Study on path analysis in forage sorghum [*Sorghum bicolor* (L) Moench]

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ABSTRACT

Present study comprising 45 F_1s along with 10 parents diallel fashion design was conducted during kharif season at the Crop Research Centre, Sardar Vallabhbhai Patel University, Meerut, Uttar Pradesh. The analysis of variance was found differing highly significantly for all the attributes of plant height, leaf area, days to 50 per cent flowering, stem girth, leaf breadth, total soluble solids, leaf length, leaves per plant, leaf-stem ratio and green fodder yield, which indicated greater variability in the existing material among the parents with respect to fodder yield and yield contributing parammeters. Phenotypic and genotypic coefficients of variation were estimated high (more than 25%) for leaf-stem ratio, leaves per plant and green fodder yield, which suggested more variability and scope for selection in improving these attributes. High heritability coupled with high genetic advance as per cent of mean was observed for plant height, leaf area, stem girth, leaves per plant, leaf-stem ratio, total soluble solids and green fodder yield per plant which showed that these traits were highly heritable and selection of high performing genotypes is possible to improve these attributes. Green fodder yield revealed significant and positive correlation with stem girth, leaves per plant and leaf-stem ratio at both genotypic and phenotypic levels. These characters may be considered as important yield components in forage sorghum. Leaf breadth displayed high order of direct effect on green fodder yield per plant followed by leaf area, plant height and leaves per plant at both phenotypic and genotypic levels that can lead to considerable improvement of green fodder yield in sorghum.

Keywords: Sorghum; path analysis; phenotypic coefficient; genotypic coefficient; heritability

INTRODUCTION

Sorghum [*Sorghum bicolor* (L) Moench], which belongs to family Poaceae, is the most important fodder crop grown widely during summer and monsoon seasons in northwestern states and to a limited scale in central and southern states of India. It is one of the widely preferred forage crops due to its quick growing habit, high yield potential, better palatability and digestibility and various forms of its utilization like green chop, stover, silage, hay etc. It is also relatively drought tolerant and has potential to tap with subsoil moisture reserves that make it suitable for cultivation in rainfed areas. In India, sorghum is locally known as Jowar and ranks third in area and production, after rice and wheat (Basavaraja et al 2005).

The grain of sorghum forms a staple food in the diets of the rural people in these areas and the fodder is fed to livestock. Sorghum has generally been grown as a rainfed crop since it is grown on soils of low fertility and withstands drought better than most other cereals. Under these conditions, production is generally low. It is an important kharif season crop which is widely grown to meet the green as well as dry fodder requirement of the livestock. It is a fast growing, adaptive to vast environmental conditions and provides palatable nutritious fodder to the animals. Sorghum is one of the most important fodder crops in the rainfed conditions of India as well as in Uttar Pradesh. Sorghum being a short duration, drought and salt tolerant crop, well adaptive to arid regions, is considered promising fodder crop. During the last 30 years the role of sorghum as a major source of fodder has not diminished while its importance as a forage crop has increased.

The average fodder yield of sorghum in Uttar Pradesh is low because major area is covered by local and outdated varieties and selections. Low fodder production and lesser feed availability are the major limiting factors for increasing livestock productivity in India. Improvement in livestock production depends on the proper quality and quantity of feed and fodder. It is estimated that the 60-70 per cent of total cost in livestock production is due to feed and fodder (Veena and Nagratna 2019).

As per the estimates of the Indian Council for Agricultural Research (ICAR)-affiliated National Institute of Animal Nutrition and Physiology (NIANP), the deficit in the requirement and the availability of dry fodder, green fodder and concentrates during 2015 was to the extent of 21, 26 and 34 per cent respectively (Parmar and Misra 2020).

The average fodder yield of sorghum in Uttar Pradesh is low because major area is covered by local and outdated varieties and selections, which are not responsive to improved cultural and fertility practices. The area under high forage yielding varieties is negligible in western Uttar Pradesh. Hence, it is essential to develop superior varieties with a significant superiority in term of green fodder yield. The total area, production and productivity of sorghum are 4.71 million hectares, 4.73 million tonnes and 1,005 kg per hectare respectively in India and the total area, production and productivity are 0.17 million hectares, 0.23 million tonnes and 1,349 kg per hectare respectively in Uttar Pradesh (Anon 2020).

Knowledge about variability, heritability and genetic advance help the plant breeder in selection of elite genotypes from diverse genetic population. Correlation coefficient and path analysis provide the mutual relationship between various plants and the association of these characters with yield.

