

Effect of tillage system and spacing on growth and yield of sugar beet (*Beta vulgaris* L.), Kassala State, Sudan

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ABSTRACT

Field experiments were conducted during 2011- 2013 in Kassala Agricultural Research Station to study the effect of different tillage operations, inter and intra-row spacing, on growth and yield of sugar beet. The experimental design was a split-split-plot design, with three replicates. The treatments used were tillage system (ploughing and harrowing) as the main plot, row spacing (60, 80 and 100 cm) as the sub-plot and intra-row spacing (10, 20 and 30 cm) as the sub-sub-plot. Statistical analysis revealed no significant difference between tillage operations on soil clod size distribution. The treatments disc harrow, inter-row spacing of 60cm, intra-row of 20 cm had highly significant ($P \leq 0.001$) effect on yield in both seasons. Based on the results of this study, it is recommended to use disc harrow for land preparation and plant sugar beet at an inter and intra- row spacing of 60 and 20 cm.

INTRODUCTION

Sugar Beet (*Beta vulgaris* L.) is one of the most important sugar producing crops after sugar cane in the world. It is grown in a wide range of temperatures. It is a biennial plant with a large storage root (1-2 kg) and a high amount of sucrose (15%-20%). Sugar beet accounts for 30% of the world's sugar production (Jafari *et al.*, 2006).

Tillage is used to improve the physical characteristics of the soil in order to provide favorable conditions for crop growth. Some of tillage objectives are to produce suitable tilth or soil conditions and weed control. Sharma *et al.* (1988) reported that tillage significantly decreased soil penetration resistance and bulk density of the surface soil layers. Disc harrows are used to prepare sugar beet seedbeds. Larney *et al.* (1988) 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, disc harrows were just as efficient and could produce an even larger proportion of fine aggregates.

The crop is grown widely under irrigation in the subtropics in addition to being grown in temperate and dry areas of the world. It requires a soil that is not stony or clayey. It has a relatively high tolerance to saline and alkaline soils and has relatively low water requirements. The growing period is relatively long, normally from 140 to 160 days. The gross yield of sugar beet is 40 to 60 ton/ha, sugar ratio in the root is often greater than 15% of fresh weight. Under certain conditions fresh yields of up to 70 to 80 tons/ha, are obtained. The most important producing countries are; France, USA and Germany (Abdelhadi *et al.*, 2008).

Sugar beet is grown as an annual crop and propagated by seed. It has a thickened taproot that accumulates sugar. Under tropical conditions, the growth period is about six months. This makes it possible to grow two crops per year. It should be kept in mind that sugar beet requires crop rotation in which sugar beet is recommended to be grown in the same land only once every three years to prevent pests and diseases (Wolter and Leo, 2010).

In the tropics, sugar beet is still a crop of marginal potentiality. It has been grown in higher regions or in dry or saline conditions where sugarcane is not an option (Wolter and Leo, 2010). The world average yield of sugar beet is 46 tons/ha. For the new Syngenta

varieties, yields from 60 to 80 tons/ ha are expected, corresponding to 9.5 to 14 tons of sugar, and equivalent to 5000 to 7500 liters of bioethanol (Wolter and Leo, 2010).

In the Sudan, preliminary trials on sugar beet showed a successful crop growth in the Gezira environment (Ahmed, 2003). The crop water requirement in Gezira was estimated at 600 to 750 mm for the growing season by Abdelhadi *et al.* (2008).

The Sudan has six sugarcane factories, five of them are governmental owned, namely, New Halfa, Elguneid, North West Sinnar, Assalaya and White Nile, whereas the sixth is Kenana Sugar company. However, these factories do not satisfy Sudan needs of sugar, therefore, there is a need to increase sugar production for self satisfaction.

Sugarcane is the main sugar crop in the Sudan. However, it needs more operations for land preparation (tillage, leveling and planting). Sugarcane is grown in Vertisols and needs more water. Sugar beet is sometimes grown in the same areas of sugarcane. This is important because the production season of sugar factories will be increased.

