25 Egypt. J. Soil Sci. **Vol. 61,** No. 3, pp. 367 – 372 (2021)

Egyptian Journal of Soil Science

http://ejss.journals.ekb.eg/

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

Omar M. Yassin[1*], Saleh M. Ismail[2], Gameh M.A.[2], Khalil F. A.F[1], and Ezzat M. Ahmed[2]

[1]*Soils, Water, and Environment Research Institute, Agricultural Research Center, Giza, Egypt*

[2] *Soils and Water Department, Faculty of Agriculture, Assiut University, Assiut, Egypt.*

Abstract

A field experiment was carried out at Shandaweel Agricultural Research Station, Sohag, Egypt to study the effects of deficit irrigation and harvesting dates on yield and water productivity of three sugar beet varieties. A split split block design with three replications was used. Main blokes were assigned to three irrigation water regimes (100%, 85%, and 70% of water requirement).The sub blots were occupied by three harvesting dates (180, 195 and 210 days). Sub- sub plots were comprised three sugar beet varieties namely (RAVEL, SV1841and SA1686). Results indicated that reducing water supply reduced roots, sugar and biomass yields but increased water use efficiency (WUE). Increasing harvesting date increased roots and sugar yields but reduced biomass yield. Roots, sugar and biomass yields of RAVEL and SA1686 varieties were almost comparable but higher than those of SV1841 variety. The highest sugar WUE was obtained from SA1686 at 70% WR treatment under 210 days harvesting date followed by RAVEL variety at 70 % WR and 210 day harvesting date. Results clarified that cultivating either RAVEL or SA1686 variety with 70% of water requirement and for 210 growing days under Upper Egypt conditions optimized roots and sugar yields and WUE of sugar beets.

Keywords: Water regime; Sugar beet; Water use efficiency; Sugar yield

1. Introduction

Sugar beet (*Beta vulgaris* var. *saccharifera*, L.) ranks the first important sugar crops in Egypt, producing about 57% of sugar production 2016/2017 season. In Egypt, it could be cultivated widely in newly, without competition with other winter crops due to its tolerance to salinity and ability to produce high sugar yield under saline conditions and limited water requirements in comparison to the other traditional winter crops (Nagib et al., 2018). Sugar beet is considered one of the temperate regions for sugar production. Where, ranked as the second important one after sugar cane for sugar production in Egypt (Amer et al. 2019) Sugar beet is a drought resistant plant that could produce economic yield even with declined irrigation. Its annual water consuming is ranging from 350 to 1150 mm in different regions of the world (Winter, 1980). Drought stress is a major abiotic stress, which has adverse effects on crops. In Egypt, water shortage has become a significant limiting factor for agricultural production (Ali et al., 2019). Optimal crop production is highly dependent on available soil water. Thus, it is very important to know when and how much of irrigation water to be added in order to attain agronomic potential (Abdel-Nasser and Hussein, 2001). Also, it is far better than sugar can when water use efficiency is concerned, on kilogram of sugar needs about 1.4 and 4.0 m^3 water by sugar beet and sugar cane, respectively, (Ouda, 2011). Results also, revealed that mean root weight, roots yield and white sugar yield were significantly affected

*Corresponding author e-mail: E-mail address: omar66004510@gmail.com
Rceived: 12/11/2021; Accepted: 6/12/2021
DOI: 10.21608/ejss.2021.105612.1476

by increasing water deficit from 100% up to 50% of the irrigation water requirements. Harvesting age is one of the main factors directly affects maturity and consequently juice quality which has direct effect on root and sugar yields of sugar beet. Gadallah and Tawfik (2017) found that beets harvested at age of 180 days produced the highest value of top fresh weight/fed in two consecutive growing seasons. Harvesting sugar beet after 210 days from sowing recorded the highest root weight, roots and sugar yields/fed compared to that harvested at 170, 180 and 190 days after sowing (Aly 2006; Nasr andAbd-El-Razek, 2008; Mahmoud, et al., 2008).Sugar beet varieties is considered one of the essential wings of sugar production, in terms of its root yield and quality characteristics. They differ inherently in their maturity ages, which extend from 150 to 240 days because the changes in quality, yield and its components occurred until they reach their maximum values (Mohamed and Yasin, 2013).Increasing sugar beet productivity and quality could be achieved by selecting high yielding varieties. Many investigators (Gadallah and Tawfik, 2017; Enan et al., 2016; Mekdad and Rady, 2016) recorded significant differences among sugar beet varieties in most studied traits especially in top, root and sugar yields. Shalaby et al. (2011) found that Kawemira variety significantly exceeded on the others in root weight/plant and root and yield/fed. Farida cultivar increased the sugar yields/fed significantly. (Enan et al., 2009). As from previous literatures, optimizing sugar beet productivity is significantly affected by water requirement, harvesting date and variety. Therefore, the main objective of this study was to evaluate the roots yield, sugar yield, above ground biomass yield and water use efficiency of three sugar beets varieties growing under different water deficit and harvesting dates in Upper Egypt.

