Effect of Intra-row Sett Spacing on Yield and Yield Components of Sugarcane Varieties at Metahara Sugar Estate

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Abstract: Sugarcane stalk population is a key determinant of cane yield. However, increasing cane stalk population requires denser planting, which incurs additional costs of planting material. Therefore, an experiment was conducted at Metahara Sugar Estate plantation from 2005-2010 to determine the effect of four intra-row sett spacing [10 cm between setts, 5 cm between setts, setts placed end-to-end, and setts placed ear-to-ear (5 cm overlapping)] on the performance of three sugarcane varieties (B52298, NCo334 and B41227). The experiment was carried out on class II (light) and class IV (heavy) soils in a split plot design. Combined analysis of the data over soils indicated that sucrose percent of cane, cane yield, and estimated sugar yield did not show significant differences in response to spacing as well as due to the interaction effect of spacing and variety. However, the number of millable canes at harvest was significantly ($P \leq 0.01$) affected by the main effect of spacing for the plant cane and mean of crops (plant cane and ratoons). Ten (10) cm intra-row spacing between setts was found to be best to use since it economized planting material of all three sugarcane varieties without compromising both cane and sugar yields.

Keywords: Ear-to-ear; Intra-row Spacing; Plant Cane Crop; Ratoon Crop; Sett Spacing; Sugarcane

1. Introduction

Sugarcane (*Saccharum officinarum* L.) is an important industrial crop propagated vegetatively under commercial production (Verma, 2004) and its yield is affected primarily by the stalk population. According to Roach (1976), cane yield is a function of stalk population, cane height and cane weight, where stalk population accounts for nearly 70% of the variation in cane yield. Therefore, stalk population is the key component in determining cane yield (Roach, 1976) and is affected primarily by the density of planting (Ahmed and Khaled, 2008). According to Collins (2002), sugarcane planting density is a function of inter and intra-row spacing, in addition to varietal differences (Sundara, 2000) and environmental conditions (Amolo and Abayo, ND; Verma, 2004).

In many sugarcane-growing countries, it is common to use high density planting through planting canes setts by partially overlapping them (Faucconier, 1993; Verma, 2004). The amount of setts required for planting a unit area depends on the way the cane sets are arranged in the furrow during planting. The importance of optimal planting density is to obtain optimum sprouts for an adequate initial stand establishment. High density planting results in higher cane population with weak and thinner stalks (Rao, 1990). Furthermore, high density planting reduces the number of tillers produced per planting material due to mutual shading and competition for light, nutrients and water (Verma, 2004). On the other hand, sub-optimal density planting results in a loss of yield due to inefficient use of the land space (Azhar *et al.*, 2007).

The use of large numbers of planting materials incurs high costs to sugar estates resulting in shortages of planting materials to cover commercial fields planned-annually for planting. The use of large numbers of planting material also leads estates to allocate large areas of land to seed cane production, which competes for fertile land that could be used for production of crop for milling. This is because partial overlapping (ear-to-ear) method of propagation requires large quantities of planting materials to cover a unit area (Verma, 2004). Therefore, optimization of planting density is vital for sugarcane production due to its effect on stalk population, which is an important component of yield.

Studies in other countries indicated that with low density planting, it was possible to minimize the planting material required per unit area. An experiment conducted on plant cane and ratoon cane with pre-seasonal planting indicated that cane girth, number of millable canes per clump and average cane weight were significantly ($P \leq 0.01$) higher at the intra-row spacing of 90 cm rather than at the intra-row spacing off 30 cm and 60 cm (Raskar and Bhoi, 2003). This indicated that naturally sugarcane has the capacity of tillering and compensating for population densities and maintaining potential yields under different plant spacing.

