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Genetic variability, correlation and path analysis studies in R parental lines of *kharif* sorghum (*Sorghum bicolor* (L.) Moench)

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Abstract
The field experiment consists of 26 R lines evaluated at Sorghum Research station, VNMKV, Parbhani to study genetic variability, correlation and path analysis for yield and yield attributing traits. The experiment was conducted by using randomized block design with 3 replications during *kharif* 2020. The analysis of variance showed high significant differences among genotypes indicating the presence of sufficient variability. High estimates of GCV and PCV was observed for grain yield per plant and fodder yield per plant. Number of primaries per cob, number of grains per primary, panicle width, panicle length and 1000 grain weight had positive correlation with grain yield per plant through direct and indirect effects. KR 192-2, KR 219, KR 218, AKR 456, IS 28744 were found to be superior for all characters studied. Thus, selection of such R lines with superior characters contributing to yield will prove beneficial for development of hybrids in plant breeding programme.

Keywords: *kharif* sorghum, genetic variability, correlation, path analysis, R lines

Introduction
Sorghum (*Sorghum bicolor* (L.) Moench) is one of the top cereal crops grown all over the world. It is nutritionally superior to other cereals such as rice and wheat with high fibre content, minerals and slow digestibility (Dayakar Rao *et al.* 2017) [7]. With increase in human population and food demand, sorghum has gained importance in grain, fodder and stalk. Due to its multiple uses, stability of yield and wide adaptability, sorghum has maintained its dependability and value. Therefore, it can play a vital role for the uplift of socio-economic status of the farmers in the areas through development of high yielding varieties (Mulualem *et al*., 2018) [17]. Sorghum is predominantly a self-pollinated crop but it is considered as an often-cross pollinated species, with outcrossing upto 6 % depending on the genotype and growing conditions. The male sterility system has utilized the availability of fertility restorer sources to develop hybrids and commercially use the fertile hybrid seeds. The knowledge of parameters *viz.* Genetic variability, heritability, and genetic advance are perquisite factors for determining potential genotypes in crop improvement programmes. Presence of heritable and non heritable variation and their further inheritance can enable the breeder to plan successful breeding programme. Characters that are economically important are highly influenced by environmental conditions; further exploitation of genetic variability can accelerate these characters. In plant breeding programmes, correlation coefficient analysis measures the mutual relationship between various traits and helps in determining the component characters through which selection can be carried on for genetic improvement of yield. Since grain yield being a complex character, it is necessary to understand the association of independent characters to dependent character grain yield for a crop improvement programme. Path analysis technique was developed and first used for plant selection by Dewey and Lu (1959) [9] was carried out to find the direct and indirect effects of various component traits on grain yield. These biometrical techniques thus make it possible for the selection of elite parental lines.

Materials and Methods
The investigation was carried out using 26 R parental lines received from IIMR- Hyderabad, ICRISAT – Hyderabad, Indore and Akola (Table 1), by using randomized block design with 3 replications during *kharif* 2020 at SRS, VNMKV, Parbhani. The spacing of 45 cm x 15 cm was maintained for row to row and plant to plant respectively. The experimental material was laid out in plot size of 2 rows of 3 m length.

Recommended agronomical and plant protection practices were followed. The observations were recorded for eleven characters *viz.* plant height (cm), days to 50 % flowering, days to maturity, pollen fertility (%), number of primaries per cob, number of grains per primary, panicle width (cm), panicle length (cm), 1000 grain weight (g), grain yield per plant (g) and fodder yield per plant (g). For statistical analysis the mean values of five randomly selected plants were taken for observation in each replication. The data were subjected to statistical analysis as suggested by Panse and Sukhatme (1985) [18]. The genotypic and phenotypic variance was calculated by using mean square from variance table (Burton 1952).

Result and Discussion

The analysis revealed that the differences among the treatment respective of all the characters studied were found to be significant at 5 and 1 percent level of significance indicating the presence of sufficient amount of variability for the characters studied. Best performance on the basis of mean value for grain yield per plant was observed for KR 218 (39.40 g), followed by NR 12-15 (38.91 g). NR 10-15 (62.00 primaries per cob) exhibited high number of primaries. While maximum number of grains per primaries (102.73 grains) and panicle length (3 cm) was observed for IS 28744. NR 12-15 (8.77 cm) exhibited maximum panicle width and 1000 seed weight was maximum for genotype KR 219 (31.83 g).

