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RESEARCH ARTICLE

Genetic variability and heritability studies in some sugarcane genotypes

S. Z. Solomon , A. Emmanuel, J. J. Saba, J. Mohammed

College of Agriculture, Mokwa, Sunti Golden Sugar, 913103 Niger State, Nigeria

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solomonshaba88@gmail.com

Abstract

A field experiment was conducted at Sunti to assess the extent of genetic variability, heritability, and genetic advance for yield and its component traits in a set of sugarcane genotypes The ANOVA revealed the presence of significant differences among the genotypes for all the traits studied, indicating the existence of substantial genetic variability in the experimental material. Such variability provides ample scope for effective selection and genetic improvement in sugarcane breeding programmes. Higher estimates of GCV and PCV were observed for number of tillers per plot, leaf length, stalk height, and cane yield, suggesting a wide range of variability for these traits. The relatively close magnitude between GCV and PCV for these characters indicates a lesser influence of environmental factors and a greater role of genetic control, thereby enhancing the reliability of phenotypic selection. Correlation analysis indicated that cane yield exhibited a strong and positive association with number of millable canes, highlighting stalk population density as a major determinant of yield. The results further revealed that genotypes with higher tillering ability coupled with superior stalk development contributed significantly to increased cane yield, emphasizing the importance of these traits as key selection criteria. High heritability coupled with substantial genetic advance was recorded for most of the traits studied, indicating the predominance of additive gene action and the effectiveness of selection in improving these characters. However, traits such as sucrose percentage and number of millable canes exhibited comparatively lower genetic advance despite moderate to high heritability, suggesting the possible involvement of non-additive gene effects and environmental influence. Overall, the study indicates that selection based on traits exhibiting high variability, heritability, and genetic advance particularly number of tillers per plot, stalk height, and cane yield—would be effective for enhancing sugarcane productivity. These findings provide valuable insights for formulating efficient selection strategies in sugarcane breeding programmes aimed at yield improvement.

Keywords: Genetic variation, sugar cane, correlation, heritability, improvement

Introduction

Sugarcane (*Saccharum officinarum*) is one of the most important crops in the world. It is most efficient C4 plant grown on tropical and subtropical region of the world (Yadav *et. al.,* 2013). Sugarcane belongs to poaceae family and genus Saccharum and is one of the main sources of sugar production in the world. It contributes about 70% of the total sugar produced in the world (Khan *et. al.,* 2012). The important sugarcane growing countries in world are Australia, Cuba, Mexico, India, Brazil, Pakistan, China, Thailand and Philippines. One of the most valuable products of the plant Saccharum species is sugar; it is a major raw material in the manufacture of alcoholic beverages, soft drinks, ice-creams, chocolates, and canning industry. Its important by-products include molasses, filter muds and bagasse (Mirajkar *et. al.,* 2019). The success of any crop improvement program depends on the nature and magnitude of genetic variability present in the population. Crop improvement strategy requires reliable information on the availability of sufficient heritable genetic variation with predictable genetic advance for the desired trait within the available germplasm. A measure of the tendency of individual plant's traits in a population to differ from one another is a major contributor to successful plant breeding plans as it allows breeders to further improve the traits to develop new varieties. For effective breeding work, knowledge of the mode of inheritance of traits and the expected genetic gain is of paramount importance. Furthermore, Ullah *et. al.,* (2012) reported that identification of the heritable and the non-heritable portions of the observed variability are essential to get evidence of the genetic control over the expression of a particular trait and its phenotypic reliability to predict its breeding value. High heritability is not always associated with high genetic advance, and thus, heritability estimates and genetic advance should always be considered simultaneously (Amin *et. al.,* 2004). High heritability values should be combined with a high genetic advance to ensure effective selection for trait improvement and a high prediction of the expected genetic gains (Johanson *et. al.,* 1955). In sugarcane breeding, morphological characterization of genotypes, wild species and landraces is essential for breeders to develop varieties with superior attributes (Muhammad *et. al.,* 2016). These attributes provide peculiar plant distinctions and thus facilitate germplasm categorization (Muhammad *et. al.,* 2016). To increase cane and sugar yield through selection for yield component and quality characters, the knowledge of association of various characters is important (Tyagi and Khan, 2010). Morphological markers play important role in breeding and selection of superior genotypes from germplasm accessions with high yield contributing traits. Ahmed *et al.,* (2019) reported improvement in cane yield through straight selection for number of millable cane and single stalk weight in their study on genetic parameters including genetic variation, heritability and genetic advance. Also, Jamoza *et. al.,* (2014) reported that where genetic coefficient of variation, broad sense heritability and expected genetic advance were high, a selection strategy based on single stalk weight and number of millable cane could lead to improvement in cane yield. The result of the study of seven yield components in 20 varieties of sugar cane for correlation and path analysis indicated that; cane yield per plot and sugar yield per plot were each positively correlated with number of stalks per plot and with single stalk weight and length. Stalk diameter made the greatest contribution to single stalk weight. Single stalk weight made a major contribution to stalk yield per plot, which was the major factor in sugar yield per plot (Lu 1984; Shrestha, and Thapa, 2021).

