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Genetic variability studies for physiological, yield and yield contributing traits in 'B' and 'R' lines of *kharif* sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract
The experimental trial was conducted at the Sorghum Research Station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during the *kharif* season of 2023-24. A total of 29 lines (12B and 17R lines) were examined in a randomized block design with two replications to study genetic variability and mean performance for fifteen physiological, yield and yield contributing traits. Significant differences among all fifteen characters were observed for total 29 lines. Genotypic coefficient of variance was lower than the phenotypic coefficient of variance for all traits though the differences between them were relatively small. High estimates of both genotypic and phenotypic coefficient of variance were observed for traits such as leaf area, flag leaf area and leaf area index. Moderate values were found for plant height, number of primaries per panicle, diameter of earhead, earhead length, grain yield per plant, 100 seed weight, fodder yield per plant, harvest index and flag leaf length. Lower values were recorded for days to 50% flowering, days to maturity and SCMR (SPAD) value. Traits such as diameter of earhead, earhead length, grain yield per plant, 100 seed weight, fodder yield per plant, harvest index, flag leaf length, leaf area, flag leaf area and leaf area index demonstrated high heritability and high genetic advance as a percentage of mean indicating that selection for these traits in genetically diverse materials could lead to significant genetic improvement.

Keywords: Sorghum, variability, heritability, genetic advance, coefficient of variance

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is a versatile and important cereal crop that belongs to the grass family Poaceae. *Sorghum bicolor* commonly called sorghum and also known as great millet, broomcorn, durra, jowar or milo is a grass plant cultivated for its grain used for human consumption, animal feed and ethanol production. Sorghum is the world's fifth most important cereal crop after rice, wheat, maize and barley with 61 million metric tonnes of annual global production in 2021. India ranks fifth in total sorghum production with 4.15 million tonnes grown in an area of 3.80 million hectares with yield 1100 Kg/ha in 2022-23 (USDA). The assessment of genetic variability in parental lines are necessary. Genetic improvement for quantitative as well as qualitative traits depends upon the variability present in the genetic stock, if desirable traits having high heritability more are the chances of crop improvement through selection. So, there is need to increase productivity of sorghum by utilizing variability and heritability present in genotypes to develop high yielding varieties and hybrids. Efforts were made to assess the genetic variability in parental ('B' and 'R') lines of *kharif* sorghum to develop high yielding hybrids. The presence of significant genetic variability among sorghum genotypes suggests an opportunity for improvement of grain yield and drought tolerance through hybridization of genotypes related to divergent groups and subsequent selection from the segregating generations. The key to breeding programs for expanding the gene pool is genetic variability for physiological, yield and yield-contributing traits. To effectively plan a breeding program, accurate estimates of heritability are necessary. The most effective way to increase grain yield through yield component breeding would be to use components that are either positively correlated with grain yield or highly heritable and genetically independent.

Materials and Methods

The present experiment was carried out at Sorghum Research Station's experimental farm which is located at the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in randomized block design with two replications. The Experiment material for the proposed work were comprised of 29 genotypes of 'B' and 'R' lines consisting 12 B lines and 17 R lines of *kharif* sorghum received from Sorghum research station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *kharif* 2023-24. A total of fifteen Physiological, yield and yield contributing traits were observed on five randomly chosen plants from each genotype in each replication. These traits included plant height (cm), days to fifty percent flowering, days to maturity, No. of primaries per panicle, Diameter of earhead (cm), Earhead length (cm), Grain yield per plant (g), 100 Seed weight, Fodder yield per plant (g), Harvest index (%), Flag leaf length (cm), SCMR value (SPAD)**,** Leaf area (cm^2), Flag leaf area (cm^2) and Leaf area index. Analysis of variance (ANOVA) was calculated as per the method described.

Results and Discussion

Table 1 presents the results of the analysis of variance for the twenty-nine genotypes studied. The data reveal significant differences among all fifteen traits. This indicates substantial variability in these traits offering a valuable opportunity for selecting superior and desirable genotypes for physiologists, researchers and breeders to pursue further genetic improvements. Mean performances of the current investigation of twenty-nine *kharif* sorghum genotypes of 'B' and 'R' line for fifteen traits are presented in Table 2.

