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## Research Article

# A Study on Morphological Characters of Introduced Sugarcane Varieties (*Saccharum* spp., Hybrid) in Ethiopia

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### Abstract

**Objective:** This study was undertaken with the objective to evaluate sugarcane varieties for morphological characteristics for using them in their identification, selection, breeding and seed production. **Methodology:** Experiment consisting of 16 varieties was planted in randomized block design at Arba Minch University, Southern Ethiopia on February 16, 2015. Data were recorded on measurable and observable cane stalk and morphological characters at early stage of crop growth. **Results:** There were significant differences among varieties for cane stalk height, diameter, leaf blade length and width and leaf surface area. At 7.7 month age, cane stalk height in descending order was in varieties, Mex 54 245, B 41227, CP 69 1059, Co 622, B 59 212, Co 86 56, C 86 165, B 4906, E 188 56, N 52 219, N Co 334, DB 228 57, N 14 and B 52 298. Canes were medium thick in B 59 212, B 60 267, B 52 298; medium thin in B 41227, DB 228 57, N 14, N 53 216, Mex 54 245, B 4906, C 86 56, CP 69 1059, N 53 219, N 53 216, E 188 56 and N Co 334 and thin canes in C 86 165. Leaf blade length was more in varieties, B 59 212, C 86 165, B 52 298 and Co 622. Leaf width was broad in varieties, B 60 267 and C 86 56. Leaf surface area was high in varieties, B 60267, C 86 56, B 59212, B 52 298, Co 622 and Mex 54 245 and low leaf surface area was in varieties B 4906 and CP 69 1050. Flowering occurred in all varieties except N Co 334 and C 622. Heavy flowering occurred in varieties, CP 69 1059, E 188 56 and B 4906. Description for 41 morphological characteristics grouped as 11 discrete, 18 continuous and 12 combined characters were presented for identification of varieties. **Conclusion:** Morphological characters called, descriptors for sugarcane were presented for identification of 16 varieties. These characters are distinct and easily observed and could be used for identification, selection, breeding and seed and commercial production of sugarcane varieties.

**Key words:** Sugarcane varieties, *Saccharum* spp., hybrid, morphological characters, sugarcane variety descriptors

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

## INTRODUCTION

Sugarcane is most important sugar crop of tropical and subtropical countries for sugar production. Sugarcane varieties play pivotal role in sugar production. The detopped matured or ripened cane stalks after stripping of leaves are milled for extraction of sugar containing juice which is processed for production of sugar in sugar mills. Improved sugarcane varieties were developed at those places or countries where sugarcane varieties flowered and seed setting occurred. Sugarcane varieties were not developed through breeding in Ethiopia and were introduced from other countries such as Barbados, Coimbatore (India), Natal (South Africa), Coimbatore-Natal (South Africa), Mauritius, Mexico and Guyana<sup>1</sup> and Cuba. Improved sugarcane varieties were inter-species hybrids involving four species of the genus *Saccharum*, three cultivated species, *S. officinarum*, *S. barberi* and *S. sinense* and one wild species, *S. spontaneum*. The somatic chromosome number in the varieties varied from 90-130. Out of the total chromosomes in sugarcane varieties, 80% contribution was from *S. officinarum*, 10% from *S. spontaneum* and the remaining 10% from other species, *S. barberi* and *S. sinense*<sup>2</sup>. Thus improved sugarcane varieties were taxonomically written as *Saccharum* spp., hybrid. Varieties differed in morphological and cane and quality characters<sup>3-9</sup>. There was a need to evaluate introduced sugarcane varieties for morphological cane stalk characteristics for their identification, distinctiveness, uniformity and stability, use in breeding and selection of suitable ones for sugarcane production<sup>10,11</sup>. In view of the above, the present investigation was carried out with objective of evaluation of introduced sugarcane varieties for morphological characters at appropriate growth and development stage for their identification and selection for sugarcane production in Southern Ethiopia.

## MATERIALS AND METHODS

The materials for the investigation consisted of 16 sugarcane varieties which were collected from Ethiopian Sugar Corporation, Wonji-Shoa, where introduced sugarcane varieties from different countries were maintained.

**Study area and weather conditions:** Study was carried out at Arba Minch University Research Farm located at 6.04°N latitude, 37.36°E with an altitude of 1218 m a.s.l. The soil of the experimental plot was clay with slightly alkaline range<sup>12</sup> with average pH 7.8. Average maximum and minimum temperatures were 35 and 17.8°C during February and

March, 2015 which were suitable for sprouting buds 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). Experiment was provided irrigations at appropriate time as per requirement of sugarcane crop. Average relative humidity was more than 43% in February, 2015 which increased with receipt of rains. Averages sunshine hours varied from 10 h in February 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 to February, 2016. Thus weather conditions during experiment period from February, 2015 to March, 2016 were quite suitable for sugarcane growth and development.

**Experimental layout and design:** The experiment was planted with 16 sugarcane varieties in randomized complete block design with two replications on February 16, 2015 in furrows drawn by tractor at 20 cm depth in well prepared field. Light irrigation was given 1 day before planting. The plot size for each variety represented 3 rows of 3 m spaced 1 m. The seed pieces with two buds each or two budded 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<sup>-1</sup>. Fifty percent of N and full dose of P was applied using urea and diammonium phosphate 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 provided 6 days after planting on February 22, 2015 followed by next irrigation on February 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 and earth up in the experiment were given as and when required to raise the crop.

**Recording of data:** Data on measurable morphological characters, stalk height, stalk diameter, leaf length and leaf width were recorded at 7.7 month (232 days) after planting,

cane stalk height, stalk diameter, leaf blade length and leaf width were recorded from three random stalks, one from each of three rows from the middle clumps of the plot on October 6, 2015. Cane stalk height was measured from bottom to top visible dewlap in meter. Cane stalk diameter was measured from the middle portion of stalk by vernier caliper in centimeter. Cane diameter was classified as: Thin cane <2.0 cm, medium thin 2-2.5 cm, medium cane 2.5-3.0 cm, medium thick 3.0-3.5 cm and thick cane >3.5 cm<sup>13</sup>. Leaf blade length of the longest furled leaf (+6 leaves from spindle leaves) and leaf width at the broadest point were measured in cm on the same plants. Leaf width at the widest point between 4.0-6.0 cm was classified as medium and 6.0 and above 6.0 cm as broad leaf<sup>13-15</sup>. Leaf area was calculated by multiplying leaf blade length, leaf width and leaf shape factor<sup>16</sup> of 0.72.

