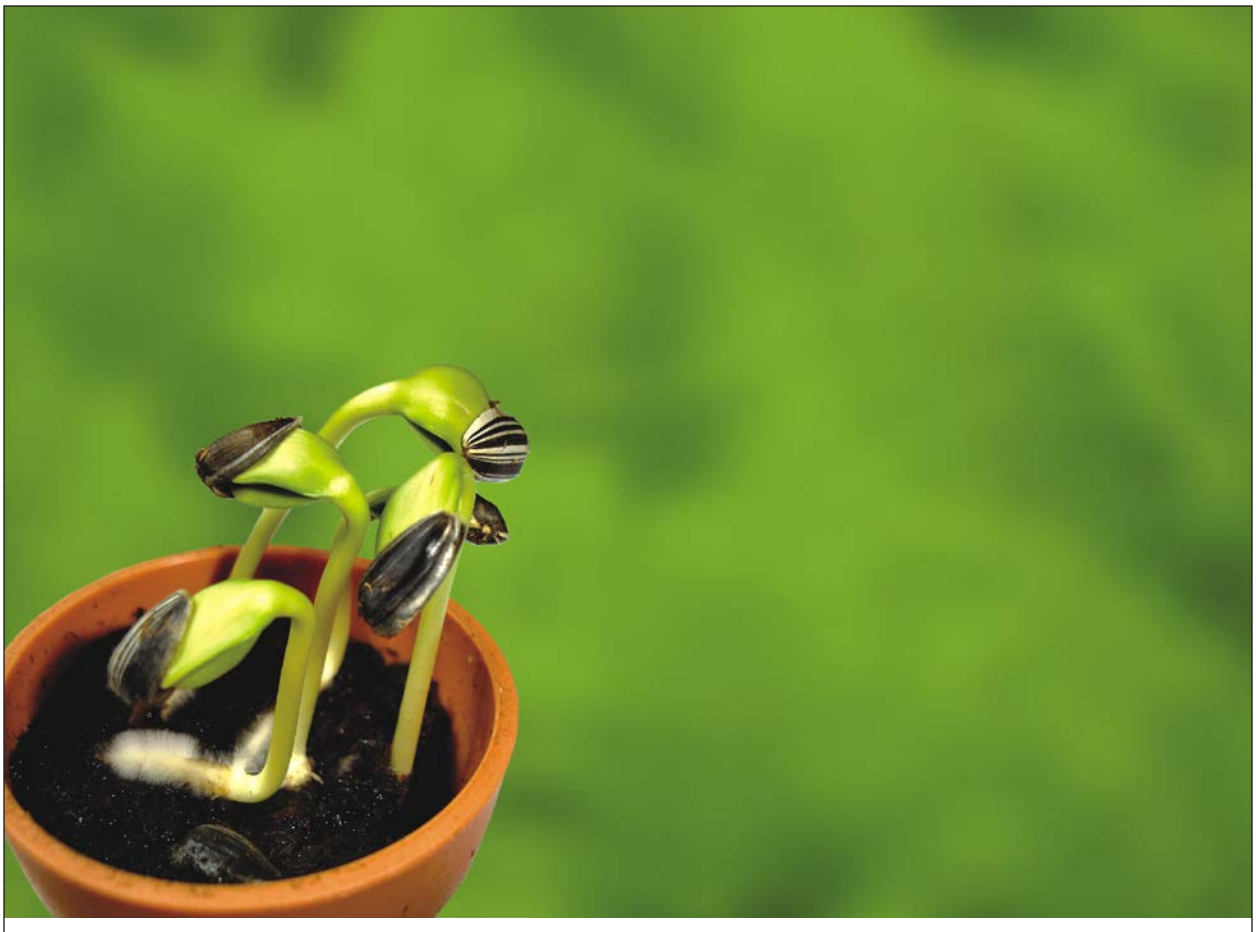

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Research Article
Quality Characteristics and their Relation with Flowering in Sugarcane (*Saccharum* spp. hybrid) in Ethiopia

