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Effect of number of buds per sett and intra-row spacing of setts on yield and yield components of sugarcane

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Abstract
The effect of four intra-row spacings (5 cm overlapping, end-to-end, 10 cm spacing between setts and 20 cm spacing between setts) and number of buds per sett (two and three-buds) were investigated to determine the optimum intra-row spacings of three sugarcane varieties (Co680, N14 and Co740) and fined out the effect of bud number for planting on yield and yield components of sugarcane. The experiment was carried out in factorial combinations in a Randomized Complete Block Design (RCBD) using three replications at Tendaho Sugar Factory Project (Dubti) from September 2007 to August 2008. Analysis of variance revealed that there was a significant ($P<0.01$) difference among varieties in stalk height, stalk girth, cane yield, sugar yield and a significant difference ($P<0.05$) in weight per stalk, number of millable canes and recoverable sucrose percent. Analysis of variance revealed that the four intra-row spacings didn't show significant difference in cane yield and percent sucrose cane while, there was significant ($P<0.01$) difference on plant population, stalk height, stalk girth, number of millable canes and a significant ($P<0.05$) difference on weight per stalk. However, the number of buds per sett didn't show significant difference for the parameters measured. Therefore, it is concluded that the 20 cm intra-row spacing of three budded setts is found to be the best intra-row spacing for Tendaho Sugar Factory Project for the three varieties.

1. Introduction

Sugarcane is an important food crop of the tropics and sub tropics that is cultivated in more than seventy countries between 40°N and 32° 5´S, encompassing approximately half the globe (FAO, 1998). It is an important industrial crop having multifarious products (Soomro *et al*. 2006). The presence of conducive condition for cane growing in Ethiopia, the Government has planned to boost sugar production to meet the current and future demand of the country and export surplus sugar abroad by the end of 2014 (MoFED, 2010). Exporting by itself requires competency in price, which makes cost minimization an inevitable issue. Thus, it is imperative to search alternative options of minimizing cost in the sugar production system of the country to be competent in the World market. Among these, optimization of the planting materials and adoption of efficient, fast and cost effective methods of planting are the important ones.

The yield of sugarcane partly depends on the initial stand density of primary shoots and their tillers onwards (Ehsanullah *et. al*, 2011). These, in turn, are influenced by the number (Ehsanullah *et. al*, 2011) and quality of setts planted (Elias, 2001). The stem cuttings generally used for planting are sections with two or more eyes (buds), usually three (Peter *et.al*., 2011), though in some places the whole length of cane is planted (Roach, 1976).

Inappropriate planting density is the most serious factors reducing sugarcane yield (Bashir *et al.*, 2000). Sub-optimal planting density result in low plant population density and hence less number of millable canes per unit area which is the key component of cane yields (Mahmood *et al.*, 2005).

Planting density directly affects the number of stalks, stalk length and stalk diameter which are positively associated with cane yield per unit area (Nazir *et al.*, 1999). Thus, optimum crop stand is important to obtain high yield of sugarcane. In line with this Roach (1976) reported that the key component in determining cane yield is stalk population. According to Collins (2002), sugarcane planting density is a function of inter and intra-row spacings, in addition to varietal differences (Sundara, 2000) and environmental conditions (Amolo and Abayo, ND; Verma, 2004).

At Tendaho Sugar Factory, it is common to use ear-to-ear (approximately 5 cm overlapping of setts) during planting. Setts can be placed in furrows in either end-to-end or 5 cm overlapping position (Onwueme and Sinah, 1991). Furthermore, setts can be aligned within furrow by leaving a space of some centimeters (Tsehay, 1993; Worku, 2001). The number of setts and cost incurred for the preparation of two-budded setts to cover one hectare can be minimized by optimizing the spacing used and shifting from the use of two-budded sett planting to three-budded sett planting. Field recorded data at Metahara Sugar Estate in Ethiopia indicated that around 39,600-52,500 two-budded setts are used to cover one hectare of land depending on the variety (MSF, 2008).

An experiment conducted at Finchaa using four varieties and four different sett arrangements (5 cm overlapping (ear-to-ear), end-to-end, 5 cm apart and 10 cm apart) indicated significant differences among the varieties in most of the characters studied although none of the intra-row alignment of setts brought significant difference on cane yield (Worku, 2001).