The impact of climate change influences the phenotypic expression of important traits. Thus, the development of high-yielding adaptable sugarcane varieties and resilient to the changing climate is critical to the sugar industry's profitability and sustainability (Tolera, 2023). Identification of traits with high heritable variation and genetic gain, and selection of individual plants with a high mean value of these traits help identify promising genotypes to be used for commercial purposes and as parents for crossing to further enhance the traits (Tolera, 2023). The objective of this study was to investigate the genetic variation existing among some selected sugarcane for yield and yield components. Therefore, the present study is to determine genetic variability, heritability and genetic advance of yield and its components in some sugarcane varieties.

Material and methods

The experiment was conducted at the Sunti Golden Sugar Estate, Mokwa, Niger State, Nigeria, during 2023/2024 and 2024/2025 growing season. The region is located on longitude 9^{o}90' N; latitude 5^{o}27' E and 93.5 m above sea level, with annual average rainfall of 1029.4 mm and annual average temperature range between 28^{o}C and 34^{o}C. The area is characterized by a well-drained sandy loam soil. The experimental materials comprised of five sugarcane varieties shown below, where Co 91017 which is common to the environment was used as a check

Variety	**Origin**
RB 82-5211	Brazil,
RB 12-5211	Brazil,
Co 91017 (Check)	India,
B 85817	Barbados,
B 00140	Papua New Guinea.

The experiment was laid out in Randomized Complete Block design (RCBD) with three replications. Each variety was planted in a plot size of 5m x 4m. Each plot consisted of 4 rows of 5m long with row-to-row distance of 1 m. All agronomic operations related to production of sugarcane such as mulching, weeding, irrigation, earthing etc. were strictly observed. Data on the morphological and yield characters of sugar cane were collected. Number of tillers was counted at 120 days of planting from five randomly selected plants per plot. Average number of millable cane per plot was determined from five randomly selected canes from each treatment. Five randomly selected canes stalk was cut with a sharp knife just above ground level de-trashed and weighted with a balance in kilograms (kg) to record stalk weight. In addition, five cane stalks were selected randomly from each treatment and average length of individual cane was determined. Stalk girth, leave length, leave width and cane yield were determined. Data on sucrose percentage was also collected at harvest. All data obtained for each character were subjected to the analysis of variance, performed by F test (Cochran and Cox, 1960). Correlation, heritability estimates, and genetic advance were determined. Heritability in broad sense (h^2) was estimated according to Robinson (1949): Genotypic (σ^2g) and phenotypic variances (σ^2ph) were obtained from the analysis of variance table according to Comstock and Robinson (1952).

The mean values were used for genetic analyses to determine Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV), according to Singh and Chaudhury (1985). Genetic advance (GA) was calculated with the method suggested by Allard (1960) and Singh and Chaudhury (1985).