Materials and Methods

Experimental design, treatments and cultural practices

A field experiment was carried out at Shandaweel Agricultural Research Station, Sohag Egypt (latitude of 26˚ 26' N, longitude of 31º 68' E and altitude of 70 m) in two consecutive seasons of 2018/2019, 2019/2020to study the effects of three irrigation water regimes and three harvest dates on biomass, root sand sugar yield and water use efficiency of three sugar beet varieties grown under upper Egypt conditions. The design of the experiment was split – split block with three replicates. The plot area was 10.5 m^2 (3 x 3.5m). The main blocks were subjected to irrigation water regimes where I_1, I_2,andI_3 represented100%, as full irrigation requirement treatment and 85 % and 70% of crop water requirement as deficit irrigation treatments. The sub plots were assigned to the three harvesting dates; H_1 = 180, H_2 = 195, and H_3 =210 days from sowing. The subsub plots were comprised three sugar beet varieties namely: V_1 = RAVEL (mono variety), V_2 = SV1841 (mono variety) and V_3 = SA1686 (multi-germ).Sugar beet seeds of the three varieties were sown on 8 and 7 November in the 1st and 2nd seasons, respectively. From 3 to 4 seeds were used in each hill with 20 cm apart between two consecutive hills. All treatments were fertilized with P-fertilizer in the form of mono-calcium (MCP) phosphate (15.5% P_2O_5) at the rate 30kg P_2O_5/fed added to the soil during land preparation. Nitrogen fertilizer was applied in the form of ammonium nitrate (33.5% N) at the rate of 100 kg N/fed vided into two equal doses (before the first and second irrigation). Potassium fertilizer in form of potassium sulfate 48% K_2O was applied at the rate of 24 K_2O/fed. and added during the second irrigation. The other farming practices required for sugar beet growth were carried out according to the common practices followed at Shandaweel station. Traditional furrow irrigation method for irrigation was used during both growing seasons. By the end of each growing season the data of seasonal water supply, consumptive water use, biomass and roots yields were recorded.

$$Sugaryield\left(\frac{t}{fad.}\right) = Rootyield\left(\frac{t}{fad.}\right) \times ES\%$$

Where ES is extracted sugar percent

Water requirement calculation

Evapotranspiration:

Evapotranspiration (ETc) was determined from the following equation:

$ET_c = ET_o * K_c$

Where ET_c the evapotranspiration in mm, ET_o is the reference evapotranspiration in mm and calculated from Meteorological data (Table 1) by using Penman-Monteith equation in CROPWAT model. K_c is crop coefficient as in Allen et al., (1998) and were 0.35, 1.20, and 0.70 for initial, mid and late growth stages.

TABLE 1. Average values of meteorological data recorded at Shandaweel Agricultural Research Station in 2018/2019 and 2019/2020 growing seasons

Months	2018/2019					2019/2020				
	Temperature (°C)		RH (%)	WSm/sec	SR (%)	Temperature (°C)		RH (%)	WSm/sec	SR (%)
	Max.	Min.				Max.	Min.			
Nov.	26.6	13.0	54	2.3	13	28.8	14.5	59	2.3	17
Dec.	20.3	7.1	65	2.5	15	21.7	7.9	58	2.4	15
Jan.	18.8	5.0	60	2.1	15	18.3	4.3	58	2.5	15
Feb.	21.5	7.1	48	2.6	18	21.4	6.6	52	2.6	19
Mar.	25.1	9.1	35	2.9	23	27.2	10.6	45	3.1	22
Apr.	30.1	13.8	34	3.2	24	30.1	14.0	37	3.4	25
May	38.4	20.8	30	3.0	27	36.0	19.8	36	3.4	27

WS= wind speed m/sec ; SR = solar radiation, MJ/m2/day, RH =relative humidity in % ETo= evapotranspiration, mm

Water supply

Once the evapotranspiration is calculated, the amount of irrigation water supply for full irrigation water requirement treatment (100%WR) was calculated from the following equation:

Water supply in mm $=ET_c/E_a$

Where E_a is the irrigation application efficiency and was 60% during both growing seasons. The amount of irrigation water supply in full irrigation treatment (100%WR) was reduced to be 85% and 70% for deficit irrigation treatments of 85%WR and 70%WR respectively. The calculated amount of water supply was added to each treatment using a flow meter connected directly to the irrigation pump.

Water consumptive use (CU):

Water consumptive use (CU) for each irrigation at 0.0-0.6 m soil depth (4 layers with 0.15 m apart) was calculating as in Israelsen and Hansen (1962):

$$CU = \sum_{i=1}^{i=4} \left(\frac{Q2-Q1}{100}\right) * pb * D$$

Whereθ_2 is soil moisture content after irrigation, $\theta 1$ is soil moisture content just before irrigation,pb is soil bulk density (g/cm^3),D is the depth of soil layer and is soil layers.

Water use efficiency

Water use efficiency in kg m^{-3}ha^{-1} for roots and sugar yields were calculated for each by dividing total yield in kg ha^{-1} on seasonal water consumptive use (CU) of 0.6 m soil depth in m^3.

Statistical analysis

The analysis of variance (ANOVA) wasperformed on different parameters as described byGomez and Gomez (1984). The difference betweenmeans was tested at probability levels 0.05 using Duncan's Multiple Range Test (DMRT)

Results and Dicussion

Seasonal water supply

Results of seasonal water supply for sugar beet crop during both growing seasons are presented in Fig. (1). the results revealed that seasonal water supply during both growing seasons was gradually decreased from 100%WR to 70%WR. The highest seasonal water supply was recorded in I_1 (100% WR) followed by I_2 (85% WR) and I_3 (70% WR) respectively.

