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RESEARCH ARTICLE

Relative contribution and associations studies among cane yield and their components in sugarcane (*Saccharum* spp. hybrid)

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SUMMARY

The present investigation was carried out at five locations with 25 sugarcane clones including six standard checks to estimate the association pattern, repeatability and path analysis of the various quantitative parameters during 2011 and 2012. Correlation co-efficients indicated that cane yield was positively correlated with single cane weight (kg) and number of millable canes, whereas sucrose % and CCS % showed significant negative correlation with cane yield. Repeatability of characters was 0.32*, 0.33*, 0.52*, 0.15, 0.60* and 0.71* for HR brix sucrose %, cane yield, cane height, NMC and cane girth, respectively. Path analysis revealed that the number of millable canes was the most important character with the highest direct (1.9473) and indirect effects on cane yield, followed by single cane weight (0.957), Regression analysis concluded 81.13% of total cane yield was contributed by SCW and NMC.

Key Words : Association, Regression, Repeatability, Sugarcane

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Sugarcane is an important commercial crop in the Indian sub-continent and cultivated in tropical and subtropical climatic regions of the country. Sugarcane varietal improvement programmes primarily envisage breeding of varieties with high cane yield and high sugar content suitable for specific climatic conditions. In this crop, varietal improvement by using newly developed scientific concepts to bring out the maximum expression of yield potential possessed by varieties are the factors desiring more attention of the researchers. Various traits are responsible for variations in cane and sugar yields. Many of these character components are quantitatively inherited and inter-related with each other.

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Knowledge of interrelationship among various characters is considered to be important in devising proper selection strategies in a sugarcane breeding programme.

Correlation co-efficient analysis has been extensively used by plant breeders to obtain precise information on interrelationship among plant traits to better assess outcome of selecting one or more trait. Number of millable canes per plot had the greatest influence on cane yield, followed by stalk weight (Reddy and Reddy, 1996). As far as association of components with quality is concerned, the apparent non-complementary and often negative association between yield and quality characters was reported by many researchers. Sucrose percentage in the juice has been reported to have either negative or no correlation with cane yield and CCS yield (Premachandran, 1995).

The knowledge of association of cane and sugar yields with other traits helps breeders to select suitable and desirable plant type. In multiple objective selections, correlation between characters in varying environmental conditions is of immense importance for overall response to selection. Pattern of association existing in the yield and quality components in subtropical environment has not been thoroughly examined over the years in this crop. With this aim in view, the present research was conducted to study association of components with cane and sugar yields by employing biometrical technique of correlation co-efficient analysis which may help to enhance the response in cultivar selection.

Breeding decisions based only on correlation co-efficients may not always be effective since they provide only one-dimensional information neglecting important and complex interrelationships among plant traits (Kang, 1994). Path co-efficient analysis separates the direct effect from the indirect effects through other related traits by partitioning the simple correlation co-efficients (Dewey and Lu, 1959). Although the path analysis provides a clear picture of the pattern of association, but it cannot construct a prediction equation for sugar yield using its components. Considering this point of view, the multiple linear regression analysis was also done.

MATERIAL AND METHODS

The experiment was conducted in five locations *viz.*, ARS Sankeshwar, Khadaklat, Shegunsi, KSI Khanapur, and Main Agricultural Research Station, UAS Dharwad. The experimental material for the present study consisted of 25 genotypes of sugarcane including six standard checks *viz.*, CoC 671, Co-94012, Co-86032, CoM-265, Co-92005 and Co 2001-15. Sugarcane was planted in Randomized Block Design with three replications during Feb 2011and Jan 2012. The crop was planted with plot size of 6.0 x 3.6 sq m with seed rate of 12 eye buds per meter. The crop was grown with recommended package of practices. All agronomical practices were adopted during the entire crop season. Data were recorded on 5 randomly selected canes for different quantitative characters in each genotypes and mean was taken for the analysis purpose. Analysis of variance was used for calculating genotypic, phenotypic and environmental variations.

