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Genetic Variability Analysis of Early Maturing Sugarcane (*Saccharum officinarum* L.) Clones Using Morphological Characters

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RS and DNK designed, executed the experiment, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author BK managed the analyses of the study. Authors PK and ZRG managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An investigation was undertaken to identify sugarcane clones suitable for the identification of early maturing genotypes for higher sugar yield at Research Farm of DRPCAU, Pusa, Samastipur, Bihar in Randomized Block Design with three replications during spring season 2018-19. Variability, correlation, and path analysis in twelve early maturing clones of sugarcane for twenty-one different morphological and juice quality characters were studied in relation to the checks *viz.* CoLk94184 and CoSe95422. Analysis of variance revealed highly significant differences for all characters studied. Genotypic and phenotypic coefficient of variation was highest for Sugar yield (CCS) at harvest (t/ha) among the early maturing clones. The highest heritability was obtained for Brix at 8-month stage, Pol in juice at 8-month stage and Brix at 10-month stage. Genetic advance as per cent

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of mean was found to be highest in sugar yield (CCS) at harvest, cane yield and single cane weight indicating effectiveness of selection due to preponderance of additive gene action and breeder may consider these traits as main selection criteria.

Keywords: Early maturing clones; genetic advance as percent of mean; genetic variability; heritability; sugarcane.

1. INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is an important cash crop of the entire world including India. It contributes to 75% of the worldwide sugar trade. Sugar industry is the second largest agro-based industry after textile contributing 2.0% of the total gross domestic product in India. Sugarcane is grown under diverse Agro-climatic conditions in India and worldwide having separate breeding programmes. Sugarcane is polyploidy in nature, having a high number of chromosomes, cross pollination, vegetative propagation, perennial growth habit, wind dissemination and axillary node formation [1]. In India, it is grown in 54.35 lakh hectares with a total production of 350-355 lakh tonnes and productivity of 69.1 t/ha whereas, in Bihar it is grown in an area of 0.302 million hectare with production of 1.490 million tonnes and productivity 50 t/ha (Anonymous, Indian Sugar 2018-19). Sugarcane breeding involves the production and evaluation of several thousand seedlings from different crosses every year and selection of the superior seedlings for further evaluation in clonal stages.

Early maturing varieties of sugarcane play an important role in enhancing cane and sugar yield. It is one of the cheapest technologies adopted by the cane growers due to its early maturity (8 to 10^{th} months after planting thereby favoring early crushing start from last week of October) and higher affordability. It is time saving and is also a source of employment for many people.

Variability is the prerequisite for any crop improvement programmes. Understanding the associations among the different traits is of great importance in breeding and selection studies especially for qualitative and low heritability traits. Variability is measured by estimation of genotypic and phenotypic variance, genotypic and phenotypic coefficient of variation (GCV and PCV), heritability, genetic advance and genetic advance as percent of mean. The knowledge of nature and extent of genetic variation available in the germplasm or breeding material helps the breeder for planning sound breeding programmes.

2. MATERIALS AND METHODS

The studied material for the experiment consists of 12 clones *viz*. CoBln15501, CoLk15466, CoLk15467, CoP15436, CoP15437, CoSe15451, CoSe15452, CoSe15455, CoSe15456, CoSe01421, CoLk94184 and CoSe95422. The experiment was conducted in the nursery block of research farm of DRPCAU, Pusa, Samastipur, Bihar in RBD design with 3 replications during the spring season of 2018-19. Experimental block is situated between 25.97^{o}N latitude and 85.66^{o}E longitude at 51.8 m above mean sea level. Observed data were recorded for 21 traits viz., Germination percentage at 45 DAP (Days After Planting), Number of shoots per hectare at 120 DAP (000/ha), Plant height at harvest (cm), Cane diameter at harvest (cm), Number of millable canes at harvest (000/ha), Number of internodes at harvest, Length of internode at harvest (cm), Single cane weight (kg), Brix at 8^{th} month stage (%), Pol in juice at 8^{th} month stage (%), Purity at 8^{th} month stage (%), Brix at 10^{th} month stage (%), Pol in juice at 10^{th} month stage (%), Purity at 10^{th} month stage (%), CCS at 8^{th} month stage (%), CCS at 10^{th} month stage (%), Cane yield (t/ha) Sugar yield (CCS) at harvest (t/ha), Extraction % at harvest, Fibre % at harvest, Pol % in cane at harvest. Five representative clones were randomly selected from each plot in each replication for the cane characteristics such as cane diameter, single cane weight, plant height, number of internodes etc. whereas a number of millable canes, sugar yield and cane yield at harvest were recorded on per plot basis and then converted into per hectare basis.

