57 tons fed^{-1}).

Also, soil amendments, Aquita and Potassium humate had a significant effect on gross sugar yield fed^{-1} in the two seasons. The two tested soil amendments significantly increased gross sugar yield fed^{-1} as compared with control treatments in the two seasons. The increase in gross sugar yield of sugarbeet was about 21.41 and 21.86 % due to adding Aquita and Potassium humate respectively (without significant difference between them) in the first season. However, in the second season, the increase in gross sugar yield was 33.84 and 22.91% for same respective soil amendments; there was significant difference between them, (Table, 3). The interaction between irrigation rates and soil amendments (I × S) on gross sugar yield was significant in the second season, only. The highest gross sugar yield fed^{-1} (4.792 tons) was obtained by adding Aquita soil amendment under high irrigation rate treatment.

There was significant difference between the two sugarbeet varieties, Farida and Marathon in growth sugar yield fed^{-1} in both seasons. Farida variety recorded the highest gross sugar yield (5.23 tons fed^{-1}) in the first season, while Marathon variety achieved the highest one (4.087 tons fed^{-1}) in the second season. Where the overall average of gross sugar yield in connection with Farida and Marathon varieties was 4.589 and 4.501 tons fed^{-1}, respectively.

The interaction between irrigation rates and sugarbeet varieties (I × V) on gross sugar yield was significant in the two seasons. The highest value of gross sugar yield (6.336 tons fed^{-1}) was given by cultivating Farida variety under 100% ETp irrigation rate in the first season, while in the second one, the highest value (4.520 tons fed^{-1}) was obtained by Marathon variety under 80% ETp irrigation rate.

The interaction between sugarbeet varieties and soil amendments (V × S) and among irrigation rates, sugarbeet varieties and soil amendments (I × V × S), were significant for gross sugar yield fed^{-1} in the second season only. The results of gross sugar yield as affected by the interaction of (V × S) in the second season are shown in Table (3). The maximum gross sugar yield value was obtained by both sugarbeet varieties, Farida (4.541 tons fed^{-1}) and Marathon (4.501 tons fed^{-1} amended with Aquita soil amendment treatments. Also, (I × V × S) interaction showed that the highest gross sugar yield value (5.092 tons fed^{-1}) was obtained by (sugarbeet variety, Marathon amended with potassium humate under 80% ETp irrigation rate) treatment.

Obtained results demonstrated that the effect of irrigation rates and soil amendments on roots and gross sugar yields is more dominate than the effect of sugarbeet varieties.

The results in this study revealed that increasing irrigation rate significantly increased roots and gross sugar yields of sugarbeet. In this respect many investigators reveled that increasing amount of irrigation water up to 3000 m^3 fed^{-1} increased roots yield and gross sugar yield fed^{-1} (El-Hawary *et al.*, 2013; Soliman *et al.*, 2013 and El-Kholi, 2017). Irrigation sugarbeet plants at 100% ETp rate gave a highest roots yield (El-Kady, 2015). Also, increasing the available soil moisture significantly increased roots yield of sugarbeet (Gharib and El-Henawy, 2011). However (Yassin *et al.*, 2021) reported that cultivating the sugarbeet with 70% of water requirements optimized roots and gross sugar yields.

On the other hand, the obtained results indicated that applying soil amendments significantly increased roots and gross sugar yields. In this concern, the positive effect of different manure sources or compost as soil amendments on the roots and gross sugar yields due to the improvement in soil physical and chemical properties as a result of application with those materials. Regarding soil amendments, many research such as Maareg *et al*. (1999 and 2008), Stumpe *et al.* (2000), Marinkovic *et al.* (2004), Margo *et al.* (2015), El-Gamal (2016) and Shrestha *et al*. (2010), reported that application of soil amendments increased roots and gross sugar yields.

B. Water Relations:

B.1. Soil water relation:

B.1.1. Potential Evapotranspiration (ETp):

Monthly values of potential evapotranspiration (ETp) are presented in Table (4), values of ETp measured by class A Pan of the experimental site. The data observed that the average of ETp values varied during both seasons. The maximum average of ETp was recorded during May in the two seasons.

Table 4. Monthly average of potential evapotranspiration (ET_p) for two sugarbeet varieties (Farida and Marathon) during the two growing seasons.

Months	ETp			
	First season		Second season	
	mm/ day	mm/ month	mm/ day	mm/ month
November	3.01	57.19	4.69	51.59
December	2.95	91.45	3.53	109.43
January	3.47	107.57	2.30	71.30
February	3.67	102.76	2.83	79.24
March	4.10	127.1	4.18	129.58
April	5.47	164.1	5.11	153.30
May	7.79	241.49	6.86	212.66
Total		891.66		807.10

The maximum ETp values was 241.49 mm (24.15 cm) in the first season, while was 212.66 mm (21.27 cm) in the second season. However, the lowest value was recorded during November in both seasons. These values were 57.19 mm (5.72 cm) and 51.59 mm (5.16 cm) in the first and second seasons, respectively as shown in Table (4). Also, the total average value (seasonal value) of ETp was 891.66 mm (89.17 cm) during the first season, corresponding to 807.71 mm (80.77 cm) during the second one. The results also, indicated that the ETp value higher in the first season than that of the second one. The fluctuation in the ETp values indicated by growing periods it could be contributed to the changes in climate conditions during the whole growth period of sugarbeet, similar results were obtained by Osman *et al.* (2005) and El-Samnoudi *et al.* (2021).

B.1.2. Amounts of applied irrigation water (AIW):

Monthly average values of applied irrigation water (AIW) in (mm) for sugarbeet crop as affected by the tested irrigation rates under drip irrigation system are presented in Table (5). The obtained results indicated that the maximum applied irrigation water (AIW) values were 104.17, 138.90 and 173.62 mm fed^{-1} in the first season, corresponding to 103.20, 137.20 and 172.0 mm in the second one for 60, 80 and 100% ETp irrigation rates, respectively occurred during May. Also, the results showed that the total average amounts (seasonal value) of the applied irrigation water to sugarbeet field were 1650.00, 2153.97 and 2657.93 m^3 fed^{-1} during the first season, while were 1680.10, 2193.41 and 2706.76 m^3 fed^{-1} during the second season for 60, 80 and 100 % ETp irrigation rates, respectively.

Table 5. Monthly average amount of applied irrigation water (mm) as affected by irrigation rates during two growing seasons.

