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Character association and path analysis for cane yield, juice quality and their component traits in sugarcane over the environment

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Abstract
Pooled analysis for correlation coefficient revealed that cane yield was found to be significantly and positively correlated with CCS (t/ha) followed by germination % at 45 days, stalk height at 360 days, stalk diameter at 360 days, internodes/stalk at 360 days, stalk weight at 360 days and NMC at harvest at both genotypic and phenotypic levels while, CCS t/ha had highly significant and positive correlation with almost all the characters except tillers at 120 days, shoots at 240 days, juice purity % at 360 days and fiber % cane. These yield contributing characters also possessed highly significant and positive association among themselves. Path analysis showed low residual effect (0.028) indicating that there were negligible components left out other than those included in present study which influence cane yield. Further, path analysis revealed that for improving cane yield and quality of juice parameters in sugarcane, weightage in selection should be given to pol % cane at harvest, juice brix % at 360 days, fibre % cane, CCS (t/ha) or sugar yield (t/ha), juice purity % at 360 days and NMC at harvest because they have positive and highest direct effect on cane yield.

Keywords: Correlation, path analysis, cane yield, juice quality, sugarcane

Introduction

Being the world's largest crop by production quantity, the whole sugarcane plant is useful in various ways *viz*., cane sugar yield, jaggery, *khandsari*, roots for fuel, ethanol, bio-compost, tops for cattle feed and trash for roof and mulch etc. About 70% of the total sugar produced globally comes from a species of sugarcane called *Saccharum officinarum* and hybrids using this species. Sugarcane is an important cash crop for farmers of nation with a credibility of an assurance against economic suffering and having the calibre to withstand the climatic uncertainty better than the other crops. In the current condition with the ever-increasing populace, climatic uncertainty and demand for consumption of sugar, the only option is to improve cane yield.

Cane and sugar yields are considered to be the complex characters which cannot be improved independently. Because, interrelationship of yield (both cane and sugar yield) at phenotypic and genotypic level is influenced by many characters which are related among themselves and with yield either favourably or unfavourably, hence prior to breeding for higher yield, information of such interrelationship would be of immense help to the sugarcane breeder since it facilitate quicker assessment of high yielding genotypes. The real association could be known only through genotypic correlation which eliminates the environmental influence.

But the interdependence of these component characters among themselves often influence the direct relationship with yield (both cane and sugar yield), as a result the information based on the correlation coefficients becomes not dependable. Path coefficient analysis on the other hand provides direct and indirect effect of component traits which helps to understand true relationship of the character. Considering these points, the present study was conducted to understand interrelationship among various traits in sugarcane and also to assess the direct and indirect effects of different component traits of cane and sugar yields.

Materials and methods

Description of the study area

The field experiment was conducted at Main Sugarcane Research Station, Navsari Agricultural University, Navsari-396 450 (Gujarat) by creating four environments.

The place is located 12 km away in the east from the great historical place "Dandi" on the Arabian seashore. Geographically, it is situated at 20°-57′N latitude and 72°-54'E longitude with an elevation of 10.0 meter above mean sea level on the western coastal belt of India. For this study, thirty genotypes of sugarcane obtained from Main Sugarcane Research Station, NAU, Navsari (Table-1) were used. Experiment was conducted in Randomized Block Design (RBD) with three replications. The gross plot size for each genotype was consisted of five rows each of six-meter length with row to row spacing of 90 cm and the net plot was consisted of middle 3 rows each of 5-meter length with row to row spacing of 90 cm (excluding 0.5 m ring line at both ends of the plot). The two budded sets of sugarcane were planted in rows keeping 12 buds per meter row length. The crop was raised under irrigated conditions following all the recommended package of practices and fertilizer application for environment 1 and environment 3 (250 kg N + 125 kg P2O5 + 125 kg K2O per ha) while for environment 2 and environment 4 half dose of recommended fertilizer (125 kg N + 62.5 kg P2O5 + 62.5 kg K2O per ha) along with *acetobacter* treatment as a drenching @ 2.5 lit/ha for nitrogen fixation was followed.Observations were recorded on yield components and quality traits *viz.*, germination % at 45 days, tillers at 120 days (000/ha), shoots at 240 days (000/ha), stalk height at 360 days (cm), stalk diameter at 360 days (cm), internodes/stalk at 360 days, stalk weight at 360 days (kg), number of millable canes/ha (NMC) at 360 days (000/ha), cane yield at harvest (t/ha), juice brix % at 360 days, sucrose % juice at 360 days, juice purity % at 360 days, CCS % at 360 days, fibre % cane at 360 days, pol % cane at 360 days and sugar yield at 360 days (t/ha).

