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Character association studies in first clonal stage of sugarcane (*Saccharum officinarum* L.)

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Abstract
Statistical correlation coefficient is a measure that denotes the magnitude and direction of interrelationship between any two casually related variables. The information on the genotypic and phenotypic inter-relationship of cane yield and sugar yield with their component characters interest would be of immense help to the sugarcane breeder. The character association will also help in the selection of superior genotypes from divergent population based on more than one interrelated characters. However, correlation coefficients, sometimes, may be misleading and thus, need to be partitioned into direct and indirect effects. It is important for a breeder to know how other characters influence a particular character before selecting the parental material for crossing purposes. Path coefficient analysis provides direct and indirect effects of component characters thereby enhancing the better understanding of true relationship of the component characters with yield.

Keywords: Correlation coefficient, cane yield, sugar yield, coefficient analysis

Introduction
Among the sugar crops, sugarcane, accounts for over 70 per cent of the world's sugar production (Anon., 2017) [1, 2]. Sugarcane (*Saccharum* spp. hybrids) is a genetically complex crop of major economic importance in tropical and subtropical countries. Cane industry requires high sugar producing varieties with other desired agronomic traits.
Globally, sugarcane is cultivated over an area of 24.10 m ha with an annual production of 1329.3 million tonnes and an annual productivity of 75.70 t/ha (Anon., 2017) [1, 2]. In India, sugarcane is grown under diverse agro-climate situations covering an area of 5.2 m ha and production of 364.0 million tonnes of sugarcane with productivity of 70.39 t/ha (Anon., 2017) [1, 2]. Principal sugarcane growing states are Karnataka, Tamilnadu, Maharashtra, Andhra Pradesh, Uttar Pradesh and Gujarat. In Karnataka sugarcane is grown in an area of 4.30 lakh hectare and production of 45.3 million tonnes of sugarcane with annual productivity of 93.80 t/ha (Anon., 2017) [1, 2]. In Cauvery Command Area sugarcane is grown in an area of 0.61 lakh hectare with the production of 77.10 lakh tonnes of sugarcane and productivity of 101.80 t/ha (Anon., 2017) [1, 2]. In India 24.39 million tonnes of sugar is produced, but the projected requirement of sugar by 2030 is 36 million tonnes which has to be achieved from the existing cane area through improved varieties and management for cane yield and sugar recovery as further expansion in area is not possible.

Material and Methods
Fifty five genotypes selected from 2308 seedling nursery based on evaluation were planted in *eksali* 2015. Each genotype was planted in two rows of 6.0 m length spaced at 90 cm apart (2R × 6m × 0.9m) with three budded setts per meter in augmented design with five blocks along with three checks *viz*., CoVC 99463, Co 86032 and Co 62175. All the recommended package of practices was adopted to raise the better crop stand.

Data recorded in First Clonal Generation (C_1) crop
Observations were recorded on the following traits for each genotype before and at the time of harvest in the settling nursery (C_1) crop.
1. Number of tillers/plot
2. Number of millable canes /plot

3. Millable cane length (cm)
4. Cane diameter (cm)
5. Number of internodes
6. Internode length (cm)
7. Single cane weight (kg)
8. Pol per cent juice
9. Brix per cent juice
10. CCS per cent
11. CCS cane yield
12. CCS yield (t/ha)
13. Purity per cent
14. Cane yield (t/ha)
15. HRB Yield (t/ha)

Results and Discussion

Phenotypic correlation coefficients between cane yield and its component characters and inter correlations among different traits are presented in the table and figure.

1. Correlation studies with Phenotypic, juice quality and other cane characters

a. Phenotypic correlation of cane yield and CCS yield with other characters

It is evident from the table. that cane yield exhibited positive and highly significant association with cane characters *viz.*, number of tillers/plot (0.856), number of millable canes/plot (0.886), millable cane length (0.341), single cane weight (0.796) and cane diameter (0.683). There was also positive and significant correlation with quality characters such as CCS yield (0.978), CCS cane yield (0.726) and HRB yield (0.991). Commercial cane sugar yield (t/ha) had highly significant positive correlation with number of millable canes (0.886), number of tillers (0.864), CCS cane yield (0.778), single cane weight (0.756), cane diameter (0.692), millable cane length (0.297) and HRB yield (0.996). There was also positive correlation with other quality characters such as pol per cent (0.204), CCS per cent (0.203), Brix per cent (0.197) purity per cent (0.132) and inter node length (0.205).