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Abstract

Background and Objective: Quality characteristics in sugarcane vary with the varieties, age of crop and the agro-climatic conditions. Study was undertaken with the objective of evaluation of cane quality and sugar yield of sugarcane varieties for identifying the promising ones for Ethiopia. **Materials and Methods:** The materials for the study consisted of sixteen introduced varieties of sugarcane which were planted in a field experiment in randomized complete block design at Arba Minch University, Ethiopia on February, 16, 2015. The soil of the field was clay, slightly alkaline and fertile. All recommended cultural practices were done to raise the crop for normal growth and development during 2015-16. Data were recorded on cane quality characters, viz., ^{0}Brix in juice from middle of canes at 10.5 months of age and ^{0}Brix, pol and purity percent juice from composite juice of canes, recoverable sugar percent cane and sugar yield at 12 months age, flowering and cane and sugar yields. Data were subjected to simple analysis system and Pearson simple correlation coefficients were worked out between flowering and quality characteristics. **Results:** ^{0}Brix in cane juice was high in varieties, CP 69 1059, B 59 212, E 188 56 and B 4906. Pol percent juice and recoverable sugar percent cane were high in varieties, CP 69 1059, B 59212, B 4906, B 60267 at 12 months of age. Varieties differed in maturity period, viz., early, CP 69 1059, mid-early, B 4906, B 60 267and C 86 165, mid maturity, B 59212, B 52 298, B 41227, N 53 219, Co 622 and E 188 56, mid- late, N Co 334, N 52 216 and C 86 56 and late maturing, Mex 54 245, N 14 and DB 22857. ^{0}Brix at 10.5 and 12 months of age and pol and recoverable sugar at 12 months were positively correlated with the flowering. **Conclusion**: Sugarcane varieties differed in quality characteristics and the maturity periods. Brix and pol percent juice and recoverable sugar percent cane were positively associated with occurrence of flowering in varieties at early stage. Sugarcane varieties, B 59212, N 53 216, Co 622, B 41227, Mex 54 245, B 52 298 with high estimated sugar yields could be tested further for confirmation of results, adaptability and selection of promising ones for Southern Ethiopia.

Key words: Sugarcane, sugar yield, agro-climate, Brix and pol percent, vegetative growth

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sugarcane is an important crop grown for production of sugar in tropical and sub-tropical countries. It is cultivated on about 37,000 ha of land in Ethiopia. About 300,000 t of sugar/year is produced by four sugar factories in the country, which is able to meet 60% of the domestic demand for sugar consumption[1-3]. The per capita consumption of sugar in Ethiopia is about 5.1 kg which is very low as compared to that in Africa and the world (16.3 and 23.7 kg)[4]. There is a need to increase sugar production by expanding sugarcane production and milling and processing capacity of sugar mills. In view of it, sugarcane plantation area is being expanded for providing cane to the enlarged capacity of existing sugar mills and for the new sugar factories being established by Ethiopian Sugar Corporation[5].

Varieties play pivotal role in increasing sugarcane and sugar production. Therefore, suitable varieties with high sugar content need to be selected that are adaptable in sugar mill area. Sugar is accumulated in the interior of its cane stalks, which is extracted in the form of juice by cane milling tandem operation followed by processing of it in sugar factory for recovery of crystallized sugar. Recovery of sugar depends on the quality of cane, age of the crop, soil and environmental conditions and genotype by environment interaction[6]. Sugarcane varieties differ in cane quality characteristics, sugar yield, maturity, flowering and other attributes owing to genotypic differences arising from inter-species hybridization involving four species of the genus *Saccharum*, namely, *S. officinarum*, *S. barberi, S. sinense* and *S. spontaneum*[7,8] and thus are taxonomically written as *Saccharum* spp. hybrid.