Metahara Sugar Estate uses ear-to-ear (5 cm overlapping) alignment of two budded setts within a furrow at the time of planting and even denser planting due to fears of failure of the sett buds to sprout. Previous studies conducted in Ethiopian sugar estates have indicated the possibilities of reducing planting material through manipulation of sett alignments and spacing. Results of an experiment conducted on plant cane crop

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on two soil types at Wonji-Shoa Sugar Estate using three varieties (B52298, B41227 and NCo334) with five different sett spacing (10 cm overlapping, 5 cm overlapping, end-to-end, 5 and 10 cm spacing between setts) indicated that there were significant ($P \leq 0.01$) differences among the varieties in most of the characters studied (Tsehay, 1993). However, the studies indicated that none of the intra-row spacing of setts resulted in significant differences in cane and sugar yields Similarly, a study conducted at Finchaa Sugar Estate in Central Western Ethiopia using different planting densities (5 cm overlapping, end-to-end, double and double + end-to-end alternatively) for the varieties B41227, B52298, Co449 and NCo334 indicated that the four planting densities had non-significant ($P \geq 0.01$) differences in the main sugarcane yield parameters and the ultimate sugar yield of the plant cane (Girma, 1997). Furthermore, the study indicated the possibility of reducing the amount of seed cane from 21-33%, by shifting from the 5 cm overlapping to end-to-end (butt-to-butt) alignment.

However, all of the studies conducted earlier in the country did not show the residual effect of different planting densities on the succeeding ratoon crops, and concentrated only on the plant crop. This casts doubts on the use of low density planting for commercial production due to fear of declining ratoon cane yields, which covers more than 73.1% of the annual cane harvested area of the estates (MSF, 2012). Furthermore, no appreciable work has been done on density of planting at Metahara. Therefore, this study was conducted to evaluate the effects of different intra-row spacing on both plant and ratoon sugarcane yields.

2. Materials and Methods

2.1. Site Description

Metahara Sugar Estate is located in the Rift Valley region of Ethiopia at latitude of 8^0 51' N and longitude of 39^0 52' E with an elevation of 950 meters above sea level. The area has a mean annual maximum temperature of 32.6 ^{0}C and a mean annual minimum temperature of 17.5 ^{0}C. The area has a mean annual rainfall of 554 mm. The experiment was conducted from 2005-2010 on plant cane and two successive ratoon crops.

2.2. Treatments and Experimental Design

The treatments consisted of four intra-row spacing [10 cm between setts, 5 cm between setts, setts placed end-to-end and setts placed ear-to-ear (5 cm overlapping)]. The last spacing mentioned here was used as a check since it is the spacing conventionally used by the Sugar Estate. The sugarcane varieties used were B52298, NCo334 and B41227. The study was carried out on Class II (light) and Class IV (heavy) soils (Anonymous, 2009) and three crop types viz-; plant cane (PC), first ratoon (RI) and second ratoon (RII). The sugarcane varieties were selected for their high yielding potential and large area coverage in the Sugar Estate.

The experimental design was split-plot with three replications. The main plots and sub plots were sugarcane varieties and intra-row spacing of setts, respectively. The size of each experimental plot was 29 m^2 (four furrows of 5 m length and 1.45 m width). The distance between adjacent plots and replications were 1.5 and 2.9 meters, respectively. The plant cane crop was raised using healthy stalk planting materials selected from an 8 month-old seed cane field for planting. Ammonium sulphate nitrate (26% N) fertilizer was applied as a source of nitrogen. The fertilizer was applied at the rates of 400, 500 and 650 kg ha^{-1} for the plant cane, first ratoon crop and second ratoon crop, respectively. Furthermore, a foliar application of ferrous sulphate ($FeSO_4$) was done at the rate of 30 kg ha^{-1} with a spray volume of 300 L ha^{-1} for the ratoons as soon as iron deficiency symptoms were detected in the 2nd week after harvesting. Weeds were removed manually as required until full canopy coverage was attained. Irrigation was provided according to the norm of the Estate.

2.3. Data Collection and Measurement

Plant population count data were recorded starting from the 4th month of planting until the plant age of 8 months. The number of millable canes in each plot was counted at the age of 10 months. An average cane weight of 20 stalks was taken per plot at harvest.

