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Effect of Tillage Systems and Irrigation Intervals on Sugar Beet (*Beta vulgaris* L.) Production in Guneid Area, Sudan

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ABSTRACT

The present research study was carried out at Guneid Research Sugar Cane Center during the two seasons of 2014 and 2015.The objective was to investigated the effect of four tillage systems (mouldboard plowing, disc plowing, chisel plowing and disc harrowing) and three irrigation intervals (7, 10, and 14 days). The parameters measured were some crop parameters (germination ratio, root thickness, root number per hectare, leaf weight, root crop yield, polarization or sugar content, estimated recovery sugar and sugar beet production. A split plot design with four replications was used in this study. Different tillage systems significantly ($P \leq 0.05$) affected root number per hectare and germination ratio. The maximum value of root number per hectare 62254 roots/hectare, germination ratio (76.2%) and sugar beet production (10 ton/hr) and were given by disc plowing treatment, while the maximum root thickness (35.5 cm) were recorded by chisel plowing treatment and the maximum values of polarization or sugar content (18.6%) and estimated recovery sugar (16.9%) were recorded by disc harrowing treatment. While the minimum values of root crop yield, (58.55 ton/hectare) and germination ratio (66.5%) were given by chisel plowing treatment. Also irrigation intervals significantly ($P \leq 0.05$) affected root crop yield, root thickness and sugar beet production. The maximum values of root crop yield (65.45 ton/hectare) and root thickness (35.2cm) were obtained under an10 days irrigation interval, while the maximum values of sugar beet production (9.71 ton/hectare) was obtained under a 7 days irrigation interval. It was concluded that using disc plowing increased sugar production from sugar beet crops at Guneid Research Sugar Cane Center.

***Keywords*:** Tillage Systems, Irrigation interval, analysis and Sugar beet

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1. INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is one of the most important sugar production crops [1, 2]. It is a hardly biennial plant whose root contains a high concentration of sucrose (15-20%). It is grown commercially for sugar production in a wide variety of temperate climates. Tillage is one of the most important production factors that influence soil physical and mechanical properties [3], and consequently crop yield [4]. Although, for most situations conventional tillage has been the main tillage method for establishing sugar beet since the first part of the 20th century, they are now expensive operations in terms of work rate and fuel consumption [5]. [6] found that they were very efficient in preparing seedbeds in few passes on poorly structured soils with hard, dry or cloddy surface layers overlying moist, plastic layers. On well-structured soils, however, towed harrows were just as efficient and could produce an even larger proportion of fine aggregates.

Different tillage systems loosen soils at different depths and change soil physical properties at different scales [7, 8]. [9] were studied the effect of different tillage methods on yield and quality of sugar beet. Tillage treatments were moldboard plow + two passes of disk harrow (MDD) and moldboard plow + one pass of rotavator (MR) as conventional tillage methods; chisel plow + one pass of rotavator (CR) and two passes of disk harrow (DD) as reduced tillage methods; one pass of rotavator (R) and one pass of tine cultivator (C) as minimum tillage methods and no-tillage (NT).

The root yield and quality characteristics of sugar beet were measured for different tillage treatments. Results of the study indicated that different tillage methods significantly affected K, but no significant differences were found in root yield, sugar content, Na, alpha-amino nitrogen and molasses. Although, there was no significant difference in most studied traits, tillage operations were useful in improving the root yield and quality characteristics of sugar beet. [10] studied the effect of different conservation primary soil tillage on sugar beet. The aim of the trial was to establish the influence of reduced soil tillage intensity on some soil physical properties, sugar beet yield and quality, and weed infestation. Sugar beet seed germination in shallow loosened soil (disc harrow) was higher in comparison with control treatment (mouldbord plow).

Average data showed that germination of directly sowed seeds was less by 37% in comparison with conventional ploughing (mouldbord plow).

Reducing of soil tillage intensity to zero tillage had no significant influence on sugar beet yield, ramification and sucrose content of root-crop. [11] studied the response of root yield and yield components of sugar beet (*Beta vulgaris*) to different tillage methods. Tillage treatments in the study were moldboard plow + two passes of disk harrow (MDD) as conventional tillage method; moldboard plow + one pass of rotavator (MR), chisel plow + one pass of rotavator (CR) and two passes of disk harrow (DD) as reduced tillage methods; one pass of rotavator (R) and one pass of tine cultivator (C) as minimum tillage methods, and no-tillage (NT) as direct drilling method. Different tillage methods significantly affected RNPH, but there was no significant difference in other studied traits.