Months	First season			Second season		
	I_1	I_2	I_3	I_1	I_2	I_3
November	32.89	32.89	32.89	33.38	33.38	33.38
December	39.45	52.60	65.75	53.11	70.81	88.51
January	46.40	61.87	77.34	34.60	46.14	57.67
February	44.33	59.10	73.88	38.45	51.27	64.09
March	54.83	73.10	91.38	62.88	83.85	104.81
April	70.79	94.38	117.98	74.40	99.19	123.99
May	104.17	138.90	173.62	103.20	137.60	172.00
Total mm	392.86	512.85	632.84	400.02	522.24	644.45
Total m^3 fed^{-1}	1650.00	2153.97	2657.93	1680.10	2193.41	2706.76

Irrigation treatments: I_1= 60% ETp, I_2= 80% ETp and I_3= 100% ETp

Regarding the effect of irrigation rates on AIW, the results revealed that seasonal AIW during both growing seasons was gradually decreased with decreasing irrigation rate from 100 to 80 and 60% ETp. The highest seasonal AIW value was recorded with full irrigation rate (100% ETp) and the least was found with lower irrigation rate (60% ETp).

B.1.3. Water consumptive use (WCU):

Irrigation water requirements are based on the water consumptive use (WCU) or actual evapotranspiration (ETa), which represents the amount of consumed water by plants. Water consumptive use (WCU) values of two sugarbeet varieties as affected by three irrigation rates and two soil amendments are presented in Table (6). Results of WCU of sugarbeet varieties in both growing seasons revealed that, WCU is gradually increased from 1193.45 to 1591.61 and 1970.98 m^3 fed^{-1} with increasing irrigation rate from 60 to 80 and 100% ETp, respectively. The highest WCU value was recorded with 100% ETp irrigation rate followed by 80 and 60% ETp rates, respectively.

The total water consumptive use values of the Farida variety were 1210.99, 1596.59 and 1996.85 m^3fed^{-1} in the first season, while were 1199.94, 1597.55 and 1973.24 m^3 fed^{-1} in the second one, for the irrigation rates 60 , 80 , 100% ETp., respectively. The respective value for the Marathon variety were 1195.24, 1574.29 and 1971.69 m^3fed^{-1} in the first season, while were 1167.64, 1598.0 and 1942.12 m^3fed^{-1} in the second one (Table 6). Differences in water consumptive use values were mainly due to the prevailing climate conditions. It is apparent that the monthly values of (WCU) by sugarbeet varieties were lower at the beginning of the growing seasons, it increased as the plants grown up till the time of peak (March), there after declined to the end of the growing seasons. Sugarbeet varieties slightly affected on WCU. The WCU of Farida variety was slightly higher than that of Marathon variety in both seasons at all irrigation rates.

The results in Tables (5 & 6) revealed that the increase in irrigation rate had a positive effect on AIW and WCU values for tested two sugarbeet varieties. Increasing irrigation rate increased of AIW and WCU and any increase in the rate of irrigation followed by increase in AIW and WCU values in the two growing seasons. Similar results were obtained by Eid *et al.* (1987), Awad *et al.* (2003) and Osman *et al.* (2005).

B.1.4. Crop coefficient (Kc):

The monthly average of Kc of the two tested sugarbeet varieties as affected by irrigation rates during the two growing seasons are tabled in Table (7).

The results showed that the Kc value of sugarbeet crop was not affected by irrigation rates and sugarbeet varieties during both seasons as the same crop and the relations between amounts of applied irrigation water and consumptive use of two varieties. The overall seasonal average of Kc of sugarbeet crop was 0.66, 0.65 and 0.65 under 60, 80 and 100% ETp irrigation rates, respectively. Also, the two sugarbeet varieties Farida and Marathon during the two growing seasons have approximately the same Kc values with the three tested irrigation rates (60, 80 and 100% ETp. The seasonal average of Farida Kc was 0.66, 0.65 and 0.65, while was 0.65, 0.65 and 0.64 for Marathon variety under the irrigation rates 60, 80 and 100% ETp, respectively. Generally, the calculated Kc values of the two tested sugarbeet varieties increased gradually from Initial stage and reached their maximum values in Mid-season (February and March) to decrease in the late season. The Kc average was 0.34, 0.60, 1.02, 1.00, 0.68 and 0.27 for Farida variety, and was 0.33, 0.58, 1.03, 0.99, 0.67 and 0.27 for Marathon variety within all season 210 days respectively, as shown in Table (7).

These results are in line with those reported by Osman *et al.* (2005), Tawfik *et al.* (2005) and Wang *et al.* (2021). They found that the Kc value of sugarbeet was low at earlier stages of growth, then gradually increased on the percentage of crop cover increased, then crop coefficient decreased again when plants reached to maturity.

B.2. Crop water relation:

B.2.1. Productivity irrigation water (PIW):

Data of PIW (Productivity of the added irrigation water unit as kg yield/m^3 or the yield obtained from each of irrigation water with "kg/m^3 AIW") as affected by three drip irrigation rates (60, 80 and 100% ETp), two soil amendments (Aquita and potassium humate and two sugarbeet varieties (Farida and Marathon) for the two growing seasons were computed in Tables (8 and 9Table).

The data in Table (8) showed that the PIW value for roots yield was gradually decreased with increased irrigation rate from 60 to 80 and 100 ETp in both seasons. The rate of 60% ETp was accompanied with highest PIW values of 13.86 and 11.60 kg roots/m^3 AIW in the first and second seasons, respectively. While the lowest values (11.131 and 8.29 kg roots/m^3 AIW were resulted from 100% ETp irrigation rate in the first season and the second one, respectively. Other irrigation rate (80% ETp) had value in between. The same trend was found for gross sugar yield in the two growing seasons.

Table 6. Monthly average of water consumptive use (WCU) of sugarbeet varieties (Farida and Marathon) as affected by the three irrigation rates in the first and second growing seasons.