Evaluation of sugarcane varieties for their quality is important for selection of promising high cane and sugar yielding non-flowering varieties adaptable in an area. Flowering is undesirable in commercial sugarcane cultivation as it stops further vegetative growth of stalk leading to sprouting of buds at the nodes of top portion of stalk or even development of suckers or late shoots. Flowering in sugarcane varies with the varieties, latitude and the environmental conditions. It influences quality of cane and sugar yield depending on the time interval between flowering and harvesting of cane and the atmospheric conditions at the latitude and the altitude[9]. Sugarcane varieties in Ethiopia have been introduced from different countries[10]. These need to be evaluated for their quality characteristics at suitable places representing agro-climatic conditions of the sugar mill zone. Arba Minch is near to Omo- Kuraz sugar development project where six new sugar factories are being established. In view of the above, present study was undertaken for evaluation of sugarcane varieties for quality characteristics and sugar yield and their relation with flowering at Arba Minch University.

MATERIALS AND METHODS

Materials: Materials for the study consisted of 16 introduced varieties of sugarcane whose seed materials were collected from the Research Division of Ethiopian Sugar Corporation, Wonji-Shoa on February 14, 2016. The name of introduced sugarcane varieties along with their parentage and place of breeding and selection are provided in the Table 1[11].

Description of study area and meteorological conditions: The study was carried out at Arba Minch University Research Farm, which is 505 km away in South of Addis Ababa. It is located at 6.04^0N latitude, 37.36^0E with an altitude of 1218 m above mean sea level. Average maximum and minimum temperatures were 35 and 17.8°C during February and March, 2015 which were suitable for good bud sprouting during the period. Average temperatures at latter months both maximum (35-28°C) and minimum (17-18.4°C) were also suitable for growth and development. Rains occurred during April, May, June, September, October, November and December, 2015 (60.5-54 mm), but the experiment was provided supplementary irrigations at appropriate time. Average relative humidity was more than 43% in February, 2015 which increased with receipt of rains. Averages sun shine hours varied from 10 h in February, 2015 to 7.4 h in May, 5.8 h in June to 7.6 h in October and around 10.5 h in November, 2015-February, 2016. Thus weather conditions during experiment period from February, 2015-March, 2016 were quite suitable for sugarcane growth and development.

Soil characteristics of experimental field: Soil samples collected from 0-20 cm depth in the experimental field were analyzed in Soil Testing Laboratory of Ethiopian Sugar Corporation, Wonji-Shoa. Average proportions of sand, silt and clay textural particles in the soil were: 12.0, 37.30 and 50.70%, respectively. The pH of soil was 7.8. On the basis of the proportions of particles and the pH, the soil was rated as clay slightly alkaline[12]. Average organic carbon percent of soil (1.68) was medium[13]and total nitrogen percent (0.3) was in high range[12-13]. Cation exchange capacity of the soil (66.30 meq/100 g) was very high. The soil had good amount of available phosphorus (25.43 ppm) and potassium (413.70 ppm)[12,14]. Cations (meq/100g) were: Na^+ (0.84) K^+

Table 1: Sugarcane varieties with their parentage and place of breeding and selection

Sugarcane variety	Parentage	Place of breeding and selection in the country
B 41227	B 35207 X POJ 2878	Barbados
DB 228 57	Co 413 X B 4098	Demerara, Barbados
N 14	N 17 X Unknown	Natal, South Africa
N 52 219	N Co 339 X HM 214	Natal, South Africa
N Co 334	Co 421 X Co 312	Natal- Coimbatore (India)
B 52 298	Co 421 X B 41211	Barbados
E 188 56	E 1/37 X M147/44	Ebene, Mauritius
B 59 212		Barbados
B 4906		Barbados
CP 69 1059	CP 52-68 X CP 63-588	Canal Point, Florida, USA
N 53 216	N 53 X Co 453	Natal, South Africa
Mex 54 245	CB 46-40 X Unknown	Mexico
B 60267	B 4145 X B 45151	Barbados
Co 622	Co 421 X Co331	Coimbatore, India
C 86 56		Cuba
C 86 165		Cuba

(0.98), Ca^{++}(44.70) and Mg^{++}(10.0)[12-14]. Thus, on the basis of physico-chemical characteristics, the soil of the experimental field was suitable for growing sugarcane.