Although there was no significant difference in RY, SUGY, RODM, ROTL and RIMD, results of the study showed that tillage practices were beneficial in improving the yield of sugar beet. Results also showed that tillage method affected the yield of sugar beet in the order of MR > CR > R > MDD > DD > C > NT. Therefore, the reduced tillage treatments MR and CR, and the minimum tillage treatment R were considered as more appropriate and profitable tillage methods in improving the yield of sugar beet. [12] studied effect of tillage in Central Greece on sugar beet the tested methods were: reduced tillage with a heavy cultivator (HC), rotary cultivator (RC), disk harrow (DH) and no-tillage (NT) compared with a conventional tillage method (CT) using plough. Plant growth was better in the methods of CT and HC. Conservation tillage reduced yields compared to CT method, by 1, 2-8, 9% in the HC by 19, 7-34, 3% in the RH, by 20,4-31,3% in the DH and by 26, 1-46, 6% in the NT. Sugar beet can be cultivated under any irrigation system. The method selected depends mostly on the technical and economic possibilities of the area [13].

World wide, the most prevalent irrigation system is gravity-fed furrow irrigation. This system is very common in the USA, Turkey, Egypt and Iran, whereas in most European and Mediterranean countries sprinkler irrigation is favored. One drawback of flood irrigation is the leaching of nitrogen and the difficulty of maintaining soil water availability when the interval between irrigations increases [14]. Management and optimization is important for any irrigation system. For instance, it is possible to save 23% of water in furrow irrigation by watering alternate furrows and increasing the irrigation frequency [15].

Specific problems in irrigation coverage that limit efficiency (design, materials, nozzles, ...etc.) also have been reviewed [16]. Sugar beet is well adapted to drip irrigation, which has been used with success in semi-arid and arid regions. However, others showed an improvement in yield and efficiency with the smaller amounts of water that can be applied using drip irrigation [17].

An increase in frequency permits the application of reduced doses, which results in an economization of water and increases irrigation efficiency [15]. The main conclusion reached from many studies on irrigation frequency is that different irrigation frequencies can be used and still attain maximum yields. In 1987, [18] indicated that a 3-week irrigation frequency reduced ETc as a result of a slight stress compared to irrigation every 1 or 2 weeks. [19] found a reduction in root and sugar yields when irrigation frequency increased, but applying only 40% of the ET.

In well-drained soils, [20] concluded that sugar beet offers great flexibility in volumes and intervals of irrigation without affecting root growth. An increase in frequency from one to two irrigations per week significantly increased root development and [21]. Changes in irrigation frequency can affect rooting patterns. When the quantity of soil water consumed was increased from 30% to 70% by increasing the frequency and decreasing the dosage, there was an 85% increase in water uptake from deep soil layers [22]. In summary, high-frequency irrigation on heavier soils starting at field capacity gives satisfactory results even if total volumes are well below ET.

2. MATERIALS AND METHODS

2. 1. Materials

Research site

This study was conducted at Guneid Sugar Cane Research Center which lies on the eastern bank of the Blue Nile, 117 km south of Khartoum, latitude 14°30′N and longitude 33°15′E. The experiment was carried out for two successive growing seasons, October 2013 – April 2014 and October 2014- April 2015 (Fig. 1).

