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Effect of Nitrophoska® and irrigation interval on root and sugar yield of sugar beet (*Beta vulgaris* L.), Gezira State, Sudan

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ABSTRACT

Sugar beet is one of the promising crops in the Sudan due to its high root, sugar yield and by-products as an industrial crop. The crop is also a promising alternative energy crop for the production of ethanol. An experiment was conducted at the experimental Farm of the Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan, during seasons 2012/13 and 2013/14. The objective was to investigate the effects of irrigation intervals (7, 14 and 21 days) and Nitrophoska (NPK compound fertilizer) rates (0, 100, 150 and 200 kg/ha) on root and sugar yield of sugar beet (Ballade cultivar) under Gezira conditions. Split-plot design with three replicates was used. Irrigation intervals were allotted to the main plots and Nitrophoska rates to the subplots. Results showed that shortening irrigation intervals from 21 to 14 and 7 days increased root diameter, root weight and root and sugar yields in both seasons. In addition, Nitrophoska rate of 150 kg/ha substantially improved most of the studied root characters and sugar yield in both seasons. Depending on the results of this study, to obtain high root and sugar yields from sugar beet Ballade cultivar, it could be recommended to apply 150 kg/ha of Nitrophoska and irrigate every 7 to14 days.

INTRODUCTION

Sugar beet *(Beta vulgaris* L.) is a member of Chenopodiaceae family. It is the second important sugar crop after sugarcane, producing about 40% of sugar annually all over the world (Amr and Gaffer, 2010). Sugar beet roots contain high concentration of sucrose (Memon *et al.*, 2004). It can be grown in a wide range of climatic conditions and renowned for its tolerance to salinity but water scarcity causes profit loss of the sugar beet crop (Abo-Shady *et al.,* 2010).

The European Union, the United States, and Russia are the world three largest sugar beet producers in the world. This crop is also a promising alternative energy crop for the production of ethanol (BSRI, 2005). Recently, some tropical sugar beet varieties have been developed which can be grown in tropical as well as subtropical regions of the world.

Production of sugar beet has got many benefits compared to sugarcane production. It 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%) (Anonymous, 2004).

Sugar beet is one of the major strategic crops in the world grown in different regions of Europe, America, Asia and Africa. Sugar is the major product of beet whereas molasses and beet pulp are by-products of high importance for both agricultural as well as industrial sectors (SSC, 2005).

NPK fertilizer is needed for sugar beet which plays an important role in plant nutrition in association with yield and quality of the crop. Numerous field trials, in many countries, studied the yield increasing effect of balanced fertilization on sugar beet. Many studies indicated that yield of sugar beet in Hungary increased from 53.4 t/ha at NP to 68.9 t/ha at NPK + Mg which gave an increase of 29% and increased sugar content from about 17.5% at NP only to more than 19% at balanced fertilization with NPK + Mg (IPI, 2009).

Abdelhadi (2012) 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. Isoda *et al.* (2007) found that irrigation led to an increase in the net sugar yield due to an increase in the root yield.

Therefore, manipulation of the management practices of sugar beet under the semi–arid tropical environments is one way of improving its nutritional needs for commercial production. Information about cultural practices that affect sugar beet production in the Sudan such as fertilization and irrigation intervals is meager. Therefore, the objectives of this work was to determine the optimum rate of balanced NPK fertilizer (Nitrophoska 18:18:18) and irrigation interval that maximize root growth and sugar yield of sugar beet under the clay soils condition of the Gezira, Sudan.

MATERIALS AND METHODS

An experiment was carried out at the experimental farm of the Faculty of Agricultural Sciences, University of Gezira in seasons 2012/13 and 2013/14, latitude $14^0\ 6^/$ N and longitude $33^0\ 38^/$ E. The soil of the site is a typical sulemic series, dark brown, deep cracking clays with very low permeability when moist. The pH of the soil ranges from 7.6 to 8.4 with nitrogen concentration of 0.03% and available phosphorus of 4.3 to 6.9 mg/kg of soil. The soil is non saline and non-sodic (Soil Survey Staff, 1999).

The experiment comprised three irrigation intervals *viz*; 7, 14 and 21 days and four NPK fertilizer (Nitrophoska 18: 18: 18) levels of 0, 100, 150 and 200 kg/ha. The split–plot design with four replicates was used. The main plots were assigned to irrigation intervals, whereas subplots were assigned to NPK fertilizer levels. The size of the plot was 3.5 x 6 m.