Data on observable morphological characters of sugarcane were recorded at 7.5 months after planting when varieties showed distinct morphological characteristics<sup>10,17,18</sup>. Morphological descriptors included above ground stem characters-stool habit, stem colour, ivory marks, internode shape, alignment, splits and wax, stem diameter, height, node characters-node swelling, root zone colour, root eye number and arrangement, bud characters, bud size, shape, cushion gerpore position and bud groove and growth ring colour; leaf characters-leaf length, width, leaf sheath colour, waxiness, spines and clasping, leaf carriage, leaf joint characters-dewlap colour, shape of ligule, ligular process, auricle shape and flowering. Besides the above morphological characters, data on <sup>0</sup>Brix in juice from the middle portion of cane stalk was recorded at 10.5 months. Different forms of these characters were grouped into discrete, continuous and combined characters called standard descriptors for sugarcane by Shahi<sup>10</sup> were as follows:

#### **Discrete characters:**

- Stool habit (Spreading and non-spreading)
- Stem colour unexposed (Green to purple)
- Ivory marks on internodes (Present/absent)
- Bud shape (Triangular-pointed/oval/obovate/pentagonal/rhomboid/round/ovate/rectangular beaked)
- Germ pore position (Apical/sub-apical/medium)
- Bud cushion (Present/absent)
- Leaf colour (Green/light green/light yellow)
- Ligule shape at leaf-sheath joint (Crescent/deltoid/strap/triangular)
- Auricle shape at leaf sheath margin

- <sup>0</sup>Brix percentage juice at 10.5 months
- Lodging resistance (Tolerant/moderately tolerant)

#### **Continuous characters:**

- Colour of exposed stem
- Stem height (numerical value indicated)
- Stem girth (diameter in cm)
- Corky patches on internodes (Present/absent)
- Wax bloom on internodes (Light/medium/heavy)
- Node swelling (Swollen/not swollen)
- Root zone swelling (Swollen/not swollen)
- Root zone colour (Green/yellow/greenish yellow/light green/light yellow/yellowish green)
- Growth ring colour (Green/yellow/greenish yellow/light green/light yellow/yellowish green)
- Leaf blade length (Fully expanded green leaf)
- Leaf width (At the widest portion of the lamina)
- Leaf colour (Green/light green/greenish yellow)
- Leaf sheath colour (Green/greenish yellow/light green/green with purple blotches/green with purple tinge/purple)
- Leaf sheath spines (Present/absent)
- Leaf sheath waxiness (Medium/light)
- Dewlap colour (Green/yellow/greenish yellow/light green/light yellow/yellowish green/dark brown/green with purple tinge/light-greenish purple/purple)
- Flowering/low (<10%)/medium (10-40%)/heavy (100%)
- Lodging (Lodging/non lodging)

#### **Combined characters:**

- Internode shape (Bobbin/conidial/cylindrical/oval)
- Internode alignment (Straight/zigzag)
- Internode diameter
- Pith in the interior of stem (Present/absent)
- Splits or growth cracks on internodes
- No. of root eyes rows at the node
- Root eyes arrangement (Regular/irregular)
- Bud size (Big, medium, small)
- Bud groove (Present/absent)
- Leaf carriage (Erect/semi-drooping/drooping)
- Leaf sheath spines (Glabrous/dense/sparse)
- Leaf sheath clasping (Loose/tight/self-trashing)

**Statistical analysis:** Data were subjected to General linear Model procedure of statistical analysis for randomized complete block design following SAS software package<sup>19</sup>.

Variety means for the characters were compared with least significance difference at 5% level of significance.

## RESULTS AND DISCUSSION

### Measurable morphological characters at 7.7 month age:

Mean cane stalk height and diameter, leaf blade length, leaf blade width and leaf surface area for 16 sugarcane varieties were presented in Table 1. Varieties differed significantly for cane stalk height, thickness, leaf blade length and blade width and leaf area. Maximum cane stalk height was recorded in variety, Mex 54 245 (2.89 m) followed by varieties, B 41227, CP 69 1059, Co 622, B 59 212, C 85 56, C 86 165, N 53 216 and B 60 267 (2.83-2.63 m). Medium cane height was in varieties, B 4906, E 188 56, N 52 219, N Co 334, DB 228 57 and N 14 (2.53-2.24 m). The lowest cane stalk height was in variety B 52 298 (2.20 m). As in the present study, cane height in descending order at Ethiopian sugar estate, Tendaho by Tadesse *et al.*<sup>20</sup>. Similarly, cane height in varieties, N 52 219, N 53 216 and N Co 334 was observed in descending order at Ethiopian sugar estate, Finchaa by Getaneh *et al.*<sup>21</sup> and Tadesse *et al.*<sup>22</sup>. This showed that the cane stalk height was a genetic or varietal characteristic which was stable over environments<sup>3-5,11,13,23,24</sup>.

Cane stalk diameter at the middle portion of cane stalk was significantly more in varieties B 50 212, B 60267 and B 52 298 (2.70-2.64 cm). This indicated that the cane thickness in these varieties was medium<sup>13,17</sup>. Stalk diameter was medium thin (<2.5 cm) in varieties, B 41 227, DB 228 57, N 14 and Mex 54 245, B 4906, C 86 56, CP 69 1059, N 53 219, N 53 216, E 188 56 and N Co 334. Cane stalks were thin (<2 cm) in variety<sup>13</sup>, C 86 165. As in the present study, cane diameter in varieties, N 53 219, N 53 216 and N Co 334 was found in descending order at Ethiopian sugar estate, Finchaa<sup>21,22</sup>. This showed that measurable morphological character cane diameter was a genetic or varietal characteristic and was stable over environments<sup>3-9,13-15</sup>.

