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COMBINING ABILITY FOR FORAGE YIELD AND QUALITY CHARACTERS IN SORGHUM (*SORGHUM BICOLOR* L.) MOENCH*

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THE present day available varieties of forage sorghum, although high yielders, are poor in characters like protein, energy value and dry-matter digestibility. It may be on account of the fact that forage breeders have been emphasizing more on forage yield rather on the nutritive characters. The importance of nutritive characters has been advocated by Sullivan (1962); Gangstad (1964); Wagner (1968) and Raymond (1969). A genetic analysis of forage quality characters is very necessary before any breeding methodology can be effectively applied for improvement of sorghum material for these characters. The development of the concept of combining ability, helps in choosing the parents for hybridization. The present paper deals with the information gathered from diallel analysis on combining ability for forage yield and quality characters.

MATERIALS AND METHODS

The material consisted of eight diverse parents (I. S. 607-13, I. S. 607-40, I. S. 7149, I. S. 7237, I. S. 8007, I. S. 8345, I. S. 10719 and I. S. 12306), their 8×8 non-reciprocal diallel set of crosses and their 28 F_2's. The 64 entries (8 parents + 28 F_1's + 28 F_2's) were grown in randomized blocks with four replications. The plot size was two rows of three meters length with thirty centimeters distance between the rows. Hills were planted ten centimeters apart in a row. Twenty plants were selected at random in each plot for observations. Ten plants were used for analysis of total soluble solids (hand refractometry) and HCN content (Hogg

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and Ahlgren, 1942) and the remaining characters namely green forge yield per plant, dry-matter digestibility (nylon bag technique by Lawrey, 1969), crude protein (micro Kjeldahl) and dry-matter percentage, were studied on other ten plants. All the observations were recorded when genotypes had reached fifty per cent flowering stage.

Analysis of variance of the data collected was done according to the methods given by Panse and Sukhatme (1967). Angular transformation was applied for all the characters except green forage yield per plant. The error variance obtained in this analysis was used as the error component in the analysis of combining ability. The analysis of general and specific combining ability was done according to the method 2 model 1 of Griffing (1956), as the present study include only the parents and one set of F_1's.

Results

The plot means for green forage yield per plant, dry-matter digestibility, crude protein, total soluble solids and dry-matter percentage for the eight parents and their 28 single crosses are presented in Table 1. The analysis of means of each of the five characters (Table 2) revealed significant differences among the treatments.

The partitioning of the genetic variation among the treatments (Table 2) into those due to combining ability effects revealed highly significant differences for general combining ability (GCA) for all the characters. The variance due to specific combining ability (SCA) effect was significant for green forage yield per plant, crude protein and total soluble solids. The estimates of variances due to GCA and SCA effects revealed that both additive gene effects were important for green forage yield per plant, crude protein and total soluble solids and for remaining characters only additive gene effect was involved. However GCA variance for green forage yield per plant, crude protein and total soluble solids was about 1.9, 3.4 and 11.9 times larger than those due to SCA.

General Combining Ability Effects : Observations on the eight parents with regard to their GCA effects for five characters are presented in Table 3.

Green forage yield per plant : The parents I. S. 7149, I. S. 7237 and I. S. 8007 had positive GCA effects for forage yield and only I. S. 7149 contributed significantly. I. S. 12306 and I. S. 8345 had significant negative GCA effects.

Dry-matter digestibility : Three parents namely I. S. 8007 (2.849), I. S. 7149 (2.331) and I. S. 7237 (1.902) contributed significantly to GCA effects for dry-matter digestibility. The remaining five parents had negative contribution out of which only I. S. 8345, I. S. 12306 and I. S. 10719 did so significantly.

Crude protein : I. S. 10719 (0.717) and I. S. 607-13 (0.312) showed positive significant GCA effect while the parents I. S. 7149 and I. S. 607-40 had positive but not significant. The parents I. S. 8007, I. S. 8345 and I. S. 12306 contributed significantly negative GCA effects for crude protein.