The experimental site was disc ploughed, harrowed, leveled and ridged 80cm apart. Sowing was done in holes 15 cm apart. Three to four seeds were sown per hole and then four weeks later were thinned to one plant per hole. Sowing of the experiment was in mid October. Weeds were controlled by hand hoeing when necessary. The crop was harvested 150 days after sowing. Harvesting was done by pulling the beet manually and cleaned beet roots were weighed for yield and yield components. Samples were taken for determination of sugar content using the polarometer method (Payne, 1968).

Data collected consisted of root length, diameter, weight, yield, sugar yield and sugar beet quality traits (brix %, pol % and purity %). Data were analysed using the standard analysis of variance procedure. Means were separated using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Root length (cm)

Irrigation interval had a significant effect ($P \leq 0.05$) on root length of sugar beet in both seasons (Table1). The highest root length (37.2 and 39.3 cm) was obtained when an irrigation interval of 21 days was used in both seasons. These results were in line with those of El-Harriri and Mirvat (2001) who found that application of 110 kg/ha +48 K_2O/fed markedly increased the root characters (root length, diameter and weight) of sugar beet. NPK fertilizer and the interaction between NPK and irrigation intervals had no significant effect on root length in both seasons.

Table 1. Effect of irrigation interval, NPK fertilizer levels and their interaction on root length (cm) at the Experimental Farm of Gezira University, during 2012/13 and 2013/14 seasons.

Irrigation intervals (days)	2012/13 NPK fertilizer levels (kg/ha)				Mean
	0	100	150	200	
7	33.1 a	32.2 a	33.4 a	33.3 a	33.0 B
14	33.1 a	32.7 a	33.0 a	34.0 a	33.2 B
21	37.4 a	36.5 a	37.3 a	37.4 a	37.2 A
Mean	34.5 A	33.8 A	34.6 A	34.9 A	34.5
SE±			0.64		
CV (%)			3.19		
		2013/14			
7	35.4 a	34.9 a	35.6 a	33.9 a	35.0 C
14	37.7 a	36.8 a	37.8 a	35.4 a	36.9 B
21	40.9 a	37.9 a	40.0 a	38.5 a	39.3 A
Mean	38.0 A	36.5 A	37.8 A	35.9 A	37.1
SE±			0.70		
CV (%)			3.3		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Root diameter (cm)

Irrigation interval had a significant effect ($P \leq 0.05$) on root diameter of sugar beet in both seasons (Table 2). The highest root diameter (33.0 and 32.9 cm) was obtained when the crop was irrigated every 14 and 7 days in seasons 2012/13 and 2013/14, respectively. NPK fertilizer had a significant effect ($P \leq 0.05$) on root diameter in season 2013/14 only. The highest root diameter (33.2 cm) was obtained when 150 kg NPK/ha was applied. These results were in line with those of El-Harriri and Mirvat (2001) who reported that application of 110 kg/ha

+ 115.2/ha K_2O markedly increased the root diameter. The interaction between NPK fertilizer and irrigation interval had no significant effect on root diameter in both seasons.

Table 2. Effect of irrigation interval, NPK fertilizer levels and their interaction on root diameter (cm) of sugar beet grown at the Experimental Farm of University of Gezira during 2012/13 and 2013/14 seasons.

Irrigation intervals (days)	2012/13 NPK fertilizer levels (kg/ha)				Mean
	0	100	150	200	
7	32.6 a	32.9 a	32.7 a	32.3 a	32.6 A
14	32.7 a	33.4 a	32.9 a	32.9 a	33.0 A
21	30.9 a	30.6 a	31.7 a	30.6 a	31.0 B
Mean	32.1 A	32.3 A	32.4 A	31.9 A	32.2
SE±			0.32		
CV (%)			1.71		
			2013/14		
7	32.3 a	33.4 a	34.0 a	31.7 a	32.9 A
14	32.1 a	32.7 a	33.3 a	32.8 a	32.7 A
21	31.0 a	31.5 a	32.3 a	31.1 a	31.5 B
Mean	31.8 B	32.6A B	33.2 A	31.9 B	32.4
SE±			0.45		
CV (%)			2.41		

Means followed by the same letter(s) are not significantly different at 5% level of
probability according to Duncan's Multiple Range Test.

Root weight (kg)

Table 3 shows the effect of irrigation intervals, NPK fertilizer levels and their interaction on root weight. The interaction between irrigation intervals and NPK fertilizer levels had highly significant effect ($P \leq 0.01$) on root weight during both seasons. The heaviest root weight (1.66 and 1.53

kg) was obtained when sugar beet was irrigated every 7 days coupled with the application of 150 kg NPK. These results confirm those of El-Harriri and Mirvat (2001) who reported that application of 110 kg/ha + 115.2/ha K_2O significantly increased root weight.

