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STUDIES ON PATH ANALYSIS IN FORAGE SORGHUM

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SUMMARY

Analysis of variance observed considerable differences among the genotypes for all the traits *viz*., days to 50% flowering, plant height, leaf length, leaf breadth, leaf area, stem girth, number of leaves per plant, leaf stem ratio, total soluble solids and green fodder yield, which indicates that wide spectrum of variation among the genotypes. Genotypic and phenotypic coefficient of variation were showed high (more than 25%) for stem girth, leaf stem ratio and green fodder yield, indicating that scope of importance with respect to these characters through selection. High heritability coupled with high genetic advance were revealed for plant height, leaf breadth, leaf area, leaf stem ratio and green fodder yield, which indicates that preponderance of additive gene effects for these attributes and hence may prove useful for effective selection. Correlation coefficient studies indicated that phenotypic correlation coefficient were found to be higher than genotypic correlation coefficients for most of the characters, indicating the phenotypic expression of the association were influenced by the environmental factors among the various traits. Green fodder yield recorded significant and strong positive correlation with leaf area at both genotypic and phenotypic level. Therefore, this character is useful to the breeders in selecting suitable plant type. Path coefficient analysis exhibited high positive and direct influence of plant height, leaf breadth, stem girth and leaf stem ratio towards green fodder yield. In order to exercise a suitable selection programme it would be worth to concentrate on characters like plant height, leaf breadth, stem girth and leaf stem ratio controlling green fodder yield directly and days to 50% flowering and number of leaf area governing green fodder yield indirectly.

Key words : *Sorghum bicolor*, path analysis

Sorghum belongs to the same species as grain sorghum, grass sorghum and broom sorghum. This sorghum is characterized by abundant sweet juice in the stalks and the height usually ranges from 1.5 m to 3.0 m. Sorghum is a potential source of sugar and a multipurpose industrial crop. Sorghum is also grown for green forage. Varieties with sweet, juicy stems are used to produce syrup. Sorghum grain is used to make bread, biscuits, starch, sugar, syrups, alcohol, beer and malt products. The industrial use of sorghum is, however, limited to India. The demand for sorghum fodder, grain and feed purposes is increasing in India. It is grown mainly for its sweet stems which are chewed as a snack and to quench thirst while working in the fields. It is commonly grown in mixtures of crops such as maize, grain sorghum, cowpea, groundnut and melon. The stalks are sold as delicacies at roadside stalls. Hence, the crop has recently attracted interest as a potential cash crop for small scale farmers. Forage sorghum (*Sorghum bicolor* L. Moench) 2n = 20, which belongs to family *Poaceae* is the most important fodder crop grown widely in north-western states and to a limited scale in central and southern states during summer and monsoon seasons. It is one of the widely preferred forage crops due to its quick growing habit, high yield potential, better palatability, 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. Sorghum is a *rabi* season crop in western and southern India. Among the sorghum growing countries India ranks first in acreage but second in production (Singh, *et al*., 2017). Sorghum is cultivated as dual purpose crop ranking fourth among all cereals. It is a drought tolerant crop, but fairly salt tolerant which makes its wide applications in feed and fodder. Sorghum is of two types: forage sorghum (for forage and animal feed) and grain sorghum (for human consumption). The fodder sorghum is grown in 8.3 million ha mainly in Western U.P., Haryana, Punjab and Rajasthan and fulfils more than 65 per cent of the fodder demand during *Kharif* season. The area under fodder cultivation is estimated to be about four per cent of the gross cropped area, which remained static for the last four decades. The traditional grazing lands are gradually diminishing because of urbanization, expansion of cultivable area, grazing pressure and industrialization *etc*. In India, only 4.4% area is under fodder crops, out of which fodder sorghum is grown on 2.3 million ha. India faces a net deficit of 36% and 11% of green fodder and dry fodder, respectively. To reduce the demand and supply gap, the production and productivity of fodder crops needs to be enhanced. The horizontal expansion of cultivable area under fodder crops is difficult due to severe competition from food crops. Apart from vertical expansion, utilization of non cultivable areas for pastures is one of the most viable options to balance the demand. Seed are the best propagating material for wide spread regeneration of marginal and uncultivable lands. One of the reasons reported to stumble the green fodder production is non availability of quality seed in sufficient quantities. As per estimation only 25-30 per cent of required quantity of quality seed is available in cultivated fodders and produce abundant. The great quality seed is pre-essential to improve the production and yield of sorghum (Nisha *et al*., 2020).