Mean data collected on cane and sugar yields and its components were subjected to analysis of variance and correlation co-efficients obtained for each pair of character associations were studied, using simple correlation between each two characters, y and x (Singh, 1995). The methodology proposed by (Dewey and Lu, 1959) was used to partition the simple correlation co-efficients into direct and indirect effects. Full model regression and co-efficient of determination (R^2) were estimated according to (Hussain *et al.*, 2012) using sugar yield as resultant variable and its related characters as explanatory variables.

RESULTS AND DISCUSSION

The analysis of variance for all the characters showed that genotypes included in the test differed significantly with respect to all characters studied (Table 1). This indicates that there was significant amount of phenotypic variability among the genotypes with regard to the characters providing a scope for further improvement through simple selection (Punia *et al.*, 1983).

Correlation analysis:

The pair-wise simple correlation co-efficients (r) among various characters are presented in Table 2. The association of cane yield with other quantitative characters indicated that, there was a significant and positive association between cane yield with total shoots (r=0.320**), number of cane formed shoots (0.312**), cane height (0.850**), plant height (0.325**), single cane weight (0.911**), number of millable canes (0.869**), intermodal length (0.29**), number of internodes (0.344**), cane girth (0.678**). A positive and highly significant correlation between cane yield and its components, *viz.*, single cane weight, stalk length and millable cane number was reported (Balsundaram and Bhagyalakshmi, 1978) and (Punia *et al.*, 1983). Cane diameter having significant positive correlation with cane yield was also reported (Hooda *et al.*, 1979). Whereas, there was also significant and negative association observed between cane yield and HR brix% (-0.273**), sucrose% (-0.358**), and CCS % (-0.299**).

Total shoots showed significant and negative association with number of cane formed shoots (-0.250*), number of millable canes (-0.333**), cane height (-0.293**) and single

Table 1 : Analysis of variance for important cane yield and sugar yield parameters

Source	df	MSS for the characters: Germination per cent	Tillers per plot	Millable cane height (cm)	Cane girth (cm)	Number of internodes	Single cane weight kg)	Number of millable canes per plot	Juice extract per cent	Brix per cent	Sucrose per cent	Cane yield (kg/ plot)	CCS yield (kg/plot)
Replication	2	140.69	30.69	1147.18	0.04	0.85	0.28	187.35	99.92	5.44	4.516	1369.8	0.28
Genotype	24	340.20*	13511**	4290.33	0.42*	16.12*	0.479**	2163.10**	51.33	4.01**	2.43*	14933**	191.6*
Error	48	162.40	1428	4759.79	0.10	2.67	0.055	963.80	60.27	1.14	1.00	507.29	10.92
S.E.±		7.35	21.81	39.83	0.07	0.94	0.135	36.34	4.48	0.61	0.57	13.00	2.07
C.D. (P=0.05)		21.47	63.68	115.696	0.20	2.75	0.395	97.10	12.408	1.80	1.69	37.95	6.05
C.D. (P=0.01)		28.914	86.29	156.695	0.27	3.73	0.530	106.75	16.750	2.45	2.169	51.43	8.21

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 2 : Genotypic correlation among cane yield and other yield related characters in sugarcane

Characters	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
X_1	-0.250*	-0.333**	-0.293*	-0.458**	-0.215	-0.244	-0.193	-0.231	0.198	0.222	0.199	0.250*	0.222	0.320*
X_2	1.000	0.299*	-0.286*	-0.211	-0.237*	0.169	-0.186	-0.249	0.149	0.134	0.201	0.234	0.245	0.312*
X_3		1.000	-0.412**	-0.698**	-0.521**	-0.208	0.200	-0.721**	0.205	0.241	0.301*	0.369**	0.687**	0.869**
X_4			1.000	-0.490	0.349**	0.269*	0.310*	-0.406**	0.211	0.264*	0.168	0.250*	0.144	0.850**
X_5				1.000	-0.378**	-0.268*	-0.217	0.557**	0.237	0.101	0.099	0.204	0.216	0.911**
X_6					1.000	0.233	0.311*	-0.267**	0.155	0.194	0.166	-0.211	0.179	0.325**
X_7						1.000	-0.438**	-0.311**	0.178	0.182	0.173	0.153	0.216	0.344**
X_8							1.000	-0.398**	0.161	0.242	0.237	-0.198	0.167	0.290*
X_9								1.000	0.018	0.084	0.035	0.174	0.215	0.678**
X_{10}									1.000	0.644**	0.246	0.211	0.811**	-0.273*
X_{11}										1.000	0.768**	0.191	0.911**	-0.358**
X_{12}											1.000	0.200	0.866**	0.248
X_{13}												1.000	0.198	0.300*
X_{14}													1.000	-0.299*
X_{15}														1.000