Grain yield is a crucial trait for identifying the best physiological, grain yield and yield-contributing characteristics and for selecting traits that will enhance productivity in breeding programs. Achieving a higher grain yield is the primary goal of any breeding programme. On the basis of mean performance, genotypes PMS 8B (56.8 g), KR 222 (55.7 g), KR 231 (54.5), PMS 131B (53.9 g), KR 229 (52.5 g) and KR 123 (49.3 g) exhibited the highest average grain yields. The highest plants height were found in genotypes PMS 8B (205 cm) and KR 229 (186 cm) with other higher genotypes being KR 235 (184 cm) and KR 133 (183 cm). The number of days to reach fifty percent flowering is measured by the time it takes for 50% of the plants in a plot to have at least one open flower. A shorter duration to reach fifty percent flowering generally leads to a quicker attainment of physiological maturity. Genotypes KR 130, KR 214, KR 133 and KR 230 required the fewest days to reach fifty percent flowering of 76 days. Genotypes KR 130 (117 days), KR 214 (118 days), PMS 150B (119 days) and KR 225 (119 days) reached physiological maturity in the shortest time. The genotype KR 123 recorded the highest number of primaries per panicle of 74 followed by KR 222 (73), KR 196 (73), KR 231 (73), PMS 131B (73) and KR 229 (71). The genotypes KR 231 and KR 222 exhibited the highest earhead diameter of 6.1 cm followed closely by KR 232 (5.9 cm), PMS 8B (5.8 cm), KR 229 (5.7 cm) and PMS 71B (5.5 cm). Among the 29 genotypes, KR 231 had the longest earhead of 32.3 cm followed by KR 123 (30 cm), KR 196 (29.2 cm), PMS 1004B (29.1 cm), PMS 71B (28.5 cm) and PMS 237B (28.3 cm).

The higher 100 seed weight were observed in PMS 8B (3.62 g), PMS 49B (3.50 g) and KR 133 (3.42 g), while moderate values were seen in KR 235 (2.67 g), PMS 42B (2.61 g) and KR 196 (2.44 g). fodder yield was observed higher in genotypes KR 235 (195.8 g), PMS 237B (169.4 g) and KR 130 (169.3 g) followed by KR 133 (167.7 g), KR 214 (166.4 g) and PMS 8B (164.9 g). The highest harvest index was observed in genotypes PMS 8B (28.62%) and KR 231 (28.22%) followed by KR 222 (28.06%), KR 229 (27.95%), PMS 131B (27.48%), KR 234 (26.77%) and PMS 71B (25.16%). The genotype PMS 1004B had the longest flag leaf of 60.3 cm followed by PMS 28B (59.2 cm), PMS 71B (58.4 cm), KR 225 (56.8 cm), PMS 38B (53.0 cm) and PMS 126B (52.5 cm). Out of the twenty-nine genotypes, PMS 1004B (54.90), PMS 126B (54.88), and KR 230 (54.62) showed the highest SCMR values. The higher leaf area were found in genotypes PMS 38B (532.3 cm^2), KR 222 (507.9 cm^2), PMS 71B (488.8 cm^2), PMS 42B (479.8 cm^2) and KR 130 (472.1 cm^2). The higher flag leaf areas were found in genotypes PMS 28B (356.2 cm^2), PMS 1004B (352.5 cm^2), PMS 38B (349.8 cm^2) and PMS 71B (331.0 cm^2). Genotypes PMS 38B (3.68) showed highest leaf area index followed by PMS 1004B (3.66), PMS 28B (3.45) and KR 231 (3.42).

Genotypic and phenotypic coefficient of variance matrix

The data were analyzed to estimate variability matrix including phenotypic coefficient of variance (PCV), genotypic coefficient of variance (GCV), heritability, genetic advance and genetic advance as a percentage of the mean. The results shown in the Table 3 indicated that genotypic coefficient of variance was lower than the phenotypic coefficient of variance for all traits though the differences between them were relatively small. The small differences between the phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) suggest that the traits have relative resistance to environmental fluctuations. This indicates that environmental factors have a lesser impact on the phenotypic expression of genotypes making it more feasible to improve these traits through selection. High values of PCV and GCV imply a greater potential for trait enhancement through direct selection.