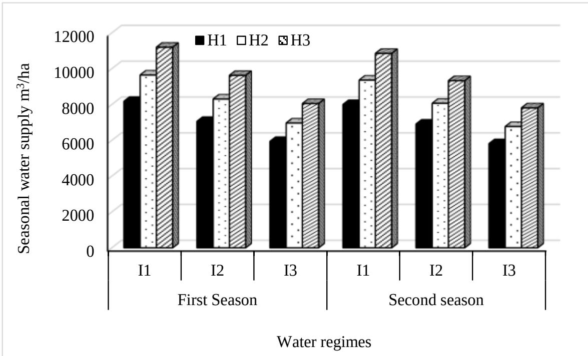

Fig. 1. Seasonal water supply for sugar beet as affected by water regime, harvesting dates and varieties

Sharp and gradual increase in seasonal water supply was noticed by increasing harvesting dates in both growing seasons. The highest seasonal water supply was recorded in the longest harvesting date, H_3 (210 days) followed by the H_2 (195 days). The least seasonal water supply was recorded in the shortest harvesting date (180 days) (Fig. 1).

Water consumptive use

Results of water consumptive use of sugar beet varieties in both growing seasons presented in Figure (2) revealed that, water consumptive use is gradually decreased from 100% WR to 70% WR. The highest water consumptive used was found in full irrigation water treatment I_1, (100% WR) followed by I_2, (85%WR) and the least was recorded in I_3 (70% WR).

Water consumptive use is also increased by increasing harvesting dates. The highest water consumptive use was obtained from the longest harvesting date 210 days followed by 195days and 180days respectively (Fig. 2). Sugar beet varieties slightly affected on water consumptive use. Water consumptive used of $V_1$and V_3 was slightly higher than that of V_2, in both growing seasons. The results also indicated that water consumptive use was higher in the first growing season than that of the second growing season for all irrigation treatments and harvesting dates, (Fig. 2).

Effect of irrigation water regimes on roots, biomass and sugar yields

The results presented in Tables (2, 3, 4) clearly indicated that decreasing irrigation water supply significantly decreased roots, biomass and sugar yields in both growing seasons. Irrigation ate 100% WR and 85% WR treatments increased roots yield by about 25.6% and 14.1% in 2018/19 season and by 23.7% and 10.4 % in the 2019/20 seasonas compared by 70% WR treatment, respectively. Similarly, biomass yield of 100% WR and 85% WR irrigation treatments increased by 23.1% and 12.3 % in 2018/19 season and by 24.8 % and 10.4 % in the 2019/20 season as compared by 70% WR, respectively. Also, the same treatments increased sugar yield by 24.5% and 15.9% in 2018/19 season and 22.1% and 14.9% in 2019/20 season compared to 70% WR treatment, respectively.

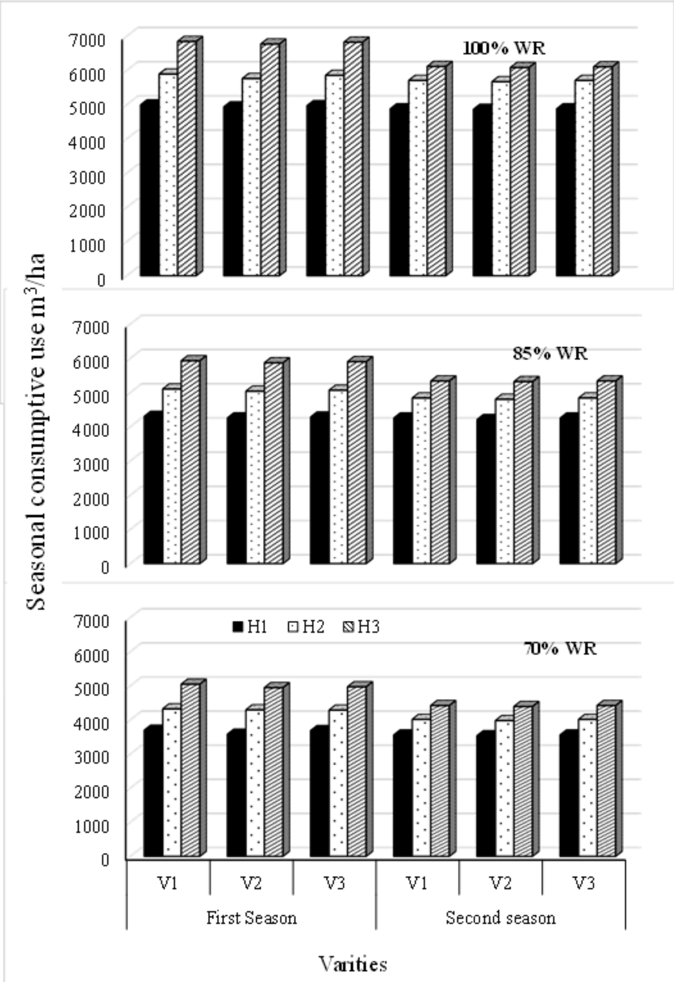

Fig. 2.Seasonal water consumptive use for sugar beet as affected by water regime, harvesting dates and varieties

