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EFFECT OF CULTIVATION METHOD AND DIFFERENT IRRIGATION LEVELS ON WATER RELATIONS FOR SUGAR BEET CROP IN NORTH NILE DELTA REGION.

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ABSTRACT

Two field investigations were performed at Sakha Agricultural Research Station (31^0 07ˉ N Latitude and 30^0 57ˉ E longitude with an elevation of about 6 metres above mean sea level, MSL). Kafr El-Sheikh Governorate during the two successive winter growing seasons 2013/2014 and 2014/2015to investigate the effect of cultivation method and irrigation treatments on sugar beet yield, yield components, quality and some water relations. The trial was designed split plot with three replicates. The main plots were randomly assigned by cultivation method, A (normal furrows, 60 cm. apart) and B (raised-bed method, 120 cm. apart). While, sub-plots were randomly assigned by irrigation treatments (scheduling treatments). I_1 (Traditional irrigation, like to practice by local farmers), I_2 (1.2 of cumulative evaporation pan, CEP), I_3 (1.0 of cumulative evaporation pan, CEP), I_4 (0.8 of cumulative evaporation pan, CEP) and I_5 (0.6 of cumulative evaporation pan, CEP).

The main findings can be summarized as follows:-

- The highest mean values for seasonal water applied and water cons umptive use were recorded under normal cultivation method comparing with raised-bed method and the values are 2802.00 and 2553.55 m^3/ fed. for water applied and 1878.67 and 1818.88 m^3/ fed. for water consumptive use under normal and raised-bed methods, respectively. Concerning, the effect of irrigation treatments, the highest mean values were recorded under I_1 but the lowest were recorded under I_5 for the two studied parameters.
- The highest mean values for consumptive use efficiency (Ecu, %), water productivity (WP) and productivity of irrigation water (PIW) were recorded under raised-bed method and the values are 71.38%, 16.44 (kg/ m^3) and 11.74 (kg/ m^3) for Ecu, WP and WIP, respectively. The corresponding values under .normal method were 67.335, 14.85 (kg/ m^3) and 10.00 (kg/ m^3) for Ecu, WP and WIP, respectively. Regarding, the effect of irrigation treatments, the highest mean values were recorded under I_5 for Ecu and I_4 for WP and PIW.

Concerning, yield, yield components, sucrose percentage, sugar yield and Purity were highly significant affected by both cultivation method and irrigation treatments showed significant effect on the abovementioned studied parameters except top yield (ton/ fed.) in the second season, sucrose % in the first season, root length in the first season, root diameter and purity (%) in the two seasons showed no significant effect on the abovementioned parameters.

Keywords: - Cultivation method, Irrigation levels, Water efficiencies, Sugar beet.

INTRODUCTION

In Egypt, water is the most critical factor in crop production. Under the climatic conditions of Egypt amount of rainfall is low with erratic distribution. Therefore, almost agricultural production is mainly dependent upon artificial watering or which so-called irrigated agriculture. Water resources are limited and concentrated on the Nile River that supplies Egypt with about 95% or more from fresh water. The Egyptian water budget from the Nile is 55.5 milliard cubic metre according to the international agreements among the countries of the Nile basin. There are other water resources which sometimes negligible such as rainfall, and sometimes high in expenses for using such as drainage water, sea water and ground water.

The present share of water in Egypt is less than 1000 m^3/ capital/ year which equivalent to the international standards of water poverty limit or water safety limit *(El-Quosy, 1998)*. Irrigation is the main sector in water demand at the national level. Water allocated to irrigation is about 85% from the total renewable water. So, effective water management at the irrigation sector is the principal way towards the rationalization policy for the country. In this aspect, effective on farm irrigation management becomes a must.

Sugar beet (Beta Vulgaris L.) is considered the second producing sugar crop in Egypt following to sugar cane. Recently, sugar beet crop has received an important position in Egyptian crop rotation as a winter crop not only in fertile soils, but also in poor, saline, alkaline and calcareous soils. Agriculture is the main sector in water consumption as abovementioned. However, water productivity (WP) is very low. The main reason for decreasing (WP) is the over irrigation by the farmers. Farmers normally over irrigation the fields due to lack of proper knowledge about irrigation scheduling; and they believe that more water applied may result in low in water productivity and low in net income.

Irrigation scheduling is the decision of when to irrigate and how much water to apply to a field. Its purpose is to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level. It saves water and energy, *Jensen (1980)*. It has been described as the primary tool to improve water use efficiency, increase crop yields, increase the availability of water resources, and provoke a positive effect on the quality of soil and ground water, *FAO (1996)*. The meteorological based on irrigation scheduling approach, such as pan evaporation replenishment, cumulative pan evaporation (CPE), etc., was used by many researchers due to its simplicity, data availability and higher degree of adaptability at farmers level (*Imtiyaz et al., 2000; Singh et al., 1997 and Powar et al., 1991*). Many researchers in Egypt (*Khalil, 1996; Ashraf et al., 2002; Khalil and Mohamed, 2006*) have extensively tested the technique of using pan evaporation for irrigation scheduling. It proved to save up to 20% of the applied irrigation water by the farmers. Therefore, under Egyptian conditions, extension agricultural is recommending scheduling irrigation by using pan evaporation technique to the farmers as a way to conserve irrigation water. In spite of the difficult for a common farmer to maintain and to read exact level in the pan, they can be attached with a farm to make it simple for a common farmer to design irrigation scheduling.

