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Variability studies in kharif sorghum (*Sorghum bicolor* L. Moench)

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Abstract
High estimates of genotypic and phenotypic coefficient of variation were recorded for plant height, number of primaries per panicle, panicle type, glume coverage, grain color field grain mold rating, threshed grain mold rating, grain yield per plant, fodder yield, glume color, germination percentage and grain hardness. While traits with moderate GCV and PCV values were panicle length and 100-seed weight. Days to 50% flowering, days to maturity and grain density were categorized as low. The characters plant height, number of primaries per panicle, grain color, FGMR, grain yield, TGMR, fodder yield, glume color and grain hardness expressed high estimate of heritability accompanied with moderate to high genetic advance indicating additive gene action and thus selection for these characters in genetically diverse material would be more effective for desired genetic improvement. significant and positive correlation of grain yield were observed with characters *viz.*, panicle length, number of primaries per plant, fodder yield per plant, 100- seed weight days to 50% flowering, plant height, panicle length, number of primaries per panicle and fodder yield per plant positive direct effect on grain yield per plant at both genotypic and phenotypic level.

Keywords: Sorghum, variability and correlation

Introduction
Genetic variability for agronomic traits is the key component of breeding programs for broadening the gene pool and would require reliable estimates of heritability in order to plan an efficient breeding program. Yield component breeding to increase grain yield would be most effective, if the components involved are highly heritable and genetically independent or positively correlated with grain yield. However, it is very difficult to judge whether observed variability is highly heritable or not. Moreover, knowledge of heritability is essential for selection based improvement as it indicates the extent of transmissibility of a character into future generations (Sabesan *et al*., 2009).
The information on the nature of association between yield and its components helps in simultaneous selection for many characters associated with yield improvements. Grain yield is complex trait, depend on many attributes. The intensity of association of characters is determined by correlation studies. Such correlation studies help us to know which character should be chosen for selection to bring about the maximum increase in the ultimate. The utilization of heritability and genetic advance of grain yield, grain mould and its attributing traits and inferences from significant genotypic correlation between dependent and independent components should permit selection of predictable genotypes for kharif sorghum improvement.
Simple correlation coefficients were of limited value in selecting superior plants and hence, it is important to study the cause and effect relationship between yield and its components. Direct effect of any component characters on grain yield gives an idea about reliability of indirect selections to be made through that character to bring about improvement in grain yield. If both correlation (genotypic and phenotypic) and the direct effect are high and desirable then correlation explains its true relationship and selection for the character will be effective.

Materials and Methods
The present investigation was carried out at Sorghum Research Station, V.N.M.K.V., Parbhani during kharif 2017 to study 87 genotypes of kharif sorghum including 3 checks (PVK 801, 296 B and B58586) grown in randomised block design in 2 replications with an object to estimate genetic variability and to determine character association among yield and its contributing traits. Observations were recorded on five randomly selected plants in each genotype, raised in a single line of 4.0m length from each replication for plant height (cm), number of primary branches per panicle, panicle length (cm), 100 seed weight (g), grain yield per plant (g), fodder

yield per plant (g), field grain mould rating (%) and threshed grain mould rating (%) where for days to 50 per cent flowering and days to physiological maturity observations were recorded on plot basis.

The mean values of five random plants selected in each plot were used for statistical analysis. The data were subjected to statistical analysis as suggested by Panse and Sukhatme (1967) [5]. Genotypic and phenotypic variances were calculated by using the respective mean squares from variance table (Johnson *et al.*, 1955) [4].

Results and Discussion

The analysis of variance showed significant differences among the genotypes for all the characters. This indicates that wide range of variability among genotypes is present for yield and yield contributing characters and ample scope of improvement by selection (Table 1).

On the basis of mean performance, genotypes GM 2, GM 7, GM 12, GM 59, GM 61, GM 71 were found early for days to 50 per cent flowering. The GM 71, GM 27, GM 36, GM 41, GM 55, GM 68 and GM 80 were found taller than check. Among the genotypes GM 40 and GM 45 were found to longer panicle length than other genotypes and checks. The genotype GM 46 recorded highest number of primaries per panicle followed by GM 1, GM 3, GM 78 and GM 11.

The genotype GM 7 exhibited minimum threshed grain mold rating which was closely followed by GM 69, GM 75, GM 76, GM 1, GM 74 and GM 76. However, maximum grain yield was recorded GM 1 as compared to other genotypes and checks PVK 801, 296 B and B 58586 followed by GM 3, GM 22 and GM 51.

According to Deshmukh *et al*., (1986) [3], Phenotypic Coefficient of Variance (PCV) and Genotypic Coefficient of Variation (GCV) can be categorized as low (<10%), moderate (10-20%) and high (>20%). In the present study, high estimates of genotypic and phenotypic coefficient of variation were recorded for plant height, number of primaries per panicle, field grain mold rating, threshed grain mold rating, grain yield per plant, fodder yield, while traits with moderate GCV and PCV values were panicle length and 100-seed weight. Days to 50% flowering, days to maturity were categorized as low (Table 2).

