



Effects of Intra-Row Spacing on Yield and Yield Components of Sugarcane (*Saccharum spp. hybrid*) Varieties at Omo Kuraz, Southern Ethiopia

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Abstract

Sugarcane stalk population is a key determinant of cane yield and knowing the right intra-row spacing is a critical factor in sugarcane production for a given environment. Therefore, a field experiment was conducted at Omo Kuraz Sugar Estate during the 2018/ 2019 cropping season to determine the effect of intra-row spacings (5 cm overlapping, end-to-end, 5 cm spacing between setts and 10 cm spacing between setts) on growth, yield, yield components and quality parameters of sugarcane varieties (N14, Mex54/245 and C86/112). The treatments were arranged in a split-plot design with three replications. Varieties were represented as the main plot whereas setts spacing treatments were assigned to sub-plots. Analysis of variance revealed that the intra-row spacing effect didn't show a significant difference in the number of tillers, plant population, millable cane, cane yield, sugar yield, and Brix percent whereas significant ($P < 0.05$) differences were observed in stalk height, stalk girth, number of internodes and weight per stalk. Therefore, the 10 cm intra-row spacing of three budded setts can be recommended for better productivity and profitability of N14 and Mex54/245 varieties at the Omo Kuraz Sugar factory.

Keywords: Cane sett; Cane yield; Recoverable sucrose; Sugar yield.

1. Introduction

Sugarcane (*Saccharum spp. hybrid*) is an important industrial crop propagated vegetatively under commercial production [1] which is grown over the sub tropics (land surface of the earth) between latitude 30° N and 35° S [2].

Due to its multifarious advantages coupled with the immense potential available for its cultivation, Ethiopia has given due focus for the crop to boost production and export for world market [3] through expanding the existing factors and establishing several new large sugar factories including Omo Kuraz Sugar Project.

Productivity and profitability of sugarcane production largely depends on intra-row spacing, nature of varieties considered for production and growing environment [1, 4-8]. Moreover, proper planting technique of sugarcane is pre-requisite to enable the crop plants to fully utilize environmental conditions and to exhibit their optimum potential [9] whereas improper intra-row spacing, set position and seeding density are the most critical factors reducing sugarcane yield [10, 11]. Scanty information is available regarding optimum level intra-row spacing for widely produced varieties in the study area. Hence, this study was aimed to determine the best intra-row spacing for better productivity and profitability of sugarcane production in Omo Kuraz sugar project.

2. Materials and Methods

2.1. Description of Study Area

The experiment was conducted during 2018/19 crop season at Omo Kuraz Sugar project area, which is located between 5° 8' 18" – 6° 16' 59" latitude and 35° 43' 37" - 36° 13' 54" longitude in South Nations, Nationalities and Peoples Regional State, of Ethiopia, about 918 km S of Addis Ababa and its elevation ranges from 370 – 500 m.a.s.l. The mean minimum and maximum air temperatures are 23.5 °C and 35.7 °C, respectively. The area has also annual rainfall of 714.24 mm. Selected physicochemical properties of soil of the study site is presented in Table 1.

Table-1. Selected physicochemical properties of soil of the study area (0-30)

Physical properties				
Sand (%)	Silt (%)	Clay (%)	Textural class	Bulk density (g/m)
12	10	78	Clay	1.55
Chemical properties				
Total nitrogen (%)	Organic carbon (%)	pH (1:2.5)	EC (ds/m)	CEC (Cmol/Kg)
0.05	1.69	8.56	0.20	54.49
Available Phosphorus (mg/kg)	Exchangeable base (Cmol (+) /Kg)			
	Ca	K	Mg	Na
6.61	36.8	1.84	14.8	1.05

2.2. Land Preparation of the Experimental Field

Land preparation was done using tractors (Heavy duty and light duty tractors) with different implements. The field was selected, cleared, ploughed, disked, leveled and furrowed properly 5 days before planting, pre-planting irrigation was given and furrow slope correction was done according to the gravity of irrigation water. After leveling the plots, furrows were also prepared at a spacing of 145 cm between rows.

2.3. Seed Cane Preparation and Planting

After furrow correction, seed canes from well fertilized crop with good growth performance, free from disease were selected and prepared for each variety. Three-budded cane setts having viable buds were prepared from 8-month old healthy cane stalks. Dettol Antiseptic Disinfectant 4.8% w/v concentrate was used as a Knife disinfectant during cutting and chopping in 1:20 ratio with water for protection of disease transmission. One disinfected knife was used to chop a single stalk.

After the setts were prepared, planting was done by placing the three budded setts in the furrows with four setts spacing, covering them at 2.5-5 cm depth and placing buds of all setts parallel to prevent them from exposure to sun and from delaying to germination.

