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HETEROSIS AND COMBINING ABILITY EVALUATION FOR QUALITY TRAITS IN FORAGE SORGHUM (*Sorghum bicolor* L.)

A.S. TARIQ[1]*, Z. AKRAM[1], G. SHABBIR[1], K.S. KHAN[2], T. MAHMOOD[1] and M.S. IQBAL[1, 3]

[1]Department of Plant Breeding and Genetic, PMAS-Arid Agriculture University, Rawalpindi, Pakistan
[2]Department of Soil Science and Soil and Water Conservation PMAS- Arid Agriculture University, Rawalpindi, Pakistan
[3]Cotton Research Institute, Ayub Agricultural Research, Faisalabad, Pakistan
*Corresponding author's email: chheena99@gmail.com

SUMMARY

Genetic variability and inheritance mechanism for some forage quality traits were analyzed in 9 sorghum crosses along with their 6 parents in randomized complete block design with 3 repeats under irrigated conditions. All the characters under investigation showed highly significant differences for genotype, general combining ability and specific combining ability. However, the specific combining ability variances were greater than the general combining ability variances in all the traits under study. All the characters under evaluation showed lesser additive variance than the dominant variance and degree of dominance was greater than unity. The sorghum line CVS-13 indicated highest general combining ability effects in the desired directions for total sugar content and crude fiber, V-1 for total ash, SV-6 for total cyanide content and TSS-9 for crude protein. The cross SPV-462 x YSS-9 showed significant and positive mid parent as well as better parent heterosis for total sugar content, crude protein and crude fat but significant and negative average heterosis was observed for total cyanide content. This investigation revealed that progress in forage quality is possible due to sufficient genetic variability among genotypes, general combining ability effects in the desired direction and significant heterobeltiosis for almost all the traits under evaluation.

Keywords: Sorghum bicolor, forage quality, combining ability, heterosis, proximate analysis

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INTRODUCTION

The performance of dairy animals depends on the continuous availability of quality forage in adequate amount. Therefore, the critical limitation on profitable animal production in developing countries is the insufficient availability of quality forage (Sarwar *et al*., 2002). Sorghum is becoming an increasingly important forage crop in many regions of the world (Zerbini and Thomas, 2003). Its high resistance to drought makes it a suitable crop for semi-arid areas especially in light of its higher productivity under dry conditions compared to corn (Tabosa *et al*., 1999). Forage yield in quantity alone cannot measure the feeding value of the crops. So the quality value of forages like palatability and nutritional value of forage must be determined for measuring the feeding value. The sorghum varieties at blooming stage had higher essential nutrient content like protein than at later stages of the crop (Nabi *et al*., 2006).

Improving the nutritive value of forage sorghum for productive ruminants is an important goal. The main selection criterion for improving forage nutritional value must include increased *in vitro* dry matter digestibility and reduced content of lignin. Such improvements may be promoted by genetic breeding and selection, choosing the optimal stage for harvest and improving growth factors (Carmi *et al*., 2006.) Sweet sorghum (*Sorghum bicolor* L.) being a multipurpose crop can provide, food, feed, forage and fuel. Sweet sorghum has high biomass production, high brix percentage, short duration and low water requirement and wider adaptability (Reddy *et al*., 2005).The palatability and quality of forage will increase by increasing the sugar content of sorghum stalk .Therefore, the important goals of sorghum forage breeding programs are to increase sweetness, leafiness and juiciness in sorghum (Poehlman, 2006).

Before initiating any crop improvement program, it is necessary to understand the genetic nature of the parents. Combining ability analysis helps in identifying the parents and these parents can be used for hybridization program in order to produce superior hybrids. As a general rule, general combining ability (GCA) is the result of additive gene effects, while the specific combining ability (SCA) is the result of non-allelic interactions (Jinks, 1954). The estimates of combining ability are useful to predict the relative performance of different lines in hybrid combinations. The information on the nature and magnitude of gene action is important in understanding the genetic potential of a population and deciding the breeding procedure to be adopted in a given population (Prabhakar, 2010).