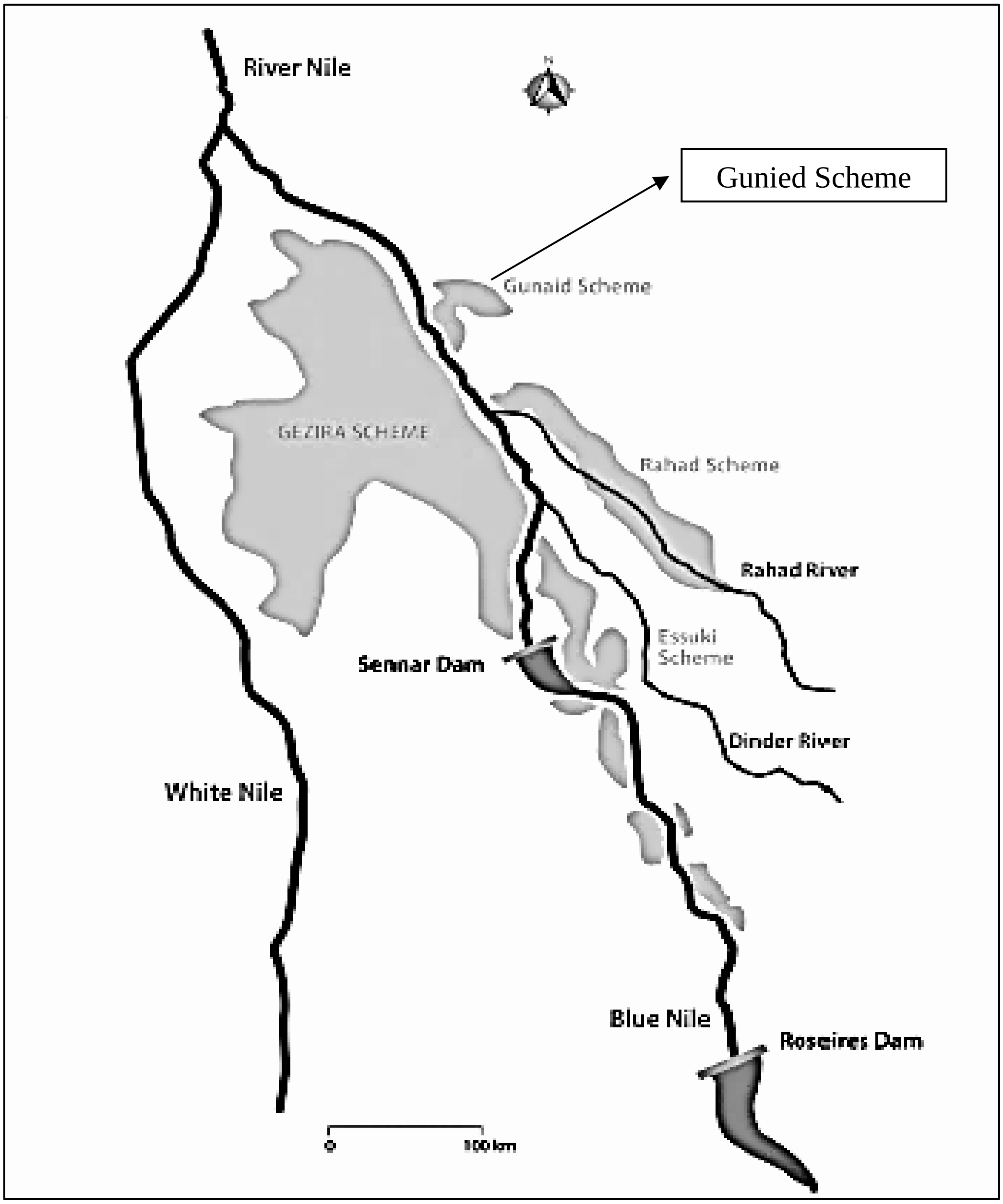

Figure 1. Gunied location map and its satelite image from space [23]

Soil of the experimental area

The soil is classified as aridosol low in organic matter (O.M), total nitrogen (< 0.05 %), organic carbon 0.41%, hydraulic conductivity 1.04 Cmh^{-1}, pH 8.7, ESP 3 and low in available P (< 10 ppm). The mechanical analysis of the soil clay 45%, sand 28% and silt 27%. The average bulk density 1.75% and the average moisture content 15%. Guneid Sugarcane Scheme falls within the aridic climatic zone which is characterized by relatively cool winters, hot summers, low rainfall, low relative humidity and a potential evapotranspiration exceeding precipitation throughout the year.

2. 2. Methods

Experimental treatments and design

The tillage treatments used in the experiment were the following:

T_1 = Moldboard plow plus disk harrow plus ridging
T_2 = Disk plow plus disk harrow plus ridging
T_3 = Chisel plow plus disk harrow plus ridging
T_4 = Two passes of disk harrowing plus ridging.

The irrigation treatments were the following intervals of irrigation:

I_1 = Seven days irrigation interval.
I_2 = Ten days irrigation interval.
I_3 = Fourteen days irrigation interval.

The treatments were arranged in a split plot design with four replications. Each replication divided into four plots (method of tillage) and each plot was further divided into three subplot for irrigation intervals. The block was 7 meters wide and 50 meters long. The space between the plots was five meters and seven meters between replications.

