Original Research Paper

Volume - 15 | Issue - 08 | August - 2025 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Plant Science

MORPHO-PHYSIOLOGICAL VARIABILITY ENHANCES EFFECTIVENESS OF SELECTION OF SUGARCANE

Md. Noor Alam	Bangladesh Sugarcrop Research Institute, Ishurdi, Pabna.
Gayatri Goswami	Department of Genetics and Plant Breeding, Patuakhali Science and Technology University, Patuakhali.
Priya Lal Biswas	Bangladesh Rice Research Institute, Joydevpur, Gazipur.
Ujjal Kumar Nath*	Department of Genetics and Plant Breeding, Bangladesh Agricultural University, Mymensingh. *Corresponding Author

ABSTRACT Genetic variability plays a vital role in sugarcane breeding, facilitating the selection and development of enhanced varieties with preferred characteristics. Sugarcane, being a complex polyploid and heterozygous crop, inherently displays variability, which breeders utilize to improve traits such as yield, sugar content, and disease resistance. A comprehensive understanding of the nature and extent of this variability is critical for successful selection programs. Consequently, a study was undertaken to investigate the morphophysiological variability among sugarcane genotypes. The experiment was designed using a Randomized Complete Block Design (RCBD) with three replications. A total of forty sugarcane genotypes were utilized as planting materials, and data were collected on twelve different variables. The genotypic coefficient of variation (GCV) consistently approached the phenotypic coefficient of variation (PCV) across all variables. The highest GCV and PCV values were recorded for the stalk weight of sugarcane. Heritability exceeded 80% for all variables, with the highest genetic advance of 61.59 observed for plant height. The findings indicated significant differences across all variables among the forty sugarcane genotypes. Among the variables, %brix content contributed the most, accounting for 53.61% of the divergence among the variables, leading to the classification of the forty sugarcane genotypes into five distinct clusters. Cluster II contained the largest number of genotypes, totaling 27. This study concluded that the variability of sugarcane genotypes is influenced by morphophysiological parameters and low environmental factors. The studied materials could be improved through selection and could be used for future sugarcane breeding programs.

KEYWORDS : Sugarcane, Variability, Diversity, %brix content, Selection, Genetic Advance.

INTRODUCTION

Sugarcane is a perennial grass (C4 plant) native to tropical regions of South and Southeast Asia. Various species are believed to have originated in distinct locations, with *Saccharum barberi* tracing its roots to India, while S. edule and S. officinarum are from New Guinea (Peter 1998). It is classified under the genus *Saccharum* L., within the tribe Andropogonae of the grass family Poaceae. The Saccharum genus includes six species: *S. spontaneum*, *S. officinarum*, *S. robustum*, S. edule, *S. barberi*, and *S. sinense* (D'Hont et al. 1998). The sugarcane varieties cultivated commercially are complex polyploids. The heterozygous and polyploid characteristics of this crop have led to the generation of significant genetic variability. To develop an improved sugarcane variety, it is essential to have reliable information regarding the availability of sufficient heritable genetic variation that can predict genetic advancement for the desired traits within the existing germplasm. Genetic variability, which measures the extent to which individual plant traits in a population differ from one another, plays a crucial role in successful plant breeding, as it enables breeders to enhance traits and create new varieties. A wider range of trait variation in the germplasm provides a better opportunity for trait enhancement through selection.

The understanding of the nature and extent of variability in genetic material is crucial for breeders to launch any successful selection program. The genotypic and phenotypic coefficients of variation, along with heritability and genetic advance, are vital for enhancing any sugarcane trait, as they provide insight into whether the desired goals can be achieved with the available material (Tyagi and Singh 1998). Furthermore, comprehending the inheritance patterns of traits and the anticipated genetic gains is critical for designing effective breeding experiments, particularly for perennial crops such as sugarcane. Additionally, distinguishing between heritable and non-heritable components of the observed variability is necessary to demonstrate the genetic control over the expression of specific traits and their phenotypic reliability in predicting breeding value (Ullah et al. 2012). It is important to note that high heritability does not always correlate with high genetic advance; therefore, heritability estimates and genetic advance should be evaluated together (Amin et al. 2004). To ensure effective selection for trait enhancement and accurate predictions of expected genetic gains, high heritability values must be paired with high genetic advance (Udeh and Ogbu 2011).

Knowledge regarding the genetic variability or heritability of the traits under enhancement is crucial and plays a vital role in forecasting progress. The cultivated sugarcane varieties are interspecific hybrids that encompass at least three species: *S. officinarum*, *S. barberi*, and *S. spontaneum*, which themselves exhibit complex polyploidy. The chromosome count among these varieties ranges from 2n = 80 to 120. The heterozygous and polyploid characteristics of this crop have led to the generation of increased genetic variability. Understanding the nature and extent of genetic variation present in the germplasm or breeding materials assists breeders in devising effective breeding programs. Therefore, the current study was designed to evaluate genetic variability, heritability, and genetic advancement to identify the most suitable sugarcane genotypes based on morpho-physiological characteristics for commercial cultivation.

MATERIALS AND METHODS

Experimental Site and Weather Condition

The study was carried out at the Bangladesh Sugarcrop Research Institute, Regional Station located in Gazipur. This site is geographically positioned between 23°53′ and 24°11′ North latitudes, as well as between 90°20′ and 92°30′ East longitudes. The experimental area is classified as medium high land within the Madhupur Tract; Agroecological Zone 28 (Brammer, 1994). The soil is loamy in texture, with a pH range of 4.8-5.5, characterized by low organic matter content and a low level of fertility. The climate is marked by relatively high temperatures and significant rainfall during the Kharif or summer season (April-October), while the Rabi or winter season (November-March) experiences lower temperatures and minimal rainfall.

