The Andhra Agric. J 62(3): 544-550, 2015

Genetic Variability and Character Association Analysis in Forage Sorghum (*Sorghum bicolor* L. Moench)

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ABSTRACT

Genetic variability, correlation and path coefficient analysis was carried out on fifty four sorghum genotypes for fodder yield and related characters. The results revealed that high PCV, GCV, heritability and genetic advance as per cent of mean observed for stem weight, biomass per plant, green fodder yield, green fodder yield per day, dry fodder yield and dry fodder yield per day. Green fodder yield was positively and significantly correlated with early vigour, days to 50 per cent flowering, plant height, leaf length, stem weight, stem girth, biomass per plant and dry fodder yield at both phenotypic and genotypic level. Estimates of direct and indirect effects of component characters on green fodder yield at phenotypic level revealed that biomass per plant contributed maximum direct effect on green fodder yield followed by plant height and leaf length, whereas the study on direct and indirect effects of component characters on dry fodder yield revealed that highest positive direct effect on dry fodder yield was exhibited by green fodder yield followed by plant height. The correlation and path analyses studies when considered together suggested that the traits *viz.,* biomass per plant, plant height, leaf length, stem weight, stem girth, days to 50 per cent flowering should be given importance to isolate superior lines with genetic potentiality for high green forage yield, whereas green forage yield alone could be given emphasis in direct selection for dry fodder yield enhancement.

Key words : Correlation, Forage sorghum, Genetic variability and Path analysis.

Sorghum (*Sorghum bicolor* L. Moench) is an important *kharif* fodder crop grown throughout world. In India, it is the third largest cereal crop which covers an area of 7.53 M.ha. with a production of 7.25 M.t. and productivity of 963 kg ha^{-1}. The major sorghum growing states are Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Tamil Nadu. In Andhra Pradesh, it covers an area of 0.28 M.ha. with an annual production of 0.44 M.t. and productivity of 1420 kg ha^{-1} according to Centre for Monitoring Indian Economy (CMIE, 2009). Among the forage crops, forage sorghum could be an ideal crop because of the crop's xerophilic characteristics, adaptation potential, quick growing habit, high ratoonability, palatability, digestibility, and wide range of potential uses as green fodder, dry roughage, and silage. In order to make forage sorghum as an enterprising and remunerative crop, there is a need to develop varieties and hybrids having prominent characters coupled with high forage yield. To develop such forage varieties or hybrids, knowledge and information on genetic architecture of green and dry fodder yields is essential for the formulation of an efficient breeding strategy for genetic improvement of sorghum as forage crop. Studies on the correlation of the traits and their direct and indirect effects on green and dry fodder yield are important, as it is helpful in selection of desirable traits. Hence, an attempt was made to study fodder yield and related components, their correlations and effects on genotypes of sorghum.

MATERIAL AND METHODS

The material for the present study comprised of fifty four genotypes includes local forage lines from different states, sweet sorghum lines, brown midrib lines and dual purpose lines and evaluated in randomized block design with three replications during *kharif,* 2011 at Directorate of Sorghum Research Farm, Rajendranagar, Hyderabad. Each entry in each replication was sown in 2 rows of 4 m length spaced 45 cm apart from each other with plant to plant distance of 15 cm. Recommended package of practices were followed for raising a normal crop. Five plants of each genotype in each replication were selected

Table 1. Estimation of variability, heritability and genetic advance as per cent of mean for fifteen characters in forage sorghum.