Adaptation of sugar beet to tropical conditions has been recently successful. In the Sudan, cultural practices of sugar beet need to be studied, especially the tillage. Sugar beet is sown by seeds, the minute size of seeds requires fine seedbed for good contact with soil particles to secure sufficient amount of moisture for germination. Moreover, due to high sensitivity of the crop to water logging, a suitable ridge size for quick sippage of moisture to the top is very important.

The objectives of this study were to determine the effects of tillage system and spacing on growth and yield of sugar beet in Kassala State, Sudan.

MATERIALS AND METHODS

This study was conducted at Kassala Research Station farm for two seasons during 2011-2013.

The farm lies in the semi-arid climate at intersection of latitude 15^o 28' N, longitude 35^o 24' E and an altitude of 500 masl. The soil is light with 73% silt and 23% clay. The experimental design was a split-split-plot design, with three replications. Primary tillage treatment consisted of disc harrowing (h) *versus* disc ploughing (p) as main plot. Inter- row spacing (R) (subplot) were 60,80 and 100 cm and intra- row spacing (S) (sub-sub plot) were 10, 15 and 20 cm.

Sowing dates of sugar beet were 9 December and 15 December for first and second seasons, respectively. The crop was fertilized twice where nitrogen was applied 3 and 7 weeks after sowing. The size of the main plot was 15×15m and the sub plot was 5×15m and the sub-sub plot was 5×5m. Seeds were sown in one line at inter-row spacing of 60 cm but in two line at inter-row spacing of 80 and 100 cm.

Soil clod size distribution percentage

Soil clods size distribution percentage for the primary tillage operation was determined with the use of two dimensional metallic frames (50×50×5cm). Then the loose soil within the frame was sieved by sieves of opening diameters of 0.5 and 2cm for separation of soil sample into two groups of clod size distribution. Each clod size group was weighed to determine the percentage of each group to total weight of the soil sample.

Soil bulk density and soil moisture content

To test the effects of final seed bed preparation on some soil physical properties, the soil bulk density and its corresponding soil moisture content were determined. The soil bulk density g/cm^3 and soil moisture content were taken from each sub plots and main plot for all replicates at sowing and pre sowing, respectively.

Soil bulk density was determined using the core method described by Blake, (1965) at depths of 0-15 and 15-30 cm. The core was driven vertically and very carefully by knocking with a hammer to its full depth, then carefully removed by a shovel. With the use of a flat edged knife, the soil on the cores wall was removed, weighed, oven dried at 105°C for 24 hours, then reweighed again. The oven-dry weight was divided by the initial volume of the sample to give the soil bulk density in gm cm^{-3} .

Soil moisture content was determined using the gravimetric methods described by Michael (1978). The soil samples were fresh weighed, oven dried at 105 °c for 24 hours, reweighed and then gravimetric moisture content was calculated using the following equation (Skaggs *et al.*, 1980);

$$Q_w = \frac{\text{Weight of moist soil} - \text{weight of oven dried soil}}{\text{Weight of oven dried soil}} \times 100 \quad \dots (1)$$

where:

$$Q_w = \text{Moisture content on dry basis (\%)}$$

Yield components and total yield

Yield components consisted of root length and circumference. Total yield was determined in tons/ha. Total Soluble Solids (TSS) percentages were also determined using a hand refractometer.

Statistical analysis

Data were analyzed using the standard analysis of variance (ANOVA) following Gomez and Gomez (1984) using SAS statistical computer software. Means were separated using DMRT at P = 0.05 and 0.01.

RESULTS AND DISCUSSION

Table 1 shows soil clod size distribution for the tillage operations. The result of soil clod size revealed no significant differences between the disc harrow and disc plough.