For cane quality analysis, juice was extracted from 10 stalk samples using a sample mill. Percent recoverable sucrose (*rendiment*) was calculated using the Winter Carp indirect method of cane juice analysis (Kassa, 2010):

Rendiment (%) = [pol percentage - (percent brix – percent pol) non-sugar factor]*cane factor

In this calculation, the non-sugar factor was 0.70. The cane factors used both for the varieties B52298 and NCo334 were 0.75, 0.75 and 0.73 for the three crops (plant cane, first ratoon and second ratoon), respectively. However, for the third variety B41227, the factors were 0.76, 0.75 and 0.72, respectively, for the three crops (plant cane, first, and second ratoons).

Cane yield was taken from the middle two rows and calculated on a hectare basis. Then, commercial sugar yield per hectare was calculated as follows:

$$ESY\ (t/ha) = CYH\ (t/ha)\ x\ \mathrm{E}RS\ (\%)$$

where ESY is estimated sugar yield, ERS is estimated recoverable sucrose (%) and CYH is cane yield per hectare The cane and sugar yields were described as suggested by Sweet and Patel (1985) according to the COTCHM method (corrected tones cane per hectare per month).

Finally, the data collected were subjected to analysis of variance using SAS software (SAS Institute, 2002).

Comparisons among treatment means with significant differences for the measured and counted parameters were done based on the Duncan Multiple Range Test (DMRT).

3. Results and Discussion

3.1. Plant Population Dynamics

The results on plant population dynamics showed a sharp declining trend (Figure 1). In the plant cane, earthing-up drastically affected plant population. This may be because heavy earthing-up apparently buried small tillers and checked further formation of new tillers. This practice did not modify the differences between sett spacing treatments. Generally, after earthing-up, the population remained more or less stable indicating minimum rates of stalk mortality. In agreement with this result, Sundara (2000) also stated that earthing-up checks further tillering.

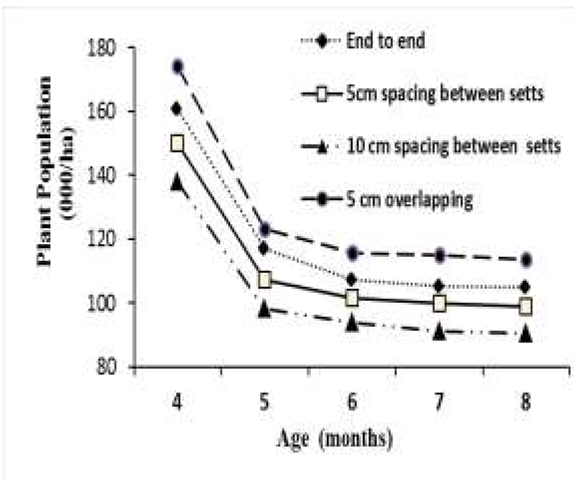


Figure 1. Mean sugarcane plant population dynamics as influenced by sett spacing at the Metahara Sugar Estate.

