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Research Article

Evaluation of advanced sugarcane clones for cane yield and quality traits in plant and ratoon crops

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Abstract
Sugarcane clones were assessed for cane yield and quality traits in Advanced Varietal Trials in I plant, II plant and ratoon crops during 2019-21. Fifteen genotypes along with three standards were evaluated using Randomized Block design with three replications at K. J. Somaiya Institute of Applied Agricultural Research (KIAAR), Sameerwadi, Karnataka. Data were collected on eleven important yield contributing and quality traits. Individual and pooled analysis of variance in two plants and a ratoon crop indicated highly significant differences among the treatments for most of the traits under study. Genotype Co 14016 recorded significantly higher cane yield and numerically higher commercial cane sugar (CCS) yield in AVT II Plant, AVT Ratoon and pooled analysis. Co 14002 variety recorded significantly higher cane and CCS yield over all three standards, (Co 86032, CoC 671 and Co 05103) in II plants. Two varieties, CoN 14002 and CoVC 14062 recorded significantly higher cane and CCS yield over all three standards, (Co 86032, CoC 671 and Co 05103) in only ratoon crop indicating the good ratoonability of these varieties. Character association studies of cane yield with its contributing traits indicated positive significant correlations of the number of shoots (0.346), millable canes (0.591) and CCS yield (0.883) with cane yield. Among the yield parameters, a positive significant association of cane height with the number of tillers, the number of shoots, Brix^{0} and Pol% has been observed, indicating the contribution of cane height to yield and quality. The present study demonstrated the superiority of three genotypes *viz*., Co 14016, Co 14002 and CoVC 14062 for cane yield and quality and scope for indirect selection based on the number of shoots, millable canes and CCS yield in sugarcane breeding.

Keywords: Sugarcane, Ratoon, Cane yield, CCS, Genetic variability, Correlation

INTRODUCTION

Sugarcane (*Saccharum sp*. hybrids) is one of the main crops in the world and the major producer of sugar and ethanol (Silva *et al.,* 2016). Sugarcane is grown in the tropics and subtropics and serves numerous economic and ecological functions (Suprasanna *et al*, 2011). In addition to the well-known edible properties, sugarcane lignocellulosic biomass (including bagasse, straw, and tops) is a type of cheap, abundant, and renewable raw materials that promotes sustainable development and can be utilized for biofuel, bioenergy and several valuable biomolecules (Jayapal *et al*., 2013; Pereira *et al*., 2016). Brazil is the largest sugar-producing country in the world, yielding 37 million metric tons of sugar followed by India, the second largest producer of sugar yielding 27 million metric tons of sugar (Shahbandeh, 2022).

Genetic improvement has played a major role in yield increase in the last decades in most of the sugarcane-producing regions around the world. Farmers prefer high cane yielding and early maturing varieties while the industries demand those with high sucrose. Hence, varietal improvement of sugarcane is targeted for high cane yields and high sucrose quality. Though many traits such as agronomic variables, plant characters, duration, disease resistance and ratooning ability, are considered for sugarcane improvement, breeders have directed their efforts to address the needs of farmers in spite of varying climate and edaphic conditions, and also for industrial use in terms of high sucrose content to comply with the increasing pressure to enhance productivity and to sustain profitable sugar industries (Tiwari *et al*., 2010).

Sugarcane breeding involves several successive stages of selection using clonal multiplication to select desirable genotypes (Alarmelu *et al.,* 2015). In sugarcane breeding programmes, large numbers of clones are evaluated every year over different seasons, regions and harvests (Almeida *et al*., 2014). Sugarcane varietal release requires data that are recorded across different environments over the years. In the most advanced selection stages, the elite candidates are tested in multi environment trials (MET) at representative locations using replicated experiments. MET carried out over several crop years allows testing of genotypes over locations (GL), seasons (GC) and interactions to identify either consistently high yielding genotypes across the environments or best performing clones at a few environments.

Data collected in multi-location trials are complex in nature and need suitable statistical analysis for accurate interpretation. MET often reveal significant genotype environment interaction, making the selection of genotypes imprecise (Walker *et al*., 2011). In the presence of significant genotype environment interaction (GEI), selection should be location specific with adaptability. Various statistical models help to choose the genotypes, predict their phenotypic response to environmental changes, and thereby reduce the impact of G × E interaction (Sheelamary and Karthigeyan, 2021). These multi-environmental trial data are analyzed by two-way ANOVA, by treating genotypes, environments and their interaction as sources of variation. Genetic variance in crop traits is most commonly studied, as reflected in the high rate of scientific and technological progress in plant breeding (Edwards *et al.,* 2013; Edmeades, 2013).

Suitable genotypes for a locality can be identified when selection criteria are based on the characters that are having significant contributions for the desired characters. Inter association of different quality traits of sugarcane, their effect on cane yield and appropriate selection strategy based on quality traits is essential for appropriate and efficient selection strategy for the improvement of desirable traits.

The present investigation was aimed to identify promising clones with a high cane and CCS yield for further evaluation in larger fields and to study the character association of different yield and quality traits of sugarcane to facilitate the indirect selection.