Leaf blade length was more in varieties, B 59 212, C 86 165, B 52 298 and Co 622 (>1.90 m). Short leaf length was in CP 69 1059 and B 4906 (>1.53 m). Leaf width was broad in varieties, B 60 267 and C 86 56 (>6.00 cm)<sup>13-15</sup>. Leaf width was medium in B 59 212 and Mex 54 245 (>5.83 cm). Narrow leaf width was narrow in varieties B 4906, N 52 219 and N Co 334 (>4.18 cm). Leaf surface area was higher (>7.29 cm<sup>2</sup>) in varieties, B 60267, C 86 56, B 59212, B 59298, Co 622 and Mex 54 245 than the general mean (6.67 cm<sup>2</sup>), whereas varieties B 4906 and CP 69 1050 had significantly

lower leaf area (>4.89 cm<sup>2</sup>) than general mean leaf area. Besides leaf blade length and width, the differences in leaf area were reported to be influenced by leaf surface in sugarcane varieties<sup>16</sup>.

Results on flowering and <sup>0</sup>Brixin juice at 10.5 month age are provided in Table 2. 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 recorded later except

Table 1: Cane stalk height (CH), cane diameter (CD), leaf blade length (LL), leaf blade width (LW) and leaf area (LA) at 7.7 month (232 days) age in sugarcane varieties

Varieties	CH (m)	CD (cm)	LL (m)	LW (cm)	LA (cm <sup>2</sup> )
B 41 227	2.83 <sup>a</sup>	2.47 <sup>c</sup>	1.77 <sup>c</sup>	5.72 <sup>c</sup>	7.29 <sup>e</sup>
DB 228 57	2.35 <sup>c</sup>	2.43 <sup>c</sup>	1.78 <sup>c</sup>	5.45 <sup>f</sup>	6.97 <sup>f</sup>
N 14	2.24 <sup>c</sup>	2.43 <sup>c</sup>	1.88 <sup>b</sup>	4.47 <sup>f</sup>	6.03 <sup>f</sup>
N 52 219	2.43 <sup>c</sup>	2.13 <sup>d</sup>	1.82 <sup>b</sup>	4.23 <sup>g</sup>	5.53 <sup>g</sup>
N Co 334	2.43 <sup>c</sup>	2.04 <sup>d</sup>	1.73 <sup>c</sup>	4.32 <sup>g</sup>	5.38 <sup>h</sup>
B 52 298	2.20 <sup>d</sup>	2.64 <sup>b</sup>	1.92 <sup>a</sup>	5.58 <sup>d</sup>	7.73 <sup>c</sup>
E 188 56	2.52 <sup>c</sup>	2.10 <sup>d</sup>	1.71 <sup>c</sup>	5.13 <sup>e</sup>	6.32 <sup>f</sup>
B 59 212	2.68 <sup>c</sup>	2.70 <sup>a</sup>	1.95 <sup>a</sup>	5.87 <sup>c</sup>	8.22 <sup>b</sup>
B 4906	2.53 <sup>c</sup>	2.21 <sup>d</sup>	1.62 <sup>d</sup>	4.18 <sup>g</sup>	4.89 <sup>h</sup>
CP 69 105	2.82 <sup>b</sup>	2.13 <sup>d</sup>	1.53 <sup>e</sup>	4.65 <sup>f</sup>	5.10 <sup>h</sup>
N 53 216	2.66 <sup>c</sup>	2.11 <sup>d</sup>	1.76 <sup>c</sup>	4.64 <sup>f</sup>	5.90 <sup>f</sup>
Mex 54 245	2.89 <sup>a</sup>	2.36 <sup>c</sup>	1.74 <sup>c</sup>	5.83 <sup>c</sup>	7.29 <sup>e</sup>
B 60 267	2.63 <sup>c</sup>	2.70 <sup>a</sup>	1.84 <sup>b</sup>	6.45 <sup>a</sup>	8.54 <sup>a</sup>
Co 622	2.73 <sup>c</sup>	2.28 <sup>d</sup>	1.90 <sup>b</sup>	5.48 <sup>d</sup>	7.48 <sup>d</sup>
C 8656	2.68 <sup>c</sup>	2.14 <sup>d</sup>	1.93 <sup>a</sup>	6.00 <sup>b</sup>	8.34 <sup>b</sup>
C 86 165	2.68 <sup>c</sup>	1.95 <sup>e</sup>	1.79 <sup>c</sup>	4.42	5.71 <sup>g</sup>
Grand mean	2.58	2.30	1.79	5.15	6.67
SE (±)	0.17	0.10	0.08	0.24	1.46
LSD (5%)	0.51*	0.30*	0.25*	0.73*	0.49*
CV (%)	9.23	6.17	6.47	6.66	10.29

\*Significant at 5% level of significance

Table 2: Flowering and <sup>0</sup>Brix in juice in cane stalks of sugarcane varieties at 10.5 month age

Varieties	Flowering (%)	<sup>0</sup> Brix (%)
B 41227	27.00 <sup>e</sup>	15.67 <sup>d</sup>
DB 228 57	7.57 <sup>g</sup>	13.92 <sup>e</sup>
N 14	5.57 <sup>g</sup>	15.46 <sup>d</sup>
N 52 219	2.00 <sup>g</sup>	16.88 <sup>c</sup>
N Co334	1.00 <sup>g</sup>	14.79 <sup>d</sup>
B 52 298	3.83 <sup>g</sup>	17.17 <sup>c</sup>
E 188 56	75.66 <sup>b</sup>	17.29 <sup>c</sup>
B 59 212	17.60 <sup>f</sup>	17.96 <sup>b</sup>
B 4906	50.37 <sup>c</sup>	17.09 <sup>c</sup>
CP 69 105	100.00 <sup>a</sup>	19.17 <sup>a</sup>
N 53 216	5.52 <sup>g</sup>	16.67 <sup>d</sup>
Mex 54 245	39.86 <sup>d</sup>	15.13 <sup>d</sup>
B 60267	12.06 <sup>f</sup>	14.25 <sup>e</sup>
Co 622	1.00 <sup>g</sup>	15.15 <sup>d</sup>
C 86 56	3.39 <sup>g</sup>	14.67 <sup>d</sup>
C 86 165	9.07 <sup>g</sup>	13.46 <sup>f</sup>
General mean	22.59	15.92
SE (±)	4.89	0.98
LSD (5%)	14.65	2.95
CV (%)	29.83	8.68

