Water stress effects on yield and Quality of sugar beet crop in sandy soils

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ABSTRACT

The present investigation was carried out during the two growing seasons of 2014/2015 and 2015/2016 at the farm of Nubaria sugar and reefing company. El-Bohera Governorate, Egypt to study the effect of water stress regimes (60%, 80%, and 100 % of irrigation water requirement (IWR) on growth and yield quality of sugar beet plant grown under drip and sprinkler irrigation systems and sandy soil conditions. Results revealed that drip irrigation system with 80% of (IWR) recorded the highest significant leaf area index, sucrose percentage, purity percentage and extractable sugar percentage in both seasons of sugar beet crop. While application of sprinkler irrigation at 100% (IWR) gave the heaviest root weight, root Number /fed, purity percentage and root yield in both growing seasons.

Drip irrigation system with 1322 m^3/fed water (60 % of IWR) give the best satisfy yield and good quality of sugar beet crop under sandy soil and the experimental condition.

Key words: sugar beet – drip-sprinkler – water stress-growth – yield.

INTRODUCTION

Sugar beet is the second sugar crop after sugar can for the production process of sugar in Egypt. Water is one of the most essential parameters for crop production. So, the challenge facing the growers of sugar beet is to optimize (IWR) with suitable irrigation methods and the water regime needed.

There is a directed relation between crop yield and water use by plants. Agriculture in arid regions has special aspects; so, agriculture is limited by water and irrigation therefore, agriculture practices are organized for optimal water use and maximum yield per unit volume of used water. Irrigation system is one of the methods which have an important role in suitable use of water and increasing water use efficiency. Irrigated agriculture is still practiced in many areas in the world with complete disregard to basic principles of resource conservation and sustains ability. Therefore irrigation water management in an area of water scarcity will have to be carried out most efficiently, aiming at saving water and at maximizing is productivity. Irrigation is applied to avoid water deficits that reduce crop production. The process of crop water use has two main components. One due to evaporation losses from the soil and the crop, usually called evapotranspiration, and the other that includes all the losses resulting from the distribution of water to the field.(English, 1990 Fereres and Soriano, 2007) Irrigation system are selected, designed and operated to supply the irrigation requirements of each crop on the farm while controlling deep percolation, run off, evaporation, and operation losses, to establish a sustainable production process. To crop with scare supplies, deficit irrigation defined as the application of water below full crop – water requirements, is an important tool to achieve the goal of reducing irrigation water use. There is potential for improving water productivity in many field crops and there is sufficient information for defining the best deficit irrigation strategy for many situations. Irrigation is necessary to provide moisture for seed germinate and in many areas to control salinity over irrigation at early stages may tend to leach nitrates, and enhance seeding diseases. During periods of growth, there is several light irrigation may be more important, At midseason sugar beet plants option most of their moisture from the upper 3 feet of soil and heavier irrigations are required to supply this moisture. Moderate moisture stress just before harvest tends to increase sugar percentage without limited sugar yield per acre (Kirda, 2002). Sugar beet (Bata Valgaris L.) has been recognized as an important essential plant nutrient for more than a century. The past go years have brought marked advanced in the capacity to manufacture and apply nitrogen as commercial fertilizers the marked increases in N- fertilizers application to the soil have raised concern about the environmental important of N T escapes from the root zone (Di and Cameron, 2002). The rate of N in plant nutrition has been recognized to be connected to the production of vigorous vegetation growth crop response to N fertilization can be expressed in terms of highest yield and improved crop quality. Some of the most significantly advances in nitrogen fertilization of crop have been occurred during its beneficial capacity to provide both in come from the harvested root as well as live stock in the form of above – ground biomass (tops) and root processing by products such as pulp and molasses (Stev et al., 2008). There for, the present investigation aimed to study water stress effects (60%, 80%, and 100% from

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irrigation water requirement on yield and quality of sugar beet plants in sandy soils under condition of drip and sprinkler irrigation systems

MATERIALS AND METHODS

Two field experiments were carried out in 2014/2015 and 2015/2016 seasons at Nubaria sugar factory , El-Behiera Governorate , Egypt to study the effects of water stress on yield and quality of sugar beet crop in sandy soil Nubaria sugar factory is situated at $30^o,38^o,00.$ 4" N latitude, 30^o, 13.35, 9" E longitude and the altitude is 28 m above the sea level.