Range of variation on the basis of mean performance displayed considerable amount of differences but variation was more for characters *viz.,* plant height, number of grains per primaries, fodder yield per plant, panicle length and panicle width. Similar results were reported by Arunkumar *et al.* (2004)) [2], Sharma *et al.* (2004) and Godbharle *et al.* (2010) [13]. The genetic parameters are represented in Table 2.

Sivasubramanian and Menon (1973) [23] categorized GCV and PCV as Low (0 - 10%), moderate (10 - 20%) and High (20% and above). The GCV was lower than PCV for all the characters. High estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were observed for traits *viz.* grain yield per plant and fodder yield per plant whereas moderate GCV and PCV was observed for number of grains per primary, number of primaries per cob, panicle length and panicle width. Similar results were reported by Chavan *et al*. (2010) [5], Arunkumar *et al*. (2013) [2], Jain *et al*. (2016) [14], Gebregergs *et al*. (2020) [11].

According to Johnson *et al.* (1955), Heritability was categorized as Low (0 - 30%), Medium (31 - 60%) and High (61% and above). High heritability was obtained for number of grains per primary, grain yield per plant, panicle length, number of primaries per cob, panicle width, 1000 grain weight, days to maturity, fodder yield per plant. These results were in accordance with findings of Chavan *et al.* (2010) [5]. Moderate heritability was observed for days to 50 per cent flowering and plant height, similar results were given by Gebreyohannes *et al.* (2018) [12] and Warkad *et al.* (2008) [25] respectively while low heritability was observed for pollen fertility.

Genetic advance ranged from 6.80 % to 83.72 %. Johnson *et al.* (1955) [15] classified genetic advance as per cent of mean as low (<10%), moderate (10-20%) and high as (>20%). On the basis of this classification, high mean genetic advance was obtained for plant height, number of primaries per cob, number of grains per cob, panicle length, panicle width, grain yield, fodder yield per plant. Similar findings were recorded by Deepalakshmi *et al.* (2007) [8], Warkad *et al.* (2008) [25], Sabiel *et al.* (2015) [20], Jain *et al.* (2016) [14], Bhagasara *et al.* (2017) [3], Gebregergs *et al.* (2020) [11] for trait plant height, Chavan *et al.* (2010) [5] for number of primaries per cob, number of grains per primary, panicle length, panicle width and grain yield per plant, Arunkumar *et al.* (2013) [2] for fodder yield per plant respectively. High heritability coupled with high genetic advance were observed for characters *viz.* Number of primaries per cob, number of grains per primary, panicle length, panicle width, grain yield per plant and fodder yield per plant respectively.

Correlation

At both genotypic and phenotypic level grain yield was significant and positively correlated with days to maturity, 1000 grain weight, number of primaries per cob, panicle length, panicle width while fodder yield per plant was significant and positive to grain yield at genotypic level only, similar results were obtained by Godbharle *et al.* (2010) [13], Arunkumar *et al.* (2013) [2], Dhutmal *et al.* (2020) [10]. While negative and significant correlation of grain yield was obtained for pollen fertility (Table 3 and 4).

Path Analysis

Direct and positive effect on grain yield per plant was obtained for characters *viz.* Number of primaries per cob, panicle width, panicle length, days to maturity, 1000 grain weight at both genotypic and phenotypic level (Table 5 and 6). The results were in accordance with findings of Chaudhary *et al.* (2001) [6], Deepalakshmi *et al.* (2007) [8], Subhashini *et al.* (2019), Dhutmal *et al.* (2020) [10] for number of primaries, Chaudhary *et al.* (2001) [6], Sharma *et al.* (2006) [22], Akatwijuka *et al.* (2019) [1] for panicle width, Ramaling *et al.* (2016) [19] for 1000 grain weight while negative direct effect for grain yield was obtained for number of grains per primary, fodder yield and pollen fertility.

Positive indirect effects on grain yield were obtained for characters *viz.* Plant height, days to 50 per cent flowering, number of grains per primary, number of primaries per cob, panicle length, Panicle width, fodder yield per plant and 1000 grain weight at both genotypic and phenotypic level. Similar results were given by Dhutmal *et al.* (2020) [10] for plant height and 1000 grain weight, Khandelwal *et al.* (2016), Ramaling *et al.* (2016) [19] for days to 50 per cent flowering and 1000 grain weight, Subhashini *et al.* (2019) [24] for number of primaries per cob, Gebreyohannes *et al.* (2018) [12] for number of grains per primary, Chaudhary *et al.* (2001) [6], Arunkumar *et al.* (2013) [2], Khandelwal *et al.* (2016), Subalakshmi *et al.* (2019) for panicle length and panicle width. Whereas pollen fertility had negative indirect effect on grain yield at genotypic and phenotypic level. Moderate residual values were observed which indicates the effect of other characters contributing to grain yield.