N Co 334 and Co 622. At 10 month age, flowering in stalks of CP 69 1059 was 100% followed by varieties, E 188 56, B4906 (76.03-50.36%). Medium flowering occurred in varieties, B 41 227, Mex 54 245, B 59 212, B 60267 (27-10.04%). Low flowering was observed in varieties, DB 228 57 (N 14 (5%), C 86 56 (3.38%), B 59 298 (3.33%), N 52 219 (1.89%) and C 86 165 (7.48-1.62%). Flowering in commercial cultivation was undesirable as on occurrence of flowering normal vegetative growth of stalk is terminated leading to sprouting of buds at the nodes of top portion of stalk or even development of suckers or late shoots<sup>18,24</sup>. Flowering varieties needed to be harvested earlier than non-flowering varieties otherwise there could be losses to sugar in juice and to the cane weight or cane yield. The extent of losses might vary with the agro-climatic conditions following flowering. However, flowering was desirable for hybridization between varieties for developing improved varieties<sup>18</sup>.

The °Brix in juice extracted from middle of standing cane stalks was determined by hand refractometer at 10.5 months, which provided information on percentage of soluble solids in juice. Most of the soluble solids in sugarcane juice were sugars<sup>20</sup>. Highest °Brix was recorded in variety CP 69 1059 (19.17) which was significantly higher than general mean of varieties (15.92). Next high °Brix was in varieties B 59 212 (17.96), E 188 56 (17.29) and B 4906 (17.09). Next high °Brix was in varieties, N 52 219, N 53 216, B 41 227, N 14, Co 622, Mex 54 245, N Co 334, C 85 56 and B 60267 (16.88-14.25) low °Brix was recorded in C 86 56 (13.46) and DB 228 57 (13.92) and B 60267 (14.25). The °Brix in juice was generally high in varieties recording high flowering. Sugar in juice in varieties generally agreed with that observed at Ethiopian sugar estates at Tandaho and Finchaa<sup>20-22</sup>. Sugar in juice of sugarcane varieties was a varietal or genetic characteristic<sup>3-5,8,14,20-24</sup>.

#### **Observable morphological characters at 7.5 month age:**

Observable morphological characteristics were recorded at 7.5 months when the expression of stem, internode, node, bud and leaf characteristics was optimum and the differences among varieties were discernible<sup>4</sup>. Morphological characters were grouped into three categories, (A) Discrete, (B) Continuous and (C) Combined characters. Discrete characters were distinctive, stable and less affected by environment<sup>17,18</sup>. Continuous characters showed distinct variation but were influenced by environmental conditions to some extent<sup>13</sup>. Combined characters were quasi-discrete and continuous which were influenced by the growth and development stage of the stalk or the crop age<sup>11,13</sup>. These three groups of morphological characters were called as standard descriptors for identification of sugarcane varieties<sup>10</sup>.

The data on above discrete, continuous and combined characters were recorded at mostly at 7.5 month age in 16 sugarcane varieties and the results on the standard descriptors for 16 varieties are presented in Table 3 and 4.

**Discrete characters:** There were differences in varieties for 11 discrete morphological characters: (1) Stool habit in 9 varieties, N14, B 52 298, E 188 56, B 52 212, CP 69 1059, Mex 54 245, B 60267, C 86 56 and C 86 165 was spreading type, whereas seven varieties, B 41227, DB 228 57, N 52 219, N Co 334, B 4906, N 53216 and Co 622 had non-spreading type. (2) Unexposed stem colour varied with varieties. Variety, B 41227 had brownish green, DB 228 57 green purplish, N 14 purplish; N Co 334 yellowish dull green; B 52298 purplish brownish green; B 4906 purplish dull green; Co 622 purple; C 86 56 light green; C 86 165 dull green and varieties, N 52 219, B 59 212, CP 69 1059, N 53 216, Mex 54 245 and B 60267 had green colour of unexposed stem. (3) Ivory marks on the internodes were absent in 14 varieties and present in B 52 298 and C 86 56. (4) Bud shape was round in varieties, B 41227, DB 228 57 and B 4906; rhomboid in N 14; obovate in N 52 219, N Co 334, B 52298, B 50212, CP 69 1059 and N 53 216; ovate in C 622 and rectangular beaked in E 188 56. (5) Bud germ pore position was medium in varieties, B 41227, DB 228 57, B 59212 and CP 691059; subapical in N 14, B 52 219, B 52 298, Mex 54 245 and B 60 267 and apical position in N CO 334, B 4906, C 86 65 and C 86 165. (6) Bud cushion was present in varieties, B 41227, DB 228 57, N 14, N 52219, N Co 334, E 188 56, N 53 216 and Mex 54 245, whereas it was absent in varieties, B 52298, B 59 212, B 4906, CP 69 1059, B 60267, Co 622, C 86 56 and C86 165. (7) Leaf colour was light green in varieties, B 41227 and B 4906; green in DB 228 57, N Co 334, B 52298, B 59212, CP 69 1059, N 53 216, Mex 54 245, B 60 267 and Co 622; light green colour in N 14 and C 86 165 and dark green leaf colour in varieties, N 52 219, E 188 56 and C 85 56. (8) Ligule shape was deltoid in varieties, Mex 54 245, B 60267, Co 622 and C 86 165; the remaining varieties had crescent shape of the ligule. (9) Auricle shape was deltoid slight to deltoid sloppy in varieties, B 41227, DB 228 57, N Co 334 and E 188 56; deltoid shape in N 14, B 4906, N 53 216 and Mex 54 245; sloppy in N 52 219 and B 52 298; lanceolate in B 59 212, CP 69 1059, C 86 56 and C 86 165; dentoid in varieties, B 60267 and Co 622. (10) °Brix in juice or percent soluble solids in juice at 10.5 month was maximum in variety CP 69 1059 followed by varieties, B 59 212, E188 56, B 52 298, B 4906, N 52 219, N 53 216, B 41227, N 14, Co 622, Mex 54 245, N Co 334, C 86 56, B 60267, C 86 56 and DB 228 57. (11) Lodging resistance behavior was judged from the crop stand position in the field. Varieties were