Total soluble solids : Five parents, I. S. 8007, I. S. 8345, I. S. 12306, I. S. 7149 and I. S. 7237 in that order, contributed to GCA effects for this

TABLE 1. Mean performance of parents and F_1's.

Treatments	Green forage yield/plant (gm)	Dry-matter digestibility (%)	Crude protein (%)	T. S. S. (%)	Dry-matter (%)
Parents					
I. S. 607-13 (P1)	289.42	41.99	8.24	8.67	18.25
I. S. 607-40 (P2)	255.75	44.06	6.54	12.04	23.23
I. S. 7149 (P3)	257.18	49.89	8.06	13.23	22.95
I. S. 7237 (P4)	251.75	49.47	6.62	12.81	20.82
I. S. 8007 (P5)	200.95	54.05	5.78	15.23	24.72
I. S. 8345 (P6)	215.00	35.57	6.00	14.39	34.53
I. S. 10719 (P7)	218.28	41.55	8.18	9.34	16.55
I. S. 12306 (P8)	262.75	38.65	6.84	11.64	28.33
F_1's					
P1 × P2	257.15	42.66	6.48	10.60	21.94
P1 × P3	382.80	45.70	6.85	10.70	19.38
P1 × P4	302.75	46.12	6.85	11.22	23.36
P1 × P5	297.75	47.46	6.41	12.30	20.40
P1 × P6	229.50	35.76	6.53	10.98	29.42
P1 × P7	282.45	37.15	7.24	9.01	19.31
P1 × P8	180.15	38.36	6.07	13.03	13.70
P2 × P3	379.00	50.31	6.99	11.78	20.67
P2 × P4	338.00	45.78	6.60	10.77	19.92
P2 × P5	345.75	43.27	6.48	12.70	21.77
P2 × P6	272.40	34.98	6.82	11.48	29.12
P2 × P7	293.25	38.42	7.20	10.57	19.18
P2 × P8	291.00	39.88	6.80	12.46	24.77
P3 × P4	358.00	49.24	7.28	12.14	21.28
P3 × P5	400.75	54.24	6.49	12.70	21.42
P3 × P6	306.50	41.30	6.04	13.66	28.24
P3 × P7	320.25	44.41	6.39	11.30	20.38
P3 × P8	336.38	43.91	5.63	12.43	27.53
P4 × P5	358.00	49.23	6.75	11.71	20.09
P4 × P6	304.50	45.23	5.24	14.43	28.34
P4 × P7	353.75	43.38	7.22	11.03	20.72
P4 × P8	261.50	43.47	5.42	13.23	26.92
P5 × P6	366.75	43.19	6.03	13.24	25.64
P5 × P7	285.25	47.78	6.64	12.45	20.87
P5 × P8	284.00	44.37	5.95	13.82	27.21
P6 × P7	233.75	37.35	8.06	10.18	25.45
P6 × P8	246.50	34.59	3.36	12.99	29.86
P7 × P8	231.42	32.94	7.33	10.22	25.24
S. Em. ±	34.22	1.66	0.54	0.63	1.21
C. D. at 5% level	94.85	4.60	1.49	1.74	3.37
C. D. at 1% level	124.66	6.05	1.96	2.28	4.42

TABLE 2. ANOVA for five forage characters in 8 × 8 diallel crosses of forage sorghum.

Sources	D. F.	Green forage yield/plant (gm)	Dry-matter digestibility (%)	Crude protein (%)	Total soluble solids (%)	Dry-matter percentage (%)
Blocks	3	9889.33	246.67**	8.724**	15.266**	51.64**
Treatments	63	17367.04**	38.57**	2.279**	7.764**	27.34**
Error	189	4683.81	11.04	1.158	1.568	5.90
GCA	7	5066.27**	44.12**	1.574**	6.931**	33.96**
SCA	28	2546.91**	1.69	0.466**	0.579*	1.47
Error	189	1170.95	2.76	0.290	0.392	1.47

*, ** Significant at 5 and 1 per cent level, respectively.

TABLE 3. Estimates of general combining ability effects (gi) of parents for characters under study.

