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Genetic evaluation of climate resilient sugarcane genotypes under drought conditions (*Saccharum Officinarum L*)

Dr. M Charumathi[1], Dr. PV Padmavathi[1], Dr. K Madhu Kumar[1], Dr. Ch Mukunda Raio[2], Dr.M Bharathalakhmi[3]
[1] Department of Genetics, Plant Breeding, Acharya NG Ranga Agricultural University, Guntur, Lam, Andhra Pradesh, India
[2] Department of Plant Physiology, Acharya NG Ranga Agricultural University, Guntur, Lam, Andhra Pradesh, India
[3] Department of Agronomy, Acharya NG Ranga Agricultural University, Guntur, Lam, Andhra Pradesh, India

Abstract
The present study evaluated the extent of genetic variability, correlation of traits among promising popular released and prerelease clones along with a standard CoA92081 were tested under drought conditions at RARS, Anakapalle from 2018-19 to 2020-21. Moderate phenotypic and genotypic coefficient of variation coupled with high heritability and genetic advance as percent of mean were observed for Stalk population at 120DAP, NMC, Cane length, LAI at 120DAP, CCS yield and cane yield suggested predominance of additive gene action in governing these characters amenable for improvement through simple selection. In contrast low to moderate GCV, PCV, moderate to high heritability and low GAM for traits like germination, brix percent, sucrose percent, purity percent, pol percent cane, juice extraction per cent, fibre percent in the present study implies the narrow range of variability and importance of non-additive gene action in inheritance of the characters. Low to moderate GCV, PCV coupled with moderate to high heritability and GAM for traits of number of green leaves at 120 DAP, LAI at 120 DAP, SCMR at 120 DAP, cane girth and single cane weight indicative of both additive and non-additive gene action in inheritance of characters. positive and significant correlation with cane yield recorded for CCS yield, single cane weight cane girth cane length brix % purity% NMC stalk population at 120 DAP and germination percent These traits should be regarded as important selection criteria for cane yield improvement program. The elite clones identified *viz.*,2005A128, 2006A223,2009A107,2009A252,2014A224,2014A142 can serve as valuable genetic resources for developing climate resilient sugarcane genotypes through targeted breeding efforts

Keywords: Genetic analysis, correlation studies, drought conditions, sugarcane

Introduction

In India sugarcane is growing in Subtropical and tropical Zones Tropical zone comprises of southern States of Andhra Pradesh, Tamilnadu, Kerala, Karnataka and parts of Odisha.Cane productivity is low and stagnant in these states compared to neighboring states like Maharastra and Uttar Pradesh. Increase in cane area in marginal soils, rainfed conditions and moisture stress during formative phase, non-adoption of recommended package of practice in plant and ratoon crops are some of the major constraints of cane production Drought severely depress cane yield to the tune of 20-45% whereas the sucrose formation and sucrose recovery up to 6%. The severe drought causes the complete failure of crop and sucrose recovery. A number of technologies like soaking setts in lime water and potash application etc., for managing drought situation but they are impractical and farmers are reluctant to use those technologies. The most efficient way of managing drought in water deficit area is the use of proper drought resistant/tolerant Varieties, there morpho-physiological studies besides agronomic management.