Treatments	Irrigation rates											
	60% ET_p				80 %ET_p				100% ET_p			
months	First season		Second season		First season		Second season		First season		Second season	
	Farida	Marathon	Farida	Marathon	Farida	Marathon	Farida	Marathon	Farida	Marathon	Farida	Marathon
December	19.43	19.17	24.93	23.63	24.93	24.22	32.25	31.50	30.85	30.58	30.90	29.33
January	29.81	29.05	30.57	29.54	39.48	38.44	42.42	41.78	49.96	49.42	52.32	51.48
February	58.08	57.45	51.40	54.20	76.47	75.37	69.20	71.20	95.60	93.25	92.40	91.10
March	78.02	77.48	76.50	76.25	103.51	102.96	101.20	99.80	129.64	128.77	125.50	122.50
April	66.09	65.16	66.10	58.80	86.55	85.48	87.80	88.20	107.89	106.98	105.50	104.50
May	36.90	36.27	36.20	35.60	49.20	48.36	47.50	48.00	61.50	60.45	63.20	63.50
Total, mm	288.33	284.58	285.70	278.01	380.14	374.83	380.37	380.48	475.44	469.45	469.82	462.41
m^3 fed^{-1}	1210.99	1195.24	1199.94	1167.64	1596.59	1574.29	1597.55	1598.00	1996.85	1971.69	1973.24	1942.12
treat. Average	1193.45				1591.61				1970.98			

Table 7. Monthly average of crop coefficient (Kc) for two sugarbeet varieties (Farida and Marathon) during the two growing seasons under three irrigation rates.

Treatments	**60% ETp**						**80% ETp**						**100% ETp**						**Overall Variety average**	
	Farida			**Marathon**			**Farida**			**Marathon**			**Farida**			**Marathon**				
Months	**1st Season**	**2nd season**	**Mean**	**1st Season**	**2nd season**	**Mean**	**1st Season**	**2nd season**	**Mean**	**1st Season**	**2nd season**	**Mean**	**1st Season**	**2nd season**	**Mean**	**1st Season**	**2nd season**	**Mean**	**Farida**	**Marathon**
December	0.35	0.38	0.37	0.35	0.36	0.35	0.34	0.37	0.35	0.33	0.36	0.35	0.34	0.28	0.31	0.33	0.27	0.30	0.34	0.33
January	0.46	0.71	0.59	0.45	0.69	0.57	0.46	0.74	0.60	0.45	0.73	0.59	0.46	0.73	0.60	0.46	0.72	0.59	0.60	0.58
February	0.94	1.08	1.01	0.93	1.14	1.04	0.93	1.09	1.01	0.92	1.12	1.02	0.93	1.17	1.05	0.91	1.15	1.03	1.02	1.03
March	1.02	0.98	1.00	1.02	0.98	1.00	1.02	0.98	1.00	1.01	0.96	0.99	1.02	0.97	0.99	1.01	0.95	0.98	1.00	0.99
April	0.67	0.72	0.69	0.66	0.64	0.65	0.66	0.72	0.69	0.65	0.72	0.69	0.66	0.69	0.67	0.65	0.68	0.67	0.69	0.67
May	0.25	0.28	0.27	0.25	0.28	0.26	0.25	0.28	0.27	0.25	0.28	0.27	0.25	0.30	0.28	0.25	0.30	0.27	0.27	0.27
Variety Average		0.66			0.65			0.65			0.65			0.65			0.64		0.65	0.64
Seasonal Overall average			0.66						0.65						0.65				0.65	0.64

Increasing irrigation rate from 60 to 80 and 100% ETp decreased PIW value for gross sugar yield from 2.57 to 2.44 and 2.15 Kg gross sugar /m^3 AIW in the first season, and from 2.12 to 1.97 and 1.54 kg gross sugar/m^3 AIW in the second one, respectively as showed in Table (9). Soil amendments, Aquita and potassium humate exerted effect on values of PIW for roots and gross sugar yields in both seasons. Generally, soil amendments increased the PIW value for roots and gross sugar yields (kg/m3 AIW) as compared with control treatment in both seasons. Regarding values of PIW for roots yield in the Table (8), the beet plants amended with Aquita soil amendment exceeded those amended with potassium humate in the values of PIW for roots yield in both seasons. The values of PIW for roots yield in the first season were 13.26 and 13.04 kg/m3 AIW, and in the second one were 11.29 and 10.28 kg/m3 AIW for Aquita and potassium humate, respectively.

Also, beet plants received Aquita soil amendment exceeded those received potassium humate in PIW value for gross sugar yield in the second season only. The PIW values for gross sugar yield in the second season were 2.11 and 1.94kg /m^3 AIW for Aquita and potassium humate soil amendments, respectively (Table 9).

On the other hand, Aquita and potassium humate under 60% ETp irrigation rate recorded the highest PIW values for roots and gross sugar yields as compared to the other tested rates (80 and 100 % ETp). Regarding PIW values of roots yield, potassium humate and Aquita were recorded 14.82 and 14.44 kg roots/m^3 AIW, respectively, in the first season, corresponding to 12.99 and 11.75 kg roots/m^3 AIW in the second one, (Table, 8). Regard in values of PIW for gross sugar yield, Aquita and potassium humate under 60% ETp irrigation rate were obtained 2.80 and 2.76 kg gross sugar/m^3 AIW, respectively in the first season, corresponding to 2.44 and 2.16 kg roots/m^3 AIW in the second one (Table, 9). The PIW for roots values of sugarbeet varieties, Farida and Marathon were 12.48 and 12.29 kg/m^3 AIW, in the first season, corresponding to 9.99 and 10.28 kg/m^3 AIW in the second one, respectively.

Also, under the 60% ET_p low irrigation rate, the Farida and Marathon varieties recorded the highest PIW values for roots/m^3. These values were 13.64 and 14.08 kg roots/m^3 in the first season, while were 11.82 and 11.39 kg roots/m^3 AIW in the second one, respectively. Also, Farida and Marathon varieties with Aquita amendment under low irrigation rate treatment achieved the highest values of PIW for roots yield in the two seasons; the values were 14.58 and 15.06 kg/m^3 AIW in the first season, corresponding to 12.94 and 13.03 kg roots/m^3 AIW, respectively.

Table 8. Effect of three irrigation rates, two soil amendments and two sugarbeet varieties on productivity irrigation water (PIW) for roots yield during the two growing seasons.

