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Sugar Beet (*Beta vulgaris* L.) Production as Affected by Irrigation Intervals and Planting Methods in Guneid Area, Sudan

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ABSTRACT

The present study was carried out at Guneid Research Sugar Cane Center during the two seasons of 2014 and 2015.The objective was to investigate the effect of three irrigation intervals 7, 10 and 14 days and two planting methods manual and mechanical on sugar beet crop growth and yield. The parameters measured were germination ratio, root thickness, root number/ha, leaf weight, root crop yield, polarization, estimated recovery sugar and sugar beet production. A split plot design with four replications was used. Irrigation intervals significantly ($P \leq 0.05$) affected root crop yield, root thickness and sugar beet production. The maximum values of root crop yield (65.4 ton/ha) and root thickness (35.2 cm) were obtained under 10 days irrigation interval, while the maximum values of sugar beet production (10 ton/ha) was obtained under 7 days interval. Methods of planting significantly ($P \leq 0.05$) affected root crop yield, root thickness, root number/ha, germination ratio, polarization, estimated recovery sugar and sugar beet production. The maximum values of root crop yield (65.2 ton/ha), root number/ha (67375 roots/ha), germination ratio (79.8%) and sugar beet production (9.7 ton/ha) were recorded for the manual planting method, while the maximum values of root thickness (35.6 cm), polarization (18.4%) and estimated recovery sugar (15.8%) were recorded for the mechanical planting method. The combined of irrigation intervals and sowing methods (irrigation intervals 7 days with manual planting methods and irrigation intervals 10 days with mechanical planting methods) resulted in hiegh polarization (18.5, 18.5 %), estimated recovery sugar (16, 16 %) and sugar beet production (10.7, 9.7 ton/ha), respectively, compared to other treatments. Irrigation intervals 10 days with mechanical planting method can be recommended to prevent loss of sugar content in sugar beet roots.

***Keywords*:** Irrigation intervals, planting methods, crop yield and Sugar beet, *Beta vulgaris*

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1. INTRODUCTION

Root crops include beet, potato, sweet potato, onion, parsnip, rutabaga and radish [1]. These crops grow in a large fleshy structure called the root, and the enlarged root consists of both root and stem tissues. The Consultative Group on International Agricultural Research (CGIAR) envisions that by 2020 roots and tubers will be integrated into emerging markets through the efficient and environmentally sound production of a diverse range of high-quality, competitive food, feed, and industrial products [2].The first extensive field production of beet, which occurred during the seventeenth century, was directed towards producing fodder for cattle [3]. Sugar beet is a short duration crop (5-6 months) with high sucrose content (14-20%) while sugarcane is a long duration crop (12-14 months) with low sucrose content (10-12%) [4]. Water was applied to furrows in order to keep the ridge fully moist. A number of field studies have been conducted to determine the optimum plant density for irrigated sugar beet using conventional tillage systems. A common irrigation method in sugar beet production in Sudan is surface irrigation, and crop yield may increase if proper irrigation methods are followed.

Irrigation scheduling is one of the most important tools in the development of best management practices for irrigated areas [5], and this is especially the case in semi-arid areas that are prone to frequent droughts and with limited water resources. [6] reported that furrow bed system saved 25-53% of water and increased the yield of cotton by 6-52% as compared to basin system. In addition to water saving, bed planting has also been shown to improve the efficiency of fertilizer, reduced weed infestation and reduced seed rate without sacrificing yield [7]. [8] stated that water application interval of one week increased root yield of sugar beet compared with two and three weeks. He concluded that sugar beet offers great flexibility in volumes and intervals of irrigation without affecting root growth and increase in frequency from one to two irrigations per week significantly increased root development and yield. [9] reported that to obtain high root and sugar yields, it is recommended to apply 150 kg/ha of NPK fertilizer and irrigate every 7 to 14 days.

Producers must try to use an optimum sowing methods which is consider to be one of the most important elements of sugar beet production. There are a few investigations with respect to the effect of sowing methods on sugar beet productivity. In this concern, [10] showed that planting methods significantly affected the root and foliage weights, of sugar beet crop. [11] showed that mechanical sowing of sugar beet (planter technique) increased root and sugar yield and its components as compared with traditional method (manual sowing). [12] reported that sowing of sugar beet in a laser leveled soil + deep ploughing gave a significant increase in root length, root diameter in comparison to other treatments. [13] revealed that highest root yield (79.1 ton/ha) was resulted from using the rotary harrow or rotovator as compared with sowing with conventional drilling [19-29].

