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Genetic Evaluation of Agronomic Parameters for Green Fodder Yield in Sorghum (*Sorghum bicolor* L.)

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ABSTRACT

For green fodder yield and its contributing traits in Sorghum (*Sorghum bicolor* L.), genotypic and phenotypic coefficients of variability, heritability and genetic advance were estimated. Higher estimates of genetic variability were computed in internodal length followed by green fodder yield, plant height, number of leaves per plant and leaf area, whereas the least genetic coefficient of variability was observed in the days to 50% flowering. Higher amount of heritability was expressed by plant height followed by internodal length, number of leaves per plant, leaf area and green fodder yield. High estimates of genetic advance were computed for plant height followed by leaf area and internodal length. Correlation analysis at a genotypic level of the present breeding material indicated that plant height mainly increases with the increase in internodal length and with the increase in plant height, leaf area and number of leaves per plant, green fodder yield would increase. Path coefficients were computed to estimate the contribution of individual characters to green fodder yield in sorghum (*Sorghum bicolor* L.). Highest overall effect on green fodder yield was observed associated with plant height followed by internodal length, leaf area and number of leaves per plant.

Introduction

Total area under different fodder crops in Pakistan is 2.51 million hectares producing 56.08 million tons green fodder annually with an average production of 22.3 t ha^{-1} (Govt. of Pakistan 2003). An estimate of the digestibility of the fodder is given by total digestible nutrients (TDN). It refers to the sum total of digestible protein, carbohydrates and fats. About 150 kg TDN is provided by one ton of good pasture grass. At present, livestock is receiving 51% of nutrients from green fodder crops (Sarwar et al. 2002). Currently, 121.1 million heads of animals in Pakistan annually require about 93.36 million tons total digestible nutrients (TDN). However, the availability of nutrients is 69.0 million tons, and thus TDN is 24.02% deficient per annum. At present, livestock is receiving 51% of nutrients from green fodder crops (Sarwar et al. 2002). Livestock is humans' main source of milk, meat, skin and bones. The country is spending about Rs. 300 to 400 million annually to import milk and milk byproducts to meet the domestic demands. Similarly, skin products, wool products are also imported worth the valuable foreign exchange. Annual demand of livestock products in the country is increasing due to increase in human population, where per-capita consumption has been already very low compared to advanced countries. Local production of livestock-related commodities could be increased by providing good fodder to livestock. Therefore, the situation strongly urges to increase in fodder quantity as well as quality.

Forage Sorghum (*Sorghum bicolor* L.) is an important kharif fodder, hay and silage crop. It is grown for dual purposes, i.e. grain and forage. Sorghum is characterized by abundant sweet juice in the stalks, and the height usually ranges from 1.5 m to 3.0 m. It is consumed as food for poor masses and feed by poultry and cattle. Plant foliage is used for green chop hay, silage and pasture (Sartaj et al. 1984). A number of reports have shown that sweet sorghum is a potential source of sugar and multipurpose industrial crop.

It is a short-duration crop possessing tolerance to drought due to its extensive root system. It provides a soft and palatable nutritionally balanced fodder during summer months. (Keerio and Singh 1985). Owing to its natural drought resistance qualities, sorghum is a promising crop to overcome the fodder shortage. These factors contribute green fodder production both directly and indirectly and breeder naturally interested in explaining the extent and type of association of such traits. Several methods have been proposed to evaluate the genetic potential of populations.

Analysis of variance and covariance helps in partitioning the total variance into its component parts. The least significant difference (LSD) reveals the statistically significant differences among the accessions. Heritability is an index of transmissibility of traits and as such partitions the total variance into genetic and environmental components (Falconer and Mackay 1996). Genetic advance is simply the expected genetic gain with one cycle of selection (Poehlman and Sleper 1995). Correlation analysis provides information on the relationship of important plant traits. Working knowledge of the direct and indirect contributions of different components toward final productivity also aids to identify the potential of accessions. Path coefficients have been used to develop selection criteria for complex traits in several crop species (Dewey and Lu. 1959, Pokle et al. 1973, Chauhan and Singh 1975, Dremlyuk and Gamandii 1986, Yadav et al., 2003).

The present studies were undertaken to estimate the genetic variability, heritability, genetic advance, correlation and path coefficient analysis for green fodder yield and its contributing traits in forty accessions of *Sorghum bicolor* L., in order to evolve an efficient selection criterion.