Treatment	Sugarbeet varieties	First season				Second season			
		Soil amendments			Mean	Soil amendments			Mean
		Control	Potassium Humate	Aquita		Control	Potassium Humate	Aquita	
I_1	V_1	11.95	14.39	14.58	13.64	10.74	11.79	12.94	11.82
	V_2	12.69	14.49	15.06	14.08	9.42	11.71	13.03	11.39
Mean		12.32	14.44	14.82	13.86	10.08	11.75	12.99	11.60
I_2	V_1	11.36	12.77	13.12	12.42	8.86	9.71	11.53	10.03
	V_2	12.15	12.78	12.95	12.63	10.11	11.81	11.05	10.99
Mean		11.76	12.77	13.04	12.52	9.48	10.76	11.29	10.51
I_3	V_1	11.01	12.92	13.45	12.46	6.98	7.55	9.80	8.11
	V_2	9.21	10.89	10.36	10.15	6.87	9.14	9.42	8.47
Mean		10.11	11.91	11.91	11.31	6.92	8.34	9.61	8.29
V x S	V_1	9.21	10.73	11.05	10.33	6.94	7.58	9.06	7.86
	V_2	8.98	10.08	10.07	9.71	6.97	8.66	8.82	8.15
Mean		9.09	10.41	10.56	10.02	6.95	8.12	8.94	8.00

* Irrigation treatments I_1= 60%, I_2= 80% and I_3= 100% ET_p

* V_1 = Farida and V_2 = Marathon S= Soil amendment

Table 9. Effect of three irrigation rates, two soil amendments and two sugarbeet varieties on productivity irrigation water (PIW) for gross sugar yield during the two growing seasons.

Treatment	Sugarbeet varieties	First season				Second season			
		Soil amendments			Mean	Soil amendments			Mean
		Control	Potassium Humate	Aquita		Control	Potassium Humate	Aquita	
I_1	V_1	2.09	2.68	2.65	2.47	1.88	2.21	2.33	2.14
	V_2	2.21	2.85	2.94	2.67	1.68	2.10	2.54	2.11
Mean		2.15	2.76	2.80	2.57	1.78	2.16	2.44	2.12
I_2	V_1	2.19	2.58	2.58	2.45	1.59	1.84	2.21	1.88
	V_2	2.19	2.54	2.54	2.43	1.80	2.32	2.06	2.06
Mean		2.19	2.56	2.56	2.44	1.70	2.08	2.13	1.97
I_3	V_1	2.08	2.55	2.52	2.38	1.29	1.47	1.80	1.52
	V_2	1.70	2.05	2.01	1.92	1.24	1.67	1.74	1.55
Mean		1.89	2.30	2.26	2.15	1.26	1.57	1.77	1.54
V x S	V_1	1.72	2.10	2.08	1.97	1.25	1.45	1.68	1.46
	V_2	1.62	1.96	1.97	1.85	1.25	1.62	1.66	1.51
Mean		1.67	2.03	2.02	1.91	1.25	1.53	1.67	1.48

* Irrigation treatments I_1= 60%, I_2= 80% and I_3= 100% ET_p

* V_1 = Farida and V_2 = Marathon S= Soil amendment

On the other hand, under low irrigation rate Farida variety with Aquita treatment was recorded the highest PIW value for roots (14.58 and 12.94 kg roots/m^3 AIW), while Marathon variety recorded (15.06 and 13.30 kg roots/m^3 AIW) in the first and second season, respectively (Table, 8).

Also, Farida and Marathon sugarbeet varieties were recorded 1.97 and 1.85 kg gross sugar/m^3 AIW for PIW in the first season, while were 1.46 and 1.51 kg gross sugar/m^3 AIW in the second one, respectively. Farida and Marathon varieties under low irrigation rate observed the highest PIW for gross sugar yield. These values were 2.47 and 2.67 kg gross sugar/m^3 AIW in the first season, corresponding to 2.14 and 2.11 kg gross sugar/m^3 AIW, respectively as compared to the other irrigation rates.

With soil amendments, Farida and Marathon varieties under potassium humate amendment recorded the highest PIW for gross sugar yield values, 2.60 and 2.48 kg/m^3 AIW in the first season, however, Farida and Marathon varieties with Aquita amendment obtained the highest PIW values for gross sugar yield, 2.27 and 2.11 kg/m^3 AIW, respectively in the second season. On the other site, Marathon variety with Aquita under low irrigation rate was achieved the highest PIW for gross sugar yield. These values were 2.94 and 2.54 kg gross sugar/m^3 AIW in the first and second seasons, respectively as shown in Table (9).

B, 2.2. Water Productivity (WP):

Data of WP (the productivity of water consumptive use (WCU "unit m^3) for roots and gross sugar yields as influenced by the three irrigation rates (60, 80 and 100% ETp), two soil amendments (Aquita and Potassium humate) and two sugarbeet varieties (Marathon and Farida) were tabulated in Tables (10 &11). The results of WP for roots yield showed that the WP for roots yield was affected by the irrigation rates addition in the two seasons. Decreasing irrigation rate increased the WP for roots value and any decrease in irrigation water was always followed by increase in the WP for roots yield, as shown in Table (10).

In the first season, when sugarbeet plants were irrigated with 60 and 80% ETp rates, WP for roots yield value increased by about 3.87 and 5 kg roots/m^3 WCU (25.5and 43.59 %), respectively as compared with 100% ETp irrigation rate. Also, the increase in WP for roots yield due to adding 60 and 80% ETp irrigation rates reached about 4.44 and 2.42 kg roots yield/m^3 WCU (33.38 and 18.2%), respectively as compared with high irrigation rate (100% ETp rate) in the second season (Table 10). Irrigation amounts exerted effect on WP for gross sugar yield in the two growing seasons, adding irrigation water at the rate of 60% ETp increased WP for gross sugar yield value as compared with the other two irrigation rates (80 and 100% ETp) in the two seasons.

Table 10. Effect of three irrigation rates, two soil amendments and two sugarbeet varieties on water productivity (WP) for roots yield during the two growing seasons.

Treatment	Sugarbeet varieties	First season				Second season			
		Soil amendments			Mean	Soil amendments			Mean
		Control	Potassium Humate	Aquita		Control	Potassium Humate	Aquita	
I_1	V_1	16.28	19.60	19.87	18.58	15.04	16.50	18.11	16.55
	V_2	17.52	20.00	20.80	19.44	13.56	16.84	18.76	16.39
Mean		16.90	19.80	20.33	19.01	14.30	16.67	18.43	16.47
I_2	V_1	15.33	17.22	17.71	16.75	12.16	13.33	15.83	13.77
	V_2	16.63	17.49	17.72	17.28	13.87	16.21	15.16	15.08
Mean		15.98	17.35	17.71	17.02	13.02	14.77	15.50	14.43
I_3	V_1	14.66	17.20	17.91	16.59	9.57	10.36	13.45	11.12
	V_2	12.41	14.68	13.96	13.69	9.57	12.74	13.13	11.81
Mean		13.54	15.94	15.94	15.14	9.57	11.55	13.29	11.47
V x S	V_1	12.26	14.29	14.70	13.75	9.52	10.39	12.42	10.78
	V_2	12.10	13.59	13.57	13.09	9.71	12.07	12.29	11.36
Mean		12.18	13.94	14.14	13.42	9.62	11.23	12.36	11.07

