RESEARCH ARTICLE

VARIABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS STUDIES IN FORAGE SORGHUM

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Abstract: Economic yield attributing characters were studied in forage sorghum for crop improvement through selecting high yielding characters. Significant variations were recorded among the genotypes for various yield traits studied. High values for phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was noted for plant height, leaf breadth, internode length and green fodder yield per plant. High heritability coupled with high genetic advance as percent of mean was revealed for plant height, leaf breadth, internode length, number of leaves per plant, leaf stem ratio, leaf area, total soluble solids and green fodder yield per plant. Green fodder yield per plant observed positive and significant correlation with plant height, number of leaves per plant, internode length, leaf area and protein content at both the levels. The result of path coefficient analysis showed that leaf area, leaf breadth, leaf length, plant height and protein content had positive direct effect on green fodder yield. Sorghum is one of the important food crops of the world. To exploit the potentiality of sorghum several crop improvement programmes have been undertaken. Yield is a complex character, which depends upon many independent contributing characters. Knowledge of the magnitude and type of association between yield and its components themselves greatly help in evaluating the contribution of different components towards yield. Yield being a polygenic character is highly influenced by the fluctuations in environment. Hence, selection of plants based directly on yield would not be very reliable. Improvement in sorghum yield depends on the nature and extent of genetic variability, heritability and genetic advance in the base population and besides the information on the nature of association between yield and its components helps in simultaneous selection for many characters associated with yield improvements. It was concluded that these characters could be considered as significant selection criteria for yield improvement in forage sorghum.

Keywords: *Sorghum bicolor,* Variability, Correlation, Path coefficient analysis

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) 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, well adaptive to arid regions is considered promising fodder crop. It is a palatable and nutritious fodder crop for animals and there is enormous demand for green and dry fodder particularly during lean winter and summer seasons in the arid and semi arid region. It is estimated that sorghum fodder constitutes 20-45 per cent of the total dry weight of feed of dairy animals during normal seasons and up to 60 per cent during lean summer and winter season. During the last 30 years the role of sorghum as a major source of fodder has not diminished while its important 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 out dated varieties and selection which are not responsive to improved high fodder yielding varieties for Uttar Pradesh. Low fodder production and lesser feed availability is the major limiting factor 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. In India, hardly 5 per cent of the cropped area is utilized to grow fodder. India is deficit in dry fodder by 11 per cent, green fodder by 35 per cent and concentrates feed by 28 per cent. The common grazing lands too have been deteriorating quantitatively and qualitatively. This situation leads to poor feeding of the animal, resulting in low milk and meat yields. Due to low per capita availability of the quality products from livestock, our nation is facing the problems of malnourishment, high disease incidence and low life expectancy. Demand for animal products for human consumption is increase day by day because of expanding human population and improvement in life style of citizens (Jain and Patel, 2013). Productivity of the crop is less and if varies from year to year. This low productivity is accounted for various factors. Sorghum is grown as a irrigated crop, but availability of irrigation facilities is limited and lack of rainfall during crop growth period. Production of sorghum is also limited owing to non adoption of recommended practices and high yielding and high protein content varieties etc., which reduces the yield to a greater extent. The magnitude of variability present in a crop species is of utmost importance as it provides the basis for

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effective selection. The variation present in a population is measured by phenotypic, genotypic coefficient of variation, heritability and genetic advance under selection help the plant breeder in selection of elite genotype from diverse genetic population. Correlation coefficient and path analysis provide the mutual relationship between various plants and the association of these characters with yield. Hence the present study to find the genetic parameter, association of certain characters, their direct contribution to yield and indirect effects through other characters on yield of forage sorghum and their F_1 were carried out.

Table 1. Analysis of variance for twelve characters in parents and F_1 generation of forage sorghum

Source of variance	d.f.	Days to 50% flowering	Plant height (cm)	No. of leaves per plant	Stem girth (cm)	Leaf length (cm)	Leaf breadth (cm)	Internode length (cm)	Total soluble solid (%)	Leaf area (cm^2)	Leaf stem ratio (w/w)	Protein content (%)	Green fodder yield (g)
Replication	2	0.67	2.70	0.96	0.35	0.78	0.42	0.97	0.79	60.63	04	0.81	58.52
Treatment	78	51.16**	6162.39**	7.64**	0.15**	80.45**	3.32**	30.84**	5.17**	8869.80**	0.21**	2.93**	8789.49**
Error	156	4.60	22.41	0.82	0.53	1.81	0.66	0.45	0.36	411.44	0.09	0.21	23.66

