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GENETIC VARIABILITY AND ASSOCIATION STUDIES IN GRAIN SORGHUM (*SORGHUM BICOLOR* L. MOENCH)

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ABSTRACT

The current research was carried out under the aegis of AICRP on Sorghum, ARS Chamarajanagar, to evaluate the extent of genetic variability and the interrelationship of traits among sixteen sorghum genotypes including two checks during the *kharif* season of 2023. The experimental design adopted was the Randomized Complete Block Design (RCBD). Observations revealed that phenotypic variance surpassed genotypic variance across all measured traits. Substantial phenotypic and genotypic variance was noted for attributes such as plant height, stem diameter, the number of primary branches per panicle, ear head weight, and grain yield per plant. Most traits exhibited high heritability coupled with significant genetic advance as a percentage of the mean (GAM). A strong positive correlation was detected between grain yield per plant and ear head weight. Furthermore, path coefficient analysis identified traits such as days to fifty per cent flowering, ear head length, ear head width, ear head weight and number of leaves per plant were having a direct positive influence on grain yield per plant, underscoring their critical role in improving yield potential.

Key words : Genetic variability, Correlation, Path analysis, Sorghum.

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] has been classified under the family Poaceae, sub-family Panicoideae, tribe Andropogoneae and genus Sorghum, with diploid chromosome number 2n = 20 and a genome size of 730 Mb (Paterson *et al.*, 2004). It has a C_4 photosynthetic pathway, due to which there is an increase in the photosynthetic efficiency under intense light and high temperature. Sorghum is said to have originated in Africa. It is a significant millet crop, ranking fifth globally after wheat, rice, maize and barley. Its capacity to grow in diverse climatic conditions enables cultivation in regions with scarce water resources, especially in areas susceptible to drought. Sorghum is popularly known as a 4F crop, i.e., it is used for food, fodder, feed, and fuel purposes. It serves as a key staple food in the diet of over 300 million people and feed for cattle in Asia and Africa. It is under cultivation in tropical, sub-tropical and even in the temperate regions of the world extending throughout the six continents as great millet. In developing countries, sorghum is primarily used as a food and fodder crop. India ranks fifth in the world for sorghum production after the United States, Nigeria, Sudan and Ethiopia with a production of 4.4 million metric tons (Anonumous, 2023-24). It is acclimated to latitudinal ranges spanning 40°S to 45°N of the equator. In India, kharif sorghum regions range from 9°N to 25°N, whereas rabi sorghum areas are confined to the narrow belt of 14°N to 21°N latitudes (Sivakumar and Virmani, 1982). It flourishes in semi-arid tropics, extending from sea level to elevations of 3,000 meters, across regions with variable rainfall. Sorghum requires warm conditions but can be grown under a wide range of soil and environmental conditions. It can tolerate moisture stress and outperforms other crops in handling high temperatures.

The success of any crop improvement initiative hinges significantly on the extent of genetic variability and heritability within the germplasm. Evaluating variability is imperative to determine its suitability as foundational material for crop enhancement programs. Yield, being a complex trait governed by multiple genes, is profoundly influenced by environmental factors. This underscores the necessity of comprehending the heritable component of genetic variation and the extent of genetic progress achievable through selection. Since heritability estimates are also subject to environmental effects, relying solely on heritability may not accurately identify traits suitable for selection. However, combining heritability estimates with anticipated genetic advance offers a more dependable framework (Johnson *et al.*, 1955). While heritability provides insight into the degree of inheritance of quantitative traits, genetic advance serves as a valuable guide for devising effective breeding strategies.

The yield is an intricate trait shaped by the dynamic interplay of multiple yield-contributing factors, each exhibiting either a positive or negative correlation with yield and interacting among themselves in varying degrees. Correlation studies indicate the magnitude of association between pairs of characters and useful for opting for genotypes with desirable combinations of characters which aids the plant breeder in improving crop yield. Further, various components directly and/or indirectly influence the grain yield *via.,* other traits that create a complex situation for a breeder in the process of selection. Path analysis proves indispensable in this context, as it deconstructs correlation coefficients into their direct and indirect contributions, revealing the effects of independent variables on the dependent variable. Consequently, the combined application of correlation studies and path coefficient analysis provides a comprehensive understanding of the cause-and-effect dynamics among various traits.

Hence, the current investigation was carried out to examine key genetic parameters, including variance, coefficients of variation, heritability, genetic advance, correlation and path analysis, within kharif sorghum-derived lines.