* Irrigation treatments I_1= 60%, I_2= 80% and I_3= 100% ET_p

* V_1 = Farida and V_2 = Marathon S= Soil amendment

In general, beet plants irrigated with 100% ETp rate produced the lowest WP for gross sugar yield values (2.88 and 2.12 kg gross sugar/m^3 WCU) in the first and second seasons, respectively. While beet plants irrigated with rate of 60% ETp produced the highest values of WP for gross sugar yield (3.53 and 3.02 kg gross sugar/m^3 WCU) in the first and second seasons, respectively as shown in Table (11). Regarding soil amendments, Aquita and Potassium humate increased the values of WP for roots yield and gross sugar yield as compared with control treatment in both seasons. Aquita soil amendment increased WP for roots value in the two seasons, and values of WP for gross sugar yield in the second season only as compared by potassium humate amendment. The increase in the WP for roots yield and gross sugar yield due to applying Aquita amendment reached about 0.12 and 1.41 kg roots yield/m^3 WCU in the first and second seasons, respectively, and about 0.0 and 0.25 kg gross sugar yield/m^3 WCU in the second season as compared with Potassium humate amendment treatment (Tables, 10 &11).

Also, under low irrigation rate (60% ETp), the Aquita and Potassium humate recorded the highest WP for roots and gross sugar values in the two seasons. These highest values were (20.33 kg roots and 3.84 gross sugar yields/m^3 WCU) and (19.80 kg roots and 3.79 gross sugar yields/m^3 WCU) for Aquita and Potassium humate, respectively in the first season, corresponding to (18.43 kg roots and 3.46 gross sugar yields/m^3 WCU) and (16.67 kg roots and 3.06 gross sugar yields/m^3 WCU) in the second one as shown in Table (10). Also, sugarbeet varieties, Farida and Marathon with low irrigation rate (60% ETp) obtained the highest WP values for roots and gross sugar yields in both seasons. Farida and Marathon varieties were recorded (18.58 kg roots & 3.37 kg gross sugar yields/m^3 WCU) and (19.44 kg roots & 3.68 kg gross sugar yields/m^3 WCU), respectively in the first season, corresponding to (16.55 kg roots & 3.0 kg gross sugar yields/m^3 WCU) and (16.39 kg roots & 3.03 kg gross sugar yields/m^3 WCU), respectively in the second one. On the other hand, beet varieties, Farida and Marathon amended with Aquita were obtained the highest WP for roots yield (18.49 and 17.49 kg roots/m^3 WCU) in the first season, and (15.79 and 15.68 kg roots/m^3 WCU) in the second one, respectively as compared with potassium humate.

However, the two sugarbeet varieties with the two amendments values of WP for gross sugar yield ranged between (3.50 and 3.41 sugar/m^3 WCU) and (2.74 and 2.91 sugar/m^3 WCU) in the first and second seasons, respectively. Obtained results demonstrated that the effect of irrigation rates and soil amendments were more dominant on PIW and WP than sugarbeet varieties.

Table 11. Effect of three irrigation rates, two soil amendments and two sugarbeet varieties on water productivity (WP) for gross sugar yield during the two growing seasons.

Treatment	Sugarbeet varieties	First season				Second season			
		Soil amendments			Mean	Soil amendments			Mean
		Control	Potassium Humate	Aquita		Control	Potassium Humate	Aquita	
I_1	V_1	2.85	3.65	3.61	3.37	2.63	3.10	3.26	3.00
	V_2	3.05	3.94	4.07	3.68	2.42	3.03	3.66	3.03
Mean		2.95	3.79	3.84	3.53	2.53	3.06	3.46	3.02
I_2	V_1	2.96	3.49	3.48	3.31	2.19	2.53	3.03	2.58
	V_2	3.00	3.48	3.48	3.32	2.47	3.19	2.83	2.83
Mean		2.98	3.48	3.48	3.31	2.33	2.86	2.93	2.71
I_3	V_1	2.77	3.40	3.35	3.17	1.77	2.02	2.47	2.09
	V_2	2.30	2.77	2.71	2.59	1.72	2.33	2.43	2.16
Mean		2.53	3.08	3.03	2.88	1.75	2.18	2.45	2.12
V x S	V_1	2.29	2.80	2.77	2.62	1.71	1.99	2.30	2.00
	V_2	2.18	2.64	2.65	2.49	1.74	2.26	2.32	2.10
Mean		2.23	2.72	2.71	2.56	1.73	2.12	2.31	2.05

* Irrigation treatments I_1= 60%, I_2= 80% and I_3= 100% ET_p

* V_1 = Farida and V_2 = Marathon S= Soil amendment

The obtained results that productivity of the water added (PIW) and consumed unit (WP) for roots and gross sugar yields/ m^3 of water were gradually decreased with increasing water irrigation rate and increased with adding soil amendments. In this respect, many investigators showed that water utilization efficiency (productivity of water added unit, (PIW) for roots and gross sugar yields/ m^3 AIW for sugarbeet crop decreased with in rising applied water irrigation under drip irrigation system (Osman *et al*., 2005; Topak *et al*., 2011; Ghamarania *et al*., 2012 and El-Kholi, 2017). But El-Askari *et al*., 2003 and Ucan and Gencoglan (2004) reported that PIW and WP values were gained at the highest irrigation conditions.

Also, the present data revealed that the beet amended with soil amendments recorded the highest PIW and WP values as compared with control treatment. In this concern, El- Hady *et al*. (1990) found that increasing both water and fertilizers use efficiencies by plants are monthly to the improvement effect of applied soil amendments on soil structure, the water holding capacity of roosting media and consequently on the availability of plant nutrients.

CONCLUSIONS

Obtained data could be summarized as follows:

- The results indicated that the increase in the irrigation rate had a positive effect on the roots yield, gross sugar yield, AIW and WCU values, and a negative effect on both PIW and WP values of the two sugarbeet crops.
- Increasing in irrigation rate significantly increased roots and gross sugar yields in the two seasons. The highest values of roots (30.55 tons) and gross sugar yields (5.724 tons fed^{-1}) values were recorded with 100% ETp rate treatment in the first season, while were (23.053 tons fed^{-1}) and (4.325 tons fed^{-1}) with 80% ETp in the second one.
- Adding soil amendments increased roots and gross sugar yields in the second season only. The Aquita was more efficient on the roots and gross sugar grass yields than Potassium humate.
- The interaction of (I × V) cleared significant effect on roots and gross sugar yields in the two seasons. Farida variety plants with 100% ETp rate recorded the highest roots yield (33.124) and gross sugar (6.336 tons fed^{-1}) in the first season, while Marathon variety with 80% ETp rate combination achieved the

highest ones (24.1 and 4.520 tons fed^{-1}) in the second one.