It is possible to optimize stalk population per unit area by adjusting the number of setts planted in the intra-row space in a furrow and their placement. The number of buds to be used per sett also affects plant population per unit area and needs due attention. There is no scientific research conducted in the Tendaho Sugar Estate so far in relation to these aspects. Therefore, the objectives of this study were to determine the optimum intra-row spacing of three varieties of sugarcane and to find out the effect of bud number for planting sugarcane.

2. Materials and Methods

The experiment was conducted at Tendaho Sugar Factory Project (Dubti) in Afar Regional Estate from September 2007 to August 2008. The site is found in the Rift Valley of Ethiopia at an altitude and longitude ranging between 11^0 30' to 11^0 50' N and 40^0 45' to 41^0 03' E, respectively with elevation ranging from 365 m to 340 m. The area has a mean maximum and minimum temperature of 37.20 and 21.88 ^{0}C, respectively, with long-term (23 years) average annual rainfall and relative humidity of 221.8 mm and 60.4%, respectively. The area has mean sunshine hours of 8.9 hr per day. The soil type of the experimental field had Vertisol property dominated with clay.

The treatments were four levels of intra-row spacings (5 cm overlapping or ear-to-ear, end-to-end, 10 cm and 20 cm) and two levels of number of buds (two and three-budded setts). The sugarcane varieties used for the study were Co680, N14 and Co740. The experiment was conducted using 4 x 3 x 2 factorial combination of intra-row spacing, variety and bud levels in a randomized complete block design (RCBD) with three replications. Each experimental plot was composed of four rows of length 20 m with an area of 29 m^2 (20 m x 1.45 m).

The method of planting conventionally used at Tendaho Sugar Project is 5 cm overlapping or ear-to-ear having two budded setts with an inter-row spacing of 1.45 m. In the current experiment, the inter-row spacing was maintained while the intra-row spacing was varied.

Healthy stalks from the three varieties were selected from 8-month-old seed cane fields for planting. Then, the setts were planted on furrows at 30 cm depth. After planting all managements were made as per the norm of the plantation.

Growth, yield and yield component data were collected at appropriate time throughout the experimental periods. Millable canes in each plot were counted before harvesting from the net plot area (14.5 m^2) at harvesting and then converted to the hectare base.

Plant population count was made at harvesting. Girth measurement was taken from 20 sample stalks taken randomly from the middle two rows. Measurement was made using a caliper on three points of the stalks (upper, middle and bottom part of the stalk) after removal of the sheath. Weight per stalk was determined by taking 20 samples randomly from the middle two rows and by measuring the weight of each sample using a 40 kg by 100 gm spring balance. Then the average weight per stalk was taken. Cane yield (t ha^{-1}) was calculated based on cane stalk weight harvested from the central two rows.

Percent recoverable sucrose (*rendiment*) was calculated using Winter Carp indirect method of cane juice analysis (James and Chung, 1993) and the commercial sugar (t/ha) yield was calculated as the product of cane yield per middle rows and recoverable sucrose percent per plot. Then Commercial sugar yield per hectare was calculated as follows;

$$\text{CSY (t/ha)} = \text{CYH (t/ha)} \times \text{RS (\%)}$$

Where;

CSY = commercial sugar yield

RS = Recoverable cane sucrose

Finally, data were analyzed using SAS general linear model (GLM) procedure (SAS Institue, 2000). Comparisons among treatments with significant differences for the measured and counted parameters were based on Tukey's Studentized Range (HSD) Test.

3. Results

3.1. Weather Condition during the Study Period

A total rainfall of 417 mm was recorded during the study period, however, the distribution was not even and maximum rainfall of 225 mm was recorded in May. The mean maximum and minimum temperature during the study period were 38.0 and 26.6 ^{0}C, respectively. The mean monthly temperature distribution of Dubti indicated that low temperature prevailed from November to February (Figure 1).