Data analysis

The data recorded for all the characters were subjected to various statistical analysis. Prior to calculating the correlation coefficients, the analysis of covariance for all the possible pairs of the characters under investigation was carried out using the procedure described by Panse and Sukhatme (1978) [12]. The genotypic (rg) and phenotypic (rp) correlation coefficients were calculated by adopting the procedure expounded by Miller *et al.* (1958) [10]. According to method of Fisher and Yates (1943) [5], the significance of correlation was tested. Simple correlation coefficients do not explain the cause and effect relationship between two variables. Therefore, the data were subjected to a standard regression analysis known as path analysis to unravel whether the association of different traits with yield is due to their direct effect or it is a consequence of their indirect effect via some other traits according to the procedure of Wright (1921) [20] and Dewey and Lu (1959) [4]. The genotypic correlations among fifteen characters were partitioned into their direct and indirect effects on cane yield as well as causal variable and their direct and indirect effects on cane yield were estimated.

Results and discussion

Character association

Prior to breeding crops for higher yield, it is imperative to obtain the information regarding the inter-relationship of different characters with yield and among themselves since it facilitate quicker assessment of high yielding genotypes. The real association could be known only through genotypic correlation which eliminates the environmental influence.

Selection for a specific character is known to result in correlated response in certain other character. Generally plant breeder make selection for one or two attributes at a time and then it becomes important to know the effect on other characters. Simple phenotypic correlations indicate broadly the type of association that exists between various attributes. But simple phenotypic correlations by themselves do not provide any reliable basis for selection. Hence the genotypic correlations which are based on the heritable part of the observed variation enable the assessment of the pattern of inherent relationship that exists between various traits. Therefore, correlation coefficients between cane yield and its components and among the component characters were estimated at genotypic and phenotypic levels pooled over environments for sixteen different characters are presented in Table 2.

The results of present study which revealed comparatively higher degree of genotypic correlation coefficient than phenotypic counterpart, indicated that though there was a high degree of association between two characters at genotypic level, their phenotypic association was lessened due to influence of environment. In few cases, however, the phenotypic correlations were slightly higher than their genotypic counterparts which implied that the non-genetic causes inflated the value of genotypic correlation because of the influence of the environmental factors. Similar findings were reported by Singh *et al.* (2002a) [17], Kumar *et al.* (2004) [8], Patel *et al.* (2006a) [13], Murthy (2007) [11], Sahu *et al.* (2008) [16], Rahman *et al.* (2008b) [15], Ahmed *et al.* (2010) [1] and Patel (2012) [14].

Cane yield showed highly significant positive and strong association with CCS (t/ha) followed by germination % at 45 days, stalk height at 360 days, stalk diameter at 360 days, internodes/stalk at 360 days, stalk weight at 360 days and NMC at harvest at both genotypic and phenotypic levels indicating that these attributes were mainly influencing the cane yield in sugarcane. Thus selection practiced for the improvement in one character will automatically result in the improvement in the other, even though direct selection for improvement has not been made for the complex yield character. The results of this study were also in conformity with those reported by Tyagi and Singh (2000) [19], Kumar *et al.* (2001) [9] and Singh *et al.* (2002a) [17]. Kumar *et al.* (2004) [8] recorded correlation of cane yield with number of tillers at 120 days, number of shoots at 240 days, NMC/ha, cane height (cm), cane girth (cm) and single cane weight (kg). Patel *et al.* (2006a) [13] observed correlation of cane yield with number of shoots/ha, single cane weight, stalk length, stalk diameter, number of internodes, NMC/ha and CCS t/ha. Murthy (2007) [11] recorded correlation of cane yield with number of tillers, NMC/ha, cane length (cm), cane girth (cm) and number of internodes. Similar results were akin to the findings of Sahu *et al.* (2008) [16], Rahman *et al.* (2008b) [15] and Ahmed *et al.* (2010) [1] who found that cane yield was significantly correlated with sugar yield purity per cent, tillers number and number of millable canes. In present investigation cane yield had non-significant positive correlation with tillers at 120 days and shoots at 240 days. It indicated that they have least influence on this trait.