Experimental Materials, Design and Intercultural Operations

Forty sugarcane genotypes were sourced from the Bangladesh Sugarcrop Research Institute (BSRI) located in Ishurdi and the Quarantine Station in Gazipur to fulfill the aims of this study. Among the genotypes evaluated, ten were of exotic origin while the remaining thirty were developed by BSRI (refer to Table 1). Each plant was prepared for planting by separating the setts, ensuring each had two eyes, and placing them in the soil furrow. The land was cultivated using a power-operated plough, and fertilizers along with manure were applied in accordance with the Fertilizer Recommendation Guide (FRG, 2012). During the final land preparation, fertilizers including Triple Super Phosphate (TSP), Muriate of Potash (MOP), and gypsum were applied uniformly. One-third of the urea and MOP were incorporated during the final land preparation, while the remaining

two-thirds of urea and MOP were applied in two equal splits as top-dressing, once at the early tillering stage and again at the late tillering stage. The experimental design was established using a Randomized Complete Block Design (RCBD) with three replicates. Each plot measured 4 m × 4 m, with a spacing of 1.5 m between blocks and 1.0 m between plots. The distance between rows was maintained at 1 m. Weeding was conducted three times: the first weeding occurred two months after sett placement, the second after four months, and the final weeding took place five months post-planting. Irrigation was administered three times throughout the experiment: once at the time of sett placement and twice after germination, with a 30-day interval between irrigations.

Table 1 List of Genotypes Used for Morpho-physiological Study at Bangladesh Sugarcrop Research Institute (BSRI), Regional Station, Gazipur

Name of genotypes	Country of origin	Name of genotypes	Country of origin	Name of genotypes	Country of origin	Name of genotypes	Country of origin
GT 11	China	Rangbilash	Bangladesh	Isd 31	Bangladesh	Isd 19	Bangladesh
Q 69	Australia	Misridana	Bangladesh	Isd 32	Bangladesh	Isd 20	Bangladesh
GT 15	China	Amrita	Bangladesh	Isd 33	Bangladesh	Isd 21	Bangladesh
GT 17	China	Isd 1/53	Bangladesh	Isd 34	Bangladesh	Isd 24	Bangladesh
VMC 86-550	Philippine	Isd 2/54	Bangladesh	Isd 35	Bangladesh	Isd 25	Bangladesh
HoCP 85-845	USA	LJC	Bangladesh	Isd 36	Bangladesh	Isd 26	Bangladesh
HoCP 96-540	USA	Isd 15	Bangladesh	Isd 37	Bangladesh	Isd 27	Bangladesh
HoCP 95-988	USA	Isd 16	Bangladesh	Isd 38	Bangladesh	Isd 28	Bangladesh
HoCP 91-555	USA	Isd 17	Bangladesh	Isd 39	Bangladesh	Isd 29	Bangladesh
CB 45-3	Philippine	Isd 18	Bangladesh	Isd 40	Bangladesh	Isd 30	Bangladesh

Data Collection

Data were gathered on various morpho-physiological characteristics such as leaf length, leaf width, fresh leaf weight, dried leaf weight, number of tillers, number of millable stalks, stalk diameter, internode length, plant height, stalk length, %Brix content, and stalk weight at two growth stages: one at 7-8 months and another at 10-12 months during the harvesting stage. The height of the stalks was measured from the ground level to the top of the stalk using a measuring tape in centimeters. The count of tillers during the tillering stage and the number of millable stalks at the harvesting stage was recorded. Leaf chlorophyll content (SPAD index) was assessed using a SPAD-502plus chlorophyll meter (Markwell et al., 1995). The internode length was measured in centimeters from three distinct locations (the bottom, middle, and top of the stalk) using a meter rod, and the total number of nodes was counted. Vernier Slide Calipers were employed to measure the stalk thickness at the top, middle, and bottom.

Analysis of Genetic Parameters and Divergence

The gathered data were examined using the statistical tools MSTAT-C (Russell, 1986) and the STAR (Gulles et al. 2014) program for the analysis of variability and diversity. The data were scrutinized for variance (Johnson et al. 1955 and Hill et al. 1998), components of phenotypic and genotypic variance (Singh and Chaudhury 1985), heritability (Johnson et al. 1955; Hanson et al. 1956; Hill et al. 1998 and Allard 1960), and genetic advance (Fehr 1987 and Johnson et al. 1955), as well as correlation and path coefficients (Lynch and Walsh 1998). Employing Mahalanobis D^2-statistics and its supplementary analysis, genetic divergence among the genotypes was evaluated. This technique estimates divergences among a collection of genotypes on a multivariate scale (Singh and Chaudhury 1985).

RESULTS AND DISCUSSION

Variance Components

Morpho-physiological parameters are the primary focus of sugarcane cultivar enhancement programs aimed at achieving high sugar yield. Various morpho-physiological characteristics are taken into account to select the preferred line in a breeding initiative. The analysis of variance for all traits revealed highly significant ($p < 0.01$) differences among the genotypes (Table 2). According to Shivasubramanian and Menon (1973), the phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values were categorized as low, medium, and high, corresponding to 0 to 10%, 10 to 20%, and greater than 20%, respectively. Genotypic variances were found to be highest for plant height and lowest for stalk diameter. A high GCV was noted solely for stalk weight, followed by fresh leaf weight. Moderate GCV was observed in leaf width, fresh leaf weight, dried leaf weight, number of tillers, millable stalk, and stalk diameter. The lowest GCV was recorded for leaf length, internode length, plant height, stalk length, and %brix content. A high PCV was also noted for stalk weight; however, it was moderate for leaf width, fresh leaf weight, dried leaf weight, number of tillers, millable stalk, and stalk diameter, while it was low for leaf length, internode length, plant height, stalk length, and %brix content (Table 2).

The estimated phenotypic coefficient of variation (PCV) exceeded the genotypic coefficient of variation (GCV) across all traits, suggesting a greater environmental impact on genetic diversity (Tadesse et al. 2014). A high GCV implies that selection could be effective based on these traits, and their phenotypic manifestation would serve as a reliable indicator of genotypic potential (Singh et al. 1994). Heritability refers to the assessment of the extent of variation in phenotypic traits within a population, which is attributed to genetic diversity. The traits such as leaf length, leaf width, fresh leaf weight, dried leaf weight, number of tillers, millable stalks, stalk diameter, internode count, internode length, plant height, stalk length, %brix content, and stalk weight exhibited high heritability, exceeding 60% (Table 2). Genetic advance is also a crucial factor in selecting a line for a breeding program. The highest genetic advance was observed in plant height (61.59), followed by stalk length (58.35), while the lowest was recorded in stalk diameter (0.58) (Table 3).