MATERIALS AND METHODS

This study was conducted at K.J.Somaiya Institute of Applied Agricultural Research, Sameerwadi, Karnataka, India. Plant materials comprised 15 advanced varieties of All India Coordinated Research Project (AICRP) on sugarcane and three commercial cultivars as standards. The genotypes and standards were grown in a randomized complete block design with three replications. The plot area was 43.2 m^2, which includes six rows of 6 m length, spaced at 1.2 m between rows. Crops were raised during January 2019 and January 2020 with 36 two budded cane pieces in each row at the rate of 12 eye buds per meter. The field was irrigated after planting and all other recommended agronomic and cultural practices were followed. Plant crop was ratooned after harvest. Both the plant crops and the ratoon crop were harvested at the age of 12 months.

The total number of shoots and millable canes per plot were recorded at 8^{th} month (240 days) and 12^{th} month (360 days) after planting respectively. Five randomly selected cane samples were taken to determine the cane and juice quality traits at harvest. Details of data recorded in the trials are presented below.

1. Number of shoots per ha: The number of shoots per plot was recorded at 8 months after planting and converted to shoots per hectare
2. Number of internodes: The number of internodes in each cane recorded
3. Stalk height (cm): Stalk length was measured from soil surface to the visible dewlap
4. Stalk diameter (cm), Diameter was measured at the middle part of stalk with Vernier Caliper
5. Number of millable canes at harvest: The number of millable canes per plot was recorded at harvest and converted to per hectare
6. Single Cane Weight: Cane weight of the stalk was measured in kg
7. Brix (total soluble solids %): Brix was determined using a hydrometer
8. Sucrose percentage, was determined using a Polari meter, according to A.O.A.C. (1980)
9. Commercial Cane Sugar (CCS) % was calculated according to the formula described by Yadav and Sharma (1980) [Sucrose % − 0.4 (Brix-sucrose %)] × 0.73 (SR)
10. Cane yield (ton), was recorded per plot and calculated per hectare basis
11. Commercial Cane Sugar yield (ton) was estimated by multiplying net cane yield (ton) with CCS %

The data collected were analyzed separately for two plant crops and a ratoon crop for analysis of variance (ANOVA) using OPSTAT software. The pooled data over two years (two plant and ratoon crop cycles) was subjected to pooled analyses of variance as outlined by Gomez and Gomez (1984) as the coefficient of variation (CV %) for the individual experiments was lower than 20%. Mean separation was conducted using the Least Significant Difference wherever significant differences were detected in the F-test. Phenotypic (σ2 p) and genotypic (σ2 g) variances were estimated following Baye (2002). The mean values were used for genetic analyses to determine the phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV), according to Singh and Chaudhury (1985). Simple correlation coefficients between various pairs of the studied characters were computed using OPSTAT and further subjected to path analysis to determine the direct and indirect effects of different traits on cane yield.

RESULTS AND DISCUSSION

The mean values of cane yield, juice quality and related characters for the fifteen sugarcane genotypes along with three standards pooled across two plant cane and first ratoon crop seasons are provided in **Tables 1 and 2**. Results revealed the presence of significant differences among the mean performance of all the genotypes across the seasons except for the number of internodes, brix and sucrose%. Similar results of high variability among the sugarcane genotypes for cane yield, yield components and quality traits have been reported by Ganapathy and Purushothaman, 2017. The coefficient of variation (CV %) values for all studied characters was in the statistically acceptable range (less than 20) except CCS yield of ratoon crop. Results showed that the first plant crop had higher mean values for most of the traits as compared to the ratoon and second plant crop.

ANOVA for two plants and one ratoon crop indicated significant differences among the genotypes (clones) for all the traits except sucrose%, pol% and CCS yield in first plant; cane girth, the number of millable canes and CCS% in the second plant and sucrose% and number of tillers, cane height and CCS% in ratoon crop. Similarly pooled ANOVA over two plants and a ratoon crop indicated insignificant seasonal effect for all the quality traits like Brix, sucrose%, CCS% and CCS yield and significant differences among the genotypes for all the yield related traits indicating that the yield parameters are affected by different seasons. Similar observations of significant interaction between genotypes and seasons for all the traits except CCS% and CCS yield have been reported by previous co-workers (Farrag *et al.,* 2020). Significant effects of cultivars × crop cycles on the characters were indicative of the consequences of environment and difference in ratoonability of the cultivars. A significant effect of crop cycles for all the yield characters has been reported by Ogunniyan *et al.,* 2020. On the other hand, non-

Table 1. Mean performance of advanced sugarcane clones for cane yield characters as two plant and one ratoon crop