Germination % at 45 days had highly significant and positive correlation with cane yield (t/ha), tillers at 120 days, shoots at 240 days, stalk diameter (cm) at 360 days, NMC at harvest and CCS (t/ha). Kumar *et al.* (2001) [9] recorded correlation of germination percentage with number of tillers per plot, NMC per plot, stalk girth and cane yield. The results of this study were also in conformity with those reported by Thippeswamy *et al.* (2003) [18]. Kumar *et al.* (2004) [8] observed correlation of germination percentage with number of tillers at 120 days and number of tillers at 240 days. Similar correlation of cane yield was reported by Murthy (2007) [11].

Tillers at 120 days and shoots at 240 days had highly significant and positive correlation with each other and they were also positively correlated with stalk diameter, no. of millable canes at harvest and CCS (t/ha). Similar correlation of cane yield was reported by Khan *et al.* (1991) [7] with NMC at harvest and Choudhari and Singh (1994) [2] with all characters mentioned above. Thippeswamy *et al.* (2003) [18] reported positive correlation with cane yield (t/ha). Kumar *et al.* (2004) [8] observed positive correlation of Tillers at 120 days and shoots at 240 days with NMC at harvest. Patel *et al.* (2006a) [13] with NMC at harvest, stalk diameter and sugar yield (t/ha). Murthy (2007) [11] with number of millable canes, cane length and sugar yield.

In results it was observed that number of millable canes at harvest was an important attribute for cane yield because it was significantly and positively correlated with cane yield (t/ha).

The important yield contributing trait NMC at harvest had highly significant and positive correlation with germination % at 45 days, tillers at 120 days, shoots at 240 days, stalk diameter at 360 days and CCS or sugar yield (t/ha).

All quantitative characters had significant association with each other and non significant association with qualitative characters except sugar yield which was significantly associated with cane yield (t/ha), germination % at 45 days, stalk height at 360 days, stalk diameter at 360 days, internodes/stalk at 360 days stalk weight at 360 days, NMC at harvest, juice brix % at 360 days, sucrose % juice at 360 days, CCS % 360 at 360 days and pol % cane at 360 days. Result of this investigation showed that improvement in one character will improve the other character due to strong association. Chaudhry and Singh (1994) [2], Das *et al.* (1996) [3], Patel *et al.* (2006a) [13] also obtained strong association of quantitative characters, which were in conformity with these results. Also similar results were reported by Rahman *et al.* (2008b) [15], Ahmed *et al.* (2010) [1] and Patel (2012) [14].

These experimental results indicated that breeder could improve cane yield by selection pressure with characters like with CCS (t/ha) followed by germination % at 45 days, stalk height at 360 days, stalk diameter at 360 days, internodes/stalk at 360 days, stalk weight at 360 days and NMC at harvest and sugar yield, which are highly significantly correlated with each other. While for quality improvement trait sugar yield (t/ha) which had significant association with quality parameters.

Path coefficient analysis

Yield is a complex character and is the multiplicative end product of several component traits. Some of them may be grouped as main components which directly contribute towards yield, whereas, others may indirectly influence the yield by changing the behavior and growth of different components, therefore, it would be better to know how the yield is directly and indirectly influenced by other characters. In order to achieve a clear picture of inter-relationship of various component characters with yield, direct and indirect effects were calculated using path coefficient analysis at genotypic level presented in Table 3.