The present study was conducted to find out the genetic parameter, association of certain characters, their direct contribution to yield and indirect effects through other characters on yield of forage sorghum.

MATERIAL and METHODS

The experimental material for the present study comprising 45 F_1s along with 10 parents diallel fashion design was evaluated in a completely randomized block design with three replications during kharif season at the Crop Research Centre, Sardar Vallabhbhai Patel University, Meerut, Uttar Pradesh. Each of 45 F_1s was planted in five meter long two-row plot and the parents were planted in two rows. The rows were spaced 30 cm apart and plant to plant distance was maintained at 10 cm. Observations were recorded on five competitive plants for days to 50 per cent flowering, plant height, leaf length, leaf breadth, stem girth, leaves per plant, leaf area, leaf-stem ratio, total soluble solids and green fodder yield per plant. The coefficients of variation, heritability in broad sense and expected genetic advance were estimated as suggested by Panse and Sukhatme (1985), Burton (1952), Crumpacker and Allard (1962), Robinson et al (1949) and Johnson et al (1955). Correlation coefficients were calculated as per the methods suggested by Croxton and Couden (1964) and path coefficient was worked out as per the method of Dewey and Lu (1959).

RESULTS and DISCUSSION

Analysis of variance (Table 1) indicated highly significant mean differences among the parents and hybrids for days to 50 per cent flowering, plant height, leaf breadth, leaf length, leaf area, stem girth, leaves per plant, leaf-stem ratio, total soluble solids and green fodder yield. High amount of genetic variability for these characters has also been reported earlier by Parmar et al (2019) and Prasad and Sridhar (2020).

Genotypic and phenotypic variances are of little meaning as they do not have any clear limit or ceiling and at the same time, the categorization of the genotypic variance as low or high is difficult, rendering them unsuitable for comparison of two populations with desired precision when expressed in absolute values.

To overcome this difficulty, the genotypic and phenotypic coefficients of variation that are free from the unit of measurement, can be conveniently employed for making comparisons between populations and different metric traits of population.

Phenotypic and genotypic coefficients of variation were observed high (more than 25%) for leaves per plant (29.66 and 33.80), leaf-stem ratio (38.74 and 37.88) and green fodder yield (29.99 and 34.01) respectively, which indicated more variability and scope for selection in improving these characters (Table 2). Similar results were obtained by Nyadanu and Dikera (2014) and Singh et al (2016).

Table1. Analysis of variance for fodder yield and its components in forage sorghum

Source of variation	df	Days to 50% flowering	Plant height (cm)	Leaf breadth (cm)	Leaf length (cm)	Leaf area (cm^2)	Stem girth (mm)	Leaves/ plant	Leaf-stem ratio	Total soluble solids (%)	Green fodder yield (g/plant)
Parents	9	111.21**	3089.33**	1.70**	73.20**	9701.07**	8.72**	8.35**	0.98*	3.49**	19,738.78**
Treatments	54	77.89**	2666.00**	1.48**	75.38**	5844.45**	13.29**	8.49**	0.64*	3.85**	14,805.22**
Crosses	44	72.99**	2444.32**	1.78**	65.86**	5169.77**	11.62**	8.90**	0.77*	3.00**	12,384.39**
Parents vs Crosse	1	7.39**	168.55**	0.90**	25.99**	258.88**	1.80**	1.87**	0.08	1.08**	77,771.30**
Replications	2	16.55	263.99	0.60	43.07	3554.66	7.99	2.79	0.18	0.07	3,890.19
Error	108	3.59	74.11	0.07	4.90	282.11	0.69	0.38	0.27	0.18	237.05

*Significant at 5% level of significance, **Significant at 1% level of significance; df = Degrees of freedom

Genotypic coefficients of variation were generally higher than their corresponding phenotypic coefficients of variation for most of the characters studied, that indicated that the variability existing in these traits was due to genetic factors and they were little affected by environmental factors. Jain et al (2017) also reported similar findings with respect to phenotypic and genotypic coefficients of variation.

Estimate of high (>60%) heritability (broad sense) was observed for all the traits viz days to 50 per cent flowering (88.12), plant height (92.29), leaf breadth (88.54), leaf length (81.18), leaf area (82.66), stem girth (91.33), leaves per plant (92.21), leaf-stem ratio (95.64), total soluble solids (81.49) and green fodder yield (91.88) that suggested that these characters were under genotypic control (Table 2). Similar observations were also reported by Damor et al (2018), Prasad and Sridhar (2020) and Arvinth et al (2021).