Drought is one of the most important environmental stress factors limiting sugarcane production worldwide. Due to the erratic nature of rainfall, sugarcane productions rely heavily on irrigation to meet production goals. The crop experience moisture stress at various stages of crop growth resulting in low cane yields. However, farmers continue to grow sugarcane under such condition only crop that gives minimum guaranteed income. Therefore, there is a need of evolving drought resistant/ tolerant varieties of high yielding, optimum sucrose per cent with desire morpho-physiological and agronomic characters with a view to manage drought and save crop from colossal loss. High tillering variety with rapid initial growth, deep root system, thin stalk with narrow, erect leaves can tolerate, moisture stress (Sundara, 2002) [29]. Rainfed tolerant varieties recover faster on availability of moisture. Yield is the best measurement for measuring rainfed tolerance of genotypes under field conditions. Moisture stress affects tillering, leaf area, cane elongation, Stalk number, stalk height, Stalk yield and sucrose (Venkataramana, 2003) [32]. Hemaprabha *et al* (2004) [14] observed that there is drastic reduction in sugarcane weight, cane length and cane yield of 55 sugarcane clones out of 97 clones studied. Six clones recorded better sucrose and high yield under drought situation. Vasantha *et al* (2005) [31] evaluated 15 sugarcane genotypes for their tolerance to drought and revealed that leaf area, leaf number, leaf area index, tiller population and number of millable canes was significantly less in drought treatment when compared to control, but the potential genotypes *viz.*, Co 95003, Co 95005 and Co 95006 recorded higher cane and sugar yields underdroughttreatment.

Gomathi and Vasantha (2006) [10] evaluated advanced breeders' material for drought tolerance and the genotypes Co 99004 and Co99012 recorded higher cane and sugar yields under drought conditions. The reduction in individual leaf area, leaf area index, tiller population, plant height, photosynthetic rate was significant due to drought treatment. Alarmelu *et al* (2012) [2] stated that 10crosses are identified superior for cane yield and sucrose per cent along with high stalk number, stalk length and width under drought conditions. Hemaprabha *et al* (2012) [16] evaluated 28 elite

sugarcane hybrids under normal and drought conditions and revealed that brix per cent increased, sucrose per cent decreased and cane length was reduced by the shortening of internodes than number of internodes.
Gomathi *et al* (2012) [11] screened advanced varietal trail clones for drought tolerance and the clones Co 06022, Co 06010, Co 06013, Co 06015 and Co 06027 showed relatively higher photo chemical efficiency with better growth attributes *viz.*, leaf area index, number of green leaves, leaf production, plant height, shoot population, SCMR attributed to tolerance nature under drought.

Materials and Methods

The present study was taken up with objective of Screening and evaluation of water use efficient cultivars for rainfed situation and Study of morpho-physiological parameters under rainfed conditions. Twentypromising popular released and prerelease clones*viz.*,2005A128,2006A223.2007A81,2009A 107,2009A252,2010A229,2012A340,2012A249,2012A277,2012A319,2013A102,2013A177,2014A23,2014A251,2014A2242014A95,2014A210,2014A122,2014A23,2014A142along with a standard CoA92081 were tested under drought conditions from 2018-19 to 2020-21 at RARS, Anakapalle. The experiment was carried out in Randomized Block Design with three replications. Gross plot size of 6mt X 0.9mt X 8R = 43.20m^2 and Net plot size of 6mt X 0.9mt X 6R=32.40 m^2, 80 cm between rows. Fertilizers applied 100 kg P_2O_5 + 120 kg K_2O /ha at the time of planting are applied as basal dressing. Nitrogen @ 60 kg N/ha in the form of urea will be applied in two split doses. Data on physiological parameters, number of millable canes, length of stalk, Stalk girth, single cane weight and cane yield per plot were recorded at harvest. Juice extraction percent and fibre per cent was calculated before harvest. Estimated CCS yield was determined based on CCS per cent and cane yield. Statistical analysis was performed as per the procedure of Panse and Sukhatme (1978) [24].
observations included number of green leaves at 120 days after planting (DAP), leaf area index (LAI) at 120 DAP, shoot population at 120 DAP, number of millable canes at harvest, cane yield, single cane weight, cane length, cane diameter and juice quality parameters including Brix and sucrose percentages. Cane yield and Commercial Cane Sugar (CCS) yield was also calculated using standard protocols. under drought conditions. SPAD &LAI were recorded at formative phase under stress conditions, enabling simultaneous selection for drought tolerance.
The number of green leaves were counted manually in five tagged canes at 120 DAP and expressed as mean per plot. LAI was estimated using the linear measurement method standardized for sugarcane, by multiplying maximum leaf length, leaf breadth, a constant factor, and the number of green leaves. SPAD chlorophyll meter readings (SCMR) were taken on the third leaf from the apex on 20 randomly selected plants per genotype during first and second clonal stages, and the mean values were used for analysis. The CCS percentage was calculated using the formula $CCS\% = 1.03 \times S - 0.3 \times B$, where S and B represent sucrose and Brix percentages, respectively (Meade and Chen, 1977; Ramiah and Varahulu, 2023) [22, 27]. CCS yield per plot was computed by multiplying CCS percentage with cane yield per plot and dividing by 100.
The mean data of above observations were subjected to analysis of genotypic and phenotypic coefficients of variation (GCV and PCV) as per the method of Burton and Devane (1953) [5] and the same were classified as suggested by Sivasubramanian and Menon (1973) [28]. Broad-sense heritability was calculated as per Hanson *et al.*, (1963) [13], while genetic advance and genetic advance as percentage of mean (GAM) were computed based on formulas from Lush (1949) [20] and Johnson *et al.*, (1955) [18]. Genotypic and phenotypic correlations were derived following Falconer (1964). All statistical computations were performed using appropriate biometric tools in SPAR 2.0 for reliable interpretation.