Soil samples were collected from three depths (0-20, 20-40 and 40-60 cm) to determine the main soil physical and chemical properties at the experimental site. The soil physical parameters (particle size distributions and soil texture class) were determined according to FAO (1970), soil-moisture constants (soil field capacity, F.C.; wilting point. W.P.; and available water, A.W.) Were determined on mass basis by a pressure extractor apparatus, and soil bulk density values were determined in undisturbed soil samples using the core method (Black and Hartge, 1986). The soil chemical parameters (electrical conductivity (EC), soil reaction (pH), soluble cations, and anions), organic matter, and total calcium carbonate were determined according to Page et al. (1982). The soil main physical and chemical properties are listed in Tables 1 and 2.

Irrigation water used in the experiment was pumped from Nubaria canal. The chemical analysis of irrigation water According to A. O.A.C.(1970)is given in table (3).

Experimental Design

A split-split plot design with three replications was used for each irrigation system.The water stress treatments occupied the main plots‹ while the sub plots were assigned for the two organic fertilization levels. Meantime, the three nitrogen levels were randomly distributed in the sub-sub plots. Multi-green variety viz. Gazelle imported from Germany water sown on the first week of October of each season .seeds was on ridges 60 cm apart and 20 cm between hills. Each sub – sub plot size was 15 m^2 (125 plants).

The sugar beet plants were harvested 190-200 days after sowing in both seasons. Ten guarded plants were selected at random from each treatment of three replications.

Crop water-use parameters:

Reference Evapotranspiration (ETo): Data from the agricultural weather station were available and the Penman-Monteith method was used in CROPWAT model (Smith, 1992), described by Allen et al. (1998) was used to calculate ETo.

The ETo values were calculated as follows:

Penman-Monteith Method: **Penman-Monteith equation is given as:**

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

where:

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

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

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

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

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

e_s-e_a= vapor pressure deficit (kPa)

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

Table 1. Soil Particle size distribution, Field capacity, wilting point, available water, and bulk density values of the experimental site

Soil depth (cm)	Particle size distribution %			Texture class	Field Capacity (%)	Wilting Point (%)	Available water (%)	Bulk density (g cm^{-3})
	Sand	Silt	Clay					
0-20	94.5	3.5	2.0	Sandy	13.25	5.50	7.75	1.65
20-40	95.0	3.3	1.7	Sandy	14.25	4.90	9.35	1.56
40-60	95.7	3.0	1.3	Sandy	14.50	4.30	10.20	1.44

Table 2. Main soil chemical properties of the the experimental site before sowing

Soil depth (cm)	EC dS m^{-1}	pH 1:2.5	Total $CaCO_3$ %	Soluble cations (meq L^{-1})				Soluble anions (meq L^{-1})				OM %
				Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	
0 – 20	1.46	8.23	4.9	6.23	2.24	3.44	0.51	-	0.93	1.88	9.61	1.025
20 – 40	1.56	8.11	5.8	6.45	2.26	3.76	0.58	-	1.15	2.05	9.85	-
40 - 60	1.63	7.97	4.2	6.65	2.29	3.91	0.65	-	1.33	2.01	10.16	-
Average	1.55	8.10	4.97	6.44	2.26	3.70	0.58		1.14	1.98	9.87	1.03

Table 3. Chemical characteristics of irrigation water

$EC (dsm^{-1})$	pH	Soluble cations (meq L^{-1})				Soluble anions (meq L^{-1})				SAR	E.S.P (%)
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}		
1.18	7.14	2.0	2.98	2.0	1.0	0.0	1.3	1.25	2.98	12.1	78.1

Table 4. average Agro- meteorological data of the experimental site during the growth period at Wadi- El-Natrun station