The GCV and PCV, along with heritability and genetic advancements, play a crucial role in the improvement of any sugarcane trait, as they offer insights into the feasibility of achieving the desired objectives with the existing material (Tyagi and Singh 1998). High GCV and PCV values were recorded for the number of tillers (Diribu et al. 2020; Esayas et al. 2016a), and cane yield (Esayas et al. 2016b; Feyissa et al. 2014; Anbanandan and Eswaran 2018; Diribu et al. 2020). Moderate GCV and high PCV values were noted for stalk number (Feyissa et al. 2014), single cane weight (Esayas et al. 2018), and sugar yield (Gowda et al. 2016), which aligns with the findings of the current study. Contradictory results regarding stalk number and single cane weight (Anbanandan and Eswaran 2018; Chaudhary 2001; Mali and Patel 2013); as well as sugar yield (Feyissa et al. 2014; Behou and Pene 2019) have been documented. This variation may be due to differences in genotype and the environmental conditions under which the genotypes were assessed.

Moderate GCV values combined with high PCV values, as well as low GCV values paired with moderate PCV values, suggest that these traits are significantly affected by environmental or non-genetic factors. This implies that enhancing these traits through direct selection poses challenges. The present findings regarding the number of internodes per stalk are consistent with the earlier research conducted by Esayas et al. (2016b). However, contrasting results concerning recoverable sucrose percentage and stalk diameter were reported by Feyissa et al. (2014), Chaudhary (2001), and Belwal and Ahmad (2020). Low GCV and PCV values for brix percentage, pol percentage, and purity percentage have been documented (Esayas et al. 2018; Belwal and Ahmad 2020; Gowda et al. 2016; Marwa et al. 2018), which aligns with the findings of the current study. Additionally, low GCV and PCV values were noted for brix percentage (Alam et al. 2017; Mali and Patel 2013), and pol percentage (Mali and Patel 2013; Kumar et al. 2018; Japheth et al. 2019), which is consistent with the results of the current study.

Table 2 Estimation Component of Variances for Twelve Variables of Forty Sugarcane Genotypes

Characters	Genotyic variance (GV)	Error variance (EV)	Phenotypic variance (PV)	Genotypic co-efficient of variation (GCV)	Phenotypic co-efficient of variation (PCV)	Heritability (%)
Leaf length	76.17	8.14	84.31	6.25	6.58	95

Leaf width	0.35	0.02	0.37	15.57	16.06	96
Fresh leaf weight	537.25	16.43	553.68	19.59	19.88	98
Dried leaf weight	28.29	12.11	40.41	15.27	18.25	83
Number of tiller	3.17	1.52	4.70	15.84	19.27	82
Millable stalk	2.16	0.71	2.88	17.22	19.86	86
Stalk diameter	0.07	0.007	0.08	13.60	14.19	95
Internode Length	1.23	0.17	1.40	9.80	10.45	94
Plant height	893.79	259.55	1153.34	6.60	7.50	88
Stalk length	802.37	131.03	933.41	9.39	10.12	92
%Brix content	1.12	0.27	1.40	5.78	6.46	89
Stalk weight	0.11	0.004	0.12	27.79	28.27	98

Table 3 Genetic Advance and Genetic Advance in Percent of a Mean of Twelve Variables Using Forty Sugarcane Genotypes

Characters	Phenotypic variance	Phenotypic standard deviation	Selection differential (K value)	Genetic advance (GA)	Mean values	Genetic advance in % of mean
Leaf length	84.32	9.18	2.06	17.98	139.51	12.89
Leaf width	0.38	0.62		1.23	3.83	32.08
Fresh leaf weight	553.69	23.53		47.75	118.32	40.36
Dried leaf weight	40.41	6.36		10.96	34.83	31.46
Number of tiller	4.70	2.17		3.67	11.25	32.63
Millable stalk	2.89	1.70		3.03	8.55	35.48
Stalk diameter	0.09	0.29		0.58	2.07	28.03
Internode length	1.41	1.19		2.29	11.35	20.19
Plant height	1153.34	33.96		61.59	452.66	13.61
Stalk length	933.41	30.55		58.35	301.69	19.34
%Brix content	1.40	1.18		2.18	18.31	11.92
Stalk weight	0.12	0.34		0.70	1.22	57.26

Mean Performance of Different Morpho-physiological Characters

Leaf

The leaf serves as a potentially active factory for the assimilation of CO_2, converting it into sugar. Consequently, it is crucial to characterize the leaf trait to gain an overview of the efficiency of sugarcane genotypes as a C4 plant. It was observed that all genotypes exhibited significant differences in the mean performance of the leaf trait. The genotype Isd 40 had the longest leaf at 156.27 cm, followed by Isd 28 at 155.68 cm and Isd 39 at 154.82 cm among all genotypes, while the genotype Isd 15 had the shortest leaf measuring 119.14 cm. Regarding leaf width, the genotype Rangbilash had the greatest leaf width at 5.35 cm, followed by Amrita at 5.12 cm, whereas the genotype CB 45-3 had the least width at 2.33 cm. Significant differences were also noted among the genotypes in both fresh and dried leaf weight. The genotype Amrita exhibited the highest fresh leaf weight at 188.67 g, followed by Isd 40 at 154.67 g, while the genotype Isd 1/53 showed the lowest fresh leaf weight at 64.00 g. In terms of dry leaf weight, the highest recorded was 48.0 g in Amrita, followed by Isd 32 at 46.67 g, with the lowest being 20.67 g in genotype Isd 1/53 (Table 3).