Experimental layout and design: The experiment with 16 varieties was planted in randomized complete block design with 2 replications on February 16, 2015 in furrows drawn by tractor at 20 cm depth in well prepared field. Light irrigated in furrows was given 1 day before planting on February 15, 2015. The plot size for variety represented 3 rows of 3 m spaced. The two budded seed pieces or setts were treated in hot water at 50°C for 2 h followed by fungicidal treatment at the hot water treatment unit at Sugar factory, Wonji- Shoa. Two budded setts were placed in furrows with buds facing sides at intra row spacing of 60 cm between setts accommodating 5 two budded setts in 3 m row. The distance between blocks or replications was kept 2.5 m. Experiment was fertilized at the rate of 150 kg N and 69 kg P ha^{-1}. Fifty percent of N and full dose of P was applied using diammonium phosphate and urea at the time planting in furrows. Insecticide, ethiozinone water emulsion was sprayed on the setts in furrows at the rate 1.0 kg active ingredient per hectare to control insects. The setts were covered by 5 cm layer of soil followed by light irrigation in the afternoon. The next irrigation was given 6 days after planting on Feb. 22, 2015 followed by irrigation on Feb. 26, 2015. The exposed setts were covered by the soil 3 days after planting and also after next irrigation. The remaining 50% dose of N was applied in two splits using urea, one after germination at 45 days and the other at tillering phase 90 days after planting. Weeding, irrigation, earth up and tying of cane stalks operations in the experiment were done as and when required to raise the crop.

Data recording: Brix in juice of cane stalks and other quality characters were recorded at 10.5 and 12 months age of the crop. ^{0}Brix in juice was recorded by hand refractometer, HATAGO make by extracting juice using cane piercing needle in internode in the middle portion of two random stalks/stool in each of 3 rows of the plot excluding border stools at 10.5 months age on December 31, 2015. Brix reading of juice from 6 stalks/plot was recorded and averaged. ^{0}Brix in juice represented the total soluble solids in sugarcane juice.

At 12 months age,^{0}Brix, pol and purity percent juice were determined from the composite juice of six canes samples. The juice was extracted by three roller horizontal cane crusher at the Research and Training Division of Ethiopian Sugar Corporation, Wonji on February 22, 2016. ^{0}Brix in juice was recorded using Rudolf Automatic Refractometer made by Rudolf Research Analytical, USA which gives direct reading of refractometric dry substance (Brix or soluble solids) from the refraction angle in juice.

Pol percent juice was determined using Autopol 880 Automatic Saccharimeter made by Rudolf Research analytical, USA by polarizing the clarified filtered juice. Clear juice was obtained after precipitation of non-sugars by addition of small quality of basic lead acetate (1.0 g/100 mL juice) and filtering through Whatman 91 filter paper and using Celite-512 filtering aid. Pol or apparent sucrose percent juice was noted from the table corresponding to Brix reading and pol readings. Purity percent juice was derived from ratio of pol and Brix readings[15]. Recoverable sugar percent was calculated using the Winter Carp formula for indirect method of cane juice analysis as follows[16]:

$$ERS(\%) = \left[Pol\% - (Brix\% - Pol\%) \times NSF\right]CF$$

Where:
ERS = Estimated recoverable sucrose percent
NSF = Non sugar factor (0.70) and
CF = Cane factor (0.57)[17]

Estimated sugar yield was calculated by multiplying estimated recoverable sugar percent cane with estimated cane yield in t ha^{-1} at 12 months age.

Statistical analysis: Data were subjected to General Linear Model procedure of statistical analysis for randomized complete block design following SAS software package version 9.00[18]. Variety means for the characters were compared with critical difference (5% level). Pearson simple correlation coefficients were calculated between quality characters and flowering[19].