- The interaction (I × S) and (S × V) were significant effect for roots yield in both seasons, and gross sugar yield in the second one only, respectively. (Aquita amendment under 100% ETp irrigation rate) combination recorded the highest roots in the first and second seasons. However, (Farida variety plants amended with Aquita) treatment obtained the highest gross yield in the second season.
- Also, the interaction (I × S × V) was effect on roots and gross sugar yields in the second season. The maximum roots yield was obtained by (Farida variety amended with Aquita under 100% ETp irrigation rate) treatment, while the gross sugar highest yield was recorded by (Marathon variety amended with Potassium humate under 80% ETp rate) treatment.
- Increasing irrigation rate resulted on increase in AIW and WCU values of the two sugarbeet varieties. The values (as overall average) of AIW, which corresponds to irrigation rates (60, 80 and 100 ETp) were 1665.05, 2173.68 and 2682.37 m^3 fed^{-1}. Also, the overall average of WCU values parallel to the same irrigation rates for Farida and Marathon varieties were (1205.46, 1597.07 and 1985.05 m^3 fed^{-1}) and (1181.44, 1586.14 and 1956.91 m^3 fed^{-1}), respectively.
- Reducing irrigation rate from 100 to 60 % ETp increased the PIW and WP values for roots and gross sugar yield kg/m^3.
- PIW values increased from 9.8 to 12.73 kg roots/m^3 AIW and from 1.84 to 2.35 kg gross sugar/m^3 AIW, and WP values increased from 13.30 to 17.74 kg roots/m^3 WCU and from 2.50 to 3.27 kg sugar/m^3 WCU as overall average.
- Also, the overall average of roots and gross sugar yields in connection with Frida and Marathon varieties were (24.365 and 23.932 roots tons fed^{-1}) and (4.589 and 4.501 gross sugar tones fed^{-1},) respectively.
- Seasonal average crop coefficient (Kc) for three stages (Initial, Mid. and Late season) of Farida were (0.47, 1.02 and 0.48) and Marathon were (0.46, 1.01 and 0.47) sugarbeet varieties, respectively**.**

REFERENCES

Abdel-Nasser, G. and A.H.A. Hussein. 2001. Effect of different manure sources on some soil properties and sunflowers plant growth. I – soil physical and chemical properties. Alex. J. Agric. Res. 46: 227 – 251.

Ali, M.H., M.R. Hoque, A.A. Hassan and A. khair. 2007. Effects of deficit irrigation on yield, water productivity and economic returns of wheat. Agric. Water Manag. 92: 151-161.

Awad, M.A., M. A. Mourad, K. I. El-Sayed and K. A. Allam. 2003. Effects of sprinkler irrigation and nitrogen fertilization on sugarbeet yield. The 11th Annual Conversion of the Miser society of Agric. Eng. 131-145.

Black, C.A. 1965. Methods of soil analysis. Part 1 and 2. American society of Agronomy, Madison, Wisconsin, USA.

Doorenbos, J. and A. Kassam. 1979. Yield response to water by FAO irrigation and Drainage Papers No. 33, Rome, Italy.

Eid, H.M., N.G. Ainer and M. Metwally. 1987. Estimation of irrigation and temperature needs for the new land in Egypt. In Mansoura Univ. Conf. of Agric. Sci. on Food Deficiency over Coming through Autonomous Efforts in Egypt. 22, 24: 907-914.

El-Askari, K., M. Melaha, A. Swelam, and A.A. Gharieb. 2003. Effect of different irrigation water amounts on sugarbeet yield and water use efficiency in Eastern Delta. Paper nr 136. 9th ICID International Drainage Workshop, Utrecht, The Netherlands. 10-13 September. International Commission on Irrigation and Drainage (ICID), New Delhi, India.

EL-Darder, A.M., M.A. Gamaa, M.A. Sayed and M. Z. Kamel. 2017. Water stress effects on yield and Quality of sugarbeet crop in sandy soils. Alex. Sci. Exchange J. 38 828- 836.

El-Gamal, I.S. 2016. Physiological studies on improving growth and productivity of sugarbeet using some nutrients. Ph.D. Thesis Fac of Agric. Benha, Univ., Egypt.

El-Hady, O.A., S.H. Pieh and S. Osman.1990. Modified polyacrylamide hydrogels as conditioners for sandy soils. III: Influence on growth, water and fertilizers use efficiency by plants, Egypt. J. Soil Sci. 30: 423-432.

El-Hawary, M.A., E.M. Soliman, I.M. Abdel-Aziz, M. El-Shereif and A.M. Shadia. 2013. Effect of irrigation water quantity, sources and rates of nitrogen on growth, yield and quality of sugarbeet. Res. J. Agric. & Biol. Sci. 9: 58-69.

El-kady, M.S.M. 2015. Study of water and fertilization stresses on yield and quality of sugarbeet under two modern irrigation systems in sandy soils. Ph D Thesis, Cairo Univ. Fac. Of Agric., 129 p.

El-Kholi, M.M. 2017. Response of sugarbeet to nitrogen and potassium fertilization treatments under different quantities of irrigation water in the sandy soils.Ph.D. Thesis, Fac. Agric.Saba Basha, Alexandria Univ.

El-Samnoudi, I., A. E. A. Ibrahim., A. E. Tawwab and N. Abdou. 2021. Evaluation of direct and indirect methods used to determine crop coefficient and crop evapotranspiration of sugar beet plants grown under fayoum conditions. Fayoum J. Agric. Res. Dev. 35: 495-504.

Ghamarania, H., I. Arji, S. Sepehri, S. Norozpour and E. Khodaei. 2012. Evaluation and comparison of drip and conventional irrigation methods on sugar beets in a semiarid region. J. Irrig. Drain. Eng. 138: 90-97.

Gharib, H.S. and A. S. El-Henawy. 2011. Response of sugarbeet (beta vulgare, L) to irrigation regime nitrogen rate and micronutrients application. Alex. Sci. Exch. J. 32: 140- 156.

Greets, S. and D. Raes. 2009. Deficit irrigation as an on-farm strategy to maximize crop productivity in dry areas. Agric. Water Manage. 96: 1275-1284.