S. No	Characters	Mean	Range		PCV (%)	GCV (%)	ECV (%)	h^2_{bs} (%)	Gnetic Adavance as % of mean (5%)
			Minimum	Maximum					
1	Early vigour	2.94	1.66	3.66	18.44	14.58	11.29	62.5	23.75
2	Days to 50% flowering	69.58	55.66	81.66	9.76	9.27	3.07	90.1	18.12
3	Plant height (cm)	310.70	162.00	448.00	21.51	19.22	9.66	79.8	35.38
4	Number of leaves	15.10	48.11	7.50	39.38	37.61	11.68	91.2	73.98
5	Leaf length (cm)	85.70	62.93	115.20	11.69	9.69	6.54	68.7	16.55
6	Leaf width (cm)	8.16	3.65	10.33	16.39	15.34	5.77	87.6	29.57
7	Stem weight (g)	383.00	132.00	987.30	42.82	41.37	11.04	93.4	82.35
8	Stem girth (mm)	1.634	1.15	2.40	16.92	15.44	6.92	83.3	29.02
9	Biomass (Kg)	0.637	0.28	1.17	34.13	32.15	11.44	88.8	62.40
10	Green fodder yield (Q ha^{-1})	335.80	148.90	584.70	32.33	27.07	17.69	70.1	46.67
11	Green fodder yield per day	4.811	2.48	8.35	30.12	23.69	18.61	61.8	38.37
12	Dry fodder yield (Q ha^{-1})	90.44	27.68	162.80	38.02	32.83	19.17	74.6	58.41
13	Dry fodder yield per day	1.295	0.45	2.33	36.30	30.33	19.95	69.8	51.19
14	Brix (%)	11.56	5.60	16.62	24.19	17.87	16.30	54.6	27.20
15	Crude protein (%)	8.77	5.48	12.58	19.26	18.29	6.04	90.2	35.77

PCV= Phenotypic coefficient of variation, ECV= Environmental coefficient of variation and GCV= Genotypic coefficient of variation,

h^2_{bs}= broad sense heritability.

Table 2. Estimates of phenotypic (r_p) and genotypic (r_g) correlation coefficients of fodder yield and yield components in forage sorghum

Character		Early vigour	Days to 50% flowering	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Leaf width (cm)	Stem weight (g)	Stem girth (mm)	Biomass per plant (kg)	Brix (%)	Crude protein (%)	Green fodder yield (Q ha^{-1})	Dry fodder yield (Q ha^{-1})
EV	r_p	**1.0000**	-0.0493	0.2306 **	-0.1701 *	0.1644 *	0.0681	0.1854 *	0.2055 **	0.1971 *	0.0032	-0.0611	0.2314 **	0.1937 *
	r_g	**1.0000**	0.0009	0.2551 **	-0.2442 **	0.1257	0.0582	0.2130 **	0.1908 *	0.2257 **	-0.0813	-0.0875	0.2396 **	0.1641 *
DFF	r_p		**1.0000**	0.4105 **	0.2722 **	0.5496 **	0.2226 **	0.6586 **	0.6584 **	0.5992 **	-0.1605 *	-0.0451	0.3815 **	0.3338 **
	r_g		**1.0000**	0.5236 **	0.3116 **	0.7487 **	0.2881 **	0.7300 **	0.7626 **	0.6970 **	-0.2136 **	-0.0477	0.5287 **	0.4406 **
PH	r_p			**1.0000**	0.3652 **	0.3115 **	-0.0774	0.4658 **	0.2672 **	0.3608 **	0.093	-0.0549	0.3634 **	0.5381 **
	r_g			**1.0000**	0.4053 **	0.3490 **	-0.149	0.4919 **	0.2880 **	0.3729 **	0.113	-0.0427	0.4701 **	0.6953 **
NL	r_p				**1.0000**	0.0718	-0.3505 **	0.0241	-0.057	-0.0203	-0.0726	-0.0509	0.0553	0.2106 **
	r_g				**1.0000**	0.0438	-0.4109 **	0.0283	-0.0702	-0.0301	-0.0811	-0.0577	0.0975	0.2675 **
LL	r_p					**1.0000**	0.2351 **	0.4437 **	0.5315 **	0.4373 **	-0.0788	-0.2128 **	0.3792 **	0.3309 **
	r_g					**1.0000**	0.2511 **	0.5445 **	0.6918 **	0.5515 **	-0.1630 *	-0.2570 **	0.5673 **	0.4847 **
LW	r_p						**1.0000**	0.4068 **	0.5314 **	0.5088 **	0.0133	-0.0368	0.0874	-0.0524
	r_g						**1.0000**	0.4424 **	0.5839 **	0.5319 **	-0.0121	-0.029	0.1432	-0.0242
SW	r_p							**1.0000**	0.7707 **	0.8845 **	-0.0962	-0.0568	0.4826 **	0.3435 **
	r_g							**1.0000**	0.8541 **	0.9333 **	-0.1527	-0.0529	0.5629 **	0.3971 **
SG	r_p								**1.0000**	0.7948 **	-0.2177 *	0.0465	0.3802 **	0.2470 **
	r_g								**1.0000**	0.8604 **	-0.3817 **	0.0512	0.4645 **	0.2905 **
BM	r_p									**1.0000**	-0.1244	-0.0406	0.4813 **	0.3079 **
	r_g									**1.0000**	-0.2231 **	-0.0376	0.5793 **	0.3711 **
Brix	r_p										**1.0000**	-0.1009	-0.0277	0.2031 **
	r_g										**1.0000**	-0.1127	-0.0234	0.2960 **
CP	r_p											**1.0000**	-0.2641 **	-0.1973 *
	r_g											**1.0000**	-0.3450 **	-0.2431 **
GFY	r_p												**1.00000**	0.8313 **
	r_g												**1.00000**	0.8178 **