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Material and methods:

The studies reported were conducted in an experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. Forty sorghum (*Sorghum bicolor* L.) accessions were sown in the experimental field utilizing triplicated Randomized Complete Block Design (RCBD). The sowing was done in the month of July, which was appropriate for high fodder yield as suggested by Batta et al. (1996), in 600 mm apart rows, maintaining plant to plant distance 150 mm with the help of dibbler. Tomeu (1974) suggested that row spacing had no effect on total forage production in sorghum. Three seeds per hole were planted and were not thinned. Each entry comprised of two rows each of 3 m length. Identical cultural and agronomic practices were applied to all accessions. Soil texture of the field is sandy loam, suitable for crop growth but soil is deficient in the nutrients and organic matter, so fertilizer DAP at the rate of one bag per acre and Urea half a bag per acre was applied at the sowing time. Remaining half a bag of Urea was applied with second irrigation. Total 4-5 irrigations were applied during the entire stand of crop. Each entry comprised of two rows each of 3m length.

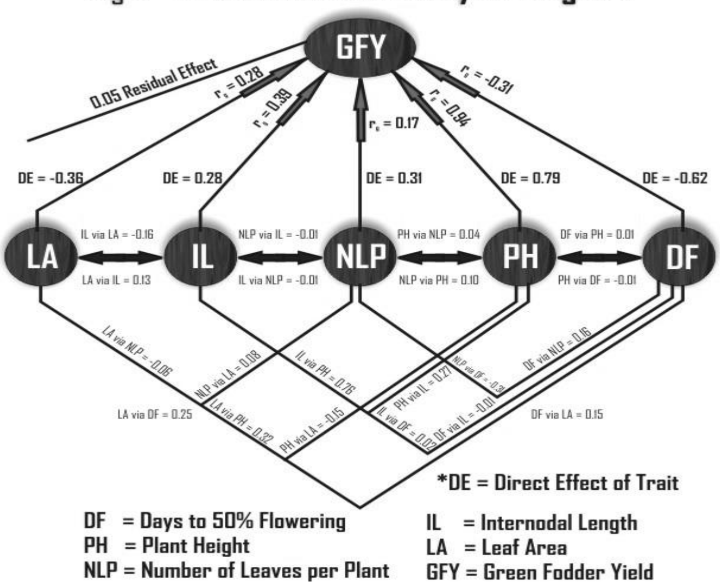
The climatic conditions of Faisalabad, wherein the present experiment was conducted, is located between 31°- 26° N Latitude and 73° -06° E Longitude on the globe with the Altitude of 184.4 m from sea level (Govt. of Pakistan, 2003). Meteorological data in the field showed the range of temperature 5.00° C to 43.50° C, humidity 42.00% to 93.00%, rainfall 0.00 mm to 57.20 mm, pan evaporation 1.00 mm to 10.00 mm, net radiation 2.90 MJ m^{-2} per day to 19.00 MJ m^{-2} per day, Evapotranspiration 0.90 mm to 7.00 mm and wind speed 0.80 km h^{-1} to 9.20 km h^{-1}. The experimental material comprised of the following sorghum accessions.

1. PARC-SS-II	21. 9806
2. 1677	22. 1763
3. PARC-SV-5	23. JS-100
4. 1716	24. FC-26-II
5. No. 70	25. 1641
6. 1572	26. B-169
7. SS-93-3	27. SS-1563
8. SS-95-1 (WG)	28. Local R. Pindi
9. 1518	29. YSS-89
10. SS-98-8	30. SS-97-5
11. F-9706	31. SS-95-5
12. 9603	32. SS-97-1
13. SS-95-8	33. T3 Dadu
14. SS-95-4	34. 1500
15. 1826	35. SS-97-10
16. SS-97-2 (S1)	36. BJ-1914
17. 1863	37. F-9706
18. SS-95 (RG)	38. L2-10-89
19. PARC-SS-I	39. 1828 Red
20. Pak-47	40. SS-97-9

These Sorghum accessions were collected by the fodder research team, Department of Plant Breeding and Genetics and Institute of Plant Genetic Resources, National Agriculture Research Centre, Islamabad. When the emergence of heads started, the data on the following traits were recorded from ten randomly taken plants of each entry in each replication. Days to 50% flowering, Plant height (cm), Number of leaves per plant, Internodal length (cm), Leaf area (cm^2) and Green fodder yield (kg per unit area $1\times0.06m^2$).