TABLE (2) Effect of irrigation treatments, harvest date and sugar beet varieties on Root yield (T /fed). for two growing seasons of 2018/2019 and 2019/202

Irrigation	Harvest Time	First Season			Avg.	Second Season			Avg.
		RAVEL	SV1841	SA1686		RAVEL	SV1841	SA1686	
100%	180	34.4a	29.1a	32.8a	32.1a	31.1a	26.5a	30.6a	29.4a
	195	38.7a	32.6a	36.3a	35.9a	35.7a	32.8a	34.2a	34.2a
	210	43.4a	36.2a	37.7a	39.1a	39.8a	35.5a	39.3a	38.2a
Avg.		38.8a	32.6a	35.6a	35.7a	35.5a	31.6a	34.7a	33.9a
85%	180	31.6a	26.7a	29.9a	29.4a	26.1a	23.6a	26.2a	25.3a
	195	34.8a	29.6a	33.2a	32.5a	31.5a	28.0a	30.8a	30.1a
	210	39.3a	33.2a	33.6a	35.4a	37.5a	32.0a	36.8a	35.4a
Avg.		35.2a	29.8a	32.2a	32.4b	31.7a	27.9a	31.2a	30.3b
70%	180	27.5a	21.9a	26.7a	25.4a	23.0a	21.2a	24.0a	22.7a
	195	29.4a	26.3a	29.1a	28.3a	29.8a	24.2a	28.9a	27.6a
	210	34.1a	30.8a	29.8a	31.6a	33.6a	28.9a	33.3a	31.9a
Avg.		30.3a	26.3a	28.5a	28.4c	28.8a	24.8a	28.7a	27.4c
Harvest Treatment Average	180	31.1d	25.9f	29.8e	28.9c	26.7a	23.8a	26.9a	25.8c
	195	34.3b	29.5e	32.9c	32.2b	32.3a	28.3a	31.3a	30.6b
	210	39.0a	33.4bc	33.7bc	35.4a	37.0a	32.1a	36.5a	35.2a
Grand Avg.		34.8a	29.6b	32.1c		32.0a	28.1b	31.6c	

TABLE (3) Effect of irrigation treatments, harvest date and sugar beet varieties on Biomass yield (T /fed).for two growing seasons of 2018/2019 and 2019/2020

Irrigation	Harvest Time	First Season			Avg.	Second Season			Avg.
		RAVEL	SV1841	SA1686		RAVEL	SV1841	SA1686	
100%	180	21.7a	18.1a	18.8a	19.5a	19.9a	17.7a	19.6a	19.1a
	195	19.3a	16.3a	17.1a	17.6a	17.8a	16.4a	17.1a	17.1a
	210	17.2a	14.5a	16.4a	16.0a	15.5a	14.6a	15.3a	15.1a
Avg.		19.4a	16.3a	17.5a	17.7a	17.7a	16.2a	17.3a	17.1a
85%	180	19.6a	16.6a	16.6a	17.6a	18.7a	16.0a	18.4a	17.7a
	195	17.4a	14.8a	15.8a	16.0a	15.7a	14.0a	15.4a	15.0a
	210	15.8a	13.3a	15.6a	14.9a	13.0a	11.8a	13.1a	12.6a
Avg.		17.4a	14.9a	16.0a	16.2b	15.8a	13.9a	15.6a	15.1b
70%	180	17.0a	15.4a	14.9a	15.8a	16.8a	14.4a	16.6a	15.9a
	195	15.7a	13.1a	14.5a	14.4a	14.9a	12.1a	14.4a	13.8a
	210	13.7a	10.9a	14.1a	12.9a	11.5a	10.6a	12.0a	11.3a
Avg.		15.5a	13.1a	14.5a	14.4c	14.4a	12.4a	14.3a	13.7c
Harvest Treatment Average	180	19.5a	16.7c	16.8c	17.6a	18.5a	16.0b	18.2a	17.6a
	195	17.5b	14.7e	15.8d	16.0b	16.1b	14.1d	15.6c	15.3b
	210	15.5d	12.9f	15.4d	14.6c	13.3e	12.3f	13.4e	13.0c
Grand Avg.		17.5a	14.8c	16.0b		16.0a	14.2b	15.8a	

TABLE (4) Effect of irrigation treatments, harvest date and sugar beet varieties on Sugar yield (T /fed).for two growing seasons of 2018/2019 and 2019/2020