*, ** significant at 5 and 1 per cent level, respectively.EV = Early vigour, DFF = Days to 50 per cent flowering, PH = Plant height (cm), NL= Number of leaves per plant, LL= Leaf length (cm), LW= Leaf width (cm), SW= Stem weight (g), SG = Stem girth (mm), BM = Biomass per plant (kg), GFY = Green fodder yield (Q ha^{-1}), Brix (%), CP = Crude protein (%), DFY= Dry fodder yield (Q ha^{-1}).

Table 3. Estimates of phenotypic direct (diagonal and bold) and indirect (non diagonal) effects of different variables on green fodder yield in forage sorghum.

Character	Early vigour	Days to 50% flowering	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Leaf width (cm)	Stem weight (g)	Stem girth (mm)	Biomass per plant (kg)	Brix (%)	Crude protein (%)	Green fodder yield (Q ha^{-1})
EV	0.0968	-0.0039	0.0265	0.0124	0.0172	-0.0133	0.0112	-0.0016	0.0728	0.0000	0.0133	0.2314 **
DFF	-0.0048	0.0800	0.0472	-0.0198	0.0575	-0.0433	0.0400	-0.0053	0.2214	-0.0013	0.0098	0.3815 **
PH	0.0223	0.0328	0.1151	-0.0266	0.0326	0.0151	0.0283	-0.0021	0.1333	0.0007	0.0119	0.3634 **
NL	-0.0165	0.0218	0.0420	-0.0727	0.0075	0.0682	0.0015	0.0005	-0.0075	-0.0006	0.0111	0.0553
LL	0.0159	0.0440	0.0358	-0.0052	0.1046	-0.0458	0.0269	-0.0043	0.1616	-0.0006	0.0462	0.3792 **
LW	0.0066	0.0178	-0.0089	0.0255	0.0246	-0.1947	0.0247	-0.0043	0.188	0.0001	0.008	0.0874
SW	0.0179	0.0527	0.0536	-0.0017	0.0464	-0.0792	0.0607	-0.0062	0.3268	-0.0008	0.0123	0.4826 **
SG	0.0199	0.0527	0.0307	0.0041	0.0556	-0.1035	0.0468	-0.0080	0.2937	-0.0017	-0.0101	0.3802 **
BM	0.0191	0.0479	0.0415	0.0015	0.0457	-0.0991	0.0537	-0.0064	0.3695	-0.0010	0.0088	0.4813 **
Brix	0.0003	-0.0128	0.0107	0.0053	-0.0082	-0.0026	-0.0058	0.0017	-0.0460	0.0078	0.0219	-0.0277
CP	-0.0059	-0.0036	-0.0063	0.0037	-0.0223	0.0072	-0.0034	-0.0004	-0.0150	-0.0008	-0.2173	-0.2641 **

*, ** significant at 5 and 1 per cent level, respectively. Residual effects: P = 0.7908 at phenotypic level.