Materials and Methods

The experimental material for the present study consisted of 16 genotypes of grain sorghum including two checks (CSV-23 and CSV-27), cultivated at AICRP on Sorghum, ARS, Chamarajanagar, during the *kharif* season of 2023, with a planting arrangement of 45 cm × 15 cm. The experiment was structured using a Randomized Complete Block Design (RCBD) with two replications. Data were recorded from five robust plants within each genotype across two replications for traits such as days to fifty per cent flowering, plant height, number of leaves per plant, leaf length, days to maturity, stem diameter, ear head length, ear head width, number of primary branches per panicle, ear head weight, hundred-seed weight and grain yield per plant. The mean values of these five randomly selected plants were employed for statistical analysis. The dataset was analysed for genotypic and phenotypic coefficients of variation (as per Burton, 1952), heritability (Allard, 1960), and genetic advance (Johnson *et al.*, 1955). Additionally, heatmaps illustrating Karl Pearson's correlation coefficients and path coefficient analysis were generated using R Studio version 4.4.2.

Results and Discussion

The efficacy of plant breeding programs is profoundly dependent on the occurrence of genetic variability within plant populations for specific traits. The mean sum of squares for replications and genotypes of the evaluated lines, as presented in Table 1, underscores this variability. The ANOVA demonstrated that the mean sum of squares for replication was non-significant across all the quantitative traits studied. However, significant variations among genotypes were evident for all traits, signifying substantial genetic variability within the genotypes under investigation and highlighting the potential for enhancement through selective breeding.

Mean performance, maximum value, minimum value, Phenotypic Coefficient of Variance (PCV), Genotypic Coefficient of Variance (GCV), Heritability and Genetic advance as per cent of mean of the genotypes studied are given in Table 2. The mean for days to fifty per cent flowering was 67.70 while the range for this character was 46.00 (SOR3182) to 74.00 days (SOR3289 & SOR11943), the variation was 28 days for this trait which indicates that earliness can be selected amongst the genotypes by virtue of selection. Similarly, the variation for plant height was 184.85 cm with a range from 105.80 (463 B) to 290.65 (SOR11942), variation for leaf length was 46 cm with a range of 52.50 (SOR3182) to 99.20 cm (SOR11938). For the number of primary branches per panicle variation was 44.30 ranging from 40.95 (SOR4346) to 85.25 (CSV-27), variation for ear head weight was 90.30, ranging from 28.60 (SOR3182) to 118.90 (SOR3570) and mean for the character grain yield per plant was 56.00 g and the variation of 38.69 g, which ranged from 36.77 (SOR3182) to 75.46 g (SOR3350), depicting great variation among the studied genotypes for the character grain yield per plant, paving way for the development of varieties with greater yield capacity with the aid of selection.

Genotypic Coefficient of Variance (GCV) and Phenotypic Coefficient of Variance (PCV)

Analysis of the Genotypic Coefficient of Variance

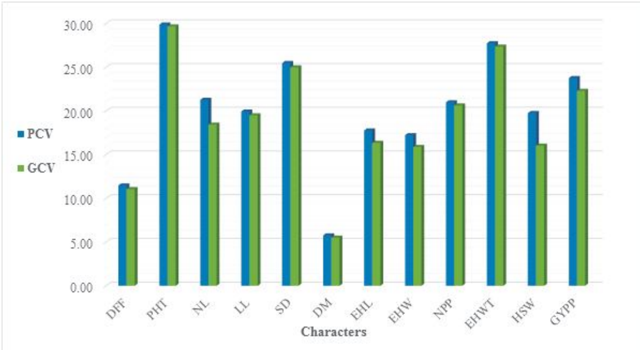

Fig. 1 : Graph depicting PCV and GCV values of all the components of grain Sorghum.

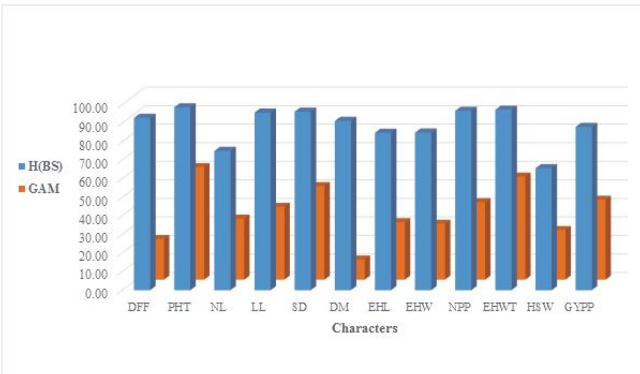

Fig. 2 : Graph depicting broad sense Heritability (H(BS)) and Genetic Advance as per cent of mean (GAM) values of all the components of grain Sorghum.

