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Nature and Magnitude of Variation for Different Quantitative Characters in Sugarcane (*Saccharum* Species Complex)

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Abstract

Genetic variability parameters were studied for various cane yield and juice quality characters using 142 sugarcane clones, two parental varieties and five standards. Analysis of variance revealed that all the genotypes differ significantly for thirteen characters studied. Clone PC-2013-14-175 exhibited superior mean for juice brix per cent, polarity per cent, sucrose per cent and CCS per cent over the best standard, thus identified as best performer for juice quality characters. Similarly, PC-2013-14-221 exhibited superior performance for number of tillers, number of millable canes, cane height and CCS yield, therefore considered as best clone for cane yield contributing characters. Results revealed that PCV estimates were higher than GCV for all the characters and the closeness between GCV and PCV values for all the characters except cane height and CCS per cent indicated that majority of the characters are less influenced by the environment. Moderate to high magnitude of GCV, PCV along with high h^2_b and GAM were recorded for germination per cent, number of tillers, NMC, cane yield and CCS yield, indicated wider range of variability in the material and importance of additive gene action in inheritance of these characters in sugarcane.

Key words : *Saccharum, genotypic coefficients of variations, phenotypic coefficients of variations, heritability in broad sense, genetic advance.*

Introduction

Sugarcane is one of the important cash crops which is cultivated in tropical and sub- tropical regions of the world. It is valuable because it store high concentrations of sucrose in the stem and also for the production of ethanol (1). It is main source of commercial sugar at global level and produce approximately two thirds of world sugar. India is the second largest producer of sugarcane and is the largest producer and consumer of sugar in the world. 50-60 per cent of the canes produced used to manufacture crystal sugar, 30-40 per cent canes are utilized to manufacture *gur* and *khandsari* sugar in India and about 10 per cent canes are used as seed for planting a new crop (2). Sugarcane belongs to genus *Saccharum* of family Poaceae. *Saccharum* species complex is widely cultivated in India after nobalization because of high sucrose content and adaptability to adverse environmental conditions. Sugarcane cultivation occurs in most of the states of India *viz.,* Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Bihar and Andhra Pradesh etc and is considered as the second most important agro-industrial crop next only to cotton (3). In India during 2017-18, sugar production was 32137 thousand MT from 4774 thousand hectares area with 74.4 MT/ha cane yield. Sugar recovery was recorded to 9.30% (4).

The extent of genetic variability is of great value for any crop improvement programme. For the development of superior improved cultivars, utilization of existing variability in a crop species and its related species is important to fulfill different kinds of needs of the present day and future. Existing genetic variability for important characters plays an important role in plant breeding as it offers ample scope of selection for the improvement of specific characters. Variability can be created through hybridization but it needs to be assessed for revealing the scope of improvement under selection. Genotypic and phenotypic coefficients of variation provide a broad idea about the amount and nature of variability present in any breeding population. However, according to Burton (1953) it is not possible to determine the amount of heritable variation with the help of genetic coefficient of variation alone. To further increase the yield potential should be given to traits which were having high heritability (%) combining with high genetic advance (Ajitha et al., 2020). Therefore, it should be considered together with heritability estimates to obtain the best picture of the extent of heritable variation. The fraction of total variation which is heritable was termed as heritability in broad sense (7) or degree of genetic determination (8). The concept of heritability plays a vital role in formulating breeding plans for crop improvement. Estimates of heritability are useful in predicting the transmission of

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Table-1 : Analysis of variance for thirteen traits in sugarcane.

Source of Variation	DF	Germ	NT	NMC	SCW	Ht	Dia
Replications	1	505.938	808.122	2979.813	0.043	5.471	0.422
Treatments	148	78.844**	513.162**	403.0464**	0.076**	0.154**	0.149**
Error	148	13.860	125.200	68.749	0.015	0.077	0.037
CV%		9.145	13.264	12.286	10.868	12.881	8.349

Table-1 : Contd....

