Variation and Association among Fodder Yield and other Traits in Germplasm of Forage Sorghum (*Sorghum bicolor* (L.) Moench)

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An evaluation of 105 forage sorghum germplasm, for days to 50% flowering, plant height, number of leaves/plant, leaf length, leaf breadth, stem girth, leaf stem ratio and green and dry fodder yield/plant in Augmented Block Design during 2008-09 and 2009-10, revealed highly significant difference amongst the accessions. The phenotypic coefficient of variation was higher than the corresponding genotypic coefficients for all the characters, denoting environmental factors influenced their expression. Broad sense heritability was moderate (61.21% for number of leaves/plant) to high (92.49 for stem girth) confirming that genotypic variance has contributed substantially to the total variance. The association and path coefficient analysis revealed that stem girth, number of leaves/plant, plant height, leaf length and leaf breadth were the important characters and may be selected to increase the fodder yield. Based on the results of the means of the two years considering together the various traits, the accession IS-3665 and EJ-16 was found to be superior for days to 50% flowering, RAJ-21 for plant height and leaf characters, IS-2887 and IS-3266 for green fodder yield. Therefore, these accessions may be utilized in further breeding programme for developing superior varieties.

Key Words: Forage Sorghum, Germplasm, Heritability

Introduction

Forage crops are important for the economy of India as these crops provide major nutritional base for the livestock. With the increase in the world human population and economic growth, the demand of animal products such as milk, meat and eggs in the human diet is bound to increase. Improvement in the quality of cattle and buffalo depends upon the adequate supply of required feed and fodders (Patil and Singh, 2006). In northern Gujarat, livestock is an important component of rural and urban economy. However, the low productivity of livestock is a matter of concern, which is primarily due to insufficient fodder and feed resources and non availability of quality fodder. To sustain the wealth and provide nutritional security for animal health the large quantity of quality green fodder is required (Anonymous, 2006). Sorghum (*Sorghum bicolor* (L.) Moench) because of its high tolerance to high temperature and better ability to withstand drought is suited for arid and semi-arid regions of Gujarat and can play a vital role for the uplift of socio-economic status of the farmers. Sorghum is preferred over maize in *kharif* and summer season because of its high tolerance to various stress and its superiority to pearlmillet in having lower oxalate and fiber content (Prakash *et al*., 2010). The production potential of the sorghum varieties is low in Gujarat. The majority of the farmers in this area grow sorghum for fodder purpose and harvest these landraces along with the ear head at the time of maturity to feed the cattle.

Plant genetic resources play an important role in generating new crop varieties with the high yield potential and resistance to biotic and abiotic stresses. It is well established fact that the progress in improvement of a crop depends on the degree of variability in the desired character in the base material *vis-à-vis* germplasm collection. The study of relationships among quantitative traits is important for assessing the feasibility of joint selection of two or more traits and hence for evaluating the effect of selection for secondary traits on genetic gain for the primary trait under consideration. A positive genetic correlation between two desirable traits makes the job of the plant breeder easy for improving both traits simultaneously. The path coefficient analysis allows partitioning of correlation coefficient into direct and indirect contributions (effects) of various traits towards dependent variable and thus, helps in assessing the cause-effect relationship as well as effective selection. In the present study, therefore, variability for fodder yield and related attributes was estimated in a collection of 105 accessions over the two years.

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Materials and Methods

One hundred five forage sorghum genotypes collected from Directorate of Sorghum Research, Hyderabad and local landraces of Gujarat were used for the present study. The trial was grown in Augmented Block Design for two seasons *kharif* 2008 and *kharif* 2009 at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa (Gujarat). In both seasons these accessions were divided in to the seven blocks and each block consisted of 15 accessions with three check varieties *viz.*, GJ-39, GFS-5 and CSV-21 (F). Deesa is situated at latitude of 24.5^{o} N and longitude 72^{o} E and at an elevation of 136 M msl. The soil of the field was sandy in texture with pH value of 7.5 to 8.00 having good physical and chemical properties (Organic Carbon= 0.23, EC dsm^{-} = 0.232, K_2O= 259.9 kg/ha and P_2O_5= 46.2 kg/ha). The experimental unit was a single-row plot of 6.75 m long, spaced at 0.45 m apart. NPK 120:40:00 fertilizer was applied as half basal dose of nitrogen and full dose of phosphorus at the time of sowing and half nitrogen applied after one month of sowing. Plots were thinned down after two weeks of crop emergence and plant-to-plant distance of 0.10 m was maintained. The experimental years showed different temperature regimes, humidity, rain fall and sunshine hours during the crop durations. The all other recommended agronomical practices were followed to raise a good crop in both the seasons. Data were taken on days to 50% flowering, plant height (cm), number of leaves/plant, leaf length (cm), leaf breadth (cm), stem girth (cm), leaf stem ratio, green fodder yield/plant(g) and dry fodder yield/plant (g). Statistical analysis was done according to the standard statistical procedures (Federer, 1996; Burton, 1952; Johnson *et al.*, 1955; Al-Jibouri *et al.*, 1958; Dewey and Lu, 1959).