Irrigation	Harvest Time	First Season			Avg.	Second Season			Avg.
		RAVEL	SV1841	SA1686		RAVEL	SV1841	SA1686	
100%	180	6.00a	3.76a	5.17a	4.98a	5.46a	3.63a	4.94a	4.68a
	195	6.85a	4.41a	5.77a	5.68a	6.41a	4.66a	5.59a	5.55a
	210	8.03a	4.98a	5.95a	6.32a	7.37a	5.24a	6.39a	6.33a
Avg.		6.96a	4.38a	5.63a	5.66a	6.41a	4.51a	5.64a	5.52a
85%	180	5.97a	3.77a	4.77a	4.84a	4.75a	3.57a	4.27a	4.20a
	195	6.75a	4.28a	5.42a	5.48a	5.84a	4.39a	5.19a	5.14a
	210	7.75a	4.91a	5.45a	6.04a	7.19a	4.98a	6.25a	6.14
Avg.		6.82a	4.32a	5.21a	5.45a	5.93a	4.31a	5.24a	5.16b
70%	180	5.55a	3.29a	4.52a	4.45a	4.49a	3.32a	4.13a	3.98a
	195	6.13a	3.96a	4.87a	4.99a	5.95a	3.81a	5.04a	4.93a
	210	7.31a	4.78a	5.16a	5.75a	6.97a	4.63a	5.83a	5.81a
Avg.		6.33a	4.01a	4.85a	5.06b	5.80a	3.92a	5.00a	4.91c
Harvest Treatment Average	180	5.84a	3.61a	4.82a	4.76b	4.90a	3.51a	4.45a	4.28c
	195	6.58a	4.22a	5.35a	5.38b	6.07a	4.29a	5.27a	5.21b
	210	7.70a	4.89a	5.52a	6.04a	7.18a	4.95a	6.16a	6.09a
Grand Avg.		6.70a	4.24bc	5.23ab		6.05a	4.25c	5.29b	

Effect of harvesting dates on roots, biomass and sugar yields

Delaying harvesting date to 210 and 195 days after sowing resulted in significant and gradual increase in root yields (Tables 2, 3 and 4). The increases were about 22.1% and 11.3% in the first season and 36.2 % and 18.6% in the second season compared to harvesting date of 180 days. In a reverse behavior delaying harvesting date reduced biomass yield. Harvesting at age of 180- and 195-daysincreased biomass yield by 20.6 % and 9.4 % in 2018/19 season and by 34.6% and 17.3 % in 2019/20 compared to harvesting after210 days, respectively. However, the highest sugar yield was obtained from the longest harvesting date. Sugar yield of 210- and 195-daystreatments was significantly increased by 20.2% and 8.5% in 2018/19 season and by 34.9% and 19.2 % in the second season as compared by harvesting at 180 days, respectively.

Effect of sugar beet varieties on roots, biomass and sugar yields

The results in Table (2,3,and 4) clearly showed that RAVEL and SA1686 varieties increased roots yield by 17.4% and 8.4 % in 2018/19 and 14% and 12.4% in

2019/20 as compared bySV1841 variety, respectively .Sugar beet varieties significantly affected on biomass yield. RAVEL and SA1686 varieties increased biomass yield by 18.2 % and 8 % in 2018/19 season and by 12.8 % and 11.2 % in 2019/20 season as compared bySV1841 variety, respectively (Table, 2). Sugar yield was also increased by 13.9% and 9.1% in 2018/19 season and by 12.2% and 7.7% in 2019/20 season for RAVEL and SA1686 varieties compared to SV1841 variety, respectively.

Effects of the interactions on roots, biomass and sugar yields

The results of the effect of the interaction between harvesting date and varieties presented in Table (2) indicates that the highest significant roots yield was obtained from RAVEL variety (39.0. 86 t/fad. in the first season and 37.0 t/fad. in the second season) for the longest harvesting date (210 days). SA1686 variety of the second growing season and 210 harvesting date came in the second order by producing 36.5 t/fad.of roots yield. Generally, root yield production was highest in the longest harvesting date flowed by harvesting date 195 and 180 days respectively. Biomass yield show reverse behaviour compared with root yield where the highest significant biomass yield was found in the shortest harvesting date(180 days). The highest biomass yield obtained from RAVEL variety (19.5 t/fad. in the first season and 18.5 t/fad. in the second season) for harvesting date of 180 days followed by the biomass yield (18.2 t/fad.) of SA1686 variety of the same harvesting date in the second growing season. Generally, biomass yield was reduced by increasing the length of harvesting dates (Table, 3)

All levels of the interaction's effects presented in Table (2 and 3) indicated that only HxV showed significant effects on roots yield during the first growing season only and on biomass yield during both growing seasons.

Effects of irrigation water regimes and harvesting dates on water use efficiency

The results of water use efficiency (WUE) for roots and sugar yields are presented in Fig. 3. The results clearly indicated that decreasing irrigation water supply gradually increased WUE of roots yield (Fig. 3 A.).The highest roots WUE obtained from irrigation treatment of 70% WR followed by 85% WR and 100% WR, respectively especially in 195 and 210 harvesting dates treatments. Increasing harvesting date increased roots WUE where the WUE of 210 harvest days was the highest followed by 195 and 180 days respectively. Roots WUE of the second season was higher than that of the first season in 195 and 210 harvesting dates treatments but was lower than that of the first season in 180 harvesting date.

Sugar beet varieties RAVEL and SA1686 increased roots WUE compared with SV1841 variety but the differences in root WUE of RAVEL and SA1686 varieties were not significant. the main propose of sugar beet cultivation is to produce sugar therefor, the sugar WUE in relation to irrigation water regimes and harvesting dates also presented in (Table, 5). Results are varied based on variety and harvesting date. In 180 days harvesting date the highest sugar WUE obtained from SA1686 variety of 70% WR treatment. For 195 days harvesting date RAVEL variety of 70% WR treatment showed the highest sugar WUE. SA1686 and RAVEL varieties of 70% WR treatment resulted in the highest sugar WUE under 210 days harvesting date. Generally, sugar WUE under 210 days harvesting date was better than that of other two harvesting dates (Table, 6).