Source of Variation	DF	Brix %	Polarity %	Sucrose %	Purity %	CCS %	CY	CCSY
Replications	1	11.514	575.747	28.378	112.998	20.039	1957.798	18.563
Treatments	148	1.393**	62.432**	3.274**	55.751**	2.885**	709.829**	27.049**
Error	148	0.533	26.943	1.592	32.844	1.508	80.878	3.0269
CV%		3.543	6.572	6.649	6.221	9.181	11.955	12.201

Note : *= significance at 5%, **= significance at 1%, (Germ = Germination %, NT = No of tillers (000 /ha), NMC = Number of Millable Canes (000/ha), SCW = Single cane weight (Kg), Ht = Cane Height (m), Dia = Cane Diameter (cm), CCS = Commercial cane sugar, CY = Cane yield (t/ha), CCSY = C.C.S. yield(t/ha).

characters from the parents to their offspring. It gives an indication of repeatability of performance if selection is practiced for a particular character. Genetic advance is the most useful estimate as it is the improvement in the genotypic value in the new population in comparison to the base population. It can be defined as improvement in the mean genotypic value of selected plants over the parental population. It is the measure of genetic gain under selection. Therefore keeping these points in mind the present study was conducted to assess the genetic variability among the sugarcane clonal population by estimating their mean performance, genotypic and phenotypic coefficients of variation, heritability in broad sense and genetic advance as per cent of mean.

Materials and Methods

The present investigation was conducted at Sugarcane Breeding Block, Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture & Technology Pantnagar, Uttarakhand with 142 sugarcane clones, two parental varieties (Co 1148 and BO 91) and 5 standards (CoPant97222, Co238, CoS8436, CoJ64 and CoS767). Each entry was allotted to a single row plot measuring 5.0 m long and plot to plot spacing was kept to 0.90 m. The data were recorded for 13 yield and juice quality parameters *viz.,* germination per cent, number of tillers (000/ha), number of millable canes (000/ha), single cane weight (kg), cane height (m), cane diameter (cm), brix per cent, polarity per cent, sucrose per cent, purity per cent, CCS per cent, cane yield (t/ha) and CCS yield (t/ha). All the clones were evaluated during 2017-18 and 2018-19 in Augmented Block Design. In order to perform pooled analysis of variances, homogeneity of error variances test was performed as suggested by (9). The pooled ANOVA was carried out taking each season as one replication. The pooled Analysis of variance was carried out as explained by (10). Genotypic and phenotypic coefficients of variability were calculated for each character as per the method suggested by (5). Heritability in broad sense (h^2_b) was estimated as suggested by (11). Genetic advance (GA) for each character was calculated as given by (13).

Results and Discussion

Analysis of variances was carried out and the results (Table-1) revealed that all the genotypes differ significantly for all the thirteen characters namely cane yield, number of tillers, number of millable canes, germination per cent, polarity per cent, purity per cent, CCS yield, sucrose per cent, CCS per cent, brix per cent, cane height, cane diameter and single cane weight. The existence of significant differences for all the characters indicated that sufficient amount of variability was existed among the clones evaluated in the present study.

The simplest way for assessing the amount of variability in the experimental material is by examining the range of variation present in the material (Tabassum et al., 2019). The mean performance of 144 clones along with five standards *viz.*, Co0238, CoJ64, CoS767, CoS8436 and CoPant97222 were summarized for different morphological and juice quality characters and presented in Table-2. Most of the characters exhibited high mean and wider range of variation and revealed the presence of sufficient variability in the material under study. Germination percent (27.25-54.08%), number of tillers (48.89-140.00), number of millable canes (37.78-128.89), single cane weight (0.70-1.80 Kg), cane height (1.48-3.17 m), sucrose per cent (13.26-21.47 %), cane yield (39.11-140.00 t/ha) and CCS yield (6.6-24.13 t/ha) recorded a very wide range indicating higher variability level in the present population. More number of millable canes, cane height and single cane weight are important

Table-2 : Mean performance of sugarcane genotypes for different morphological and juice quality characters over two seasons.