Results and Discussion

Analysis of variance showed there is significant variability among the characters studied. (Table1) Germination%, Number of millable canes (NMC), Brix%, Sucrose%, juice extraction %, CCS%, CCS yield, Cane yield, Number of green leaves at 120DAP, SCMR, Stalk girth, Stalk length and single cane weight showed significant variability Whereas Pol/% cane, fibre per cent, purity per cent and LAI at 120DAP showed non-significant variability

Table 1: Estimates of Genotypic Mean sum of squares and Error Mean Sum of squares Significance

Character	Genotypic Mean sum of squares	Error Mean Sum of squares
Germination %	75.02 **	12.20
Stalk population at 120 DAP	82.36	28.06
Number of millable canes (NMC)	158.36 **	22.86
Brix %	2.82 **	1.02
Sucrose %	2.93**	1.06
CCS %	3.61**	0.08
Purity %	3.82	1.95
Pol % cane	3.40	2.83
Juice Extraction %	34.13**	11.85
Fibre %	2.60	1.02
CCS yield (t/ha)	13.82**	2.58
Cane yield (t/ha)	58.35**	2.67
Number of green leaves at 120DAP	10.02**	2.22
LAI at 120 DAP	1.65	0.98
SCMR at 120DAP	20.18**	2.12
Cane length(m)	4.52**	1.06
Cane girth (m)	4.31**	1.04
Single cane weight (Kg)	6.53**	2.81

The given data revealed that all the traits were differed significantly when studied during the study (Sivasubramanian and Menon.,1973) [28]. The values of range, mean performance, phenotypic coefficient of variance (PCV), Genotypic coefficient of variance (GCV), heritability and Genetic advance as per cent of mean of the genotypes studied (Sivasubramanian and Menon.,1973) [28] were given in Table 2. The mean for germination percent was 59.92 with a range from 54.28 to 65.82 (2014A 224 & 2009A107). Variation for NMC with a range of 80.28 (2007A81) to 100.68 (2005A128). The quality parameters of brix, sucrose, ccs and purity percent ranged from 18.22%, 16.89, 15.88% and 85.12% to 22.08%, 20.06%, 17.02% and 92.08% respectively with mean values of 19.43, 17.93, 16.22 and 89.99 respectively in the experiment. Juice extraction percent was lower in 2014A 210 and higher in CoA92081. Variation for fibre was 13.52 with a range from 13.32 (CoA92081) to 15.02 (2009A252). Cane and CCS yields were ranged from 69.08 &11.32 ((2010A229) to 100.66 & 15.64 (2009A107) with a mean value of 69.08 t/ha and 11.32 t/ha respectively at harvest. Physiological parameters like number of green leaves, LAI and SCMR at 120DAP were higher in2005A128 and lower in 2007A81 with a mean of 14.65, 2.08 and 45.50 respectively at 120 days after planting. The yield components *viz.*, cane length (1.19), cane girth (1.88) and single cane weight (1.05) recorded higher in the genotypes 2006A223,2009A107,2009A252,2014A224 and 2014A142 which indicated maximum variability exists in the genotypes.