Table 1: List of R line treatment materials used for the study

Sr. No.	R Line (Parental lines)	Source	Sr. No.	R Line (Parental lines)	Source
1	AKR 456	Akola	14	KR 196	Parbhani
2	AKR 504	Akola	15	KR 125	Parbhani
3	AKR 524	Akola	16	KR 130	Parbhani
4	KR 192-2	Parbhani	17	IR 26	Indore
5	KR 218	Parbhani	18	AKR 426	Akola
6	KR 219	Parbhani	19	C 43	IIMR, Hyderabad
7	C 85	IIMR, Hyderabad	20	IS 28744	IIMR, Hyderabad
8	NR 10-15	IIMR, Hyderabad	21	KR 210	Parbhani
9	NR 12-15	IIMR, Hyderabad	22	REC 9825	ICRISAT, Hyderabad
10	NR 39-15	IIMR, Hyderabad	23	98-25 RIL	Parbhani
11	Indore 12	Indore	24	KR196 x AKR 492	Parbhani
12	KR 123	Parbhani	25	KR133 x C43	Parbhani
13	ICSR 196	ICRISAT, Hyderabad	26	PVK 400 x RIL 9743	Parbhani

Table 2: Genetic variability parameters for eleven characters of R parental lines of *kharif* sorghum

Parameters	Plant height (cm)	Days to 50% flowering	Pollen Fertility (%)	Days to maturity	No. of primaries/ cob	No. of grains/ primaries	Panicle length (cm)	Panicle width (cm)	Grain yield/ plant (g)	Fodder yield/ plant (g)	1000 grain weight (g)
Mean	182.23	73.01	89.42	107.14	52.24	78.11	28.47	7.30	28.15	85.67	28.42
Range Lowest	140.00	67.00	71.67	101.67	42.00	51.13	21.93	6.10	21.81	56.67	23.03
Range Highest	242.00	80.33	95.00	112.33	62.00	102.73	35.67	8.77	39.40	123.33	31.82
GCV	15.917	4.293	3.518	3.005	11.232	16.204	14.935	10.112	20.658	21.683	8.468
PCV	20.832	5.581	7.921	3.494	12.017	16.651	15.942	10.973	21.805	27.562	9.582
h^2(Broad Sense)	58.4	59.2	19.7	74	87.4	94.7	87.8	84.9	89.8	61.9	78.1
Gen. Adv 5%	45.657	4.967	2.879	5.705	11.299	25.374	8.206	1.402	11.348	30.104	4.381
Gen. Adv as % of mean 5%	25.054	6.803	3.219	5.325	21.628	32.486	28.821	19.196	40.315	35.14	15.415

Table 3: Genotypic correlation coefficient matrix for R lines

Characters	Plant height (cm)	Days to 50% flowering	Pollen fertility (%)	Days to maturity	No. of primaries/ cob	No. of grains per primary	Panicle length (cm)	Panicle width (cm)	Fodder yield per plant (g)	1000 grain weight (g)	Grain yield per pl
	1	2	3	4	5	6	7	8	9	10	11
Plant height (cm)	1	-0.0739	-0.046	0.0727	0.0275	0.354**	0.1143	0.1301	-0.0207	-0.1333	0.078
Days to 50% flowering		1	-0.416**	0.0365	0.0535	0.1204	0.1398	0.231*	-0.005	0.260*	0.1445
Pollen fertility (%)			1	-0.349**	0.249*	0.0467	-0.448**	-0.243*	-0.233*	-0.273*	-0.228*
Days to maturity				1	0.1633	0.1243	-0.0914	0.1543	0.410**	0.1661	0.500**
No. of primaries/ cob					1	0.570**	0.544**	0.746**	0.441**	0.460**	0.532**
No. of grains per primary						1	0.573**	0.684**	0.0589	0.1692	0.2038
Panicle length (cm)							1	0.545**	0.1303	0.257*	0.362**
Panicle width (cm)								1	0.2146	0.446**	0.491**
Fodder yield per plant (g)									1	0.391**	0.306**
1000 grain weight (g)										1	0.408**
Grain yield per pl											1