Experimental land preparation

The land was prepared by the main tillage treatments (moldboard plow, disc plow, chisel plow and disc harrow) before three weeks from planting for every replication, then the land was harrowed by the disc harrow before one week from planting and also furrowed by ridger at the same time of planting.

Irrigation water application

The first irrigation water was applied after planting and the second one was applied after five days from the first one for closing the cracks on the top of furrow to protect the small sugar beet plants from falling. From the second irrigation three intervals of irrigation (7, 10 and 14 days) were applied and this was fixed during the growing season according to Crop Watt program version- 8. After the plant water requirement was determined for 7, 10 and 14 days by the program for every subplot the water quantity per subplot was discharged through an opening between the plot and the channel which distributed water to all plots. A plastic pipe with a length of 50 cm and 11 cm in diameter and two gallon made of plastic (17 litter) were used to determine the amount of water per minute. The plastic pipe was fixed at the channel with a level to enter the plot besides the opening and the other was closed until the water was covered and then the closed end was opened to discharge the water on the plastic gallon which was in the hole. The time of irrigation per subplot was calculated as follows:

1 minute = 220 liters
Time of irrigation = quantity of water in liters per subplot.

Two weedings were carried out using a hand tool (Naggama), the first after one month from planting and the second was after two months as shown in Plate (1) The thinning for manual planting was done during the second weeding.

Plate 1. The sugar beet weeding by using hand tool (Naggama).

Crop performance measurements

Plant germination percentage

The plant germination ratio was determined for the tillage treatments by the following equation:

$$\text{Germination ratio} = \frac{\text{Number of germinated seeds}}{\text{Number of actual seeds per row}} \times 100\% \qquad (1)$$

Root thickness

The tab meter was used to measure the thickness of the tuber at harvest. It was measured by putting the measuring tab around the middle of the tuber and measuring the root thickness. Five plants per sub subplot were selected randomly and measured from harvested rows and then the average was taken.

Plant population

At harvest, the number of tubers was counted for an area of 7.5 m^2 (area of one row). The number of tubers per hectare was determined by the following equation:

$$\text{Number of tubers/ha} = \frac{10000 \times \text{ number of tubers counted per area}}{7.5\ m^2} \quad (2)$$

where:

7.5 = Area of one row (m^2)
10000 = Area of hectare (m^2)

Crop yield (tuber and leaf)

A spring balance was used to determine the weight of the sugar beet tuber and the weight of the leaves at the end of the season by harvesting one row 7.5 m^2 from each treatment. The leaves were separated from tuber and weighted. The weight of the sugar beet tubers and the weight of the leaves were determined by the following equations:

$$\text{Sugar beet ton per hectare} = \frac{10000 \times \text{ yield of one row kg}}{7.5 \times 1000} \quad (3)$$

$$\text{Leaves weight in ton per hectare} = \frac{10000 \times \text{ yield of one row kg}}{7.5 \times 1000} \quad (4)$$

where:

7.5 = Area of one row (m^2)
10000 = Area of hectare (m^2)

Sugar Beet chemicals analysis

Before beet was harvested, 5 tubers were selected randomly from each sub subplot and then topped, cleaned from soil , crushed and sliced fine enough and samples were taken to determine the sugar beet chemical components.

Sucrose percent in beet (Pol%) analysis

The polarization or sugar content was determined by taking twenty six mg of sliced beet + reagents (174 cm^3 lead acetate), mixed in a blender and filtered. 200 ml of the extract was read in a Saccharimeter following [24, 25].

Estimated recovery sugar (ERS%) analysis

The sugar beet estimated recovery sugar (ERS%) was determined by following equation:

ERS % = Pol% - 2.5 ……………………………………(5)

where:

2.5 = Expected losses of sugar content through production.

Sugar production from sugar beet

The sugar production from sugar beet ton sugar per feddan was determined by the following equation:

$$\text{Sugar ton/ha} = \frac{\text{ERS\%} \times \text{Yield of sugar beet/ha kg}}{1000} \tag{6}$$

3. RESULTS AND DISCUSSION

Germination percentage

The results obtained for germination percentage of the crop is shown in Table (1). The analysis of variance showed a significant difference ($P \leq 0.05$) due to tillage systems. Disc plowing and moldboard plowing recorded the highest germination percentage of 76.2% and 73.4%, respectively. The average germination percentage for the first season and second season were 75.4% and 67.5%, respectively while the analysis of variance showed no significant differences due to irrigation intervals where the means were 71.9%, 71.7% and 70.7% for 10, 14 and 7 days intervals, respectively. The results of interactions between treatments are shown in Table (2). The analysis of variance of the interaction effect showed no significant difference between the means of germination percentages.