Results and Discussion

In an augmented design, the evaluation of the checks is first done to get an estimate of error, which is used for deriving adjusted values of entries. The data obtained from both seasons was significant for most of the traits indicating the effects of season x genotype interactions. Hence, the ANOVA was done season wise. Evaluation of 105 accessions in both the season showed significant differences for the traits *viz.*, days to 50% flowering, plant height, number of leaves/plant, leaf length, stem girth, green fodder yield and dry fodder yield suggesting the estimate of significant variation among the entries. These results support the selection programme for high yielding genotypes. Similar pattern of variability in germplasm evaluation of different sizes have been reported by earlier workers (Alhassan *et al.*, 2008; Warked *et al.*, 2008; Jain *et al.*, 2009).

The genetic constants for the characters revealed that the magnitude of phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV) for all the traits denoting environmental factors influencing their expression to some degree or other (Table1). Wide differences between PCV and GCV implied their susceptibility to environmental fluctuation, whereas narrow differences between PCV and GCV suggested their relative resistance to environmental alterations. The estimate of GCV and PCV alone is not much helpful in determining the heritable portion. The amount of advance to be expected from selection can be achieved by estimating heritability along with coefficient of variability. Burton (1952) also suggested that GCV and heritability estimate would give better information about the efficiency of selection. The heritability in broad sense was observed to be high 61.21 to 92.49 for all the traits which had significant differences among the accessions in both the seasons. The high degree of heritability estimates for most of the traits suggested that the characters are under genotypic control. Similar result was also reported by earlier workers (Sharma *et al.*, 2006; Jain *et al.*, 2009). High heritability coupled with high genetic advance and GCV were noticed for days to 50% flowering, green fodder yield/plant, dry fodder yield/plant and plant height. From the study of heritability and genetic advance it is inferred that simple selection among germplasm accessions can bring about significant improvement in these traits as the heritability and estimated genetic advance were high. The expected genetic advance might have been biased upward as it is based on the estimates of heritability in broad sense, secondly in the augmented design the estimation of mean square due to the error is based on the check variety only, and hence, it might have given the high estimates of genetic variances in it.

The genotypic and phenotypic correlation coefficients worked out among different characters including green and dry fodder yield/plant revealed that in general

Table 1. Range, mean, coefficient of variation, heritability and expected genetic advance for green fodder yield other characters in sorghum

Characters	Years	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability (broad sense) (%)	Expected genetic advance % of Mean
Days to 50% flowering	I	13.52	12.36	83.56	17.40
	II	12.51	13.21	80.21	17.40
Plant height	I	29.95	36.90	92.17	67.87
	II	28.21	37.21	91.52	65.54
Number of leaves/plant	I	36.60	29.91	61.79	4.44
	II	37.41	32.01	61.21	4.10
Leaf length	I	13.88	9.00	90.00	0.17
	II	14.21	10.21	91.41	0.31
Leaf breath	I	24.06	21.69	81.24	1.85
	II	24.51	23.21	82.54	2.10
Stem girth	I	49.67	47.77	92.49	2.90
	II	44.21	46.54	91.42	3.21
Leaf: stem ratio	I	43.29	35.99	69.09	0.21
	II	42.10	36.21	66.54	0.32
Green fodder yield/plant	I	50.73	45.87	81.75	109.50
	II	52.10	44.21	80.41	100.2
Dry fodder yield/plant	I	54.89	48.69	78.70	47.90
	II	52.31	41.54	75.21	42.21

Table 2. Phenotypic correlation coefficient on the basis of unadjusted values between different characters in sorghum over two years

Character	Year	Plant height	No. of leaves/ plant	Leaf length	Leaf breadth	Stem girth	Leaf stem ratio	Green fodder yield/plant	Dry fodder yield/ plant
Days to 50 % flowering	I	0.2139	0.2147	0.2132	0.2952	-0.2048	-0.0107	-0.1204	0.0913
	II	0.1594	0.1939	0.1717	0.2381	-0.2135	-0.016	-0.1258	0.0924
Plant height (cm)	I	-	0.4342**	0.2742	0.2162	0.0736	-0.2435	0.3494**	0.1967
	II	-	0.4151**	0.2715	0.089	0.1233	-0.1525	0.425**	0.2385
No. of leaves/plant	I		-	0.4405**	0.3323*	0.0537	-0.2104	0.4138**	0.2046
	II		-	0.3905**	0.3074*	0.0596	-0.1557	0.4382**	0.2107
Leaf length	I			-	0.4866**	0.1077	-0.3277*	0.1819	0.2922*
	II			-	0.4784**	0.144	-0.3065*	0.3222*	0.2827*
Leaf breadth	I				-	-0.2195	-0.3696*	-0.2243	-0.0082
	II				-	-0.2566	-0.317*	-0.3233*	-0.0356
Stem girth	I					-	-0.0042	0.6992**	0.4723**
	II					-	0.005	0.6698**	0.4799**
Leaf stem ratio	I						-	0.0065	-0.1112
	II						-	-0.0029	-0.103
Dry fodder yield/ plant	I							-	0.7982
	II							-	0.8121