S.No.	Variety	Number of tillers (000/ha) at 4MAP				Number of Shoots (000/ha) at 8MAP				Number of Internodes at harvest			
		AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean	AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean	AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean
1	Co 14002	149.54	140.51	151.62	147.22	104.45	88.08	107.64	100.06	20.67	18.00	22.33	20.33
2	Co 14004	106.57	108.22	148.03	120.94	116.95	89.24	121.41	109.20	20.00	24.00	20.67	21.56
3	Co 14012	117.41	130.90	112.96	120.42	100.65	89.12	104.51	98.09	19.67	23.67	19.33	20.89
4	Co 14016	130.00	132.99	140.05	134.35	118.52	97.22	100.58	105.44	20.67	21.67	19.67	20.67
5	Co 14027	107.96	115.05	104.28	109.10	92.32	78.93	82.41	84.55	24.33	23.00	21.00	22.78
6	Co 14030	124.54	134.26	152.20	137.00	120.83	87.27	106.71	104.94	20.33	20.33	21.00	20.56
7	Co 14032	115.56	94.79	145.60	118.65	103.80	87.15	100.69	97.21	21.33	24.00	18.67	21.33
8	CoN 14073	120.93	121.88	167.48	136.76	99.54	90.86	93.75	94.71	19.67	23.67	17.67	20.33
9	CoSnk 14102	115.37	129.74	140.51	128.54	126.20	82.87	91.32	100.13	21.00	24.33	23.00	22.78
10	CoSnk 14103	101.20	101.97	139.70	114.29	114.54	83.45	97.80	98.60	22.00	26.00	24.00	24.00
11	CoT 14367	113.43	136.34	146.18	131.98	92.96	94.21	78.24	88.47	21.33	24.00	21.33	22.22
12	CoT 14111	127.32	125.81	116.90	123.34	123.24	88.77	93.87	101.96	20.33	20.33	23.00	21.22
13	CoVC 14062	94.91	111.46	143.29	116.55	107.87	92.82	82.06	94.25	20.67	19.33	24.00	21.33
14	MS 14081	124.35	135.54	139.24	133.04	108.70	92.48	82.41	94.53	21.00	26.67	24.33	24.00
15	MS 14082	162.41	144.79	175.93	161.04	111.48	107.64	97.92	105.68	23.00	25.33	21.33	23.22
16	Co 86032	130.55	149.54	144.68	141.59	123.89	110.77	110.19	114.95	21.33	23.33	19.67	21.44
17	CoC 671	106.94	133.68	130.79	123.80	117.78	103.12	85.99	102.30	21.00	25.00	22.00	22.67
18	CoSnk 05103	145.83	156.13	156.71	152.89	122.59	116.44	120.26	119.76	24.33	24.00	18.67	22.33
	Mean	121.93	127.98	142.01	130.64	111.46	93.36	97.65	100.82	21.26	23.15	21.20	21.87
	CD (5%)	21.22	26.65	NS	20.59	10.48	17.27	17.46	17.13	1.45	3.30	NS	NS
	CV (%)	10.48	12.50	19.89	9.46	5.64	11.10	10.73	10.19	4.09	8.55	12.66	8.64

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Table 1. Continued.

S.No.	Variety	Cane girth (cm) at harvest				Cane height at harvest (cm)				Number of millable canes (000/ha) at harvest			
		AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean	AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean	AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean
1	Co 14002	2.67	2.56	3.03	2.75	253.33	292.33	267.33	271.00	75.00	62.42	137.27	91.56
2	Co 14004	2.90	2.77	2.89	2.85	217.33	304.33	253.67	258.44	82.72	70.91	109.34	87.65
3	Co 14012	2.87	2.58	2.78	2.74	215.33	287.33	221.67	241.44	72.99	70.14	104.55	82.56
4	Co 14016	2.80	2.79	2.78	2.79	241.67	272.67	198.33	237.56	83.10	75.31	115.43	91.28
5	Co 14027	2.93	2.73	2.90	2.85	220.00	268.33	233.67	240.67	67.67	70.06	93.83	77.19
6	Co 14030	3.03	2.59	2.66	2.76	206.33	253.00	189.33	216.22	85.57	84.64	111.26	93.83
7	Co 14032	3.07	2.73	2.85	2.88	213.33	292.67	252.67	252.89	70.06	74.85	92.13	79.01
8	CoN 14073	3.03	2.67	2.68	2.80	216.67	326.67	220.00	254.44	80.48	71.76	120.83	91.02
9	CoSnk 14102	2.73	2.51	2.51	2.58	215.33	325.00	216.33	252.22	89.51	65.12	104.94	86.52
10	CoSnk 14103	3.03	2.73	2.91	2.89	205.33	296.33	269.67	257.11	82.10	72.22	90.97	81.76
11	CoT 14367	3.07	2.83	3.00	2.97	183.67	294.67	253.67	244.00	72.92	70.06	87.12	76.70
12	CoT 14111	2.87	2.90	2.75	2.84	255.00	299.33	233.00	262.44	83.56	71.76	97.22	84.18
13	CoVC 14062	3.13	2.87	3.24	3.08	244.33	276.33	230.00	250.22	77.70	65.20	111.42	84.77
14	MS 14081	3.10	2.83	3.05	3.00	230.00	306.33	247.33	261.22	71.14	67.82	91.51	76.83
15	MS 14082	2.87	2.64	2.76	2.76	247.00	273.67	253.00	257.89	74.23	69.68	83.45	75.79
16	Co 86032	3.07	2.88	2.91	2.95	238.33	302.00	217.00	252.44	83.41	59.49	106.79	83.23
17	CoC 671	2.90	2.89	2.67	2.82	264.33	316.67	250.00	277.00	81.40	67.05	94.14	80.87
18	CoSnk 05103	2.67	2.59	2.55	2.60	260.33	308.67	230.00	266.33	86.27	60.26	79.40	75.31
	Mean	2.93	2.73	2.83	2.83	229.32	294.24	235.37	252.98	78.88	69.38	101.76	83.34
	CD (5%)	0.13	NS	0.30	0.23	15.99	NS	NS	36.67	15.54	9.86	NS	15.54
	CV (%)	2.56	6.09	6.40	4.98	4.18	8.50	13.94	8.74	11.24	7.50	15.40	11.24