The objective of present study was to determine nature of gene action, evaluation of enviable parents for hybridization and performance of hybrids over their parent in sorghum for forage quality under irrigated conditions of the Punjab.

MATERIALS AND METHODS

Experimental Material

Six sorghum parents (Table 1) 3 parents i.e. V-1, SV=6, CVS-13 had the lowest while 3 parents i.e. SPV-462, RARI-S-10 and TSS-9 had the highest hydrocyanic acid content along with their 9 crosses were used as experimental material. The parents were crossed in partial diallel pattern given by Kempthorne and Kurnow, 1961 (Table 1). Kempthorne and Curnow (1961) presented the concept of partial diallel in which only a random samples of crosses "s" is analyzed where "s" is less than n-1. Both "s" and 'n" should be neither odd nor even. With "n" lines the total number of crosses to analyze in a partial diallel is thus (ns/2). The precision of estimates in partial diallel depends on the sample size "s" in relation to number of parental lines "n". Thus observations by various workers have shown that biases in the estimates are more common when "s" is less than n-1.

Table 1. Format for Partial Diallel Crosses.

Parents	V-1	SV-6	CVS-13	SPV-462	RARAI-S-10	TSS-9
V-1			X	x	x	
SV-6				x	x	x
CVS-13					x	x
SPV-462						x
RARI-S-10						
TSS-9						

Sample crosses with n= 6, s= 3, k= 2 n= Number of line/parents involved in crossing; s=sample size; x= cross made

Partial diallel have a tendency to ignore certain crosses according to a definite plan, thus reducing number of crosses per parent exerting less crossing load without losing much of precision. Using the circulant design of partial diallel mating, we can rapidly screen the genetic stock. The crosses were made at Koont Farm, PMAS- Arid Agriculture University Rawalpindi in September, 2009.

Experimental Design

The experimental material was sown in a Randomized Complete Block Design with 3 replications during July, 2010 at Arid Zone Agricultural Research Institute (AZRI), Bhakkar under irrigated conditions. It is different location about 400 km away toward South West from Rawalpindi. 4-meter long rows were sown at 30 cm apart from each other. The plant to plant distance was maintained at 30 cm. Three irrigations were given at the critical stages i.e. tillering, maximum vegetative growth and panicle initiation sorghum of the crop. Approved agronomic practices like hoeing, fertilizer application, irrigation, insect pest control were followed for better crop production and maintenance.

Data Collection

Data for the following quality traits of sorghum mentioned below were recorded during cropping season of sorghum. The traits under evaluation were crude protein, crude fat, crude fiber, total ash, nitrogen free extract, total sugar content and total cyanide content. The quality analysis was made in the laboratory of Animal Science Institute, National Agricultural Research Center, Islamabad following the method of AOAC (2002) and data for crude protein (%), crude fat (%), crude fiber (%), total ash (%) and nitrogen free extract (%) were collected. The data for total cyanide content (ppm) were collected by picrate paper method proposed by Eagan *et al*. (1998) and total sugar content (%) were determined using hand refractometer (Yun-long *et al*., 2006).

Data analysis

Data were subjected to analysis of variance following Randomized Complete Block Design (RCBD) format using MSTAT-C Software (Steel *et al*., 1996) and combining ability analysis was made using circulant design in partial diallel using MS EXCEL SOFTWARE (Kempthorne and Curnow, 1961).

RESULTS

Analysis of variance

The mean squares of the 7 quality parameters under evaluation for 9 crosses are given in Table 2. The mean squares for genotype, general combining ability were significant for all the traits under investigation except for nitrogen free extract. Mean squares for specific combining ability showed significant differences for total sugar content, total cyanide content, crude protein, and crude fat and total ash.

Estimates of genetic components of variance

The estimates of genetic components and their derivatives for the evaluated quality traits of 9 crosses are given in Table 3. In all the traits, phenotypic component of variance was greater than the genotypic component of variance. Similarly the estimates of specific combining ability variance σ^2_{sca} were greater than those of general combining ability variance (σ^2_{gca}) for all the traits under assessment and ratio between specific combining ability variance and general combining ability (σ^2_{gca}/ σ^2_{sca}) was less than unity (Table 3).