2.4. Treatments and Experimental Design

The treatments consisted of three sugarcane varieties (N14, Mex 54/245 and C86/112) and four levels of intra-row setts spacing (5 cm overlapping setts, end to end setts, and 5 cm, and 10 cm space between setts). The varieties were selected based on their high yielding potential and area coverage in the Omo Kuraz sugar estate. The experiment was conducted in split plot design with three replications. Varieties were assigned to main plot while intra-row setts spacing was assigned to subplots. Area of each experimental plot was 52.2 m² (six furrows of 6 m length and 1.45 m width) and data was collected from the middle rows of net area 34.8 m² (four rows of 6 m length and 1.45 m width). The distance between adjacent plots and replications were 1.50 and 2.90 meters, respectively. All management practices were uniformly applied to each plot as per recommendations except the treatments.

2.5. Data Collection and Analysis

Data were collected on cane weight, cane girth, tiller number, number of cane forming stalks, number of millable canes, number of internodes, cane length, estimated cane yield, juice quality characters including brix percent, sucrose /pol percent/, juice purity, recoverable sucrose (%) and sugar yield (t/ha) following standard procedures. Data were analyzed using the PROC GLM procedure using SAS 9.0 statistical package. Means were compared based on LSD (Least significance difference) test using Genstat (17th Edition) for parameters significantly influenced by the treatments.

2.6. Economic Analysis

The cost of pertinent variable inputs and the crop management cost, were worked out for economic analysis of the experiment. Seed cane production, preparation and transportation costs were taken as variable costs while prevailing market value of sugar at harvesting stage of the crop was estimated to 10 Ethiopian Birr kg⁻¹. Estimated sugar yield was adjusted down to 10%. For economic analysis, partial budgeting technique described by CIMMYT International Maize and Wheat Improvement Center [12] was followed.

3. Results and Discussions

3.1. Effect of Intra Row Spacing on Sugarcane growth Parameters

3.1.1. Cane Weight

Cane weight was significantly influenced only by the main effects of variety and intra row spacing (Table 2). The highest significant (16.0) and lowest significant (13.83) values of cane weight were recorded in N14 and C86/112 varieties, respectively.

Planting setts at 10cm gap (15.67 kg/stalk) and 5cm gap (15.33 kg/stalk) showed statistically similar and higher cane weight compared with the remaining intra-spacing treatments. The minimum significant cane weight was observed due to planting of setts at 5cm overlapping.

talk [13, 14].

The variation in cane weight due to variety effects might be associated with genetic nature of the tested varieties. The significant increment in cane weight with an increase in intra row spacing could be related to better availability of growth resources which promotes thickness of s

3.1.2. Cane Girth

Cane girth was also significantly influenced only by the main effects of variety and intra row spacing (Table 2). Accordingly, N14 and C86/112 varieties showed statistically similar and higher cane girth values compared with Mex54/245 variety. Increasing intra-row spacing was significantly associated with improvement in cane girth (Table 2). 5cm overlapping and 10cm gap planning resulted in minimum (2.49cm) and maximum (2.71cm) values of cane girths, respectively.

The variation in cane girth among varieties might be related to genetic nature of varieties and growing environment. On the other hand, the increment in cane girth with an increase in intra row spacing could be attributed to the availability of growth resources and lesser competition among plants like light, minerals and water under wider intra- row spacing [5, 15, 16].

Table-2. Main effects of variety and intra-row spacing on can weight and cane girth

Variety	Cane weight (kg/ stalk)	Cane girth (cm)	Spacing (cm)	Cane weight (kg)/stalk)	Cane girth (cm)
N14	16.00 ^a	2.68 ^a	5cm overlapping	14.00 ^c	2.486 ^c
Mex54/245	15.08 ^b	2.35 ^b	End to end	14.89 ^b	2.540 ^{bc}
C86/112	13.83 ^c	2.71 ^a	5 cm gap	15.33 ^{ab}	2.591 ^b
Grand Mean	14.89	2.58	10cm gap	15.67 ^a	2.706 ^a
SE (±)	0.197	0.016	Grand Mean	14.97	2.58
LSD (5%)	0.58	0.05	SE (±)	0.227	0.018
CV (%)	4.60	3.50	LSD (5%)	0.67	0.05
			CV (%)	4.56	2.14

Within a column means followed by the same letter are not significantly different at $P < 0.05$ level of significance using Tukey's Studentized Range (HSD) Test. SE (±) = standard error, LSD = least significance difference, CV = coefficient of variation

3.1.3. Interaction Effects of Treatments on Yield and Yield Components of Sugarcane Varieties

Tiller number, cane forming stalk, millable cane, number of internodes and cane length were significantly influenced by the interaction effect of intra-row spacing and variety (Table 3).