Stalk

The stalk of sugarcane contains juice, which is a primary focus for yield enhancement. Consequently, breeders are aiming to select robust stalks with elongated internodes. This study revealed a significant variation among the genotypes concerning stalk length. The genotype Isd 31 exhibited the greatest stalk length at 367.43 cm, followed by Isd 39 at 350.7 cm, Isd 40 at 344.03 cm, Isd 29 at 342.9 cm, Isd 32 at 340.53 cm, Isd 15 at 338.43 cm, and Amrita at 328.73 cm; conversely, the shortest stalk length was recorded in genotype Isd 25 at 230.33 cm (Table 4). Stalk diameter had a more substantial impact on stalk weight than stalk length, irrespective of the crop's age. These findings suggest that a better understanding of the relationships among sugar yield components could enhance the selection efficiency for sugar yield. In recent decades, improvements in sugar yield have primarily been achieved through increases in cane yield rather than sugar content (Jackson 2005). Based on the average stalk diameter, the following classifications are established: <2 cm diameter = Thin, 2-2.5 cm diameter = Medium-thin, 2.5-3 cm diameter = Medium, 3-3.5 cm diameter = Medium-thick, and >3.5 cm diameter = Thick (Akhtar et al. 2001). The highest stalk diameter was recorded in genotype Amrita at 2.75 cm, followed by Rangbilash at 2.69 cm, GT 11 at 2.64 cm, Q 69 at 2.52 cm, and Misridana at 2.48 cm, with the lowest being genotype CB 45-3 at 1.36 cm. Similar findings were noted by various researchers. Gowda et al. (2016) reported variability in stalk length, whereas Esayas et al. (2018) identified variability in internode length in sugarcane. Both Gowda et al. (2016) and Abdul et al. (2017) also reported a significant degree of variability in plant height in sugarcane, which is consistent with the results of the current study. Additionally, significant differences in internode length were observed among the genotypes. The longest internode was found in genotype Isd 31 at 14.28 cm, followed by Isd 20 at 13.51 cm, while the shortest was in Rangbilash at 9.21 cm. Average stalk weight is a crucial parameter contributing to cane yield; thus, emphasis was placed on increasing average stalk weight to achieve higher cane yield. The highest average stalk weight was recorded in genotype Amrita at 2.16 kg, followed by GT 11 at 1.88 kg, HoCP 85-845 at 1.78 kg, GT 15 at 1.68 kg, and GT 17 at 1.64 kg, with the lowest from genotype CB 45-3 at 0.39 kg (Table 4). This indicates that sugarcane varieties exhibiting enhanced cane yield may be cultivated by choosing the most favorable genotypes from the assessed materials. The existence of variability in cane yield within sugarcane has been documented (Gowda et al., 2016; Kumar et al., 2018; Esayas et al., 2018), which aligns with the findings of the present study.

Tillers and Millable Stalk

Significant variations were noted among the genotypes regarding the number of tillers per unit area (Table 4). The genotype CB 45-3 exhibited the highest number of tillers at 16.33 per square meter, followed by Isd 28 at 15.00 per square meter, while the lowest count was found in genotype Isd 37 at 8 per square meter. In contrast, the highest number of millable stalks was recorded in genotype CB 45-3 at 14.67 per square meter, followed by HoCP 91-555 with 10.50 per square meter, and the lowest count of 6 per square meter was observed in genotypes Isd 36 and Isd 26 (Table 4).

Plant Height

The height of the plant was defined as the measurement from the base of the stalk to the tip of the flag leaf, and to a certain degree, the yield of sugarcane is indirectly associated with plant height. A notable variation in plant height was observed among the different genotypes. The genotype Isd 40 exhibited the tallest height at 511.57 cm, while genotypes Isd 31 and Isd 39 recorded heights of 499.27 cm and 497.47 cm, respectively. The shortest height was found in genotype Isd 25, measuring 376.43 cm (Table 4).

%Brix Content and Pol (%) of Cane

The brix content (%) and pol (%) reflect the sugar concentration in sugarcane stalks and serve as indicators of sugarcane maturity. The percentage of brix content and pol (%) directly represent the sugar levels in sugarcane stalks. A genotype exhibiting a high percentage of brix content and pol (%) is regarded as superior in terms of sugar production when compared to those with lower values. The genotype HoCP 96-540 demonstrated the highest brix percentage at 20.54, whereas the lowest was recorded at 15.88% in the CB 45-3 genotype (refer to Table 4). The brix content for each genotype was assessed during the months of October, November, and December. Among all genotypes, HoCP 85-845, Misridana, Isd 17, Isd 18, Isd 28, Isd 29, Isd 32, Isd 35, and Isd 37 exhibited no significant differences in brix content across different months (see Table 4). The pol (%) varied between 10 and 16 across the 40 genotypes, with the majority (26 genotypes) falling within the average pol (%) range of 12-14. A notable number of genotypes displayed an average pol (%) of 14-16, while a few were categorized with a pol (%) of 10-12 (refer to Table 4 and Figure 1). The highest recorded percentage of pol in cane was 15.62% for the genotype HoCP 95-888, while the lowest was 11.55% for Isd 29 (see Table 4 and Figure 2). Kumar et al. (2018) indicated a restricted variability in biochemical traits of sugarcane, which aligns with the findings of the present study. Conversely, in earlier research on sugarcane, Esayas et al. (2018) observed a broader variability in biochemical traits, which contradicts the results of this study.

Chlorophyll Content

Chlorophyll is an essential molecule for photosynthesis, facilitating the conversion of solar energy into chemical energy. During photosynthesis, chlorophyll captures energy and subsequently converts water and carbon dioxide into oxygen and carbohydrates. The chlorophyll content varied between 25 and 58, with the majority of the genotypes (20 in total)

exhibiting chlorophyll levels within the range of 35-45. In contrast, four genotypes displayed notably low chlorophyll content (25-35), while only two genotypes had elevated chlorophyll levels (55-65) (refer to Table 4 and Figure 2). The highest chlorophyll content was recorded in the genotype Amrita (58 SPAD), followed closely by the genotype HoCP 96-540 (57.40 SPAD), whereas the lowest was found in the genotype Isd 30 (25.23 SPAD; see Table 4).