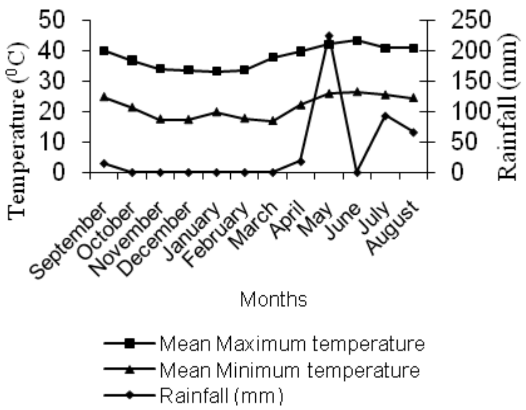

Figure 1. *Monthly total rainfall distribution and the mean maximum and minimum temperature variation during the study period in 2007/2008 at Dubti, Ethiopia.*

3.2. Effect of Variety, Intra-Row Spacing and Number of Buds on Plant Population, girth, Cane Height and Cane Weight

Plant population was significantly (P<0.01%) affected by the effect of varieties, spacing and number of buds on setts. Co740 and N14 had significantly higher plant population than Co680 (Table 1). Similarly, Feyissa *et al.* (2008) also observed differences in plant population among these varieties of sugarcane.

The 5 cm overlap spacing followed by the end-to-end spacing gave significantly higher number of plants per hectare while the lowest was recorded when setts were planted at a spacing of 10 and 20 cm which were not significantly different (Table 1). As expected, plant population per hectare significantly reduced as the intra-row spacing increased from end-to-end to 20 cm spacing. There was also significant difference among the number of buds on setts with regard to plant population.

Stalk height was significantly affected by variety and spacing effects (Table 1). The sugarcane varieties studied were significantly differed from each other in their stalk height in that Co680 had the tallest stalk height whereas Co740 had the shortest. Habib *et al.* (1991) also observed varietal difference in stalk height among sugarcane varieties.

Among the spacings, the end-to-end spacing and 5 cm spacings gave significantly higher stalk height as compared to the 20 cm spacing; however, 10 cm spacing was not significantly different from all the spacings (Table 1). In general 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 competition for light under high plant population. Different authors also reported taller plants under high population than under low population conditions (Irvine and Benda, 1980). Recently, Pate *et al.* (2002) found that the use of narrow row spacing cause sugarcane stalks to be longer and thin. Unlike intra-row spacings and varieties, number of buds per sett had no significant effect on stalk height. This result contradicts with the findings of Worku (1992), who found that three-budded setts were more superior in height than two-budded setts.

Stalk girth was significantly affected by the main effects of variety and spacing but not by bud number of setts and the interaction of the treatments (Table 1). The variety Co740 had significantly higher stalk girth than N14 and Co680 which had similar values (Table 1). A significantly higher stalk girth was observed in the 20 cm intra-row spacing followed by 10 and end-to-end spacings which were not differed significantly. Whereas the 5 cm overlapping gave significantly lower stalk girth per stalk.

The present results are in agreement with the results of Hunsigni (1993) who stated that higher stalk girth is observed under wider spacing than under narrow spacings and also varietal differences in stalk girth. The increase in stalk girth diameter as spacing increases is a well-documented fact. According to Rao (1990), tillering per clump was more and canes were thicker under wider spacing while in closer spacing, tillering per clump is less and canes were thinner under narrow spacing. Similarly, Pate *et al.* (2002) also reported that the use of narrow row spacing caused sugarcane stalks to be longer and thinner. However, bud number of planting material didn't affect stalk girth.

Weight per stalk was significantly affected by variety and spacing treatments but not by bud number of setts and the interaction of the treatments. There was a highly significant (P<0.01) difference among the three varieties in weight per stalk (Table 1). The highest weight per stalk was recorded from Co740 while the lowest was recorded from N14. Similarly, Muhammad *et al.* (2002) found significant difference among different sugarcane genotypes in weight per stalk.

There was also significant (P<0.05) difference among the different intra-row spacings on weight per stalk (Table 1). The highest mean weight per stalk was obtained in 20 cm intra-row spacing followed by the 10 cm intra-row spacing and end-to-end spacings which were not differed significantly (Table 1). Whereas the 5 cm overlapping gave significantly lower weight per stalk. Similar to the current results obtained, Orgeron (2003) also observed lower weight per stalk under narrow spacings than under wider spacings. Additionally, Orgeron *et al.* (2007) also observed a similar observation that stalk weight decreased as planting rate increased.

In general, mean weight per stalk decreased steadily with decrease in intra-row spacing. This could be ascribed to the increase in population density per unit area due to the decrease in intra-row spacing. This decrease in weight was partially due to the decrease in cane thickness, stalk height and stalk density as a result of high density of planting in the narrower intra-row spacings.

