Forage Res., **47** (2) : pp. 153-158 (2021) **http://forageresearch.in**

GENETIC VARIABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS OF FORAGE SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH]

ARVINTH S.[1], R. N. PATEL[2], R. A. GAMI[3]* AND A. H. JOSHI[1]

[1]Department of Genetics and Plant Breeding, CPCA, S. D. Agricultural University, Sardarkrushinagar (Gujarat)
[2]Potato Research Station, S.D. Agricultural University, Deesa-385 535 (Gujarat)
[3]Sorghum Research Station, S.D. Agricultural University, Deesa-385 535 (Gujarat)
**(e-mail : ramangami@gmail.com)*

(Received : 01 September 2021; Accepted : 27 September 2021)

SUMMARY

The present investigation was carried out to assess the genetic variability, character association and path analysis in twenty-two sorghum genotypes during kharif-2020 at Sorghum Research Station, Deesa. The magnitude of the phenotypic coefficient of variations was higher than the genotypic coefficient of variations denoting favourable environment influence to some extent for all the characters. GCV and PCV were higher for HCN content, green fodder yield per plant, dry fodder yield per plant, leaf: stem ratio, and stem girth. High heritability coupled with high genetic advance as per cent of mean was manifested by HCN content, green fodder yield per plant, dry fodder yield per plant, leaf: stem ratio, stem girth, crude protein content, leaf width of blade and Brix content indicated the additive gene action and selection would be effective for these characters. The association study implies that the magnitude of genotypic correlation coefficients was higher than phenotypic correlation coefficients for all the characters studied. Green fodder yield per plant showed highly significant and favourable association with a number of leaves per plant, stem girth, leaf length of blade, leaf width of blade, dry fodder yield per plant at genotypic and phenotypic levels and Brix content was highly significantly correlated at the phenotypic level and significantly correlated at the genotypic level. Hence improvement in forage yield of sorghum can be done by simultaneous selection for these traits. Genotypic path analysis showed that the dry fodder yield per plant had a high positive direct effect on green fodder yield per plant, followed by days to 50 per cent flowering, leaf length of blade, number of leaves per plant and leaf width of blade.

Key words : GCV, PCV, heritability, correlation and path analysis

Sorghum bicolor, commonly called sorghum, is an often cross-pollinated crop with a chromosome number 2n = 20. It belongs to the grass family Poaceae, subfamily Panicoidae, tribe Andropogonae, and therefore the subtribe Sorghastrae (Price *et al*., 2005). Sorghum ranks first among cereal fodder crops and is preferred over maize and pearl millet forage because of its high tolerance to wide variation in soil and moisture conditions and better regeneration capacity. It also has moderately salt tolerant nature (Devi *et al.,* 2018).

Livestock is a backbone of Indian agriculture, likewise as the most vital component of the rural economy. In livestock production, feed and fodder constitute about 60 – 70 per cent of the total cost. So, a continuous and steady supply of green fodder to the animals is essential to increase milk production and reduce livestock production costs. However, within the total net cropped area, hardly 5% is used to grow fodder. That's why, in recent years India is facing an acute shortage of feeds and fodder. The demand will reach 1012 million tonnes of green fodder and 631 million tonnes of dry fodder by 2050. At the present level of growth in forage resources, there will be an 18.4% deficit in green fodder and a 13.2% deficit in dry fodder within the year 2050. To meet out the deficit, green forage has to grow at 1.69% annually. (IGFRI, 2015).

There's little or no scope for increasing the cultivation area due to rapid urbanization and industrialization *etc*. Therefore, it is urgent to emphasize increasing forage crop production per unit area to meet the fodder requirement by evolving high yielding and improved varieties of forage crops. Any plant breeding programme's success in developing improved varieties depends on the better understanding of nature and magnitude of genetic variability present within the breeding material. Correlation analysis measures the intensity and direction of associations among characters that are important in a breeding programme and path coefficient analysis allow partitioning of parametric statistic into direct and indirect effects of various traits and therefore help in assessing the cause-effect relationship as well as effective selection. Therefore, the present study was undertaken to assess the genetic variability and to determine the yield components through correlation coefficient and path coefficient analysis.

