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Genetic Variability, Correlation and Path Analysis of Agronomic Traits in Elite Sugarcane (*Saccharum* Spp.) Clones

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Abstract

To examine the relationship of certain agronomic and quality traits with cane yield, atrial was conducted at PAU, regional research station Gurdaspur (Pb). The trial includes 32 sugarcane clones, which were tested in randomized complete block design with three replications. Observations were recorded on cane yield and its component traits. Analysis of variance showed significant differences (P <0.01) for all the traits studied. Traits like no. of shoots, no. of millable canes, single cane weight and cane yield had high genotypic and phenotypic coefficient of variation, high heritability and high genetic advance as percentage of mean manifest that these traits are controlled by additive gene action and phenotypic selection for these traits will be productive. Cane yield exhibit robust positive and highly significant correlation with no. of shoots, no. of millable canes, stalk length, no. of internodes and single cane weight. Path analysis showed the highest positive direct effect of no. of shoots on cane yield accompanied by no. of internodes, single cane weight and brix percent at 300 days. However, stalk length had small direct effects and large indirect positive effects through no. of shoots and single cane weight on cane yield at genotypic level. Consequently, in view of their marked positive correlation with cane yield, indirect effects of stalk length should be added before making selection. Sugarcane clones should be preferred on the basis of no. of shoots, no. of millable caneand single cane weight to obtain higher cane yield.

Key words : *Sugarcane, genetic variability, heritability, genetic advance as percent of mean, correlation and path analysis.*

Introduction

Sugarcane (*Saccharum officinarum* L.) is an important cash crop in many countries including India, because of its high trade value (1). Sugar industry is the second largest agro-based industry after textile contributing 2.0% of the total gross domestic product in India. The importance of sugarcane has increased in recent years because of its importance in industrial raw material of sugar and allied industries producing alcohol, acetic acid, butanol, paper, plywood, industrial enzymes and animal feed (2). Modern sugarcane hybrids are obtained from inter-specific hybridization between *S. spontaneum* and *S. officinarum* followed by several backcrosses with *S. officinarum* (3). Sugarcane breeding strategies have suffered from a narrow genetic base in sugarcane hybrids because only a handful of ancestral clones were involved in the initial hybridization programmes. Sugarcane breeding involves the production and evaluation of large number of seedlings from different crosses every year and superior seedlings are selected from different clonal stages for further evaluation. The principal goal of sugarcane breeding programs is to develop new clones that perform better than the existing one with respect to many traits. In this pursuit, special focus is given to cane yield and brix percent.

Variability is the prerequisite for any crop improvement programmes. It is assessed by estimation of phenotypic and genotypic variance, phenotypic and genotypic coefficient of variation (PCV and GCV), heritability and genetic advance as percent of mean. Coefficients of variation with heritability as well as genetic advance are very vital to ameliorate any trait of sugarcane as this would aid in informing whether or not the selected objective can be obtained from the material (4). Cane yield is a complex quantitative trait affected by a number of factors. Therefore, the knowledge of interrelationships between cane yield and its associated traits to improves the effectiveness of breeding programs through the use of appropriate selection indices (5, 6, 7). The implication of Path coefficient analysis has been extensively employed in plant breeding strategies to examine the nature of association between cane yield and its associated traits and to find the traits with marked effects on cane yield to be used as criteria for selection. Path analysis exhibit the direct and indirect effects of cause variables on effect variables (8, 9, 10, 11). As reported by this method, the correlation coefficient between two traits is divided into sections that calculate the direct and indirect effects. This study reveals the results that focused on variability, genotypic and phenotypic correlations among cane yield and agronomic traits and estimating the direct and indirect effects of agronomic traits on cane yield.

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Materials and Methods

Thirty-two sugarcane clones including four checks (CoJ 85, CoJ 64, Co 0238 and CoJ 88) representing early and mid-late maturing group) were planted in randomized complete block design with three replications having the plot size of 2 rows x 3 meter x 0.75 meter at Punjab Agricultural University, Regional Research Station, Gurdaspur representing sub-tropical conditions during 2015-16. Three budded setts of each clone at the rate of 12 buds per running metre were planted. The recommended agronomic practices were followed to raise the ideal crop growth stand. The soil of trial site was clay loam with neutral pH and normal EC, medium in organic carbon and phosphorus and low in potassium.