RESULTS

^{0}Brix in juice: ^{0}Brix in juice at 10.5 months was recorded highest in variety, CP 69 1059 followed by varieties, B 59 212, E188 56 and B 4906 (Table 2). Next high ^{0}Brix was in varieties, N 52 219, N 53 216. Low ^{0}Brix was observed in varieties, C 86 56 and DB 228 57. At 12 months age (370 days), ^{0}Brix in composite juice was recorded maximum in varieties, CP 69 1059 and B59212. The next high ^{0}Brix in descending order was found in varieties, B52 298, B 60 267, N 53 216, C 85 165, B 4906 and Mex 54 245. The low Brix was found in varieties, C 86 56 and DB 228 57 which was significantly lower than the general mean for all varieties.

Pol percent juice: Pol or sucrose percent in juice at 12 months age was recorded maximum in variety, CP 69 1059 followed by B 59212, B 4906, B 60267 and C 86 165. The next high pol percent in descending order were noted in varieties, B 52 298, N 53 216, B 41227, E 188 56 and Co 622. Pol in juice in descending order was numerically less than the general mean in varieties, N Co 334, Mex 54 245,C 86 56, N 14 and DB 228 57.

Juice purity percent: Juice purity was above 85% with relatively high pol percent was in varieties, CP 69 1059, B4906, B 60 267 and C 86 165 which indicated that these varieties attained maturity earlier, whereas varieties, N Co 334 and C 86 56 with low pol percent indicated mid late maturity. Other varieties with juice purity less than 85 % but good pol percent were mid to mid- late maturing. Varieties, Mex 54 245, N 14 and DB 228 57 with less than 80 % juice purity and lowest pol were late maturing.

Flowering: Flowering in cane stalks was observed on October 18, 2015 in varieties, B 41227, B 4906 and CP 69 1059 followed by in E 188 56 and Mex 54 245. Flowering in other varieties was noted at later dates. Flowering was recorded in all varieties except N Co 334 and Co 622. Highest flowering was observed in variety CP 69 1059 followed by E 188 56 and B4906. Next high flowering in descending order was recorded in varieties, B 41227, Mex 54 245, B 59212 indicating medium

Table 2: Brix HR and Brix, Pol and purity percent juice in cane and flowering percent in sugarcane varieties

Varieties	Brix HR	Brix (%)	Pol (%)	Purity (%)	Flowering (%)
B41227	15.67^{d}	14.95^{b}	12.71^{c}	85.03^{c}	27.00^{e}
DB 228 57	13.92^{e}	12.85^{c}	10.05^{e}	78.06^{d}	7.57^{g}
N 14	15.46^{d}	13.60^{c}	10.99^{d}	79.61^{c}	5.57^{g}
N 52 219	16.88^{c}	14.59^{b}	12.19^{c}	83.57^{c}	2.00^{g}
N Co 334	14.79^{d}	13.66^{c}	11.89^{c}	87.01^{b}	1.00^{g}
B 52 298	17.17^{c}	15.87^{b}	12.92^{c}	81.51^{c}	3.83^{g}
E 188 56	17.29^{c}	14.90^{b}	12.67^{c}	85.02^{c}	75.66^{b}
B 59 212	17.96^{b}	17.23a	13.68^{b}	79.42^{c}	27.86^{f}
B 4906	17.09^{c}	15.36^{b}	13.50^{b}	87.68a	50.37^{c}
CP 69 1059	19.17^{a}	17.52^{a}	14.90^{a}	85.03^{c}	100.00
N 53 216	16.67^{d}	15.58^{b}	12.76^{c}	82.00^{c}	5.52^{g}
Mex 54 245	15.13^{d}	15.32^{b}	11.60^{c}	75.84^{e}	39.86^{d}
B 60267	14.25^{e}	15.74^{b}	13.42^{b}	85.25^{b}	12.06^{f}
Co 622	15.15^{d}	15.06^{b}	12.58^{c}	83.58^{c}	1.00^{g}
C 86 56	14.67^{d}	12.87^{c}	11.09^{d}	86.10^{b}	3.39^{g}
C 86 165	13.46^{f}	15.56^{b}	13.38^{b}	86.08^{b}	9.07^{g}
Grand Mean	15.92	15.04	12.52	83.17	22.59
SE (±)	0.98	0.9	0.95	2.68	4.89
CD (at 5%)	2.95*	2.76*	2.87*	2.54*	14.65
CV %	8.68	8.45	10.71	4.55	29.83