MATERIALS AND METHODS

The experimental material comprising of twenty-two genotypes was evaluated in randomized block design with three replications at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa during *kharif* – 2020. Each genotype was sown in one row of three-metre length with an optimum spacing of 45cm × 15cm. The observations were recorded both as visual assessment for days to 50 per cent flowering and measurement on five randomly selected plants for plant height (cm), a number of leaves per plant, stem girth (mm), leaf length of blade (cm), leaf width of blade (cm), leaf: stem ratio, dry fodder yield per plant (g), brix content (%), hydrocyanic acid content (ppm), crude protein content (%) and green fodder yield per plant (g). The analysis of variance was carried out as per the procedure suggested by Panse and Sukhatme (1985). The replication wise mean values were used for statistical analysis. The GCV and PCV were estimated as per Burton (1952), while, classification of GCV and PCV was followed by Sivasubramanian and Menon (1973), heritability in a broad sense and genetic advance (GA) as suggested by Johnson *et al.* (1955). The Path analysis was performed according to the method suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variance depicting the mean sum of squares for 12 traits revealed highly significant differences among the genotypes for all the characters studied, which suggest that each genotype are genetically diverse from each other and there is ample scope for selection of characters from these sources for forage sorghum improvement.

The phenotypic and genotypic coefficient of variation were calculated for all the twelve characters and presented in Table 1. In the present study, the little difference between PCV and GCV suggested their relative resistance to environmental alteration whereas magnitude of phenotypic coefficient of variation was higher than the genotypic coefficient of variation denoting favorable influence of the environment to some extent. The similar results also reported by Jayaramachandran *et al.* (2012). A high GCV and PCV were noted for HCN content, green fodder yield per plant, dry fodder yield per plant and leaf: stem ratio suggesting that these traits are influenced by genetic control. Hence, selection can be relied upon these traits for further improvement. These results were in

TABLE 1
The estimates of genetic parameters for different traits in forage sorghum

S. No.	Characters	Heritability (%)	GCV (%)	PCV (%)	GA	GAM (%)
1.	Days to 50% flowering	64.50	6.17	7.68	7.24	10.21
2.	Plant height (cm)	51.60	9.10	12.68	27.45	13.47
3.	Number of leaves per plant (no)	39.30	7.54	12.02	0.81	9.73
4.	Stem girth (mm)	67.40	17.99	21.93	2.82	30.39
5.	Leaf length of blade (cm)	46.60	10.26	15.04	8.90	14.42
6.	Leaf width of blade (cm)	61.00	14.25	18.25	1.41	22.96
7.	Leaf : Stem ratio	73.70	22.35	26.03	0.11	40.74
8.	Dry fodder yield per plant (g)	87.10	26.03	27.89	40.85	50.03
9.	Brix (%)	72.60	11.69	13.71	2.03	20.48
10.	Hydrocyanic acid content (ppm)	96.40	31.50	32.09	14.48	63.70
11.	Crude protein (%)	85.70	12.18	13.16	2.14	23.21
12.	Green fodder yield per plant (g)	88.50	29.16	31.01	106.35	56.50

Where,
GCV (%) and PCV (%) are genotypic and phenotypic coefficient of variation, respectively.
GA and GAM (%) are genetic advance and genetic advance as per cent of mean.

accordance with Kour and Pradhan (2016), Rana *et al*. (2016) and Kumar *et al*. (2020).

Moderate GCV and PCV were noted for crude protein content, brix content, leaf length of blade and leaf width of blade, which shows average chances for selection. Kavipriya *et al*. (2020) reported similar findings. Low GCV and PCV were recorded for days to 50 per cent flowering, suggesting the need for creating variability followed by selection. Similar results were reported by Ranjith *et al*. (2017). Besides, stem girth exerted high to moderate PCV and GCV. In contrast, plant height and number of leaves per plant exerted moderate to low PCV and GCV provide average chances of selection due to influence of environmental factors. Ranjith *et al*. (2017) and Kavipriya *et al*. (2020) also observed differences among PCV and GCV for these traits.