S. No.	Characters	Mean	SEM	Range in clones	Best check with mean value	No. of clone superior over best check	Top five clones
1	Germ	40.71	2.63	27.25-54.08	Co Pant 97222 (52.63)	2	PC-2013-14-144, PC-2013-14-149
2	NT	84.36	7.91	53.51-129.29	Co238 (89.63)	46	PC-2013-14-546, PC-2013-14-221, PC-2013-14-180, PC-2013-14-143, PC-2013-14-186
3	NMC	67.49	5.86	38.33-116.33	Co238 (74.07)	43	PC-2013-14-143, PC-2013-14-221, PC-2013-14-186, PC-2013-14-144, PC-2013-14-530
4	SCW	1.13	0.086	0.75-1.77	Co-Pant 97222 (1.30)	25	PC-2013-14-507, PC-2013-14-187, PC-2013-14-224, PC-2013-14-126, PC-2013-14-552
5	Ht	2.15	0.19	1.41-2.72	Co-Pant 97222 (2.21)	53	PC-2013-14-504, PC-2013-14-206, PC-2013-14-518, PC-2013-14-221, PC-2013-14-520
6	Dia	2.29	0.13	1.67-3.25	Co238 (2.51)	22	PC-2013-14-507, PC-2013-14-500, PC-2013-14-502, PC-2013-14-504, PC-2013-14-509
7	Brix %	20.62	0.51	17.97-22.77	Co238 (21.62)	16	PC-2013-14-376, PC-2013-14-303, PC-2013-14-175, PC-2013-14-266, PC-2013-14-330
8	Polarity %	78.98	3.67	55.15-90.85	CoPant97222 (86.33)	8	PC-2013-14-476, PC-2013-14-175, PC-2013-14-376, PC-2013-14-387, PC-2013-14-392
9	Sucrose %	18.98	0.89	13.5-21.57	CoPant97222 (20.75)	6	PC-2013-14-175, PC-2013-14-476, PC-2013-14-392, PC-2013-14-105, PC-2013-14-387
10	Purity %	92.12	4.05	71.6-99.45	CoPant97222 (96.92)	15	PC-2013-14-525, PC-2013-14-392, PC-2013-14-542, PC-2013-14-398, PC-2013-14-502
11	CCS %	13.38	0.86	8.55-15.6	CoPant97222 (14.95)	5	PC-2013-14-476, PC-2013-14-175, PC-2013-14-392, PC-2013-14-387, PC-2013-14-105
12	CY	75.23	6.35	34.1-138.62	Co238 (91.00)	24	PC-2013-14-180, PC-2013-14-187, PC-2013-14-221, PC-2013-14-552, PC-2013-14-126
13	CCSY	14.25	1.23	6.6-24.13	Co238 (18.38)	19	PC-2013-14-180, PC-2013-14-221, PC-2013-14-187, PC-2013-14-552, PC-2013-14-144

Germ = Germination %, NT = No of tillers (000/ha), NMC = Number of Millable Canes (000/ha), SCW = Single cane weight (Kg), Ht = Cane Height (m), Dia = Cane Diameter (cm), CCS = Commercial cane sugar, CY = Cane yield (t/ha), CCSY = CCS yield (t/ha)

to obtain good cane yield. A wide range present for all the characters aid to selection as wider range gives chance to select better individuals. Higher mean range for various cane yield and juice quality traits were also recorded by (14).

It was observed that among standards, Co Pant 97222 recorded high mean values for germination per cent, single cane weight, cane height, polarity per cent, sucrose per cent, purity per cent and CCS per cent, while Co 238 recorded high mean values for number of tillers, number of millable canes, cane diameter, juice brix per cent, cane yield and CCS yield. From analysis of mean performance of clones, best clones identified were PC-2013-14-144 for germination per cent, PC-2013-14-546 for number of tillers, PC-2013-14-507 for single cane weight and cane diameter, PC-2013-14-504 for cane height, PC-2013-14-376 for juice brix Per cent, PC-2013-14-476 for polarity per cent and CCS per cent, PC-2013-14-175 for sucrose per cent, PC-2013-14-525 for purity per cent, PC-2013-14-180 for cane yield and CCS yield as they exhibited superiority over the best performing standard for the respective character.

After analysing overall mean performance, clone PC-2013-14-175 was identified as best clone exhibiting superior performance over the best standard for juice brix per cent, polarity per cent, sucrose per cent and CCS per cent, thus identified as best performer for juice quality characters. Similarly, PC-2013-14-221 exhibited superior performance for number of tillers, number of millable canes, cane height and CCS yield, therefore considered as best clone for cane yield contributing characters. It was also revealed that top five clones for cane diameter were the progenies of the same cross *i.e.,* BO91xCo453. Therefore, parents of this cross can be used as donor to increase the cane diameter in future. Similarly, for cane yield and CCS yield two clones PC-2013-14-180 and PC-2013-14-187 (general collection progeny clones of parent CoLk7901) were fall under top five performing clones against the best performing standard for these characters. It indicated that CoLk7901is a good donor of yield contributing traits for improving cane yield and CCS yield.