Five stalks of sugarcane sample were randomly selected and crushed with a cane crusher to get juice for analysis. 500 ml juice was poured in measuring cylinder and Brix was determined by Brix hydrometer standardized at 20^{0}C and for Pol % 100 ml of juice from each sample was taken in a beaker and about 1-1.5 gm of basic lead

acetate anhydrous was added, stirred and placed the sample for sometimes for precipitation of non-soluble substance. The precipitated impurities were filtered off and clear filtrate juice was collected. The clear filtered juice was filled in 20 cm long Polarimeter tube. This tube was placed in the body of Polarimeter and Pol reading was recorded. Using Schmitz table [2], the sucrose percent in juice was noted for corresponding values of the brix and Pol reading. CCS % was calculated by the following formula:

$$[S-(B-S) \times 0.4] \times 0.73$$

Where,

S = Sucrose percent in juice (Pol %)
B = Brix percent in juice

Purity is the proportion of the sucrose in the total solids present in the juice called purity percentage. Purity % is calculated by the following formula:

$$\text{Purity \%} = \frac{\text{Pol in juice}}{\text{Juice Brix}} \times 100$$

The data recorded for all the characters were subjected to analysis of variance (ANOVA) with the usual standard statistical procedure outlined by [3]. The analysis of variance was used to derive variance components [4]. For estimation of variance components viz., phenotypic variances (σ^2p) and genotypic variances (σ^2g) both were estimated using the following formula as suggested by [3].

$$\text{Genotypic Variance} = (vMSS - eMSS) \times CF$$

$$\text{Phenotypic Variance} = \sigma^2g + EMS$$

Genotypic and phenotypic coefficient of variation was calculated by the formulae given by [5].

Genotypic Coefficient of Variation (GCV) = Genotypic standard deviation divided by grand mean of the character × 100

Phenotypic Coefficient of Variation (PCV) = Phenotypic standard deviation divided by grand mean of the character × 100

2.1 Heritability (Broad Sense)

Heritability in a broad sense was calculated by the formula given by [6]. The heritability was categorized as low, moderate and high as given by [7].

2.2 Genetic Advance as Percent of Mean

Genetic advance were computed by the formula given by [8], [6] and [9].

$$GAM(\%) = \frac{GA}{\overline{X}} \times 100$$

The classification range of genetic advance is determined as suggested by [6].

2.3 Extraction Percentage

To evaluate the average extraction percentage of each sample, 3 samples from each plot were taken and crushed them individually and noted down the reading of the volume of juice from each sample. The average value of 3 samples the extraction percentage was calculated from each plot. Extraction % was calculated by simple arithmetic formula.

$$\text{Extraction \%} = \frac{\text{Weight of the juice}}{\text{Weight of the cane}} \times 100$$

2.4 Fibre Percentage

To figure out the fibre % from each sample, 250 gm of small pieces from the top, middle and bottom portion of cane were taken and put into the Rapipol and added 1000 ml of water. Rapipol was set for 35 minutes for each sample. Rapipol was automatically stopped after 35 minutes and fibre pieces mixed with water. The mixture was filtered through a muslin cloth. The fibres were dried at 65^0C to constant weight and fibre % was calculated by the following arithmetic formula;

$$\text{Fibre \% cane} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3. RESULTS AND DISCUSSION

The analysis of variance (Table 1) for 21 characters of 12 early maturing sugarcane clones revealed a highly significant difference for all the traits. The results pointed out that clones have differed significantly it means an extension range of variability existing among the clones for all the characters it means the presence of sufficient variability in the genotypes which provides ample scope for selecting superior and desirable clones by the plant breeder for further improvement. Earlier workers namely [10-18]

Table 1. Analysis of variance for twenty-one characters in early maturing sugarcane clones