Basically, cane weight is a function of stalk thickness, stalk height and stalk density (Orgeron, 2003). Furthermore, Nosheen and Ashraf (2003) observed that stalk girth plays an important and dominant role in improving cane yield per unit area, which could be due to the indirect increase in stalk weight. Thus, the increase in cane girth as plant density decreased might have imparted an increase in cane weight. Moreover, high plant population produced thinner cane stalks due to crowding effect, whereas low plant population produced thicker cane stalks because of the availability of wider space. This finding is in agreement with the works of Raskar and Bhoi (2003) in which in the wider spacings there was a higher stalk weight than in the narrower spacings. Furthermore, weight per stalk was not significantly different between the numbers of buds (Table 1). This contradicts with the observation of Worku (1992) who found that three budded setts were greater in stalk weight than two-budded setts in Finchaa condition.

3.3. Effect of Variety, Intra-Row Spacing and Number of Buds per Sett on Millable Canes and Cane Yield of Sugarcane

The number of millable canes was significantly affected by variety and spacing effects but not by number of buds on setts and the interaction effect of the treatments (Table 2). The results indicated that the three varieties were significantly different (P<0.01) in number of millable canes. The variety Co740 had significantly higher number of millable canes than Co680; however N14 was not significantly differed from Co680 and Co740 (Table 2). Similar to this result, Feyissa *et al.* (2008) also observed variation among these varieties on number of millable canes.

Table 1. *Effects of sugarcane varieties, intra-row spacings and number of buds on plant population, stalk girth, stalk height and weight per stalk at Dubti in 2007-2008*

Treatment	Plant Population (000/ha)	Stalk Girth (cm)	Stalk height (cm)	Weight per stalk (kg)
Variety				
Co680	125.9b	2.548b	276.1a	1.449ab
N14	129.8a	2.519b	256.8b	1.404b
Co740	132.7a	2.819a	227.2c	1.473a
LSD (5%)	3.90	0.072	8.75	0.055
SE (±)	1.14	0.021	2.55	0.016
Spacing				
End-to-End	136b	2.592ab	259.3a	1.427ab
10 cm gap	122c	2.666ab	249.4ab	1.455ab
20 cm gap	118c	2.678a	250.1b	1.480a
5 cm overlap	142a	2.578b	258.0a	1.401b
LSD (5%)	4.95	0.092	11.12	0.07
SE (±)	1.31	0.024	2.93	0.019
Number of buds				
Two-budded	127.2b	2.627	253.3	1.43
Three-budded	131.7a	2.629	252.9	1.45
LSD (5%)	2.64	NS	NS	NS
SE (±)	0.93	0.017	2.07	0.013
CV	4.33	3.93	4.92	5.50

Means followed by the same letter in a column are not significantly different from each other;

Furthermore, there was a highly significant difference among the intra-row spacings on the number of millable canes (Table 2). A significantly higher number of millable canes was recorded by 5 cm overlapping, end-to-end; however, the 20 cm intra-row spacing gave a significantly lower mean number of millable canes than 5 cm overlapping and end-to-end intra-row spacing. (Table 2). This observation is in agreement with the findings of Netsanet *et al.* (2014) that high density planting rates result in higher number of millable canes the low density plantings. Besides, Preecha (2006) also found that numbers of millable canes per unit area were influenced by plant spacings.

Cane yield was significantly affected by the main effects of variety but not by any of the other treatments and interaction effects (Table 2). There was a highly significant difference among the varieties in cane yield. Co740 had significantly higher cane yield (156.17 t ha^{-1}) than both Co680 (147.20 t ha^{-1}) and N14 (144.76 t ha^{-1}) which had similar values (Table 2). The presence of variation of cane yield among varieties indicated the difference in their inherent yielding ability (Soomro *et al*. 2006).