Month	Min temperature (°C)	Max temperature (°C)	Relative humidity (%)	Wind speed (m/sec)	Sun shine (hr)	ETo (mm/day)
October 2014	16.24	28.79	50.26	2.24	9.02	2.54
November 2014	11.67	22.44	57.59	2.13	7.76	1.58
December 2014	11.10	21.44	59.14	2.39	6.50	1.20
January 2015	7.89	17.74	50.54	2.88	6.79	1.17
February 2015	8.09	18.33	50.00	2.86	7.47	1.55
March 2015	9.48	21.78	49.53	3.30	8.34	2.31
April 2015	13.12	27.16	48.28	2.43	9.41	3.29
Average	11.08	22.53	52.19	2.60	7.90	1.95

The input parameters needed to calculate ETo using the CROPWAT model (Smith, 1992) are air temperature, relative humidity, sunshine hours, and wind speed. The data from Wadi- El-Natrun Station were used in this study. The average monthly meteorological data used in calculating ETo values are listed in Table 4.

The amounts of irrigation water were calculated according to the equation given by vermeiren and Jopling (1984) as follows:

$$AIW = \frac{ETo \times Kc\, I}{Ea\,(1 - LR)}$$

Where:

AIW= depth of applied irrigation water in mm

ETo= Reference evapotranspiration, mmd^{-1}

Kc = crop coefficient (for sugar beet crop as reported by FAO, Allen et al. 1998).

I= irrigation intervals (days)

Ea= irrigation application efficiency of the drip and sprinkler irrigation system.

L.R = leaching requirements,

Irrigation time for drip irrigation system was determined before an event by measuring the actual emitter discharges according the equation given by Ismail (2002) as follows:

$$t = \frac{AIW \times A}{q}$$

Where:

t = irrigation time (h)

A = wetted area (cm^2)

q = emitter discharge (L/h)

AIW = applied irrigation water (cm)

While, the irrigation time for sprinkler irrigation water was calculated

according to the equation as follows :

$$Irrigation\ time\ (h) = \frac{AIW}{AR}$$

Where:

AR= application rate (mm/h)

$$Ar = \frac{1000 \times Q}{L\,l \times Ls}$$

Q = sprinkler discharge (m^3/h)

L_L = distance between lateral (m)

Ls = distance between sprinkler (m)

Water utilization efficiency (WUtE): The WUtE values were calculated according to Jensen (1983) as follows:

$$WUtE = \frac{\text{Sugar beet yield (kg/fed)}}{Applied\ irrigation\ \text{water}\ (m^3 / fed)}$$

Determinations related to sugar beet crop as follow:

A-Growth traits:

At harvesting, a sample of ten plants was taken at random from each sub-sub plot and topped to determine the following traits in both seasons:

1-Root weight (kg)

2-Leaf area index (LAI): Leaf area index [(LAI) = unit leaf area per plant (cm^2)/ plant ground area (cm^2)] was determined after 90 days from planting according to Watson (1958) and leaf area was determined using area meter, ATA60, Model 3100

B-Yield quality traits:

At harvesting, a sample of ten roots was taken at random from each sub-sub plot and cleaned to determine the following traits in both seasons:

1-Sucrose percentage: was determined by using sacharometer lead acetate extract of fresh macerated roots according to Carruthers and Oldfield (1960).

2 -**Extractable sugar percentage (ES%):** According to Renfield et al. (1974), it was determined using the following formula:

ES% = pol-[0.343(K + Na) + 0.094 α-amino N + 0.29] where Pol = sucrose percentage.

3 -**Juice purity percentage (QZ)** = (ES% / pol) × 100 and

4 -**Impurities percentage** = [0.343(K + Na) + 0.094 α-amino N + 0.29] Were determined according to Renfield et al.(١٩٧٤).

C-Yield:

At harvesting, the guarded ridges of sugar beet in each sub-sub plot were up-rooted, topped, cleaned and weighed to determine:

1 -Root number/fed.

2 -Root yield (ton/fe).

2-White sugar yield (ton/fed) = root yield (ton/fed) x (Extractable sugar %/100).