High heritability coupled with high genetic advance as per cent of mean was observed for hydrocyanic acid content, green fodder yield per plant, dry fodder yield per plant, leaf: stem ratio, stem girth, crude protein content, leaf width of blade and brix content suggesting a wide scope for improvement through a selection of these traits. Similarly, high heritability coupled with high genetic advance for some of these traits have been reported by Rana *et al*. (2016), Kour and Pradhan (2016), Sen *et al*. (2019) and Kumar *et al*. (2020). Besides, days to 50 per cent flowering shows high heritability and moderate genetic gain. A similar finding was reported by Ranjith *et al*. (2017). Plant height and leaf length of blade showed moderate heritability and moderate genetic gain, indicating delayed selection may be effective for these traits. Jayaramachandran *et al*. (2012) also reported similar result for plant height. Moderate value of heritability coupled with low genetic advance was recorded for number of leaves per plant. This variation might be due to high environmental influence in development of this trait in forage sorghum.

The results of genotypic and phenotypic correlation coefficients are given in Table 2. The correlation coefficient analysis shows that genotypic correlation coefficients were higher in magnitude than their corresponding phenotypic correlation coefficients for all the characters studied, indicated the high degree of association between the two characters genetically,

TABLE 2

Genotypic and phenotypic correlation coefficients among different characters in forage sorghum

Characters		PH	LN	SG	LL	LW	LS	DFY	TSS	HCN	CP	GFY
DF	r_g	-0.090	0.889**	0.717**	0.544**	0.618**	0.456*	0.296	0.193	0.022	0.501*	0.482*
	r_p	-0.147	0.538**	0.588**	0.438**	0.463**	0.364**	0.277*	0.191	-0.008	0.426**	0.405**
PH	r_g		0.366	-0.031	-0.079	-0.130	0.051	0.073	-0.107	-0.367	-0.063	0.007
	r_p		0.358**	-0.039	-0.026	-0.046	0.011	0.066	0.008	-0.268*	-0.006	-0.059
LN	r_g			0.613**	0.134	0.567**	0.504*	0.570**	0.432*	-0.139	0.518*	0.581**
	r_p			0.442**	0.219	0.485**	0.271*	0.396**	0.234	-0.112	0.313**	0.435**
SG	r_g				0.775**	0.824**	0.121	0.778**	0.440*	0.443*	0.26	0.863**
	r_p				0.684**	0.748**	0.184	0.648**	0.308*	0.367**	0.182	0.760**
LL	r_g					0.661**	0.143	0.47*	0.157	0.260	0.154	0.564**
	r_p					0.501**	0.143	0.358**	0.138	0.210	0.139	0.454**
LW	r_g						0.239	0.682**	0.475*	0.316	0.371	0.710**
	r_p						0.220	0.564**	0.286*	0.233	0.286*	0.617**
LS	r_g							-0.030	-0.015	-0.378	0.046	-0.108
	r_p							-0.051	-0.035	-0.304*	0.021	-0.041
DFY	r_g								0.468*	0.592**	0.174	0.974**
	r_p								0.424**	0.554**	0.173	0.894**
TSS	r_g									0.105	-0.037	0.444*
	r_p									0.091	0.041	0.348**
HCN	r_g										0.058	0.622**
	r_p										0.050	0.582**
CP	r_g											0.232
	r_p											0.213

Where, DF - Days to 50 per cent flowering, PH - Plant height, LN - Number of leaves per plant, SG - Stem girth, LL - Leaf length of blade, LW - Leaf width of blade, L:S - Leaf: stem ratio, DFY - Dry fodder yield per plant, TSS - Brix content, HCN - Hydrocyanic acid content, CP - Crude protein content, GFY - Green fodder yield per plant.