Deshmukh *et al.* (1986) [5] classified the genotypic and phenotypic coefficient of variance as low (≤ 10%), moderate (10-20%), and high (≥ 20%). In this study, high estimates of both genotypic and phenotypic coefficient of variance were observed for traits such as leaf area, flag leaf area and leaf area index. Moderate values were found for plant height, number of primaries per panicle, diameter of earhead, earhead length, grain yield per plant, 100 seed weight, fodder yield per plant, harvest index and flag leaf length. Similar result recorded by Kumar and Sahib (2003) [12], Arunkumar *et al.* (2004) [2], Arunkumar (2013) [1], Chittapur and Biradar (2015) [4], Dhutmal *et al.* (2015) [6], Khandelwal *et al.* (2015) [11], Gebergergs *et al.* (2020) [8]. Lower values were recorded for days to 50% flowering, days to maturity and SCMR (SPAD) value.

Heritability and genetic advance

The genotypic coefficient of variance alone does not fully represent the proportion of heritable variation. High heritability indicates the effectiveness of selection based on phenotypic performance but does not guarantee high genetic gain for a single trait. According to Singh (2001) [13], heritability is categorized as very high or high when above 60%, moderate between 30-60% and low below 30%. In this study heritability ranged from 31% to 95%. High heritability was observed for traits such as plant height, number of primaries per panicle, diameter of earhead, earhead length, grain yield per plant, 100 seed weight, fodder yield per plant, harvest index, flag leaf length, leaf area, flag leaf area and leaf area index indicating a favorable environmental effect and significant genotypic control making selective breeding a viable option for improvement.

The genetic advance as a percentage of the mean ranges from 38.34% for grain yield per plant to 1.68% for days to maturity. Deshmukh *et al.* (1986) [5] categorized genetic advance as a percentage of the mean into low (≤ 10%), moderate (10-20%) and high (≥ 20%). In this study, all traits except days to 50% flowering, days to maturity and SCMR value showed high to moderate genetic advance as a percentage of the mean. Johnson *et al.* (1955) [10] recommended that considering both heritability and genetic advance together rather than individually to assess the potential progress through selection. High heritability combined with a high genetic advance suggests that the heritability is likely due to additive gene effects making selection more effective. Traits such as diameter of earhead, earhead length, grain yield per plant, 100 seed weight, fodder yield per plant, harvest index, flag leaf length, leaf area, flag leaf area and leaf area index demonstrated high heritability and high genetic advance indicating that selection for these traits in genetically diverse materials could lead to significant genetic improvement. Similar findings of high heritability combined with high genetic advance for diameter of earhead have been reported by Swamy *et al.* (2018) [14], Tirkey *et al.* (2021) [15] and Vinodhini *et al.* (2022) [17]. Similar findings of high heritability coupled with high genetic advance for fodder yield per plant were reported by Warkad *et al.* (2008) [18], Godbharle *et al.* (2010) [9], Arunkumar *et al.* (2013) [1], Swamy *et al.* (2018) [14], Dhutmal *et al.* (2020) [7], Tirkey *et al.* (2021) [15], Chavhan *et al.* (2023) [3] and Vinodhini *et al.* (2022) [17].

Table 1: Analysis of variance for fifteen characters in 'B' and 'R' lines of *kharif* sorghum

Sr. No	Source of variation	d.f	Plant height	Days to 50% Flowering	Days to maturity	No. of primaries per panicle	Diameter of earhead	Earhead length	Grain yield per plant	100 seed weight	Fodder yield per plant	Harvest index	Flag leaf length	SPAD (SCMR) value	Leaf area	Flag leaf area	Leaf area index
1	Replication	1	1.397	2.483	6.897	44.845	0.004	6.029	0.099	0.047	16.676	0.003	24.766	19.442	1,854.90	132.004	0.049
2	Treatment	28	733.712**	12.824*	13.214*	107.836**	1.332**	23.070**	133.959**	0.551**	571.876**	29.818**	114.269**	31.905*	9729.133**	4682.917**	0.504**
3	Error	28	134.754	6.59	6.897	25.309	0.102	3.199	4.501	0.028	15.61	0.938	8.892	13.369	654.734	283.71	0.03

Table 2: The Mean performances of fifteen characters studied in 'B' and 'R' lines of *kharif* sorghum.