b. Correlation among juice quality traits

Brix per cent showed highly significant positive correlation with pol per cent (0.941) and CCS per cent (0.900), CCS cane yield (0.358) and purity per cent (0.435). Pol per cent had highly positive and significant associations with Brix per cent (0.941) CCS per cent (0.994) CCS cane yield (0.398) and purity per cent (0.714). Purity per cent was highly positive correlation with commercial pol per cent (0.714), Brix per cent (0.435) CCS per cent (0.782) and CCS cane yield (0.316). CCS per cent had high significant positive correlation with pol per cent (0.994), Brix per cent (0.900), Purity per cent (0.782) and CCS cane yield (0.404).

c. Correlation among other cane characters

Number of tillers showed highly significant positive association with number of millable canes (0.984) and CCS cane yield (0.399). Number of millable canes exhibited highly significant positive correlation with CCS cane yield (0.428) and HRB yield (0.894).

Millable cane length (0.072) had positive correlation and single cane weight (-0.045) which had negative correlation with number of millable canes. Millable cane length recorded highly significant positive correlation with single cane weight (0.576), number of internodes (0.317), inter node length (0.483), CCS cane yield (0.465) and HRB yield (0.311). Cane diameter was positively and highly significant positive association with single cane weight (0.617), commercial cane sugar (0.647) and HRB yield (0.699). Internode length exhibited non significant negative correlation with all the traits except single cane weight, purity per cent, commercial cane sugar, HRB yield and cane yield. Number of internodes had positive and highly significant association with single cane weight (0.303) and significant negative association with Internode length (-0.471).

2. Association of cane yield and CCS yield with other characters in sugarcane

Simple correlation studies furnish the information on nature and extent of association between yield and its determinants. Selection for specific characters is known to result in correlated response in certain other characters (Falconer, 1964). Generally, plant breeders make selection at time for one or two attributes and then it becomes important to know the effect on other characters.

In present investigation, phenotypic correlation coefficients (Table) indicated that cane yield was positively and highly significant correlation with CCS yield, CCS cane yield, number of tillers, single cane weight, cane diameter, millable cane length and BR Brix yield. Hence these traits play a major role as an important contributing character for higher cane yield. While number of internodes and internode length showed narrow non-significant positive association with cane yield. Whereas, quality characters *viz.*, pol per cent, CCS per cent and Brix per cent had positive and non-significant correlation with cane yield at phenotypic level. This indicates possibility of simultaneous improvement of these characters at a time to obtain higher cane and sugar yield.

Singh and khan (2004) [10] reported that cane yield had significant positive association with number of millable canes, stalk height, and cane weight. Whereas, Patel *et al.* (2006) [8] observed that cane yield showed positive and high significant correlation with the number of shoots per hectare, single cane weight, stalk length, millable cane number, cane diameter and number of internodes. Cane yield also had significant positive association with Brix per cent juice was noticed earlier by Smiullah *et al.* (2013) [12]. Similar results were also observed by Guruprasad Hiremath (2012) [4], Masri (2015) [7] and Kasayya (2016) [5].

The ultimate objective in sugarcane breeding is to improve the sugar productivity per unit area. The quantum of commercial cane sugar (CCS), the ultimate product of sugarcane crop depends both on cane yield and its quality characters.

Commercial cane sugar yield (t/ha) showed positive and highly significant correlation with CCS cane yield, number of millable canes, cane diameter, single cane weight, HR Brix yield and also positive and non significant correlation with quality characters *viz.*, pol per cent, CCS per cent and purity per cent. Hence cane and sugar yields can be improved by selection based on these characters. Further, it was observed that cane yield also exhibited positive and highly significant associations with CCS yield, it can be inferred that cane yield is much more important than sucrose per cent in juice or other quality characters in determining the CCS yield. Singh and Khan (2004) [10] reported that highly significant and positive association of CCS yield with cane yield, cane weight and stalk height indicating importance of these traits in improving CCS yield.

3. Association among the juice quality and with other cane characters

With regard to correlation studies among the quality characters, there was an existence of highly significant positive association among Brix per cent, pol per cent, purity per cent and CCS per cent as expected indicating the interrelationship among themselves. Thus any of these quality characters would be considered for selection leading to the simultaneous improvement in the remaining quality traits. Similar findings were observed by Daggar *et al.* (2004) [3] and Singh *et al.* (2005) [11]. Improvement in one attributes would certainly lead to simultaneous improvement in other quality traits in desired direction. Single cane weight had positive and non significant association with purity per cent and commercial cane sugar per cent. These observations are in accordance with findings of Smiullah *et al.* (2013) [12] and Khan *et al.* (2015) [6].