Table 3: Morphological Descriptors for sugarcane varieties; B 41 227, DB 228 56, N 14, N 53 219, N Co 334, B 52 298, E 188 56 and B 59 212

Characters	B 41 227	DB 228 57	N 14	N 53 219	N Co 334	B 52 298	E 188 56	B 59 212
<b>Discrete characters</b>								
1 Stool habit	Non-spreading	Non-spreading	Spreading slight	Slight spreading	Non-spreading	Spreading	Spreading	Spreading
2 Stem colour unexposed	Brownish-greenish	Green-purplish	Purplish	Green	Yellowish-dull green	Purplish-brownish green	Purplish	Green
3 Ivory marks on internodes	Absent	Absent	Absent	Absent	Absent	Present	Absent	Absent
4 Bud shape	Round	Round	Rhomboid	Obovate	Obovate	Obovate	Rectangular beaked	Obovate
5 Bud germ pore position	Medium	Medium	Sub-apical	Sub-apical	Apical	Sub-apical	Sub-apical	Medium
6 Bud cushion	Present	Present	Present	Present	Present	Absent	Present	Absent
7 Leaf colour	Light green	Green	Dark green	Lush green	Green	Green	Dark green	Green
8 Ligule shape at leaf-sheath joint	Crescent	Crescent	Crescent	Crescent	Crescent	Crescent	Crescent	Crescent
9 Auricle shape at leaf sheath margin	Deltoid slight to deltoide sloppy	Sloppy deltoide to sloppy	Deltoid	Sloppy	Deltoid and sloppy	Sloppy	Deltoid and sloppy	Lanceolate and sloppy
10 %Brix percentage juice at 10.5 months (348 days)	15.67	13.92	15.46	16.88	14.79	17.17	17.29	17.96
11 Lodging resistance	Tolerant	Tolerant	Tolerant	Moderately tolerant	Moderately tolerant	Tolerant	Moderately tolerant	Moderately tolerant
<b>Continuous characters</b>								
1 Colour of exposed stem	Purplish	Purple	Purplish	Purplish	Purplish	Purplish	Purplish	Green
2 Stem height at 7.7 months (m)	2.83	2.35	2.24	2.43	2.43	2.20	2.52	2.68
3 Stem diameter at 7.7 months (cm)	2.47	2.43	2.40	2.13	2.04	2.64	2.10	2.70
4 Corky patches on internodes	Absent	Absent	Absent	Absent	Absent	Present	Absent	Absent
5 Wax bloom on internodes	Light	Heavy	Heavy	Medium	Heavy	Light	Heavy	Medium
6 Node swelling	Slight-swollen	Slight-swollen	Slight-swollen	Slight-swollen	Not-swollen	Slight-swollen	Slight-swollen	Not-swollen
7 Root zone swelling	Not-swollen	Not-swollen	Not-swollen	Not-swollen	Not-swollen	Not-swollen	Slight-swollen	Not-swollen
8 Root zone colour	Greenish	Light green	Dull green	Green	Dull green	Purplish green	Green	Dull green
9 Growth ring colour	Light green	Green	Light green	Light green	Dull green	Light green	Green	Dull green
10 Leaf blade length (cm) (Fully expanded green leaf)	177	178	188	182	173	192	171	195
11 Leaf width (At the widest portion of the lamina) (cm)	5.72	5.45	4.47	4.23	4.32	5.58	5.13	5.87
12 Leaf colour	Light green	Green	Dark green	Lush green	Green	Green	Dark green	Green
13 Leaf sheath colour	Light green with margin straw colour	Green	Green	Light green	Green	Green	Green	Green
14 Leaf sheath spines	Present	Absent	Present	Absent	Absent	Present	Absent	Absent
15 Leaf sheath waxiness	Slight	Light	Medium	Slight	Light	Slight	Slight	Slight
16 Dewlap colour	Green	Green	Dull green	Dull green	Dull green	Green	Green	Dull green
17 Flowering	Medium flowering (27.0%)	Low flowering (7.48%)	Low flowering (5%)	Low flowering (1.89%)	Non flowering	Low flowering (3.33%)	Heavy flowering (76.03%)	Medium flowering (17.5%)
18 Lodging	Non-lodging	Non-lodging	Non-lodging	Lodging	Non-lodging	Non-lodging	Lodging	Non-lodging

Table 3: Continue

Characters	B 41 227	DB 228 57	N 14	N 53 219	N Co 334	B 52 298	E 188 56	B 59 212
<b>Combined characters</b>								
1 Internode shape	Obconoid bobbin	Bobbin	Cylindrical	Cylindrical	Cylindrical	Cylindrical	Cylindrical	Cylindrical
2 Internode alignment	Straight	Straight	Straight	Straight	Straight	Zigzag	Zigzag	Zigzag
3 Internode diameter (cm)	2.47	2.43	2.43	2.13	2.04	2.64	2.10	2.70
4 Pith	Absent but developed in flowered stalks	Absent but developed in flowered stalks	Absent but developed in flowered stalks	Absent	Absent	Absent	Present, developed in flowered stalks	Absent but developed in flowered stalks
5 Splits or growth cracks	Present on exposed ones	Absent	Absent	Rarely present	Absent	Present	Absent	Absent
6 Root eyes	2	2-3	2	2	2	2	Not definite	Not definite
7 Root eyes arrangement	Regular	Irregular	Regular	Irregular	Regular	Irregular	Irregular	Irregular
8 Bud size	Small	Small	Medium	Medium	Medium	Small	Big	Small
9 Bud groove	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
10 Leaf carriage	Erect	Erect	Erect	Semi-drooping	Semi-drooping	Erect	Erect	Drooping
11 Leaf sheath spines	Sparse	Glabrous	Dense	Glabrous	Glabrous	Sparse	Glabrous	Glabrous
12 Leaf sheath clasping	Tight	Loose	Tight	Tight	Tight	Tight	Tight	Tight