* = Significant at 5% level, Means with the same alphabet are not significantly different. Brix HR = ^{0}Brix recorded by hand refractometer at 10.5 months age, Brix, Pol and Purity = ^{0}Brix, Pol and Purity percent juice at 12 months age, flowering = Percentage of flowered stalks at 10.5 months age

Table 3: Estimated recoverable sugar, cane and sugar yields in sugarcane varieties at 12 months age

Varieties	ERS (%)	ECY (t ha^{-1})	ESY (t ha^{-1})
B 41227	10.74^{c}	162.04^{c}	17.65^{b}
DB 228 57	7.76^{e}	150.35^{c}	11.67^{c}
N 14	8.81^{d}	153.70^{c}	14.01^{c}
N 52 219	10.12^{c}	136.11^{d}	13.78^{c}
N Co 334	10.18^{c}	144.03^{d}	14.70^{b}
B 52 298	10.53^{c}	157.50^{c}	16.59^{b}
E 188 56	10.70^{c}	128.13^{d}	13.69^{c}
B 59 212	10.96^{c}	217.09^{a}	23.77^{a}
B 4906	11.73^{b}	117.19^{d}	13.91^{c}
CP 69 1059	12.71^{a}	97.99^{e}	12.33^{c}
N 53 216	10.46^{c}	174.67^{b}	18.28^{b}
Mex 54 245	8.78^{d}	158.54^{c}	13.69^{c}
B 60267	11.40^{c}	146.68^{d}	16.74^{b}
Co 622	10.48^{c}	172.93^{b}	18.03^{b}
C 86 56	9.37^{c}	113.35^{d}	10.55^{c}
C 86 165	11.44^{c}	147.99^{d}	16.89^{b}
General mean	10.39	148.98	15.45
SE (±)	1.09	20.07	2.69
LSD (at 5%)	3.27*	60.18*	8.08*
CV (%)	14.87	19.10	24.75

*Significant at 5% level, Means with the same alphabet are not significantly different. ERS = Estimated recoverable sugar percent cane at 12 months age, ECY = Estimated cane yield t ha^{-1} at 12 months age, ESY = Estimated sugar yield tons per hectare at 12 months age

Table 4: Correlation coefficients (r) of quality characteristics and cane and sugar yields with flowering in sugarcane varieties

Correlation between	^{0}Brix HR	Brix	Pol	Purity	ERS	ECY	ESY
Flowering	0.652*	0.546*	0.569*	0.142ns	0.531*	- 0.48ns	- 0.23ns

*significant at 5% level, ns, non-significant, ^{0}BrixHR = ^{0}Brix recorded by hand refractometer at 10.5 months age, Brix, Pol and Purity = Brix, Pol and Purity percent juice at 12 months age, ERS = Estimated recoverable sugar percent, ECY= Estimated cane yield t ha^{-1}, ESY = Estimated sugar yield t ha^{-1} flowering = Percentage of flowered stalks in varieties

flowering habit. Low flowering in descending order was observed in varieties, B 60267, DB 228 57, N 53 216, N 14,C 86 56, B 52 298, N 52 219 and C 86 165.

Estimated recoverable sugar percent: Estimated recoverable sugar percent cane at 12 months age was found maximum in variety, CP 69 1059 followed by next high sugar recovery in varieties, B 4906, C 86 156, B 60267, B 59212, B 41227 and E 188 56 (Table 3). Sugar recovery in varieties, B 52 298, Co 622, N 53 216, C 86 56, N Co 334 and N 52 218 was in medium range. Low sugar recovery was recorded in DB 228 57, Mex 54 245, N 14 and C 86 56.