From the present study it was observed that pol % cane at harvest has the highest positive direct effect on cane yield followed by juice brix % at 360 days, fibre % cane, CCS (t/ha) or sugar yield (t/ha), juice purity % at 360 days and NMC at harvest. Singh *et al.* (2002a) [17] revealed that NMC/clump, cane height, shoots at 240 days, single cane weight and stalk diameter reflected highly positive direct effect on cane yield at genotypic level. Patel *et al.* (2006a) [13] reported sucrose % juice and CCS (t/ha) directly contributed to cane yield (t/ha). The results are akin to the findings of Rahman *et al.* (2008b) [15] and Gana *et al.* (2009) [6].

Sucrose or (pol) % cane at harvest had the highest positive direct effect but it had negative and non significant correlation with cane yield, while highest indirect effect on cane yield by pol % cane at harvest via sucrose % juice at 360 days followed by CCS % at harvest, juice brix % at 360 days, CCS (t/ha) at harvest or sugar yield (t/ha) and fibre % cane. As well as sugar yield (t/ha) also having high direct effect on cane yield and it had positive and highly significant strong association with cane yield. Thus, it is the most important and reliable character and can be utilized in direct selection for improving cane yield. Das *et al.* (1996) [3] also reported the highest positive direct effect and highest genotypic correlation of CCS (t/ha) with cane yield. Patel *et al.* (2006a) [13] reported that the highest positive direct effect and highest genotypic correlation of CCS (t/ha) with cane yield. Gana *et al.* (2009) [6] reported highest direct and indirect effects on sugar yield.

Sugar yield had high positive direct effect and highly significant correlation with cane yield and its indirect effect via other characters is also found positive and high. Thus it indicates that sugar yield is very important character to improve cane yield. Since cane yield is very complex character being affecting by so many characters. Under these circumstances, provision is made for a residual path which would take care of all such factors excluded. In the present study the residual effect at genotypic level was 0.0280 which suggest that there is no other traits directly or indirectly influenced the cane yield other than those character included in this study.

From ongoing discussion it may be concluded that for improving cane yield, emphasis should be made on all yield contributing characters which are influencing it directly or indirectly. In the present study overall picture of path analysis revealed that for improving cane yield and quality of juice parameters in sugarcane, weightage in selection should be given to pol % cane at harvest, juice brix % at 360 days, fibre % cane, CCS (t/ha) or sugar yield (t/ha), juice purity % at 360 days and NMC at harvest because they have positive and highest direct effect on cane yield.

Table 1: List of genotypes used in the study

1. Co 85004	11. Co 07012	21. CoSnk 07104
2. Co 86032	12. Co 07015	22. CoSnk 07105
3. Co 94008	13. Co 07017	23. CoJn 07092
4. Co 99004	14. Co 07020	24. CoJn 07093
5. Co 07003	15. CoN 95132	25. CoJn 07094
6. Co 07006	16. 2005 N 699	26. PI 07131
7. Co 07007	17. CoN 07072	27. PI 07132
8. Co 07008	18. CoN 07073	28. MS 07081
9. Co 07009	19. CoSnk 07101	29. CoM 07083
10. Co 07010	20. CoSnk 07103	30. CoVC 07061

Table 2: Genotypic and phenotypic correlation coefficients of sugarcane yield with various growth and quality components (Pooled)