Table 4: Morphological descriptors for sugarcane varieties, B 4906, CP 69 105, N 53 216, Mex 54 245, B 60 267, Co 622, C 86 56 and C 86 165

Characters	B 4906	CP 69 105	N 53 216	Mex 54 245	B 60 267	Co 622	C 86 56	C 86 165
<b>Discrete characters</b>								
1	Stool habit	Slight spreading	Non-spreading	Spreading	Spreading	Non-spreading	Spreading	Spreading
2	Stem colour unexposed	Purplish-dull green	Green	Green	Green	Purple	Light green	Dull green
3	Ivory marks on internodes	Absent	Absent	Absent	Absent	Absent	Present	Absent
4	Bud shape	Round	Obovate	Ovate	Oval	Oval	Triangular	Oval
5	Bud germ pore position	Apical	Apical	Sub-apical	Sub-apical	Apical	Apical	Apical
6	Bud cushion	Absent	Present	Present	Absent	Absent	Absent	Absent
7	Leaf colour	Light green	Green	Green	Green	Green	Dark green	Lush green
8	Ligule shape at leaf-sheath joint	Crescent	Crescent	Deltoid	Deltoid	Deltoid	Crescent	Deltoid
9	Auricle shape at leaf sheath margin	Deltoid	Deltoid	Deltoid and sloppy	Deltoid and sloppy	Deltoid	Lanceolate and deltoid	Lanceolate
10	<sup>o</sup> Brix percentage juice at 10.5 months (348 days)	17.09	16.67	115.13	14.25	15.50	14.67	13.46
11	Lodging resistance	Tolerant	Moderately tolerant	Moderately tolerant	Tolerant	Tolerant	Lodging susceptible	Lodging susceptible
<b>Continuous characters</b>								
1	Colour of exposed stem	Purple dull green	Purple-green	Green	Green	Purple	Purple	Purple
2	Stem height at 7.7 months (m)	2.53	2.66	2.89	2.63	2.73	2.68	2.68
3	Stem diameter at 7.7 months (cm)	2.21	2.11	2.36	2.70	2.28	2.14	1.95
4	Corky patches on internodes	Absent	Present	Present	Absent	Absent	Absent	Absent
5	Wax bloom on internodes	Medium	Light	Light	Medium	Heavy	Heavy	Medium
6	Node swelling	Not-swollen	Not-swollen	Not-swollen	Not-swollen	Not-swollen	Not-swollen	Not-swollen
7	Root zone swelling	Not-swollen	Not-swollen	Not-swollen	Not-swollen	Not-swollen	Swollen	Not-swollen
8	Root zone colour	Dull green	Yellowish green	Green	Light green	Purple	Green	Light green
9	Growth ring colour	Light green	Green	Yellowish green	Green	Green	Green	Green
10	Leaf blade length (Fully expanded green leaf) (cm)	162	176	174	184	190	193	179
11	Leaf width (At the widest portion of the lamina) (cm)	4.18	4.64	5.83	6.45	5.48	6.00	4.42
12	Leaf colour	Light green	Green	Green	Green	Green	Dark green	Lush green
13	Leaf sheath colour	Light green	Light green	Green	Green	Light green purple at the base	Green	Green
14	Leaf sheath spines	Absent	Present	Present	Absent	Absent	Present	Present
15	Leaf sheath waxiness	Slight	Slight	Slight	Slight	Light	Slight	Slight
16	Dewlap colour	Green	Green	Dull green	Dull green	Dull green	Dull green	Dull green
17	Flowering	Heavy flowering (50.36%)	Low flowering (5.40%)	Medium flowering (20.66%)	Medium flowering (10.04%)	Non-flowering	Low flowering (3.38%)	Low flowering (-1.62%)
18	Lodging	Non-lodging	Non-lodging	Non-lodging	Non-lodging	Non-lodging	Lodging susceptible	Lodging susceptible

Table 4: Continue

Characters	B 4906	CP 69 105	N53 216	Mex 54 245	B 60 267	Co 622	C 86 56	C 86 165
<b>Combined characters</b>								
1 Internode shape	Cylindrical	Cylindrical	Cylindrical	Slight conical	Cylindrical	Cylindrical	Cylindrical	Cylindrical
2 Internode alignment	Zigzag	Zigzag	Straight	Straight	Zigzag	Straight	Straight	Straight
3 Internode diameter (cm)	2.21	2.13	2.11	2.36	2.70	2.28	2.14	1.95
4 Pith	Present, develop in flowered stalks	Present, develop in flowered stalks	Absent	Absent, developed in flowered stalks	Absent, develop in flowered stalks	Absent	Absent	Absent
5 Splits or growth cracks	Absent	Rarely present	Rarely present	Rarely present	Big long splits present	Absent	Absent	Absent
6 Root eyes	Not definite	Not definite	Not definite	2	2-3	2	2	2
7 Root eyes arrangement	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular
8 Bud size	Small	Small	Small	Small	Small	Medium	Medium	Medium
9 Bud groove	Present	Present	Absent	Slight present	Absent	Absent	Absent	Absent
10 Leaf carriage	Erect	Erect	Erect	Erect	Erect	Erect	Drooping	Semi-drooping
11 Leaf sheath spines	Glabrous	Glabrous	Dense	Dense	Glabrous	Glabrous	Dense	Dense
12 Leaf sheath clasping	Loose	Loose	Loose	Loose	Loose	Loose	Loose	Loose

grouped into three lodging classes, tolerant, moderately tolerant and susceptible to lodging. Varieties tolerant to lodging were: B 41227, DB 228 57, N 14, B 52298, B 4906, CP 69 1059, B 60 267 and Co 622. Moderately tolerant were N 52 219, N Co 334, E 188 56, B 59 212, N 53 216 and Mex 54 245 and the lodging susceptible varieties were C 86 56 and C 86 165.