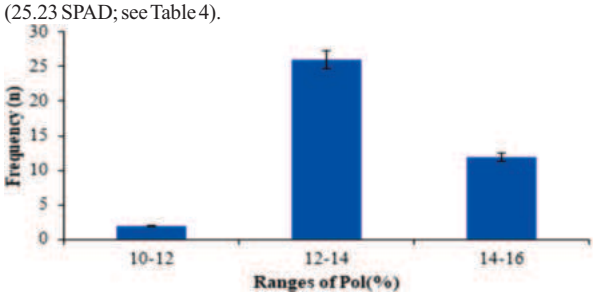

Figure 1 Categorization of forty sugarcane genotypes based on average pol (%).

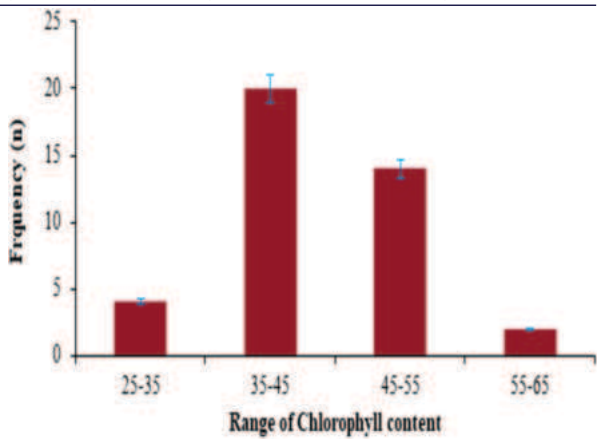

Figure 2 Categorization of forty sugarcane genotypes based on chlorophyll content in leaf.6

Table 4 Mean Performance for Different Variables of Forty Sugarcane Genotypes Grown at RSRS Gazipur Farm During 2012-2013 Cropping Year

Genotypes	Leaf length (cm)	Leaf width (cm)	Fresh leaf weight (g)	Dried leaf weight (g)	Number of tiller sqm^{-1}	Number of millable stalk sqm^{-1}	Stalk diameter (cm)	Internode length (cm)	Plant height (cm)	Stalk length (cm)	%Brix content	Stalk weight (kg)
GT 11	143.28	4.56	136.67	38.67	9.67	8.00	2.64	12.24	481.63	313.03	19.83	1.88
GT 15	143.71	4.31	133.33	38.00	10.33	7.33	2.35	12.19	476.40	304.43	19.38	1.68
GT 17	150.35	3.87	128.67	37.33	13.00	10.33	2.45	11.47	493.40	313.50	19.02	1.64
VMC 86-550	143.66	3.62	144.33	36.00	11.67	9.67	2.29	11.06	389.70	314.40	19.77	1.48
HoCP 85-845	133.28	3.69	106.00	31.33	12.00	9.67	1.89	9.44	439.77	237.93	20.22	0.78
HoCP 96-540	132.03	3.16	89.33	25.33	10.33	7.67	1.96	11.34	460.50	301.10	20.54	1.20
HoCP 95-988	140.53	3.00	85.33	28.00	13.33	11.00	2.00	10.64	444.83	276.33	20.41	1.00
HoCP 91-555	150.82	3.12	105.33	30.00	12.67	10.50	2.07	10.57	441.00	298.83	19.83	1.57
CB 45-3	143.60	2.33	74.67	26.00	16.33	14.67	1.36	9.92	416.00	276.83	15.88	0.39
Rangbilash	134.01	5.35	153.33	40.00	8.33	7.33	2.69	9.21	419.13	269.17	16.72	1.48
Q 69	137.46	3.64	123.67	35.33	9.33	8.00	2.52	11.97	444.17	302.93	16.88	1.30
Misridana	137.95	4.47	107.67	31.33	10.33	6.67	2.48	10.06	416.27	281.03	17.14	1.50
Amrita	146.39	5.12	188.67	48.00	14.33	9.00	2.75	11.46	486.00	328.73	17.81	2.16
Isd 1/53	126.85	3.08	64.00	20.67	13.33	9.33	1.54	11.60	432.00	307.60	17.83	0.66
Isd 2/54	138.60	3.74	118.00	37.33	11.00	9.00	1.99	11.54	443.97	293.37	17.78	1.01
LJC	142.76	3.60	106.67	34.00	9.33	8.33	1.91	10.97	421.33	258.00	18.05	1.02
Isd 15	119.14	4.06	104.67	32.00	10.33	8.67	2.09	10.43	494.13	338.43	17.78	1.44
Isd 16	135.36	3.49	114.67	33.33	11.67	8.00	2.05	11.49	440.43	297.93	18.89	1.22
Isd 17	136.80	3.68	124.00	34.67	11.33	9.00	1.99	11.49	457.67	296.07	19.52	1.31
Isd 18	133.25	3.55	110.00	34.67	11.33	7.67	1.99	11.52	452.57	316.73	17.90	1.17
Isd 19	133.17	3.52	118.67	34.00	9.67	9.00	2.08	10.15	417.70	263.53	17.57	1.02
Isd 20	133.17	3.20	94.67	29.33	14.33	10.00	1.80	13.51	443.50	311.57	17.86	0.99
Isd 21	139.84	4.09	133.00	40.67	10.00	8.33	2.02	10.83	428.57	282.30	17.84	1.55
Isd 24	127.96	3.90	105.33	29.33	9.33	7.67	2.15	10.07	437.77	286.73	18.42	1.49
Isd 25	125.61	3.84	101.33	31.33	11.00	9.33	1.79	10.44	376.43	230.33	17.60	0.66
Isd 26	124.76	3.68	103.00	29.33	9.33	6.00	1.92	9.43	418.67	287.37	17.75	0.87
Isd 27	135.17	4.31	136.00	38.00	12.67	8.33	2.11	12.24	457.77	317.70	18.33	1.24
Isd 28	155.68	3.16	139.33	40.00	15.00	9.33	1.97	11.26	465.93	319.50	18.74	1.11
Isd 29	148.87	3.41	118.67	38.67	10.00	6.67	2.09	12.57	493.10	342.90	17.53	1.25
Isd 30	149.08	4.28	128.00	36.67	9.67	6.67	2.07	11.76	455.00	306.23	17.85	1.20
Isd 31	150.62	3.56	130.00	38.00	12.67	9.33	2.07	14.28	499.27	367.43	17.56	1.19
Isd 32	141.26	4.93	148.00	46.67	10.00	8.00	2.19	12.94	493.40	340.53	17.55	1.41
Isd 33	135.87	4.22	119.33	38.67	11.00	9.33	1.89	13.26	466.10	323.43	18.37	1.02
Isd 34	139.73	3.72	106.67	32.00	10.67	8.33	1.90	11.71	465.33	285.33	16.25	0.94
Isd 35	141.30	3.57	96.67	32.00	11.67	9.33	1.64	11.88	421.57	285.97	17.63	0.82
Isd 36	129.09	3.88	109.33	32.00	9.33	6.00	2.00	11.02	470.20	293.40	18.82	1.14
Isd 37	139.81	4.44	120.67	38.00	8.00	7.33	2.06	11.23	475.37	317.60	18.78	1.24
Isd 38	148.66	3.40	109.00	30.67	9.33	8.00	1.97	10.09	460.87	284.53	19.59	1.11
Isd 39	154.82	4.32	141.33	41.33	14.00	7.33	1.91	12.78	497.47	350.70	18.58	1.23
Isd 40	156.27	4.23	154.67	44.67	12.33	7.67	2.07	11.91	511.57	344.03	18.79	1.42
$Lsd_{(0.05)}$	4.64	0.25	6.59	5.66	2.01	1.38	0.14	0.67	26.19	18.61	0.86	0.10
Mean	139.51	3.83	118.32	34.83	11.25	8.55	2.07	11.35	452.66	301.69	18.31	1.22
Min.	119.14	2.30	64.00	20.67	8.00	6.00	1.36	9.21	376.43	230.33	15.88	0.39
Max.	156.27	5.35	188.67	48.00	16.33	14.67	2.75	14.28	511.57	367.43	20.54	2.16