The root thickness

The result obtained for root thickness or diameter are shown in Table (1). The analysis of variance showed in significant difference between tillage systems. The root thickness was higher by 1.7 cm, 0.8 cm and 0.3 cm for chisel plowing, disc harrowing and moldboard plowing respectively, as compared with disc plowing. This is in agreement with results of [11],while there was a significant difference ($P \leq 0.05$) between irrigation intervals in the root thickness, where the highest root thickness was recorded for the 10- day interval (35.2 cm) and the lowest root thickness was recorded for the 14- day interval (33.2) cm. This was in contrast with that found by [19]. The results of interactions between treatments were shown in Table (2). The analysis of variance for the interactions showed insignificant differences between the effects of the treatments.

The plant population

The results of plant population (plants/hectare) were shown in Table (1). The analysis of variance showed significant difference ($P \leq 0.05$) between tillage systems the highest plant population was recorded by disc plowing and moldboard plowing treatments as 62254 and 61237 plants/hectare, respectively. The lowest plant population was recorded by the chisel plowing treatment (53341 plant/hectare). This was in agreement with results of [11]. The analysis of variance showed no significant difference in plant population between the irrigation intervals where the average values were 58772, 58415 and 57727 plants/hectare for the 7, 10 and 14 days intervals, respectively. The analysis of variance for plant population showed no significant difference due to the interaction between the treatments Table (2).

The crop leaf weight

The results obtained for crop leaf weight were shown in Table (1). The analysis of variance showed no significant difference between tillage systems regarding to leaf weight. the moldboard plowing, chisel plowing and disc harrowing treatments recorded lower leaf weight by 6%, 8.4% and 8.6%, respectively, as compared to disc plowing. Also the analysis of variance showed no significant difference between irrigation intervals due to leaf weight, where 14- day interval recorded the highest mean leaf weight of 10.71 ton/hectare, and the lowest was recorded by the 7- day interval as 10 ton/hectare. The results of interactions between the treatments were shown in Table (2). The analysis of variance showed no significant difference according to the interaction between the different treatments.

The crop yield

The results obtained for crop yield (ton/hectare) were shown in Table (1). The analysis of variance showed no significant difference in the yield due to tillage systems. The moldboard plowing, disc harrowing and chisel plowing were recorded lower crop yield by 3.81 ton, 8.8 ton and 9.04 ton than disc plowing, respectively. This is in agreement with [9], [10], [11] and [24] results. The analysis of variance showed a highl significant difference ($P \leq 0.01$) in yield due to intervals of irrigation where the highest crop yield was obtained by the 10- day interval (65.45 ton/hectare) and the lowest crop yield was obtained by the 14- day interval (57.60 ton/hectare). This is in agreements with results of [18], [19], [21] and [22]. The results of interactions between tillage systems and shown in Table (2). The analysis of variance showed no significant difference between mean effects.

Table 1. Effect of tillage systems and irrigation intervals on sugar beet performance.

Parameters					
Treatments	**RIMD(cm)**	**RY (t/hr)**	**RNPH**	**LW (t/hr)**	**GR (%)**
T_1	34.0	63.78	61237	10.47	73.4
T_2	33.8	67.59	62254	11.19	76.2
T_3	35.5	58.55	53341	10.23	66.5
T_4	34.5	58.79	57672	10.23	69.5
C.V	15.88	35.69	9.91	16.90	12.56
S.E	0.79	1.35	350.32	0.11	1.29
L.S	ns	ns	*	ns	*
I_1	35	63.55	58772	10	70.7
I_2	35.2	65.45	58415	10.47	71.9
I_3	33.2	57.60	57727	10.71	71.7
C.V	11.95	18.67	20.70	17.10	15.26

S.E	0.51	0.61	633.43	0.09	1.36
L.S	*	**	ns	ns	Ns
S1	36.5	70.21	57598	11.66	75.3
S2	32	54.27	59019	9.05	67.5
S.E	0.56	0.95	247.62	0.08	0.91

where:

T_1 = Moldboard plow plus disk harrow plus ridging, T_2 = Disk plow plus disk harrow plus ridging, T_3 = Chisel plow plus disk harrow plus ridging, T_4 = Two passes of disk harrowing plus ridging. I_1 = Seven days irrigation interval, I_2 = Ten days irrigation interval, I_3 = Fourteen days irrigation interval, RIMD: root thickness, RY: root yield, RNPF: root number per feddan, LW: Leaf weight and GR: germination percentage.