Hamed, L. M. M. and E.I.R. Emara. 2019. Varietal tolerance of sugarbeet (beta vulgaris l.) To water stress. Misr J. Ag. Eng. 36: 217-238.

Israelson, O.W. and V.E. Hansen. 1962. Irrigation principles and practices. 3rd Edit, John Willey and Sons, Inc. New York.

James, L.C. 1988. Principles of farm irrigation system design. John Wiley and Sons, Inc., NY, USA.

Maareg, M. F., A. Y. El-Gindi, K. M. Agmi and I. M. A. Goher. 2018. Evaluation of deficit irrigation effects on sugarbeet productivity and control of root-kont nematode, Meloidogyne incognita infection. Egypt J. Agronematol. 17: 13-27.

Maareg, M.F., I.M.A. Gohar and S.F. Tewfik. 2008. Effect of certain organic soil amendments on sugarbeet (*Beta vulgaris* L.) infested with root knot nematode, *Meloidogyne javanica* under field conditions. Egypt J Biol Pest Control. 18: 235-241.

Maareg, M.F., S.T.A. Badr and B.A. Oteifa. 1999. Effect of two city waste organic compost, finamiphos and ammonium nitrogen on controlling *Meloidogyne Javanica* and productivity sugarbeet. Egypt J. Agronematol. 3: 95-113.

Margo, F.O., E. G. Da Silva, W. H. S. Takata, A. I. I. Cardoso, D.M. Fernandes and R. M. Evangelista. 2015. Organic compost and potassium top dressing fertilization on production and quality of beet root. Australian. J. Crop. Sci. 9: 962- 967.

Marinkovic, B., L. Starevic, J. Crnobarac, G. Jacimovic and M. Rajic. 2004. By- products of sugarbeet- quality animal feet. Glas. zašt. bilja. 27: 14- 118.

Masri, M.I., B.S.B. Ramadan, A.M.A. El-Shafai and M.S. El-Kady. 2015. Effect of water stress and fertilization on yield and quality of sugarbeet under drip and sprinkler irrigation systems in sandy soil. Int. J. Agric. Sci. 5: 414-425.

Mc Ginnis, R.A. 1982. Beet sugar technology, 3rd ed. Sugarbeet development foundation fort Collns 855 pp.

National Council of Sugar crops. 2020. Sugarbeet production in Egypt, Annual Report, Cairo, Egypt, 141 pp., (in Arabic)

Novica, V. 1979. Irrigation of agriculture crops. Fac. Agric. Press, Novia sad, Yugoslavia.

Osman, A.M., H.E. Khalifa, M.M. Attia and M.A. Sayed. 2005. Effect of drip irrigation treatments on sugarbeet yield and quality and some water relations in sandy soils. The 13th Annual conversion of Misr Society of Agric. Eng. 22: 774- 787.

Shrestha, N., S. Geerts, D. Raes, S. Horemans, S. Soentjens and F. Maupas. 2010. Yield response of sugar beets to water stress under Western European conditions. Agric. Water Manag. 97: 346-350.

Soliman, E. M., M. A. El-Hawary, I. M. Abdel-Aziz, O. A. O. Mazen and Sh. A. Mohamed. 2013. Effect of irrigation water quality, sources and rates of nitrogen on growth and quality of sugarbeet. J. Plant Prod. 4 : 537-550.

Steel, R.G.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics with Special Reference to the Biological Sciences. McGraw Hill, New York. 187-287.

Stumpe, H., L. Wittenmayer and W. Merbach. 2000. Effect and residual effect of straw farmyard manuring and mineral fertilization at field of the long-term trial in Halle (Saale) Germany. J. Plant Nutr. Soil Sci. 163: 649-656.

Tawfik, S. F., A. M. Zayton, and M. A. El-Saadawy. 2005. Sugar beet yields and crop coefficient as affected by nitrogen fertilizer application under different irrigation systems. Misr J. Ag. Eng., Egypt 22: 513-531.

Topak, R., S. Süheri and B. Acar. 2011. Effect of different drip irrigation regimes on sugarbeet (*Beta vulgaris* L.) yield, quality and water use efficiency in Middle Anatolian, Turkey. Irrig. Sci. 29: 79-89.

Uçan, K. and C. Gençoğlan. 2004. The effect of water deficit on yield and yield components of sugarbeet. Turk. J. Agric. For. Agric. 28: 163-172.

Wang, T., F. S. Melton, I. Pôças, L. F. Johnson, T. Thao, K., Post and F. Cassel-Sharma. 2021. Evaluation of crop coefficient and evapotranspiration data for sugar beets from Landsat surface reflectance's using micrometeorological measurements and weighing lysimetry. Agric. Water Manag. 244, 106533.

Yassin, M. O., S.M. Ismail, H.A. Gameh, F.A.F. Khalil and E.M. Ahmed. 2021. Optimizing Roots and Sugar Yields and Water Use Efficiency of Different Sugar Beet Varieties Grown Under Upper Egypt Conditions Using Deficit Irrigation and Harvesting Dates. Egypt. J. Soil Sci. 61: 367-372.

Zoghdan, M.G., M.A. Aiad, M. M. A. Shabana and H. M. Aboelsoud. 2019. Improvement of Soil and Water Productivity for Sugarbeet under Salt Affected Soils at North Nile Delta, Egypt. J. Soil Sci. Agric. Eng. 10: 41-50.

الملخص العربي

العلاقات المائية الأرضية والمحصولية والإنتاجية لصنفين بنجر السكر متأثرة بمعدلات الري ومحسنات التربة تحت نظام الري بالتنقيط

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أجريت تجربتان حقليتان خلال موسمين متعاقبين ٢٠١٨/١٩ و٢٠١٩/٢٠ بمحطة البحوث الزراعية بالنوبارية (٥٤" ٥٤ ′ ٣٠° شمال – ٥٣" ٥٧ ′ ٢٩° شرق) فى أراضي جيرية تحت الرى بالتنقيط لدراسة تأثير ثلاث معدلات للري بالتنقيط (وهى الري بكميات مياه تعادل ٦٠ و٨٠ و١٠٠ % من جهد البخرنتح المقدر باستخدام وعاء البخر القياسي) وثلاث معاملات لإضافة محسنات التربة (بدون محسن – المحسن أكويتا – المحسن هيومات البوتاسيوم) على الإنتاجية والعلاقات المائية ومعامل المحصول لصنفين من بنجر السكر (فريدا "وحيد الاجنة" – ماراثون "عديد الاجنة") باستخدام تصميم القطع المنشقة مرتين مع ثلاث مكررات.