**Continuous characters:** There were differences in varieties for 18 continuous characters: (1) Colour of exposed stem of 16 varieties was differentiated into five types. Purplish stem colour in varieties, B 41227, N 14, B 52 219, N Co 334, B 52 298 and E 188 56; purple in varieties, DB 228 57, Co 622, C 86 56 and C 86 165; purple dull green in B 4906 and CP 69 1059; purple green in N 53 216 and green colour of stem in varieties, B 59 212 and B 60 267. (2) Tall cane stalks were formed in varieties, Mex 54 245, B 41227, CP 69 1059, Co 622, B 59 212, C 85 56, C 86 165, N 53 216 and B 60 267. Medium cane stalk length was in varieties, B 4906, E 188 56, N 52 219, N Co 334, DB 228 57 and N 14 and shortest in variety B 52 298. (3) Medium thick cane stalks were in varieties B 50 212, B 60267 and B 52 298; medium thin canes in fourteen varieties and thin canes were in variety, C 86 165.

(4) Corky patches on internodes were present in B 52 298, CP 69 1059, N 53 216 and Mex 54 245 but were absent in other 12 varieties. (5) Wax bloom on internodes was light in varieties, B 41227, B 52 298, N 53 216 and Mex 54 245; medium in N 53 219, B 59212, B 4906, CP 69 1059, B 60 267 and C 86 165 and heavy bloom in varieties, DB 228 57, N 14, N Co 334, E 188 56, Co 622 and C 86 56. (6) Node swelling was slight in E 188 56 but absent in other varieties. (7) Root zone swelling was present in C 86 65 but absent in other 15 varieties. (8) Root zone colour was greenish in variety B 41227; light green in DB 228 57; green colour in varieties, N 52 219, E 188 56, Mex 54 245 and C 86 56; dull green in N 14, N Co 334, B 59 212 and B 4906; yellowish green in varieties, N 52 216, CP 69 1059, B 60 267 and C 86 165; purplish green in B 52 298 and purple in Co 622. (9) Growth ring colour was light green in varieties, B 41227, N 14, N 53 219, B 52 298, B 4906 and CP 69 1059; yellowish green in Mex 54 245; green in DB 228 57, E 188 56, N 53 216, B 60 267, Co 622, C 86 56 and C 86 165; dull green in N Co 334 and B 59 212.

(10) Leaf blade length was long in varieties, Co 622, N 52 298, C 86 56 and B 59212, medium in E 188 56, Mex 54 245, N 53 216, B 41227, DB 228 57, C 86 165, B 60267, N 53 216 and N 14 (>171 cm). (11) Leaf blade width was broad in varieties, C 86 56 and B 60 267 and medium in N Co 334, N 53 219, C 86 165, N 14, N 53 216, CP 60 1059,

E 188 56, DB 228 57, CP 69 1059, B 41 227, B 59 212 and B 52 298. (12) Leaf colour was light green in varieties, B 41227 and B 4906; green in DB 228 57, N Co 334, B 52 298, B 59 212, CP 69 1059, N 52 216, Mex 54 245, B 60 267 and Co 622; lush green in N 53219 and C 86 165 and dark green in N 14, E 188 56 and C 86 56. (13) Leaf sheath colour was light green in varieties, B 41227, N 53 219, B 4906 and N 52 216; light green with purplish tinge at the base in variety, C 622; green colour in varieties, DB 228 57, N 14, N Co 334, B 52 298, E 188 56, B 59 212, CP 69 1059, Mex 54 245, B 60267, 86 56 and C 86 165.

(14) Leaf sheath spines were absent in varieties, DB 228 7, N Co 334, E 188 56, B 59 212, B 4906, CP 601059, N 52 216, Mex 54 245, B 60 267 and Co 622. Leaf sheath spines were present in varieties, B 41 227, N 14, B 52 298, C 86 56 and C 86 165. (15) Leaf sheath waxiness was slight in varieties, B 41227, N 53 219, B 52 298, E 188 56, B 4906, CP 69 1059, N 52 216, Mex 54 245, B 60 267, Co 622, C 86 56 and C 86 165; light sheath waxiness was in DB 228 57 and N Co 334 and medium in N 14. (16) Dewlap colour was green in varieties, B 41 227, DB 228 57, B 52 298, E 188 56, B 4906 and N 52 216 and dull green colour in varieties, N 14, N 53 219, N Co 334, B 59 212, CP 69 1059, Mex 54 245, B 60 267, Co 622, C 86 56 and C 86 165.

(17) Flowering occurred in all varieties except N Co 334 and Co 622. Heavy flowering was in varieties, CP 69 1059, E 188 56 and B 4906. Medium flowering was in B 41227, B 59212, Mex 54 245 and B 60 267. Low flowering occurred in DB 228 57, N 53 216, N 14, C 86 56, N 53 219, B 52 298, B 52 298 and C 86 165. (18) Lodging occurred in varieties, N 53 219, E 188 56, C 86 56 and C 86 165, while varieties tolerant to lodging were: B 41227, DB 228 57, N 14, N Co 334, B 52 298, B 59 212, B 49 06, CP 69 1059, N 52 216, Mex 54 245 and Co 622.

**Combined characters:** Varieties differed in 12 combined morphological characters: (1) Internode shape was cylindrical in varieties, N 14, N 5 219, N Co 334, B 52 298, E 188 56, B 59 212, B 4906, CP 691059, N 52 216, B 60267, Co 622, C 86 56 and C 86 165. Bobbin shape internode was in variety DB 228 57; obconoid in B 41 227 and slight conoidal in Mex 54 245. (2) Internode alignment was straight in varieties, B 41227, DB 228 57, N 14, N 53 219, N Co 334, N 52 216, Mex 54 245, Co 622, C 86 56 and C 86 165, whereas, zigzag shape internode alignment was in varieties, B 52 298, E 188 56, B 59 212, B 4906, CP 69 1059 and B 60 267. (3) Internode diameter was medium thick in varieties, B 59 212, B 60267 and B 52 298 (>2.64 cm). Thin internode diameter canes in variety, C 86 165 (1.95 cm). Remaining 14 varieties had medium thin internode diameter (<2.5 cm).