2. MATERIALS AND METHODS

2. 1. Experimental 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.

2. 2. Experimental equipment

The equipments used in this experiment were commonly used for soil tillage in Sudan. The land was prepared by disc plow, then the land was harrowed by the disc harrow and also furrowed by ridger at the same time of planting.

2. 3. Irrigation water application

Applied water was fixed during the growing season according to CropWatt program version-8. A plastic pipe with a length of 50cm and 11cm in diameter and two gallon made of plastic (17 litter) were used to determine the amount of water per minute. The time of irrigation per subplot was calculated as follows:

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

2. 4. Experimental treatments and design

The experiment comprised three irrigation intervals *viz*; 7, 10 and 14 days and two planting methods. The split–plot design with four replicates was used. The main plots were assigned to planting methods, whereas subplots were assigned to irrigation intervals.
The size of the plot was $3.5 \times 7\ m^2$.

2. 5. Planting and seed rate

After the soil was prepared two methods of planting were used

2. 5. 1. Manual planting

Twelve labors were used for planting the 12 subplots using a piece of iron of 1.5 meter long. The space between plants was 15 cm while between rows was 75 cm.

2. 5. 2. Mechanical planting

A pneumatic planter with four units was calibrated and used for planting the other 12 subplots to plant the seed 75 cm between rows and 15 cm between plants. Lenard, monogerm seed type was used for planting the experiment field.

2. 6. Data collection

2. 6. 1. Plant germination percentage

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

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

2. 6. 2. Root thickness

A tape meter was used to measure the thickness of the tuber at harvest. Five plants per subplot were selected randomly and measured from harvested rows and then the average was taken.

2. 6. 3. Plant population

At harvest, the number of tubers was counted for an area of 7.5 m^2 in each sub subplot. The number of tubers per ha (10000 m^2) was determined by the following equation:

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

2. 6. 4. 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:

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

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

2. 6. 5. 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.

2. 6. 6. 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 [14].

2. 6. 7. Estimated recovery sugar (ERS%) analysis

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

$$\text{ERS \%} = \text{Pol\%} - 2.5 \qquad (5)$$

where: 2.5 = Expected losses of sugar content through production.

2. 6. 8. Sugar production from sugar beet

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

$$\text{Sugar ton per feddan} = \frac{\text{ERS\%} \times \text{ Yield of sugar beet per feddan (kg)}}{1000} \qquad (6)$$

3. RESULTS AND DISCUSSION

3. 1. Germination percentage (GR%)

The analysis of variance showed there were 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 (Table 1). On the other hand the analysis of variance showed a significant difference ($P \leq 0.05$) due to the method of planting where the manual planting resulted in the highest germination percentage 79.8% compared to the mechanical planting (63%) and this may be attributed to the shallow depth at which the seeds were placed in the manual planting. The average germination percentage for the first season and second season were 75.4% and 67.5%, 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.

3. 2. Plant population (plants/ha)

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/ha for the 7, 10 and 14 days intervals, respectively (Table 1). On the other hand the analysis of variance showed a highly significant difference ($P \leq 0.01$) between the planting methods. The manual planting recorded the highest plant population of 67375 plant/ha. This can be attributed to the high germination percentage recorded by the manual planting method. The average plant population for the first and second seasons were 57598 and 59019 plant/ha, respectively. The results of the interactions between the treatments are shown in Table 2. The analysis of variance for plant population showed no significant difference due to the interaction between the treatments.

3. 3. Root thickness (cm)

The analysis of variance showed a significant difference ($P \leq 0.05$) between irrigation intervals in the root thickness (Table 1). 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 [15]. Analysis of variance showed also a significant difference ($p \leq 0.05$) between methods of planting where the mechanical planting recorded higher root thickness (35.6 cm) and this may be due to the low germination percentage which made big spaces between plants. The average root thickness for the first season was 36.5 cm while for the second season it was 32.4 cm. 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.