Table 2. *Effects of sugarcane varieties, intra-row spacings and number of buds per sett on stalk girth and weight per stalk at Dubti in 2007-2008*

Treatment	Number of millable Cane (000/ha)	Cane Yield (t ha^{-1})	Recoverable Sucrose (%)	Sugar Yield (t ha^{-1})
Variety				
Co680	101.75b	147.20b	6.601b	9.71b
N14	103.19ab	144.76b	6.850ab	9.92b
Co740	106.06a	156.16a	6.886a	10.75a
LSD (5%)	3.94	7.25	0.27	0.60
SE (±)	1.151	2.12	0.079	0.176
Spacing				
End-to-End	105.33a	150.4	6.78	10.20
10 cm gap	103.76ab	150.9	6.80	10.26
20 cm gap	99.196b	146.7	6.70	9.83
5 cm overlap	106.40a	149.6	6.83	10.22
LSD (5%)	5.01	NS	NS	NS
SE (±)	1.33	0.019	0.091	0.204
Number of buds				
Two-budded	103.32	147.84	6.76	10.00
Three-budded	104.02	150.91	6.80	10.26
LSD (5%)	NS	NS	NS	NS
SE (±)	0.9397	1.73	0.065	0.144
CV (%)	5.44	5.44	5.72	7.48

Means followed by the same letter in a column are not significantly different from each other.

There was no statistical difference among the various intra-row spacings on cane yield (Table 2). Moreover, the presence of variation on the different early growth parameters did not affect the final major yield component cane yield. This indicates that naturally sugarcane has a high compensating ability to maintain potential yield under different cases of spacing and population density (Netsanet et al. 2014).

Moreover, there was no significant difference between the numbers of buds per sett on cane yield (Table 2). This implies that the use of three-budded sett does not bring any change in cane yield as compared to two budded setts used in the plantation. Contrary to this result, Kakde (1985) stated that the ultimate harvest was more by three-budded sett than two-budded sett.

3.4. Effect of Variety, Spacing and Number of Buds per Sett on Recoverable Sucrose and Sugar Yield

The analysis of variance indicated that recoverable sucrose and sugar yield were significantly affected by varietal difference but not by the other treatments and their interactions (Table 2).

A significantly higher recoverable sucrose value was recorded from the variety Co740 as compared to Co680 which was lower significantly; however N14 was not significantly differed from the former two (Table 2). In agreement with current finding Tsehay (1993) also found difference among varieties in percent recoverable sucrose. Sugar yield was significantly affected by varietal difference but not by any of the treatments and their interactions. The highest sugar yield was obtained from Co740, as compared to the values recorded from Co680 and N14 which gave similar sugar yield.

In this investigation, percent recoverable sucrose) was lower than the required values. According to Faucconier (1993) and Blackburn (1984), sucrose content ranges from 10-18% in different growing conditions. However, the sucrose recovery from the three varieties, in general, ranged from 6 to 10%. The low percent recovery of sucrose was due to the severe climatic condition and the intermittent rainfall occurred prior to harvest. Harvesting was made at the end of August, when the cane was 12 months age, as per the Tendaho Sugar Factory Project Consultancy Documents (TDSP, 2005); however, the high temperature prevailed during this period and the presence of small rains caused the cane sucrose content lower. A rainfall ranging from 2.7 to 14.2 mm was recorded during the dry-off period in July and August (Figure 1). Moreover, the average temperature registered during this period was higher (Figure 1). The mean maximum and minimum temperatures recorded during the study period were 41 and 24.5 ^{0}C respectively.

According to Verma (2004), ripening requires cool and dry weather and proceeds well under bright days with temperature of 23-30 ^{0}C, cool nights (temperature 7- 14 ^{0}C) and low relative humidity (50-55%). In line with this, Kakde (1985) and Verma (2004) stated that diurnal temperature variation between the day and night and higher evaporation tend to produce richer and pure sugar cane juice. Furthermore, the prevailing high temperature coupled with a minimum diurnal temperature variation period before harvesting might induced reversion of sugar (Sundara, 2000).

However, from the aforementioned discussion it can be deduced that the environmental condition at the moment of harvesting was not conducive. Perhaps, this will remain one of the major challenges at Tendaho.

4. Conclusion

Information on plant population, number of buds on planting materials and varietal response is crucial for a profitable sugarcane production. The study indicated that the four intra-row spacings didn't affect the sugar and cane yields. Furthermore, number of buds per sett also didn't affect cane and sugar yield. The use of two budded sett makes cost higher as opposed to three budded sett preparation under production condition at Tendaho Sugar Factory Project. Therefore, it is recommended that the plantation should use 20 cm intra-row spacings of three budded sett during planting for the varieties considered under this study.

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