The data collected was subjected to analysis of variance (Steel and Torrie, 1980) and variance was partitioned into genotypic and phenotypic components. Heritability in the broad sense was estimated according to Burton and DeVane (1953). Genetic advance was computed at 20% selection intensity, according to the formula of Poehlman and Sleper (1995). Correlation analysis was performed according to the statistical technique outlined by Kwon and Torrie (1964). Genotypic correlations were tested against the double value of S.E. according to the methodology given by Lothrop et al. (1985). The standard error for heritability was calculated by the formula prescribed by Reeve (1955) and Robertson (1959). A genetic correlation was considered significant statistically if its absolute value exceeded the twice of the respective standard error. Statistical significance of phenotypic correlation was determined by using t-test as described by Steel and Torrie (1980). Correlation was considered significant if t-calculated was greater than t-tabulated. Path coefficient analysis was performed according to the method prescribed by Dewey and Lu (1959), by solving the simultaneous equations using genotypic correlations, whereas green fodder yield per plot was kept as the resultant variable (effect) and yield contributing characters as causal variables (causes).

Fig-1 Path Coefficient Analysis Diagram



Results and discussion:

In sorghum accessions under study, highest genetic variability was present in internodal length along with the second highest estimate of the phenotypic coefficient of variability followed by internodal length, green fodder yield, plant height and leaf area while the least coefficient of variability was observed in case of days to 50% flowering (Table-1). Results are in accordance with the conclusions of Asthana et al. (1995), Biradar et al. (1996) and Sankarapandian et al. (1996) who noticed that phenotypic and genotypic coefficient of variation was high for the internodal length.

It is obvious from the Table-4 that plant height exhibits highest estimates of heritability (0.94) coupled with the highest estimate of genetic advance (76.22) followed by internodal length, number of leaves per plant and leaf area, which indicated the presence of a high proportion of total variability was due to genetic causes. This is confirmed by a minute difference between genotypic and phenotypic coefficients of variability. The results are in accordance with the observations of a number of workers who reported high estimates of heritability and genetic advance in case of plant height (Sidhu and Mehndiratta 1980, Amirthadevarathinam and Sankarapandian 1994, Biradar et al. 1996, Rao and Patil 1996, Sankarapandian et al. 1996, Anup and Vijayakumar 2000, Desai et al. 2000 and Salunke et al. 2000).

Table 1. Genetic parameters for green fodder yield and its components in *Sorghum bicolor* L. accessions

	$σ^2_g$	$σ^2_p$	Gcv	Pcv	h^2	G.A.
Days to 50% flowering	1.66	4.92	1.78	3.07	0.34	1.05
Plant height	3138.74	3325.85	21.88	22.52	0.94	76.22
No. of leaves per plant	1.72	2.62	8.98	11.10	0.66	1.55
Internodal length	23.89	27.20	28.71	30.64	0.88	6.41
Leaf area	1699.53	4106.02	8.94	13.89	0.41	37.14
Green fodder yield	0.35	0.90	26.85	43.06	0.39	0.51

$σ^2_g$ = Genotypic variance, $σ^2_p$ = Phenotypic variance, Gcv = Genotypic coefficient of variance,
Pcv = Phenotypic coefficient of variance, h^2 = Heritability *(Broad sense)* and G.A. = Genetic Advance

Table 2. Genotypic correlation coefficients of green fodder yield and its components in *Sorghum bicolor* L

VARIABLES	Days to 50% flowering	Plant height	No. of leaves per plant	Internodal length	Leaf area
Days to 50% flowering	1				
Plant height	0.01	1			
No. of leaves per plant	0.51 **	0.12 **	1		
Internodal length	-0.03	0.96 **	-0.01 **	1	
Leaf area	-0.41 **	0.40 **	-0.21 **	0.45 **	1
Green fodder yield	-0.31 *	0.94 **	0.17 **	0.89 **	0.28 **

* stands for Significant and ** for Highly Significant

Table 3. Mean performance of different sorghum accessions for green fodder yield and its contributing traits in sorghum (*Sorghum bicolor* L.)