EV = Early vigour, DFF = Days to 50 per cent flowering, PH = Plant height (cm), NL = Number of leaves per plant, LL = Leaf length (cm), LW = Leaf width (cm), SW = Stem weight (g), SG = Stem girth (mm), BM = Biomass per plant (kg), Brix (%), CP = Crude protein (%), GFY = Green fodder yield (Q ha^{-1}).

randomly from central rows, used to record data on the following traits viz., early vigour, days to 50 per cent flowering, plant height (cm), number of leaves per plant, leaf length (cm), leaf width (cm), stem weight (g), stem girth (mm), biomass per plant (kg), green fodder yield (Q ha^{-1}), green fodder yield per day (Q ha^{-1} day^{-1}), dry fodder yield (Q ha^{-1}), dry fodder yield per day (Q ha^{-1} day^{-1}), brix per cent and crude protein per cent. The phenotypic and genotypic coefficients of variation (PCV and GCV) were calculated using the formula suggested by Burton and De Vane (1953). Heritability in broad sense was calculated using the formula suggested by Allard (1960). Genetic advance as per cent of mean is estimated as per Johnson *et al*. (1955). The data were statistically analyzed for estimating correlation coefficients and path coefficients as per procedure suggested by Falconer (1964) and Dewey and Lu (1959).

RESULTS AND DISCUSSION

The estimates of PCV, GCV, heritability and genetic advance as per cent of mean are presented in Table 1. Most of the characters showed a wide range of values *viz.,* plant height, number of leaves per plant, leaf width, stem weight, biomass per plant, green fodder yield, green fodder yield per day, dry fodder yield, dry fodder yield per day and brix per cent. While, moderate range was noticed for early vigour, days to 50 per cent flowering, leaf length, stem girth, and crude protein. This indicated ample scope for exploitation of the above characters through the process of selection. The phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the traits under study but the GCV was greater than the variation produced by environment for all the characters. These results are in agreement with the findings of Srivas and Singh (2004) in maize, Singh *et al.* (2011) in forage sorghum. There is almost perfect relation between PCV and GCV of each character. This could be seen from the highest magnitude of both PCV (42.82%) and GCV (41.37%) for stem weight. In the present study, the other characters *viz.,* number of leaves per plant, dry fodder yield, dry fodder yield per day, biomass per plant,

Table 4. Estimates of phenotypic direct (diagonal and bold) and indirect (non diagonal) effects of different variables on dry fodder yield in forage sorghum

Character	Early vigour	Days to 50% flowering	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Leaf width (cm)	Stem weight (g)	Stem girth (mm)	Biomass per plant (kg)	Brix (%)	Crude protein (%)	Green fodder yield (Q ha^{-1})	Dry fodder yield (Q ha^{-1})
EV	**-0.0176**	-0.0005	0.0606	-0.0134	0.0017	-0.0019	-0.0262	0.025	-0.0235	0.1914	0.0007	-0.0026	0.1937 *
DFF	0.0009	**0.0094**	0.1078	0.0214	0.0056	-0.0062	-0.0932	0.0801	-0.0715	0.3155	-0.0341	-0.0019	0.3338 **
PH	-0.0041	0.0039	**0.2627**	0.0287	0.0032	0.0021	-0.0659	0.0325	-0.0431	0.3006	0.0198	-0.0024	0.5381 **
NL	0.0030	0.0026	0.0959	**0.0785**	0.0007	0.0097	-0.0034	-0.0069	0.0024	0.0457	-0.0154	-0.0022	0.2106 **
LL	-0.0029	0.0052	0.0818	0.0056	**0.0102**	-0.0065	-0.0628	0.0646	-0.0522	0.3137	-0.0167	-0.0091	0.3309 **
LW	-0.0012	0.0021	-0.0203	-0.0275	0.0024	**-0.0277**	-0.0575	0.0646	-0.0607	0.0723	0.0028	-0.0016	-0.0524
SW	-0.0033	0.0062	0.1224	0.0019	0.0045	-0.0113	**-0.1415**	0.0937	-0.1056	0.3992	-0.0204	-0.0024	0.3435 **
SG	-0.0036	0.0062	0.0702	-0.0045	0.0054	-0.0147	-0.1090	**0.1216**	-0.0949	0.3145	-0.0462	0.0020	0.2470 **
BM	-0.0035	0.0056	0.0948	-0.0016	0.0045	-0.0141	-0.1251	0.0967	**-0.1194**	0.3982	-0.0264	-0.0017	0.3079 **
GFY	-0.0041	0.0036	0.0955	0.0043	0.0039	-0.0024	-0.0683	0.0462	-0.0575	**0.8272**	-0.0059	-0.0113	0.8313 **
Brix	-0.0001	-0.0015	0.0244	-0.0057	-0.0008	-0.0004	0.0136	-0.0265	0.0148	-0.0229	**0.2124**	-0.0043	0.2031 **
CP	0.0011	-0.0004	-0.0144	-0.0040	-0.0022	0.0010	0.008	0.0056	0.0048	-0.2185	-0.0214	**0.0430**	-0.1973 *