Parents	(1)	(2)	(3)	(4)	(5)
I. S. 607-13	10.163	–0.674	0.312*	–1.131*	–0.984*
I. S. 607-40	7.562	–0.315	0.050	–0.262	–0.702
I. S. 7149	38.499*	2.331*	0.201	0.332	–0.628
I. S. 7237	16.757	1.902*	–0.179	0.236	–0.842*
I. S. 8007	12.772	2.849*	–0.428*	1.046*	–0.467
I. S. 8345	–22.253*	–2.660*	–0.346*	0.697*	3.316*
I. S. 10719	–17.576	–1.425*	0.717*	–1.274	–2.074*
I. S. 12306	–25.598*	–2.008*	–0.327*	0.356	2.381*
S. E. (g_i)	10.122	0.491	0.159	0.185	0.359
C.D. at 5% (g_i-g_j)	29.994	1.456	0.472	0.549	0.064

(1) Green forage yield per plant (gm)
(2) Dry-matter digestibility (%)
(3) Crude Protein (%)
(4) Total soluble solids (%)
(5) Dry-matter percentage

* Significant at 5 per cent level of significance.

character but only the contributions of I. S. 8007 (1.046) and I. S. 8345 (0.697) were significant. I. S. 10719 and I. S. 607-13 contributed significantly negative GCA effects for total soluble solids.

Dry-matter percentage : In respect of dry-matter precentage, I. S. 8345 was the highest significant positive contributor for GCA effect (3.316), followed by I. S. 12306 which also had the significant positive contributions. The remaining parents were negative contributors to the GCA effect and only I. S. 10719, I. S. 607-13 and I. S. 7237 were the significant negative contributors.

Specific Combining Ability Effects: The estimates of the SCA effect for the 28 crosses of the CSA effect, for the 28 crosses in respect of the three characters where variance due to SCA effect was significant are presented in Table 4.

Green Forage Yield per Plant : Three crosses showed significant positive SCA effects for forage yield, the maximum value being for the cross I. S. 8007 × I. S. 8345 (85.961), followed by I. S. 7237 × I. S. 10719 (64.298) and I. S. 607-13 × I. S. 7149 (63.594). On the other hand the single cross, I. S. 607-13 × I. S. 12306 had significant but negative estimates of SCA effect.

Crude Protein : I. S. 8345 was a poor general combiner but

TABLE 4. Estimates of specific combining ability effects of 28 single crosses for the characters under study.

Crosses	Green forage yield per plant (gm)	Crude protein (%)	Total soluble solids (%)
P1 × P2	–30.519	–0.629	0.153
P1 × P3	63.594*	–0.284	–0.313
P1 × P4	5.886	0.040	0.258
P1 × P5	4.871	–0.179	0.446
P1 × P6	28.354	–0.111	–0.429
P1 × P7	19.919	–0.372	–0.295
P1 × P8	–74.359*	–0.656	1.752*
P2 × P3	42.668	0.140	–0.194
P2 × P4	23.411	0.038	–0.984
P2 × P5	35.146	0.156	–0.074
P2 × P6	– 3.179	0.485	–0.844
P2 × P7	12.993	–0.184	0.300
P2 × P8	18.766	0.441	0.359
P3 × P4	12.374	0.655	–0.358
P3 × P5	59.208	0.048	–0.714
P3 × P6	– 0.016	–0.562	0.428
P3 × P7	9.056	–1.216*	0.402
P3 × P8	33.204	–1.083*	–0.233
P4 × P5	28.201	0.716	1.441*
P4 × P6	19.726	–1.173*	1.166*
P4 × P7	64.298*	0.086	0.261
P4 × P8	–19.929	–0.986*	0.524
P5 × P6	85.961*	0.045	–0.586
P5 × P7	– 0.216	–0.300	0.714
P5 × P8	6.556	–0.074	0.241
P6 × P7	–16.691	1.171*	–1.050
P6 × P8	4.081	0.309	–0.100
P7 × P8	–15.671	0.329	–0.666
SE (s_{ij})	31.029	0.488	0.568
C. D. at 5% ($s_{ij} - s_{ik}$)	89.993	1.415	1.647
C. D. at 5% ($s_{ij} - s_{ik}$)	84.837	1.334	1.552

in combination with I. S. 10719, it showed positive and significant SCA effect (1.171). Four crosses namely I. S. 7149 × I. S. 10719, I. S. 7237 × I. S. 8345, I. S. 7149 × I. S. 12306 and I. S. 7237 × I. S. 12306 exhibited significant negative SCA effects.