Accessions	DF	PH	NL	IL	LA	GFY
1	73.00	320.23	16.63	20.53	480.97	3.50
2	75.00	294.30	13.85	21.49	429.77	2.10
3	74.33	252.77	16.72	14.96	432.45	2.07
4	75.67	268.08	17.13	17.28	451.21	1.65
5	72.00	272.83	15.46	18.33	569.76	2.57
6	71.00	182.03	16.67	9.67	437.42	0.90
7	72.33	242.40	13.59	18.59	511.48	1.73
8	71.00	310.70	15.63	20.51	503.68	2.95
9	71.67	304.64	15.12	20.53	381.61	2.97
10	73.67	267.03	14.37	17.92	465.76	2.60
11	70.67	275.51	14.06	19.16	480.02	2.90
12	71.00	272.23	14.19	21.62	512.31	3.07
13	71.00	266.37	12.85	17.86	551.65	2.20
14	70.67	260.23	13.00	17.80	553.51	2.07
15	74.00	234.81	13.72	14.33	513.15	1.13
16	69.00	128.30	12.07	5.46	442.11	0.97
17	72.67	195.06	15.80	9.59	439.67	1.63
18	71.00	256.47	15.41	13.86	422.57	2.33
19	71.67	319.80	15.22	21.38	423.22	2.00
20	71.00	123.43	13.93	6.67	398.26	1.27
21	72.67	252.50	13.26	19.02	394.94	2.12
22	73.00	242.07	14.00	15.28	427.40	2.50
23	74.67	136.19	14.31	7.25	388.37	1.67
24	73.00	266.53	13.52	16.91	423.33	1.93
25	74.00	333.80	17.15	21.34	480.53	3.87
26	71.33	257.95	14.38	20.01	539.79	1.57
27	69.67	164.33	14.68	11.93	381.43	1.70
28	70.00	317.98	14.92	23.49	509.96	2.57
29	75.00	218.79	13.59	13.79	430.66	1.45
30	70.33	303.47	13.37	23.30	466.69	3.07
31	73.00	228.76	11.41	14.02	503.07	2.02
32	73.33	318.03	15.22	23.46	463.66	2.33
33	71.67	319.83	14.93	24.23	457.50	3.13
34	72.33	238.99	13.45	16.34	510.82	1.60
35	72.00	308.72	13.28	22.80	412.90	2.65
36	73.33	178.16	17.58	8.65	422.67	1.03
37	71.00	324.43	14.11	21.62	518.23	2.03
38	74.67	204.33	16.32	13.61	420.88	1.65
39	69.67	275.03	13.59	16.44	435.23	3.47
40	73.00	308.23	14.96	19.71	462.45	2.78

DF= Days to 50% flowering, PL= Plant height, NL= No. of leaves per plant, IL= Internodal length, LA= Leaf area and GFY= Green fodder yield

Table 4. Mean squares and F. Ratio of analysis of variance (ANOVA) for green fodder yield and its components in *Sorghum bicolor* L

Characters	MS (Rep.)	F. Ratio (Rep.)	MS (Accessions)	F. Ratio (Accessions)	MS (Error)	St. Error
Days to 50% flowering	4.41	1.35 ns	8.24	2.52 **	3.26	1.04
Plant height	468.25	2.50 ns	9603.33	51.33 **	187.10	7.90
No. of leaves per plant	1.03	1.14 ns	6.06	6.70 **	0.90	0.55
Internodal length	0.24	0.07 ns	74.97	22.64 **	3.31	1.49
Leaf area	22967	9.54 **	7505.08	3.12 **	2406.49	40.05
Green fodder yield	0.05	0.10 ns	1.60	2.91 **	0.55	0.61

** = Highly significant; ns = Non significant; Degree of freedom for accessions is 39 and for error is 78; MS stands for Mean Square; Rep. denotes for Replicate and St. Error denotes for Standard Error.

Table 5. Direct and indirect effects of days to 50% flowering, plant height, number of leaves per plant, internodal length and leaf area on green fodder yield in sorghum (*Sorghum bicolor* L. Moench.).

Path ways of association	Direct effect (P)	Indirect effects (P x r)	(r)
1- Days to 50% Flowering			
(a) Direct effect	-0.62		
(b) Indirect effect via			
Plant Height		0.01	
Number of Leaves per Plant		0.16	
Internodal Length		-0.01	
Leaf area		0.15	
(c) Total effect			-0.31
2- Plant Height			
(a) Direct effect	0.79		
(b) Indirect effect via			
Days to 50% Flowering		-0.01	
Number of Leaves per Plant		0.04	
Internodal Length		0.27	
Leaf area		-0.15	
(c) Total effect			0.94
3- Number of Leaves per Plant			
(a) Direct effect	0.31		
(b) Indirect effect via			
Days to 50% Flowering		-0.31	
Plant Height		0.10	
Internodal Length		-0.01	
Leaf area		0.08	
(c) Total effect			0.17
4- Internodal Length			
(a) Direct effect	0.28		
(b) Indirect effect via			
Days to 50% Flowering		0.02	
Plant Height		0.76	
Number of Leaves per Plant		-0.01	
Leaf area		-0.16	
(c) Total effect			0.89
5- Leaf Area			
(a) Direct effect	-0.36		
(b) Indirect effect via			
Days to 50% Flowering		0.25	
Plant Height		0.32	
Number of Leaves per Plant		-0.06	
Internodal Length		0.13	
(c) Total effect			0.28

P = Path Coefficient, (P x r) = Path Coefficients

Whilst Prasad et al. (2002) and Sankarapandian (2002) reported high heritability and moderate genetic advance estimates in case of plant height. On the other hand, Kanaka (1982) reported that heritability was moderate for plant height. Least amount of heritability and genetic advance was observed in case of days to 50% flowering.