High (>20%) estimates of genetic advance expressed as per cent of mean were observed for plant height (23.22), leaf area (24.77), stem girth (22.77), leaves per plant (25.45), leaf-stem ratio (74.48), total soluble solids (22.22) and green fodder yield per plant (33.97), thereby, suggesting good response for selection based on per se performance. These findings are in agreement with those of Kumar and Sahib (2003) and Parmar et al (2019).

High heritability accompanied with high genetic advance as per cent of mean was noted for plant height, leaf area, stem girth, leaves per plant, leaf-stem ratio, total soluble solids and green fodder yield per plant. This indicates that these traits are highly heritable and selection of high performing genotypes is possible to improve these attributes. High heritability coupled with high genetic advance for these characters has also been reported earlier by Malik et al (2015) and Arvinth et al (2021). Therefore, on the basis of the study of all the variability parameters, it may be interpreted that maximum improvement through direct selection can be brought for these attributes.

In general, phenotypic correlation estimates (Table 3) were similar in direction and slightly higher than genotypic correlation, which indicated that these were influenced by the environmental factors, however, the higher genotypic expression indicated the inherent relationship among the characters. Similar results were obtained by Kumar and Singh (2009), Khandelwal et al (2015) and Arvinth et al (2021).

Green fodder yield exhibited significant stable and positive correlation with stem girth (0.97 and 0.99), leaves per plant (0.88 and 0.90) and leaf-stem ratio (0.89 and 0.90) at both genotypic and phenotypic levels respectively. These attributes may be considered as important yield components in forage sorghum (Table 3). These results are similar to earlier reports of Damor et al (2018) and Malaghan and Kajjidoni (2019).

Leaf breadth (0.91 and 0.92) displayed high order of direct effect on green fodder yield per plant followed by leaf area (0.85 and 0.86), plant height (0.83 and 0.84) and leaves per plant (0.81 and 0.82) at both phenotypic and genotypic levels respectively (Table 4), which indicated that the contribution of individual attributes to fodder yield is of importance in planning a sound breeding programme for developing for high yielding varieties in forage sorghum. These findings are in accordance with the results obtained in sorghum by Patil et al (2014) and Jain et al (2017).

Table 2. Phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance as per cent of mean in forage sorghum

Parameter	PCV	GCV	Heritability (%)	Genetic advance	Genetic advance as per cent of mean
Days to 50% flowering	7.81	8.99	88.12	11.44	13.66
Plant height (cm)	22.00	25.07	92.29	68.88	23.22
Leaf breadth (cm)	9.88	11.12	88.54	2.32	19.89
Leaf length (cm)	7.68	7.97	81.18	9.78	14.11
Leaf area (cm^2)	14.94	16.07	82.66	74.55	24.77
Stem girth (mm)	11.01	12.67	91.33	5.00	22.77
Leaves/plant	29.66	33.80	92.21	4.57	25.45
Leaf-stem ratio	38.74	37.88	95.64	0.59	74.48
Total soluble solids (%)	13.72	13.37	81.49	1.89	22.22
Green fodder yield (g/plant)	29.99	34.01	91.88	99.11	33.97

Table 3. Estimates of genotypic and phenotypic correlation coefficients for different characters in forage sorghum

Parameters		Days to 50% flowering	Plant height (cm)	Leaf breadth (cm)	Leaf length (cm)	Leaf area (cm^2)	Stem girth (mm)	Leaves/ plant	Leaf-stem ratio	Total soluble solids (%)	Green fodder yield (g/plant)
Days to 50% flowering	G	1.00	0.18	–0.32**	0.15	0.97*	0.09	–0.09	0.25	0.50**	–0.47
	P	1.00	0.22	–0.37**	0.17	0.96*	0.09	–0.12	0.26	0.53**	–0.45
Plant height (cm)	G		1.00	0.76**	0.89**	0.23	0.79**	0.67**	0.65**	0.65**	–0.11
	P		1.00	0.77**	0.91**	0.32	0.80**	0.69**	0.67**	0.68**	–0.12
Leaf breadth (cm)	G			1.00	0.73**	0.79**	0.18	0.10	–0.10	0.07	0.13
	P			1.00	0.75**	0.81**	0.20	0.11	–0.11	0.07	0.13
Leaf length (cm)	G				1.00	0.66**	0.12	0.74**	0.16	0.68**	–0.04
	P				1.00	0.67**	0.17	0.75**	0.16	0.69**	–0.05
Leaf area (cm^2)	G					1.00	–0.15	0.72**	–0.08	0.15	0.12
	P					1.00	–0.16	0.75**	–0.03	0.17	0.13
Stem girth (mm)	G						1.00	0.85**	0.47	0.34	0.97**
	P						1.00	0.88**	0.49	0.35	0.99**
Leaves/plant	G							1.00	0.10	0.55**	0.88**
	P							1.00	0.11	0.57**	0.90**
Leaf-stem ratio	G								1.00	0.06	0.89**
	P								1.00	0.06	0.90**
Total soluble solids (%)	G									1.00	0.07
	P									1.00	0.09
Green fodder yield (g/plant)	G										1.00
	P										1.00