Observations were recorded on number of shoots (000/ha), number of millable canes (000/ha), stalk length (cm), stalk diameter (cm), no. of internodes, single cane weight (kg), cane yield (t/ha), brix (%) at 240 days and brix (%) at 300 days. Number of shoots, NMC and cane yield were recorded on plot basis and converted to hectare unit; while stalk length, stalk diameter and no. of internodes were recorded on cane basis (ten randomly selected canes). Stalk length (cm) was measured at maturity of the crop i.e. from ground level to the point where tops are easily removable. Stalk diameter (cm) was measured for ten stalks with the use of Vernier Calliper (Insize Digital Caliper 1112-125). No. of millable canes was the total number of matured canes excluding the tillers which were not developed into mature stalks. Brix (%) was measured using a Hand Refractometer in the field itself in the standing crop.

Statistical analyses : To determine phenotypic, genotypic and environmental correlation coefficients, analysis of co-variance was executed in all possible pairs of combinations of the traits following (12). The genotypic and phenotypic correlation coefficients were used to determine the direct and indirect contribution towards yield per plant as suggested by (13). The direct and indirect paths were accomplished by following (14).

Results and Discussion

The analysis of variance exhibits that sugarcane clones were highly significant for all the traits under consideration**.** The analysis of variance for nine traits including cane yield and its related traits in the present set of sugarcane clones exhibit significant differences for all the traits. This indicates that these traits have inherent genetic dissimilarity among the sugarcane clones. Highly significant differences between the clones were recorded (Table-1) which expressed adequate genetic variability needed to check out an effective breeding program of crop improvement. The estimates of range, mean, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (broad sense) and genetic advance (% mean) are given in Table-1. Substantial range of variation was recorded for all the traits under study indicating ample scope for bringing enhancement in desirable direction.

Estimates of coefficients of variation, heritability and genetic advance : The GCV values ranges from 5.04 % for brix (%) at 240 days to 23.29 % for cane yield. The Cane yield, no. of millable cane, no. of shoots, and single cane weight recorded high GCV value. The PCV value ranges from 5.05 % for brix (%) at 240 days to 24.92 % for cane yield. The cane yield, no. of millable canes, no. of shoots and single cane weight recorded high PCV value. Brix (%), no. of internodes per stalk, stalk length and stalk diameter recorded low PCV (Table-1). According to Deshmukh *et al.,*(1986), PCV and GCV values more than 20% are considered as high, whereas values lesser than 10% are considered to be low and values between 10 and 20 % to be medium. According to this, no. of shoots, no. of millable canes, single cane weight and cane yield recorded high PCV and GCV but stalk length, stalk diameter, internodes per stalk and brix (%) had lesser PCV and GCV. It suggests that selection may be productive based on these traits with high phenotypic and genotypic coefficient of variation and their phenotypic expression would be a good index of genetic potential. Singh *et al.,* 2020 reported similar findings for cane yield and no. of millable cane and for single cane weight by (15) and for no. of shoots by (15).

The phenotypic coefficient of variation was greater than the genotypic coefficient of variation for all the traits, which considers that the visible variations were not only due to genotypes alone but environment also. Since PCV evaluates the effects of genotypes and environment, higher PCV than GCV shows a significant contribution of environment and genotypes by environment interaction in the expression of all traits. These findings are in agreements with the results of Agrawal and Kumar, 2017. Although aclose association was observed between GCV and PCV for all traits except stalk length and internodes per stalk. The lesser the difference between PCV and GCV for no. of shoots, no. of millable canes, stalk diameter, single cane weight, cane yield and brix (%) at 240 and 300 days indicates lower impact of environment on these traits.

The coefficient of variation only suggested the extent of total variability existing for the traits and does not split the variability into heritable and non-heritable portions as reported (16, 17). Thus, the calculations of heritability appear to be of huge significance. Heritability estimates

Table-1 : Estimates of range, mean, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (broad sense) and genetic advance (% mean).