(4) Pith in stem was absent in varieties, N 53 219, N Co 334, B 52 298, N 52 216, Co 622, C 86 56 and C 86 165. Pith in the stem was absent but developed in flowered stalks in varieties, B 41 227, DB 228 57, N 14, B 59 212, B 4906, CP 69 1059, Mex 54 245 and B 60 267. (5) Splits or growth cracks on the internodes were present in varieties, B 41227, B 52 298 and B 60267, latter variety having big long splits; splits were rarely present in N 52 219, CP 69 1059, N 52 216 and Mex 54 245. Splits were absent in varieties, DB 228 57, N 14, N Co 334, E 188 56, B 59 212, B 4906, Co 622, C 86 56 and C 86 165.

(6) Root eyes rows were 2 in number in varieties, B 41 227, N 14, N 53 219, N Co 334, B 52 298, Mex 54 245, Co 622, C 86 56 and C 86 165; 2-3 in DB 228 57 and B 60 267 and not definite in E 188 56, B 59 212, B 4906, CP 69 1059 and N 52 216. (7) Root eyes arrangement was regular in varieties, B 41 227, N 14 and N Co 334 and irregular arrangement in varieties, DB 228 57, N 53 219, B 52 298, E 188 56, B 59 212, B 4906, CP 69 1059, N 52 216, Mex 54 245, B 60 267, Co 622, C 86 56 and C 86 165. (8) Bud size was small in varieties, B 41227, DB 228 57, N 14, N 53 219, B 52 298, B 59 212, B 4906, CP 69 1059, N 52 216, Mex 54 245 and B 60 267; medium size in N Co 334, Co 622, C 86 56 and C 86 165 and big bud size in E 188 56. (9) Bud groove was present in B 4906 and CP 69 1059; slight groove in Mex 54 245 and bud groove absent in B 41 227, DB 228 57, N 14, N 53 219, N Co 334, N 52 298, E 188 56, B 59 212, N 52 216, B 60 267, Co 622, C 86 56 and C 86 165.

(10) Leaf carriage was erect in varieties, B 41227, DB 228 57, N 14, B 52 298, E 188 56, B 4906, CP 69 1059, N 52 216, Mex 54 245, B 60 267 and Co 622; semi-drooping in varieties, N 53 219, N Co 334, C 86 165 and drooping in B 59 212 and C 86 56. (11) Leaf sheath spines were sparse in varieties, B 41227 and B 52 298; dense in N 14, N 52 216, Mex 54 245, C 86 56 and C 86 165; leaf sheath was glabrous in varieties, DB 228 57, N 53 219, N Co 334, E 188 56, B 59 212, B 4906, CP 69 1059, B 60267 and Co 622. (12) Leaf sheath clasping was tight in varieties, B 41227, N 14, N 53 219, N Co 334, B 52 298, E 188 56 and B 59 212; loose in varieties, DB 228 57, B 4906, CP 69 1059, N 52 216, Mex 54 245, B 60 267, Co 622, C 86 56 and C 86 165.

Varieties can be identified by examining the above 11 discrete, 18 continuous and 12 combined characters, called as standard descriptors for sugarcane<sup>16</sup>. Morphological characters though were influenced by environmental conditions to some extent, the varieties had distinct phenotypes in respect of observable stem, node, internode, bud, leaf, leaf joint characters and measurable characters. The above ground morphological characters were called as

descriptors for sugarcane for identification, release and notification of varieties<sup>19</sup> and could be used for proprietary rights by plant breeders<sup>25</sup> and for testing of distinctiveness, uniformity and stability of performance of sugarcane varieties<sup>11</sup>.

## CONCLUSION

Sugarcane varieties differed in measurable morphological characters, cane height and cane diameter leaf blade length and leaf width. Lengthy cane stalks were formed in varieties, Mex 54 245, B 41227, CP 69 1059, Co 622, B 59 2112, C 85 56, C 86 165, N 53 216 and B 60 267. Cane stalks were medium thick in varieties, B 50 212, B 60267 and B 52 298 followed by medium thin in descending order in B 41 227, DB 228 57, N 14, Mex 54 245, B 4906, C 86 56, CP 69 1059, N 53 219, N 53 216, E 188 56 and N Co 334 and thin canes in C 86 165. Leaf blade length was long in varieties, B 59 212, C 86 165, B 52 298 and Co 622. Leaf width was broad in varieties, B 60 267 and C 86 56. Flowering occurred in all varieties except N Co 334 and Co 622. Heavy flowering was observed in varieties, CP 69 1059, E 188 56 and B 4906. The <sup>o</sup>Brix percent juice was generally high in heavy flowering varieties, CP 69 1059, E 188 56 and B 4906. Description for 11 discrete, 18 continuous and 12 combined morphological characters for 16 varieties were presented for their identification in field conditions. These characters could be used as descriptors for identification, distinctiveness, uniformity and stability performance of varieties and maintaining purity in sugarcane seed and commercial production.

## SIGNIFICANCE STATEMENTS

Improved sugarcane varieties were the basic requirements for sustaining sugarcane and sugar production in any country. Sugarcane varieties were developed where sugarcane hybridization work was carried out between chosen parents. However, in those countries where sugarcane varieties were not developed through breeding improved varieties are introduced from other countries as in Ethiopia and Pakistan for sustaining sugarcane production. Introduced varieties needed to be evaluated for their morphological, cane yield and quality characteristics for selection of suitable varieties for production and breeding. Morphological characteristics of above ground part of stalk, internode, node, leaf, leaf joint and leaf carriage varied with the varieties and were best expressed at the early stage of growth and development. In view of it, the study was undertaken on introduced varieties of sugarcane in Southern Ethiopia.

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