Sl. No.	Characters	Mean sum of squares		
		Replication df=2	Genotype df=11	Error df=22
1	Germination percentage at 45 DAP (Days After Planting)	1.20	85.66**	9.59
2	Number of shoots per hectare at 120 DAP (000/ha)	14.17	448.36**	60.29
3	Plant height at harvest (cm)	261.50	2381.54**	345.22
4	Cane diameter at harvest(cm)	0.02	0.35**	0.03
5	Number of millable canes at harvest (000/ha)	16.80	136.28**	53.41
6	Number of internode at harvest	0.31	10.64**	2.46
7	Length of internodes at harvest (cm)	0.46	4.37**	0.42
8	Single cane weight (Kg)	0.00	0.04**	0.00
9	Brix at 8^{th} month stage (%)	0.05	10.59**	0.46
10	Pol in juice at 8^{th} month stage (%)	0.66	10.70**	0.49
11	Purity at 8^{th} month stage (%)	1.76	3.90**	4.95
12	Brix at 10^{th} month stage (%)	0.26	6.93**	0.34
13	Pol in juice at 10^{th} month stage (%)	0.29	4.18**	0.24
14	Purity at 10^{th} month stage (%)	0.52	2.57**	1.82
15	CCS at 8^{th} month stage (%)	1.30	6.24**	0.46
16	CCS at 10^{th} month stage (%)	0.58	1.95**	0.24
17	Cane yield (t/ha)	13.24	614.01**	35.09
18	Sugar yield (CCS) at harvest (t/ha)	0.11	10.50**	0.60
19	Extraction % at harvest	0.03	23.05**	1.19
20	Fibre % at harvest	0.03	1.02**	0.30
21	Pol % in cane at harvest	0.16	2.81**	0.15

** Significant at 5%, ** significant at 1%*

Table 2. Genotypic variance, phenotypic variance, genotypic and phenotypic coefficient of variation, heritability, genetic advance and genetic advance as per cent of mean for 21 characters in early maturing sugarcane clones

Sl. No.	Character	Range	σ^2G	σ^2P	GCV	PCV	heritability	Genetic advance	Genetic advance as percent of mean
1	Germination percentage at 45 DAP	29.73-44.80	25.36	28.55	13.26	14.07	88.8	9.77	27.75
2	Number of shoots at 120 DAP (000/ha)	87.73-125.55	129.35	149.45	10.77	11.58	86.5	21.79	20.64
3	Plant height at harvest (cm)	166.68-267.30	678.77	793.85	11.98	12.96	85.5	49.62	22.83
4	Cane diameter at harvest(cm)	2.08-3.19	0.11	0.119	12.92	13.61	90.1	0.63	25.27
5	Number of millable canes at harvest (000/ha)	78.69-103.09	27.62	45.43	5.94	7.17	60.8	8.44	8.98
6	Number of internodes at harvest	17.77-23.90	2.72	3.54	7.85	8.96	76.9	2.98	14.18
7	Length of internode at harvest (cm)	8.19-11.44	1.32	1.45	12.13	12.77	90.3	2.24	23.75
8	Single cane weight (Kg)	0.56-0.95	0.01	0.014	14.81	15.279	94.0	0.22	29.57
9	Brix % at 8 month stage	15.16-20.40	3.38	3.53	9.84	10.06	95.7	3.70	19.84
10	Pol in juice at 8 month stage (%)	12.75-18.03	3.40	3.56	11.38	11.65	95.4	3.71	22.91
11	Purity % at 8 month stage	85.40-89.17	-0.35	1.29	0.67	1.30	27.1	0.63	0.72
12	Brix % at 10 month stage	17.17-22.00	2.19	2.30	7.43	7.62	95.1	2.97	14.93
13	Pol in juice at 10 month stage (%)	15.63-19.35	1.31	1.39	6.42	6.61	94.3	2.29	12.85
14	Purity % 10 month stage	85.77-88.97	0.25	0.86	0.56	1.05	29.0	0.55	0.62
15	CCS % at 8 month stage	8.56-12.67	1.93	2.080	12.45	12.94	92.7	2.75	24.69
16	CCS % at 10 month stage	10.96-13.45	0.57	0.65	6.11	6.53	87.7	1.45	11.79
17	Cane yield (t/ha)	44.01-94.47	192.97	204.67	19.25	19.83	94.3	27.78	38.51
18	Sugar yield (CCS t/ha)	4.83-12.18	3.30	3.50	20.36	20.97	94.3	3.63	40.73
19	Extraction % at harvest	55.67-64.37	7.29	7.68	4.51	4.63	94.9	5.41	9.05
20	Fibre % at harvest	12.01-13.59	0.24	0.34	3.81	4.55	70.2	0.84	6.58
21	Pol % in cane at harvest	12.94-16.05	0.89	0.94	6.43	6.61	94.8	1.89	12.90