4. Correlation among yield attributing characters

Number of tillers had highly significant positive correlation with number of millable canes, CCS cane yield and HR Brix yield. Number of millable canes had significant positive association with CCS cane yield and HR Brix yield where as internode length shows non significant positive association. Millable cane length showed positive and highly significant correlation with number of internodes, internode length and single cane weight. Cane diameter had positive and significant association with single cane weight and CCS cane yield and HR Brix yield. Hence there will be simultaneous improvement of these traits at a time could lead to improvement in both cane yield and sugar yield. These results were also in conformity with the findings made earlier by Guruprasad Hiremath (2012) [4].

Sanjay Kumar and Kumar (2014) reported that number of tillers showed highly positive and significant association with number of millable canes and it had negative association with stalk diameter and stalk weight. Number of millable canes showed significant positive association with number of internodes and single cane weight. Stalk length had positive and highly significant correlation with number of internodes and single cane weight. Stalk diameter had significant positive correlation with stalk weight and number of internodes.

Single cane weight exhibited significant positive association with cane yield, CCS yield and CCS cane yield, number of internodes, cane diameter and millable cane lenght. Thus the stalk weight being an important yield contributing character should be taken into consideration during parental as well as varietal selection. These results were in conformity with reports made by Guruprasad Hiremath (2012) [4] and Kasayya (2016) [5].

Present investigation, results revealed that the CCS cane yield showed highly significant and positive correlation with single cane weight, number of internodes, millable cane length, cane diameter, CCS yield and quality characters like Brix per cent, pol per cent, purity per cent and CCS per cent showed non significant and positive correlation.

Table 1: Phenotypic correlations among different quantitative traits in first clonal stage of sugarcane genotypes.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.000	0.984**	0.046	0.553**	-0.099	0.135	0.405**	0.085	0.101	0.078	0.399**	0.864**	0.014	0.867**	0.856**
2		1.000	0.072	- 0.059	-0.083	0.128	0.445**	0.069	0.092	0.060	0.428**	0.886**	-0.013	0.894**	0.886**
3			1.000	0.059	0.317*	0.483**	0.576**	-0.142	-0.159	-0.130	0.465**	0.297*	-0.041	0.311*	0.341**
4				1.000	0.082	-0.072	0.617**	0.201	0.249	0.182	0.647**	0.692**	0.012	0.699**	0.683**
5					1.000	-0.471**	0.303*	-0.179	-0.140	-0.184	0.238	0.038	-0.182	0.053	0.070
6						1.000	0.232	-0.020	-0.047	-0.009	0.163	0.205	0.051	0.212	0.233
7							1.000	0.002	-0.006	0.006	0.910**	0.765**	0.016	0.776**	0.796**
8								1.000	0.941**	0.994**	0.398**	0.204	0.714**	0.139	0.023
9									1.000	0.900**	0.358**	0.197	0.435**	0.153	0.034
10										1.000	0.404**	0.203	0.782**	0.132	0.019
11											1.000	0.778**	0.316*	0.758**	0.726**
12												1.000	0.132	0.996**	0.978**
13													1.000	0.050	-0.014
14														1.000	0.991**
15															1.000

* Significant at 5% probability level ** Significant at 1% probability level

1. Tiller number
2. NMC
3. Millable cane length (cm)
4. Cane diameter (cm)
5. Number of internodes
6. Internode length (cm)
7. Single cane weight (kg)
8. Pol per cent
9. Brix per cent
10. CCS per cent
11. CCS cane yield
12. CCS yield (t/ha)
13. Purity per cent
14. HRB Yield (t/ha)
15. Cane yield (t/ha)

TLR	Tiller number	BRIX C	Brix per cent
Nmc	Number of Millable cane	CCS %	CCS per cent
C. Lght	Millable cane length (cm)	CCS YLD	CCS cane yield
Dia	Cane diameter (cm)	CCS T/HA	CCS yield (t/ha)
No.intr	Number of internodes	PURITY	Purity per cent
Intr. Lght	Internode length (cm)	HRB	HRB Yield (t/ha)
Swt	Single cane weight (kg)	CANE YLD	Cane yield (t/ha)
Pol %	Pol per cent		