MATERIALS AND METHODS

The present investigation entitled "Studies on genetic divergence and selection parameters for quantitative traits in forage sorghum (*Sorghum bicolor* L. Moench)" was conducted during *kharif* season 2017 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. The experimental material for present investigation comprised of thirty genotypes of forage purpose sorghum. Considering each genotype to represent one treatment the experiment was laid out in randomized block design (RBD) with three replications. Experiment was sown on 23 june 2017 in a 4 row plot of 5 meter length. The row to row spacing was 30 cm and plant to plant distance was 10 cm. The observations on green fodder yield and its ten components were recorded from five randomly selected tagged plants. Ten characters *viz*., days to 50% flowering, plant height, leaf length, leaf breadth, leaf area, stem girth, number of leaves per plant, leaf stem ratio, total soluble solids and green fodder yield are studied. The data was analyzed statistically for genotypic and phenotypic coefficients of variation, heritability (Allard, 1960) and genetic advance (Johnson *et al*., 1955). Correlation was estimated by (Searle 1961) and path-coefficient was suggested by Wright (1921) and as elaborated by Dewey and Lu (1959).

RESULTS AND DISCUSSION

A through screening of the material study under present investigation showed sufficient variability for all the attributes *i.e*., days to 50% flowering, plant height, leaf length, leaf breadth, leaf area, stem girth, number of leaves per plant, leaf stem ratio, total soluble solids and green fodder yield (Table 1). High amount of genetic variability for many of these traits has also been reported earlier by Wadikar *et al.* (2018) and Sumonthant *et al.* (2021). Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high (>25%) for stem girth (25.247 and 27.262), leaf stem ratio (53.615 and 55.018) and green fodder yield (37.550 and 37.674) and recorded moderate (10-25%) for plant height (17.198 and 17.302), leaf breadth (14.853 and 16.979), leaf area (17.479 and 19.354) and total soluble solids (11.011 and 17.382). Noted low (<10%) for days to 50% flowering (4.946 and 5.350), leaf length

TABLE 1
Analysis of variance (ANOVA) for ten characters of thirty genotypes in forage sorghum

Source of variations	d. f.	Days to 50% flowering	Plant height (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)	Stem girth (mm)	No. of Leaves/ plant	Leaf stem ratio (w/w)	Total soluble solids (%)	Green fodder yield (q/ha)
Replication	2	16.877	24.477	5.076	1.889	3406.180	0.058	0.0 90	0.001	2.038	31.726
Treatment	29	53.160**	4465.317**	51.931**	2.739**	8453.797**	2.854**	3.862**	4.006**	2.119**	5515.817**
Error	58	2.854	18.009	11.799	0.254	592.305	0.676	1.437	1.330	0.159	60.282

*, ** Significant at 5% and 1%level, respectively.