One of the main national strategies in agriculture is cultivating sugar beet instead of sugar cane, the highest water need crop. To produce one ton of sugar from beet, it needs almost one quarter of water in comparison with that for sugar cane, *Doorenbos and Kassam (1979)*. The traditional planting method for sugar beet at Kafr El-Sheikh Governorate, (the main area in national sugar beet production), is planting in furrows. The soil type and the cultivation practice influence the spacing of furrows. On clay soils, double-ridged furrows, sometimes called beds, can be also used. Their advantage is that more plant rows are possible on each ridge, facilitating manual weeding. The ridges can be slightly rounded at the top to drain off water that would otherwise tend to pond on the ridge surface during heavy rainfall, *Wang et al. (1999)*. The method of planting in beds, which tested on some field and vegetable crops, and proved effective in increasing crop yield and water use efficiency. *Anonymous, (2006) and Raut et al. (2000)* reported that the method of planting in beds was tested on some field and vegetable crops and proved to be effective in increasing crop yield and water use efficiency, so far, sugar beet planting in beds not yet tested.

Under limitation of irrigation water resources and the importance of sugar beet yield. So, studying water behavior of this crop is very important. Therefore, the main aim for this present study was to investigate the effect of irrigation scheduling by using pan evaporation under two planting methods, furrows and beds on sugar beet yield, some yield attributes, quality and some water relations in the North Middle Nile Delta region to identify the most suitable planting method and water treatment to Maximize sugar beet yield and irrigation water efficiencies.

MATERIALS AND METHODS

Two field investigations were conducted at the experimental farm, Sakha Agricultural Research Station, kafr El–Sheikh Governorate. The site is located at 31^{o}-07' N latitude, 30^{o}-57' E longitude with an elevation of about 6 metres above mean sea level during the two successive winter growing seasons 2013/ 2014 and 2014/ 2015. This present investigation aimed at studying water behavior of sugar beet crop under the conditions of the North Middle Nile Delta region through studying the effect of cultivation methods (normal furrows and raised- beds methods) under different irrigation levels from pan evaporation readings (irrigation scheduling process) on sugar beet yield, some yield attributes, quality and some water relations. This trial was designed in split plot with three replicates. The main plots were randomly assigned by cultivation methods which were A (normal cultivation method, 60 cm. apart), B (raised- beds cultivation method, 120 cm. apart) While, sub plots were randomly assigned by irrigation scheduling treatments which were I_1 9traditional irrigation, like to practice by local farmers in the studied area), I_2 (1.2 of cumulative pan evaporation, CPE), I_3 (1.0 of cumulative pan evaporation, CPE), I_4 (0.8 of cumulative pan evaporation, CPE) and I_5 (0.6 of cumulative pan evaporation, CPE). Soil samples at different depths from the experimental site were collected each 15 cm. depth up to 60 cm. and analyzed for some physical and chemical properties according to Jackson (1973) and Klute (1986) and were presented in Tables (1 and 2). Also, some meterological data at Sakha Agricultural Research Station through the two studied growing seasons were daily recorded and their monthly mean values were tabulated in Table (3).

Table (1): The mean values of some physical characteristics of the studied site before cultivation

Soil Depth, cm.	Particle Size Distribution			Texture Classes	F.C %	P.W.P %	AW %	Bd, Mg/m^3
	Sand%	Silt %	Clay %					
0 – 15	15.3	14.5	70.2	Clay	47.8	24.7	23.1	1.17
15 – 30	17.2	15.3	67.5	Clay	40.6	20.5	20.1	1.21
30 – 45	16.9	15.7	67.4	Clay	39.5	20.1	19.4	1.25
45 – 60	15.0	15.5	69.5	Clay	38.8	19.7	19.1	1.33
Mean	16.1	15.3	68.7	Clay	41.7	21.3	20.4	1.24

Where:-

F.C % = Soil field capacity,
P.W.P % = Permanent wilting point,
AW % = Available water and
Bd, Mg/m^3 = Soil bulk density.

Table (2): The mean values of some chemical characteristics of the studied site before cultivation

Soil Depth, Cm	Ec, ds/m	PH 1: 2.5 soil water suspension	Soluble ions, meq/ L							
			Soluble cations, meq/ L				Soluble anions, meq/ L			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
0-15	1.69	7.95	4.52	0.96	7.14	5.17	0.00	5.10	5.03	7.66
15-30	1.72	7.73	5.18	0.87	7.06	4.63	0.00	5.62	5.51	6.61
30-45	1.77	7.57	6.31	0.72	6.67	4.25	0.00	5.83	5.97	6.15
45-60	1.80	7.42	6.97	0.68	6.51	4.10	0.00	6.05	6.25	5.96
Mean	1.75	7.67	5.75	0.81	6.85	4.54	0.00	5.65	5.69	6.60

Table (3): Mean of some meteorological data for kafr El –Sheikh area during the two growing seasons.

a-2013/2014 season.

Month	T (C^0)			RH (%)			W_s, m/sec	Pan Evap., mm/ day.	Rain, mm
	Max.	Min.	Mean	Max.	Min.	Mean			
Nov.	25.39	15.14	20.27	87.00	64.43	75.72	0.80	2.28	-------
Dec.	19.64	8.51	14.06	92.07	67.61	79.84	0.61	4.15	81.9
Jan.	20.34	7.55	13.95	93.69	70.55	80.55	0.54	1.60	20.7
Feb.	20.64	8.19	14.42	91.90	67.15	79.53	0.79	2.52	16.5
Mar.	22.94	11.71	17.33	86.10	56.80	71.45	0.96	3.14	26.2
April.	27.50	15.53	21.52	81.80	49.80	65.8	1.07	4.91	20.2
May	30.47	19.57	25.02	77.20	48.60	62.90	1.14	5.87	-----

b- 2014/2015 season.