Estimated sugar yield: Sugar yields at 12 months age differed significantly among varieties. Sugar yield was maximum in variety B 59 212 followed by next high sugar yield in descending order in varieties, N 53 216, Co 622, B 41227, Mex 54 245, B 52 298, N 14 and DB 228 57. Sugar yields were significantly less in varieties, CP 69 1059 and B 4906.

Correlation of cane quality characters with flowering: Simple correlation coefficients between flowering percent and quality characteristics,^{0}Brix at 10.5 months, ^{0}Brix, Pol or sucrose percent juice and estimated recoverable percent cane at 12 months age were positive and significant (Table 4). This showed that the Brix, sucrose percent in juice and estimated recoverable sugar percent cane were positively associated with the occurrence of flowering, or there was a relationship of cane quality characteristics with extent of flowering in sugarcane varieties at early stage. Juice purity had no relation with flowering. Estimated cane and sugar yields had non-significant negative correlation with flowering.

DISCUSSION

At early age of 10.5 months, varieties, CP 69 1059,B 59 212, E188 56 and B 4906 had relatively higher ^{0}Brix in juice than other varieties. At 12 months age ^{0}Brix in composite cane juice was high in varieties, CP 69 105, B59 212, B52 298, B 60 267, N 53 216, C 85 165 and B 4906. These results indicated that varieties, CP 69 1059, B 59 212 and B 4906 had high soluble solids or sugars in juice.^{0}Brix in juice from the middle of cane stalks at 10.5 months was numerically more than ^{0}Brix in composite cane juice at 12 months age. It was because of the fact that the composite cane juice represented juice of the whole cane stalk including bottom, middle and top portions of stalk. The top portion of cane stalk generally had low Brix in juice because of newly formed immature internodes of the stalk[6].

Pol or sucrose percent in juice was high in varieties, CP 69 1059, B 59 212, B 4906, B 60 267 and C 86 165. These varieties also had around 85% juice purity which indicated that the varieties reached maturity at 12 months age. Other varieties with lower pol than these varieties were likely to mature later which could be considered as mid late in maturity. On the basis of low pol in juice, varieties, DB 228 57, N 14 and Mex 54 245 appeared late maturing. Estimated sugar recovery percent cane was highest in variety CP 69 1059 followed by B 4906, C 86 165, B 60 267, B 59 212, B 41227 and E 188 56. This indicated that these varieties were high sugared and could be harvested earlier (11-12 months age) than other varieties.

On the basis of Brix, Pol, purity and recoverable sugar percent, variety, CP 69 1059 appeared early maturing. Varieties, B 4906, B 59 212, B 60267 and C 86 165 could be grouped as mid early maturing; varieties B 52 298, B 41227, N52 216, E 188 56 and Co 622 as medium maturing and the remaining varieties, N Co 334, N 14, N 53 219, DB 228 57, Mex 54 245 and C 86 56 as late maturing. Accumulation of sugar or sucrose in juice and the maturity period or duration was a varietal characteristic, that is, there existed genetic differences among varieties for sugar content in juice and the maturity duration. Irrespective of the location early maturing variety recorded higher sugar content in juice at early period than other varieties. The mid early maturing varieties recorded relatively less sugar in juice at early period but had high sugar at mid early period in juice. Similarly, varieties with medium and late maturity duration had less sugar in juice at early and mid- early periods. As in the present study, variety CP 69 1059 recorded high recoverable sugar followed by B 4906, B 60267, E 188 56, Co 622 B 52298 and DB 228 57 at Ethiopian sugar estate, Wonji-Shoa[20]. Similarly, pol percent juice in varieties, N 53216, N 52 219 and N Co 334 recorded in present study matched with that at Ethiopian sugar estate, Finchaa[21].