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

the phenotypic correlation coefficient were similar to genotypic correlation coefficient (Table 2). In some cases the phenotypic correlation was slightly higher then the genotypic correlation coefficients, which may be a result of modifying effect of environments on the association of the characters. The green fodder yield/ plant showed positive and significant correlation with stem girth, number of leaves/plant, plant height and leaf breadth in both the seasons while with the leaf length although a positive association was observed in both

Table 3. Direct (diagonal) and indirect (non diagonal) effects of different characters on green fodder yield in sorghum at genotypic level over two years

Characters		Days to 50% flowering	Plant height	No. of Leaves/ plant	Leaf length	Leaf breadth	Stem girth	Leaf stem ratio	Dry fodder Yield/ plant
Days to 50 % flowering	I	**-0.0871**	-0.0186	-0.0187	-0.0186	-0.0257	0.0178	0.0009	-0.0079
	II	**-0.1176**	-0.0188	-0.0228	-0.0202	-0.028	0.0251	0.0019	-0.0109
Plant height	I	0.0104	**0.2487**	0.0211	0.0133	0.0105	0.0036	-0.0119	0.0096
	II	0.008	**0.2502**	0.0209	0.0136	0.0045	0.0062	-0.0077	0.012
No. of leaves/plant	I	-0.0004	-0.0008	**0.2018**	-0.0008	-0.0006	-0.0001	0.0004	-0.0004
	II	0.0003	0.0007	**0.2016**	0.0006	0.0005	0.0001	-0.0002	0.0003
Leaf length	I	0.0107	0.0138	0.0221	**0.0502**	0.0244	0.0054	-0.0165	0.0147
	II	0.0136	0.0216	0.031	**0.0794**	0.038	0.0114	-0.0243	0.0224
Leaf breadth	I	-0.0384	-0.0282	-0.0433	-0.0634	**-0.1302**	0.0286	0.0481	0.0011
	II	-0.03	-0.0112	-0.0388	-0.0603	**-0.1261**	0.0324	0.04	0.0045
Stem girth	I	-0.0718	0.0258	0.0188	0.0377	-0.0769	**0.3504**	-0.0015	0.1655
	II	-0.0598	0.0345	0.0167	0.0403	-0.0719	**0.2801**	0.0014	0.1344
Leaf stem ratio	I	-0.0006	-0.0136	-0.0118	-0.0183	-0.0207	-0.0002	**0.056**	-0.0062
	II	-0.0009	-0.0082	-0.0083	-0.0164	-0.017	0.0003	**0.0535**	-0.0055
Dry fodder yield/plant	I	0.0568	0.1224	0.1273	0.1817	-0.0051	0.2937	-0.0691	**0.6219**
	II	0.0605	0.1561	0.138	0.1851	-0.0233	0.3142	-0.0675	**0.6548**

Residual effects: 0.449 (I Year), Residual effects: 0.456 (II Year)

the seasons the value was significant only in the II year. Green fodder yield exhibited negative correlation with leaf breadth; however, the value was significant in II year only. It is also noticed that characters *viz*., number of leaves/plant, plant height, leaf length and stem girth exhibited positive associations with fodder yield have also showed positive associations among themselves in both the years. Out of these traits some traits like plant height and stem girth are having the high broad sense heritability and high expected genetic advance should be used in selection programme. Similar views have been reported by earlier workers (Anup *et al*., 2000; Sankarapandian, 2010).

Correlation co-efficient indicates only the general associations between any two traits without tracing any possible causes of such associations. In such situations, the path coefficient analysis at phenotypic level (Table 3) is done to partition the correlation coefficients in to direct and indirect effects. Green fodder yield/plant was taken as dependent variable while computing the path coefficient. The path coefficient analysis based on both the seasons revealed that the characters like stem girth, number of leaves/plant, plant height and leaf length which had positive significant association with green fodder yield also exerted positive and high direct effects on green fodder yield (Table 3). This confirms the role of these traits in determining the green fodder yield and therefore, their values in constructing the selection criterion. Whereas leaf breadth showed positive significant association with green and dry fodder yield in both the seasons. But the direct effect of leaf breadth was negative with fodder yield in both the season, which may be a result of the indirect effect of this trait *via* other traits.