1. Total shoots 2. Number of cane formed shoot 3. NMC (Number of millable canes) 4. Cane height (cm) 5. Single cane weight (kg) 6. Plant height (cm)
7. No of Internodes 8. Internodal length (cm) 9. Cane girth (cm) 10. HR Brix (%) 11. Pol % 12. Purity %
13. Juice extract % 14. CCS % 15. Cane yield (kg/plot)

cane weight (-0.458**). Where as positive association with juice extraction % (0.250*). Number of millable canes (NMC) showed significant and positive association with purity (0.301*), juice extraction % (0.369**) and CCS% (0.687**) and NMC showed significant and negative association with cane height (-0.412**), single cane weight (SCW) (-0.698**), plant height (-0.521**), cane girth (-0.721**). Similar results were reported by Balasundaram and Bhagyalakshmi, 1978 and Singh *et al.*, 1981. Positive correlation of single cane weight with cane yield was reported which agreed with our present studies (Singh *et al.*, 1981 and Abdelmahamud *et al.*, 2010).

There was highly significant and positive correlation of single cane weight with cane diameter (0.557*), where as it showed significant negative association with ,plant height (-0.378**) and number of internode (-0.268*).

The quality parameters like HR Brix showed significant positive association with sucrose (0.644**). Sucrose showed significant and positive association with purity (0.768**) and CCS% (0.911**). Similarly CCS% showed significant and positive association with HR Brix (0.811**) and purity (0.866**) but showed significant negative association with cane yield (-0.299**).

Several researchers estimated the repeatability of selection traits at maturity in sugarcane, but limited information is available on the genetic parameters of quantitative and qualitative traits and their relationship with yield at maturity. Repeatability, however, varies with change in the environment (Tyagi and Lai, 2007).

Repeatability values obtained for cane yield and quality components are presented in Table 3. Repeatability of characters between crops was 0.32*, 0.33*, 0.52*, 0.15, 0.60* and 0.71* for juice brix, pol per cent (8 months), cane yield (12 months), cane height, NMC and cane girth (10 months), respectively, indicated that these characters had high degree of repeatability during early ripening stage (240 days/ September), high degree of repeatability for NMC (0.82) and brix (0.85) also estimated by some researchers (Mariotti, 1971). Cane girth was the most repeatable characteristics, followed by refractometer brix and NMC (Cuenya *et al.*, 1981). It may be concluded that due to high degree of repeatability, the selection for juice brix, pol (%), cane height,

Table 3 : Inter-stage correlation(Repeatability) (r) values for important traits between Clone IV and Clone V

Characters	Repeatability
NMC	0.60*
Millable cane height (cm)	0.15
Cane girth (cm)	0.71*
Single cane weight (SCW)(kg)	0.50*
HR brix	0.32*
Sucrose (%) in juice	0.33*
Cane yield (kg/plot)	0.52*

NMC and cane girth along with cane yield gave more stability during this stage (300 days) than low repeatable characters (at maturity stage).

Path analysis:

Information obtained from simple correlation co-efficient can be enlarged by partitioning it into direct and indirect effects for a given set of casual interrelationships. The matrix of direct and joint effects for the studied characters is shown in Table 4. The maximum direct effects were obtained for single cane weight (1.9473), followed by number of millable canes (0.9570),

It is noted that the indirect effects of number of millable canes and single cane weight were less important compared to their direct effects. The high positive direct effects of the number of millable canes and single cane weight in addition to their highly significant co-efficients of correlation is an evidence that the direct selection through the two traits would be effective for improving cane yield of sugarcane.