Estimates of general combining ability effects and gene action

The estimates of additive and dominance variance along with degree of dominance for all the quality traits under evaluation are presented in Table 4. The dominance variance was greater than the additive variance for all the traits under evaluation having degree of dominance greater than unity.

Table 2. Mean squares for quality traits of 9 sorghum crosses grown under irrigated conditions during the year 2010.

Parameters	MSg	MSe	MS gca	MS sca
Total sugar content	7.06**	1.03	8.29**	5.00*
Total cyanide content	6327.21**	689.85	6689.80**	5722.89**
Crude protein	3.04**	0.39	3.16**	2.85**
Crude fat	0.52**	0.08	0.59**	0.39*
Crude fiber	12.74*	4.72	14.76**	9.37
Total ash	18.18**	0.62	18.99**	16.83**
Nitrogen free extract	15.91	14.99	16.29	15.25

*Significant at 5% level ** highly significant at 1% level; MSg= Mean square for genotype, MSe=; Mean square for error; MSgca= Mean square for general combining ability; MSsca= Mean square for specific combining ability

Table 3. Estimates of genetic components and their derivatives for quality traits of 9 sorghum crosses grown under irrigated conditions during the year 2010.

Parameters	$б^2_g$	$б^2_p$	$б^2_{gca}$	$б^2_{sca}$	$б^2_{gca}/ б^2_{sca}$
Total sugar content	2.01	3.03	0.33	13.99	0.33
Total cyanide content	1879	2569	0.11	14.32	0.08
Crude protein	0.88	1.27	0.04	0.83	0.05
Crude fat	0.14	0.23	0.03	0.10	0.27
Crude fiber	2.67	7.39	0.75	1.73	0.43
Total ash	5.85	6.47	0.30	5.43	0.06
Nitrogen free extract	0.31	15.29	0.14	0.64	0.22

$б^2_g$ = Estimates of genotypic variance; $б^2_p$= Estimates of phenotypic variance; $б^2_{gca}$= Estimates of general combining ability variance; $б^2_{sca}$= Estimates of specific combining ability variance

Table 4. Estimates of additive and dominant components of variance and degree of dominance for quality traits of 9 sorghum crosses grown under irrigated conditions during the year 2010.

Parameters	$б^2_a$	$б^2_d$	$б^2_a / б^2_d$	$б^2d / б^2a$	D.D.
Total sugar content	0.91	1.37	0.67	1.50	1.22
Total cyanide content	268.59	1703.23	0.16	6.34	2.52
Crude protein	0.09	0.83	0.10	9.81	3.13
Crude fat	0.06	0.10	0.54	1.84	1.36
Crude fiber	1.50	1.73	0.87	1.15	1.07
Total ash	0.60	5.43	0.11	9.05	3.01
Nitrogen free extract	0.29	0.64	0.45	2.23	1.49

$б^2_a$= Estimates of additive variance; $б^2_d$= Estimates of dominant variance; S.E. = Standard error; D.D. =Degree of dominance

Table 5. General combining ability effects for quality traits of 6 of sorghum parents grown under irrigated condition during the year 2010.

Parents	General combining ability effects						
	Total sugar content	Total cyanide content	Crude protein	Crude fat	Crude fiber	Total ash	Nitrogen free extract
V-1	1.10**	36.03**	0.21	-0.14	-0.33	2.34**	-1.97
SV-6	-0.89**	-20.13**	-0.21	-0.16	-0.25	-0.68**	1.37
CVS-13	1.82**	0.24	0.03	0.13	3.04**	-2.28**	-1.03
SPV-462	-0.60	15.75	-0.23	0.14	-0.79	0.49	0.39
RARI-S-10	0.36	-9.27	-0.16	-0.02	-1.01	0.11	0.99
TSS-9	-0.31	-11.88	0.35	0.06	0.36	-0.25	-0.52

Table 6. Estimates of mid parent heterosis for quality traits from 9 crosses of sorghum grown under irrigated conditions during the year 2010.