*, ** significant at 5 and 1 per cent level, respectively. Residual effects: P = 0.7908 at phenotypiclevel.

EV = Early vigour, DFF = Days to 50 per cent flowering, PH = Plant height (cm), NL = Number of leaves per plant, LL = Leaf length (cm), LW = Leaf width (cm), SW = Stem weight (g), SG = Stem girth (mm), BM = Biomass per plant (kg), Brix (%), CP = Crude protein (%), GFY = Green fodder yield (Q ha^{-1}).

green fodder yield and green fodder yield per day also showed higher magnitudes of both PCV and GCV, respectively, whereas traits like, brix per cent and plant height had high PCV and moderate GCV respectively. The characters crude protein per cent, early vigour, stem girth and leaf width were recorded for moderate magnitudes of both PCV and GCV, respectively. However, leaf length had moderate PCV and low GCV, respectively. The character days to 50 per cent flowering showed low magnitude of PCV and GCV, respectively. Environmental influence was very meagre on the expression of all the characters except green fodder yield, green fodder yield per day, dry fodder yield, dry fodder yield per day and brix per cent, as there was a narrow gap between genotypic and phenotypic coefficients of variation.

All the characters showed high estimates of heritability except brix (54.6%). Broad sense heritability estimates ranged from 54.6 per cent (brix) to 93.4 per cent (stem weight). However, the selection for improvement of such characters may not be useful, because broad sense heritability is based on total genetic variance which includes additive, dominant and epistatic variances. Thus, heritability values coupled with genetic advance would be more reliable and useful on correlating selection criteria. The genetic advance expressed as percentage of mean values ranged from 16.55 to 82.35 per cent. The character stem weight recorded for higher magnitude of GAM followed by number of leaves per plant and biomass per plant. The characters *viz.,* dry fodder yield, dry fodder yield per day, green fodder yield, green fodder yield per day, crude protein per cent, plant height, leaf width, stem girth, brix per cent and early vigour also showed high magnitudes of GAM value. While the characters leaf length and days to 50 per cent flowering were recorded for moderately high magnitudes of GAM. The characters *viz.,* early vigour, plant height, number of leaves per plant, leaf width, stem weight, stem girth, biomass per plant, green fodder yield, green fodder yield per day, dry fodder yield, dry fodder yield per day and crude protein per cent exhibited high heritability estimates coupled with high genetic advance as per cent of mean which suggested that early vigour, plant height, number of leaves per plant, leaf width, stem weight, stem girth and biomass per plant were amenable for further improvement by following simple selection methods.

The phenotypic and genotypic correlations among green fodder yield and dry fodder yield with yield contributing characters were presented in Table 2. Traits like dry fodder yield (0.8313, 0.8178), stem weight (0.4826, 0.5629), biomass per plant (0.4813, 0.5793), days to 50 per cent flowering (0.3815, 0.5287), stem girth (0.3802, 0.4645), leaf length (0.3792, 0.5673), plant height (0.3634, 0.4701) and early vigour (0.2314, 0.2396) manifested significant and positive correlation with green fodder yield at both phenotypic and genotypic levels, whereas crude protein per cent (-0.2641, -0.3450) showed a significant negative association with green fodder yield at both phenotypic and genotypic levels. Thus it can be inferred that selection based on any one of these traits either alone or in combination, will result in identifying high forage yielding strains. Green fodder yield had significantly negative association with crude protein per cent (-0.2641, -0.3450) at both the levels. In similar studies, significant association of green fodder with different traits were reported by Borad *et al.* (2007) for stem girth and stem weight, Jadhav *et al.* (2009) and Singh *et al.* (2009) for days to 50 per cent flowering, plant height and leaf length, Iyanar *et al.* (2010) for dry fodder yield, plant height, days to fifty per cent flowering, leaf length and stem thickness, Prakash *et al.* (2010) for plant height, leaf length and stem diameter, Jain and Patel (2012) for leaf length and plant height. Among the inter-character correlations days to 50 per cent flowering, plant height, leaf length, stem weight, stem girth and biomass per plant were significantly and positively associated with one another at both phenotypic and genotypic levels. Moreover, these traits had high significant association with green and dry fodder yield. Thus improvement of any of these traits would simultaneously improve fodder yield because of correlated response of yield by applying strong, selection on these traits.