Characters		Germination % at 45 days	Tillers at 120 days (000/ha)	Shoots at 240 days (000/ha)	Stalk height (cm) at 360 days	Stalk diameter (cm) at 360 days	Internodes /stalk at 360 days	Stalk weight (kg) at 360 days	NMC at harvest (000/ha)	Juice brix % at 360 days	Sucrose % juice at 360 days	Juice purity % at 360 days	CCS %	Fibre % cane	Pol % cane	CCS (t/ha)
Cane yield (t/ha)	r_g	0.569**	0.154	0.178	0.449**	0.572**	0.397**	0.476**	0.530**	-0.022	-0.076	-0.280**	-0.102	-0.139	-0.058	0.866**
	r_p	0.455**	0.120	0.164	0.334**	0.436**	0.308**	0.425**	0.474**	-0.092	-0.117	-0.096	-0.127	-0.225*	-0.086	0.358**
Germination % at 45 days	r_g	1.000	0.394**	0.441**	0.114	0.296**	0.196	0.138	0.350**	-0.059	-0.103	-0.183	-0.121	-0.070	-0.093	0.460**
	r_p	1.000	0.370**	0.408**	0.094	0.255*	0.116	0.113	0.304**	-0.066	-0.089	-0.079	-0.098	-0.065	-0.080	0.355**
Tillers at 120 days (000/ha)	r_g		1.000	0.974**	-0.246*	0.089	-0.083	-0.102	0.621**	-0.247*	-0.276**	-0.037	-0.286**	0.051	-0.292**	0.002
	r_p		1.000	0.910**	-0.213*	0.022	-0.056	-0.098	0.521**	-0.174	-0.198	-0.051	-0.203	0.016	-0.200	0.003
Shoots at 240 days (000/ha)	r_g			1.000	-0.259*	0.066	-0.044	-0.113	0.684**	-0.239*	-0.270*	-0.051	-0.280**	0.005	-0.277**	0.025
	r_p			1.000	-0.248*	0.022	-0.000	-0.097	0.573**	-0.137	-0.145	0.004	-0.145	-0.031	-0.141	0.069
Stalk height (cm) at 360 days	r_g				1.000	0.116	0.191	0.227*	0.105	0.112	0.086	-0.188	0.073	-0.124	0.107	0.443**
	r_p				1.000	0.087	0.103	0.224*	0.079	0.028	-0.002	-0.135	-0.014	-0.061	0.008	0.287**
Stalk diameter (cm) at 360 days	r_g					1.000	-0.071	-0.045	0.444**	-0.107	-0.178	-0.357**	-0.211*	0.017	-0.188	0.432**
	r_p					1.000	-0.043	0.012	0.325**	-0.116	-0.147	-0.131	-0.158	0.034	-0.154	0.312**
Internodes /stalk at 360 days	r_g						1.000	0.539**	0.081	0.082	0.090	0.013	0.093	-0.236*	0.127	0.405**
	r_p						1.000	0.402**	0.051	0.074	0.077	0.002	0.076	-0.169	0.100	0.307**
Stalk weight (kg) at 360 days	r_g							1.000	0.185	0.066	0.067	-0.027	0.066	-0.148	0.092	0.468**
	r_p							1.000	0.169	0.034	0.033	-0.012	0.032	-0.133	0.052	0.392**
NMC at harvest (000/ha)	r_g								1.000	-0.176	-0.207	-0.126	-0.221*	-0.272**	-0.172	0.384**
	r_p								1.000	-0.092	-0.117	-0.096	-0.127	-0.225*	-0.086	0.358**
Juice brix % at 360 days	r_g									1.000	0.981**	-0.278**	0.961**	0.307**	0.974**	0.464**
	r_p									1.000	0.967**	-0.145	0.933**	0.157	0.958**	0.470**
Sucrose % juice at 360 days	r_g										1.000	-0.089	0.996**	0.330**	0.990**	0.432**
	r_p										1.000	0.112	0.994**	0.160	0.991**	0.480**
Juice purity % at 360 days	r_g											1.000	-0.004	0.044	-0.099	-0.260*
	r_p											1.000	0.220*	0.005	0.111	0.024
CCS %	r_g												1.000	0.334**	0.986**	0.409**
	r_p												1.000	0.157	0.985**	0.473**
Fibre % cane	r_g													1.000	0.195	0.045
	r_p													1.000	0.024	0.002
Pol % cane	r_g														1.000	0.443**
	r_p														1.000	0.486**

*,** significant at 5 and 1 per cent levels respectively

Table 3: Direct and indirect effects of different characters on cane yield in sugarcane (Pooled)