3.1.4. Number of Tillers

Planting N14 at 5cm overlap, end to end and 10 cm gap produced significantly higher number of tillers over the remaining treatment combinations (Table 3). On the other hand, the minimum number of tillers (72988.69) was obtained from planting of C86/12 variety at end to end planting. The variation in tiller number due to interaction effect of treatments showed that tiller number is the function of both genetic variation and density of planting material.

3.1.5. Cane Forming Stalk

Planting N14 variety at all intra-row spacing levels showed statistically similar and higher number of can forming stalks compared with values obtained from the other treatment combinations (Table 3). Contrarily, the minimum number of cane forming stalks (72605.33) was obtained from planting of C86/12 variety at end to end spacing. The variation in cane forming stalk due to variety effects might be associated with genetic makeup of the variety as reported by Netsanet, *et al.* [13], who reported that plant population, was a function of varieties and sett spacing effect. The significant increment in cane forming stalk with an increase in intra row spacing could be also be resulted from the availability of growth resources like soil, light, air and space in wider intra-row spacing.

3.1.6. Number of Millable Cane/ha

Similar to cane forming stalk, planting of N14 variety at all intra-row spacing levels showed statistically similar and higher number of millable cane/ha compared with values obtained from the other treatment combinations. On the other hand, the minimum number of millable cane/ha (72605.33) was obtained from planting of C86/12 variety at end to end space planting.

The variation in number of millable cane due to interaction effect of variety might be associated with genetic makeup of the variety [17] which results in their differential response to sett spacing.

3.1.7. Number of Internodes

Planting N14 variety at 5cm overlapping and Mex54/245 variety at 5cm overlapping, end to end and 5cm gap showed statistically similar and higher number of internodes compared with the values obtained from other treatment combinations. In contrast, the minimum number of internodes (20.17) was observed in N14 variety at 10cm gap space planting. The variation in number of internodes due to interaction effect of the treatments could be attributed to increased length of cane due to competition for light under narrow intra-row spacing [5, 18].

3.1.8. Cane Length

Planting of N14 variety at all intra-row spacing levels, except at 10cm gap, and Mex54/245 variety at all intra-row spacing gave statistically similar and longer canes compared with the resulted observed from the effect of other treatment combinations. Numerically, the shortest (204.9cm) canes were resulted from planting of C86/12 variety at 5cm overlapping spacing.

The significant increment in cane stalk length with a decrease in intra row spacing among the varieties could be related to lesser availability of growth resources like light. This indicated that sett spacings had an impact on the growth of cane stalk. The result is in agreement with the observation of Irvine and Brenda [19]; Habib, *et al.* [20]; Pate, *et al.* [16] and Netsanet, *et al.* [5] who indicated that, mean stalk height increased with a decrease in intra row spacing and decreased with an increase in intra-row spacing, suggesting the existence of intra-row competition for light under high plant population

Table-3. Interaction effects of intra-row spacing and variety on number of tillers and cane parameters

Treatment combinations		Number of tillers	Cane forming stalk	Number of millable cane per ha	Number of internodes	Cane length(cm)
Variety	Intra-row spacing					
N14	5cm overlapping	167816.00 ^a	132183.67 ^a	124521.00 ^{ab}	24.37 ^{abc}	251.93 ^{ab}
N14	end to end	177490.33 ^a	132471.33 ^a	130938.67 ^a	21.67 ^{de}	249.93 ^{ab}
N14	5cm gap	124808.70 ^b	118965.67 ^{ab}	119061.33 ^{abc}	21.57 ^{de}	249.30 ^{ab}
N14	10 cm gap	186590.30 ^a	130747.30 ^a	129214.3 ^a	20.17 ^e	224.37 ^c
Mex 54/245	5cm overlapping	115613.00 ^{bc}	93774.00 ^c	102873.67 ^{bcd}	26.80 ^a	263.16 ^a
Mex 54/245	end to end	114099.67 ^{bc}	99617.00 ^c	99617.00 ^{cde}	26.20 ^{ab}	259.97 ^{ab}
Mex 54/245	5cm gap	116092.00 ^{bc}	89272.33 ^c	78735.67 ^{ef}	24.47 ^{abc}	256.070 ^{ab}
Mex 54/245	10 cm gap	95210.68 ^{cd}	92624.33 ^c	96168.67 ^{cdef}	24.33 ^{bcd}	255.60 ^{ab}
C86/12	5cm overlapping	93774.00 ^{cd}	85249.00 ^{cd}	88122.67 ^{def}	22.17 ^{cde}	204.90 ^d
C86/12	end to end	72988.69 ^d	72605.33 ^{bc}	72605.33 ^f	21.83 ^{cde}	220.03 ^c
C86/12	5cm gap	105314.00 ^{bc}	88314.33 ^c	93008.00 ^{def}	21.57 ^{de}	216.87 ^{cd}
C86/12	10 cm gap	96839.00 ^{cd}	84386.67 ^{cd}	86398.33 ^{def}	21.17 ^e	205.03 ^d
LSD		8176.2	6745	7223.35	0.71	3.01
SE (±)		4906.13	4139.28	4524.39	0.47	2.28
CV (%)		6.95	7.06	7.70	3.56	1.66