Table1. Soil clod size distribution in the two tillage operations

Treatment	Soil clod size distribution (%)		
	≤0.5cm	0.5 < and ≤2cm	>2cm
Disc harrow	70.6	15.3	14.0
Disc plough	69.6	14.5	15.0
Mean	70.2	14.8	14.5
SE±	2.16	1.43	1.47
CV%	5.3	16.9	17.6

Table 2 shows the soil moisture content (SMC%) and bulk density (g/cm^3) (BD). Result revealed no significance difference between the disc harrow and disc plough regarding was soil moisture content and bulk density. However, at 60 cm spacing there were highly significant ($P \leq 0.01$) increase in soil moisture content and decrease in bulk density compared to the 80 and 100cm spacing (Table 3). The results reported by other researchers (Khurshid *et al.*, 2006; Rashidi and Khabaz, 2009 and Iqbal *et al.*, 2005) showed that tillage practices were associated with improved soil physical and mechanical properties (increased pore space, decreased bulk density, increased moisture preservation, decreased penetration resistance, enhanced soil structure, better seed-soil/root-soil contact and superior weed control) which positively influence the root yield of sugar beet. Similar results were also reported by Romaneckas *et al.* (2006) and Jabro *et al.* (2010).

Table 2. Soil moisture content (SMC%) and corresponding bulk density (g/cm^3).

Treatment	0-15 cm		15- 30 cm	
	SMC (%)	BD (g/cm^3)	SMC (%)	BD (g/cm^3).
Disc harrow	21	1.22	23.4	1.21
Disc plough	21	1.22	24.4	1.21
Mean	21	1.22	23.9	1.21
SE (\pm)	0.28	0.002	1.63	0.005
CV (%)	13.6	1.1	24	1.7

Table 3. Soil moisture content and correspond bulk density (g/cm^3)

Spacing (cm)	0-15 cm		15-30cm	
	SMC (%)	BD (g/cm^3)	SMC (%)	BD (g/cm^3)
60	24 a	1.21 ab	27.8 a	1.19 b
80	21.6 b	1.22 ab	25.6 b	1.20 ab
100	17.5 c	1.23 a	18.3 c	1.22 a
Mean	21	1.22	23.9	1.21
SE (\pm)	1.17	0.0054	2.37	0.008
CV (%)	13.6	1.1	24	1.7

Means in columns having the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Tables 4 and 5 show the effects of tillage system, inter and intra-row spacing on yield and yield components of sugar beet for the first season and second season, respectively. The results of first season showed that (H- R60-S20) resulted in the highest fresh yield (113 ton/ ha) and root circumference (35.4 cm) compared to other treatments. The treatment (P- R60-S20) resulted in the highest root weight (1.67 kg) compared to other treatments. The parameters root length and total soluble solids were not significantly different among treatments. The results agreed with that obtained by (FAO, 2011).

Table 5 showed the results of the second season. The treatments H- R60-S20 and P- R60-S20 resulted in the highest total yield (83 and 80 ton/ ha, respectively), compared to other treatments. Also, the treatment H- R60-S20 had the highest root weight of 0.84 kg and root length of 31.6 cm compared to other treatments, but the

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treatment P- R60-S20 had the highest root circumference of 29.6 cm. Percentage total soluble solids were not significantly different among treatments.

The treatment H-R60cm-S20 cm recorded higher fresh yield than treatment P- R 60 cm-S20 cm by 9% to 4% for the first and the second season, respectively. The disc harrow was better than the disc plough for land preparation for sugar beet in light soil. These results agree with those reported by Majid (2011) who showed similar the responses of root yield and yield components of sugar beet to different tillage methods.

Table 4. Effects of tillage system, inter and intra-row spacing on yield and yield components and total yield of sugar beet in the first season.