Results and discussion

Agronomic performance of sugarcane genotypes

The individual performance (mean) of the genotypes for all quantitative traits is shown in Table 1. The highest number of tillers per plot was found in genotype RB 82-5211 (92.6) followed by RB 12-5211 (88.7) and Co 91017 (85.2) the check RB 82-5211 produced maximum plant population significantly superior to next best genotype RB 12-5211 and the check which may be attributed to its tillering ability controlled by genetic traits, Kumar *et al.,* (2012) reported similar observations. Genotype, RB 82-5211 produced maximum millable canes (14.1/m2) and stalk height (2.6 m), higher than the other genotype and the check. The highest cane yield (91.86 t/ha) was produced by the genotype RB 82-5211 which was significantly higher than those of all other genotypes in this study. Furthermore, among the genotypes, RB 82-5211 produced highest percentage of sucrose (19.6) which was significantly higher than rest of the genotypes, similar result was reported by Abhisek and Bharti (2021). The superior performance of RB 82-5211 can be attributed to the optimal relationship of yield components (Table 2). The high tillering capacity (92.6 per plot) coupled with excellent stalk development (14.1 stalks/m) resulted in its high yield (91.86 t/ha), this result is similar to those of Kumar *et. al.,* (2014) and Kumar and Pandey, (2017). These findings expose the existence of significant genetic differences amongst the genotypes tested, and could be attributed to genetic diversity among the clones, indicating possibility of substantial enhancement through careful selection. This result finds support with the earlier reports of Gowda, *et. al.,* (2016), Hiremath and Nagaraja (2016) and Repale *et. al.,* (2024).

Correlation matrix for agronomic traits in sugarcane genotypes

The result in table 2 shows the Pearson correlation coefficients (r) between the traits studied. A significant and strong positive correlations was recorded ($r > 0.8$) between millable cane and cane yield ($r = 0.9$); stalk height and cane yield ($r = 0.8$) tillers and millable cane ($r = 0.8$); stalk height and millable cane ($r = 0.8$); leaf length and leaf width ($r = 0.8$). Stalk girth and stalk height ($r = 0.8$). There was also a display of moderate but positive correlations ($r = 0.6–0.8$) between leaf width and cane yield ($r = 0.6$), cane yield and sucrose % ($r = 0.66$). Similarly, a weak but significant positive correlation ($r = < 0.6$) between tillers and sucrose % ($r = 0.5$) was observed.

Genetic component of variation

The data in Table 3 revealed significant variation across all traits tested, showing a wide range of both phenotypic and genotypic coefficients of variation. Generally, the values for the genotypic coefficient of variation (GCV) were lower than those for the corresponding phenotypic coefficient of variation (PCV). This comparison exposes the relative magnitudes of phenotypic and genotypic variances across the traits, providing insight into the magnitude of genetic variation present and the potential for selection and improvement in future breeding efforts. This result is in line with the reports of Agarwal and Kumar, (2017) and Repale *et. al.,* (2024).

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Table 1: Mean Performance of five cane varieties

Variety	No tillers / plot	Millable cane (m^2)	Stalk height (m)	Stalk girth (cm)	Leaf length (m)	Leaf width (cm)	Cane yield (t/ha)	Sucrose (%)
RB 82-5211	92.6	14.1	2.6	4.2	1.3	5.7	91.8	19.6
RB 12-5211	88.7	13.5	2.5	4.0	1.2	5.4	87.4	19.0
B 00140	78.4	10.5	2.3	3.4	1.1	4.7	72.5	16.8
B 85817	80.1	11.2	2.3	3.6	1.1	4.9	78.6	17.5
Co 91017 (Check)	85.2	12.3	2.4	3.8	1.2	5.1	82.3	18.4
TOTAL	85.0	12.3	2.4	3.8	1.2	5.2	82.5	18.2

Table 2: Correlation matrix for agronomic traits in sugarcane genotypes

Trait	Tillers (per plot)	Millable cane (cane/m)	Stalk height (m)	Stalk girth (cm)	Leaf length (m)	Leaf width (cm)	Cane yield (t/ha)	Sucrose (%)
Tillers (per plot)	1							
Millable Cane (cane/m)	0.8**	1						
Stalk Height (m)	0.7**	0.8**	1					
Stalk Girth (cm)	0.7**	0.7**	0.8**	1				
Leaf Length (m)	0.6*	0.7*	0.7**	0.6*	1			
Leaf Width (cm)	0.6*	0.6*	0.7*	0.6*	0.8**	1		
Cane Yield (t/ha)	0.8**	0.9**	0.8**	0.7**	0.7**	0.6*	1	
Sucrose (%)	0.5**	0.6*	0.5*	0.6*	0.4*	0.4*	0.6*	1