The PCV was relatively greater than GCV for the traits; however, the magnitude of the difference was low for all the traits except panicle type and panicle length. Further, high values of GCV and PCV for grain yield, panicle type, field grain mold rating and threshed grain mold rating suggested that there was a possibility of improvement of these traits through direct selection. The narrow differences between PCV and GCV suggested their relative resistance to environmental alterations following higher chance of improvement of these traits through selection based on the phenotype performance.

According to Singh (2001) [7], heritability of a trait is considered as very high or high when the values is 80% or more and moderate when it ranged from 40-80% and when it is less than 40%, it is low. Accordingly, high heritability was computed for all the traits under study (Table 2). High degree of heritability estimates suggested that the characters were under genotypic control and selection could be fairly easy and improvement is possible using selection breeding for these traits improvement. In present investigation, heritability ranged from 92.3 to 39.6 per cent. High estimates of heritability in broad sense were obtained for plant height, number of primaries per panicle, FGMR, grain yield, fodder yield and TGMR, Genetic advance as percent mean ranged from 82.38 for Threshed grain mold rating to 7.40 for physiological maturity. Deshmukh *et al*., (1986) [3] classified genetic advance as percent of mean as low (<10%), moderate (10-20%) and high (>20%). Based on this classification, all of the characters except for days to 50% flowering, panicle length and days to maturity had high genetic advance as percent of mean in the current study. However, therefore said traits exhibited moderate to low Genetic advance.

It was suggested that the importance of considering both the genetic advance and heritability of traits rather than considering separately in determining how much can progress be made through selection (Johnson *et al*., 1955) [4]. The heritability estimates along with expected genetic advance are more useful for predicting yield under phenotypic selection than heritability estimates alone. High heritability accompanied with high genetic advance indicates preponderance of additive gene effect, in such case selection may be effective.

The characters plant height, number of primaries per panicle, FGMR, grain yield, TGMR and fodder yield, expressed high estimate of heritability accompanied with moderate to high genetic advance indicating additive gene action and thus selection for these characters in genetically diverse material would be more effective for desired genetic improvement.

High heritability with low genetic advance reveals preponderance of non-additive gene action. Further, days to 50% flowering and days to maturity showed moderate heritability but, did not showed equally high genetic advance.

Similar results were reported by Ambekar *et al*. (2000) [1], Tariq *et al*. (2012) [8] and Chttapur and Biradar (2015) [2].

Correlation

In the present investigation, significant and positive correlation of grain yield were observed with characters *viz.*, panicle length, number of primaries per plant, fodder yield per plant, 100 seed weight (Table 3) were considered most important and selection of these characters could be more effective for improving grain yield in kharif sorghum. Days to 50% flowering, plant height, panicle length, number of primaries per panicle and fodder yield per plant positive direct effect on grain yield per plant at both genotypic and phenotypic level (Table 4). These results are in agreement with the results reported by Sriram and Rao (1983), Lamani *et al.* (1997) and Khandelwal *et al.* (2015) for number of primaries per panicle, plant height and fodder yield per plant. It is important to note that the characters which are significant and positively correlated with grain yield could be considered as important traits for improving yield in kharif sorghum.

The present results revealed that days to 50% flowering, plant height, panicle length, number of primaries per panicle and fodder yield per plant positive direct effect on grain yield per plant at both genotypic and phenotypic level. These results are in agreement with the results reported by Khandelwal *et al.* (2015) for number of primaries per panicle, plant height and fodder yield per plant.

Thus considering the estimates of genetic parameters like GCV, PCV, heritability and genetic advance together, it is evident that the characters viz. number of primaries, FGMR and grain yield, which showed high values for GCV, PCV, heritability and genetic advance were considered most important and selection of these characters could be more effective for improving grain yield in kharif sorghum.

Hence, due consideration should be given to these characters, while planning a breeding strategy for increased grain yield in kharif sorghum. The residual effect was found to be moderate which indicates that there may be some more components that are contributing towards dependent traits.

Table 1: Analysis of variance for seventeen characters of kharif sorghum

Sr. No	Sources of variation	d.f	Days to 50% flowering	Days to physiological maturity	Plant height (cm)	Number of primaries per panicle	Panicle length (cm)	100-seed weight (g)	Grain yield per plant (g)	Fodder yield per plant (g)	Field grain mold rating (1-9 scale)	Threshed grain mold rating (1-9 scale)	Germination percentage (%)	Panicle type (1-9 Scale)	Grain color (1-5 Scale)	Grain hardness (kg/cm^2)	Glume coverage (%)	Glume color (1-7 Scale)	Grain density (kg/ml)
1	Replication	1	2.78	0.02	22.81	18.02	13.79	0.06	11.79	5.88	0.44	0.44	8.29	6.25	0.04	0.08	11.12	0.36	0.01
2	Treatments	86	41.85**	36.36**	5623.63**	251.76**	29.88**	0.37**	357.86**	1650.45**	6.16**	5.34**	374.93**	9.15**	2.52**	2.09**	642.30**	5.07**	0.01**
3	Error	86	9.57	4.39	226.99	11.65	12.91	0.06	37.66	65.88	0.53	0.31	44.29	2.37	0.12	0.14	93.95	0.29	0.00