Characters	Mean	Range	PCV	GCV	Hbs (%)	GA	GA (% Mean)	CV
No. of Shoots (000, ha)	134.83	51.11-175.56	23.18	22.01	90.13	58.02	43.04	7.28
No. of Millable Canes (000, ha)	96.04	41.11-131.11	23.94	23.03	92.54	43.83	45.63	6.54
Stalk Length (cm)	237.59	176.50-262.00	9.98	6.60	43.77	21.37	8.99	5.08
Stalk diameter (cm)	2.14	16.00-21.50	10.37	9.15	77.85	0.36	16.63	6.99
Internodes per stalk	19.17	1.75-2.75	8.36	4.58	30.05	0.99	5.18	4.88
Single Cane Weight (kg)	1.07	0.63-1.78	21.36	20.48	91.92	0.43	40.45	6.03
Cane Yield (t/ha)	93.44	40.32-127.68	24.92	23.29	87.40	41.91	44.86	8.84
Brix (%) at 240 days	17.20	15.88-19.11	5.05	5.04	99.71	1.78	10.37	0.26
Brix (%) at 300 days	18.94	16.60-21.70	5.87	5.86	99.54	2.28	12.04	0.40

Table-2 : Phenotypic (above diagonal) and Genotypic (below diagonal) correlation coefficient among nine traits in sugarcane clones.

Characters	Shoots (000, ha)	NMC (000, ha)	SL (cm)	SD (cm)	IN	SCW (kg)	CY (t/ha)	Brix (%) at 240 days	Brix (%) at 300 days
Shoots (000, ha)	P G	0.852**	0.244NS	0.092NS	0.222NS	-0.232NS	0.674**	0.162NS	-0.077NS
NMC (000, ha)	0.893**		0.198NS	-0.016NS	0.235NS	-0.394**	0.675**	0.206NS	0.041NS
SL (cm)	0.405**	0.378**		0.115NS	0.589**	0.146NS	0.349**	-0.173NS	-0.120NS
SD (cm)	0.091NS	-0.028NS	-0.039NS		0.151NS	0.235NS	0.214NS	0.278*	0.318*
IN	0.402**	0.561**	0.446**	0.126NS		0.141NS	0.371**	0.009NS	0.077NS
SCW (kg)	-0.230NS	-0.409**	0.119NS	0.267*	0.224NS		0.339**	-0.249*	0.002NS
CY (t/ha)	0.743**	0.685**	0.622**	0.217NS	0.863**	0.323**		0.010NS	0.066NS
Brix (%) at 240 days	0.173NS	0.217NS	-0.251*	0.315*	0.030NS	-0.265*	0.008NS		0.723**
Brix (%) at 300 days	-0.087NS	0.045NS	-0.192NS	0.361**	0.121NS	0.001NS	0.073NS	0.727**	

*Statistically significant correlation at p = 0.05; **statistically significant correlation at p = 0.01.

are useful in forecasting the predicted response to be achieved through the process of selection. Genotypic coefficient of variation together with heritability estimate provides a reliable estimate of the proportion of genetic advance to be predicted through phenotypic selection (13).

In the present study, high heritability was recorded for most all the characters except internodes per stalk and stalk length. Heritability estimates ranged from 99.71 % for brix (%) at 240 days to 30.05 % for no. of internodes per stalk. As stated by (18), traits having heritability estimates more than 80% are considered as very high, between 60-79% are moderately high, from 40-59% are medium and less than 40% are considered as low. Traits brix (%), no. of millable canes, single cane weight, no. of shoots, cane yield and stalk diameter recorded high heritability estimates (>77 %). Traits stalk length and no. of internodes per stalk recorded medium heritability. Similar finding were observed by (18) for traits like no. of millable cane, stalk diameter, single cane weight and stalk length. Heritability estimates indicates that selection will be productive for the traits having high heritability.