Table 3. Effect of irrigation interval, NPK fertilizer levels and their interaction on root weight (kg) of sugar beet grown at the Experimental Farm of University of Gezira during seasons 2012/13 and 2013/14.

Irrigation intervals (days)	2012/13 NPK fertilizer levels (kg/ha)				Mean
	0	100	150	200	
7	1.45 d	1.55 c	1.66 a	1.56 bc	1.56 A
14	1.38 e	1.45 d	1.57 b	1.44 d	1.46 B
21	1.12 i	1.18 g	1.24 f	1.17 h	1.18 C
Mean	1.32 C	1.39 B	1.49A	1.39B	1.4
SE±			0.01		
CV (%)			1.30		
		2013/14			
7	1.37g	1.47c	1.53a	1.45e	1.46A
14	1.44f	1.44f	1.50b	1.46d	1.46A
21	0.78k	1.17i	1.25h	1.15j	1.09B
Mean	1.20D	1.36B	1.43A	1.35C	1.33
SE±			0.10		
CV (%)			13.34		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Root yield (t/ha)

Irrigation intervals, NPK levels and their interaction had highly significant effects ($P \leq 0.01$) on root yield of sugar beet in both seasons (Table 4). The highest root yield (87.16 and 84.05 t/ha) was obtained when the crop was irrigated every 7 days coupled with 150 kg NPK during seasons 2012/13 and 2013/14, respectively. These results were in agreement with those of Isoda *et al.* (2007) who found that irrigation led to an increase in net sugar yield due to an increase in root yield. Furthermore, Abdelhadi (2012) stated that water application interval of one week increased root yield of sugar beet compared with two and three weeks. These results were in agreement with those of Ramadan (2005) who stated that increasing nitrogen fertilizer significantly increased root and sugar yields.

Table 4. Effect of irrigation interval, NPK fertilizer levels and their interaction on root yield (t/ha) at the Experimental Farm of University of Gezira during seasons 2012/13 and 2013/14.

Irrigation intervals (days)	2012/13 NPK fertilizer levels (kg/ha)				Mean
	0	100	150	200	
7	74.38d	79.33b	87.16a	79.51b	80.09 A
14	73.65d	78.68b	86.33a	76.84c	78.88 B
21	62.18g	65.17f	69.74e	65.25f	65.58 C
Mean	70.07 C	74.39 B	81.08 A	73.87 B	74.85
SE±			0.50		
CV (%)			1.15		
		2013/14			
7	72.07c	74.90b	84.05a	72.23c	75.81A
14	71.21c	74.06b	82.92a	71.86c	75.01B
21	61.97e	63.33e	67.31d	62.55e	63.79C
Mean	68.42C	70.76B	78.09A	68.88C	71.54
SE±			0.62		
CV (%)			1.49		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Brix %

Effect of irrigation interval, NPK levels and their interaction on sugar quality is shown in Table 5. NPK levels had a significant ($P \leq 0.05$) effect on brix% during both seasons. The highest brix (25.50% and 24.21%) was obtained when 150 NPK kg/ha was applied in both seasons. These results agreed with those of Sohier (2001) who revealed that increasing nitrogen fertilizer levels from 0 to 24 and 48 kg /fed caused a significant increase in brix and sucrose percentages. Irrigation intervals and their interaction had no significant effect on brix % in both seasons.

Table 5. Effect of irrigation interval, NPK fertilizer levels and their interaction on brix (%) at the Experimental Farm of University of Gezira during seasons 2012/13 and 2013/14.

Irrigation intervals (days)	2012/13 NPK fertilizer levels (kg/ha)				Mean
	0	100	150	200	
7	22.71a	23.25a	24.70a	23.03a	23.42 A
14	21.46a	25.14a	26.11a	23.25a	23.99 A
21	22.78a	23.66a	25.70a	22.61a	23.69 A
Mean	22.32 C	24.02 B	25.50 A	22.96 C	23.70
SE±			0.56		
CV (%)			4.13		
		2013/14			
7	22.87a	22.86a	.2401a	23.02a	.2319A
14	22.40a	23.91a	24.40a	23.35a	23.52A
21	22.78a	24.87a	24.23a	24.12a	24.00A
Mean	22.68B	23.88A	24.21A	23.50A	23.57
SE±			0.41		
CV (%)			3%		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Pol%

The effect of irrigation interval, NPK levels and their interaction on pol% is shown in Table 6. NPK levels had significant effect ($P \leq 0.05$) on pol% in season 2012/13 only. The highest sugar content (22.9%) was obtained when 150 kg NPK/ha was applied. These results were in agreement with those of Bieniaszweski *et al.* (1996) who found that NPK combination of 120 kg N +96 kg P_2O_5 + 144 kg K_2O/ha gave the highest sugar content and increased root yield. IPI (2009) stated that increased sugar content from 17.5% at nitrogen and phosphorus (NP) only to more than 19% at balanced fertilization with NPK + Mg. Irrigation intervals and their interaction with NPK rates had no significant effect on pol % in both seasons.