Total Soluble Solids : Only two single crosses, I. S. 607-13 × I. S. 12306 (1.752) and I. S. 7237 × I. S. 8345 (1.666) had significant and positive SCA effects. The single cross I. S. 7237 × I. S. 8007 showed significant but negative SCA effect.

DISCUSSION

The varieties of sorghum developed as a grain crop are generally being used as a fodder crop. The attributes which determine the quality of a good grain crop are different than that of a forage crop. A good forage sorghum variety should have fast and high vegetative growth giving high green forage yield coupled with good dry-matter digestibility, high crude protein percentage, total soluble solids, dry-matter percentage and leaf-stem ratio and free from toxic susbtances such as prussic acid (Cizek, 1964; Wagner, 1968, Rabas et al 1969 and Raymond, 1969). No serious attempts were made to study the genetic architecture of forage yield and quality characters. An understanding of the genetic nature of complex quantitative characters is essential for systematic handling of the populations for achieving maximum possible genetic advance. The non-additive genetic variations in forage sorghum can be exploited usefuhy, since hybrid seed production is commercially feasible. The estimates of combining ability effects, which gave an indication of relative magnitudes of genetic variances, provide guidelines in choosing parents for hybridization.

In the present investigation variances due to general and specific combining ability and the estimates of GCA and SCA effects for five forage characters have been obtained. Two characters, namely, hydrocyanic acid content and leaf-stem ratio were excluded from the present study, since the variation among the treatments for these characters was not significant. The variance due to GCA was highly significant for all the characters where as the SCA variance was not significant for dry-matter digestibility and dry-matter percentage. The GCA variances were about two to twelve times higher than the SCA variances for green forage per plant, crude protein and total soluble solids. It suggested a predominant role of additive type of gene action for all the characters and non-additive type of gene action was also important for green forage yield per plant, crude protein and total soluble solids. Under such a situation where both additive and non-additive type of gene action are important, it is adviseable to adopt recurrent selection for handling such populations. After a couple cycles of recurrent selection, the selected elite lines should be subjected to multilocation test for further evaluation.

The parents *per se* was an indication of their combining ability but this was not true for green forage yield per plant. It means parents *per se* is not always related with the combining ability effects and therefore such studies are of great importance for practical breeding.

The choice of a parent for hybridization should be based on the performance of the parent *per se*, the F_1 performance and combining ability effects. The parent I. S. 7149 with an average forage yield had highest GCA effect and the parent I. S. 607-13 with highest forage yield had negative GCA effect. The mean performance of single crosses was invariably observed to be correlated with SCA effects for crude protein and total soluble solids, indicating thereby the importance of non-additive type of gene action for these characters. This further suggests that both the type of gene action played a role in determining crude protein, total soluble solids and green forage yield per plant and only additive type of gene action was involved in the expression of dry-matter digestibility and dry-matter percentage. The best single cross hybrids were obtained invariably from either one or both good general combiners for all the characters under study (Singh et al. 1969 and Singh and Jain, 1971).

SUMMARY

An 8×8 diallel analysis of combining ability for forage yield and quality characters in sorghum was conducted with the aim to obtain informations on the genetic architecture of the population and also to isolate best parents for hybridization. The variance due to GCA was significant for all the characters studied, however the variance due to SCA was significant only for green forage yield per plant, crude protein and total soluble solids. The magnitude of the GCA variances were 2 to 12 times higher than the SCA variances, indicating thereby the more prevalence of additive type of gene action for all the above three characters. Recurrent selection for the improvement of the parents is suggested.

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