High sugar yields were recorded in varieties, B 59 212, N 53216, Co 622 and B 41227, C 86 165, B 60267 and B 52 298. Sugar yields were below average in varieties, N Co334, N 14, B 4906, N 52 219, E 188 56 and CP 69 1059 and the lowest sugar yields were in varieties, C 86 56 and DB 228 57. The level and order of estimated sugar yield in varieties in present study generally matched with varieties evaluated at four Ethiopian Sugar Estates at Wonji-Shoa, Finchaa, Tendaho and Metahara[20-24]. However, variety, B 4906 which had low sugar yield in present study gave high sugar yield at Wonji-Shoa sugar estate[20], which could possibly be due to the favourable response of this variety to agro climatic conditions at Wonji-Shoa sugar estate.

Cane quality characteristics, ^{0}Brix in juice at 10.5 months and ^{0}Brix, pol percent juice and recoverable sugar percent cane at 12 months age were positively associated with occurrence of flowering in varieties. It was due to genetic characteristics of varieties whose cane stalks had relatively high sugar content at the flowering time. It could be due to translocation of sugars quickly from the photosynthesizing leaves to accumulation in the internodes of cane stalks in varieties completing their vegetative growth early. On the onset of flower primordial initiation, no new leaves and internodes were formed. Thus, the sugars produced by already formed leaves were relatively accumulated more in the storage tissues of cane stalks until the time that photosynthesis declined below the rate of respiration. This could be the reason that the quality of cane was positively associated with the flowering. Improved cane quality on flowering was reported by several researchers[9]. The flowered stalks ripened earlier and their quality was superior to non-flowered ones[6]. The quality of flowered stalk was better than non-flowered ones as the flowered stalks were more vigorous prior to flowering than non-flowered stalks of the same variety[9]. Flowering affected sugarcane ripening and the consequences of juice quality varied with the varieties and the environmental conditions[25]. Flowered canes recorded high juice purity and lower reducing sugars than non-flowered ones. If the temperature remained too low during winter months, no significant loss was noticed in juice quality and cane weight within 3 months of flowering[6]. Flowering increased sugar yield at the time of anthesis as compared to non- flowered canes and continued to produce high cane and sugar yields than non- flowered ones even for several months after anthesis when cooler conditions prevailed at higher latitudes[9].

Estimated cane and sugar yields had non- significant negative correlation with flowering which indicated that the flowering at early stage had adverse effect on sugar yields. As in the present study, negative relation was found between proportion of flowering and cane and sugar yields[10].The response to sugar content and sugar yield after flowering varied with the varieties. An inverse relationship was observed between field Brix and cane yield in Savannah ecology of Nigeria[26].

Flowering led to increase in size of leaf sheath and decrease in size of leaf blade, decrease in the thickness of top internodes and the development of pith in top portion of stalk with less sugar[9]. Hot weather conditions after flowering led to serious loss to cane and sugar yields. Flowering varies with the varieties, time of planting and nutrition, moisture status and

the atmospheric conditions. Quality characteristics of flowered stalks were maintained for some period and must be harvested before there was decline in quality. Evaluation of quality characteristics of varieties was, therefore, important for harvesting of crop at their peak quality for maximum sugar yield.

CONCLUSION

Sugarcane varieties differed in quality characteristics and maturity periods. Brix and pol in cane juice and recoverable sugar percent cane were positively associated with flowering at early stage. Seven varieties, B 59 212, N 53216, Co 622, B 41227, C 86 165, B 60267 and B 52 298 recorded high sugar yield, which could be tested for confirmation of results, adaptation and the selection of most promising ones for cultivation in Southern Ethiopia.

SIGNIFICANCE STATEMENT

The present study evaluated quality characteristics, sugar yield and flowering habit in introduced sugarcane varieties and studied the association of quality characteristics with flowering at early stage. High sugar yields were recorded in seven varieties, which could be helpful in future studies by testing for confirmation of results, adaptation and the selection of most promising ones for cultivation in Southern Ethiopia.

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