*Significant at 5% probability level, **Significant at 1% probability level; G = Genotypic, P = Phenotypic

The high indirect contribution of days to 50 per cent flowering via plant height, leaf length and stem girth; plant height through stem girth; leaf length via stem girth; leaf area through stem girth and leaf length; stem girth via days to 50 per cnet flowering, leaf breadth, leaf length, leaf area, leaves per plant and leaf-stem ratio; leaves per plant through stem girth and leaf-stem ratio via stem girth was also observed which is in line with Jain et al (2017) and Arvinth et al (2021).

In order to exercise a suitable selection programme, it would be worth to concentrate on traits like leaf breadth, leaf area, plant height and leaves per plant governing fodder yield directly, while controlling the green fodder yield indirectly via stem girth. The contribution of residual effect was low at both genotypic and phenotypic levels in the present analysis, which indicated that almost all the important yield attributes were taken into consideration.

Table 4. Estimates of direct and indirect effect of different characters on forage yield/plant in forage sorghum

Parameter		Days to 50% flowering	Plant height (cm)	Leaf breadth (cm)	Leaf length (cm)	Leaf area (cm^2)	Stem girth (mm)	Leaves/ plant	Leaf-stem ratio	Total soluble solids (%)
Days to 50% flowering	G	–0.17	–0.51	0.07	–0.41	–0.07	0.51	0.02	0.15	0.31
	P	–0.20	–0.53	0.08	–0.42	–0.09	0.54	0.03	0.19	0.33
Plant height (cm)	G	0.71	0.83	0.06	–0.47	0.05	0.23	–0.27	0.02	0.07
	P	0.81	0.84	0.09	–0.49	0.07	0.25	–0.28	0.05	0.08
Leaf breadth (cm)	G	0.17	0.34	0.91	–0.70	0.03	0.76	–0.03	–0.02	0.05
	P	0.18	0.37	0.92	–0.72	0.10	0.79	–0.05	–0.05	0.06
Leaf length (cm)	G	0.70	–0.38	–0.06	–0.02	0.67	0.61	–0.34	0.06	0.05
	P	0.80	–0.40	–0.08	–0.04	0.69	0.64	–0.36	0.05	0.03
Leaf area (cm2)	G	0.13	–0.77	–0.10	–0.22	0.85	0.71	–0.07	–0.04	0.19
	P	0.14	–0.79	–0.10	–0.24	0.86	0.74	–0.08	–0.05	0.22
Stem girth (mm)	G	0.56	0.82	0.31	0.65	0.91	0.09	0.71	0.59	0.24
	P	0.65	0.84	0.33	0.67	0.93	0.10	0.73	0.63	0.26
Leaves/plant	G	0.21	–0.57	–0.44	–0.04	0.06	0.44	0.81	0.02	0.11
	P	0.23	–0.61	–0.46	–0.04	0.08	0.46	0.82	0.05	0.12
Leaf–stem ratio	G	–0.05	–0.79	0.31	–0.31	–0.05	0.67	–0.05	0.06	0.37
	P	–0.06	–0.88	0.33	–0.40	–0.06	0.79	–0.03	0.07	0.39
Total soluble solids (%)	G	–0.04	–0.18	–0.52	–0.05	0.88	0.41	–0.33	0.06	–0.03
	P	–0.06	–0.28	–0.61	–0.09	0.89	0.57	–0.36	0.04	–0.03

*Significant at 5% probability level, **Significant at 1% probability level; G = Genotypic, P = Phenotypic

REFERENCES

Anonymous 2020. Agricultural statistics at a glance 2020. Directorate of Economics and Statistics, Department of Agriculture and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare, Government of India.

Arvinth S, Patel RN, Gami RA and Joshi AH 2021. Genetic variability, character association and path analysis of forage sorghum [*Sorghum bicolor* (L) Moench]. Forage Research **47(2):** 153-158.