Genetic parameters, heritability and GAM (GCV, PCV, h^2 and GAM

Analysis of genotypic coefficient of variance (GCV) and Phenotypic Coefficient of Variance (PCV) of different characters were presented in Table 2, Table 3 and Fig. 1. The results indicated that the PCV values were slightly greater than GCV values for most of the traits which indicated the traits under study were less influenced by the environment.

Moderate phenotypic and genotypic coefficient of variation coupled with high heritability and genetic advance as percent of mean (GAM) were observed for Stalk population at 120DAP, NMC, Cane length, LAI at 120DAP, CCS yield and cane yield suggested predominance of additive gene action in governing these characters amenable for improvement through simple selection. In contrast low to moderate GCV, PCV, moderate to high heritability and low GAM for traits like germination, brix percent, sucrose percent, purity percent, pol percent cane, juice extraction per cent, fibre percent in the present study implies the narrow range of variability and importance of non-additive gene action in inheritance of the characters. Low to moderate GCV, PCV coupled with moderate to high heritability and GAM for traits of number of green leaves at 120 DAP, LAI at 120 DAP, SCMR at 120 DAP, cane girth and single cane weight indicative of both additive andnon-additive gene action in inheritance of characters Similar results estimated on GCV, PCV, heritability and GAM were also reported by El-Hinnawy and Mersi (2009) [7], Mali & Patel (2013) [21], Esayas *et al*, (2016) [8], Alam *et al* (2017) [1], Kumar *et al* (2018) [19], Japheth *et al* (2019) [17] Pooja kumari *et al*(2020) [20], Barreto *et al* (2021) [4] and Guljar *et al* (2022) in Sugarcane.

Table 2: Estimates of Genetic Components of Variance, Heritability and GAM of Sugarcane Genotypes

Character(s)	Min	Max	Mean	PCV	GCV	h^2	GAM
Germination %	54.28	65.82	59.92	9.05	5.05	38.02	6.15
Stalk population at 120 DAP	82.33	112.33	98.67	8.21	7.23	33.36	12.23
No. of millable canes	80.28	100.68	74.22	12.44	11.99	77.07	14.46
Brix %	18.20	22.08	19.43	5.72	5.58	68.32	8.84
Sucrose %	16.89	20.06	17.93	6.53	6.40	64.30	8.63
CCS %	15.88	17.02	16.22	9.83	9.60	44.12	6.16
Purity %	85.12	92.08	89.90	9.31	9.88	38.06	9.22
Pol % cane	13.14	15.98	14.00	8.12	8.58	46.80	6.68
Juice Extraction%	49.02	62.12	52.06	6.54	6.98	58.08	8.31
Fibre %	13.32	15.02	13.52	9.54	9.10	48.08	16.28
CCS yield	11.32	15.64	13.18	10.61	12.12	63.12	20.18
Cane yield	69.08	100.66	78.33	24.62	27.80	82.82	38.80
NGL at 120DAP	13.89	17.55	14.65	8.72	8.70	48.22	12.92
LAI at 120 DAP	2.16	2.88	2.08	14.13	14.02	56.08	18.56
SCMR at 120DAP	38.36	56.30	45.50	8.58	8.32	46.12	15.58
Cane length (m)	1.03	1.63	1.19	14.78	13.63	66.33	18.67
Cane girth	1.62	2.63	1.88	9.58	5.98	68.65	19.12
Single cane weight	0.99	1.13	1.05	9.20	9.63	69.23	16.16