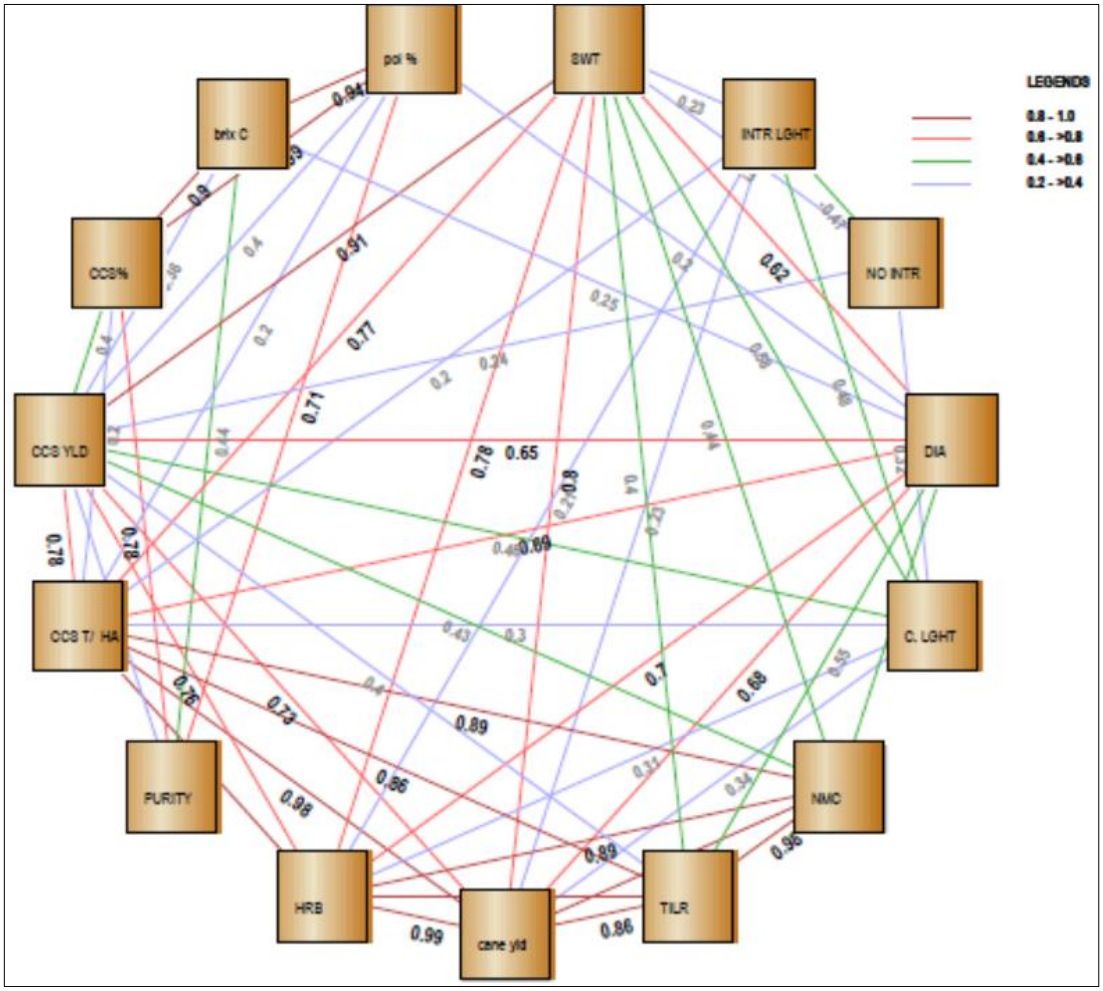

Fig 1: Phenotypic correlations among different quantitative traits in first clonal stage of sugarcane genotypes.

Conclusion

There was highly significant positive association among juice Brix, pol per cent juice, purity and CCS per cent. Number of tillers shows positive and high correlation with number of millable canes and number of internodes. Number of millable canes showed highly significant positive correlation with number of internodes and internode length. Millable cane length had strong positive correlation with number of internodes and single cane weight. Cane diameter was highly significant and positive correlation with cane weight and internode numbers. Number of internodes recorded highly significant and positive association with single cane weight, pol per cent, Brix per cent, CCS per cent and purity per cent. Single cane weight showed highly significant and positive correlation with pol per cent, CCS per cent and purity per cent.

From the results of correlation coefficient suggested that cane characters like number of tillers, number of millable canes, cane diameter, number of internodes, single cane weight, CCS cane yield and CCS yield should be taken into consideration for selecting improved sugarcane genotypes with high cane yield.

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