Table 2. Mean performance of advanced sugarcane clones for quality traits in two plant and one ratoon crops

S.No.	Variety	Single cane weight (kg) at harvest				Brix (^{0}) at harvest				Sucrose (%) at harvest			
		AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean	AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean	AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean
1	Co 14002	1.04	1.45	1.34	1.28	21.61	21.24	20.05	20.97	19.39	19.24	17.51	18.71
2	Co 14004	0.79	1.66	1.21	1.22	21.33	21.58	22.08	21.67	19.29	19.32	19.89	19.50
3	Co 14012	0.89	1.31	0.94	1.05	19.85	20.97	20.96	20.60	17.80	18.66	18.39	18.28
4	Co 14016	0.91	1.37	1.21	1.16	19.72	20.86	22.03	20.87	17.70	18.64	19.28	18.54
5	Co 14027	1.20	1.38	1.17	1.25	21.03	22.40	20.51	21.32	19.06	20.08	18.22	19.12
6	Co 14030	0.88	1.13	0.95	0.99	20.10	20.80	22.23	21.04	17.95	18.43	19.92	18.77
7	Co 14032	1.28	1.54	1.03	1.28	21.71	19.04	21.23	20.66	19.81	16.81	19.05	18.56
8	CoN 14073	1.02	1.39	0.94	1.11	20.42	18.57	21.84	20.28	18.44	16.58	19.69	18.24
9	CoSnk 14102	1.04	1.51	1.29	1.28	20.69	19.84	20.96	20.50	18.60	17.72	18.57	18.30
10	CoSnk 14103	1.28	1.40	1.21	1.30	20.61	19.43	19.95	20.00	18.46	17.24	17.46	17.72
11	CoT 14367	1.10	1.63	1.19	1.31	19.26	19.50	18.35	19.03	17.08	17.19	15.97	16.74
12	CoTl 14111	1.12	1.58	1.30	1.33	21.21	19.10	20.83	20.38	19.04	16.90	18.42	18.12
13	CoVC 14062	1.25	1.66	1.73	1.55	21.15	20.73	21.78	21.22	19.19	18.60	19.34	19.04
14	MS 14081	1.22	1.64	1.29	1.38	20.09	20.72	20.34	20.38	17.86	18.59	17.87	18.11
15	MS 14082	1.30	1.45	1.11	1.29	20.33	20.66	19.42	20.14	18.36	18.39	17.42	18.06
16	Co 86032	1.53	1.63	1.28	1.48	19.31	21.63	21.57	20.84	17.10	19.26	19.45	18.60
17	CoC 671	0.90	1.62	1.05	1.19	21.85	22.20	21.68	21.91	19.80	19.92	18.92	19.55
18	CoSnk 05103	1.03	1.38	0.97	1.12	21.96	21.31	20.70	21.32	19.37	18.69	18.66	18.91
	Mean	1.10	1.49	1.18	1.25	20.68	20.59	20.92	20.73	18.57	18.35	18.56	18.49
	CD (5%)	0.24	0.30	0.33	0.27	1.68	1.90	2.10	NS	NS	1.91	NS	NS
	CV (%)	13.26	12.10	16.93	13.20	4.88	5.53	5.94	4.62	6.14	6.26	7.05	5.08