(5.392 and 7.406) and number of leaves per plant (8.801 and 9.669) (Table 2). Further, the present findings indicated that estimates of phenotypic coefficient of variation were generally higher than their corresponding genotypic coefficient of variation for all the traits studied which showed that all these characters were more influenced by environment. These findings are similar in agreement with earlier reported by Sumonthant *et al.* (2021). The present study indicated higher contribution of stem girth, leaf stem ratio and green fodder yield suggested that there was a possibility of improvement of fodder yield through direct selection. High heritability (>60%) in broad sense was revealed for days to 50% flowering (85.450), plant height (98.800), leaf breadth (76.520), leaf area (81.560), leaf stem ratio (94.690) and green fodder yield (96.790) suggested that the traits were under genotypic control and may be adopted for improving green fodder yield. High heritability estimates for most of the characters studied have been reported earlier also by Wadikar *et al.* (2018) and Sumonthant *et al.* (2021). For an effective selection, the knowledge alone on the estimates of heritability is not sufficient and genetic advance if studies along with heritability are more useful. Estimates of genetic advance expressed as percent of mean have been high (>20%) observed for plant height (35.215), leaf breadth (26.766), leaf area (32.518), leaf stem ratio (29.631) and green fodder yield (35.030) which indicates that good response for selection based on *per se* performance for these characters (Table-2). Similar result was also noted by earlier workers Kalpande *et al.* (2018). High heritability coupled with high genetic advance estimated for plant height, leaf breadth, leaf area, leaf stem ratio and green fodder yield indicating that these attributes are governed through additive gene action and phenotypic selection for these characters will be effective. Similar views have been reported by Rajarajan *et al.* (2018) and Sumonthant *et al.* (2021). The genotypic and phenotypic correlation coefficients worked out among ten characters showed that in general phenotypic correlation coefficient was higher than the genotypic correlation coefficient which may be a result of modifying effect of environments on the association of the characters. In some cases the genotypic correlation coefficient was slightly higher than the phenotypic correlation coefficients indicating a strong inherent association between various traits. Similar results were obtained by Sumonthant *et al.* (2021). The green fodder yield showed positive and significant correlation with leaf area (0.665 and 0.548) at both genotypic and phenotypic level (Table 3). The result indicated that by improving this character green fodder yield may be enhanced in forage sorghum. These results are in general agreement with the finding of Kumar *et al.* (2020). Phenotypic and genotypic path coefficient exhibited high positive direct contribution of plant height (0.569 and 0.513), leaf breadth (0.373 and 0.346), stem girth (0.497 and 0.403) and leaf stem ratio (0.317 and 0.324) towards green fodder yield (Table 4). This confirms the role of these characters in determining the green fodder yield and therefore, their values in constructing the selection criterion. The direct contribution of plant height, leaf breadth, stem girth and leaf stem ratio with green fodder yield observed in this study is also in confirmation with the findings of Kavya *et al.* (2020). High indirect positive contribution of Days to 50% flowering via leaf length, leaf area and number of leaves per plant; Leaf area through leaf length, leaf breadth, stem girth and leaf stem ratio was observed which is in line with Kavya *et al.* (2020) and Sumonthant *et al.* (2021). and traits which influenced green fodder yield via other attributes

TABLE 2

Estimate of variability parameters for ten characters in forage sorghum

Characters	GCV (%)	PCV (%)	Heritability % (broad sense)	Genetic advance	Genetic advance (as % of mean)
Days to 50% flowering	4.946	5.350	85.450	7.797	9.419
Plant height (cm)	17.198	17.302	98.800	78.837	35.215
Leaf length (cm)	5.398	7.406	53.130	5.492	8.106
Leaf breadth (cm)	14.853	16.979	76.520	1.640	26.766
Leaf area (cm2)	17.479	19.354	81.560	95.237	32.518
Stem girth (mm)	25.247	27.262	51.780	1.263	7.777
No. of leaves per plant	8.801	9.669	36.000	1.111	10.879
Leaf stem ratio (w/w)	53.615	55.018	94.690	30.368	29.631
Total soluble solids (%)	11.011	17.382	40.130	1.232	14.370
Green fodder yield (q/ha)	37.550	37.674	96.790	86.425	35.030

TABLE 3

Estimates of correlation coefficients forgenotypic (G) and phenotypic (P) levels among different characters in forage sorghum

Characters		Days to 50% flowering	Plant height (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)	Stem girth (mm)	No. of Leaves/ plant	Leaf stem ratio (w/w)	Total soluble solids (%)	Green fodder yield (q/ha)
Days to 50% flowering	G	1.000	0.198	-0.140	0.070	-0.121	-0.205	-0.062	-0.201	-0.016	-0.324**
	P	1.000	0.213	-0.073	0.073	-0.080	-0.206	-0.022	-0.194	-0.008	-0.393**
Plant height (cm)	G		1.000	0.024	0.333**	-0.207	-0.163	0.358**	0.203	-0.106	-0.201
	P		1.000	0.027	0.393**	-0.209	-0.175	0.365**	0.198	-0.067	-0.220
Leaf length (cm)	G			1.000	0.110	0.438**	0.020	0.270	0.237	0.025	0.183
	P			1.000	0.074	0.459**	0.047	0.171	0.168	0.035	0.149
Leaf breadth (cm)	G				1.000	0.887**	0.548**	0.148	-0.192	0.204	0.047
	P				1.000	0.897**	0.610**	0.179	-0.160	0.265	0.052
Leaf area (cm2)	G					1.000	0.545**	0.152	-0.172	0.364**	0.665**
	P					1.000	0.641**	0.139	-0.148	0.375**	0.548**
Stem girth (mm)	G						1.000	-0.149	-0.112	0.057	0.208
	P						1.000	-0.049	-0.105	0.068	0.155
No. of leaves per plant	G							1.000	0.357**	0.032	-0.666**
	P							1.000	0.447**	0.046	-0.732**
Leaf stem ratio (w/w)	G								1.000	-0.084	-0.004
	P								1.000	-0.010	-0.002
Total soluble solids (%)	G									1.000	-0.136
	P									1.000	-0.085
Green fodder yield (q/ha)	G										1.000
	P										1.000

*, ** significant at 5% and 1% level, respectively.