وفى هذه الدراسة تم حساب وتقييم محصولي الجذور والسكر وكميات مياه الري المضافة وكميات الماء المستهلك بواسطة النبات ومعامل المحصول وكذلك إنتاجية وحدة المياه المضافة وانتاجية وحدة المياه المستهلك بواسطة النبات للصنفين تحت الدراسة.

- وتشير النتائج الى ان زيادة معدل الري تؤثر تأثيرا إيجابيا على إنتاجية محصولي الجذور والسكر الخام وكذلك كميات المياه المضافة والمستهلكة وتأثير عكسي على إنتاجية وحدة المياه المضافة وانتاجية وحدة الماء المستهلك للصنفين فريدا ومارثون لمحصول بنجر السكر.
- الزيادة في معدل الري ادي الى الزيادة في محصولي الجذور والسكر الخام زيادة معنوية في الموسمين.
- اعلى قيم لمحصول جذور كانت (٣٠,٥٥ طن/فدان) والسكر الخام (٥,٧٢٤ طن/فدان) تم الحصول عليها من معاملة الري ١٠٠% من البخر نتح القياسي في الموسم الأول، بينما كانت (٢٣,٠٥٣ طن/فدان) و(٤,٣٢٥ طن/فدان) مع معاملة الري ٨٠% من البخر نتح القياس في الموسم الثاني.
- اضافة المحسنات ادي الى زيادة معنوية لمحصولي الجذور والسكر الخام في الموسم الثاني فقط بالإضافة الى ان المحسن أكويتا كان اكثر تأثيرا على محصولي الجذور والسكر الخام مقارنة بالمحسن هيومات البوتاسيوم.
- للتفاعل بين معدلات الري والاصناف تأثير معنوي على محصولي الجذور والسكر الخام خلال الموسمين. لذلك نجد ان صنف فريدا مع معدل الري ١٠٠% من جهد البخر نتح القياسي أعطي اعلي قيمة لمحصولي الجذور (٣٣,١٢٤ طن/فدان) والسكر الخام (٦,٣٣٦ طن/فدان) في الموسم الأول، بينما الصنف مارثون مع معدل الري ٨٠% من جهد البخر نتج القياسي أعطي اعلى إنتاجية (٢٤,١ و٤,٥٢٠ طن/فدان) لمحصولي الجذور والسكر على التوالي.
- كذلك التفاعل بين معدلات الري ومحسنات التربة من جهة ومحسنات التربة والاصناف من جهة اخري كانت ذات تأثير معنوي على محصول الجذور في الموسمين ومحصول السكر الخام في الموسم الثاني فقط. معاملة محسن التربة أكويتا ومعدل الري ١٠٠% من جهد البخر نتح القياسي أعطت اعلى إنتاجية لمحصول الجذور ٣١,٠٤٧ و٢٦,٠١٧ طن/فدان للموسم الأول والثاني على الترتيب. على الجانب الاخر نجد ان الصنف فريدا

مع معاملة المحسن أكويتا أعطي اعلى محصول سكر خام (٤,٥٤١ طن/فدان) في الموسم الثاني.

- التفاعل بين العوامل (الري- المحسنات- الأصناف) اثر معنويا على إنتاجية محصولي الجذور والسكر الخام في الموسم الثاني. وكانت اعلى إنتاجية من الجذور ٢٦,٥٣٣ طن/فدان) تم الحصول عليها من معاملة (الصنف فريدا - المحسن أكويتا - معدل الري ١٠٠% من البخر نتح القياسي)، بينما كان اعلى محصول للسكر الخام (٥,٠٩٢ طن/فدان) تم الحصول عليها من معاملة (الصنف مارثون - المحسن هيومات البوتاسيوم - معدل الري ٨٠% من البخر نتح القياسي).
- أدت زيادة معدل الري الي زيادة قيم كميات المياه المضافة (AIW) وكميات المياه المستهلكة بواسطة النبات (WCU) وانخفاض إنتاجية المياه المضافة (PIW) وانتاجية المياه المستهلكة (WP) لصنفي بنجر السكر تحت الدراسة. وكانت المتوسطات العامة من كميات المياه المضافة مع معاملات الري ٦٠ و٨٠ و١٠٠% من البخر نتح القياسي هي ١٦٦٥,٠٥ و٢١٧٣,٦٩ و٢٦٨٢,٣١ م٣/فدان. وكذلك متوسطات الاستهلاك المائي لنفس المعاملات للصنفين فريدا ومارثون (١٢٠٥,٤٦ و١٥٩٧,٠٧ و١٩٨٥,٠٥ م٣/فدان) و(١١٨١,٤٤ و١٥٨٦,١٤ و١٩٥٦,٩١ م٣/فدان) على الترتيب.
- على عكس ذلك فان تقليل معدل الري من ١٠٠ الى ٦٠% من البخر نتح القياسي زادت من كفاءة إنتاجية كل من وحدة مياه الري المضافة ووحدة مياه الري المستهلكة بواسطة النبات لمحصولي الجذور والسكر الخام. فقد زادت إنتاجية وحدة المياه المضافة من ٩,٨٠ الى ١٢,٧٣ كجم جذور/م٣ من الماء المضاف ومن ١,٨٤ الى ٢,٣٥ كجم سكر خام/م٣ ماء مضاف وكذلك إنتاجية وحدة الماء المستهلك زادت من ١٣,٣٠ الى ١٧,٧٤ كجم جذور/م٣ من الماء المستهلك ومن ٢,٥٠ الى ٣,٢٧ كجم سكر خام/م٣ من الماء المستهلك كمتوسط عام.
- وكان المتوسط العام لمحصولي الجذور والسكر الخام مع الأصناف فريدا ومارثون (٢٤,٣٧ و٢٣,٩٣ طن جذور/فدان) و(٤,٥٨٩ و٤,٥٠١ طن سكر خام/فدان) على التوالي.
- وكان متوسط معامل المحصول للمراحل الأولية والمتوسطة والنهائية (Kc) للصنف فريدا (٠,٤٧ و١,٠٢ و٠,٤٨) والصنف مارثون (٠,٤٦ و١,٠١ و٠,٤٧) لمحصول بنجر السكر.

الكلمات المفتاحية: بنجر السكر- الإجهاد المائي- محسنات التربة- العلاقات المائية- الري بالتنقيط - أصناف بنجر السكر.