Table 2. Continued

S.No.	Variety	CCS (%) at harvest				CCS yield (t/ha) at harvest				Cane yield (t/ha)			
		AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean	AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean	AVT I Plant	AVT II Plant	AVT Ratoon	Pooled Mean
1	Co 14002	13.63	13.22	14.31	13.72	10.64	6.63	24.50	13.93	78.01	49.98	165.56	97.85
2	Co 14004	13.59	13.33	16.02	14.31	11.42	10.17	18.43	13.34	83.80	76.07	112.92	90.93
3	Co 14012	12.07	12.91	14.84	13.27	7.83	13.01	19.98	13.61	64.20	99.13	132.04	98.46
4	Co 14016	12.20	12.86	15.54	13.53	11.76	17.23	22.94	17.31	97.30	130.40	145.12	124.27
5	Co 14027	13.11	14.14	14.78	14.01	10.03	18.28	14.94	14.42	76.62	126.40	102.08	101.70
6	Co 14030	12.45	12.50	16.07	13.68	9.92	12.16	20.49	14.19	79.71	99.56	126.63	101.96
7	Co 14032	14.28	11.45	15.28	13.67	10.98	9.65	15.29	11.97	75.08	84.34	98.43	85.95
8	CoN 14073	13.03	11.18	15.95	13.39	13.46	10.16	19.82	14.48	102.70	91.31	128.26	107.42
9	CoSnk 14102	12.96	12.37	14.88	13.40	13.60	10.93	16.78	13.77	104.86	90.21	113.51	102.86
10	CoSnk 14103	12.96	11.96	13.87	12.93	12.08	11.88	13.69	12.55	92.98	99.08	94.51	95.52
11	CoT 14367	11.93	11.85	12.91	12.23	8.88	11.18	15.04	11.70	73.15	94.01	114.33	93.83
12	CoTl 14111	13.74	11.24	14.88	13.29	13.33	7.74	16.93	12.67	96.76	67.77	112.62	92.38
13	CoVC 14062	13.29	12.87	15.63	13.93	12.71	10.87	23.75	15.78	95.29	85.03	149.93	110.08
14	MS 14081	12.32	13.01	14.27	13.20	10.08	10.88	14.10	11.68	81.56	83.70	101.41	88.89
15	MS 14082	12.66	13.07	13.86	13.20	11.33	13.78	13.97	13.03	90.05	105.39	100.87	98.77
16	Co 86032	11.49	13.40	15.71	13.53	11.13	12.58	17.29	13.66	96.84	93.76	108.56	99.72
17	CoC 671	13.72	13.83	15.15	14.23	11.02	12.56	15.87	13.15	79.55	90.85	105.14	91.85
18	CoSnk 05103	13.47	12.86	15.15	13.83	12.28	9.19	11.96	11.14	90.74	71.42	79.48	80.55
	Mean	12.94	12.67	14.95	13.52	11.25	11.61	17.54	13.47	86.62	91.02	116.19	97.94
	CD (5%)	NS	NS	NS	1.31	NS	3.09	5.91	4.46	19.18	32.76	39.56	16.46
	CV (%)	10.33	10.05	10.15	5.84	19.63	17.27	23.47	19.95	13.29	21.60	20.43	18.63

significant variation for CCS% and CCS yield across crop cycles showed that sucrose accumulation in the cultivars did not vary over years. The results were concordant with that of Jamoza (2013) and Ogunniyan *et al*. (2020) who reported that significant genotype × environment interactions existed for cane yields but not for sucrose accumulation.

The means of individual seasons and pooled mean for all 11 traits are presented in **Table 3.** Pooled mean indicated that Co 14002 (147.22 thousands/ha) recorded a numerically higher number of tillers per hectare as compared to Co 86032 (141.59 thousands/ha). None of the genotypes tested recorded a significantly higher number of shoots over three standards. For the number of internodes, in the AVT I plant, three varieties CoN 14027 (24.33) and MS 14082 (23.00) were found to be significantly superior in comparison with two standards Co 86032 and CoC 671 (21.33 and 21.00 respectively). In AVT II Plant, CoVC 14062 (26.67) and CoSnk 14103 (26.00) recorded a numerically higher number of internodes over three standards, Co 86032 (23.33), CoC 671 (25.00) and CoSnk 05103 (24.00).

Number of millable canes directly influences the cane yield. An adequate number of healthy millable canes ensures a higher yield. Singh *et al*. (1985) reported that the number of millable canes is a major yield contributing factor followed by cane height and girth. For the number of millable canes at harvest in AVT I plant, CoSnk 14102 (89.51 thousands/ha) was found to be numerically superior over all the three standards Co 86032, CoC 671 and CoSnk 05103 (83.41, 81.40 and 86.27 thousands per hectare respectively), whereas, Co 14030 recorded a significantly higher number of millable canes (84.64 thousands per hectare) over all the three standards in the AVT II plant. Pooled mean also indicated the superiority of Co 14030 (93.83 thousands per hectare) over three standards. For single cane weight in AVT I and II plant, none of the genotypes could perform significantly superior over the three standards. Similar results of lack of performance of test entries over the best standard Co 99004 for single cane weight have been reported (Prabha and Sharma, 2022), whereas in ratoon crop, CoVC 14062 (1.73 kg) recorded significantly higher cane weight over all three standards, Co 86032, CoC 671 and CoSnk 05103 (1.28, 1.05 and 0.97 kg respectively). In pooled mean across the three seasons, CoVC 14062 (1.55 kg) genotype was found to be numerically superior over the three standards for single cane weight.