(GCV) and Phenotypic Coefficient of Variance (PCV) of different traits are given in Table 2. The results indicated that phenotypic coefficient variances (PCV) were slightly greater than the genotypic coefficient variances (GCV) for most of the traits (Fig. 1), this means, the traits under study were less influenced by the environment. Similar results on sorghum were also reported by Venkateswarlu *et al*. (2016), Shivaprasad *et al.* (2019) and Reddy *et al.* (2020).

Deshmukh *et al.* (1986) classified GCV and PCV as high (>20%), moderate (10% to 20%) and low (<10%). The high PCV and GCV values imply the occurrence of high variability that was observed notably for traits like plant height (PHT) (29.87 and 29.66), stem diameter (SD) (25.47 and 24.98), number of primary branches per panicle (NPP) (20.98 and 20.63), ear head weight (EHWT) (27.73 and 27.35) and grain yield per plant (GYPP) (23.75 and 22.29), indicating that selection could effectively improve these traits. Whereas moderate PCV and GCV values were found particularly for traits days to fifty per cent flowering (DFF) (11.47 and 11.06), leaf length (LL) (19.92 and 19.50), ear head length (EHL) (17.75 and 16.35), ear head width (EHW) (17.22 and 15.88) and hundred seed weight (HSW) (19.75 and 16.02) (Fig. 1) and low PCV and GCV were observed for the trait days to maturity (DM) (5.76% and 5.51%) Thus, selection for these traits would be less effective (Fig. 1). High PCV and low GCV were revealed for the trait number of leaves per plant (NL) (21.27 and 18.43), this indicates that the environment more influences the trait. The above results were in accordance with the previous studies of Warkad *et al.* (2008), Venkateswarlu and Sivajyothi (2016), Swamy *et al.* (2018), Shivaprasad *et al.* (2019), Gebregergs and Mekbib (2020), Reddy *et al.* (2020) and Santhiya *et al.* (2021).

Heritability – Broad sense [H(BS)]

Heritability is a good indicator of the transmission of characters from parents to their progeny. Heritability is classified as low (<30%), medium (30% to 60%) and high (> 60%) (Singh, 2001). The estimates of heritability help the plant breeder in the selection of genotypes from diverse genetic populations. Therefore, heritability estimates show that variation for these characters is due to high additive gene effects and consequently the scope for improving yield through selection is greater. Most of the traits in this study manifested high heritability (> 80%) except the trait, number of leaves (NL) and hundred seed weight (HSW), which exhibited moderate heritability (75.08%) (Fig. 2). Similar results of heritability were obtained in the previous studies of Warkad *et al*. (2008), Reddy *et al.* (2020) and Santhiya *et al*. (2021).

Genetic advance as per cent of mean (GAM)

Deshmukh *et al*. (1986) categorized genetic advance as a percentage of the mean into three levels: high (>20%), moderate (10–20%), and low (<10%). Genetic

Table 1 : ANOVA for twelve yield and yield attributing characters of grain sorghum.

Source of variation	df	DFF	PHT	NL	LL	SD	DM	EHL	EHW	NPP	EHWT	HSW	GYPP
Replication	1	0.07	128.40	5.44	0.11	1.55	2.53	0.38	0.51	0.44	61.47	0.03	11.17
Treatments	15	116.42**	7253.50**	8.88**	454.12**	32.40**	76.30**	35.07**	2.00*	287.01**	990.62**	0.50*	332.63**
Error	15	4.27	51.49	1.26	9.82	0.62	3.48	2.87	0.16	4.78	13.73	0.10	21.19
Total	31	120.76	7433.39	15.58	464.05	34.57	83.31	38.32	2.67	292.23	1065.82	0.63	364.99

* Significant at p=0.05 and ** Significant at p=0.01

Table 2 : Comparison of variability parameters for yield and yield attributing traits in sixteen *kharif* grain sorghum genotypes.