** = significant at 1% level

Genotypic coefficient of variation was high for leaf length (21.3), stalk height (19.1), number of tillers (18.27), leaf width (17.54), stalk girth (17.3), cane yield (16.83) and number of millable canes at harvest (15.4). Low GCV was recorded for the sucrose percentage (9.8%). The estimate of phenotypic coefficient of variation was higher for stalk height (23.4), leaf length (22.0), numbers of tiller (20.9%) and cane yield (20.5%), while number of millable and sucrose yield recorded moderate (18.1 and 12.6) PCV respectively. In contrast, the percentage sucrose exhibited moderate GCV, suggesting that this characteristic may have less underlying genetic diversity. This disparity in GCV among traits highlights the potential for enhancing improvement through selective breeding. The phenotypic coefficient of variation (PVC) and Genotypic coefficient of variation (GCV) values are ranked as low (0 – 20%), medium (10 – 20%) and high (>20%). Highest results of PCV and GCV obtained in the numbers of tiller per plot and cane yield revealed presence of sufficient variation for the traits in the available materials, suggest that selection can be successful for these traits. These results correspond with the earlier reports of Shakoor *et. al.,* (2007), and Rafiq *et al.,* (2010). However, moderate to low PCV displayed by the remaining traits; suggest that they may have less variability and potentially fewer chances for enhancement through breeding efforts. This variation in PCV across traits underscores the importance of targeted selection strategies when specific character is in focus for future development. Heritability values are categorized as low (0 – 30%), Moderate (31 – 60%) and high (> 60%) as stated by Robinson *et. al.,* 1949. The high heritability for number of tillers (87.41%) and number of millable cane (85.0%) in this test suggests that these traits are predominantly genetically controlled, making them reliable criteria for selection. Ahmed et al., (2019) and Repale *et. al.,* (2024). earlier reported high heritability for number of millable cane, numbers of tillers, stalk height, stalk weight and sucrose percentage. This result indicates that simple selection based on the phenotype may be effective for variety improvement. Genetic advance was highest for leaf length (33.6), number of tillers (32.1%), followed by stem girth (28.95%), while sucrose percentage recorded least genetic gain (3.4). Since high heritability does not always indicate a high genetic gain, heritability with genetic advance considered together should be used in predicting the ultimate effect of selection. Furthermore, Panse (1957) stated that high heritability coupled with high genetic advance indicates the additive gene effects while high heritability coupled with low genetic advance indicates the non-additive gene effects for control of the particular character. The present study indicated that number of tillers and cane yield showing high heritability and high genetic advance exhibited additive gene action and are important characters to be considered for selection and improvement of the sugarcane, similar result was reported by Ahmed, *et. al.,* (2019) and Repale *et. al.,* (2024). The high heritability in sucrose content (77.0%) with low genetic advance (18.6%) reveals the challenges in breeding for sugar content. This suggests that while genetic improvement is possible, environmental factors and genotype × environment interactions must be carefully managed. This result is in agreement with the findings of Kumari, *et al.,* (2020).

Hence, in conclusion, significant differences were observed among the sugarcane genotypes regarding all the traits studied, demonstrating higher level of genetic diversity. Number of tillers per plant, numbers of millable cane, cane yield exhibited the highest coefficients of genotypic and phenotypic variation. This estimations imply that selection base on these traits can be successful. The GCV and PCV values for these traits show that the variance was mostly under non additive gene actio

Table 3: Genetic component of variation

Trait	GCV	PCV	H²	GA	GA% of mean
No of tillers	18.2	20.9	87.4	32.1	37.8
Millable cane	15.4	18.1	85.0	4.2	34.1
Stalk height (m)	19.1	23.4	67.4	12.7	21.1
Stalk girth (cm)	17.3	19.8	71.2	30.1	23.1
Leaf length (m)	21.3	22.0	75.2	33.6	42.2
Leaf width (m)	17.5	19.0	71.5	23.8	45.0
Cane yield	16.8	20.5	81.9	28.9	35.0
Sucrose (%)	9.8	12.6	77.7	3.4	18.6

and was affected by the environment; this suggests that base on these traits selection for improvement is possible. The superior performance of RB 82-5211 over the check (Co 91017) can be attributed to its optimal combination of yield components. The high tillering capacity coupled with excellent stalk development resulted in its high yield. The strong correlation between millable cane and yield confirms that stalk population density is the primary yield determinant in this genotype.

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