* Significant at 5% level and ** Significant at 1% level

Table 2. Mean performance and parameters of variability for various traits studied in forage sorghum

Sl.No.	Character	GCV (%)	PCV (%)	Genetic Advance	GA as % mean	Heritability (%)
1.	Days to 50% Flowering	4.69	5.39	7.03	8.41	75.70
2.	Plant height (cm)	27.53	27.62	19.67	35.91	98.80
3.	Leaf length (cm)	7.19	7.38	10.29	14.42	94.80
4.	Leaf breadth (cm)	25.28	26.24	2.03	29.64	88.60
5.	Stem girth (cm)	11.31	15.40	0.30	17.10	53.90
6.	Internode length (cm)	26.79	27.14	6.42	33.88	95.90
7.	No. of leaves per plant	11.31	12.11	3.01	21.75	87.10
8.	Leaf stem ratio (w/w)	17.94	19.13	0.15	34.65	87.90
9.	Leaf area (cm^2)	15.56	16.66	12.18	29.95	87.20
10.	Total soluble solids (%)	16.56	17.49	2.41	30.35	84.20
11.	Protein content (%)	11.26	13.73	1.30	19.00	67.10
12.	Green fodder yield per plant (g)	34.40	34.46	10.90	29.54	99.20

Table: 3 Estimates of correlation coefficient for genotypic (G) and phenotypic (P) levels among different in forage sorghum

Character		Days to 50% flowering	Plant height (cm)	No. of leaves per plant	Stem girth (cm)	Leaf length (cm)	Leaf breadth (cm)	Internode length (cm)	Total soluable solids (%)	Leaf area (cm^2)	Leaf stem ratio (w/w)	Protein content (%)	Green fodder yield per plant (g)
Days to 50% flowering	G	1.00	0.05	0.11	0.26**	-0.15	0.36**	0.01	0.08	0.38**	0.25**	0.09	-0.15
	P	1.00	0.04	0.09	0.27**	-0.13	0.38**	0.01	0.07	0.31**	0.27**	0.08	-0.12
Plant height (cm)	G		1.00	0.30**	-0.07	0.07	0.40**	0.09	0.19	0.41**	0.09	0.06	0.36**
	P		1.00	0.31**	-0.05	0.06	0.41**	0.09	0.18	0.38**	0.09	0.04	0.37**
No. of leaves per plant	G			1.00	0.18	-0.08	0.26**	-0.23	0.08	0.16	-0.15	0.04	0.29**
	P			1.00	0.12	-0.06	0.22**	-0.22	0.06	0.18	-0.13	0.09	0.30**
Stem girth (cm)	G				1.00	0.38**	0.05	-0.09	0.11	0.10	0.14	-0.19	-0.12
	P				1.00	0.39**	0.06	-0.07	0.06	0.15	0.10	-0.13	-0.09
leaf length (cm)	G					1.00	-0.14	0.08	0.13	0.28**	-0.18	0.07	-0.17
	P					1.00	-0.13	0.08	0.12	0.29**	-0.17	0.04	-0.15
Leaf breadth (cm)	G						1.00	0.27**	0.13	0.09	0.20	0.14	-0.13
	P						1.00	0.28**	0.12	0.10	0.19	0.09	-0.12
Internode length (cm)	G							1.00	0.01	0.08	0.13	0.06	0.33**
	P							1.00	0.07	0.06	0.14	0.04	0.35**
Total soluable solid (%)	G								1.00	0.20	0.02	0.16	0.09
	P								1.00	0.18	0.04	0.08	0.08
Leaf area (cm^2)	G									1.00	0.10	0.16	0.27**
	P									1.00	0.17	0.10	0.28**
Leaf stem ratio (w/w)	G										1.00	-0.05	0.10
	P										1.00	-0.02	0.09
Protein content (%)	G											1.00	0.25**
	P											1.00	0.27**
Green fodder yield per plant (g)	G												1.00
	P												1.00

* Significant at 5 % probability level and ** Significant at 1 % probability level

Table 4. Estimates of direct and indirect effects for various traits studied towards green fodder yield in forage sorghum