Table 6. Effect of irrigation interval, NPK fertilizer levels and their interaction on sugar content (pol %) of sugar beet grown at the Experimental Farm of University of Gezira during seasons 2012/13 and 2013/14.

Irrigation intervals (days)	2012/13 NPK fertilizer levels (kg/ha)				Mean
	0	100	150	200	
7	20.4 a	21.2 a	22.1 a	21.2 a	21.2 A
14	19.8 a	21.3 a	23.0 a	21.4 a	21.4 A
21	20.6 a	22.2 a	23.6 a	20.9 a	21.8 A
Mean	20.3 C	21.6 B	22.9 A	21.2 BC	21.5
SE±			0.59		
CV (%)			4.78		
		2013/14			
7	20.4a	20.1a	20.2a	20.5a	20.3A
14	20.4a	21.4a	20.8a	20.8a	20.9A
21	20.5a	21.9a	20.5a	21.5a	21.1A
Mean	20.4A	21.1A	20.5A	20.9A	20.7
SE±			0.45		
CV (%)			3.75		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test .

Purity%

Irrigation intervals and their interaction had no significant effect (P≤0.05) on purity% in both seasons, however, NPK fertilizer had a significant effect (P≤0.05) on purity during

2013/14 season only (Table 7). This could be attributed to the increase of sugar content (%) and brix (%).

Table 7. Effect of irrigation intervals, NPK fertilizer levels and their interaction on purity (%) of sugar beet grown at the Experimental Farm of University of Gezira during seasons 2012/13 and 2013/14.

Irrigation intervals (days)	2012/13 NPK fertilizer levels (kg/ha)				Mean
	0	100	150	200	
7	89.54 a	91.36 a	89.39 a	92.18 a	90.62 A
14	92.19 a	84.91 a	88.09 a	92.20 a	89.34 A
21	90.56 a	93.87 a	91.99 a	92.31 a	92.18 A
Mean	90.76 A	90.05 A	89.82 A	92.23 A	90.71
SE±			2.08		
CV (%)			3.98		
		2013/14			
7	88.96a	87.78a	84.25a	88.98a	87.49A
14	90.67a	89.37a	85.62a	89.24a	88.73A
21	90.07a	89.37a	84.99a	89.08a	88.02A
Mean	89.90A	88.36A	85.95B	89.10A	88.08
SE±			1.15		
CV (%)			2.26		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Sugar yield (t/ha)

Table 8 showed that irrigation intervals, NPK levels and their interaction had highly significant effect (P≤0.01) on sugar yield in both seasons. The highest sugar yield (20.3 and 17.3 t/ha) was obtained when the crop was irrigated every 14 days coupled with the application of 150 kg NPK/ha in seasons 2012/13 and 2013/14, respectively. These findings agreed with those of Sudanese Sugar Company (SSC), (2005) which reported that irrigation every 10 days gave higher sugar yield compared with irrigation every 7 and 13 days. These results were in agreement with those of Mahdi *et al.* (2012) who reported that potassium increased root and sugar yields of sugar beet.

Table 8. Effect of irrigation intervals, NPK fertilizer levels and their interaction on sugar yield (t/ha) of sugar beet grown at the Experimental Farm of University of Gezira during seasons 2012/13 and 2013/14.

Irrigation intervals (days)	2012/13 NPK fertilizer levels (kg/ha)				Mean
	0	100	150	200	
7	15.2a	16.9a	20a	16.9a	17.2 A
14	15.2a	18.0a	20.3a	16.5a	17.5 A
21	12.8b	14.5b	16.5b	13.7a	14.4 B
Mean	14.4 B	16.5 B	18.9 A	15.7 B	16.4
SE±			0.71		
CV (%)			7.49		
			2013/14		
7	14.7c	15.0c	17.0a	14.8c	15.4A
14	14.5cd	15.8b	17.3a	15.0c	15.6A
21	12.7f	13.8de	13.8e	13.5e	13.4B
Mean	14.0BC	14.9B	16.0A	14.4B	14.8
SE±			0.24		
CV (%)			2.8		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

RECOMMENDATION

Based on the results of this study, 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.

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