Table 2. Effect of interactions between tillage systems and irrigation intervals on sugar beet yield and some yield components

	Parameters				
Treatments	**RIMD (cm)**	**RY (ton/hectare)**	**RNPH**	**LW (tone/hectare)**	**GR (%)**
$T_1 \times I_1$	34.63	66.97	58976	10.26	73.62
$T_2 \times I_1$	34.57	71.23	61559	11.33	72.91
$T_3 \times I_1$	35.46	55.48	57560	9.40	66.71
$T_4 \times I_1$	35.23	60.64	56561	9.50	69.44
$T_1 \times I_2$	35.11	68.47	62975	10.59	74.37
$T_2 \times I_2$	35.15	66.23	59873	10.33	76.87
$T_3 \times I_2$	35.8	64.97	52146	10.83	65.67
$T_4 \times I_2$	34.68	61.64	58643	10.50	70.56
$T_1 \times I_3$	32.28	55.76	57477	10.42	72.30
$T_2 \times I_3$	31.54	64.90	65307	11.57	78.88
$T_3 \times I_3$	35.18	55.31	50313	10.26	67.08
$T_4 \times I_3$	33.72	54.24	57810	10.40	68.42
S.E	1.03	1.22	1266.9	0.139	2.72
L.S	Ns	Ns	Ns	Ns	Ns

where:

T_1 = Moldboard plow plus disk harrow plus ridging, T_2 = Disk plow plus disk harrow plus ridging, T_3 = Chisel plow plus disk harrow plus ridging, T_4 = Two passes of disk harrowing plus ridging. I_1 = Seven days irrigation interval, I_2 = Ten days irrigation interval, I_3 = Fourteen days irrigation interval, RIMD: root thickness, RY: root yield, RNPF: root number per feddan, LW: Leaf weight and GR: germination percentage.

Sugar beet chemical analysis

Polarization or sugar content (Pol%)

The results of polarization or sugar content (Pol%) are shown in Table (3). The analysis of variance showed no significant differences on sugar content due to tillage treatments. Disc harrowing and moldboard plowing increased sugar content by 0.83% and 0.50% respectively, while chisel plowing decreased sugar content by 0.49% when compared to disc plowing treatment. This was in line with [9] and [10] results. Also the results of showed no significant difference in sugar content due to irrigation intervals. The results of interactions between tillage systems and irrigation intervals were shown in Table (4). The analysis of variance showed no significant difference between mean effects.

Estimated recovery sugar (ERS%)

The results obtained for estimated recovery sugar (ERS%) are shown in Table (3). The analysis of variance showed insignificant difference due to the effect of tillage systems. Also the results showed insignificant difference due to irrigation intervals. The results of interactions between treatments were shown in Table (4). The analysis of variance showed no significant difference between mean effects.

Table 3. Effect of tillage systems and irrigation intervals on sugar beet chemical analysis (Pol% and ERS%) and sugar beet production.

Treatments	Parameters		
	Pol%	**ERS%**	**TSB/Hectare**
T_1	18.3	15.8	9.76
T_2	17.8	15.3	10
T_3	17.3	14.8	8.57
T_4	18.9	16.9	9.28
C.V	10.96	13.19	20.44
S.E	0.28	0.29	0.12
L.S	ns	ns	ns
I_1	18.3	15.8	10

I_2	17.8	15.3	9.76
I_3	17.8	15.4	8.57
C.V	11.79	13.33	18.51
S.E	0.27	0.26	0.09
L.S	Ns	Ns	**

where:

T_1 = Moldboard plow plus disk harrow plus ridging, T_2 = Disk plow plus disk harrow plus ridging, T_3 = Chisel plow plus disk harrow plus ridging, T_4 = Two passes of disk harrowing plus ridging. I_1 = Seven days irrigation interval, I_2 = Ten days irrigation interval, I_3 = Fourteen days irrigation interval, Pol: polarization or sugar content ERS: estimated recovery sugar TSB: ton sugar beet.