Genetic advance percentage of mean (GAM) as classified by (19); values above 20% are considered high, 10-20% are moderate and from 0-10% are low. In reference to this, the range of GAM was from 5.18% for no. of internodes per stalk to 45.63% for no. of millable canes. No. of millable canes (45.63%), cane yield (44.86%), no. of shoots (43.04%) and single cane weight (40.45%) displayed high genetic advance as percentage of mean, while stalk diameter (16.63%), brix (%) at 300 days (12.04%) and brix (%) at 240 days (10.37%) displayed medium genetic advance as a percentage of mean. Traits stalk length (8.99%) and no. of internodes per stalk (5.18%) exhibit low genetic advance as percentage of mean (Table-1). Hence, selection for improving these traits in sugarcane clones could be achieved having high genetic advance as percentage of mean.

Table-3 : Direct (boldface) and indirect effects of different traits on cane yield.

Characters		Shoots (000, ha)	NMC (000, ha)	SL (cm)	SD (cm)	IN	SCW (kg)	Brix (%) at 240 days	Brix (%) at 300 days	Correlation with Cane Yield
Shoots (000, ha)	P	0.121	0.709	0.009	0.005	0.005	-0.151	-0.016	-0.008	0.674**
	G	1.087	-0.575	0.044	-0.005	0.279	-0.023	-0.037	-0.027	0.743**
NMC (000, ha)	P	0.103	0.832	0.007	-0.001	0.005	-0.255	-0.020	0.004	0.675**
	G	0.971	-0.643	0.041	0.002	0.389	-0.040	-0.047	0.014	0.685**
SL (cm)	P	0.030	0.164	0.036	0.006	0.012	0.095	0.017	-0.012	0.349**
	G	0.440	-0.243	0.108	0.002	0.309	0.012	0.054	-0.059	0.622**
SD (cm)	P	0.011	-0.013	0.004	0.053	0.003	0.153	-0.027	0.031	0.214NS
	G	0.099	0.018	-0.004	-0.054	0.087	0.026	-0.068	0.112	0.217NS
IN	P	0.027	0.196	0.021	0.008	0.021	0.092	-0.001	0.008	0.371**
	G	0.437	-0.361	0.048	-0.007	0.693	0.022	-0.007	0.037	0.863**
SCW (kg)	P	-0.028	-0.328	0.005	0.012	0.003	0.649	0.025	0.000	0.339**
	G	-0.250	0.263	0.013	-0.014	0.155	0.099	0.057	0.000	0.323**
Brix (%) at 240 days	P	0.020	0.171	-0.006	0.015	0.000	-0.162	-0.099	0.071	0.010NS
	G	0.188	-0.140	-0.027	-0.017	0.021	-0.026	-0.216	0.225	0.008NS
Brix (%) at 300 days	P	-0.009	0.034	-0.004	0.017	0.002	0.001	-0.071	0.098	0.066NS
	G	-0.095	-0.029	-0.021	-0.019	0.084	0.000	-0.157	0.309	0.073NS

Residual are 0.09982 (P); Residual are -0.07207 (G)

Traits like no. of shoots, no. of millable canes, single cane weight and cane yield had high GCV, PCV, heritability and genetic advance (percentage of mean), which are very essential for selection than heritability estimates alone. Similar observation for NMC and SCW, were observed by (20) for no. of Shoots by (15) and cane yield by (20). High heritability coupled with high genetic advance shows that these traits are controlled by additive gene action and phenotypic selection for these traits will be productive.

Genotypic and phenotypic correlations between nine traits of sugarcane clones are indicated in table-2. Correlation coefficient depicted that genotypic correlation were greater than phenotypic correlation coefficient for most of the traits which have negative effect of environmental on an association development. This could be due to relative stability of the genotypes as majority of them have been subjected to certain amount of selection. The result showed that cane yield (t/ha) had a positive and significant correlation except stalk diameter, brix (%) at 240 days and brix (%) at 300 days. Cane yield does not exist in isolation; it's a combined effect of yield contributing traits that form a complex association which finally influence the yield. This correlation may be in positive or negative direction. The r-value for Karl Pearson's correlation coefficient helps in finding the association between two distinct traits, although it does not estimate the magnitude of correlation but it does give the idea of the correlation. For the correlation coefficient interpretations, (20) gives a standard accepted guideline. The r-value of 0, +1, and -1 indicates no linear relationship, a perfect positive linear relationship, and negative linear relationship, respectively. The values that range from 0 to 0.3, 0.3 to 0.7, and 0.7 to 1 indicate a low, moderate, and strong positive linear relationships, respectively, while the values that range from 0 to -0.3, -0.3 to -0.7, and -0.7 to -1 suggest a low, moderate, and strong negative linear relationships, respectively.