3.2. Effect of Intra-row Spacing on the Number of Millable Canes

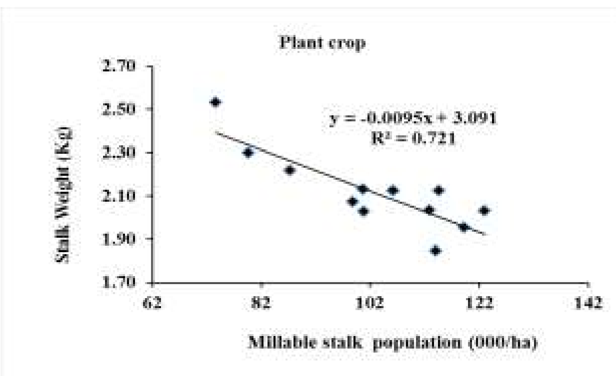
Combined analysis of the data over the two soil types revealed that the main effect of spacing significantly ($P \leq 0.01$) affected the number of millable canes of the plant cane crop as well as the mean values of the plant and the ratoon crops. The results revealed that high density planting (ear-to-ear) significantly (($P \leq 0.01$)) outperformed the low density planting in terms of the number of millable stalks of the plant crop (Table 1). However, in the first and second ratoon crops, there were no statistically significant($P \geq 0.01$) differences among the spacing treatments in terms of the number of millable canes produced (Table 1). This may be attributed to formation of more number of stalks in the plant cane for the high density planting than in the ratoon crops, which might have enhanced proliferation of more tillers (Raskar and Bhoi, 2003). Consistent with the results of this study, Bashir *et al.* (2000) reported that there was a positive relationship between seeding density and plant population of sugarcane. In the first and second ratoons, no significant differences were observed in the number of millable canes. This could be ascribed to growth of higher number of tillers in the wide-spaced ratoon crops owing to the presence of well-established stools containing ample underground buds compared to the number of buds present in the plant cane.

The correlation analysis of millable stalk populations at harvest with mean cane weight for plant cane and mean of the crops (plant cane and ratoons) showed a highly significant ($P \leq 0.01$) negative correlation. The Pearson correlation coefficients for the plant cane and mean of the crops (plant cane and ratoon cane) were $r = -0.85$ and -0.88, respectively, indicating strong negative correlations between millable stalk population density and stalk weight (Figure 2). Concurrent with the current finding, Ehsan *et al.* (2011) reported an inverse relationship between planting density and mean cane weight. This could probably be attributed to less stiff intra-plant competition for growth factors among the widely spaced plants than the plants spaced densely. The difference in stalk weight at least in part could be accounted for by sett spacing, which might have resulted in the significant variations in the stalk population. Consequently, treatments with more stalk populations produced stalks with lower weight. This could also be linked to the direct relationship between tiller population before earthing-up and millable stalk numbers at harvest, which had a positive and significant ($P \leq 0.01$) correlation ($r = 0.79$) (Figure 3).

Table 1. Main effects of soil, variety and spacing on the number of millable canes, cane yield, percent sucrose cane and estimated sugar yield at Metahara from 2005-2010.

Source of variation	Number of millable cane (000 ha^{-1})				Cane yield (t ha^{-1} m^{-1})			
	PC	RI	RII	Mean	PC	RI	RII	Mean
Soil (So)								
Light (Class II)	106.7[a]	119[a]	100	109[a]	12.4[b]	14.1[a]	12.4	12.9
Heavy (Class IV)	97.4[b]	94[b]	94.6	95[b]	15.5[a]	11.1[b]	12.7	13.1
LSD (5%)	**	**	Ns	**	**	**	Ns	Ns
Variety (V)								
B52298	110[a]	97.4[b]	93.2[b]	100[b]	13.3	11.6[b]	12.6	12.5[b]
NCo334	111[a]	118.8[a]	111[a]	114[a]	14.8	13.6[a]	13	13.8[a]
B41227	85b	103.5[b]	87.9[b]	92[c]	13.8	12.6a[b]	12	12.7[ab]
LSD (5%)	**	**	**	**	Ns	**	Ns	*
Spacing (S)								
10 cm between setts	91[c]	101	98	97[b]	13.2	11.9	12.2	12.4
5 cm between setts	99[b]	103	96	99[b]	13.5	12.5	12	12.6
End-to-end	105[b]	110	92	102[b]	14.5	13	12.3	13.3
Ear-to-ear (Check)	114[a]	112	104	110[a]	14.7	13	13.6	13.8
LSD (5%)	**	Ns	Ns	*	Ns	Ns	Ns	Ns
CV (%)	9.3	21	22.1	9.9	12.7	15.2	22.1	14.3