Sr. No	Genotypes	Plant height (cm)	Days to 50% flowering	Days to maturity	No. of primaries per panicle	Diameter of earhead	Earhead length	Grain yield per plant	100 seed weight	Fodder yield per plant	Harvest index	Flag leaf length	SCMR value	Leaf area	Flag leaf area	Leaf area index
1	PMS 71B	162	82	124	64	5.5	28.5	46.0	3.15	144.4	25.16	58.4	50.41	488.8	331.0	3.13
2	PMS 28B	135	83	123	67	3.6	21.4	32.4	2.08	142.7	18.51	59.2	48.59	465.2	356.2	3.45
3	PMS 101B	147	78	120	55	3.7	22.7	35.0	2.16	157.0	18.70	42.2	46.21	432.8	303.6	2.23
4	PMS 49B	155	80	120	57	4.7	25.8	40.4	3.50	157.4	21.42	50.8	38.12	416.2	233.4	2.77
5	PMS 42B	157	81	122	61	3.5	27.9	40.9	2.61	142.8	22.27	38.8	44.69	479.8	326.1	3.18
6	PMS 1004B	161	82	123	61	4.9	29.1	45.4	2.85	151.8	25.03	60.3	54.90	450.4	352.5	3.66
7	PMS 131B	121	84	124	73	4.6	26.1	53.9	2.23	142.2	27.48	32.2	48.88	281.7	237.9	2.47
8	PMS 8B	205	81	126	61	5.8	16.9	56.8	3.62	164.9	28.62	48.9	50.96	461.4	306.2	3.08
9	PMS 150B	140	83	119	69	4.8	21.0	33.8	2.05	133.6	20.18	33.1	48.65	440.2	292.2	2.75
10	PMS 126B	143	78	120	57	4.2	23.0	36.2	3.26	123.5	21.66	52.5	54.88	447.0	222.1	2.11
11	PMS 38B	153	82	123	52	3.4	28.3	28.1	1.73	160.2	14.93	53.0	52.99	532.3	349.8	3.68
12	PMS 237B	167	81	120	63	5.0	28.3	43.9	2.69	169.4	22.58	42.2	52.16	412.9	216.2	2.24
13	KR 130	176	76	117	51	3.7	25.7	42.6	2.78	169.3	22.11	43.7	50.14	472.1	285.2	2.80
14	KR 126	142	82	122	64	4.1	25.0	39.2	2.35	142.6	21.56	48.6	50.96	424.7	262.1	3.14
15	KR 196	137	80	125	73	5.4	29.2	46.0	2.44	144.2	24.20	49.7	52.01	381.0	223.7	2.58
16	KR 123	149	78	124	74	4.5	30.0	49.3	3.03	151.1	24.61	49.3	53.50	468.0	310.2	2.96
17	KR 214	179	76	118	56	3.4	25.7	32.2	1.88	166.4	16.23	50.6	46.75	407.3	239.9	2.80
18	KR 133	183	76	121	47	5.1	26.5	43.5	3.42	167.7	22.60	45.2	46.42	330.7	214.3	2.22
19	KR 225	145	79	119	64	4.0	24.6	39.2	2.22	136.2	21.34	56.8	47.53	443.5	235.8	2.65
20	KR 222	165	81	124	73	6.1	21.4	55.7	3.23	142.8	28.06	49.4	53.40	507.9	257.8	2.78
21	KR 227	161	85	127	63	4.5	25.9	41.3	2.40	132.4	23.78	44.9	49.02	458.5	226.5	3.35
22	KR 228	175	82	125	70	4.5	19.0	24.2	3.06	153.5	13.61	43.9	42.54	346.5	248.3	2.06
23	KR 229	186	81	126	71	5.7	26.5	52.5	3.26	149.8	27.95	45.2	49.71	387.8	214.9	2.45
24	KR 230	140	76	120	55	4.5	22.9	36.6	2.32	117.7	20.73	45.1	54.62	349.2	245.6	2.60
25	KR 231	165	81	124	73	6.1	32.3	54.5	2.00	138.6	28.22	52.4	53.90	450.1	329.3	3.42
26	KR 232	156	79	120	64	5.9	25.0	39.8	2.81	149.3	21.04	29.7	49.73	246.4	202.1	2.22
27	KR 233	136	84	120	66	3.9	22.9	35.3	2.22	126.4	21.81	42.1	46.93	290.7	259.2	1.78
28	KR 234	177	83	125	65	4.6	24.5	45.3	2.96	123.8	26.77	48.8	53.73	377.5	274.6	3.05
29	KR 235	184	83	123	62	4.7	25.7	42.0	2.67	195.8	22.67	43.3	54.56	343.6	205.9	2.31
	General Mean	158	80	122	63	4.6	25.2	41.8	2.65	148.2	22.54	46.9	49.89	413.6	267.7	2.75
	SE (m)±	8.21	1.82	1.85	3.56	0.23	1.26	1.50	0.12	2.79	0.68	2.11	2.59	18.09	11.91	0.12
	CD at 5%	23.78	5.26	5.38	10.31	0.65	3.66	4.35	0.34	8.09	1.98	6.11	7.49	52.41	34.51	0.36
	C.V	7.33	3.19	2.15	8.01	6.93	7.09	5.08	6.33	2.67	4.30	6.36	7.33	6.19	6.29	6.33