Within a column means followed by the same letter are not significantly different at $P < 0.05$ level of significance
SE (±) = Standard error, LSD = least significant difference, CV (%) = coefficient of variation in percent

3.2. Varietal Variations in Quality and Yield Parameters

Among the measured quality and yield parameters in this study, brix (%), Pol (%), estimated cane yield and estimated sugar yield were significantly influenced only the main effects of variety and the data are presented as presented in Table 4 except for non-significantly affected parameters, Maximum (19.33%) and minimum (18.23%) values of brix (%), were recorded due to N14 and C86/112, respectively. N14 variety also showed higher value of pol (17.30%) which was statistically similar pol (%) observed in Mex54/245 variety.

Regarding estimated cane yield and sugar yield, N14 variety gave maximum significant estimated cane yield (201.47 t/ha) and estimated sugar yield (24.35t/ha) which is in agreement with the report of Terefe [21] whereas the remaining two varieties showed statistically similar and lower estimated cane and sugar yields compared with N14 Variety.

The absence of significant variation in brix percent and pole percent due to main effect of intra row spacing and its interaction with sett spacing might be associated with the fact that brix level is strongly related with its genetic makeup of varieties rather than management practices including intra row spacing which is in agreement with the finding of Netsanet, *et al.* [6] and [5].

The variation in estimated cane and sugar yields between varieties might be related to genetic nature of the varieties and growing environment. Estimated sugar yield showed positive and highly significant ($P < 0.01$) linear relationship with number of tillers ($r = 0.88^{**}$), cane forming stalk ($r = 0.95^{**}$), millable cane ($r = 0.96^{**}$), cane weight ($r = 0.80^{**}$), brix percent ($r = 0.35^{**}$), pol percent ($r = 0.78^{**}$) and estimated cane yield ($r = 0.99^{*}$) implying that improvement in these parameters due to treatments effects particularly varietal nature is associated with enhancement of estimated sugar yield.

Table-4. Quality and yield characteristics of the varieties

Variety	Brix (%)	Pol (%)	Estimated cane yield (t/ha)	Estimated sugar yield (t/ha)
N14	19.33 ^a	17.30 ^a	201.47 ^a	24.35 ^a
Mex54/245	18.79 ^b	16.80 ^{ab}	142.21 ^b	16.57 ^b
C86/112	18.23 ^c	16.33 ^b	117.35 ^b	13.26 ^b
Grand Mean	18.78	16.81	153.68	18.02
SE (±)	0.12	0.22	8.75	1.12
LSD (at 5%)	0.35	0.65	25.67	3.27
CV (%)	3.80	8.20	24.37	24.52

Within a column means followed by the same letter are not significantly different at $P < 0.05$ level of significance

3.3. Economic Analysis

Result of the economic analysis of the present experiment showed that dominated treatment combinations were eliminated from further consideration because their net benefits less than those of a treatment combination with lower costs that vary (Table 5). Accordingly, maximum net benefit (223544 Ethiopian Birr/ha) was obtained from planting of N14 variety at 10cm gap spacing followed by value recorded due to planting Mex84/245 at the same intra- row spacing. Contrarily, maximum marginal rate of return (543.70%) was resulted from planting of Mex84/245 variety at 10 cm gap spacing followed by values observed in N14 variety plant at the same spacing.

Table-5. Marginal rate of return on the evaluation of sugarcane varieties response to different sett spacing levels

Treatment combination	ESY (t/ha)	Adjusted Yield (t/ha)	Gross benefit (EthB/ha)	Variable cost (EthB/ha)	Net Benefit (EthB/ha)	MRR (%)
Mex84/245/ 10 cm gap spacing	18.19	16.55	165529	3886	153193	543.70
N14/ 10 cm gap spacing	24.67	23.61	236054	4060	223544	121.20

ESY= estimated sugar yield, EthB= Ethiopian Birr, MRR= marginal rate of return

4. Conclusion

Agronomic researches should aim at identifying appropriate practices which can improve sugarcane productivity thereby increasing profitability of sugar industry in a given environment. Based on the current study, it is possible to conclude that planting N14 and Mex84/245 varieties at 10 cm gap spacing would enable growers to harvest better sugar yield and profit at Omo Kuraz sugar project and other similar environments. Since this study was conducted in single location under one season, further research should be undertaken considering additional varieties and sett spacing treatments in order to produce complete recommendations.

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