Crosses	Mid-parent heterosis (%)						
	Total sugar content	Total cyanide content	Crude protein	Crude fat	Crude fiber	Total ash	Nitrogen free extract
V-1 x CVS-13	26.94**	29.22**	4.71	-6.86	23.04**	8.13	-14.79**
V-1 x SPV-462	12.08	9.63*	3.23	-3.12	-1.95	53.75**	-11.24*
V-1 x RARI-S-10	18.18*	-2.50	5.52	2.90	-10.11	47.28**	-7.36
SV-6 x SPV-462	-2.39	-11.45**	-10.93	-0.95	-4.14	-13.44*	3.10
SV-6 x RARI-S-10	23.30**	-24.14**	7.45	-13.49	-11.69	-7.95	6.47
SV-6 x YSS-9	12.27	-10.53*	13.74	-10.36	-0.21	-3.50	-1.71
CVS-13 x RARI-S-10	44.39**	-7.40	-32.82**	11.96	6.79	-17.36*	0.02
CVS-13 x YSS-9	34.82**	-11.62**	20.10*	-15.35*	11.70	-5.84	-10.34
SPV-462 x YSS-9	37.20**	-37.46**	54.01**	24.33**	-7.70	-1.51	-3.85
Mean	22.98**	-7.36*	7.22	-1.21	0.64	6.62	-4.41

*Significant at 5% level ** highly significant at 1% level

The estimates of general combining ability effects for traits under assessment are shown in Table 5. The estimates of general combining ability effects indicated that the parents V-1 was good general combiner for total ash (2.34), SV-6 for total cyanide content (-20.13) and CVS-13 for total sugar content (1.82) and crude fiber (3.04).

Heterosis

Estimates of average heterosis for quality traits from 9 crosses of sorghum are given in Table 6. Examination of this table pointed out that total sugar content showed significant mid parent heterosis in positive direction (22.98%) while total cyanide content indicated significant average heterosis in negative direction (-7.36%). Highest, significant and positive mid parent heterosis was observed for total sugar content (44.39%) in cross CVS-13 x RARI-S-10, for total cyanide content (29.22%) and crude fiber (23.04%) in cross V-1 x CVS-13, crude protein (54.01%) and crude fat (24.33%) in cross SPV-462 x YSS-9 and total ash (53.75%) in cross V-1 x SPV-462. Whereas, the cross SPV-462 x YSS-9 showed the highest and significant mid-parent heterosis in negative direction for total cyanide content (-37.46%), cross CVS-13 x RARI-S-10 for crude protein (-32.82%), the cross CVS-13 x YSS-9 for crude fat (-15.35%) and the cross V-1 x CVS-13 for nitrogen free extract.(-14.79%).

The estimates of better parent heterosis for quality traits under evaluation are given in Table 7. Highly significant and negative heterobeltiosis was observed for total cyanide content (-26.63%) and all the other traits showed non-significant heterosis over better parent (Table 7).

Table 7. Estimates of better-parent heterosis for quality traits from 9 crosses of sorghum grown under irrigated conditions during the year 2010.

Crosses	Better-parent Heterosis (%)						
	Total sugar content	Total cyanide content	Crude protein	Crude fat	Crude fiber	Total ash	Nitrogen free extract
V-1 x CVS-13	10.28	20.50**	-3.55	-18.34*	19.10**	2.15	-15.39*
V-1 x SPV-462	-8.23	-20.74**	-8.00	-9.65	-5.84	48.36**	-13.01
V-1 x RARI-S-10	-7.98	-28.00**	1.33	0.12	-16.89*	36.84**	-13.50*
SV-6 x SPV-462	-14.06	-35.72**	-20.73*	-2.74	-5.42	-13.92	0.93
SV-6 x RARI-S-10	2.66	-43.75**	3.34	-15.70	-14.01	-11.02	3.46
SV-6 x YSS-9	-3.31	-32.68**	-0.32	-10.81	-0.76	-10.27	-2.50
CVS-13 x RARI-S-10	34.62**	-28.17**	-35.67**	0.57	-4.17	-27.14**	-7.22
CVS-13 x YSS-9	22.75**	-30.35**	-1.75	-21.78*	2.18	-19.81*	-15.18*
SPV-462 x YSS-9	33.73**	-40.75**	51.33**	22.70**	-9.42	-8.88	-6.62
Mean	7.83	-26.63**	-1.56	-6.18	-3.92	-0.41	-7.67