*,**Significance at 5 and 1 per cent probability level.

TABLE 3
Path coefficient analysis showing direct (diagonal and bold) and indirect effects of various traits on green fodder yield per plant of forage sorghum

Characters	DF	PH	LN	SG	LL	LW	LS	DFY	TSS	HCN	CP	GFY
DF	**0.403**	0.007	0.203	-0.304	0.135	0.015	-0.151	0.277	-0.012	0.002	-0.092	0.482*
PH	-0.036	**-0.074**	0.084	0.013	-0.020	-0.003	-0.017	0.068	0.007	-0.026	0.012	0.007
LN	0.358	-0.027	**0.228**	-0.260	0.033	0.013	-0.166	0.533	-0.026	-0.010	-0.095	0.581**
SG	0.289	0.002	0.140	**-0.424**	0.193	0.019	-0.040	0.727	-0.027	0.032	-0.048	0.863**
LL	0.219	0.006	0.031	-0.329	**0.249**	0.016	-0.047	0.440	-0.010	0.019	-0.028	0.564**
LW	0.249	0.010	0.129	-0.349	0.164	**0.023**	-0.079	0.638	-0.029	0.023	-0.068	0.710**
LS	0.184	-0.004	0.115	-0.051	0.036	0.006	**-0.330**	-0.028	0.001	-0.027	-0.009	-0.108
DFY	0.119	-0.005	0.130	-0.330	0.117	0.016	0.010	**0.935**	-0.029	0.043	-0.032	0.974**
TSS	0.078	0.008	0.099	-0.186	0.039	0.011	0.005	0.438	**-0.061**	0.008	0.007	0.444*
HCN	0.009	0.027	-0.032	-0.188	0.065	0.007	0.125	0.554	-0.006	**0.072**	-0.011	0.622**
CP	0.202	0.005	0.118	-0.110	0.038	0.009	-0.015	0.163	0.002	0.004	**-0.184**	0.232

Where, DF - Days to 50 per cent flowering, PH - Plant height, LN - Number of leaves per plant, SG - Stem girth, LL - Leaf length of blade, LW - Leaf width of blade, L:S - Leaf: stem ratio, DFY - Dry fodder yield per plant, TSS - Brix content, HCN - Hydrocyanic acid content, CP - Crude protein content, GFY - Green fodder yield per plant.
Residual effect = -0.0378
Values mentioned in bold are denoting direct effect.
* ,**Significance at 5 per cent and 1 per cent probability level.

and its phenotype might be lessened due to the mild interaction of environmental factors. Similar results were also reported by Goswami *et al.* (2020). The trait green fodder yield per plant recorded positive and significant association with days to 50 per cent flowering, number of leaves per plant, stem girth, leaf length of blade, leaf width of blade, dry fodder yield per plant, brix content and HCN content. Similar results were also reported by Prakash *et al.* (2010), Iyanar *et al.* (2010), Aruna *et al.* (2015), Diwakar *et al.* (2016) and Dev *et al.* (2019). Hence selection criteria should be considered on these traits to improve fodder yield and quality parameters in forage sorghum, but the positive influence of characters *viz.*, days to 50 per cent flowering and HCN content was undesirable one. The positive and non-significant association was recorded with plant height and crude protein content and also reported by Rana *et al.* (2016) and Aruna *et al.* (2015). Leaf: stem ratio recorded negative and non-significant association with green fodder yield per plant. Soujanya *et al.* (2018) recorded a similar finding.

Correlation coefficient analysis indicates only the general association between any two traits. In such cases, path coefficient analysis is done to partition the correlation coefficient into direct and indirect effects. While computing the path coefficient, the trait green fodder yield per plant was considered as a dependent variable. The direct and indirect effects of 11 traits on green fodder yield are presented in Table 3 and Fig. 1.