GCV= Genotypic Coefficient of Variation, PCV =Phenotypic Coefficient of Variation, ECV = Environmental Coefficient of Variation, H^2 = heritability, (σ^2G) = Genotypic variance and (σ^2P) = Phenotypic variance

reported high variability for distinctive traits in sugarcane. To assess the extent of genetic variability in 12 early maturing sugarcane clones range, mean and standard error were calculated. Effectiveness of selection and identification of superior genotypes depends on the magnitude of inherent variability for a particular character. Hence it is a prerequisite to study the estimates of genetic parameters such as coefficients of genotypic and phenotypic variability, heritability and genetic advance as percent of means. Phenotypic and genotypic variances for all the twenty-one morphological and juice quality characters were indicated in Table 2. The numerical value of phenotypic variances was higher than their the genotypic counterpart for all the characters ©. The magnitude of genotypic and phenotypic coefficient of variation for Sugar yield (CCS) at harvest (t/ha) was high *i.e*. 20.36 and 20.97 respectively according to the report of [19,20] and moderate for cane yield (t/ha), Single cane weight (kg), Germination percentage at 45 DAP, length of internodes at harvest (cm), plant height at harvest (cm), CCS at 8th month stage (%), Pol % at 8th month and the number of shoots per hectare at 120 DAP (000/ha) which was also reported by [17,20,21]. Knowledge on the heritability of characters is valuable to the breeders, since it indicates the possibility and extent of improvement that can be achieved through selection for a particular trait. This may be due to the same maturity group of all the clones in the study. The highest heritability in broad sense was recorded for the juice quality attributes *i.e.* brix at 8th month stage (95.7) followed by Pol in juice at 8th month stage (%) was 95.4 and so on. Similar findings were also reported by [17,20,22]. In case of genetic advance as per cent of mean, among morphological characters, the notable observation to be recorded in sugar yield (CCS) at harvest (t/ha) was 40.73 followed by cane yield (t/ha) was 38.51, single cane weight (kg) was 29.57, germination percentage at 45 DAP was 27.75, cane diameter at harvest (cm) was 25.26 and plant height at harvest (cm) was 22.83. Similar observations were also shown by [17,22,23]. Least genetic advance as per cent of mean were recorded in purity at 10th month stage (%) was 0.62 and purity at 8th month stage (%) was 0.72.

4. CONCLUSION

In conclusion, an extension range of variations was observed for all the characters studied. Genotypes differed significantly for all the characters as evidenced by 'F' test of ANOVA. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were found to be nearby to each other indicates that little influence by the environment. Moderate GCV and PCV were observed for cane yield (t/ha), single cane weight (kg), germination percentage at 45 DAP, length of internode at harvest (cm), plant height at harvest (cm), CCS at 8th month stage (%), Pol in juice at 8th months (%) and a number of shoots per hectare at 120 DAP (000/ha). Therefore, GCV and PCV values indicated that selection may be effective based on these traits for selection or rejection among candidate genotypes. The highest heritability in broad sense was recorded for the juice quality attributes *i.e.* Brix at 8th month stage. The highest heritability coupled with high genetic advance as percent of mean were recorded in sugar yield (CCS) at harvest (t/ha), cane yield (t/ha), single cane weight (kg), germination percentage at 45 DAP, cane diameter at harvest (cm) and plant height at harvest (cm) suggesting the preponderance of additive genetic effect in the determination of these traits.

The clones CoP15436, CoP15437 and CoSe15455 were found to be higher value for the cane yield which were recorded superior and the clones CoSe15455 followed by CoLk15466, CoSe15452, CoSe15452, CoLk15466 and CoLk15467 were found on par to the best check CoLk94184. The clone CoP15436 was found superior over both the checks with respect to sugar yield at harvest. Clone CoLk15467 were recorded superior and had highest Brix value at 10th months of stage and CoSe01421 was found on par to the best check CoLk94184. The clones CoP15436, CoP15437 and CoSe15455 were found statistically superior to best check CoLk94184 in respect of single cane weight. We recommend these clones to the farmers to get higher morphological as well as juice quality attributes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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