Estimates of Selection Parameters

The data was subjected to statistical analysis to find out genotypic and phenotypic coefficient of variation (GCV and PCV), heritability in broad sense (h^2_b), genetic advance (GA) and genetic advance as per cent of mean (GAM). GCV and PCV were categorized as low (0-10%), moderate (10-20%) and high (above 20%) according to (15), while heritability in broad sense was categorized as low (0-30%), moderate (30-60%) and high (60% and above) as suggested by (16). Genetic advance as per cent

Table-3 : Selection parameters for yield and quality characters in sugarcane clones.

S. No.	Characters	GCV	PCV	H^2b %	GA	GA % of mean
1.	Germination %	13.962	16.760	69.398	9.753	23.959
2.	No of tillers (000/ha)	16.485	21.200	60.464	22.274	26.406
3.	NMC (000/ha)	19.087	22.819	69.968	22.196	32.890
4.	Single cane weight (kg)	15.438	18.883	66.840	0.292	26.000
5.	Cane height (m)	9.145	15.807	33.472	0.234	10.900
6.	Cane diameter (cm)	10.403	13.329	60.922	0.383	16.727
7.	Brix %	3.192	4.756	45.051	0.910	4.414
8.	Polarity %	5.331	8.465	39.669	5.463	6.917
9.	Sucrose %	4.829	8.221	34.511	1.109	5.844
10.	Purity %	3.669	7.229	25.761	3.534	3.836
11.	CCS %	6.194	11.084	31.227	0.954	7.130
12.	Cane yield	23.541	26.464	79.129	32.449	43.138
13.	CCS yield	24.287	27.211	79.666	6.368	44.657

NMC = Number of millable canes, GCV = Genotypic coefficient of variation, PCV = Phenotypic coefficient of variation, GA = Genetic advance.

of mean was categorized as low (0-10%), moderate (10-20%) and high (20 % and above) as given by (13). The estimates of genetic parameter for different quantitative traits are presented in Table 3 and discussed here under.

Moderate phenotypic (PCV) coefficient of variation (16.760) and genotypic (GCV) coefficient of variation (13.962) were recorded for germination per cent. High heritability in broad sense (69.398 %) along with high genetic advance as per cent mean of (23.959 %) were observed for this character. Earlier, (17) reported high heritability along with high genetic advance as per cent of mean and (18) reported moderate GCV and PCV values for germination per cent during their studies.

High phenotypic (PCV) coefficient variation (21.200), moderate genotypic (GCV) coefficient of variation (16.485) along with high heritability in broad sense (60.464 %) and high genetic advance as per cent of mean (26.406 %) were recorded for number of tillers. (19) also recorded higher PCV with moderate GCV along with high heritability and genetic advance as per cent of mean for number of tillers in their experiment with thirty sugarcane clones evaluated in randomized block design.

Number of millable canes exhibited high PCV (22.819) and moderate GCV (19.087). The heritability in broad sense and genetic advance as per cent of mean was found high (69.968 % and 32.890 %, respectively) for number of millable canes. (20) reported all these estimates as high in their study using twenty sugarcane (*Saccharum officinarum*) genotypes in replicated trial.

For single cane weight moderate estimates of PCV (18.883) and GCV (15.438) were estimated. However, high estimates of heritability in broad sense (66.840 %) and genetic advance as per cent of mean (26.000 %) were recorded for this character. Similar results for all the four parameters were also obtained earlier by (21) using twenty exotic sugarcane clones evaluated in RBD with four replications.

The results revealed that moderate PCV (15.807) and low GCV (9.145) were recorded along with moderate heritability in broad sense (33.472 %) and genetic advance as per cent of mean (10.900 %) for cane height**.** Moderate PCV and low GCV with moderate GAM were recorded earlier by (22) in their study with sixteen early maturing sugarcane clones in a replicated trial.

The estimates of PCV (13.329) and GCV (10.403) were found moderate for cane diameter. The heritability in broad sense was recorded to be high (60.922 %) with moderate value of genetic advance as per cent of mean (16.727%). Moderate phenotypic and genotypic coefficients of variation and high heritability in broad sense had been reported earlier by (22) and moderate value of GAM was reported by (23).

Juice brix per cent exhibited low PCV (4.756) and GCV (3.192). The estimates of heritability in broad sense (45.051 %) were moderate while genetic advance as per cent of mean (4.414 %) was also low for this character. Low values for PCV, GCV and genetic advance as per cent of mean for juice brix per cent were recorded earlier by (24).

Results of polarity per cent revealed that low PCV (8.465) and GCV (5.331) values were recorded along with moderate heritability in broad sense (39.669 %) and low genetic advance as per cent of mean (6.917 %)**.** Similar results were observed earlier by (14) as they recorded low estimates of PCV, GCV and GAM in their experiment with fifteen sugarcane clones.