Statistical analysis

Collected data under each irrigation system were subjected to normal statistical analysis according to Snedecor and Cochran (1989). Treatment mean comparisons were done using least significant difference (LSD) at 5% level of probability. After homogeneity test, combined analysis was done to compare between the two irrigation systems.

RESULTS AND DISCUSSION

A-Applied irrigation water:

Growth stage total applied of irrigation water in mm during the growing seasons are presented in Table 4. Results showed the normal trend of increasing applied irrigation water with the advance in plant growth and the decrease at the ripening stage. The highest growth stage value of applied irrigation water occurred during Mid-season in both Irrigation systems for all irrigation treatments. The total amount of applied irrigation water for 60, 80, and 100% of ETo irrigation treatments were 1589.3, 2223.0 and 2880.8 mm in the Sprinkler irrigation system , and were 1322.0, 1943.5, and 2505.0 mm in the Drip irrigation system, respectively.

B-Effect of water stress on root weight:

Results in table 6 showed that mean root weight, sucrose, purity and impurities percentages as well as root and white sugar yields were significantly affected by increasing water deficit from 100% up to 60% of the irrigation water requirements. The highest LAI value under drip irrigation resulted from 80% of IWR. These results are in accordance with those obtained by Hosseinpour et al (2006.a) Also Watson (1952) and Good man (1968) who reported that the size longevity of sugar beet leaf canopies strongly influenced by soil moisture and soil fertility. Decreasing the amount of irrigation water from 100% to 80% and 60% of IWR under drip irrigation significantly decreased mean root weight by 8.04 and 26.79% in the 1^{st} season and 6.78 and 20.34 % in the 2^{nd} season. Under sprinkler irrigation the decrease in mean root amounted to 4.0 and 22% in the 1^{st} season and 7.41 and 27.78% in the 2^{nd} season, respectively. Sugar beet plant with 80 % of irrigation water requirements (IWR) recorded the highest percentage of sucrose (20.17 and 20.08%), purity (85.72) and 80.57%) and extractable sugar (17.30 and 16.23%) under drip irrigation in the first and second seasons, respectively. However, under sprinkler irrigation, juice quality trait values fluctuated among the three irrigation levels during the two growing seasons. Data revealed that application of 80 of (IWR) gave the highest values of extractable sucrose percentage under both irrigation systems. These results are in agreement with those reported by Roberts et al (1980) who they mentioned that deficit irrigation usually increases percent of sucrose in the root Hong and miller (1986) found that sugar concentration in well watered crop rises steadily through the growing season often leveling off before the harvest between 15 and 18% (9 sugar per100g fresh roots). In water stressed crops it rises more quickly, and under severe stress condition in can be 5% higher than in unstressed crops. Roots number was significantly affected by the irrigation water levels only under sprinkler irrigation system during the two growing season (table 6).

The conclusion of the previous discussion can briefly include the flowing three points

- Irrigation sugar beet plants with 2880 m3/fed (100%of IWR) recorded the highest and significant harvested roots number in the first season (22.20) thousand root /fed and in the second season (21.31 thou sand root /fed).
- Increasing water deficit from 100% to 60%of IWR significantly decreased root and white sugar yields under both irrigation systems during the two growing seasons (table5). Root yield retlection amounted to 26.67 and 25.52% in the first season and 20.29 and 30.45 % in the second season under

drip irrigation system, however the decrease in sugar yield accompanying high water deficit might have been due to the decrease in root yield as well as extractable sugar percentage as mention before results on root and white sugar beet yields indicted that yield of drip- irrigated sugar beet with 80% of IWR nearly matched yield of sprinkler.