Table 4. Effect of interactions between tillage systems and irrigation intervals on sugar beet chemical analysis (Pol% and ERS%) and sugar beet production.

Parameters			
Treatments	**Pol%**	**ERS%**	**TSB/Hectare**
$T_1 \times I_1$	18.49	15.96	10.56
$T_2 \times I_1$	18.37	15.87	11.14
$T_3 \times I_1$	17.67	15.17	8.38
$T_4 \times I_1$	18.77	16.27	9.85
$T_1 \times I_2$	17.61	15.11	9.95
$T_2 \times I_2$	17.87	15.37	9.95
$T_3 \times I_2$	17.44	14.94	9.52
$T_4 \times I_2$	18.14	15.64	9.40
$T_1 \times I_3$	18.69	16.22	8.38
$T_2 \times I_3$	17.09	14.59	9.19
$T_3 \times I_3$	16.71	14.28	7.93

$T_4 \times I_3$	18.84	16.34	8.62
S.E	0.53	0.53	0.18
L.S	Ns	Ns	Ns

where:

T_1 = Moldboard plow plus disk harrow plus ridging, T_2 = Disk plow plus disk harrow plus ridging, T_3 = Chisel plow plus disk harrow plus ridging, T_4 = Two passes of disk harrowing plus ridging. I_1 = Seven days irrigation interval, I_2 = Ten days irrigation interval, I_3 = Fourteen days irrigation interval, Pol: polarization or sugar content ERS: estimated recovery sugar TSB: ton sugar beet.

Sugar beet production (TSB/Hectare)

The results of sugar beet production (ton/hectare) are shown in Table (3). The analysis of variance showed no significant difference between tillage systems. The disc plowing treatment produced higher sugar beet than moldboard plowing by 2.4%, disc harrowing by 7.7% and chisel plowing by 16.67%. while the results showed high significant differences ($p \leq 0.01$) in sugar beet production between the irrigation intervals where the highest sugar beet production 10 ton/hectare was recorded for 7- day interval, while the lowest sugar beet production 8.57 ton/hectare was recorded for 14- day interval. The results obtained for the interactions between the different treatments were shown in Table (4). The analysis of variance for sugar beet production showed no significant difference between the means due to the interactions between the different variables.

4. CONCLUSIONS

From the results the following conclusions can be drawn:

1) Tillage treatments significantly ($P \leq 0.05$) affected the plant population and the germination ratio but there was no significant difference in root thickness, leaf weight, crop yield and sugar beet quality.
2) Irrigation intervals significantly ($P \leq 0.05$) affected root thickness, crop yield and sugar beet production, but there was no significant difference in the germination ratio, plant population, sugar content and estimated recovery sugar.

References

[1] Sohrabi Y. and Heidari G. Influence of withholding irrigation and harvest times on yield and quality of sugar beet (Beta vulgaris). *Int. J. Agric. Biol.* 10: 427-431 (2008)

[2] Abdel-Motagally, F.M.F. and Attia, K.K. Response of sugar beet plants to nitrogen and potassium fertilization in sandy calcareous soil. *Int. J. Agric. Biol.* 11: 695-700 (2009)

[3] Rashidi, M. and Keshavarzpour, F. Effect of different tillage methods on soil physical properties and crop yield of melon (Cucumis melo). *American-Eurasian J. Agric. and Environ. Sci.* 3: 31-36 (2008)

[4] Rashidi, M.; Gholami, M. and Khabbaz, B.G. Response of yield and yield components of tomato (Lycopersicon esculentum) to different tillage methods. *Int. J. Agric. Biol.* 11: 626-630 (2009)

[5] Ecclestone, P. To plough or not to plough? *British Sugar Beet Review* 72: 7-11 (2004)

[6] Larney, F.J.; Fortune, R.A. and Collins, J.F. Intrinsic soil physical parameters influencing intensity of cultivation procedures for sugar beet seedbed preparation. *Soil and Tillage Res.* 12: 253-267 (1988)

[7] Hamza, M.A. and Anderson, W.K. Soil compaction in cropping systems, a review of the nature, causes, and possible solutions. *Soil and Tillage Res.* 82: 12-145 (2005)