Means followed by the same letter in a column are not significantly different from each other; PC = Plant cane; RI = First Ratoon; RII = Second Ratoon; m = month; CV = Coefficient of Variation, LSD = Least significant Difference; t = tone; ha = hectare



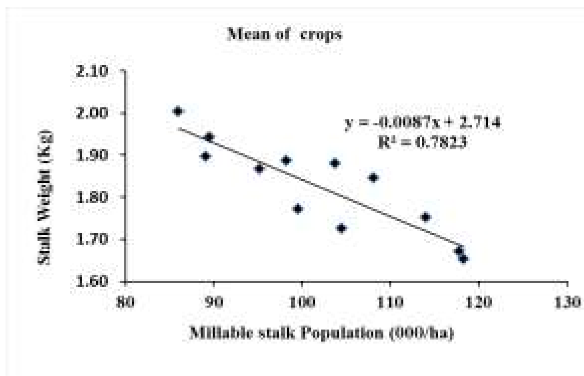


Figure 2. Relationships between millable stalk population and stalk weight at harvest at Metahara for the plant cane and mean of crops (plant cane and ratoons).

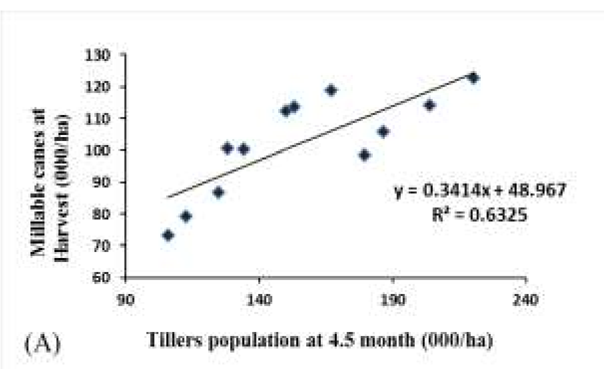


Figure 3. Relationship between mean early tillering and millable stalk population at harvest for sugarcane plant cane at Metahara

3.3. Effect of Intra-row Spacing on Cane Yield

Cane yield was significantly ($P \leq 0.01$) affected by the main effect of soil for plant cane and first ratoon crop as well as by the main effect of variety in the first ratoon and mean of crops (Table 1). However, none of the spacing treatments affected cane yield. In accord with this result, similar studies conducted earlier revealed that cane yield was influenced by soil type (Tsehay, 1993) and the crop type (Shah *et al.*, 2008). Furthermore, the current result indicated that planting at a high density may not necessarily result in a correspondingly high yield under the normal growth and management conditions.

In general, the cane yields obtained from the widely and densely spaced planting were in statistical parity (Table 1). Previous studies conducted at the Wonji-Shoa and Finchaa Sugar Estates in Ethiopia revealed a similar result (Tsehay, 1993; Worku, 2001). This means a widely-spaced planting compensates for the low stalk population. The presence of sufficient incident sunlight might have resulted in high photoassimilate production and partitioning of dry matter during the heavy tillering and root proliferation in the wider spaced planting, thereby avoiding diversion of carbohydrate away from the stalks. This may be attributed to the phenomenon that where sunlight quality and intensity are limiting, cane yield reductions arise due to the diversion of photosynthate away from the primary stalks. It is for this reason that high density planting is practiced in some countries (Amolo and Abayo, ND; Nayamuth and Koonjah, 2003).

The differences in the number of millable canes due to the treatments in the plant cane and mean of the crops were not reflected in the cane yield (Figure 2). This could be ascribed to the increased stalk weight in the wider sett spacing treatments, which might have favoured the stalks to accumulate more dry matter due to absence of stiff interplant competition. This means the lower number of stalks in the widely spaced planting might have compensated the lower stalk population by producing heavier cane stalks (Figure 2).

3.4. Effect of Intra-row Spacing on Cane Sucrose Percent

Cane sucrose percent was significantly ($P \leq 0.01$) affected by the main effect of soil in plant cane and mean of crops (plant cane and ratoons). Percent cane sucrose was also affected by the main effect of variety in all crop types and mean of crops (Table 2). However, the main effect of spacing and its interaction with variety did not have a significant influence on this parameter (Tables 2).