Discussions

The gradual reduction in seasonal water supplies and water consumptive use by increasing irrigation water deficit (Figs. 1 and 2) are due to the lower supply of irrigation water at 70% WR treatment than that supplied at 85% WR and 100% WR treatments. Increasing in water supply and water consumptive use by increasing harvesting date are attributed to the additional irrigation water added to meet the crop water needs during the extra growing days along the season. Similar findings were published by Aiad (2019) and Edrees (2019) and Ismail & El-Nakhlawy (2018). Increasing water consumptive use in the first season than that of the second season could be attributed to the differences in weather conditions of the first and the second seasons as indicated in Table (1).

The results presented in Table (2) clearly indicated that increasing water supply increased roots, biomass and sugar yields. The highest values were recorded for 100% WR treatment while the lowest values were obtained from 70% WR treatment. It is known that the growth and yield of most crops,are associated with improving soil condition including soil water availability in the soil. High available soil water in 100% WR treatment may improve growth parameters through increasing water and nutrient absorption which directly resulted in high roots, biomass and sugar yields. In the other hand water deficiency as in 70% WR treatment may affected on usual metabolic activities of plants and restricts normal crop growth resulting in great economic loss (Amer 2020;Ismail 2016; Sikuku et. al., 2012).

Delaying harvesting date from 180 to 210 days gradually and significantly increased roots and sugar yields (Table 2 and 4).

The increases could be attributed to two reasons. The first reason might be due to the continuity in plant growth and more dry matter accumulation at the end of harvest.

Table (5) Water use efficiency (WUE) of Roots yield for different sugar beet varieties under different irrigation water regimes and harvesting dates for two consecutive growing seasons

Irrigation	Harvest Time	First Season			Avg.	Second Season			Avg.
		RAVEL	SV1841	SA1686		RAVEL	SV1841	SA1686	
100%	180	16.36a	14.00a	15.70a	15.35a	15.16a	12.96a	14.90a	14.34a
	195	15.56a	13.43a	14.73a	14.57a	14.83a	13.70a	14.23a	14.25a
	210	15.06a	12.73a	13.13a	13.64a	15.46a	13.86a	15.30a	14.87a
Avg.		15.66a	13.38a	14.52a	14.52b	15.15a	13.51a	14.81a	14.49c
85%	180	17.46a	14.93a	16.56a	16.32a	14.60a	13.33a	14.63a	14.19a
	195	16.20a	13.96a	15.73a	15.30a	15.46a	13.83a	15.10a	14.80a
	210	15.80a	13.43a	13.36a	14.20a	16.40a	14.30a	16.40a	15.70a
Avg.		16.48a	14.11a	15.22a	15.27a	15.48a	13.82a	15.37a	14.89b
70%	180	17.70a	14.46a	17.20a	16.45a	15.36a	14.26a	16.03a	15.22a
	195	16.00a	14.56a	16.13a	15.56a	17.66a	14.43a	17.13a	16.41a
	210	16.06a	14.83a	14.26a	15.05a	18.06a	15.30a	17.90a	17.09a
Avg.		16.58a	14.62a	15.86a	15.69a	17.03a	14.66a	17.02a	16.24a
Harvest Treatment Average	180	17.17d	14.46f	16.49c	16.04a	15.04a	13.52a	15.19a	14.58b
	195	15.92b	13.98h	15.53g	15.14b	15.98a	13.99a	15.48a	15.15c
	210	15.64a	13.66e	13.58a	14.30c	16.64a	14.49a	16.53a	15.89a
Grand Avg.		16.24a	14.04c	15.20b		15.89a	14.00c	15.73b	

Table (6) Water use efficiency (WUE) of Sugar yield for different sugar beet varieties under different irrigation water regimes and harvesting dates for two consecutive growing seasons

Irrigation	Harvest Time	First Season			Avg.	Second Season			Avg.
		RAVEL	SV1841	SA1686		RAVEL	SV1841	SA1686	
100%	180	2.86a	1.81a	2.48a	2.38a	2.66a	1.78a	2.41a	2.28a
	195	2.77a	1.82a	2.34a	2.31a	2.67a	1.95a	2.33a	2.32a
	210	2.79a	1.75a	2.07a	2.20a	2.87a	2.05a	2.48a	2.47
Avg.		2.81a	1.79a	2.30a	2.30b	2.73a	1.93a	2.41a	2.36b
85%	180	3.30a	2.11a	2.65a	2.69a	2.66a	2.02a	2.39a	2.36a
	195	3.15a	1.93a	2.55a	2.54a	2.87a	2.18a	2.55a	2.53a
	210	3.11a	1.99a	2.20a	2.43a	3.03a	2.23a	2.78a	2.68a
Avg.		3.19a	2.01a	2.47a	2.55ab	2.85a	2.14a	2.57a	2.52ab
70%	180	3.58a	2.19a	2.92a	2.90a	3.01a	2.24a	2.77a	2.67a
	195	3.37a	2.20a	2.71a	2.76a	3.53a	2.28a	2.99a	2.93a
	210	3.45a	2.30a	2.47a	2.74a	3.75a	2.51a	3.14a	3.13a
Avg.		3.47a	2.23a	2.70a	2.80a	3.43a	2.34a	2.97a	2.91a
Harvest Treatment Average	180	3.25a	2.04a	2.68a	2.66a	2.78a	2.01a	2.52a	2.44b
	195	3.10a	1.98a	2.53a	2.54ab	3.02a	2.14a	2.62a	2.59b
	210	3.12a	2.01a	2.25a	2.46b	3.22a	2.26a	2.80a	2.76a
Grand Avg.		3.15a	2.01b	2.49ab		3.01a	2.14b	2.65ab	