Table 3: Estimation of Genetic Parameters, Heritability and GAM of Genotypes

Character(S)	PCV	GCV	Heritability	GAM
Germination %	Low	Low	Moderate	Low
Stalk population at 120DAP	Moderate	Moderate	Moderate	Moderate
No. millable canes	Moderate	Moderate	High	Moderate
Brix %	Low	Low	High	Low
Sucrose %	Low	Low	High	Low
CCS %	Low	Low	Moderate	Low
Purity %	Low	Low	Moderate	Low
Pol % cane	Low	Low	Moderate	Low

Juice Extraction%	Low	Low	Moderate	Low
Fibre %	Low	Low	Moderate	Moderate
CCS yield	Moderate	Moderate	High	High
Cane yield	High	High	High	High
NGL at 120DAP	Low	Low	Moderate	Moderate
LAI at 120 DAP	Moderate	Moderate	Moderate	Moderate
SCMR at 120DAP	Low	Low	Moderate	Moderate
Cane length	Moderate	Moderate	High	Moderate
Cane girth	Low	Low	High	Moderate
Single cane weight	Low	Low	High	Moderate

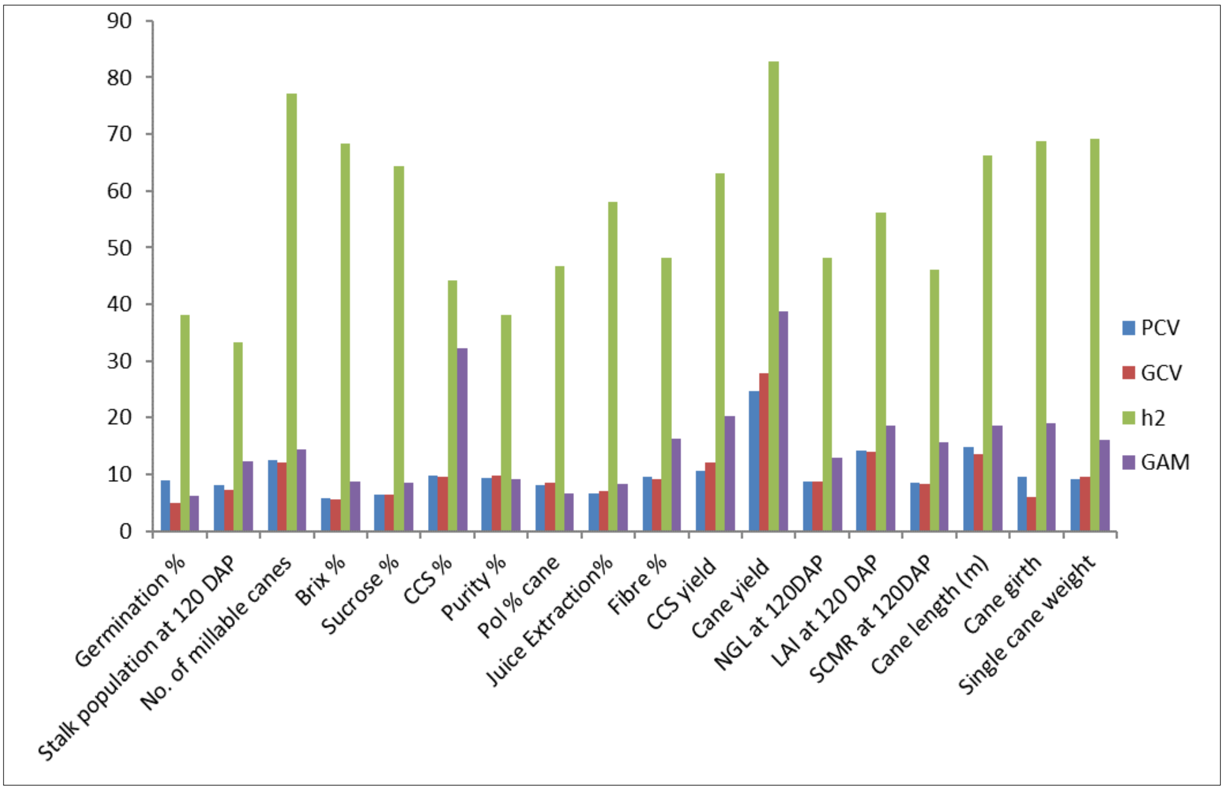

Fig 1:

Correlation Studies

The correlation coefficient is a statistical parameter that quantified the degree and strength of association between two interrelated variables which may arose from genetic linkages, pleiotropism or a combination of both effects. In the experiment, correlation coefficient analysis evaluates the inter relationship between various morpho physiological and agronomic traits.

Simple phenotypic correlation coefficients between cane yield, agronomic traits, morpho physiological traits were presented in Table 4. The data revealed that positive and significant correlation with cane yield recorded for ccs yield (0.8942**), single cane weight (0.6612**), cane girth (0.1662**), cane length (0.1703*), brix % (0.0858*), purity% (0.1132**), NMC (0.9913**), stalk population at 120 DAP (0.7521**) and germination percent (0.1124*). CCS yield had significant and positive correlation with germination per cent (0.0865*), stalk population at 120DAP (0.6542**), NMC (0.0962*), brix per cent (0.3415**), CCS per cent (0.895**), cane length (0.4321**), Cane diameter (0.7230**) and single cane weight (06692**). Quality parameters *viz*., brix, sucrose, CCS and purity percent showed significant positive correlation among themselves in the trial. Brix per cent showed positive and significant correlation with sucrose per cent(0.1691**),CCS per cent(0.1698),Purity per cent(0.6523**) and Pol per cent cane(0.0852**) where as sucrose per cent had significant correlation with CCS per cent(0.7001**) and purity per cent (0.7102**),CCS per cent was positively correlated with purity per cent(0.8892) LAI at 120 DAP and number of green leaves(0.8422**) and SCMR values(0.1492**) were found to be positive and significant which indicated the effect of biomass production also contributed for cane yield in the experiment. Number of millable canes were positively correlated with number of green leaves at 120DAP (01508**), LAI at 120DAP(0.4312**),Canelength(0.7730**),single cane weight(0.8521**) and CCS Yield (0.0962**).Similar reports had been reported by Anshuman *et al.* (2002) [3], Chaudhary and Joshi (2005) [6],Terzi *et al* (2009) [30], Mohana Krishna *et al* (2009) [23], Mali *et al* (2013) [21], Esayas *et al* (2016) [8], Barreto *et al* (2021) [4] and Rajendra *et al* (2022) [26] also reported similar kind of findings in Sugarcane

Table 4: Estimates of phenotypic correlation coefficients between cane yield and morphophysiological components and agronomic Traits