TABLE 4

Path coefficient analysis showing the direct and indirect effect of ten characters on the green fodder yield at genotypic and phenotypic level of forage sorghum (*Sorghum bicolor* L. Moench)

Characters		Days to 50% flowering	Plant height (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)	Stem girth (mm)	No. of Leaves/ plant	Leaf stem ratio (w/w)	Total soluble solids (%)	Green fodder yield (q/ha)
Days to50% flowering	G	0.171	0.236	0.224	-0.012	0.320	0.037	0.310	0.034	-0.002	-0.324**
	P	0.179	0.243	0.226	-0.016	0.317	0.025	0.305	0.042	-0.001	-0.393**
Plant height (cm)	G	-0.045	0.513	-0.005	0.071	0.057	0.034	-0.074	-0.043	0.022	-0.201
	P	-0.033	0.569	-0.004	0.049	0.041	0.021	-0.036	-0.033	0.031	-0.220
Leaf length (cm)	G	-0.014	0.002	-0.103	0.011	0.045	-0.002	0.028	0.024	0.033	0.183
	P	-0.007	0.002	-0.105	0.007	0.047	-0.005	0.018	0.027	0.043	0.149
Leaf breadth(cm)	G	-0.024	0.115	-0.038	0.346	-0.007	-0.190	-0.051	0.066	-0.088	0.047
	P	-0.012	0.050	-0.012	0.373	-0.050	-0.053	-0.031	0.027	-0.028	0.052
Leaf area (cm2)	G	-0.027	-0.061	0.299	0.202	-0.128	0.324	0.034	0.339	0.083	0.665**
	P	-0.013	-0.040	0.342	0.242	-0.163	0.355	0.022	0.310	0.093	0.548**
Stem girth (mm)	G	-0.043	-0.033	-0.004	0.111	0.110	0.403	-0.030	-0.022	0.072	0.208
	P	-0.013	-0.012	-0.004	0.030	0.033	0.497	-0.034	-0.010	0.083	0.155
Leaves per plant	G	-0.001	0.009	0.007	-0.004	-0.004	-0.004	0.027	-0.009	0.009	-0.666**
	P	0.001	0.009	0.007	-0.008	-0.006	-0.002	0.034	-0.006	0.006	-0.732**
Leaf stem ratio (w/w)	G	0.005	-0.005	-0.005	0.004	0.004	0.002	-0.008	0.324	-0.002	-0.004
	P	-0.003	-0.003	-0.002	0.002	0.002	0.001	-0.009	0.317	-0.002	-0.002
Total soluble solids (%)	G	0.001	-0.006	0.002	0.001	0.002	0.002	0.002	-0.005	0.006	-0.136
	P	0.005	-0.004	0.002	0.009	0.013	0.002	0.008	-0.006	0.059	-0.085

Residual values (G) = 0.303Residual values (P) = 0.320 *,** significant at 5% 1% level, respectively

Bold values indicate direct effects.

should also be considered to enhance green fodder yield in forage sorghum. The contribution of residual effects that influenced green fodder yield was very low at both genotypic and phenotypic levels, indicating that the characters included in the present investigation were sufficient enough to account for the variability in the dependant attribute *i.e.* green fodder yield. In order to exercise a suitable selection programme it would be worth to concentrate on traits like plant height, leaf breadth, stem girth and leaf stem ratio governing green fodder yield directly whereas days to 50% flowering and leaf area controlling green fodder yield indirectly. In the present investigation, considering correlation and path coefficient analysis together, it could be concluded that plant height, leaf breadth, stem girth, leaf stem ratio days to 50% flowering and leaf area are the most important attributes for improvement green fodder yield in forage sorghum.

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