Plants harvested at longer growth period after sowing, had the advantage to accumulated more assimilates resulted from the photosynthesis process to store more dry matter in their roots, in comparison with those harvested at younger age (Nagib et al., 2018; Gadallah and Tawfik, 2017). The second reason could be attributed to climatic conditions in particular the effect of temperature on growth, photosynthesis and respiration. The delay at the time of harvest increased root yield and root sugar content due to extending the growth period, sunny days and cool nights of autumn, which are the best conditions for sugar producing and reserving in sugar beet (Mohamed and Yasin, 2013; Al-Sayed et al., 2012). Moreover, the increase in sugar yield by delaying harvest date could be due to the increase in sucrose and purity percentages beside the roots yield which reflected on sugar yield as a final product (Ahmed et al., 2017).

Delaying harvest date from 180 to 210 days reduced the aboveground biomass yield. The resultscould be explained by the dryness and death of plant leaves by increasing the length of harvesting date. Similar result was published by Gadallah and Tawfik (2017).

Sugar beet varieties showed significant effects on roots, sugar and biomass yields. RAVEL and SA1686 varieties were almost similar but higher roots, biomass and sugar yields than SV1841 variety. These results may be due to the genetic differences among varieties in their performance. In this study RAVEL and SV1841 are monogerm cvs while SA1686 is multigerm cv. El-Kammash et al., (2011) reported that the differences among mono-germ and multi-germ seed type were insignificant.

Water use efficiency (WUE) was increased by decreasing water supply (Table5 and 6). The results could be due to the decrease in water losses as a result of decreasing losses especially deep percolation. Also, with practicing water deficit, most crops especially those growing in arid land conditions are wisely and efficiently use irrigation water. Our results are in line with those published by (Yassin et al., 2022,Edrees, 2019, Ismail and El-Nakhlawy, 2018, Ismail and Almarashadi, 2013). WUE also increased by increasing the harvesting date. The increase may be explained by the relationship between units of water use and the accumulated of more assimilates resulted from the photosynthesis process which stored more dry matter in roots, in comparison with those harvested at younger age. It seems that, the unit of water in long harvesting date (210 days) produced more roots and sugar yields than that of younger ages (180 day) resulted in high WUE (Nagib et al., 2018). WUE of sugar yield (Table 6) indicated that optimizing sugar production varied based on water deficit, harvesting date and variety. SA1686 variety of 70% WR produced the highest sugar yield at 180 days harvesting date compared to the other varieties. In general, sugar WUE under 210 days harvesting date was better than that of other two harvesting dates. These results could be due to the increase in sucrose and purity percentages and root yield which reflected on sugar yield as a final product (Ahmed et al. 2017).

Conclusion

Results of this study clearly indicated that reducing water supply reduced roots, sugar and biomass yields but increase WUE. The highest roots, sugar and biomass yields were recorded with 100% WR treatment followed by 85%WR and 70%WR treatments respectively. The highest WUE was obtained from 70%WRtreatment followed by 85%WR 100% WR treatments, respectively. Increasing harvesting date increased roots and sugar yields but reduced biomass yield. The highest roots and sugar yields were obtained from 210 days harvesting date followed by 195 days and 180 days harvesting dates respectively while the highest biomass yield was found in 180 days harvesting date followed by 195 days and 210 days harvesting dates. Roots, sugar and biomass yields of RAVEL and SA1686 varieties were almost comparable but higher than those of SV1841 variety. The highest sugar WUE obtained from SA1686 variety of 70% WR treatment under 180 days harvesting date and was similar to that obtained from SA1686 of 70% WR treatment under 210 days harvesting date followed by RAVEL variety of 70 % WR and 210 day harvesting date. In conclusion, cultivating either RAVEL or SA1686 variety with 70% of water requirement and for 210 growing days under Upper Egypt conditions optimise roots and sugar yields of sugar beets.

References

Abdel-Nasser G, Hussein AHA (2001) Response of corn to K-fertilization under different soil moisture conditions. 1- growth. *Advances in Agricultural Research,* **6**, 173-193.

Ahmed AZ, Awadalla AO, Abazid SR (2017) Possibility of sugar beet production in Toshka Region-: I. Assessment of the optimum harvesting age. *Journal of Plant Production,***8**, 1409-1415.

Aiad, M. A. E. F. (2019). Productivity of heavy clay soils as affected by some soil amendments combined with irrigation regime. *Environment, Biodiversity and Soil Security,* **3**(2019), 147-162.

Allen RG, Pereira LS, Raes D, Smith M (1998)Crop evapotranspiration: Guidelines for computing crop water requirements. *FAO Irrigation and Drainage Paper,* 56.