Table 5. the amounts of the applied water for the three water regimes, % of ET_o (average of the two growing season's amount of water (m^3/fed)

Length of growth stage days	Growth stage	Applied of irrigation water (m^3/fed)					
		Sprinkler			Drip		
		60	80	100	60	80	100
30	Initial	297.7	297.7	297.7	258.9	258.9	258.5
60	Development	326.2	483.3	652.4	283.7	425.5	567.3
60	Mid-season	624.95	931.43	1249.9	543.5	815.2	1086
30	Late –season	340.4	510.6	680.8	235.9	443.9	591.9
Applied of irrigation water(m^3/fed)		1589.3	2223.0	2880.8	1322.0	1943.5	2505.0

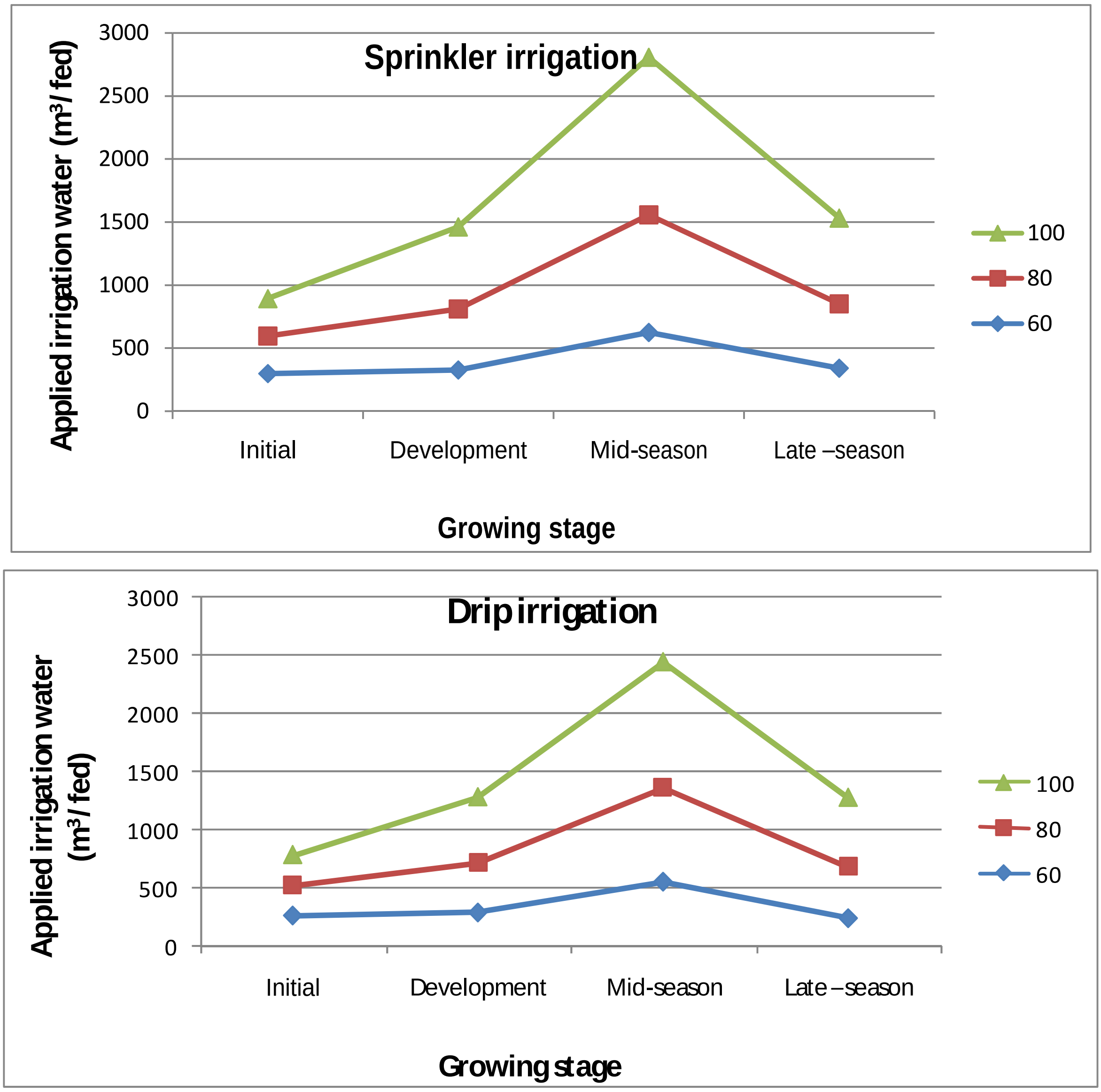

Fig 1. Applied irrigation water (AIW) on different growth stages under sprinkler and drip irrigation systems