Weight of millable stalks was the most important character with the highest direct effect on sugarcane yield, followed by stalk height, number of millable stalks and stalk thickness (Tyagi and Lai, 2007).

Multiple linear regression analysis:

Regression co-efficients and their significance for some quantitative traits in predicting Cane yield (CY) (Table 5a) and sugar yield (SY) (Table 5b) using full model regression, the prediction equation for cane yield and sugar yield was formulated as follows:

CY = -12.75 + 2.75 (SCW) - 0.007 (CH) + 0.122 (CG) + 0.032 (NI) +1.423 (NMC).

SY =-8.99+3.015 (CCS %) -0.007 (P) +0.198 (HRB) + 0.047 (JE) + 1.784 (S %).

In addition to the high significance of the used model (P < 0.01), it successfully accounted for 81.13 % of the total variation of cane yield expressed as R^2. The residuals content (18.87 %) may be attributed to unknown variation (random errors), human errors during measuring the studied traits and/or some other traits that were not in account under the present investigation. Furthermore, results showed that the single cane weight, number of millable canes, cane girth and cane height significantly contributed towards cane yield while the other traits did not (negligible contribution of 3.10). A contribution of 88.73% to sugar yield was made by CCS% alone expressed as R^2, residual was to the tune of 11.27% which is because of the random errors, so this indicated that CCS% and sucrose % are the important traits contributing to the sugar yield while a contribution of other traits for sugar yield was only 2.22.

On the other hand, the values of variance inflation factor (VIF) for all studied characters were less than ten for both cane and sugar yield, indicating trivial influence of multi collinearity problem. The present results ensured the goodness

Table 4 : Phenotypic path analysis for Cane yield (kg/plot) showing direct (diagonal) and indirect effect

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	r_{XY}
X_1	0.2090	0.0188	0.0201	-0.0239	0.0227	0.0294	-0.0274	-0.0214	0.0266	0.0241	0.0228	0.0181	-0.0210	0.0219	0.320
X_2	0.0216	0.1367	0.0833	-0.0225	0.0103	0.0050	-0.0412	0.0133	0.0277	0.0188	0.0226	0.0073	0.0233	0.0064	0.312
X_3	0.0269	-0.0973	1.9473	0.5007	-1.0872	-0.1751	0.2457	-0.0997	0.0093	-0.0834	-0.0543	-0.0992	-0.0722	-0.0913	0.869
X_4	0.2765	-0.1155	-0.9475	0.7667	0.1986	0.4339	0.1815	0.4905	-0.0986	-0.0673	-0.0366	-0.0409	-0.0930	-0.0970	0.850
X_5	0.0075	-0.0061	-0.0166	0.0591	0.9570	-0.0077	-0.0054	-0.0211	0.0267	0.0021	0.0021	-0.0064	0.0017	-0.0097	0.911
X_6	0.2624	-0.0078	-0.0237	0.2415	-0.0551	0.1889	0.2219	-0.1573	-0.0493	-0.0699	-0.0746	-0.0625	-0.0413	-0.0492	0.325
X_7	0.0154	-0.0123	-0.0055	0.0278	0.1247	0.2013	0.0519	0.0147	-0.0346	-0.0235	-0.0214	-0.0013	-0.0048	0.0096	0.344
X_8	-0.3903	0.0214	0..0651	0.2384	-0.0285	0.0658	0.3604	0.0408	-0.6313	0.3387	0.1195	0.1212	0.0653	-0.0313	0.290
X_9	-0.0823	0.0411	0.0668	-0.0479	-0.0402	0.0716	-0.1299	-0.0110	0.2933	0.2432	0.2189	-0.0032	0.0298	0.0278	0.678
X_{10}	-0.8662	0.6011	-0.6425	-0.6954	-0.2716	-0.6633	-0.3491	-0.3269	0.5468	0.1230	0.0413	0.8020	0.4401	0.9879	-0.273
X_{11}	0.9614	-0.5990	-0.8395	0.9876	0.0722	-1.0035	1.6632	-0.5631	-3.4638	4.2507	-3.4257	2.5245	-0.1410	-0.7817	-0.358
X_{12}	-0.3434	0.0696	0.0581	-0.6204	0.2521	0.2734	-0.0289	0.1287	-0.0132	0.0972	0.0610	0.1293	-0.0123	0.1963	0.248
X_{13}	0.0114	0.0105	0.0168	-0.0080	-0.0216	0.0125	-0.0053	0.0023	0.0062	0.0057	0.0052	-0.0986	0.0572	0.3055	0.300
X_{14}	0.1418	-0.0024	-0.0616	0.1537	-0.1720	-0.0979	-0.0229	-0.0092	-0.0126	-0.0277	-0.0331	-0.0435	0.0120	-0.1240	-0.299