Character	Mean	Max	Min	PCV	GCV	H(BS)	GAM
DFF	67.70	74.00	46.00	11.47	11.06	92.92	21.96
PHT	202.30	290.65	105.80	29.87	29.66	98.59	60.67
NL	10.59	13.20	6.40	21.27	18.43	75.08	32.89
LL	76.45	99.20	52.50	19.92	19.50	95.77	39.30
SD	15.95	24.36	8.69	25.47	24.98	96.25	50.49
DM	109.59	120.50	102.75	5.76	5.51	91.27	10.84
EHL	24.54	36.60	18.60	17.75	16.35	84.86	31.03
EHW	6.03	7.50	4.00	17.22	15.88	85.00	30.15
NPP	57.58	85.25	40.95	20.98	20.63	96.72	41.80
EHWT	80.80	118.90	28.60	27.73	27.35	97.27	55.57
HSW	109.59	120.50	102.75	19.75	16.02	65.77	26.77
GYPP	56.00	75.46	36.77	23.75	22.29	88.02	43.07

DFF: Days to fifty per cent flowering, PHT: Plant height (cm), NL: No. of leaves per plant, LL: Leaf length (cm), DM: Days to maturity, SD: Stem diameter (mm), EHL: Ear head length (cm), EHW: Ear head width (cm), EHWT: Ear head weight (g), NPP: Number of primary branches per panicle, HSW: Hundred seed weight (g), GYPP: Grain yield per plant (g).

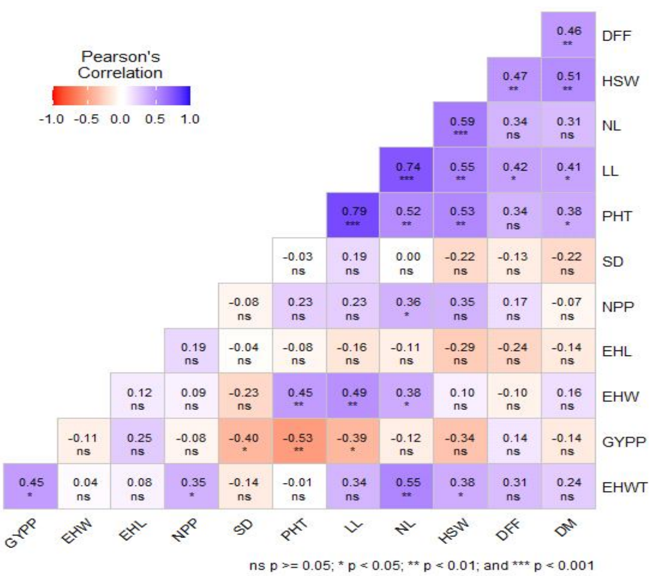

Fig. 3 : Heat map of Karl Pearson's Correlation analysis.

advance as per cent of mean serves as a valuable metric for estimating the potential effectiveness and efficiency of selection within a base population. In the current study, nearly all traits exhibited high genetic advance as a per cent of the mean (GAM), except for days to maturity (DM) (10.84%). The efficacy of selection is influenced by the genetic advance of the chosen trait in conjunction with heritability. Most traits demonstrated high heritability paired with substantial genetic advance, excluding the number of leaves (NL) (75.08% heritability and 32.89% GAM) and days to maturity (DM) (91.27% heritability and 10.84% GAM) (Fig. 2). The combination of high heritability and elevated genetic advance suggests the predominance of additive genetic effects, making such traits amenable to effective improvement through selection. Similar results were obtained in the previous studies of Warkad *et al.* (2008), Venkateswarlu and Sivajyothi (2016), Swamy *et al.* (2018), Reddy *et al.* (2020) and Santhiya *et al.* (2021).

Correlation studies

The correlation coefficient is a statistical parameter that quantifies the degree and strength of association between two interrelated variables, which may arise from pleiotropic gene effects, genetic linkage, or a combination of both. In the context of plant breeding, correlation coefficient analysis evaluates the interrelationship between traits and elucidates their associations to enhance yield and yield-contributing attributes.

An extreme correlation was observed between leaf length (LL) and plant height (PHT) (r=0.79), followed by number of leaves (NL) and leaf length (LL) (r=0.74) (Fig.3), similar findings were observed by Prakash *et al.* (2010). The most essential trait, grain yield per plant (GYPP) showed the highest positive correlation with ear head weight (EHWT) (r=0.45) (Fig. 3). This positive correlation was noted between both the traits directly influencing grain yield. By understanding and leveraging this correlation, effective management practices and selection strategies that enhance sorghum productivity can be implemented. Ultimately, this relationship plays a vital role in achieving food security and improving the economic viability of sorghum cultivation. Similar positive correlations between the traits were observed in the previous research of Shivaprasad *et al.* (2019) and Goswamy *et al.* (2020).