From the present study of path analysis together with correlation coefficient showed that dry fodder yield per plant (0.935) exhibited highly significant positive correlation and positive direct effect on green fodder yield per plant followed by days to 50 per cent flowering (0.403), leaf length of blade (0.249), number of leaves per plant (0.228), HCN content (0.072) and leaf width of blade (0.023). These traits also show positive inter-association with other traits and positive indirect effects on green fodder yield per plant. Hence the traits *viz.,* leaf width of blade, leaf length of blade, number of leaves per plant and dry fodder yield per plant may be given due importance in the selection programme to improve the fodder yield in sorghum. Similar results were reported by Jain *et al.* (2010) and Iyanar *et al.* (2010), Jain and Patel (2013) and Sumon *et al.* (2021). Whereas the traits *viz.*, plant height, stem girth and brix content showed positive association with green fodder yield per plant, the direct effect of these traits was negative, which may be the result of the indirect effect of these *via* other traits. Jain and Patel (2013) also observed a similar trend for plant height and stem girth and Diwakar *et al.* (2016) for brix content. Further, the low residual effect suggested that, the characters selected for study of association with green fodder yield per plant had maximum contribution and validated the traits chosen for the study in present investigation.

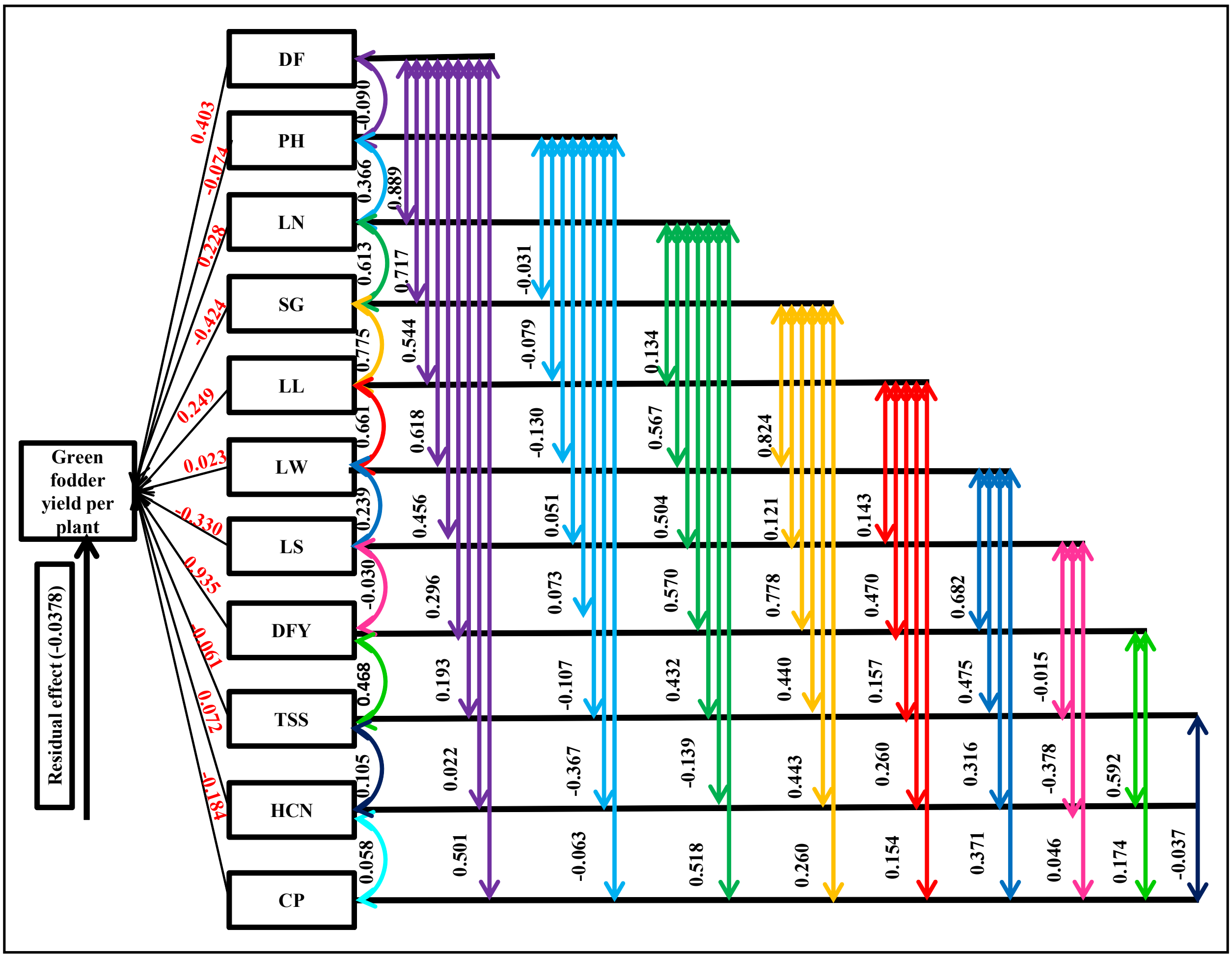

Fig. 1. Genotypic path diagram for green fodder yield per plant.

Where,
DF – Days to 50 per cent flowering, PH – Plant height, LN – Number of leaves per plant, SG – Stem girth, LL – Leaf length of blade, LW – Leaf width of blade, L:S – Leaf: stem ratio, DFY – Dry fodder yield per plant, TSS – Brix content, HCN – Hydrocyanic acid content, CP – Crude protein content.

CONCLUSION