3. 4. Crop leaf weight (LW)

The analysis of variance showed no significant difference between irrigation intervals due to leaf weight (Table 1). Treatment of 14- day interval recorded the highest mean leaf weight of 10.71 ton/ha, and the lowest was recorded by the 7-day interval as 10 ton/ha. Also, the analysis of variance showed no significant difference between methods of planting, where the manual and mechanical plantings recorded 10.71 and 10.24 ton/ha, respectively. The average crop leaf weights for the first and second seasons were 11.66 and 9.05 ton/ha, respectively.

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.

3. 5. Crop yield (RY ton/ha)

The analysis of variance showed a highly significant difference (P≤0.01) in yield due to intervals of irrigation (Table 1). The highest crop yield was obtained by the 10-day interval (65.45 ton/ha) and the lowest crop yield was obtained by the 14- day interval (57.60 ton/ha). This is in agreements with results of [15, 16, 17] and [18]. On the other hand the analysis of variance showed a highly significant difference (p≤0.001) in yield between methods of planting where the manual planting recorded the highest crop yield (65.21 ton/ha) compared to the mechanical planting which recorded (59.03 ton/ha). This may be due to the high germination percentage accomplished under the manual planting and this disagreed with the results of [10, 11] and [13]. The mean crop yields for the first and second seasons were 70.21 and 54.27 ton/ha, respectively. The low yield in the second season may be attributed to the low of germination percentage compared to the first season. The results of interactions between irrigation intervals with methods of planting shown in Table 2. The analysis of variance showed no significant difference between mean effects.

Table 1. Effect of irrigation intervals and methods of planting on sugar beet yield and some yield components

Parameters					
Treatments	GR (%)	RIMD (cm)	RNPH	LW (tone/ha)	RY (tone/ha)
I_1	70.7	35	58772	10	63.55
I_2	71.9	35.2	58415	10.47	65.45
I_3	71.7	33.2	57727	10.71	57.60
C.V	15.26	11.95	20.70	17.10	18.67
S.E	1.36	0.51	633.43	0.09	0.61
L.S	Ns	*	ns	ns	**
M_1	79.8	33.3	67375	10.71	65.21
M_2	63.1	35.6	49866	10.24	59.03
C.V	17.15	18.89	40.07	15.05	6.96
S.E	4.16	0.66	1001.2	0.08	0.19
L.S	*	*	**	Ns	**

S_1	75.3	36.5	57598	11.66	70.21
S_2	67.5	32	59019	9.05	54.27
S.E	0.91	0.56	247.62	0.08	0.95

where:

I_1: 7 days irrigation interval, I_2: 10 days irrigation interval, I_3: 14 days irrigation interval, M_1: Manual planting, M_2: Mechanical planting, S_1: first season, S_2: second season, GR: germination % RIMD: root thickness, RNPH: root number/ha, LW: Leaf weight, RY: root yield.

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

Parameters					
Treatments	GR (%)	RIMD (cm)	RNPH	LW (tone/ha)	RY (tone/ha)
$I_1 \times M_1$	79.8	38.9	67599	10.47	67.15
$I_2 \times M_1$	80.5	34.3	68016	10.95	69.50
$I_3 \times M_1$	79	31.7	66516	10.95	59.26
$I_1 \times M_2$	61.6	36.1	49730	9.79	60.22
$I_2 \times M_2$	63.3	36.1	48814	10.24	61.17
$I_3 \times M_2$	64.3	34.7	48845	10.47	55.93
S.E	1.92	0.73	895	0.13	0.86
L.S	Ns	Ns	Ns	Ns	Ns

where:

I_1: 7 days irrigation interval, I_2: 10 days irrigation interval, I_3: 14 days irrigation interval, M_1: Manual planting, M_2: Mechanical planting, GR: germination percentage, RIMD: root thickness, RNPH: root number/ha, LW: Leaf weight, RY: root yield.

3. 6. Sugar beet chemical analysis

3. 6. 1. Polarization or sugar content (Pol%)

The results of polarization or sugar content (Table 3) showed no significant difference in sugar content due to irrigation intervals while, the analysis of variance showed significant difference (P≤0.05) in sugar content due to method of planting, where the mechanical planting resulted in the highest polarization or sugar content (18.5%) compared to the manual planting (17.6%). For the first season polarization or average sugar content (Pol%) was 16.5% while in the second season it was 19.4%. The results of interactions between irrigation intervals with methods of planting were shown in Table 4. The analysis of variance for polarization or sugar content showed a significant difference (P≤0.05) for the 10- day interval with mechanical planting and7- day interval with manual planting which recorded the highest polarization or sugar content while, the lowest was recorded by the 10- day intervals with manual planting.