Month	T (C^0)			RH (%)			Ws, m/sec	Pan Evap., mm/ day.	Rain, mm
	Max.	Min.	Mean	Max.	Min.	Mean			
Nov.	24.30	13.79	19.05	87.80	60.50	74.15	0.78	2.77	24.6
Dec.	22.27	9.72	16.00	88.60	63.50	76.05	0.53	1.72	5.70
Jan.	18.79	6.46	12.63	88.10	61.10	74.60	0.82	2.70	52.55
Feb.	19.01	7.65	13.33	86.80	62.70	74.75	0.84	2.90	38.8
Mar.	22.69	11.69	17.19	82.36	58.82	70.59	1.01	3.23	15.25
April.	25.64	13.70	19.67	78.30	48.50	63.40	1.11	6.07	35.85
May	30.19	18.79	24.49	77.3	46.1	61.7	1.33	7.15	0.00

T= Air temperature,
RH= Relative humidity and,
Ws = Wind speed.
Source: Meteorological Station at Sakha Agricultural Research Station 31°-07N latitude, 30°-57E longitude with an elevation of about 6 meters a above mean sea level.

Scheduling of Irrigation:

Irrigation scheduling is the decision of when and how much water to apply to a field. In the present study, the daily class A type, pan evaporation records, by estimating the effective evaporation pan coefficient (Ef) was used (Jensen and middleton, 1965). This method is recently widely used to schedule irrigation for field and vegetable crops by many researchers, among of them Eid *et al* (1982) and Ibrahim *et al* (2003*)*. The evaporation pan method is simple, inexpensive, and readily understandable way to estimate irrigated crop water use. The scheduling by this method needs for the determination of water to be applied at each irrigation and the equivalent amount of evaporation, i.e., usable moisture and usable evaporation, as it will be shown later.

Class A pan evaporation:

Many different types of evaporation pans are being used. The best known pans are the Class A evaporation pan. This kind of pan is very common to determine evaporation rate. It is usually 120.7 cm in diameter and 25 cm deep. It is made of galvanized iron or Monel metal (0.8 mm). The pan is mounted on a wooden open frame platform which is 15 cm above ground level. The soil built up to within 5 cm of the bottom of the pan. The pan must be level. The pan is filled with water to 5 cm below the rim. The water level should be not allowed to drop to more than 7.5 cm below the rim. The water should be regularly renewed, at least weekly, to eliminate extreme turbidity. The pan, if galvanized, is painted annually with aluminum paint. Screens over the pan are not a standard requirement and should preferably not be used. Pan should be protected by fences to keep animals from drinking (*Allen et al., 1998*). Pan readings are taken daily in the early morning at the same time that precipitation is measured. Measurements are made in stilling well that is situated in the pan the pan near one edge. The stilling well is a metal cylinder of about 10 cm in diameter and 20 cm deep with a small hole at the bottom.

1- The pan is installed in the field.
2- The pan is filled with a known quantity of water (the surface area of the pan is known and the water depth is measured)
3- The water is allowed to evaporate during a certain period of time (usually 24 hours). For example, each morning at 7 o' clock a measurement is taken. The rainfall, if any, is measured simultaneously.
4- After 24 hours, the remaining quantity of water (i.e. water depth) is measured.
5- The amount of evaporation per time unit (the difference between the two measured water depths) is calculated; this is the pan evaporation: E pan (in mm/ 24 hours). The evaporation pan data through the two growing seasons are given in Table (3).
6- The E pan is multiplied by a pan coefficient, K pan, to obtain ET_0.

Plot area was 52.5 m^2 (7.5 m length * 7.0 m width). Plots were isolated by ditches of 1.5 m in width to avoid the lateral water movement. Seeds of sugar beet (Beta Vulgaris L.) variety Farida were seeded in hills spacing of 20 cm on November 10^{th} and 15^{th} in the two successive growing seasons 2013/ 2014 and 2014/ 2015, while harvesting process were carried out after 200 days in the two seasons. All agricultural practices for the crop and studied area were performed as recommended by the Egyptian Ministry of Agriculture and Land Reclamation, expect the two tested factors, cultivation methods and irrigation scheduling treatments.

Irrigation water conveyed to the experimental field through an open channel using a centrifugal pump. The water in the channel was controlled to maintain a constant head by means of fixed bar. Irrigation water was applied to the experimental plots until reaching the end of the plot length. This was measured and delivered by a constant rectangular weir with a steel gate for each plot. The rate of discharge was 0.01654 m^3/ sec at effective head of 10 cm. The amount of water for each plot of the studied treatments was calculated by the following equation;

$$\mathbf{A = Q * T}$$

Where:

A = the volume of water delivered to the plot (m^3),
Q = the discharge of the weir (m^3/ minute) and
T = the time of irrigation (minute).

Water relations:

1-Amount of irrigation applied water (m^3/ fad.)

Water applied was computed as described by *Giriappa (1983)*.

$$\mathbf{Wa = IW + Re}$$

Where:

IW = Irrigation water applied, and
Re = Effective rainfall.