*Significant at 5% level ** highly significant at 1% level

The cross SPV-462 x YSS-9 indicated highest, significant and positive better parent heterosis for the traits total sugar content (33.73%), crude protein (51.33%), and crude fat (22.70%), the cross V-1 x CVS-13 for total cyanide content (20.50%) and crude fiber (19.10%) and the cross V-1 x SPV-462 for total ash (48.36%) while no cross showed significant heterobeltiosis for nitrogen free extract in positive direction. The highest and significant better parent heterosis in the negative direction was observed for the traits, total cyanide content (-43.75%) in cross SV-6 x RARI-S-10, crude protein (-35.67%) and total ash (-27.14%) in cross CVS-13 x RARI-S-10, crude fat (-21.78%) in cross CVS-13 x YSS-9. All the crosses showed significant and negative heterobeltiosis for total cyanide content except for the cross V-1 x CVS-13 (Table 7).

DISCUSSION

Genetic variability among genotypes for desirable traits plays crucial role for proficient selection. In present investigation significant mean squares for genotypes for almost all the quality traits pointed out the presence of genetic variability to be evaluated for the improvement in forage quality traits. Existence of both additive and non-additive type of gene action was observed due to significant mean squares for general combining ability and specific combining ability. Kamdi *et al.* (2009) reported significant variability for genotype, general combining ability and specific combining ability for different characters in sorghum.

During evaluation the traits showed higher phenotypic variance than genotypic variance which proposed that these characters are highly influenced by the environmental effect. The ratio between specific combining ability variance and general combining ability variance was less than unity this pointed out the preponderance of non-additive gene action for the inheritance of the assessed traits. Therefore it came into view that the inheritance of all traits was controlled by non-additive gene effects. Such type of gene action clearly specified that heterosis breeding would be ideal for their enhancement. However, for the development of advantageous genotypes with improved quality by breeding, the selection of superior plants should be delayed to later generations. Premalatha *et al*. (2006) reported greater specific combining ability variances than general combining ability variances and described the non-additive type of gene actions for different traits in sorghum.

The mean performance of parents and their hybrids is believed to be one of the essential events for their appraisal. The parents with high mean value may or may not converse their high performance to their hybrids. This parental aptitude is expected in terms of general combining ability effects. The general combining ability effects in the desired direction provide a support in selection system. The parents having greater general combining ability effects in most wanted direction for traits of attention can be selected for further hybridization and assessment programs. In this study the parent CVS-13 had highest positive general combining ability effects for total sugar content and crude fiber. V-I parent had the highest significant general combining ability effects for total ash whereas the parents SV-6 had the highest and significant general combining ability effects in negative desirable direction for total cyanide content. On the basis of general combining ability effects, the parents CVS-13, V-1 and SV-6 could be better choice for improvement of forage quality through hybridization. Pfeiffer *et al.* (2010) reported similar findings for these traits in sorghum.

Exploitation of heterosis is imperative for increasing the forage quality in sorghum. The magnitude of 2 types of heterosis i.e, heterosis over mid parent and heterosis over better parent as shown by different crosses for the traits under estimation indicated sufficient departure from parental material for these parameters. In this study all the crosses showed significant and negative heterobeltiosis for total cyanide content during evaluation indicating the presence of non-additive gene action (dominance and epistasis) and cyanide reduction in sorghum forage is possible by manipulating the these crosses in future breeding programs.

The findings of the present investigation on the magnitude of heterosis for total cyanide content are in agreement with the earlier findings of Mohanraj *et al.* (2006) and Shaug and Lo (1995) who identified hybrids with significant negative heterosis for total cyanide content in sorghum.

CONCLUSION

In this study, the degree of dominance was greater than unity and all the traits under study showed non-additive type of gene action. Improvement in sorghum forage quality is possible by using good general combiner parent (SV-6) and the hybrid with the highest heterobeltiosis (SV-6 x RARI-S-10) in the desired negative direction for total cyanide content in further breeding and evaluation programs.

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