For Brix%, in AVT I, II plant and ratoon, none of the varieties recorded significantly higher brix over three standards. Pooled mean across the three crops indicated no significant differences among the varieties. The results were concordant with that of

Table 3. Mean squares of variations among advanced sugarcane clones studied for cane yield and juice quality parameters

Cropping Season	Source of variation	D.F.	Number of tillers	Number of shoots	Number of internodes	Cane height (cm)	Cane girth (cm)	Millable canes (000/ha)
AVT I Plant	Replication	2	2.93	4.18	1.49	0.32	0.23	0.15
	Genotype	17	106.34**	8.68**	7.48**	16.15**	11.54**	3.41**
	Error	34	34.00	1.00	1.00	1.00	1.00	1.00
AVT II Plant	Replication	2	1.66	24.59	11.95	1.21	2.89	2.31
	Genotype	17	53.80**	2.84**	4.18**	1.90*	1.75 NS	0.91 NS
	Error	34	34.00	1.00	1.00	1.00	1.00	1.00
AVT Ratoon	Replication	2	4.90	1.24	0.85	0.82	1.45	1.56
	Genotype	17	20.09NS	4.45**	1.66**	1.39 NS	3.15**	2.60**
	Error	34	34.000	1.00	1.00	1.00	1.00	1.000
Pooled ANOVA	Seasons	2	352.44**	1,319.12**	4,049.92**	4,027.36**	9,621.55**	839.62**
	Rep within Season	6	1.583	10.00	4.76	0.79	1.52	1.34
	Treatment	17	6.85**	9.19**	5.32**	7.23**	10.05**	2.63**
	Year x Season	34	1.87**	3.39**	4.00**	6.11**	3.20**	2.15**
	Pooled Error	102	1.00	1.00	1.00	1.00	1.00	1.00

Table 3. Continued

Cropping Season	Source of variation	D.F.	Cane yield (t/ha)	Cane weight (kg)	Brix (%)	Sucrose (%)	CCS (%)	CCS yield (t/ha)
AVT I Plant	Replication	2	0.52	0.03	0.92	0.75	0.65	0.64
	Genotype	17	2.90**	0.11**	2.18*	2.19 NS	1.67 NS	1.49 NS
	Error	34	1.00	0.02	1.01	1.29	1.78	1.00
AVT II Plant	Replication	2	0.67	0.12	1.24	2.87	3.08	1.76
	Genotype	17	2.83**	0.06*	3.70**	3.36**	2.16 NS	2.56**
	Error	34	1.00	0.03	1.29	1.31	1.62	1.00
AVT Ratoon	Replication	2	1.77	0.05	4.60	8.35	187.09	24.82
	Genotype	17	2.48*	0.11**	3.19*	3.20 NS	2.18 NS	2.41*
	Error	34	1.00	0.04	1.54	1.71	2.30	1.000
Pooled ANOVA	Seasons	2	138.31**	2.24**	1.56NS	0.83 NS	83.84 NS	25.26 NS
	Rep within Season	6	0.99	0.05	2.25	3.99	63.61	9.07
	Treatment	17	2.57**	0.17**	4.07**	3.93**	2.15 NS	1.70*
	Year x Season	34	2.82**	0.05*	2.50**	2.41*	1.93 NS	2.38**
	Pooled Error	102	1.00	0.03	1.28	1.44	1.90	1.00

Shanmuganathan *et al.* (2017). Similarly for sucrose%, AVT I and ratoon crop along with pooled mean over the three crops indicated no significant differences among the genotypes. Whereas in AVT II plant, Co 14027 (20.08%) exhibited numerically higher sucrose% as compared with three standards. The CCS% is determined using brix% and sucrose%. It gives the commercial cane sugar available in the cane juice. For CCS%, AVT I, AVT II plants and ratoon crops indicated no significant differences among the genotypes. Pooled mean across the three seasons indicated that Co 14002 (14.31%) genotype exhibited numerically higher CCS% as compared with three standards followed by Co 14027 (14.01%) with non-significant differences.

For CCS yield (**Fig. 1**), in the AVT II plant, Co 14027 (18.28%) exhibited significantly higher values as compared with three standards Co 86032, CoC 671 and CoSnk 05103 (12.58, 12.56 and 9.19 t/ha respectively). In AVT ratoon, three varieties *viz*., Co 14002 (24.5 t/ha),