2-Water consumptive use (m^3/ fed.):

Water consumed by growing plants was calculated based on soil moisture depletion (SMD) according to *Hansen et al., (1979).*

$$\text{Cu = SMD} = \sum_{i=1}^{i=n} \frac{\theta_2 - \theta_1}{100} * Dbi * Di * 4200$$

Where:

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

Θ_2 = Gravimetric soil moisture percentage after irrigation,

Θ_1 = Gravimetric soil moisture percentage before irrigation,

Dbi = Soil bulk density (Mg/m^3) for depth,

D_i = Soil layer depth (20 cm.),

i = Number of soil layers (1-3) depth and

4200= Area for fadden (m^2).

3-Irrigation water efficiencies:

Water productivity (WP, kg/m^3):

Water productivity is generally defined as crop yield per cubic meter of water consumption. Concept of water productivity in agricultural production systems is focused on producing more food with the same water resources or producing the same amount of food with less water resources. It was calculated according to *(Ali et al., 2007).*

$$\mathbf{Wp} = \frac{Y}{ET}$$

Where:

WP = Water productivity (kg /m^3),

Y = Root yield (kg/fed.) and

ET = Total water consumption of the growing season (m3/ fed.).

Productivity of irrigation water (PIW, kg/m^3):

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

$$\mathbf{PIW = Y/\ IW}$$

Where:

PIW = Productivity of irrigation water (kg /m^3),

Y = Root yield kg/fed. and

IW = Irrigation water applied (m^3/ fed.).

Consumptive use efficiency (Ecu, %):

Consumptive use efficiency was calculated according to *Doorenbos and Pruitt (1975).*

$$\mathbf{Ecu = (Cu\ /\ IW) *100}$$

Where:

Ecu = Consumptive use efficiency (%),

Cu = Consumptive use and

IW = Water applied.

1. Yield:

Four inner ridges or two furrows and two wide furrows (raised-beds) of each plot were harvested, collected together and cleaned. Roots and tops were separately weighed in kg and then it was converted to estimate:

- Root yield (ton/ fed.),
- Top yield (ton/ fed.),
- Sugar yield (ton/ fed.) = root yield * sucrose (%).

2. Yield attributes:

- Root length (cm.),

- Root diameter was determined as average of broad and narrow sides of root in cm.,

3. Quality parameters:

Some parameters of sugar beet roots quality have been measured and calculated such as, sucrose % and the purity % were measured at Delta Sugar Company Limited Laboratories at Kafr El-Sheikh.

Statistical analysis:

The obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) as published by Gomez and Gomez (1984). Means of the treatments were compared by the least significant difference (LSD) at 5 % level of significance which developed by Waller and Duncan (1969).

RESULTS AND DISCUSSION

Effect of cultivation methods and scheduling treatments (irrigation treatments) on:

1-Seasonal amount of water applied (m^3/fed.):

Presented data in Table (4) illustrated that; the mean values of seasonal water applied through the two growing seasons were affected by both cultivation methods and irrigation treatments (scheduling treatments). Concerning with the effect of cultivation methods under all scheduling treatments, the highest overall mean value was recorded under normal furrows cultivation method comparing with wide furrows one (raised-beds) and the mean values are 2802.00 and 2553.55 m^3/ fed. under normal and wide furrows cultivation methods, respectively. Increasing the mean values of irrigation water applied under normal furrows method comparing with wide furrows method (raised-beds) might be attributed to increasing number of both irrigation inlets and water ways and so, increasing irrigated area, amount of water percolation, seepage and evaporation under the conditions of this cultivation method, and hence, increasing amount of water applied under normal furrows method. The amount of water saving under using raised-beds cultivation method is 248.45 m^3/ fed. (8.87%) in comparison with normal cultivation method. These results are in a great harmony with those obtained by *Raut et al., 2000), and Anonymous, (2006).* Also, these results are in a close contact with those reported by *Nahed. M. Rashed and E. A. Moursi (2012)* on sage (salvia officinalis L) and concluded that the amount of water applied was increased under normal cultivation method in comparison with wide furrows cultivation one (raised-beds), also, these findings are in a great harmony with those obtained by *Mona. S. M. Eid (2012)* on sugar beet in the North Middle Nile Delta region (the same studied area).

Regarding, the effect of irrigation treatments (scheduling treatments). On the overall mean values of seasonal amount of water applied through the two growing seasons. The highest mean values were recorded under irrigation treatment I_1 (traditional irrigation, like practice by local farmers in the studied area) in comparison with other irrigation treatments I_2, I_3, I_4 and I_5 under the two cultivation methods (normal and beds). Generally, the overall mean values for water applied can be descended in order I_1> I_2> I_3> I_4> I_5. The mean values are 3105.82, 3027.21, 2803.71, 2702.61 and 2370.66 m^3/ fed. under normal furrows cultivation method. The corresponding mean values under wide furrows cultivation method (raised-beds) are 2800.56, 2715.72, 2587.11, 2460.35 and 2203.99 m^3/ fed., respectively. Increasing the seasonal mean values under irrigation treatment I_1 comparing with other irrigation treatments I_2, I_3, I_4 and I_5, this might be attributed to decreasing irrigation intervals and hence, increasing number of irrigations. These results are in a great harmony with those obtained by *Nahed. M. Rashes and E. A. Moursi (2012) and Mona. S. M. Eid (2012).*

Table (4): Effect of cultivation methods and irrigation treatments on seasonal amount water applied and seasonal water consumptive use for sugar beet in the two growing seasons.