In order to obtain a clear picture of the inter-relationship between different characters, the direct and indirect effects of the important quantitative characters on green and dry fodder yield were worked at separately, using path coefficient analysis both at genotypic and phenotypic levels. The results of phenotypic path coefficients of green fodder yield and yield contributing characters are presented in Table 3. Estimates of direct and indirect effects of component characters on green fodder yield at phenotypic level revealed that biomass per plant (0.3695) contributed maximum direct effect on green fodder yield followed by plant height (0.1151) and leaf length (0.1046). The characters, *vizes*, days to 50 per cent flowering (0.0800), stem weight (0.0607) showed positive but low direct effect on green fodder yield. Highest indirect effects of stem weight (0.3268), stem girth (0.2937), days to 50 per cent flowering (0.2214), leaf length (0.1616) and plant height (0.1333) were showed on green fodder yield *via* biomass per plant. Also, these traits had positive and significant association with green fodder yield. Thus it can be inferred that selection based on any of these traits would be rewarding in raising yield ceiling of green fodder yield. The maximum negative direct effect was exhibited through crude protein per cent (-0.2173) followed by leaf width (-0.1947). The contribution of residual effects that influenced green fodder yield was high (0.7908) at phenotypic level which indicated the contribution of remaining factors other than those studied. These results are in consonance with the findings of Borad *et al.* (2007) for stem weight and crude protein yield, Jadhav *et al.* (2009) for days to 50% flowering, plant height, leaf length, brix content and crude protein content, Singh *et al.* (2009) for days to 50 per cent flowering, plant height, leaf length. Iyanar *et al.* (2010) for plant height. However, in contrast with the present finding, many of them reported positive direct effect of the leaf width, stem girth and crude protein yield on green fodder yield.

The results of phenotypic path coefficients of dry fodder yield and yield contributing characters are presented in Table 4. The study on direct and indirect effects of component characters on dry fodder yield revealed that, highest positive direct effect on dry fodder yield was exhibited by green fodder yield (0.8272) and also the indirect effects of stem weight (0.3992), biomass per plant (0.3982), days to 50 per cent flowering (0.3155), stem girth (0.3145), leaf length (0.3137) and plant height (0.3006) on dry fodder yield through green fodder yield were high. At the same time, these traits also had high significant association with dry fodder yield. Thus, effectiveness of selection for high dry fodder yield could be enhanced by inclusion of green fodder yield as a selection criterion. Besides, selection based on stem weight, biomass per plant, days to 50 per cent flowering, stem girth, leaf length and plant height can lead to considerable improvement of dry fodder yield in sorghum. Similar results were reported by Paroda *et al.* (1975) for plant height and stem girth, Grewal *et al.* (1983) for days to 50 per cent flowering, leaf width and number of leaves, Jadhav *et al.* (2009) for green fodder yield and Iyanar *et al.* (2010) for green fodder yield per plant. The lower residual effect (0.4130) indicated that the characters chosen for path analysis were adequate and appropriate.

The correlation and path analysis studies when considered together suggested that selection of the traits *viz.,* stem weight, stem girth, days to 50 per cent flowering, leaf length and plant height would bring improvement in fodder yield and yield attributes as they possessed high positive significant associations.

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(Received on 17.06.2013 and revised on 11.09.2013)