Al-Sayed HM, El-Razek UAA, Sarhan HM, Fateh H S (2012) Effect of harvest dates on yield and quality of sugar beet varieties. Australian *Journal of Basic and Applied Sciences,***6**, 525-529.

Ali AM., Ibrahim SM, Abou-Amer I (2019).Water deficit stress mitigation by foliar application of potassium silicate for sugar beet grown in a saline calcareous soil. *Egyptian Journal of Soil Science,***59** 15-23.

Aly EFA (2006) Effect of environmental conditions on productivity and quality of some sugar beet varieties. *Ph.D. Thesis,* Fac. of Agric., Benha Univ., Egypt.

Amer, M., Aiad, M., Rashed, S. and H. El-Ramady (2019) Sustainable Irrigation and Fertilization Management of Successive Cultivated Sugar Beet and Cotton under Salt-affected Soil Conditions. *Env. Biodiv. Soil Security*, **3**, 227 – 239.

Amer MM., Gazia, EAW, Aboelsoud HM, and Rashed, SH (2020) Management of Irrigation water and organic matter app; ication contribution in improving some soil properties and yields-water productivity of sugar beet and cotton in salt affected soil. *Env. Biodiv. Soil Security,* **4**, 7-18.

Edrees GH (2019) Intercropping of Al-hassawi alfalfa on different sugar beet cultivars under the effect of nitrogen fertilizer rates. *Ph.D. Thesis.* Faculty of Meteorology, Environment, and Arid Land Agriculture, King Abdulaziz University, Saudi Arabia.

El-Kammash, TN, Abdelkader MM, Farag MA, Teama EA, Abou-SalamaAM (2011) Evaluation of some newly introduced sugar beet cultivars under Egyptian North-Delta conditions: II- quality parameters. *J. plant production, Mansoura Univ.,* **2**, 547-558.

Enan SAA, Aly EFA, Badr AI (2016) Effect of humic acid and potassium on yield and quality of some sugar beet varieties in sandy *soil. J. Plant Prod., Mansoura Univ.,* **7**, 289 -297.

Enan SAA, El-Sheikh SRE, Khaled KAM (2009) Evaluation of some sugar beet varieties under different levels of N and Mo fertilization. *J. Biol. Chem. Environ.Sci.,* **4**, 345-362.

Gadallah AF, Tawfik S F (2017) Effect of harvesting age of some sugar beet varieties grown in a new reclaimed soil in Sohag. *Alexandria Science Exchange Journal,* **38**, 975-982.

Gomez KA, Gomez AA (1984) Statistical Procedures for Agricultural Research. John Wiley and Sons.

Ismail SM, Almarshadi MH (2013) Maximizing productivity and water use efficiency of alfalfa under precise sub-surface drip irrigation in arid regions. *Irrig.and Drain.*, **62**, 57-66.

Ismail SM, El-Nakhlawy FS (2018) Optimizing water productivity and production of sunflower crop under arid land conditions. *Water Science & Technology: Water Supply,* **18**, 1861-1868.

Ismail SM. 2016. Maximizing production and irrigation water productivity of canola crop (Brassica napus L) under arid land conditions. *Irrig.and Drain.*, **65**, 254–263.

Israelsen OW, Hansen EV (Eds) (1962) Irrigation principles and practices. 3rd edition, John Wiley and Sons, Inc, New York.

Mahmoud SA, Hasanin B, El-Geddawy IH, Mosa DTA (2008) Effect of sowing and harvesting dates on yield and quality of some sugar beet varieties.*Proc.Int. Conf.* (IS-2008), Al-Arish, Egypt. Sep., **11-14**, 22-29.

Mekdad AAA, El-Sherif AMA (2016) Performance of two Sugar beet varieties under fertilization with potassium and foliar spraying with micronutrients. *Egypt J. Agron.*, **38**, 189 -207.

Mohamed YH, YasinMAT(2013) Response of some sugar beet varieties to harvesting dates and foliar application of boron and zinc in sandy Soil. *Egypt J. Agron.*, **35**, 227- 252.

Nagib SR, El-AzezA, Ali A M K (2018) Evaluation of some new sugar beet varieties as affected by different harvest ages under conditions of Minia Governorate. *Journal of Plant Production,* **9**, 1175-1180.

Nasr MI, Abd El-Razek AM (2008) Sugar beet performance under newly reclaimed soils conditions of Sinai, *Egypt Sugar Tech.*, 210-218.

Ouda, SMM (2011) Response of sugar beet to N and K fertilizers levels under sandy soil conditions. *Zagazig J. Agric. Res.*, **28**, 275 – 297.

Shalaby NME, Osman AMH, El-labbody AHSA (2011) Evaluation of some sugar beet varieties under three plant densities in newly reclaimed soil. *Egypt J. Agric. Res.*, **89**, 65-614.

Sikuku PA, Onyango JC, Netondo GW(2012) Yield components and gas exchange responses of Nerica rice varieties (*Oryza sativa* L.) to vegetative and reproductive stage water deficit. *Global J. Sci. Frontier Res.*, **12**, 51-62.

Yassin, O., Ismail, S., Gameh, M., Khalil, F., and Ahmed, E. (2022) Evaluation of chemical composition of roots of three sugar beets varieties growing under different water deficit and harvesting dates in Upper Egypt. *Current Chemistry Letters,* **11**, 1-10.