Cultivation Furrows (C)	Irrigation Treatment (I)	Seasonal amount water applied			Seasonal water consumptive use		
		1st growing season 2013/ 2014	2nd growing season 2014/ 2015	Means of the two growing seasons	1st growing season 2013/ 2014	2nd growing season 2014/ 2015	Means of the two growing seasons
Normal furrows (A)	I_1	3056.17	3155.46	3105.82	2013.46	2040.13	2026.80
	I_2	2979.18	3075.24	3027.21	1980.86	1986.60	1983.73
	I_3	2718.27	2889.14	2803.71	1830.50	1894.20	1862.35
	I_4	2644.18	2761.04	2702.61	1798.88	1813.14	1806.01
	I_5	2318.17	2423.15	2370.66	1698.48	1730.41	1714.45
Mean		2743.19	2860.81	2802.00	1864.44	1892.90	1878.67
Wide furrows (B)	I_1	2782.08	2819.04	2800.56	1920.56	1960.40	1940.48
	I_2	2695.56	2735.88	2715.72	1897.14	1920.60	1908.87
	I_3	2523.18	2651.04	2587.11	1802.18	1870.16	1836.17
	I_4	2423.82	2496.88	2460.35	1750.58	1780.60	1765.59
	I_5	2192.94	2215.04	2203.99	1640.14	1646.40	1643.27
Mean		2523.52	2583.58	2553.55	1802.12	1835.63	1818.88

- **Amount of water saving = 248.45 m^3/ fed.**
- **Water saving as a percentage = 8.87 %.**

2- Water consumptive use (Cu, m^3/ fed.):

Presented data in Table (4) also illustrated that, the mean values of sugar beet consumptive use through the two growing seasons were clearly affected by both cultivation method and irrigation treatments. Regarding, the effect of cultivation method on Cu values, the highest mean values were recorded under normal cultivation method comparing with raised-beds technique and the values are 1878.67 and 1818.88 m^3/ fed for normal cultivation and raised-beds, respectively. Increasing the values of Cu under normal cultivation method comparing with raised-beds might be attributed to increasing amount of water applied under the conditions of this method, this leads to forming strong plants with thick vegetative cover. So, the area of plant which exposes to the sunlight increases and hence, the rate of water losses by transpiration increases. Therefore, increasing the mean values of Cu under the conditions of normal furrow comparing with raised-beds technique. These results are in a great harmony with those obtained by Anonymous, (2006). Nahed, M. Rashed and E. A. Moursi (2012) and Mona, S. M. Eid (2012).

Concerning, the effect of irrigation treatments on the values of Cu for sugar beet. The highest values were recorded under irrigation treatment I_1 under cultivation methods (normal and raised-beds) and the mean values are 2026.80 and 1940.48 m^3/ fed. Generally, the mean values for Cu can be descended in order $I_1 > I_2 > I_3 > I_4 > I_5$ in the two growing seasons and the mean values under normal cultivation method are 2026.80, 1983.73, 1862.35, 1806.01 and 1714.45 m^3/ fed., while, the corresponding mean values under raised-beds cultivation method are 1940.48, 1908.87, 1836.17, 1765.59 and 1643.27 m3/ fed under I_1, I_2, I_3, I_4 and I_5, respectively.

Increasing, the mean values of water consumptive use (Cu) under irrigation treatment I_1 in comparison with other irrigation treatments I_2, I_3, I_4 and I_5 may be attributed to increasing number of irrigations and hence, increasing amount of water applied. So, provide chance for more consumption of water which resulted in increasing transpiration and evaporation from plant and soil surfaces, respectively. Also, increased the mean values of Cu under I_1 might be due to improving plant growth and perhaps luxury consumption of water. These results are in a great harmony with those reported by El-sarag (2009), Gharib and El-Henawy (2011), Mona. S. M. Eid (2012), Nahed, M. Rashed and E. A. Moursi (2012) and Moursi and Darwesh (2014).

Consumptive use efficiency (Ecu, %):

Consumptive use efficiency (Ecu) is a parameter which indicates the capability of plants to utilize the soil moisture stored in the effective root zone. Data in Table (5) showed that both cultivation method and scheduling treatments have a great effect on consumptive use efficiency in the two growing seasons. Concerning, the effect of cultivation method on the mean values of Ecu. The highest mean values through the two growing seasons under all scheduling treatments were recorded under raised-beds cultivation method in comparison with normal cultivation method and the mean values are 67.33 and 71.33 under normal and raised-beds cultivation methods, respectively.

Increasing the mean values of Ecu under raised-beds cultivation methods in comparison with normal method might be attributed to raised-beds maintained lower bulk density and high infiltration rate. Decreasing soil bulk density means decreasing soil compaction. So, giving plants a good chance to take their nutritional requirements and hence, giving good and healthy plants with athick vegetative cover. Consequently, increasing losses by transpiration from plant surface and so increasing the mean values of Cu. Therefore, increasing the mean values of Ecu. These results are in a great harmony with those obtained by *Nahed, M. Rashed and E. A. Moursi (2012).*

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Regarding, the effect of irrigation treatments (scheduling treatments). The mean values of Ecu were clearly affected by irrigation treatments under the two cultivation methods. The highest mean values were recorded under irrigation treatment I_5 (0.8 Ep which exposed to water stress) and the mean values are 72.34 and 74.56% under normal and raised-bed cultivation methods, respectively. Meanwhile, the lowest mean values were recorded under irrigation treatment I_1 (traditional irrigation) and the mean values are 65.27 and 69.29% under normal and raised-beds methods, respectively. Generally, the mean values of Ecu can be descended in order $I_5 > I_4 > I_3 > I_2 > I_1$ in the two growing seasons. The mean values are 72.34, 66.85, 65.74 and 65.27 % under normal method, while, the corresponding values under raised-bed method are 74.56, 71.77, 70.98, 70.29 and 69.29 % under I_5, I_4, I_3, I_2 and I_1, respectively.