Character		Days to 50% flowering	Plant height (cm)	No. of leaves per plant	Stem girth (cm)	Leaf length (cm)	leaf breadth (cm)	Internode length (cm)	Total soluable solid (%)	Leaf area (cm^2)	Leaf stem ratio (w/w)	Protein content (%)	Correlated with green fodder yield per plant
Days to 50% flowering	G	**-0.18**	-0.01	0.42	0.44	0.52	-0.08	-0.06	-0.01	0.37	-0.04	-0.01	-0.15
	P	**-0.15**	-0.00	0.51	0.52	0.61	-0.05	-0.16	-0.09	0.44	-0.03	-0.02	-0.12
Plant height (cm)	G	0.01	**0.32**	0.05	-0.02	0.02	0.32	0.03	0.07	0.13	0.03	0.02	0.36**
	P	0.01	**0.35**	0.09	-0.01	0.01	0.39	0.04	0.09	0.12	0.06	0.03	0.37**
No. of leaves per plant	G	0.41	0.33	**0.12**	0.32	-0.01	0.03	-0.03	0.41	0.42	-0.01	0.05	0.29**
	P	0.49	0.42	**0.19**	0.41	-0.07	0.05	-0.02	0.49	0.51	-0.02	0.06	0.30**
Stem girth (cm)	G	-0.04	0.01	-0.03	**-0.17**	0.06	-0.06	0.01	-0.01	-0.03	-0.02	0.33	-0.12
	P	-0.01	0.05	-0.01	**-0.10**	0.02	-0.02	0.07	-0.02	-0.06	-0.03	0.40	-0.09
leaf length (cm)	G	0.15	-0.07	0.38	0.40	**0.43**	0.15	0.48	-0.04	-0.09	0.49	-0.08	-0.17
	P	0.05	-0.03	0.43	0.41	**0.44**	0.06	0.57	-0.05	-0.12	0.57	-0.09	-0.15
Leaf breadth (cm)	G	0.48	-0.16	-0.10	-0.18	0.08	**0.61**	-0.13	-0.02	-0.12	-0.09	-0.06	-0.13
	P	0.57	-0.18	-0.15	-0.19	0.09	**0.71**	-0.18	-0.09	-0.14	-0.13	-0.06	-0.12
Internode length (cm)	G	0.49	-0.02	0.06	0.02	-0.05	-0.07	**-0.20**	-0.02	-0.07	-0.05	-0.01	0.33**
	P	0.50	-0.05	0.08	0.01	-0.02	-0.02	**-0.21**	-0.04	-0.07	-0.03	-0.01	0.35**
Total soluable solid (%)	G	0.36	0.08	0.04	0.05	0.06	0.06	0.05	**0.04**	0.02	0.01	0.07	0.09
	P	0.49	0.12	0.01	0.04	0.08	0.07	0.01	**0.06**	0.01	0.07	0.08	0.08
Leaf area (cm^2)	G	0.17	0.72	0.04	0.06	0.50	0.05	0.10	0.35	**0.76**	0.09	0.29	0.27**
	P	0.16	0.79	0.09	0.07	0.46	0.04	0.13	0.47	**0.81**	0.10	0.30	0.28**
Leaf stem ratio (w/w)	G	0.06	0.02	-0.08	0.03	-0.04	0.05	0.57	0.06	0.27	**0.14**	0.41	0.10
	P	0.04	0.01	-0.02	0.02	-0.03	0.03	0.62	0.08	0.29	**0.19**	0.43	0.09
Protein content (%)	G	0.02	0.01	0.13	-0.05	0.02	0.04	0.33	0.04	0.04	-0.06	**0.29**	0.25**
	P	0.01	0.08	0.10	-0.01	0.01	0.02	0.40	0.05	0.05	-0.08	**0.31**	0.27**

Residual effect (Genotypic) = 0. 3606 and (Phenotypic) = 0.4370 Bold values indicate direct effect

MATERIAL AND METHOD

Experimental material of the present investigation comprising of 60 F_1s along with 19 parents 15 lines and 4 testers were evaluated in a completely randomized block design with three replications during *kharif* 2016 at Sardar Vallabhbhai Patel University, Crop Research Centre, Meerut U.P. Each of 60 F_1s was planted in five meter long three rows plot and the parents were planted in three rows. The rows were spaced 30 cm apart and plant to plant distance was maintained 10 cm. Observations were recorded on five competitive plants for days to 50% flowering, plant height, number of leaves per plant, stem girth, leaf length, leaf breadth, internode length, total soluable solids, leaf area, leaf stem ratio, protein content 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 (1967), Fisher (1918), Burton (1952) and Johnson *et al.* (1955). Correlation coefficients were calculated as per the methods suggested by Robinson *et al.* (1951) and Fisher and Yates (1938) and path coefficient were worked out as per the method of Dewey and Lu (1959).