Table 2: Genetic variability parameters for seventeen characters studied in *kharif* sorghum

Characters	Range		MEAN	σ^2 (g) (Genotypic variance)	σ^2 (p) (Phenotypic variance)	GCV (%)	PCV (%)	h^2. bs. (%)	GA	GA as % of mean
	Minimum	maximum								
Days to 50% flowering	55	70	60.34	16.14	25.71	6.65	8.40	62.8	6.55	10.86
Days to physiological maturity	93	108	98.52	15.98	20.38	4.05	4.58	78.4	7.29	7.40
Plant height (cm)	115	315	219.76	2698.32	2925.31	23.63	24.61	92.2	102.77	46.76
Panicle length (cm)	18	35	27.36	8.48	21.39	10.64	16.90	39.6	3.77	13.80
Number of primaries per panicle	24	76	48.18	120.05	131.71	22.74	23.81	91.2	21.55	44.72
Field grain mold rating (1-9 scale)	1.00	60	3.93	2.81	3.34	41.93	45.70	84.2	3.17	79.24
Grain yield per plant (g)	12.50	60	34.18	160.09	197.76	37.01	41.14	81.0	23.45	68.60
Fodder yield per plant (g)	32	153	84.48	792.28	858.17	33.31	34.67	92.3	55.71	65.94
Threshed grain mold rating (1-9 scale)	1.00	8.00	3.74	2.51	2.82	42.39	44.93	89.0	3.08	82.38
100-seed weight (g)	1.20	3.50	2.00	0.15	0.21	19.53	23.28	70.3	0.67	33.74

Table 3: Genotypic and phenotypic correlation coefficient for grain yield characters studied in *kharif* sorghum

Characters		Days to 50% flowering	Days to physiological maturity	Plant height (cm)	Panicle length (cm)	Number of primaries per panicle	Fodder yield per plant (g)	100-seed weight (g)	Grain yield per plant (g)
Days to 50% flowering	G	1.000	1.142**	0.152	0.113	0.100	-0.156	0.074	-0.113
	P	1.000	0.825**	0.139	-0.053	0.082	-0.136	-0.005	-0.042
Days to physiological maturity	G		1.000	0.176*	0.082	0.063	-0.157	0.002	-0.127
	P		1.000	0.191*	-0.063	0.062	-0.136	0.054	-0.054
Plant height (cm)	G			1.000	0.055	-0.027	-0.016	0.055	0.032
	P			1.000	0.0244	-0.037	-0.018	0.023	0.036
Panicle length (cm)	G				1.000	0.489**	0.362**	0.025	0.514**
	P				1.000	0.271**	0.225**	-0.018	0.224*
Number of primaries per panicle	G					1.000	0.587**	0.094	0.658**
	P					1.000	0.522**	0.086	0.553**
Fodder yield per plant (g)	G						1.000	0.021	1.016**
	P						1.000	-0.003	0.878**
100-seed weight (g)	G							1.000	0.301**
	P							1.00	0.292**
Grain yield per plant (g)	G								1.000
	P								1.000

Significant at 5 per cent level, ** Significant at 1 per cent level.

Table 4: Direct and indirect effects (genotypic level) of yield components on grain yield

Characters		Days to 50% flowering	Days to physiological maturity	Plant height (cm)	Panicle length (cm)	Number of primaries per panicle	Fodder yield per plant (g)	100-seed weight (g)	Grain yield per plant (g)
Days to 50% flowering	G	0.0365	0.043	0.006	0.002	-0.009	-0.005	-0.001	-0.139
	P	0.111	0.090	0.014	-0.002	0.003	-0.015	-0.004	-0.041
Days to physiological maturity	G	-0.042	-0.035	-0.0062	0.002	-0.007	0.005	0.003	-0.139
	P	-0.032	-0.039	-0.007	-0.001	0.001	0.005	0.001	-0.059
Plant height (cm)	G	0.004	0.004	0.028	0.001	0.001	-0.000	-0.001	0.0214
	P	0.005	0.007	0.039	0.001	-0.002	-0.001	0.000	0.033
Panicle length (cm)	G	0.004	-0.004	0.002	0.072	0.105	0.027	0.018	0.450
	P	-0.001	0.001	0.002	0.076	0.001	0.016	0.003	0.264
Number of primaries per panicle	G	0.001	0.001	-0.002	0.006	0.012	0.007	0.001	0.658
	P	0.008	0.006	-0.003	0.028	0.103	0.053	0.008	0.553
Fodder yield per plant (g)	G	-0.154	-0.161	-0.016	0.386	0.497	1.022	0.342	1.026
	P	-0.120	-0.117	-0.016	0.186	0.441	0.850	0.198	0.877
100-seed weight (g)	G	0.001	0.005	0.002	-0.015	-0.002	-0.020	-0.061	0.301
	P	-0.004	-0.002	-0.001	0.004	0.001	0.022	0.094	0.292

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