Character	Germination %	Stalk population 120DAP	NMC	Brix %	Sucrose %	CCS %	Purity %	Pol % cane	Juice Extraction %	Fibre %	NGL 120 DAP	LAI 120 DAP	SCMR 120 DAP	Cane length	Cane girth	SCW	CCS yield	Cane yield
Germination%	1.0000	0.0712	-0.0156	0.0831	0.0732	0.0212	-0.1210	-0.0212	-0.0532	-0.0181	-0.0152	-0.3260	0.1131	0.0032	-0.0115	-0.0220	0.0865*	0.1124**
Stalk population 120DAP		1.0000	6520*	0.0251	0.0212	0.0241	0.0250	0.3210*	0.0256	0.4212*	0.3521	-0.0210	0.1120	0.4123*	0.2102*	0.0122	0.6542**	0.7521**
NMC			1.0000	0.0632	0.1295*	0.0712	-0.1442	-0.1512	0.0472	0.0213	0.1508**	0.4372*	-0.0431	0.7730*	0.0218	0.8521*	0.0962*	0.9913*
Brix %				1.0000	0.1691**	0.1698**	0.6523**	0.0852*	0.6234*	0.0144	-0.0012	0.0101	0.0123	0.0620	0.0839*	0.0898*	0.3415**	0.0858*
Sucrose %					1.0000	0.7001**	0.7102*	-0.0721	0.1320**	-0.0114	-0.0124	0.0567	0.0522	0.0632	0.1240**	-0.0530	0.5053**	0.05242
CCS %						1.0000	0.8892**	-0.0611	0.0112	0.0115	0.0116	0.0122	0.0321	0.1230**	0.1132**	-0.0432	0.0895*	0.0603
Purity %							1.0000	-0.0023	0.0123	-0.0382	0.0842	0.189*	0.3321*	0.0129	0.0332	-0.0736	0.1621**	0.1132**
Pol % cane								1.0000	-0.0110	0.1092**	0.0058	0.0328	0.0882	-0.0110	-0.0016	-0.0028	-0.0035	0.0195
Juice Extraction %									1.0000	-0.0013	-0.0213	-0.0152	0.0582	0.1339	-0.0182	-0.0520	-0.0948*	0.0138
Fibre %										1.0000	-0.0423	-0.0116	0.0335	0.0543	0.0320	-0.0200	0.0189	-0.0018
NGL 120 DAP											1.0000	0.8422**	0.1492*	0.5373**	0.0721	0.0432	-0.0184	-0.0155
LAI 120 DAP												1.0000	0.8872**	0.6421**	0.0502	0.0852*	-0.0583	0.0108
SCMR 120 DAP													1.0000	0.8320**	-0.0870	0.2822**	-0.0123	0.0865
cane length														1.0000	0.0172	0.1030**	0.4321*	0.1703*
cane girth															1.0000	0.0982*	0.7230**	0.1662**
SCW																1.0000	0.6692**	0.6612**
CCS yield																	1.0000	0.8942**
Cane yield																		1.0000

Conclusion

Moderate phenotypic and genotypic coefficient of variation coupled with high heritability and genetic advance as percent of mean (GAM) were observed for Stalk population at 120DAP, NMC, Cane length, LAI at 120DAP, CCS yield and cane yield suggested predominance of additive gene action in governing these characters amenable for improvement through simple selection. In contrast low to moderate GCV, PCV, moderate to high heritability and low GAM for traits like germination, brix percent, sucrose percent, purity percent, pol percent cane, juice extraction per cent, fibre percent in the present study implies the narrow range of variability and importance of non-additive gene action in inheritance of the characters. Low to moderate GCV, PCV coupled with moderate to high heritability and GAM for traits of number of green leaves at 120 DAP, LAI at 120 DAP, SCMR at 120 DAP, cane girth and single cane weight indicative of both additive and non-additive gene action in inheritance of characters

The nature and extent of correlation among various traits differs from each other. The correlation between Cane yield, NMC, Stalk length, stalk girth, single cane weight, brix, germination percent and CCS yield had positive significant correlation at both genotypic and phenotypic level.positive and significant correlation with cane yield recorded for CCS yield, single cane weight cane girth cane length brix % purity% NMC stalk population at 120 DAP and germination percent CCS yield had significant and positive correlation with germination per cent,stalk population at 120DAP,NMC,brix per cent,CCS per cent,,cane length,Cane diameterand single cane weight. LAI at 120 DAP and number of green leaves and SCMR values were found to be positive and significant which indicated the effect of biomass production also contributed for cane yield in the experiment. These traits should be regarded as important selection criteria for cane yield improvement program. The elite clones identified *viz.*,2005A128, 2006A223,2009A107,2009A252,2014A224,2014A142 can serve as valuable genetic resources for developing climate resilient sugarcane genotypes through targeted breeding efforts.

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