Genotypic correlations were computed among the green fodder yield and its components. The results achieved about genotypic correlations are presented in Table 2. Highly significant and positive, genotypic correlation was present between plant height and green fodder yield. The genotypic correlation between the number of leaves and green fodder yield also appeared significantly positive. Similarly the internodal length and leaf area showed the highly significant genotypic correlation with green fodder yield. Whereas, negative and highly significant genotypic correlation was observed between days to 50% flowering and green fodder yield. Similar correlations were observed by Phul et al. (1972), Hussain and Khan (1973), Pokle et al. (1973), Chauhan and Singh (1975), Goud and Asawa (1978), Saini and Paroda (1978), Rana et al. (1984), Chaudhary et al. (1990), Jeyaprakash et al. (1997), Desai et al. (1999), Anup and Vijayakumar (2000), Sunku et al. (2002) and Yadav et al. (2003). Correlation analysis at the genotypic level of the present breeding material indicated that plant height mainly increases with the increase in internodal length and with the increase in plant height; green fodder yield would be increased.

The path coefficient analysis showed that plant height contributed the highest (0.94) to green fodder yield followed by internodal length (0.89), leaf area (0.28) and number of leaves per plant (0.17) and other characters contributed via these characters. These four characters seem to be more important for selecting high-yielding accessions in *Sorghum bicolor* L. Direct effect of plant height to green fodder yield was positive (0.79). The indirect effect via Internodal length (0.27) was positive and noticeable whilst the indirect effect via the number of leaves per plant was positive (0.04) and merely negligible. The indirect effect via days to 50% flowering was negative (-0.01) along with indirect effect via leaf area, which was also negative (-0.15). Total correlation coefficient was mainly due to its indirect effect through Internodal length.

Direct effect of the number of leaves per plant on green fodder yield was also found positive (0.17). Indirect effect via plant height (0.10) and leaf area (0.08) was positive, whereas the indirect effect via days to 50% flowering (-0.31) and internodal length (-0.01) was negative. In case of internodal length, direct effect of internodal length on green fodder yield was positive (0.28) and genotypic correlation between these two characters was (0.89) also positive and highly significant. Indirect effect via plant height was positive and highly considerable (0.76) and via days to 50% flowering (0.02) was also positive. Whereas the indirect effect via leaf area (-0.16) was negative and via the number of leaves per plant (-0.01) was also found negative, but the amount is small enough to be negligible.

Positive and highly significant (0.28) genetic association was present between leaf area and green fodder yield. The direct effect of leaf area on green fodder yield was found (-0.36) negative. The genetic correlation between these two characters was positive, which is the result of indirect effects of leaf area via days to 50% flowering, plant height and the internodal length. Thus, the positive path coefficient analysis results between leaf area and green fodder yield seem to be the result of positive contributions of leaf area through days to 50% flowering, plant height and internodal length. Whereas other traits tended to reduce or nullify the positive correlation of leaf area with green fodder yield. The indirect effect of leaf area on green fodder yield through the days to 50% flowering (0.25) and internodal length (0.13) was medium high in magnitude but through plant height (0.32) was high. The indirect effect of leaf area on green fodder yield through the number of leaves per plant (-0.06) was the only indirect negative effect and was very small in quantity.

Table-5 revealed that direct effect of the number of days to 50% flowering was (-0.62) negative with overall effect (-0.31) so the days to 50% flowering, and green fodder yield were found negatively correlated. Thus, the correlation is supporting the path coefficient analysis. Path coefficient analysis provides information which character is directly highly contributing towards the dependent character. The direct effect of days to 50% flowering on green fodder yield is (-0.62). The indirect effect via plant height (0.01), indirect effect via the number of leaves per plant (0.16) and indirect effect via leaf area (0.15) was positive, whereas the indirect effect via internodal length (-0.01) was found negative.

It is clearly understood from the present study that the character of most influence on green fodder yield was plant height along with internodal length followed by leaf area and number of leaves per plant. These findings are highly supported by and in accordance with the results of Pokle et al. (1973), Dremlyuk and Gamandii (1986), Gamandii et al. (1988), Potdukhe et al. (1992), WeiGuang (1995), Asthana et al. (1997), Jeyaprakash et al. (1997) and Prasad et al. (2002) who reported that plant height, internodal length and total leaf area index directly contributes towards green fodder yield.

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