RESULT AND DISCUSSION

A thorough screening of the material studied (table-1) under present investigation exhibited sufficient variability for all the twelve characters *i.e.* days to 50% flowering (51.16), plant height (6162.39), number of leaves per plant (7.64), stem girth (0.15), leaf length (80.45), leaf breadth (3.32), internode length (30.84), total soluable solids (5.17), leaf area (8869.80), leaf stem ratio (0.21), protein content (2.93) and green fodder yield per plant (8789.49) which indicated that sufficient variability existed in the present set of material and further genetic analysis and study would be meaningful. High amount of genetic variability for all the characters has also been reported earlier by Jain *et al.* (2017) and Ranjith *et al.* (2017). Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high (more than 25%) revealed (table-2) for plant height (27.62, 27.53), leaf breadth (26.24, 25.28), internode length (27.14, 26.79) and green fodder yield per plant (34.46, 34.40). Moderate (10-25%) was observed for stem girth (15.40, 11.31), number of leaves per plant (12.11, 11.31), leaf stem ratio (19.13, 17.94), leaf area (16.66, 15.56), total soluble solids (17.49, 16.56) and protein content (13.73, 11.26) and showed low (<10%) for days to 50% flowering (5.39, 4.69) and leaf length (7.38, 7.19). Further, the present findings exhibited that the estimates of phenotypic coefficient of variation were generally higher than their corresponding genotypic coefficient of variation for all the characters. Earlier researchers Singh *et al.* (2016) and Jain *et al.* (2017) has reported similar findings. The high values of genotypic and phenotypic coefficient of variation for these attributes, suggested that there was a possibility of improvement of forage yield through direct selection. heritability (broad sense) was high (> 60%) for all traits *viz.*, days to 50% flowering (75.70), plant height (98.80), leaf length (94.80), leaf breadth (88.60), internode length (95.90), number of leaves per plant (87.10), leaf stem ratio (87.90), leaf area (87.20), total soluable solids (84.20), protein content (67.10) and green fodder yield per plant (99.20) except stem girth (53.90). The high or moderate degree of heritability estimates for these characters suggested that the attributes were under genotypic control. High or moderate heritability estimates for most of the traits studied, have been reported earlier by Singh *et al.* (2016) and Jain *et al.* (2017). For an effective selection, the knowledge alone on the estimates of heritability is not sufficient and genetic advance if studied along with heritability is more useful. In the present study, high (>20%) estimates of genetic advance expressed as per cent of mean have been observed for plant height (35.91), leaf breadth (29.64), internode length (33.88), number of leaves per plant (21.75), leaf stem ratio (34.65), leaf area (29.95), total soluble solids (30.35) and green fodder yield per plant (29.54) thereby, suggesting good response for selection based on *per se* performance. Earlier research have reported similar finding with respect to genetic advance, Malik *et al.* (2015) and Singh *et al.* (2016). High heritability coupled with high genetic advance was estimated for plant height, leaf breadth, internode length, number of leaves per plant, leaf stem ratio, leaf area, total soluble solids and green fodder yield per plant which indicated that these characters are governed by additive gene action. Direct selection of these attributes will be effective and profitably for yield improvement. High heritability coupled with high genetic advance for some of these traits have also been reported earlier by Diwakar *et al.* (2016) and Singh *et al.* (2016). Green fodder yield per plant showed positive and significant correlation with plant height (0.36, 0.37), number of leaves per plant (0.29, 0.30), internode length (0.33, 0.35), leaf area (0.27, 0.28) and protein content (0.25, 0.27) at genotypic and phenotypic level. The result indicated that by improving these characters green fodder yield may be enhanced in this crop. These result are in general agreement with the finding of Singh *et al.* (2016) and Jain *et al.* (2017). Thus, it can be inferred that selection based on any one of these traits either alone or in combination, will result in identifying high yielding strains. High indirect positive contribution of Days to 50% flowering through number of leaves per plant, stem girth, leaf length and leaf area; Plant height via leaf breadth; Number of leaves per plant through days to 50% flowering, plant height, stem girth, total soluble solids and leaf area; Leaf length via number of leaves per plant, stem girth, internode length and leaf stem ratio; Internode length through days to 50% flowering; Total soluble solids via days to 50% flowering; Leaf area through plant height, total soluble solids and protein content; Leaf stem ratio via internode length, leaf area and protein content and Protein content through internode length were responsible for their positive association with green fodder yield. These results are in general agreement with the findings of Singh *et al.* (2016) and Jain *et al.* (2017). The contribution of residual effects that influenced green fodder yield was very low at both genotypic and phenotypic levels, indicating that these traits included in the present investigation were sufficient enough to account for the variability in the dependant character *i.e.* green fodder yield. From the overall study, there is an indication of improvement in yield through selection with high values for days to 50% flowering and number of leaves per plant.

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