Table 5 Analysis of Variances of Twelve Characters for Forty Sugarcane Genotypesat Bangladesh Sugarcrop Research Institute (BSRI), Regional Station, Gazipur during 2012-13

Characters	Sources	DF	Mean square	Standard error (s.e.)	CV (%)
Leaf length	Cultivar	39	236.66**	1.65	2.05
Leaf width	Cultivar	39	1.09**	0.09	3.96
Fresh leaf weight	Cultivar	39	1628.19**	2.34	3.43
Dried leaf weight	Cultivar	39	97.01**	2.01	9.99
Number of tiller	Cultivar	39	11.06**	0.71	10.99
Millable stalk	Cultivar	39	7.22**	0.49	9.90
Stalk diameter	Cultivar	39	0.25**	0.05	4.17
Internode length	Cultivar	39	3.88**	0.24	3.63
Plant height	Cultivar	39	2940.92**	9.30	3.56
Stalk length	Cultivar	39	2538.16**	6.61	3.79
Brix%	Cultivar	39	3.64**	0.30	2.88
Stalk weight	Cultivar	39	0.35**	0.04	5.11

*** Indicates significant at 0.01 probability
** Indicates significant at 0.05 probability
* Indicates significant at 0.1 probability NS indicates nonsignificant

Clustering of Genotypes Based on Diversity

All the genotypes were clusteredbased on agglomerative cluster analysis method into five group's viz., cluster I, cluster II and cluster III, cluster IV, and cluster V (Table 6). Cluster I included 10 genotypes which were GT 11, GT 15, GT 17, VMC 86-550, Isd 28, Isd 29, Isd 31, Isd 32, Isd 39 and Isd 40 Similarly, Cluster II included 27 genotypes HoCP 85-845, HoCP 96-540, HoCP 95-988, HoCP 91-555, Q 69, Misridana, Isd 1/53, Isd 2/54, LJC, Isd 15, Isd 16, Isd 17, Isd 18, Isd 19, Isd 20, Isd 21, Isd 24, Isd 25, Isd 26, Isd 27, Isd 29, Isd 30, Isd 33, Isd 34, Isd 35, Isd 36, Isd 37 and Isd 38. Whereas, CB 45-3, Rangbilash, and Amrita genotype belonged to the cluster III, cluster IV, and cluster V, respectively. The divergence of sugarcane genotypes was measured based on different growth and yield parameters. Among the parameters, %brix content had maximum contribution toward divergence of forty sugarcane genotypes. It was appeared 364 times at first position in ranking and contributed 53.61% in divergence among tested sugarcane followed by stalk weight which appeared 85.00 times and contributed 12.52% toward divergence (Table 6). A dendrogram was made based on the mean performance of different variables among the genotypes which described the relationship of them (Figure 3).

Tai and Miller (2001) identified 11 groupings based on the biochemical characteristics of 147 sugarcane genotypes from four distinct species, whereas Ekpelikpeze et al. (2016) organized 42 sugarcane genotypes into three clusters. Ram and Hemaprabha (2005) categorized 153 sugarcane genotypes into five clusters, while Esayas et al. (2016a) classified 400 sugarcane genotypes into 20 clusters. The significant genetic distance observed between the clusters suggests a genetic divergence among the genotypes of the respective clusters. This implies a strong possibility that genetic recombination among the genotypes of these divergent clusters could lead to the emergence of hybrid vigor. Nonetheless, in related research, Mebrahtom et al. (2016) found the greatest genetic distance (Euclidean) between clusters 9 and 10.