Table 2. Main effects of soil, variety and spacing on number of sucrose (%) and estimated sugar yield at Metahara from 2005-2010.

	Sucrose (%)				Estimated sugar yield (t ha^{-1}m^{-1})			
Source of variation	PC	RI	RII	Mean	PC	RI	RII	Mean
Soil (So)								
Class II/Luvisol	14.1^{a}	14.1	12	13.4^{a}	1.75^{b}	1.97^{a}	1.49	1.74
Class IV/Vertisol	13.5^{b}	13.8	12.1	13.1^{b}	2.08^{a}	1.54^{b}	1.53	1.72
LSD (5%)	**	Ns	Ns	**	**	**	Ns	Ns
Variety (V)								
B52298	14.2^{a}	14.5^{a}	12.3^{a}	13.6^{a}	1.88	1.68^{b}	1.54	1.70^{ab}
NCo334	13.7^{b}	13.6^{b}	12.2^{a}	13.2^{b}	2.0	1.85^{a}	1.6	1.82^{a}
N14	13.6^{b}	13.8^{b}	11.7^{b}	13.0^{b}	1.86	1.73a^{b}	1.4	1.66^{b}
LSD (5%)	**	**	**	**	Ns	*	Ns	*
Spacing (S)								
10 cm between setts	13.7	13.8	12	13.2	1.79	1.65	1.47	1.64
5 cm between setts	14.2	14	12.1	13.4	1.91	1.75	1.46	1.7
End-to-end	13.7	13.9	12.1	13.3	1.97	1.8	1.78	1.75
Ear-to-ear (Check)	13.7	14	12	13.2	1.99	1.82	1.63	1.82
LSD (5%)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
CV (%)	4.3	3.8	5.1	3.04	13.5	14.1	22.6	13.4

Means followed by the same letter in column are not significantly different from each other; ESY = Estimated sugar yield; PC = Plant Crop; RI = First Ratoon; RII = Second Ratoon; CV = Coefficient of Variation, LSD = Least significant Difference; t = tone; ha = hectare

The current result indicated differences in response across crops (plant cane and ratoons) for main effects of soil and variety. This could be because cane sucrose percent is influenced by many factors, which include variety (Yousaf *et al.*, 2002), soil type, weather and management practices employed during ripening (Sundara, 2000). Furthermore, the main effect of spacing and its interactions with the other factors did not affect cane sucrose percent (Tables 2). This result corroborates that of Sundara (2003) who reported that sett spacing did not affect sucrose content. Corroborating the results of this study, previous experiments conducted at the Wonji-Shoa Sugar Estate also indicated that can sucrose percent was not affected by sett spacing (Tsehay, 1993).

3.5. Effect of Spacing on Estimated Sugar Yield

Estimated sugar yield (ESY) was significantly ($P \leq 0.01$) affected by the main effect of soil in the plant cane and first ratoon, and by the main effect of variety ($P \leq 0.05$) in the first ratoon and mean of the crops. However, it was affected neither by the main effect of spacing nor by its interaction with the other factors (Table 2). The absence of differences in cane yield and cane sucrose percentages in response to the different intra-row spacing obtained in this study is consistent with the results of a similar study done previously at the Wonji-Shoa and Finchaa Sugar Estates (Woku, 2001; Tsehay, 1993).

4. Conclusion

The results of this study revealed that sett spacing influenced neither cane yield nor sugar yield. Therefore, it is recommended that Metahara Sugar Estate should use the intra-row spacing of 10 cm between setts for all three varieties instead of the conventional ear-to-ear 5 cm overlapping intra-row sett spacing that the Estate is currently using. This is because the spacing of 10 cm between setts ensures economy of planting material without sacrificing both cane and sugar yields.

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