[8] Strudley, M.W. Green, T.R. and Ascough, J.C. Tillage effects on soil hydraulic properties in space and time. *Soil and Tillage Res.* 99: 4-48 (2008)

[9] Shahram, M.N.; Majid, R.; Seyyed, M.O.M. and Mehrdad, N. Effect of Different Tillage Methods on Yield and Quality of Sugar Beet. Ardabil Province Jahad-e-Keshavarzi Education Center, Ardabil, Iran Department of Agricultural Machinery, Takestan Branch, Islamic Azad University, Takestan, Iran Middle-East *Journal of Scientific Research*, 12(6): 859-863 (2012)

[10] Romanecka, K.R.; Romaneckien, C.; Šarauskis, E.; Pilipavicius, V. and Sakalauskas, A. The effect of conservation primary and zero tillage on soil bulk density, water content, sugar beet growth and weed infestation. Agronomy Research, 7(1): 73-86. (2009).

[11] Majid, R. Responses of root yield and yield component of Sugar beet (Beta vulgaris) to different tillage methods. Tehran, Iran *Journal of Agricultural and Biological Science* Vol. 6(8). (2011).

[12] Cavalaris, C.K. and T.A. Gemtos Evaluation of Four Conservation Tillage Methods in the Sugar Beet Crop. *Agricultural Engineering International* 008. Vol. IV. (2002)

[13] Dunham, R. Water use and irrigation. In: Cooke, D.A. and Scott, R.K. (eds.) The Sugar Beet Crop. Science into Practice. Chapman and Hall, London, (1993). pp. 279-309.

[14] Arroyo, J.M.; Urbano, P.; Rojo, C. and Gonzalez, F. Sugar beet irrigation: comparative study between trickle and sprinkler irrigation. *Agriculture* 803: 490–493 (2000)

[15] Sepaskhah, A.R. and Kamgar-Haghighi, A.A. Water use and yield of sugar beet grown under every-other-furrow irrigation with different irrigation intervals. *Agricultural Water Management,* 34: 71-79 (1997)

[16] Morillo-Velarde, R. and Moreno, A. Couvertures d'aspersion pour l'irrigation de la betterave a sucre: recommendations. Proceedings of IIRB Congress, Mediterranean Section. Marrakech, pp. 67-74. (2002).

[17] Sharmasarkar, F.C.; Sharmasarkar, S.; Miller, S.D.; Vance, G.F. and Zhang, R. Assessment of drip and flood irrigation on water and fertilizer use efficiencies for sugarbeets. *Agricultural Water Management,* 46: 241-251 (2001)

[18] Howell, T.A.; Ziska, L.H.; McCormick, R.L.; Burtch, L.M. and Fisher, B.B. Response of sugarbeet to irrigation frequency and cutoff on a clay loam soil. *Irrigation Science* 8: 1-17 (1987)

[19] Ezekari, M.; Boukhal, A. and Hakim, M. Effet de la frequence d´irrigation, de la dose d´azote et son fractionnement sur le rendement et la qualite technoligique de la betterave a sucre dans la plaine du tadla. Proceedings of the 56th IIRB Congress. Brussels, (1993). pp. 69-83.

[20] Cavazza, L. and Patruno, A. Irrigation de la betterave a sucre. Aspect phisiologiques. Proceedings of the 56th IIRB Congress. Brussels, (1993), pp. 5-24

[21] De Benito, A.; Estrada, M.A. and Sombrero, A. Frequence de l´irrigation et dose d´apports. Deux facteurs de base sur le developpement et rendement de la betterave a sucre. Proceedings of IIRB Congress, Mediterranean Section. Marrakech, (2002). pp. 37-47.

[22] Camposeo, S. and Rubino, P. Effect of irrigation frequency on root water uptake in sugar beet. *Plant and Soil* 253: 301-309 (2003)

[23] ICUMSA, Method Book, International Commission for Uniform Methods of Sugar Analysis, GS 6(1-3), (1994)

[24] Anna Goelnitza, Mohammad Al-Saidi. Too big to handle, too important to abandon: Reforming Sudan's Gezira Scheme. *Agricultural Water Management* 241 (2020) 106396. https://doi.org/10.1016/j.agwat.2020.106396

[25] Kuc, P. and Zimny L. Yielding and technological quality of sugar beet growing in different cultivation systems. *Annales*, 60: 133-143 (2005)