Table 4: Phenotypic correlation coefficient matrix for R lines

Characters	Plant height (cm)	Days to 50% flowering	Pollen fertility (%)	Days to maturity	No. of primaries/ cob	No. of grains per primary	Panicle length (cm)	Panicle width (cm)	Fodder yield per plant (g)	1000 grain weight (g)	Grain yield per pl
	1	2	3	4	5	6	7	8	9	10	11
Plant height (cm)	1	0.0401	-0.2559 *	0.0153	0.0407	0.2401 *	0.0226	0.1082	0.048	-0.1604	0.047
Days to 50% flowering		1	-0.1817	0.078	0.0796	0.07	0.0695	0.206	0.0441	0.1801	0.0951
Pollen fertility (%)			1	-0.0427	0.1027	0.0916	-0.1476	-0.0923	-0.1227	-0.008	-0.1353
Days to maturity				1	0.1226	0.0886	-0.1078	0.1082	0.1746	0.1377	0.386**
No. of primaries/ cob					1	0.5245 ***	0.4673 ***	0.6639 ***	0.3232 **	0.4225 ***	0.493**
No. of grains per primary						1	0.5495 ***	0.6132 ***	0.0522	0.1475	0.1901
Panicle length (cm)							1	0.4639 ***	0.1108	0.2182	0.325**
Panicle width (cm)								1	0.2320 *	0.3495 **	0.426**
Fodder yield per plant (g)									1	0.2637 *	0.2202
1000 grain weight (g)										1	0.322**
Grain yield per pl											1

Table 4: Phenotypic correlation coefficient matrix for R lines

Characters	Plant height (cm)	Days to 50% flowering	Pollen fertility (%)	Days to maturity	No. of primaries/ cob	No. of grains /primary	Panicle length (cm)	Panicle width (cm)	Fodder yield/plant (g)	1000 grain weight (g)	Grain yield/ plant (g)
Plant height (cm)	0.1158	-0.0086	-0.0053	0.0084	0.0032	0.041	0.0132	0.0151	-0.0024	-0.0154	0.078
Days to 50% flowering	-0.0047	0.0642	-0.0267	0.0023	0.0034	0.0077	0.009	0.0148	-0.0003	0.0167	0.1445
Pollen fertility (%)	0.0013	0.0116	-0.028	0.0098	-0.007	-0.0013	0.0125	0.0068	0.0065	0.0076	-0.228*
Days to maturity	0.0398	0.02	-0.1914	0.5477	0.0895	0.0681	-0.0501	0.0845	0.2248	0.091	0.500**
No. of primaries/cob	0.009	0.0176	0.0819	0.0537	0.3286	0.1874	0.1786	0.2449	0.1448	0.1511	0.532**
No. of grains/primary	-0.1554	-0.0528	-0.0205	-0.0546	-0.2503	-0.4389	-0.2516	-0.3001	-0.0259	-0.0743	0.2038
Panicle length (cm)	0.0341	0.0417	-0.1337	-0.0273	0.1623	0.1712	0.2986	0.1627	0.0389	0.0767	0.362**
Panicle width (cm)	0.0378	0.0672	-0.0705	0.0448	0.2167	0.1987	0.1584	0.2907	0.0624	0.1296	0.491**
Fodder yield/plant (g)	0.0027	0.0007	0.0307	-0.0539	-0.0579	-0.0077	-0.0171	-0.0282	-0.1314	-0.0514	0.306**
1000 grain weight (g)	-0.0056	0.0109	-0.0115	0.007	0.0193	0.0071	0.0108	0.0187	0.0164	0.042	0.408**
Grain yield/plant (g)	0.0782	0.1445	-0.2282	0.4995	0.5322	0.2038	0.3619	0.4911	0.3062	0.4076	1
Partial R^2	0.0091	0.0093	0.0064	0.2736	0.1749	-0.0894	0.1081	0.1428	-0.0402	0.0171	

Table 5: Direct and indirect effects of yield components on grain yield for R lines at genotypic level