Table 6. Effect of water stress on sugar beet yield and some of its attributes under drip and sprinkler irrigation system during 2014/2015 and 2015/2016 seasons

Water stress	Leaf area (cm^2)		Root Wight (kg)		Succors %		Purity %		Extractable sugar %		Root number /fed $*10^{-3}$		Root yield (ton/fed)		Wight sugar yield (ton/fed)	
	drip	Sprinkler	Drip	Sprinkler	drip	Sprinkler	drip	Sprinkler	drip	Sprinkler	drip	Sprinkler	drip	Sprinkler	drip	Sprinkler
2014/2015																
60%	1.54	1.93	0.82	0.78	19.70	20.68	82.53	84.86	13.43	3.2	21.23	21.21	17.38	16.52	2.82	2.89
80%	2.30	1.91	1.03	0.96	20.17	20.05	85.72	88.56	12.86	2.25	21.43	21.16	21.96	20.39	3.79	3.60
100%	2.00	2.70	1.12	1.00	19.87	20.20	58.51	88.60	12.87	2.22	21.22	22.20	23.70	22.18	4.01	3.97
LDS at 5%	0.42	N.S	0.02	0.04	0.18	N.S	1.09	0.76	0.29	0.20	N.S	0.62	0.30	0.30	0.08	0.15
2015/2016																
60%	2.19	2.59	0.94	0.78	18.62	19.80	75.98	78.77	14.17	15.67	21.21	21.21	17.38	16.52	2.82	2.89
80%	2.96	2.57	1.10	0.96	20.08	19.11	80.57	82.55	16.23	15.84	21.16	21.16	21.96	20.39	3.79	2.52
100%	2.66	3.36	1.18	1.08	19.21	18.88	79.67	82.68	15.32	15.64	22.20	22.20	23.70	22.18	4.01	3.61
LDS at 5%	N.S	N.S	0.04	0.04	0.31	0.35	1.60	1.05	0.40	N.S	0.62	0.62	0.30	0.30	0.08	0.12

- Irrigated sugar beet with 100% of IWR during the two growing seasons under drip irrigation gave highest root and white sugar yields and his might be due to the high efficiency of drip irrigation system as compared to sprinkler irrigation system (to Gneti et al., 2003). Data in the same table showed that average across seasons revealed that application of 100% of IWR gave the highest values of root and white sugar yields/fed under drip and sprinkler irrigation system (table 6).

C-Effect of irrigation system on sugar beet yield.

Data in Table (7) showed that drip irrigation system in the first season was significantly more efficient than sprinkler irrigation system due to root weight (kg), root yield (ton/fed) and white sugar yield (ton/fed), while in the second season it was significantly more efficient than sprinkler system due to root weight (kg), sucrose%, root number/fed, root yield (ton/fed) and white sugar yield (ton/fed). These results are in agreement with those of Arroyo et al. (1999).

D- Effect of water stress on water use efficiency (WUE).

Results table (8) cleared that mean values of water of water use efficiency based on root and white sugar yields (WUE root and (WUR) Sugar yield were significantly affected by in increasing water deficit from 100% up to 60% of the irrigation water requirements (IWR) under both irrigation system in the two growing seasons. Decreasing the amount of irrigation water from 100% to 80% and 60%of IWR under drip irrigation significantly increased WUE of root yield by 16.28 and 28.06 % in the 1st season and by 18.95and 33.84 % in the 2nd season while under sprinkler irrigation the increase in WUE of root yield amounted to 17.23 and 26.95 % in the 1st season and 14.79 and 20.77 % in the 2nd season, respectively. Drip irrigation sugar beet plant with 60% of irrigation water requirements (IWR) recorded the highest WUE of while sugar yield by 24.88 and 8.50% in the first and second season, respectively as compared to 100%of IWR (table 8) the same increase was accursed under sprinkler irrigation with 60% of IWR by 24.17 and 20.89 % in the 1st and 2nd seasons, respectively as compared to 100% of IWR. Also, data averaged across seasons revealed that application of