The predominant, negatively significant correlation was observed amidst grain yield per plant (GYPP) and

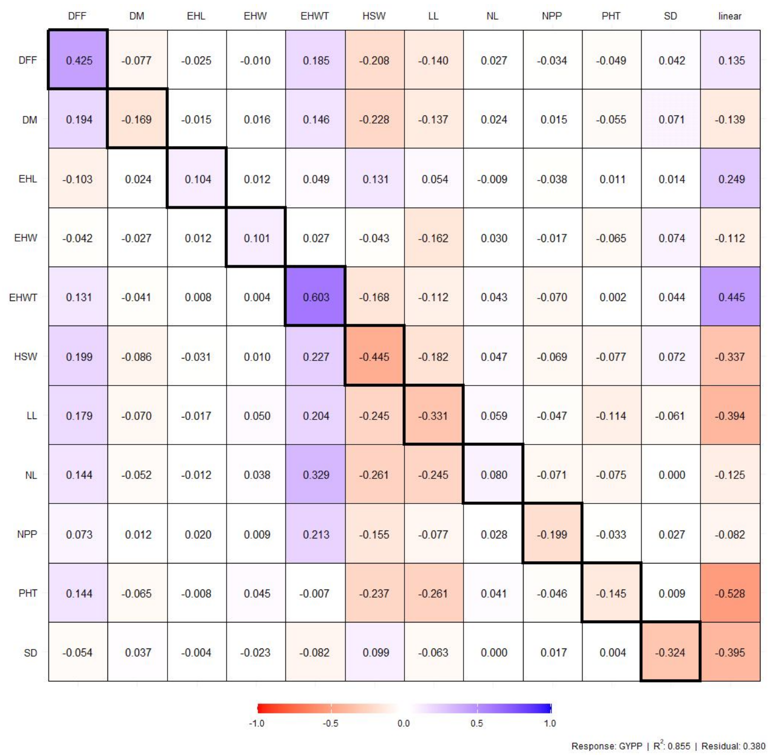

Fig. 4 : Heat map of Path coefficient analysis.

plant height (PHT) (r= -0.53) (Fig. 3) followed by grain yield per plant (GYPP) and stem diameter (SD) (r= -0.40) and leaf length (LL) (r= -0.39) (Fig. 3). The negative correlation between grain yield per plant (GYPP) and plant height (PHT) implies that taller plants may not necessarily translate to higher grain yield per plant. Tall plants may be more susceptible to lodging, which can severely affect grain yield as it makes harvesting difficult leading to grain loss due to damage or rot. Taller plants might have certain advantages but the potential for increased lodging and reduced photosynthetic efficiency can adversely affect grain yield. Also, larger stem diameters often signify greater investment in structural integrity, which can detract from the resources allocated to grain production. When plants invest more energy in growing thicker stems, fewer resources may be available for developing grains. Research indicates that sorghum plants might allocate less energy to reproductive structures as stem diameter increases, potentially leading to lower yield. Also, similar observations were recorded in the previous studies conducted by Adane (2018), Subalakhshmi *et al.* (2019), Tefera (2020) and Goswamy *et al.* (2020).

Path-coefficient analysis

The nature of the association amidst the two variables is determined by analysing the path coefficient, which was used by Dewey and Lu (1959) for plant selection. This coefficient measures the direct and indirect contribution of several independent traits to dependent traits. The correlation was partitioned into direct and indirect effects to know the relative importance of the components (Fig. 4).

In the present study, out of 11 characters, days to fifty per cent flowering, ear head length, ear head width, ear head weight and number of leaves contributed positive and direct effects towards grain yield (Fig. 4). The correlation was partitioned into direct and indirect effects to know the relative importance of the components. Among these, ear head weight (EHWT) (0.603) has a high positive direct effect followed by days to fifty per cent flowering (DFF) (0.425), whereas the direct effects of other characters namely ear head length (EHL) (0.104), ear head width (EHW) (0.101) and number of leaves (NL) (0.080) were negligible. It indicated that if other factors are held constant, an increase in these characters individually will reflect an increased yield. Amare *et al.* (2015) and Shivaprasad *et al.* (2019) also obtained similar results in their research works.

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Abbreviations:

DFF: Days to fifty per cent flowering, PHT: Plant height (cm), NL: No. of leaves per plant, LL: Leaf length (cm), DM: Days to maturity, SD: Stem diameter (mm), EHL: Ear head length (cm), EHW: Ear head width (cm), EHWT: Ear head weight (g), NPP: Number of primary branches per panicle, HSW: Hundred seed weight (g), GYPP: Grain yield per plant (g).