The correlation coefficient of phenotypic traits ranges from 0.002 to 0.852 while the genotypic traitsit ranges from 0.001 to 0.893. This shows that at genotypic level magnitude is usually higher as compared with the equivalent phenotypic level. Cane yield per hectare reflects a robust, positive and significant association with no. of shoots, no. of millable canes, stalk length, internodes per stalk and single cane weight. Similar results were also reported for no. of millable canes, stalk length and single cane weight by (18) and for number of shoots, number of millable canes, stalk diameter, stalk length, number of internodes and stalk weight by (21). Selection based on these five components will be fruitful as a result of their significant contribution towards cane yield enhancement.

Direct and indirect effects of quantitative traits on cane yield per hectare : Cane yield is the result of all the related traits (no. of shoots, no. of millable canes, stalk length, stalk diameter, internodes per stalk, single cane weight) and the correlation coefficient of these related traits with final cane yield are separated into direct and indirect effects (Table-3). These allow the separation of direct and indirect effect by other traits by allotting the correlations for better interpretation of cause and effect relationship. The study revealed a significant interrelationship among cane yield and its component traits. These traits define the limitation to cane yield per hectare and the component traits through the direct and indirect effects as a result of interrelationships between them. Hence, the use of path coefficient analysis examines the direct and indirect association among the component traits by the partitioning of correlation coefficients (22).

The outcome of phenotypic path coefficient study exhibited that the traits studied except brix (%) at 240 days had positive direct effects on grain yield. The path analysis exhibited that the maximum direct effect on cane yield per hectare was employed by no. of millable canes (0.832) accompanied by single cane weight (0.649) and no. of shoots (0.121). This implies that no. of millable canes and single cane weight leads to increased cane yield; the phenotypic correlation between no. of millable cane and cane yield (rp=0.675; p = 0.01) is chiefly attributed to the direct effect of no. of millable canesoncane yield per hectare (Table-3). Similar observation for no. of millable canes and single cane weight were observed by (8).

The results of genotypic path coefficient analysis showed that maximum direct effect on cane yield was exerted by no. of shoots (1.087), no. of internodes (0.693) and brix (%) at 300 days (0.309).This implies that no. of shoots leads to increased cane yield; the genotypic correlation between no. of shoots and cane yield (rg=0.743; p = 0.01) and between no. of internodes and cane yield (rg=0.863; p = 0.01) is predominately attributed by the direct effect of no. of shoots and no. of internodes on cane yield per hectare. The correlation describes the real relationship of cane yield with no. of millable canes, single cane weight and no. of shoots, hence selection based on these traits would be productive.

Brix (%) at 240 days revealed negative direct effect on cane yield (-0.216) as its genotypic correlation with cane yield (0.008 ^{NS}), indicating the true relationship of the two traits. Although brix (%) at 240 days yielded high positive indirect effect on cane yield by no. of millable cane (0.171) at phenotypic level and positive indirect effect on cane yield by no. of shoots (0.188) at genotypic level. The correlations and inter-correlations indicate that the eight causal traits (i.e., the causal variables) describe ample of the variability in cane yield. In fact, a residual effect of 0.09982 (Table-3) suggests that the causal traits describe about 90.02 % of the variability in the cane yield, leaving 9.98% of the variability unexplained.

Correlation coefficients manifest that all the traits studied have significant positive association with cane yield per hectare except stalk diameter and brix (%). No. of shoots, no. of millable cane, no. of internodes and Single cane wright showed high significant correlations with cane yield per hectare at genotypic and phenotypic level. Hence, it can be concluded that no. of shoots, no. of millable cane, no. of internodes and Single cane wright are the important traits for selection to boost cane yield per hectare of the sugarcane clones evaluated in the study.

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