Table 7. effect of irrigation system on sugar beet yield and some of its attributes during 2014/2015 and 2015/2016 seasons

Measurements	2014 / 2015			2015 / 2016		
	Drip	Sprinkler	Sig	Drip	Sprinkler	Sig
Leaf area index (cm^2)	1.90	2.15	*	2.57	2.82	*
Root weight (kg)	0.97	0.88	*	1.05	0.92	*
Sucrose %	19.81	20.25	*	18.99	19.24	*
Juice purity%	83.38	87.39	*	78.20	80.31	*
Imparities %	3.02	2.51	*	4.02	3.50	*
Extractable sugar %	16.78	17.71	*	15.21	15.70	*
Root number /fed*10^{-3}	20.27	20.49	*	21.29	20.90	*
Root yield (ton/fed)	21.00	19.60	*	22.81	20.00	*
White sugar yield (ton/fed)	3.52	3.47	*	3.48	3.13	*

*indicate significance at 0.05 probability level.

Table 8. Effected of water stress on water use efficiency (WUE) of sugar beet under drip and sprinkler irrigation systems during 2014/2015 and 2015/2016 seasons

Water stress	Root yield (WUE)		Sugar yield (WUE)	
	Drip	Sprinkler	Drip	Sprinkler
	2014/2015			
60%	13.15	10.39	2.13	1.82
80%	11.30	9.17	1.95	1.62
100%	9.46	7.59	1.60	1.38
LDS at 5%	0.023	0.018	0.034	0.038
	2015/2016			
60%	15.19	10.11	2.14	1.58
80%	12.40	9.40	1.94	1.48
100%	10.05	8.01	1.53	1.25
LDS at 5%	0.012	0.009	0.007	0.021

60% of IWR gave the highest values of WUE root and white sugar yields under both irrigation system these results are in agreement with those reported by Hosseinpour et al (2006 a), Esmaeili (2011), Topake (2011) and Morad et al., (2012).

CONCLUSION

Drip irrigation system with 1322 m^3/fed water (60 % of IWR) give the best satisfy yield and good quality of sugar beet crop under sandy soil and the experimental condition.

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الملخص العربي

تاثير الاجهاد المائي علي المحصول والجودة لمحصول بنجر السكر في الاراضي الرملية (Beta vulgaris L)

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أجريت تجربتان حقليتان بمزرعة البحوث بشركة النوبارية للسكر – وادي النطرون – محافظة البحيرة – مصر خلال موسمي ٢٠١٤/ ٢٠١٥، ٢٠١٥/٢٠١٦ لدراسة تأثير الاجهاد IWR المائي على المحصول والجودة لمحصول بنجر السكر في الاراضي الرملية. حيث تم استخدام ثلاث مستويات من الاجهاد المائي (٦٠ %، ٨٠ %، ١٠٠ %) من احتياجات الري تحت نظم الري بالتنقيط والرش وتأثير هذه المستويات على المحصول والجودة وأظهرت النتائج الاتي:

بنجر السكر الذي تم رية بالتنقيط تحت ٨٠% من احتياجات الري أعطي اعلي محصول معنوى لـ L.A.I ونسبة السكر والنسبة المؤية للنقاوة فى الموسميين الزراعيين ونسبة السكر المستخلصة فى الموسم الثاني فقط بينما مع الري بالرش ١٠٠% من أحتياجات المحصول أعطي أعلي محصول من الجذور وأعلي عدد للجذور بالفدان وأعلي نسبة نقاوة للسكر في الموسميين. لذلك المعاملة الموصي بها هى استخدام الري بالتنقيط مع الري بكمية مياه مقدارها ١٣٢٢ متر مكعب للفدان وهى الرى بكمية مياه تساوى ٦٠% من احتياجات الرى تحت ظروف وادي النطرون محافظة البحيرة – الاراضي الرملية.