Increasing the mean values of Ecu under irrigation treatments might be attributed to decreasing amount of water applied, higher amount of irrigation water could be beneficially used by the growing plants which resulting in decreasing water losses. These results are in a great harmony with those obtained by *Ibrahim and Emara (2010), Mona, S. M. Eid (2012).*

Water productivity (WP, kg/m^3) and productivity of irrigation water (PIW, kg/ m^3):

Water productivity (WP) is considered as an evaluation parameter of yield per unit of consumed water. Water productivity is a tool for maximizing crop production per each unit of consumed water. While, productivity of irrigation water (PIW) was considered as an evaluation parameter of yield per unit of water applied. Productivity of irrigation water is a tool for maximizing crop production per each unit of water applied. Presented data in Table (5) illustrated that the mean values of both (WP) and (PIW) were affected by the studied cultivation methods and irrigation treatments (scheduling treatments). Concerning, the effect of cultivation methods on the mean values of both WP and PIW, the highest mean values were recorded under raised-bed cultivation method in the two growing seasons comparing with normal cultivation method. The overall mean values through the two growing seasons are 14.85 and 16.44 kg/ m^3 for WP under normal and raised-bed cultivation methods, respectively. While for PIW, the values are 10.00 and 11.74 kg/ m^3 under normal and raised-bed cultivation methods, respectively.

Increasing the overall mean values for WP and PIW under raised-bed cultivation method in comparison with normal cultivation method may be attributed to decreasing the amount of water consumed (Cu) in case of WP and water applied in case of PIW. Generally, the overall mean values for WP were more the values of PIW because of the amount of water consumed is less than the amount of water applied. These results are in a great harmony with those obtained by *Mona. S. M. Eid (2012) and Nahed. M. Rashed and E. A. Moursi (2012).*

Regarding, the effect of irrigation treatments, the highest mean values were recorded under irrigation treatment I_4 for both WPand PIW comparing with other irrigation treatments in the two growing seasons. These results are in a great agreement with those reported by *Emara et al. (2000), Nahed. M. Rashed and E. A. Moursi (2012) and Moursi and Darwesh (2014).*

Effect of cultivation method and irrigation treatments on yield, yield components and quality:

- **Cultivation method:**

Presented data in Table (6) showed that cultivation method had a high significant effect on yield, yield components and quality in the two growing seasons. The highest mean values for all studied parameters were recorded under raised-beds cultivation method in comparison with normal cultivation method. The mean values under raised-beds cultivation method for root yield are 29.5 and 30.2 ton/ fed., for top yield are 12.6 and 13.0 ton/ fed., for sucrose percentage are 16.7 and 16.2 %, for sugar yield 4.91 and 4.90 ton/ fed., for juice purity are 82.94 and 83.89 %, for root length are 33.0 and 31.6 cm. and for root diameter are 12.6 and 12.9 cm in the first and second growing season, respectively. While, the corresponding mean values under normal cultivation method are 27.4 and 28.2 ton/ fed. for root yield, 11.9 and 12.2 ton/ fed. for top yield, 16.1 and 15.5 % for sucrose percentage, 4.41 and 4.38 ton/ fed for sugar yield, 81.66 and 82.41% for juice purity, 31.8 and 31.0 cm. for root length and 12.0 and 12.6 cm. for root diameter in the first and second growing seasons, respectively.

Increasing yield, yield components, sugar yield, sucrose percentage and juice purity under raised-beds cultivation method in comparison with normal cultivation one may be attributed to decreasing the competition between plants on light and nutrients by giving a suitable area for plants to grow well under the conditions of decreasing number of plants (plant density) in comparison with normal cultivation one, which plants under the conditions of this method suffer from great competition between plants on light and nutrients. So, forming weak plants with thin canopy (vegetative cover), this leads to decreasing productivity of both root, top yields, other yield components, sugar yield, sucrose percentage and juice purity. Using raised-beds cultivation method of irrigation saves considerable quantity of water and improves the fertilizer-use efficiency through line source application *(Choudhry et al., 1994)*. Lodging is also less of a problem on raised-beds. Additional light enters the canopy and strengthens the straw, and the soil around the base of the plant is drier. Reduced lodging can have a significant effect on yield. These results are in a great harmony with those obtained by *Gharib and El-Henawy (2011), Mona. S. M. Eid (2012) and Nahed, M. Rashed and E. A. Moursi (2012).*

- **Irrigation treatments:**

Data in Table (6) clearly illustrated that the mean values of root yield, top yield, some yield attributes, sugar yield and juice purity were highly significantly affected by irrigation treatments in the two growing seasons. The highest mean values for root yield ton/ fed. and sugar yield ton/ fed. were recorded under irrigation treatment I_4 (0.8 of cumulative pan evaporation, CPE) under the two cultivation methods and values for root yield are 32.4 and 33.7 ton/ fed. under raised-beds cultivation method and 30.9 and 31.6 ton/ fed. under normal cultivation method in the first and second growing seasons, respectively. Concerning, sucrose percentage and root length, the highest mean values for the two parameters were recorded under irrigation treatment I_5 (0.6 of cumulative pan evaporation, CPE) under the two cultivation methods. Regarding, juice purity and root diameter the highest mean values under the two cultivation methods were recorded under irrigation method I_1 (traditional irrigation), for top yield, the highest mean values under the two cultivation methods were recorded under irrigation treatment I_2 (1.2 of cumulative pan evaporation, CPE). These results are in a great harmony with those obtained by *Gharib and El-Henawy (2011), Mona. S. M. Eid (2012) and Moursi and Darwesh(2014)*.