Genetic variability and heritability analysis revealed that the PCV (8.221) and GCV (4.829) were low for juice

sucrose per cent while moderate estimates of heritability in broad sense (34.511 %) with low genetic advance as per cent of mean (5.844%) were also observed. (25) observed same results as lower GCV, PCV, GAM and moderate heritability using thirty sugarcane genotypes, while (24) recorded low values of GCV, PCV and GAM for juice sucrose per cent in continuously repeated trial for three years.

From analysis of juice purity percent it was revealed that all the four parameters *viz.,* PCV (7.229), GCV (3.669), heritability in broad sense (25.76 %) and genetic advance as per centof mean (3.836 %) were low for this character. Low values for all the four estimates were also observed previously by (18).

For CCS per cent, moderate estimate of PCV (11.084) and low estimate of GCV (6.194) were recorded. Moreover, moderate estimate of heritability in broad sense (31.227 %) along with low genetic advance as per cent of mean (7.130 %) were also recorded. Low GCV, moderate PCV along with lower value of GAM was recorded earlier by (23) for CCS per cent.

Cane yield exhibited high PCV (26.464) and GCV (23.541) with high heritability in broad sense (79.129 %) and genetic advance as per cent of mean (43.138 %). Earlier all the four estimates were also observed as high by (20) for cane yield character.

The estimates of GCV (27.211), PCV (24.287), heritability in broad sense (79.666 %) and advance as per cent of mean (44.657 %) were recorded high for CCS yield. Higher values of GCV, PCV, heritability in broad sense and GAM were also recorded by (26), working with 35 early generation clones of sugarcane.

A critical perusal of PCV and GCV indicated that, PCV estimates were higher than GCV for all the characters and the closeness between GCV and PCV values for almost all the characters except cane height and CCS per cent indicated that the characters are less influenced by the environment. Similar results were also observed by (27). The extent of variability as measured by GCV and PCV, gives information regarding the relative amount of variation in different characters. High values of both PCV and GCV were observed for cane yield and CCS yield, indicated that selection might be effective on these characters and their phenotypic expression is a good indication of their genotypic potential. These results indicated that these characters exhibited considerable amount of variability among genotypes and improvement in these characters would lead to a significant improvement in yield in limited selection cycles. Lower values of PCV and GCV were exhibited by juice quality characters like brix per cent, polarity per cent, sucrose per cent and Juice purity per cent indicating the presence of limited amount of genetic variability for these characters in the population under study. Therefore, it is suggested that sugarcane breeders must focus on the donors of juice quality traits during hybridization.

The high heritability in broad sense with high genetic advance was recorded for cane yield, CCS yield, germination per cent, number of tillers, number of millable canes and single cane weight. It indicated that these characters are governed by additive gene action and least influenced by the environmental effects. Therefore, selection for these characters will be effective for improvement in successive generations. High estimates of heritability in broad sense and moderate genetic advance over mean recorded for cane diameter, also indicated the importance of additive gene action in the inheritance of this character, but it require cautious selection to improve this character. Similar results were also reported by (22) for cane yield, CCS yield and germination per cent. Preponderance of additive gene action for number of millable canes was also reported earlier by (28,29).

Low estimate of heritability and GAM were recorded for cane height, lower GAM and moderate estimates of heritability were recorded for brix per cent, polarity per cent, sucrose per cent and CCS per cent. These results suggested the operation of non additive gene action in the inheritance of these characters. Therefore, it is needed to go for progeny test before selection and further hybridization should include donor parents to create the variability for these characters. Similar results were obtained earlier by (28) for brix per cent, (30) for purity per cent and (31) for CCS per cent where they reported the operation of non additive gene action in the inheritance of these characters.

Conclusions

On the basis of mean performances of clones it can be concluded that considerable amount of variability existed among the clones for all the characters under study. Based on overall mean performance for different characters, clone PC-2013-14-175 was identified as best clone for juice quality characters and PC-2013-14-221 exhibited superior performance for cane yield contributing characters. Moderate to high magnitude of GCV, PCV along with high h^2b and GAM were recorded for germination per cent, number of tillers, number of millable canes, cane yield and CCS yield, indicated wider range of variability in the material and importance of additive gene action in the inheritance of these characters in sugarcane. Therefore, these characters could be utilized as selection criteria for improvement in sugarcane yield.

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