The conclusion that can be reached from the variability, correlations and path coefficient is that number of leaves/plant, leaf length, leaf breadth and stem girth are the most important component traits for green and dry fodder yield/plant. Based on the results of the means of the two seasons some of the accessions identified superior for the different morphological characters were IS-3665 and EJ-16 was for earliness, RAJ-21 for plant height and leaf characters, IS-2887 and IS-3266 for fodder yield (Table 3). Therefore, these accessions could be utilized in further breeding programme for developing superior varieties of fodder sorghum.

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Table 4. Top ranking accessions selected on the basis of average of different characters over two years (2008-09 and 2009-10) in forage sorghum

S.No.	Days to 50 % flowering	Plant height (cm)	Number of leaves/plant	Leaf length (cm)	Leaf breadth (cm)	Stem girth (cm)	Green fodder yield/plant (g)	Dry fodder yield/plant (g)
1	IS-3265 (46.5)	RAJ-21 (285)	E-3 (14.75)	RAJ-21 (75.75)	RAJ-21 (7.75)	IS-3309 (4.9)	IS-2887 (290.05)	IS-3309 (142.6)
2	EJ-16 (49.0)	IS-3316 (250)	RAJ-21 (14.35)	IS-3922 (73.95)	RAJ-30 (7.2)	IS-2887 (4.8)	IS-3266 (288.9)	IS-3266 (113.5)
3	EJ-15 (49.0)	IS-3260 (245)	RAJ-25 (14.2)	E-14 (70.80)	RAJ-7 (6.6)	IS-3260 (4.7)	IS-3922 (278.7)	IS-3922 (105.7)
4	EJ-17 (51.0)	IS-3328 (243)	IS-3338 (14.1)	IS-6065 (72.75)	EP-59 (6.55)	IS-3215 (4.6)	IS-3309 (250.25)	IS-3342 (97.5)
5	IS-3203 (53.5)	IS-3338 (237)	IS-3336 (13.55)	E-13 (72.25)	RAJ-19 (6.55)	IS-3336 (4.45)	IS-3342 (234.6)	IS-3328 (92.9)
6	IS-3267 (54.5)	E-14 (235)	EP-59 (13.55)	RAJ-25 (72.1)	RAJ-20 (6.5)	IS-3328 (4.4)	IS-3328 (218.3)	IS-2887 (88.1)
7	IS-3250 (57.0)	IS-6014 (232)	RAJ-20 (12.95)	RAJ-20 (71.75)	RAJ-15 (6.4)	IS-3321 (4.4)	IS-3284 (202.5)	IS-3321 (83.75)
8	E-12 (58.5)	RAJ-20 (233)	IS-3267 (12.75)	IS-3306 (71.35)	EP-56 (6.35)	IS-3922 (4.35)	IS-3341 (200.25)	IS-3341 (77.5)
9	IS-3223 (59.0)	EJ-42 (223)	EP-139 (12.4)	IS-3371 (70.7)	EP-58 (6.35)	IS-700 (4.30)	IS-3321 (197.25)	IS-698 (71.75)
10	E-3 (59.0)	RAJ-7 (223)	EP-56 (12.35)	EP-56 (70.5)	RAJ-16 (6.15)	IS-3267 (4.30)	IS-3374 (194.75)	IS-3274 (71.75)
11	IS-3266 (59.5)	RAJ-25 (222)	RAJ-30 (12.35)	IS-4015 (69.6)	EP-61 (6.10)	IS-3241 (4.30)	IS-697 (184.5)	IS-3365 (70.5)
12	EJ-18 (61.0)	E-3 (221)	RAJ-15 (12.25)	IS-3342 (69.75)	RAJ-8 (6.15)	IS-4266 (4.0)	IS-703 (180.7)	IS-703 (68.15)
13	E-4 (62.5)	IS-697 (220)	IS-3276 (12.20)	IS-3336 (68.9)	SEVS-5 (5.85)	IS-3267 (4.0)	IS-3274 (179.9)	IS-3284 (65.15)
14	IS-6065 (63.5)	IS-3199 (220)	IS-3279 (12.2)	IS-3222 (68.5)	SEVS-4 5.8)	E-2 (3.95)	IS-3365 (179.0)	IS-3374 (42.4)
15	IS-18676 (63.5)	E-12 (220)	RAJ-8 (12.35)	IS-3301 (68.4)	SEVS-6 (5.65)	IS-606 (3.85)	IS-698 (177.7)	IS-697 (27.8)

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