Table (6):Effect of cultivation methods and irrigation treatments on sugar beet yield and yield components in the two growing seasons.

Cultivation Furrows (C)	Irrigation Treatment (I)	Root Yield, ton/fed.		Top Yield, ton/ fed.		Sucrose %		Sugar Yield, ton/ fed.	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Normal furrows (A)	I_1	26.90	27.60	12.93	13.20	14.67	13.80	3.97	3.81
	I_2	25.73	26.50	13.83	14.07	15.07	14.47	3.88	3.84
	I_3	29.93	30.60	12.67	12.87	16.33	15.93	4.89	4.87
	I_4	30.87	31.57	10.80	11.00	16.87	16.33	5.21	5.16
	I_5	23.77	24.60	9.33	9.60	17.33	17.23	4.12	4.24
Mean		27.44	28.17	11.91	12.15	16.05	15.55	4.41	4.38
Wide furrows (B)	I_1	29.80	30.20	13.63	13.87	15.30	14.87	4.56	4.49
	I_2	28.90	29.50	14.53	14.87	15.83	15.37	4.58	4.53
	I_3	30.90	31.50	13.37	13.63	16.87	16.13	5.21	5.08
	I_4	32.37	33.70	11.23	11.60	17.40	17.17	5.63	5.79
	I_5	25.63	26.13	10.47	10.87	17.87	17.50	4.58	4.57
Mean		29.52	30.21	12.65	12.97	16.65	16.21	4.91	4.89
L.S.D. 0.5 at I.		0.2066	0.2098	0.1598	0.1731	0.0867	0.1794	0.0465	0.0751
F. Test		**	**	**	**	**	**	**	**
L.S.D. 0.5 at C.		0.1150	0.1599	0.1277	0.1409	0.1169	0.1647	0.0239	0.0653
F. Test		**	**	**	**	**	**	**	**
I * C		**	**	*	Ns	Ns	*	**	**

Continuous Table (6):

Cultivation Furrows (C)	Irrigation Treatment (I)	Root Length , cm.		Root Diameter, cm.		Purity %	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Normal furrows (A)	I_1	28.80	27.93	13.67	13.93	83.76	84.63
	I_2	30.73	29.00	12.40	13.30	82.51	83.30
	I_3	31.77	30.00	11.80	12.80	81.93	82.37
	I_4	33.07	33.70	11.30	11.77	81.23	81.63
	I_5	34.77	34.30	10.60	10.97	78.85	80.12
Mean		31.83	30.99	11.92	12.55	81.66	82.41
Wide furrows (B)	I_1	29.93	28.57	14.20	14.53	84.85	85.80
	I_2	31.97	29.30	13.33	13.63	84.07	84.80
	I_3	32.97	30.80	12.67	12.80	83.07	84.23
	I_4	34.33	34.07	11.93	12.07	82.48	83.23
	I_5	35.90	34.97	11.10	11.50	80.20	81.40
Mean		33.02	31.54	12.65	12.91	81.65	83.89
L.S.D. 0.5 at I.		0.1570	0.1150	0.3524	0.2693	0.5022	0.3402
F. Test		**	**	**	**	**	**
L.S.D. 0.5 at C.		0.1843	0.2066	0.2213	0.1831	0.2626	0.1651
F. Test		**	**	**	**	**	**
I * C		Ns	*	Ns	Ns	Ns	Ns

***, ** and NS: significant at $p \leq 0.05$, 0.01 or not significant, respectively. Means separated at $P \leq 0.05$, LSD test.**

The interactions between cultivation method and irrigation:

The results in Table (6) showed that the interactions between cultivation method and irrigation treatments had a significant effect on the yield, yield components, sucrose percentage, sugar yield and juice purity, except top yield (ton/ fed.) in the second season, sucrose percentage in the first season, root length in the first season, root diameter and juice purity (%) in the two seasons showed no significant effect on the abovementioned parameters.

CONCLUSION AND RECOMMENDATIONS

Under limitation of water resources and the importance of sugar beet crop to narrow the wide great gap between sugar production and consumption. So, this study recommends that under the studied area, sugar beet crop should be cultivated on raised- beds cultivation method instead of normal cultivation method to obtain the highest yield, yield components, sugar yield, sucrose percentage and juice purity and irrigated it with (0.8 of cumulative pan evaporation, CPE), to obtain the highest root and sugar yields.

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تأثير طريقة الزراعة ومستويات الرى المختلفة على العلاقات المائية لمحصول بنجر السكر فى منطقة شمال دلتا النيل.