The conclusion that can be reached from the study of various variability parameters is that the characters hydrocyanic acid content, green fodder yield per plant, dry fodder yield per plant, leaf: stem ratio, stem girth, crude protein content, leaf width of blade and brix content having a high heritability as well as high genetic advance as per cent of mean suggesting a wide scope for improvement through selection of these traits. The correlation and path coefficient analysis revealed that the characters dry fodder yield per plant, number of leaves per plant, leaf length of blade and leaf width of blade may given due importance in forage sorghum improvement.

REFERENCES

Aruna, C., M. Swarnalatha, P. Praveen kumar, V. Devender, M. Suguna, M. Blummel, and J. V. Patil, 2015 : Genetic options for improving fodder yield and quality in forage sorghum, Tropical Grasslands – *Forrajes Tropicales,* **3**: 49-58.

Burton, G.W., 1952 : Quantitative inheritance of grasses, *6th Intl. Grassland Cong. Proc.*, **1**: 227-283.

Dev, A., S. K. Singh, P. Chand, M. Kumar, M. Poonia, and M. Srivastava, 2019 : Genetic variability, character association and path analysis in forage sorghum, *J. Pharmacogn. Phytochem.,* **8**(5): 1135-1139.

Devi, S., Satpal, H. S. Talwar, Ramprakash, and V. Goyal, 2018 : Performance of sorghum [*Sorghum bicolor* (L.) Moench] under salt stress, *Forage Res.,* **44**(3): 209-212.

Dewey, D. R., and K. H. Lu, 1959 : A correlation and path coefficient of component of crested wheat grass seed production, *Agron. J.,* **51**: 515-518.

Diwakar, A., B. R. Ranwah, S. Singh, and S. K. Sinha, 2016 : Correlation and path analysis in sorghum [*Sorghum bicolor* (L.) Moench], *Research in Environment and Life Sciences,* **9**(3): 382-384.

Goswami, S. J., P. T. Patel, R. A. Gami, R. N. Patel, and A. B. Khatri, 2020 : Correlation and path analysis study of different characters for grain yield and fodder purpose in sorghum [*Sorghum bicolor* (L.) Moench], *Electron. J. Plant Breed.,* **11**(4): 1053-1061.

IGFRI., 2015 : Vision-2050, Indian Grassland and Forage Research Institute, Jhansi (UP), pp. 21.

Iyanar, K., G. Vijayakumar, and A. K. Fazllullah, 2010 : Correlation and path analysis in multi-cut fodder sorghum, *Electron. J. Plant Breed.,* **1**(4): 1006-1009.