Characters	Plant height (cm)	Days to 50% flowering	Pollen fertility (%)	Days to maturity	No. of primaries/ cob	No. of grains /primary	Panicle length (cm)	Panicle width (cm)	Fodder yield/plant (g)	1000 grain weight (g)	Grain yield/ plant (g)
Plant height (cm)	0.1158	-0.0086	-0.0053	0.0084	0.0032	0.041	0.0132	0.0151	-0.0024	-0.0154	0.078
Days to 50% flowering	-0.0047	0.0642	-0.0267	0.0023	0.0034	0.0077	0.009	0.0148	-0.0003	0.0167	0.1445
Pollen fertility (%)	0.0013	0.0116	-0.028	0.0098	-0.007	-0.0013	0.0125	0.0068	0.0065	0.0076	-0.228*
Days to maturity	0.0398	0.02	-0.1914	0.5477	0.0895	0.0681	-0.0501	0.0845	0.2248	0.091	0.500**
No. of primaries/cob	0.009	0.0176	0.0819	0.0537	0.3286	0.1874	0.1786	0.2449	0.1448	0.1511	0.532**
No. of grains/primary	-0.1554	-0.0528	-0.0205	-0.0546	-0.2503	-0.4389	-0.2516	-0.3001	-0.0259	-0.0743	0.2038
Panicle length (cm)	0.0341	0.0417	-0.1337	-0.0273	0.1623	0.1712	0.2986	0.1627	0.0389	0.0767	0.362**
Panicle width (cm)	0.0378	0.0672	-0.0705	0.0448	0.2167	0.1987	0.1584	0.2907	0.0624	0.1296	0.491**
Fodder yield/plant (g)	0.0027	0.0007	0.0307	-0.0539	-0.0579	-0.0077	-0.0171	-0.0282	-0.1314	-0.0514	0.306**
1000 grain weight (g)	-0.0056	0.0109	-0.0115	0.007	0.0193	0.0071	0.0108	0.0187	0.0164	0.042	0.408**
Grain yield/plant (g)	0.0782	0.1445	-0.2282	0.4995	0.5322	0.2038	0.3619	0.4911	0.3062	0.4076	1
Partial R^2	0.0091	0.0093	0.0064	0.2736	0.1749	-0.0894	0.1081	0.1428	-0.0402	0.0171	

* Indicates significance at 5 per cent level, ** indicates significance at 1 per cent level and *** indicates significance at 0.1 per cent level

Table 6: Direct and indirect effects of yield components on grain yield for R lines at phenotypic level

Characters	Plant height (cm)	Days to 50% flowering	Pollen fertility (%)	Days to maturity	No. of primaries/ cob	No. of grains/ primary	Panicle length (cm)	Panicle width	Fodder yield/plant (g)	1000 grain weight (g)	Grain yield/pl (g)
Plant height (cm)	-0.0248	-0.001	0.0063	-0.0004	-0.001	-0.006	-0.0006	-0.0027	-0.0012	0.004	0.047
Days to 50% flowering	-0.0023	-0.0577	0.0105	-0.0045	-0.0046	-0.004	-0.004	-0.0119	-0.0025	-0.0104	0.0951
Pollen fertility (%)	0.029	0.0206	-0.1135	0.0049	-0.0117	-0.0104	0.0168	0.0105	0.0139	0.0009	-0.1353
Days to maturity	0.0055	0.0283	-0.0155	0.3632	0.0445	0.0322	-0.0392	0.0393	0.0634	0.05	0.386**
No. of primaries/cob	0.0111	0.0216	0.0279	0.0333	0.2715	0.1424	0.1269	0.1802	0.0877	0.1147	0.493**
No. of grains/primary	-0.0339	-0.0099	-0.0129	-0.0125	-0.0741	-0.1412	-0.0776	-0.0866	-0.0074	-0.0208	0.1901
Panicle length (cm)	0.0033	0.0102	-0.0216	-0.0158	0.0683	0.0803	0.1461	0.0678	0.0162	0.0319	0.325**
Panicle width (cm)	0.0263	0.05	-0.0224	0.0263	0.1611	0.1488	0.1126	0.2427	0.0563	0.0848	0.426**
Fodder yield/plant (g)	-0.0031	-0.0028	0.0079	-0.0112	-0.0208	-0.0034	-0.0071	-0.0149	-0.0644	-0.017	0.2202
1000 grain weight (g)	-0.0061	0.0068	-0.0003	0.0052	0.016	0.0056	0.0083	0.0133	0.01	0.038	0.322**
Grain yield/pl (g)	0.0465	0.0951	-0.1353	0.3861	0.4928	0.1901	0.325	0.426	0.2202	0.3218	1
Partial R^2	-0.0012	-0.0055	0.0154	0.1402	0.1338	-0.0268	0.0475	0.1034	-0.0142	0.0122	

*Indicates significance at 5 per cent level and ** indicates significance at 1 per cent level.
Genotypic and phenotypic residual effect**:** 0.405 and 0.520 respectively.

Conclusion

The present study revealed that KR 192-2, KR 219, KR 218, AKR 456, IS 28744 showed better performances for all the characters studied. Selection of traits *viz*. Number of primaries per cob, number of grains per primary, panicle length and panicle width, 1000 grain weight was suggested as per the results obtained to thereby improve the yield for successful breeding programme.

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