Table 6 Characterwise Contribution of Forty Sugarcane Genotypes Towards Divergence

Characters	Appearing first in ranking (times)	Contribution (%)
Leaf length	24	3.53
Leaf width	43	6.33
Fresh leaf weight	51	7.51
Dried leaf weight	3	0.44
Number of tiller	8	1.18
Millable stalk	17	2.50
Stalk diameter	29	4.27
Internode length	23	3.39
Plant height	2	0.29
Stalk length	30	4.42
Stalk weight	85	12.52
%Brix content	364	53.61
Total	679	100

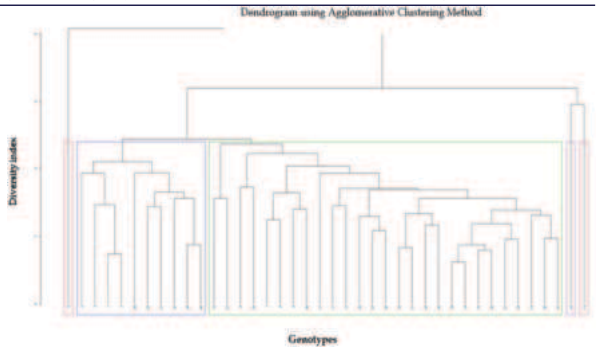

Figure 3 Dendrogram based on mean performance of variables of forty sugarcane genotypes according to average clustering and euclidean distance method; whereas 1=GT 11, 2=GT 15, 3=GT 17, 4=VMC 86-550, 5=HoCP 85-845, 6=HoCP 96-540, 7=HoCP 95-988, 8=HoCP 91-555, 9=CB 45-3, 10=Rangbilash, 11=Q 69, 12=Misridana, 13=Amrita, 14=Isd 1/53, 15=Isd 2/54, 16=LJC, 17=Isd 15, 18=Isd 16, 19=Isd 17, 20=Isd 18, 21=Isd 19, 22=Isd 20, 23=Isd 21, 24=Isd 24, 25=Isd 25, 26=Isd 26, 27=Isd 27, 28=Isd 28, 29=Isd 29, 30=Isd 30, 31=Isd 31, 32=Isd 32, 33=Isd 33, 34=Isd 34, 35=Isd 35, 36=Isd 36, 37=Isd 37, 38=Isd 38, 39=Isd 39 and 40=Isd 40.

CONCLUSIONS

The findings from the variability analysis indicated a significant range of differences in agro-morphological and biochemical traits among the genotypes examined, suggesting substantial potential for genetic enhancement through selection, as evidenced by the minimal difference between PCV and GCV, which signifies lower environmental impact alongside high heritability. Among the sugarcane genotypes evaluated, the top-performing average stalk genotypes included Amrita, GT 11, HoCP 85-845, GT 15, and GT 17. These specific genotypes exhibit a greater potential for sugar yield and should be further assessed over several seasons for commercial viability. The genetic diversity analysis, which focused on agro-morphological and biochemical traits, highlighted that %brix content and stalk weight were the primary contributors to the agro-morphological diversity of the sugarcane test materials. Cluster analysis demonstrated that clusters one and two encompassed the highest number of genotypes, with 27 and 10, respectively. Furthermore, when considering only agro-morphological characteristics, as well as clusters one and five based on a combination of agro-morphological and biochemical traits, the greatest inter-cluster distance values were observed, which may facilitate the development of the most heterotic hybrids through hybridization. The insights gained from this study could prove beneficial for sugarcane breeders in strategizing future breeding programs aimed at producing sugarcane genotypes with high sucrose content and yield.

REFERENCES

1. Abdul QK, Kiya AT, Berhanu LR. 2017. A study on morphological characters of introduced sugarcane varieties (*Saccharum* spp., Hybrid) in Ethiopia. *International Journal of Plant Breeding and Genetics*. 11(1):1–12.
2. Akhtar M, Elahi NN, Ashraf M. 2001. Morphological characters of some exotic sugarcane varieties. *Pakistan Journal of Biological Sciences*. 4(4):471-476.
3. Alam MN, Nath UK, Karim KMR, Ahmed MM, Mitul RY. 2017. Research article genetic variability of exotic sugarcane genotypes. *Scientifica*.1–10.
4. Allard RW. 1960. Principles of Plant Breeding. John Wily and Sons, Inc. New York. p. 485.
5. Amin MR, Barma NCD, Razzague MA. 2004. Variability, heritability, genetic advance, and correlation study in some quantitative character in durum wheat. *Rachis News Letter*. 11(4):30–32.
6. Anbanandan V, Eswaran R. 2018. Genetic variability, heritability and genetic advance in sugarcane. *International Journal of Recent Scientific Research*. 9(2):24217–24219.
7. Behou MY, Pene CB. 2019. Genetic variability and heritability among sugarcane genotypes in plant crop for some agronomic traits under tropical dry climate of ferke, ivory coast. *Journal of Experimental Agriculture International*. 38(1):1–14.
8. Belwal V, Ahmad S. 2020. Estimation of variability parameters in sugarcane under water logging conditions. *International Journal of Agriculture Sciences*. 12:9451–9453.
9. Brammer H. 1994. The agroecology of Bangladesh's floodplains. *Asia Pacific Journal on Environment and Development*. 1(2):1-20.
10. Chaudhary RR. 2001. Genetic variability and heritability in sugarcane. *Nepal Agriculture Research Journal*. *4 &* 5(1):56.
11. D'Hont A, Ison D, Alix K, Roux C, Glaszmann JC. 1998. Determination of basic chromosome numbers in the genus *Saccharum*by physical mapping of ribosomal RNA genes. *Genome*. 41(2):221-225.
12. Diribu T, Belay T, Esayas T, Feyisa T, Abebech S, Mebrahtom F, Feven M. 2020. Estimation of components of variances, heritability and genetic advance in sugarcane genotypes at finchaa and metahara sugar estate, ethiopia. *International Journal of Current Research and Academic*. *8*(11): 23–30.
13. Ekpelikpeze OS, Dansi A, Agbangla C, Akoegninou A, Sanni A. 2016. Biochemical Characterization of sugarcane varieties cultivated in Benin. *International Journal of Current Microbiology and Applied Sciences*. 5(2):368–379.
14. Esayas T, Mekbib F, Ayana A. 2016a. Correlation and Path Coefficient Analyses in Sugarcane genotypes of Ethiopia. *American Journal of Plant Sciences*.