Characters	Germination % at 45 days	Tillers at 120 days (000/ha)	Shoots at 240 days (000/ha)	Stalk height (cm) at 360 days	Stalk diameter (cm) at 360 days	Internodes /stalk at 360 days	Stalk weight (kg) at 360 days	NMC at harvest (000/ha)	Juice brix % at 360 days	Sucrose % juice at 360 days	Juice purity % at 360 days	CCS %	Fibre % cane	Pol % cane	CCS (t/ha)	Genotypic correlation with cane yield
Germination % at 45 days	-0.0131	-0.0052	-0.0058	-0.0015	-0.0039	-0.0026	-0.0018	-0.0046	0.0008	0.0013	0.0024	0.0016	0.0009	0.0012	-0.006	0.5690**
Tillers at 120 days (000/ha)	-0.0166	-0.0422	-0.0411	0.0104	-0.0037	0.0035	0.0043	-0.0262	0.0104	0.0117	0.0016	0.0121	-0.0022	0.0123	-0.0001	0.1537
Shoots at 240 days (000/ha)	-0.0346	-0.0764	-0.0785	0.0203	-0.0052	0.0035	0.0088	-0.0537	0.0188	0.0212	0.004	0.0219	-0.0004	0.0218	-0.002	0.1777
Stalk height (cm) at 360 days	-0.0012	0.0026	0.0027	-0.0105	-0.0012	-0.002	-0.0024	-0.0011	-0.001	-0.0009	0.002	-0.0008	0.0013	-0.0011	-0.0046	0.4491**
Stalk diameter (cm) at 360 days	-0.0157	-0.0047	-0.0035	-0.0062	-0.0531	0.0038	0.0024	-0.0236	0.0057	0.0095	0.019	0.0112	-0.0009	0.01	-0.0229	0.5723**
Internodes /stalk at 360 days	0.008	-0.0034	-0.0018	0.0078	-0.0029	0.0408	0.0219	0.0033	0.0033	0.0037	0.0005	0.0038	-0.0096	0.0052	0.0165	0.3967**
Stalk weight (kg) at 360 days	-0.0065	0.0048	0.0053	-0.0106	0.0021	-0.0252	-0.0468	-0.0086	-0.003	-0.0031	0.0012	-0.0031	0.0069	-0.0043	-0.0219	0.4764**
NMC at harvest (000/ha)	0.0235	0.0417	0.0459	0.0071	0.0298	0.0055	0.0124	0.0671	-0.012	-0.0139	-0.0085	-0.0148	-0.0183	-0.0115	0.0258	0.5304**
Juice brix % at 360 days	-0.1393	-0.5823	-0.565	0.2636	-0.2521	0.1924	0.1567	-0.4147	2.3615	2.3172	-0.6552	2.2703	0.7259	2.3005	1.0963	-0.0215
Sucrose % juice at 360 days	0.9857	2.6557	2.5921	-0.822	1.7143	-0.8617	-0.6393	1.9868	-9.434	-9.6145	0.8508	-9.5799	-3.1757	-9.5199	-4.1495	-0.0759

Juice purity % at 360 days	-0.0928	-0.0187	-0.026	-0.0952	-0.1812	0.0064	-0.0135	-0.064	-0.141	-0.0449	0.507	-0.0019	0.0224	-0.0503	-0.1316	-0.2798**
CCS %	0.1617	0.3823	0.3739	-0.0973	0.2826	-0.1238	-0.088	0.2959	-1.286	-1.3327	0.0051	-1.3376	-0.4471	-1.3185	-0.5471	-0.1024
Fibre % cane	-0.0832	0.0612	0.0055	-0.1481	0.0202	-0.2809	-0.1765	-0.3246	0.3665	0.3938	0.0526	0.3986	1.1923	0.2326	0.0532	-0.1389
Pol % cane	-0.7227	-2.2643	-2.1545	0.8337	-1.4578	0.9823	0.7132	-1.3329	7.5672	7.6913	-0.7708	7.6571	1.5155	7.7678	3.4371	-0.0577
CCS (t/ha)	0.5158	0.0026	0.0283	0.4977	0.4844	0.4547	0.5249	0.4311	0.5211	0.4845	-0.2915	0.4591	0.0501	0.4967	1.1225	0.8656**

Residual effect= 0.0280

Bold and underlined figures on main diagonal show the direct effects

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