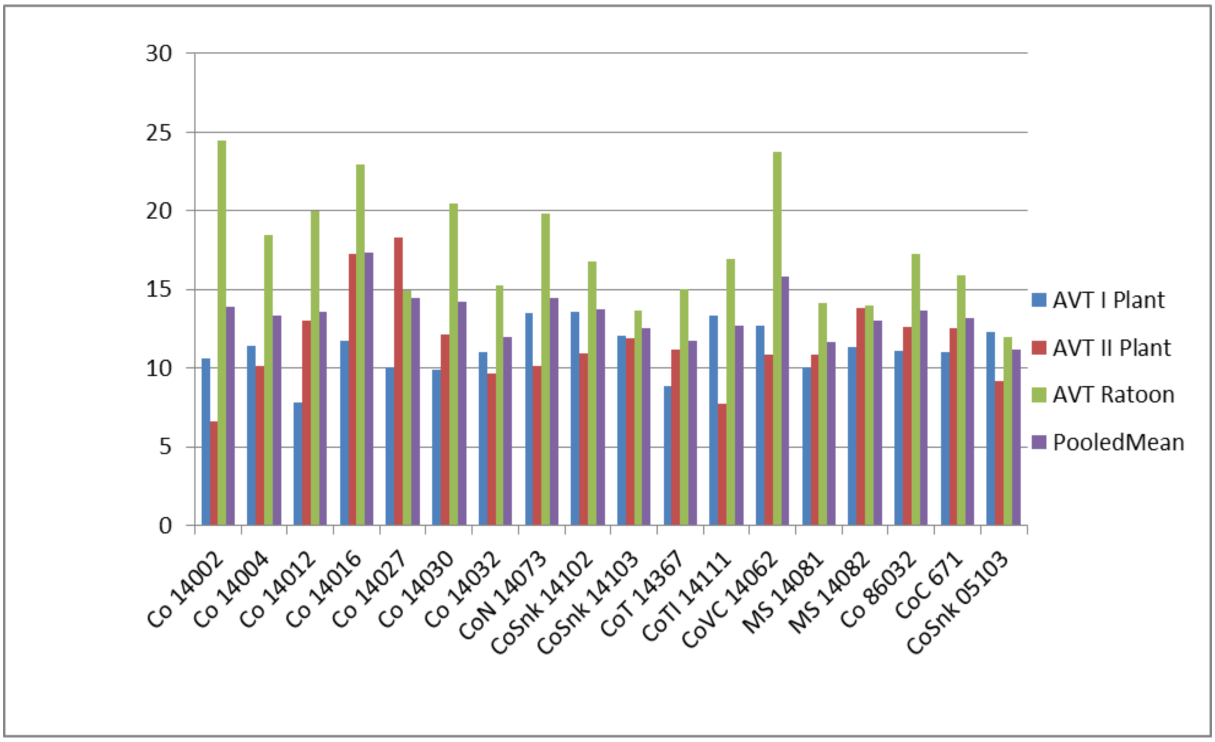

Fig. 1. Varietal performance for CCS Yield (tonnes ha^{-1})

Co 14016 (22.94 t/ha) and CoVC 14062 (23.75 t/ha) recorded significantly higher CCS yield as compared with three standards Co 86032, CoC 671 and CoSnk 05103 (17.29, 15.87 and 11.96 t/ha respectively). Pooled mean indicated that Co 14016 recorded the highest CCS yield (17.31 t/ha) with no significant differences as compared with three standards Co 86032, CoC 671 and CoSnk 05103 (13.66, 13.15 and 11.14 t/ha respectively).

For cane yield (**Fig. 2**), it was evident that two clones CoN 14073 (102.70 t/ha) and CoSnk 14102 (104.86 t/ha) in AVT I plant recorded numerically higher values over three check cultivars Co 86032, CoC 671 and CoSnk 05103 (96.84, 79.55 and 90.74 t/ha). Similarly in the AVT II plant, Co 14016 (130.40 t/ha) and Co 14027(126.40 t/ha) recorded numerically higher values over three standards. Whereas, in the AVT ratoon three clones namely Co 14002 (165.56 t/ha), CoVC 14062 (149.93 t/ha) and Co 14016 (145.12 t/ha) Co 14012 recorded significantly higher cane yield over three standards Co 86032, CoC 671 and CoSnk 05103 (108.56, 105.14 and 79.48 t/ha). Pooled mean across the three crops indicated that only one genotype Co 14016 (124.27 t/ha) recorded significantly higher cane yield as compared to three standards Co 86032, CoC 671 and CoSnk 05103 (99.72, 91.85 and 80.55 t/ha). Five clones namely, Co 14027 (101.70 t/ha), Co 14030 (101.96 t/ha), CoN 14073 (107.42 t/ha), CoSnk 14102 (102.86 t/ha) and CoVC 14062 (110.08 t/ha) recorded numerically higher cane yield as compared to all the three standards.

The correlation study provides information on the nature and magnitude of the association of different component characters with cane yield. The phenotypic association worked out in all possible combinations involving eleven characters is presented in **Table 4**. Various significant levels of positive and negative phenotypic correlations existed among the parameters pooled across the three seasons. The number of shoots (0.346), the number of millable canes (0.591) and CCS yield (0.883) recorded positive significant correlations with cane yield. This indicates improvement in these characters would simultaneously result in the improvement of cane yield and hence selection based on these characters could be advantageous. These results are in conformation with Sanjay Kumar and Devendra Kumar (2014) for the number of millable canes; Tena *et al*. (2016), Pandya and. Patel (2017)) for the number of millable canes and commercial cane sugar yield.