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أجريت تجربتان حقليتان فى المزرعة البحثية بمحطة البحوث الزراعية بسخا – محافظة كفر الشيخ . خلال موسمى النمو الشتوى. ٢٠١٤/٢٠١٣ م و ٢٠١٥/٢٠١٤ م وذلك بهدف دراسة تأثير طريقة الزراعة و معاملات الرى على محصول بنجر السكر ومكوناته ، وكذلك جودته وبعض العلاقات المائية. التجربة صممت فى قطاعات منشقة مرة واحدة فى ثلاث مكررات. حيث وزعت المعاملات الرئيسية عشوائياً بطريقة الزراعة. A (خطوط عادية ، ٦٠ سم). و B (الزراعة على مصاطب ، ١٢٠ سم). بينما المعاملات تحت الرئيسية . وزعت و بصورة عشوائية بمعاملات الرى (معاملات جدولة الرى). حيث I_1 (رى تقليدى كما يمارس بواسطة المزراع). I_2 (الرى عند ١.٢ من البخر التراكمى للوعاء). I_3 (الرى عند ١.٠ من البخر التراكمى للوعاء). I_4 (الرى عند ٠.٨ من البخر التراكمى للوعاء). I_5 (الرى عند ٠.٦ من البخر التراكمى للوعاء).

أهم النتائج يمكن تلخيصها كما يلى :

- أعلى القيم بالنسبة للماء الموسمى المضاف والاستهلاك المائى سجلت تحت طريقة الزراعة العادية مقارنة بالزراعة على المصاطب والقيم هى ٢٨٠٢.٠٠ و ٢٥٥٣.٥٥ م^3 / فدان وذلك للماء المضف و ١٨٧٨.٦٧ و ١٨١٨.٨٨ م^3 / فدان للاستهلاك المائى تحت طريقة الزراعة العادية و مصاطب على الترتيب. بالنسبة لمعاملات الرى. أعلى القيم سجلت تحت معاملة الرى I_1 والأقل تحت معاملة الرى I_5 لكلا مقاييس الدراسة سابقة الذكر.
- أعلى متوسطات القيم بالنسبة لكفاءة الاستهلاك المائى (Ecu, %) وانتاجية وحدة المياه المستهلكة (WP) والمضافة (PIW) سجلت تحت طريقة الزراعة على مصاطب والقيم هى ٧١.٣٨ % ، ١٦.٤٤ كجم/ م^3 و ١١.٧٤ كجم/ م^3 وذلك لكفاءة الاستهلاك المئى وانتاجية وحدة المياه المستهلكة والمضافة على الترتيب. ولكن القيم تحت طريقة الزراعة كانت ٦٧.٣٣ % و ١٤.٨٥ كجم/ م^3 و ١٠.٠٠ كجم/ م^3 على الترتيب. بالنسبة لمعاملات الرى فأعلى القيم سجلت تحت معاملة الرى I_5 بالنسبة لكفاءة الاستهلاك المائى ، I_4 بالنسبة الانتاجية وحدة المياه المستهلكة والمضافة معاً.
- بالنسبة للمحصول ومكوناته والنسبة المئوية للسكروز ومحصول السكر والنقاوة قد تأثرت بشكل معنوى لطريقة الزراعة ومعاملات الرى. التفاعل بين طريقة الزراعة ومعاملات الرى أوضحت تأثيراً معنوياً على الصفات سالفة الذكر ماعدا محصول العرش (طن/ فدان) فى الموسم الثانى ، وكانت المعنوية للسكروز فى الموسم الأول ، طول الجذر فى الموسم الأول وقطر الجذر والنقاوة فى الموسم الأول والثانى حيث أنها تأثرت بشكل غير معنوى بالتفاعل بين طريقة الزراعة والرى.

Table (5):Effect of cultivation methods and irrigation treatments on consumptive use efficiency (Ecu, %), water productivity (WP, kg/ m^3) and productivity of irrigation water (PIW, kg/ m^3) for sugar beet in the two growing seasons.

Cultivation Furrows (C)	Irrigation Treatment (I)	Ecu, (%)			WP, (kg/ m^3)			PIW, (kg/ m^3)		
		1st growing season 2013/2014	2nd growing season 2014/2015	Means of the two growing seasons	1st growing season 2013/2014	2nd growing season 2014/2015	Means of the two growing seasons	1st growing season 2013/2014	2nd growing season 2014/2015	Means of the two growing seasons
Normal furrows (A)	I_1	65.88	64.65	65.27	13.36	13.53	13.45	8.80	8.75	8.78
	I_2	66.49	64.98	65.74	12.97	13.34	13.16	8.63	8.61	8.62
	I_3	67.34	65.56	66.45	16.33	16.15	16.24	11.00	10.59	10.80
	I_4	68.03	65.67	66.85	17.18	17.43	17.31	11.69	11.44	11.57
	I_5	73.27	71.41	72.34	14.01	14.22	14.12	10.27	10.15	10.21
Mean		68.20	66.45	67.33	14.77	14.93	14.85	10.08	9.91	10.00
Wide furrows (B)	I_1	69.03	69.54	69.29	15.52	15.41	15.47	10.71	10.71	10.71
	I_2	70.38	70.20	70.29	15.23	15.36	15.30	10.72	10.78	10.75
	I_3	71.42	70.54	70.98	17.15	16.84	17.00	12.25	11.88	12.07
	I_4	72.22	71.31	71.77	18.51	18.93	18.72	13.37	13.50	13.44
	I_5	74.79	74.33	74.56	15.61	15.85	15.73	11.67	11.78	11.73
Mean		71.57	71.18	71.38	16.40	16.48	16.44	11.74	11.73	11.74