1. Total shoots 2. Number of cane formed shoot 3. NMC (Number of millable canes) 4. Cane height (cm) 5. Single cane weight (kg) 6. Plant height (cm)
7. No of Internodes 8. Internodal length (cm) 9. Cane girth (cm) 10. HR Brix (%) 11. Pol % 12. Purity %
13. Juice extract % 14. CCS % 15. Cane yield (kg/plot)

Table 5a : Multiple linear regression model to explain cane yield variation using some its related characters

Regression parameters for cane yield	Regression coefficient (b)	Standard error (SE)	Probability level (P-value)	Variance inflation factor (VIF)
Single cane weight (SCW)	2.75 **	0.680	000	5.42
Cane height (CH)	-0.007	0.002	0.10	4.06
Cane girth (CG)	0.122	0.318	0.47	5.45
No. internodes/cane (NI)	0.032	0.068	0.33	3.41
No. millable canes	1.423 **	0.066	000	4.20
Intercept	-12.75			
Model sig.	000			
R^2	81.13			
Adjusted R^2	76.3			
R2 of eliminated traits	3.10			

Table 5b : Multiple linear regression model to explain sugar yield variation using some its related characters

Regression parameters for sugar yield	Regression coefficient (b)	Standard error (SE)	Probability level (P-value)	Variance inflation factor (VIF)
CCS %	3.015 **	0.518	001	6.21
Purity % (P)	-0.007	0.007	0.21	3.87
HR Brix (HRB)	0.198	0.411	0.48	6.22
Juice Extract (JE)	0.047	0.077	0.27	2.88
Sucrose % (S)	1.784 **	0.101	000	3.97
Intercept	-8.99			
Model sig.	000			
R^2	88.73			
Adjusted R^2	84.63			
R^2 of eliminated traits	2.22			

of fit for the proposed model of regression (Hussain *et al.*, 2012).

In an unselected population, it has been frequently suggested that yield and sucrose content are independently inherited based on the absence of significant correlation between these two characters. Alternate or joint selection for yield and quality (sucrose %) was advocated, since these two characters were found to be independent. (Mariotti, 1977).

This indicates that most of the quality characters are negatively associated with cane yield. Hence, in order to bring an improvement in cane yields one should aim at breaking these association or make selection indices which in turn improve cane yield and ultimately the productivity.

Conclusion:

The essentially low degree of association of some of yield components such as cane girth, number of internodes with cane yield and variations observed with respect to the nature and magnitude of association discussed, warrants a cautions approach for varietal selection on the basis of these characters. However, characters like number of milliable canes, single cane weight and cane height showed consistently high significant positive association with cane yield over the years.

Regression co-efficients and their significance for both cane and sugar yield indicates that, SCW and NMC are major contributers for cane yield, where as sucrose% and CCS % are major contributors for sugar yields.

Finally based on association pattern, magnitude and regression analysis, it can be concluded that, the characters *viz.*, millable cane number (NMC), single cane weight (SCW), sucrose % and CCS % are very important that can be considered during sugarcane breeding programme. These characters could be chosen as a selection criterion for improvement of cane and sugar yields.

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