Basavaraja H, Hugar AY, Mahajanshetti SB, Angadi VV and Rao BD 2005. Kharif sorghum in Karnataka: an economic analysis. Agricultural Economics Research Review **18:** 223-240.

Burton GW 1952. Quantitative inheritance in grasses. Proceedings of the 6th International Grassland Congress, Vol 1, 17-23 August 1952, Pennsylvania State College, Pennsylvania, USA, pp 277-283.

Croxton FE and Cowden DJ 1964. Applied general statistics. 2nd Edn, Prentice-Hall of India (Pvt) Ltd, New Delhi, India.

Crumpacker DW and Allard RW 1962. A diallel cross analysis of heading date in wheat. Helgardia **32(6):** 275-318.

Damor HI, Parmar HP, Gohil DP and Patel AA 2018. Genetic variability, character association, path coefficient in forage sorghum [*Sorghum bicolour* (L) Moench]. Green Farming **9(2):** 218-233.

Dewey DR and Lu KH 1959. A correlation and path coefficient analysis of components of crested wheatgrass seed production. Argonomy Journal **9:** 515-518.

Jain SK, Elangovan M and Patel NV 2017. Correlation and path coefficient analysis for agronomical traits in forage sorghum [*Sorghum bicolour* (L) Moench]. Indian Journal Plant Genetic Resources **23(1):** 15-18.

Johnson HW, Robinson HF and Comstock RE 1955. Estimates of genetics and environmental variability in soybeans. Journal of Agronomy **47(7):** 314-318.

Khandelwal V, Shukla M, Jodha BS, Nathawat VS and Dashora SK 2015. Genetic Parameters and character association in sorghum [*Sorghum bicolour* (L) Moench]. Indian Journal of Science and Technology **8(22):** doi: 10.17485/ijst/2015/v8i22/73902.

Kumar A and Singh U 2009. Fertility status of Haryana cows. Indian Veterinary Journal **86:** 807-809.

Kumar MH and Sahib KH 2003. Genetic studies and correlations of biomass related characters in forage sorghum. Journal of Research, ANGRAU **31(3):** 35-39.

Malaghan S and Kajjidoni ST 2019. Character association and path analysis of grain yield in rabi sorghum [*Sorghum bicolour* (L) Moench]. International journal of Chemical Studies **7(1):** 2309-2313.

Malik A, Singh SK, Chand P, Singh B and Singh DK 2015. Genetic variability, heritability and genetic advance studies on forage sorghum. Progressive Agriculture **15(1):** 92-94.

Nyadanu D and Dikera E 2014. Exploring variation, relationships and heritability of traits among selected accessions of sorghum [*Sorghum bicolour* (L) Moench] in the upper east region of Ghana. Journal of Plant Breeding and Genetics **2(3):** 101-107.

Panse VG and Sukhatme PV 1985. Statistical methods for agricultural workers. 4th Edn, Indian Council of Agricultural Research, New Delhi, India.

Parmar P and Misra S 2020. Focus needed on fodder shortage in India. Businessline, 28 April 2020.

Parmar NR, Patel MP and Patel NB 2019. Combining ability studies in forage sorghum [*Sorghum bicolour* (L) Moench] for yield and quality parameters. International Journal of Current Microbiology and Applied Sciences **8(4):** 1439-1444.

Patil CN, Rathod AH, Vaghela PO, Yadav SR, Patade SS and Shinde AS 2014. Study of correlation and path analysis in dual purpose sorghum [*Sorghum bicolour* (L) Moench]. International Journal of Agricultural Sciences **10(2):** 608-611.

Prasad, BVV and Sridhar V 2020. Assessment of variability, correlation and path analysis for yield and yield related traits in yellow pericarp sorghum germplasm lines [*Sorghum bicolour* (L) Moench]. Journal of Pharmacognosy and Phytochemistry **9(1):** 870-873.

Robinson HF, Comstock RE and Harvey PH 1949. Estimates of heritability and the degree of dominance in corn. Agronomy Journal **41(8):** 353-359.

Singh SK, Singh A and Kumar R 2016. Genetic variability, character association and path analysis in forage sorghum. Progressive Agriculture **16(2):** 214-218.

Veena B and Nagratna B 2019. The impacts of feed and fodder development programmes on livestock rearing by farmers in north Karnataka. International Journal of Current Microbiology and Applied Sciences **8(2):** 1738-1746.