Table 3: Mean and genetic variability parameters for fifteen characters in 'B' and 'R' lines of *kharif* sorghum

Character	Range		Mean	Genotypic coefficient of variance	Phenotypic coefficient of variance	Heritability %	Genetic advance	Genetic advance value % mean
	Minimum	Maximum						
Plant height	121	205	158	10.921	13.150	68.967	29.605	18.683
Days to 50% flowering	76	85	80	2.196	3.874	32.111	2.061	2.563
Days to maturity	117	127	122	1.457	2.599	31.415	2.052	1.682
No. of primaries per panicle	47	74	63	10.227	12.990	61.983	10.418	16.586
Diameter of earhead	3.35	6.10	4.61	17.003	18.361	85.753	1.496	32.434
Earhead length	16.90	32.30	25.22	12.499	14.371	75.644	5.647	22.393
Grain yield per plant	24.20	56.80	41.79	19.252	19.910	93.498	16.026	38.349
100 seed weight	1.73	3.62	2.65	19.283	20.295	90.271	1.001	37.740
Fodder yield per plant	117.70	195.80	148.19	11.254	11.566	94.686	33.430	22.559
Harvest index	13.61	28.62	22.54	16.856	17.394	93.903	7.586	33.648
Flag leaf length	29.70	60.30	46.91	15.475	16.730	85.560	13.831	29.488
SCMR value	38.12	54.90	49.89	6.102	9.536	40.942	4.013	8.043
Leaf area	246.40	532.28	413.58	16.287	17.422	87.389	129.715	31.364
Flag leaf area	202.10	356.22	267.66	17.522	18.618	88.575	90.928	33.971
Leaf area index	1.78	3.68	2.75	17.675	18.771	88.659	0.944	34.284

Conclusions

The present study provides valuable insights into the genetic variability, heritability and genetic advance in twenty-nine sorghum genotypes under the *kharif* season. The significant differences observed among the fifteen traits underscore the genetic diversity within the genotypes offering a promising opportunity for trait selection. High heritability combined with high genetic advance as a percentage of mean especially for traits like earhead diameter, grain yield, 100 seed weight and fodder yield suggest these traits are primarily controlled by additive gene effects making selection highly effective for genetic improvement. Study demonstrates that targeted selection for key yield-contributing traits particularly those with high heritability and genetic advance can lead to significant gains in sorghum breeding efforts. These findings provide a solid foundation for physiologists, researchers and breeders to enhance productivity and resilience in sorghum crops.

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