7(10):1490–1497.
15. Esayas T, Mekbib F, Ayana A. 2016b. Heritability and Correlation among Sugarcane (*Saccharum* spp.) Yield and Some Agronomic and Sugar Quality Traits in Ethiopia. *American Journal of Plant Sciences*. 7(10):1453–1477.
16. Esayas TG, Firew M, Amsalu A. 2018. Sugarcane Landraces of Ethiopia: Germplasm Collection and Analysis of Regional Diversity and Distribution. *Advances in Agriculture*. 2018:1–10.
17. Fehr WR. 1987. Principles of Cultivar Development, Vol. I., MacMillan, New York.
18. Feyissa T, Negi T, Getaneh A, Dilnesaw Z, Ayele N, Teferi Y. 2014. Genetic variability and heritability of ten exotic sugarcane genotypes at Wonji Sugar Estate of Ethiopia Global Advanced Research. *Journal of Physical and Applied Sciences*. 3 & 4 xxx–xxx.
19. FRG. 2012. Fertilizer Recommendation Guide, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 1215. 232p.
20. Gowda SNS, Saravanan K, Ravishankar CR. 2016. Genetic variability, heritability and genetic advance in selected clones of sugarcane. *Plant Archives*. 2(16):700–704.
21. Gulles AA, Bartolome VI, Morantte RI, Nora LA, Relente CE, Talay DT, Caneda AA, Ye G. 2014. Randomization and analysis of data using STAR (Statistical Tool for Agricultural Research). *Philippine Journal of Crop Science*. 39:44.
22. Hanson CH, Robinson HF, Comstock RE. 1956. Biometric studies of yield in segregating population in Korean Lespedeza. *Agronomy Journal*. 48:268-272.
23. Hill J, Becker HC, Tigerstedt PM. 1998. Quantitative and Ecological Aspects of Plant Breeding. Chapman and Hall, London.
24. Jackson PA. 2005. Breeding for improved sugar content in sugarcane. *Field Crops Res*. 92:277–290.
25. Japheth EJ, James O, Oliver K. 2019. Estimates of genetic parameters and genotype by environment interactions for sugar yield and its components in sugarcane genotypes in Western Kenya. *Journal of Plant Breeding and Crop Science*. 11(9):206–212.
26. Johnson HW, Robinson HF, Comstok RE. 1955. Estimation of genetic and environmental variability in soybean. *Agronomy Journal*. 47:314-318.
27. Kumar P, Pandey SS, Kumar B, Kamat DN, Kumar M. 2018. Genetic variability, heritability and genetic advance of quantitative traits in sugarcane. *International Journal of Chemical Studies*. 6(3): 3569–3572.
28. Lynch M, Walsh B. 1998. Genetics and analysis of quantitative traits. Sin. Associates Inc. Sunderland, Massachusetts. p.823-831.
29. Mali SC, Patel AI. 2013. Correlation and heritability studies in sugarcane. *Agres-An International e-Journal*. *2*(4):466–471.
30. Markwell J, Osterman JC, Mitchell JL. 1995. Calibration of the Minolta SPAD-502 leaf chlorophyll meter. *Photosynthesis Research*. 46(3):467-472.
31. Marwa MA, Ghallab M, Ghonema A, El-Araby SRS. 2018. Variability, Heritability and Flowering Ability of some Sugarcane Germplasm. *Alexandria Science Exchange Journal*. 39(3):401–411.
32. Mebrahtom F, Mekbib F, Abraha E. 2016. Multivariate analysis of sugar yield contributing traits in sugarcane (*Saccharum officinarum* L.), in Ethiopia. *African Journal of Plant Science*. 10(8):145–156.
33. Peter S. 1998. Sugar Cane: Past and Present. Southern Illinois University. Retrieved 2012-04-02.
34. Ram B, Hemaprabha G. 2005. Genetic divergence of sugar yield and its components in flowering type Saccharum officinarum clones. *Agricultural Science Digest*. 25(2):118–120.
35. Russell DF. 1986. MSTAT-C computer package programme. Crop and Soil Science Department, Michigan State University, USA.
36. Shivasubramanian S, Menon M. 1973. Heterosis and inbreeding depression in rice. *Madras Agricultural Journal*. 60:1139.
37. Singh RK, Chaudhary BD. 1985. Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi, India. pp. 225-252.
38. Singh RK, Singh DN, Singh SK, Singh HN. 1994. Genetic variability and correlation studies in foreign commercial hybrids of sugarcane. *Agricultural Science Digest*. 14:103-107.
39. Tadesse F, Negi T, Getaneh A, Dilnesaw Z, Ayele N, Teferi Y. 2014. Genetic variability and heritability of ten exotic sugar cane genotypes at Wong Sugar Estate of Ethiopia. *Global Advanced Research Journal of Physical and Applied Science*. 3 & (4):XXX-XXX.
40. Tai PYP, Miller JD. 2001. A core collection for *Saccharum spontaneum* L. from the world collection of sugarcane. *Crop Science Society of America*. 41(3):879–885.
41. Tyagi SD, Singh DN 1998: Studies on genetic variability for stalk characters in sugarcane. *Indian Sugar*. XL VIII:259-262.
42. Udeh I, and Ogbu C. 2011. Principal component analysis of body measurements in three strains of broiler chicken. *Science World Journal*. 6(2):11–14.
43. Ullah MZ, Hassan MJ, Choudhary AZMKA, Saki AI, Rahman AHMA. 2012. Genetic variability and correlation in exotic cucumber (*Cucumis sativus* L.) Varieties. *Bangladesh Journal of Plant Breeding and Genetics*. 25(1):17–23.