The inter correlations among yield and its component characters revealed a positive significant association for cane height with the number of tillers (0.374) and the number of shoots (0.370) indicating the need to emphasis on these traits during selection. Similarly negative significant association of cane girth with cane height (-0.420), the number of tillers (-0.450) and the number of shoots (-0.248) indicated that clones with lesser girth can also contribute for higher cane yield due to higher height, more number of tillers and shoots. Similarly, a very high and positive significant association of CCS Yield with the

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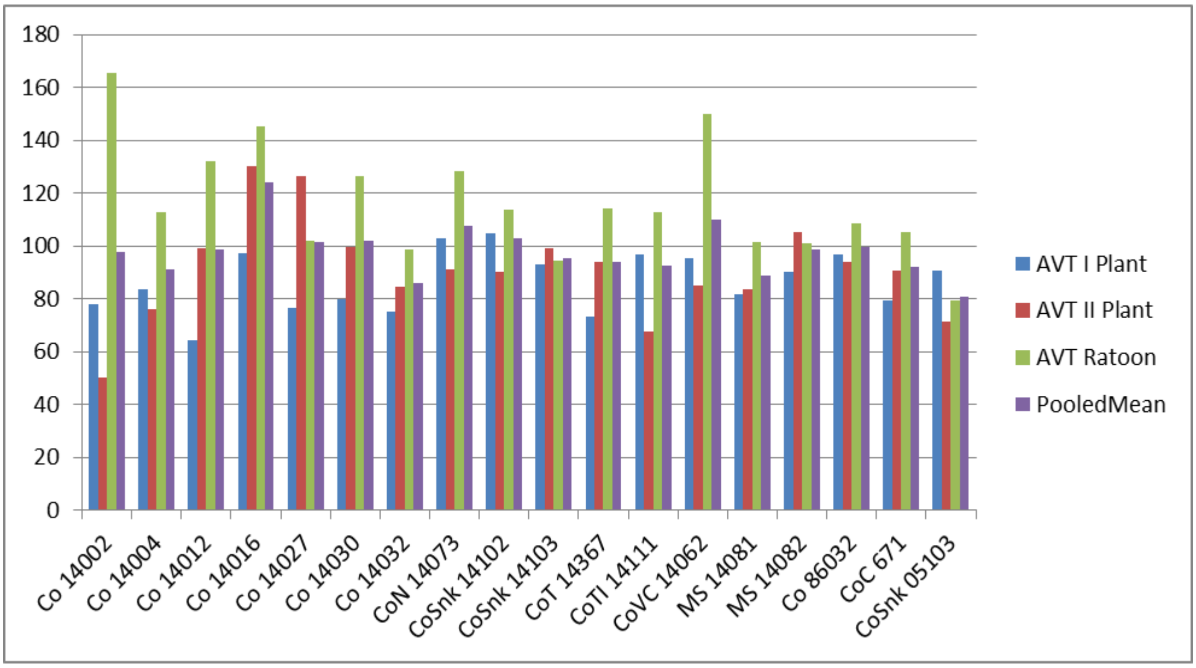

Fig. 2. Varietal performance for Cane yield (tonnes ha^{-1})

Table 4. Phenotypic correlations among the cane yield and juice quality traits (two plant and one ratoon crops)

	Tillers	Shoots	Cane height	Cane girth	NMC	SCW	Brix	Pol	CCS %	CCS yield	Cane yield
Tillers (000'/ha)	1	0.2341	0.374**	-0.450**	0.040	0.0817	0.0174	-0.0289	-0.0212	0.053	0.096
Shoots (000'/ha)	0.234	1	0.370**	-0.248	0.530**	0.006	0.081	0.023	0.004	0.268*	0.346**
Cane height (cm)	0.374**	0.370**	1	-0.420**	0.122	0.029	0.334**	0.260*	0.154	0.168	0.145
Cane Girth (cm)	-0.450**	-0.248	-0.420**	1	-0.244	0.359**	-0.231	-0.144	-0.077	-0.090	-0.074
NMC (000'/ha)	0.040	0.530**	0.122	-0.244	1	-0.114	0.120	0.138	0.169	0.533**	0.591**
SCW (kg)	0.081	0.006	0.029	0.359**	-0.114	1	-0.088	-0.067	-0.029	0.078	0.121
Brix^0	0.017	0.081	0.334*	-0.231	0.120	-0.088	1	0.906**	0.867**	0.459**	0.077
Pol%	-0.028	0.023	0.260*	-0.144	0.138	-0.067	0.906**	1	0.958**	0.586**	0.176
CCS%	-0.021	0.004	0.154	-0.077	0.169	-0.029	0.867**	0.958**	1	0.646**	0.224
CCS yield	0.053	0.268*	0.168	-0.090	0.533**	0.078	0.459**	0.586**	0.646**	1	0.883**
Cane yield	0.096	0.346**	0.145	-0.074	0.591**	0.121	0.077	0.176	0.224	0.883**	1

number of millable canes (0.533) indicating the importance of this trait in selection of clones with higher yield and quality. Similar findings of CCS yield as influenced by cane yield than the CCS% has been reported by Amjad *et al.* (2018).

The present study revealed the superiority of Co 14016, Co 14002 and CoVC 14062 for cane yield and quality. The number of shoots, the number of millable canes and CCS yield were found to be of major concern due to their high association with cane yield. It is therefore advisable for sugarcane breeders to pay attention to these characters for the selection of promising clones in sugarcane breeding.

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