Treatment	Yield (ton/ha)	Root wt (kg)	Root circ. (cm)	Root length (cm)	TSS (%)
P- R 60-S10	65 d	1.01 b	30.6 ab	31.3	17.5
P- R 60-S15	100 abc	1.40 ab	31.6 ab	32.6	17.4
P- R 60-S20	103 ab	1.76 a	32.2 ab	33.8	16.5
P- R 80-S10	40 f	0.73 d	22.4 f	26.7	18.1
P- R 80-S15	47 ef	0.80 c	23.6 e	27.0	18.6
P- R 80-S20	52 e	1.06 b	25.4 c	29.2	18.6
P- R 100-S10	47 ef	0.63 d	22.3 f	29.0	16.2
P- R 100-S15	53 e	0.80 c	24.6 d	30.2	16.9
P- R 100-S20	70 d	1.03 b	30.0 ab	30.6	17.0
H- R 60-S10	76 b	1.06 b	27.6 b	30.1	16.2
H- R 60-S15	91 abc	1.03 b	29.5 ab	34.2	17.6
H- R 60-S20	113 a	1.53 ab	35.4 a	34.6	17.4
H- R 80-S10	45 ef	0.60 d	22.9 f	33.7	17.0
H- R 80-S15	56 e	0.83 c	27.6 b	32.6	17.1
H- R 80-S20	55 e	1.16 b	31.2 ab	31.3	17.4
H- R 100S10	51 e	0.63 d	25.0 c	30.2	18.4
H- R 100-S15	60 ef	0.80 c	27.4 b	30.7	18.2
H- R 100-S20	72 c	1.03 b	29.4 ab	29.2	17.0
Mean	66	0.99	27.7	31	17.5
SE (\pm)	3.53	0.05	0.67	0.55	0.67
CV (%)	23.0	32.7	12.5	12.4	6.0

Means in columns having the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Table 5. Effects of tillage system, inter and intra-row spacing on yield and yield components on sugar beet of second season.

Treatment	Yield (ton/ha)	Root wt (kg)	Root cir. (cm)	Root length (cm)	TSS (%)
P- R 60-S10	66.6 b	0.35 d	22.3 c	28.0 ab	21.6
P- R 60-S15	74.3 ab	0.41 c	23.6 abc	27.3 ab	23.0
P- R 60-S20	80.3 a	0.81 ab	29.6 a	26.3 ab	23.6
P- R 80-S10	59.1 d	0.32 d	23.0 b	27.0 ab	24.0
P- R 80-S15	60.5 c	0.50 c	24.3 abc	29.0 ab	22.3
P- R 80-S20	72.7 abc	0.67 b	23.6 b	28.3 ab	22.0
P- R 100-S10	53.8 e	0.35 d	21.0 d	28.0 ab	21.0
P- R 100-S15	52.0 f	0.41 c	22.0 c	27.3 ab	23.6
P- R 100-S20	64.9 b	0.55 bc	25.0 abc	29.0 ab	22.0
H- R 60-S10	70.8 abc	0.51 c	24.0 abc	31.3 a	20.0
H- R 60-S15	79.6 a	0.48 c	26.3 abc	31.6 a	20.6
H- R 60-S20	83.1 a	0.84 a	29.0 ab	31.6 a	21.0
H- R 80-S10	47.2 g	0.31 e	23.3 b	28.6 ab	21.6
H- R 80-S15	56.6 e	0.47 c	23.0 b	28.3 ab	21.3
H- R 80-S20	63.3 b	0.60 b	26.6 abc	24.6 b	21.3
H- R 100-S10	44.2 g	0.50 c	27.0 ab	26.3 ab	20.3
H- R 100-S15	54.1 e	0.54 c	27.3 ab	26.0 ab	20.6
H- R 100-S20	59.7 c	0.47 c	28.6 ab	26.0 ab	21.0
Mean	63.50	0.49 c	25.00	28.00	21.70
SE(±)	1.70	0.26	0.24	0.43	0.28
CV (%)	11.0	28.5	12.7	11.1	8.78

Means in columns having the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

RECOMMENDATION

It is recommended to use disc harrow for land preparation for sugar beet and sow the crop at an inter- and intra-row spacing of 60 cm and 20 cm, respectively.

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