Jain, S. K., and P. R. Patel, 2013 : Variability, correlation and path analysis studies in sorghum [*Sorghum bicolor* (L.) Moench], *Forage Res.,* **39**(1): 27-30.

Jain, S. K., M. Elangovan, and N. V. Patel, 2010 : Correlation and path coefficient analysis for agronomical traits in forage sorghum [*Sorghum bicolor* (L.) Moench], *Indian J. Genet. Plant Breed.,* **23**(1): 15-18.

Jayaramachandran, M., N. Kumaravadivel. G. Kandasamy, and Susan Eapen, 2012 : Evaluation of somaclonal variations for quantitative traits in fodder sorghum, *Int. J. Bio-Resour. Stress Manag.*, **3**(1): 22-25.

Johnson, H. W., H. F. Robinson, and R. E. Comstock, 1955 : Estimate of genetic and environmental variability in soya bea, *Agron. J.,* **47**: 314-18.

Kavipriya, C., A. Yuvaraja, C. Vanniarajan, K. Senthil, and J. Ramalingam, 2020 : Genetic variability and multivariate analyses in coloured sorghum landraces [*Sorghum bicolor* (L.) Moench] of Tamilnadu, *Electron. J. Plant Breed.,* **11**(2): 538-542.

Kour, S., and U. K. Pradhan, 2016 : Genetic variability, heritability and expected genetic advance for yield and yield components in forage sorghum [*Sorghum bicolor* (L.) Moench], *RASI: J. Soc. Appl. Stat. Agric. Sci.,* **1**(2): 71-76.

Kumar, R., S. K. Singh, S. Singh, A. Kumar, and M. Kumar, 2020 : Study of genetic variability and heritability of yield and its components in forage sorghum [*Sorghum bicolor* (L.) Moench], *J. Pharmacogn. Phytochem.,* **9**(5): 3103-3106.

Panse, V. G., and P. V. Sukhatne, 1985 : Statistical methods for agricultural workers, "11th Ed., *ICAR, New Delhi",* **4**: 97-156.

Prakash, R., K. Ganesamurthy, A. Nirmalakumari, and P. Nagarajan, 2010 : Correlation and path analysis in sorghum [*Sorghum bicolor* (L.) Moench], *Electron. J. Plant Breed.,* **1**(3): 315-318.

Price, J. H., S. D. Dillon, G. Hodnett, W. L. Rooney, L. Ross, and J. S. Johnston, 2005 : Genome evolution in the genus sorghum (Poaceae), *Ann. Bot.,* **95**(1): 219-227.

Rana, H. R., K. N. Prajapati, K. J. Suthar, and H. R. Kher, 2016 : Study of variability, correlation and path analysis in forage sorghum [*Sorghum bicolor* (L.) Moench], *The Bioscan*, **11**(1): 259-263.

Ranjith, P., R. B. Ghorade, V. V. Kalpande, and A. M. Dange, 2017 : Genetic variability, heritability and genetic advance for grain yield and yield components in sorghum, *Int. J. Farm Sci.,* **7**(1): 90-93.

Sen, R., R. K. Saini, S. K. Singh, and Ashish Kumar, 2019 : Study of genetic variability of fodder yield and its components in forage sorghum [*Sorghum bicolor* (L.) Moench], *Forage Res.,* **45**(2): 156-158.

Sivasubramanian, S., and P. M. Menon, 1973 : Genotypic and phenotypic variability in rice, *Madras Agric. J.,* **60**(9-13): 1093-1096.

Soujanya, T., T. Shashikala, and V. Umakanth, 2018 : Studies on character association and path analysis for fodder yield and its components in sweet sorghum [*Sorghum bicolor* (L.)], *Int. J. Pure Appl. Biosci.*, **6**(3): 2320-7051.

Sumon, T., P. Kumari, S. K. Pahuja, J. Tokas, and S. Yashveer, 2021 : Identification of dual type sorghum genotypes based on correlation and path coefficient studies, *Forage Res.,* **46**(4): 302-307.