3 .6. 2. Estimated recovery sugar (ERS%)

The results obtained for estimated recovery sugar (Table 3) showed insignificant difference due to irrigation intervals, a significant difference (P≤0.05) was observed between methods of planting where the mechanical planting resulted a high ERS% (15.8%) compared to manual planting (15.1%). The average ERS% for the first and second seasons were 14.1% and 16.9%, respectively. The results of interactions between treatments were shown in Table 4. The interactions between irrigation intervals with methods of planting showed a significant difference at (P≤0.05) where 10- day interval with mechanical planting and 7- day interval with manual planting recorded the highest estimated recovery sugar (ERS%) while the lowest was shown by the 10- day intervals with manual planting.

3. 6. 3. Sugar beet production (TSB)

The results of sugar beet production (Table 3) showed highly significant differences (p ≤ 0.01) in sugar beet production between the irrigation intervals where the highest sugar beet production 10 ton/ha was recorded for 7-day interval, while the lowest sugar beet production 8.57 ton/ha was recorded for 14-day interval. The analysis of variance showed highly significant differences (p≤0.001) between methods of planting where the manual planting resulted in high sugar beet production (9.76 ton/ha) than the mechanical planting (9.28 ton/ha) and this may be due to the high yield of sugar beet root and sugar beet content (Pol%) by this treatment. Sugar beet production for the first and second seasons were 9.76 and 9.28 ton/ha, respectively. 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.

Table 3. Effect of irrigation intervals and methods of planting on sugar beet chemical analysis

Parameters			
Treatments	Pol%	ERS%	TSB (ton/ha)
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	**
M_1	17.6	15.1	9.76
M_2	18.4	15.8	9.28
C.V	7.70	9.29	13.11
S.E	0.14	0.15	0.05
L.S	*	*	*
S_1	16.5	14.1	9.76
S_2	19.4	16.9	9.28
S.E	0.20	0.21	0.08

where:

I_1: 7 days irrigation interval, I_2: 10 days irrigation interval, I_3: 14 days irrigation interval, M_1: Manual planting. M_2: Mechanical planting, Pol: polarization or sugar content, ERS: estimated recovery sugar, TSB: ton sugar beet.

Table 4. Effect of interactions between irrigation intervals and methods of planting on sugar beet chemical analysis

Treatments	**Parameters**		
	Pol%	**ERS%**	**TSB/ha**
$I_1 \times M_1$	18.5	16	10.71
$I_2 \times M_1$	17.1	14.5	9.76
$I_3 \times M_1$	17.3	14.8	8.57
$I_1 \times M_2$	18.1	15.6	9.28
$I_2 \times M_2$	18.5	16	9.76
$I_3 \times M_2$	18.4	15.9	8.81
S.E	0.43	0.37	0.13
L.S	*	*	Ns

where:

I_1: 7 days irrigation interval, I_2: 10 days irrigation interval, I_3: 14 days irrigation interval, M_1: Manual planting, M_2: Mechanical planting, Pol: polarization or sugar content, ERS: estimated recovery sugar, TSB: ton sugar beet.

4. CONCLUSIONS

From the results the following conclusions can be drawn:

1) Treatments of Irrigation intervals significantly ($P \leq 0.05$) affected root thickness, crop yield and sugar beet production.
2) Methods of planting significantly ($P \leq 0.05$) affected the germination ratio, root thickness, plant population, crop yield, sugar content, estimated recovery sugar and sugar beet production.
3) The combined of irrigation intervals and sowing methods (I_1XM_1 and I_2XM_2) resulted in hiegh Pol% (18.5, 18.5 %), ESR% (16, 16 %) and TSB (10.71, 9.76 ton/ha), respectively.

5. RECOMMENDATIONS

From the results and conclusions of this study the following recommendations can be made:

1) Irrigation intervals 10 days with mechanical sowing method can be recommended to prevent loss of sugar content in sugar beet roots.
2) Effect of irrigation water quantities and methods of planting may need more investigation.

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