Electronic Journal of Plant Breeding, 5(2): 152-157 (June 2014)
ISSN 0975-928X

Research Article

Combining ability and heterosis for grain yield, fodder yield and other agronomic traits in Sorghum [*Sorghum bicolor* (L.) Moench]

S. K. Jain and P. R. Patel
Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa 385535 (BK) Gujarat, India
Email: skjain_sdau@yahoo.co.in

(Received: 28 Jan 2014; Accepted:28 Mar 2014)

Abstract
Thirty six hybrids derived from a diallel mating design of nine parents and one standard check GJ-39 were evaluated for general and specific combining ability effects and standard heterosis for grain yield/plant, dry fodder yield/plant, days to 50 per cent flowering, plant height, number of leaves/plant, leaf length, leaf breadth and 100- seed weight. The mean square due to general and specific combining ability was significant for all the characters. Both additive and non additive genetic effects were present in the material under study. However the ratio of σ2gca/ σ^2sca suggested that the preponderance of non additive gene action in expression of all the characters under study. Out of the nine parents GJ-39, GFS-5, CSV-15, SSV 84 and SPV 2113 identified as good general combiner for grain yield/plant, dry fodder yield/plant and other agronomical traits. The hybrid SPV 2110 x GFS 5 and GFS 5 x GJ 39 for grain yield/plant and hybrid CSV 15 x SSV 84, SPV 2113 x SPV 1616 and SPV 2110 x GFS 5 for dry fodder yield/plant exhibited higher magnitude of positive significant specific combining ability effect with highest standard heterosis and *per se* performance. These hybrids were also found suitable for two or three yield contributing traits. In general, close association between specific combining ability effects and standard heterosis was observed among the best hybrids identified on the basis of specific combining ability effects for grain and dry fodder yield.

Key words: Sorghum, combining ability, standard heterosis, gene action, diallel analysis

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is an often self-pollinating, diploid (2n = 2x = 20) crop with a genome, about 25% the size of maize or sugarcane. It is a C4 plant with higher photosynthetic efficiency and higher abiotic stress tolerance (Nagy et al., 1995; Reddy et al., 2009). Sorghum is fifth most important cereal crop globally and is the dietary staple of more than 500 million people in 30 countries. It is grown on 40 m ha in 105 countries of Africa, Asia, Oceania and the Americas. Africa and India account for the largest share (> 70%) of global sorghum area while USA, India, Mexico, Nigeria, Sudan and Ethiopia are the major sorghum producers (Kumar et al., 2011). It is the third most important grain crop in India, next only to rice (*Oryza sativa*) and wheat (*Triticum aestivum*). Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Rajasthan and Gujarat are the major sorghum growing states of India. Besides being an important food, feed and forage crop, sorghum also provides raw material for the production of starch, fiber, dextrose syrup, biofuels, alcohol, and other products.

Classical plant breeding has resulted in the successful development of high yielding, highly adapted sorghum cultivars. Vast diversity is available in sorghum and it is distributed among different sorghum races. Therefore, further enhancement of yield potential and the productivity of newly developed varieties needs urgent attention. The traits like grain and fodder yield are governed by polygenes with complex gene action and hence understanding the nature and magnitude of gene action help the breeder in selection of an appropriate breeding method. For improvement in such an important crop, the most important prerequisite is the selection of suitable parents, which could combine well and produce desirable hybrids and segregants. In the present study, an attempt has been made to estimate the heterosis in F_1 hybrids with respect to yield, the combining ability and gene action governing the quantitative traits in sorghum, using diallel mating designs.

Material and methods

The nine genetically diverse lines of sorghum presented in Table 1 were crossed in diallel mating design excluding reciprocals to produce 36 experimental hybrids during *kharif* 2011. The 36 F_1s including nine parents and a popular local check GJ-39 were grown at the Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa (Gujarat) during *kharif* 2012. Deesa is situated at latitude of 24.5° N and longitude 72° E and at an elevation of 136 M above the Mean Sea Level. The soil of the field was sandy to deep sandy loam (49.8 % coarse and, 34.0 % fine sand, 9.7 % silt and 6.3 % clay) in texture with pH value of 8.0 having 0.30 *per cent* organic matter and 0.25-36 EC at 25 C mm/holc.. The crop received 362 mm rainfall during the growing season and average minimum and maximum temperature was 19.26 and 33.54° C, respectively while average minimum and maximum humidity was 48.44 and 76.25 per cent respectively. The experiment was laid out in randomized block design with three replication in a single-row plot of 6.75 m long, spaced at 0.45 m apart. NPK 120:40:00 fertilizers 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 0.15 m was maintained. All other recommended agronomical practices were followed to raise a good crop. The biometrical observations recorded on grain yield/plant (g), dry fodder yield/plant (g), plant height (cm), number of leaves/plant, leaf length (cm), leaf breadth (cm) and 100- seed weight (g) on five randomly selected competitive plants of each genotype and each replication. The observation for days to 50% flowering and days to maturity were recorded on the plot basis. The mean values of observations were subjected to diallel analysis to estimate general combining ability (gca) and specific combining ability (sca) effects as per procedure given by Griffing method 2 Model I (Griffing, 1956) and standard heterosis was calculated as per standard procedure given by Meredith and Bridge (1972). Analysis of variance (ANOVA) was performed to test the significance of differences among the genotypes including crosses and parents as per standard procedure given by Panse and Sakhatme **(**1964).

Results and discussion

The analysis of variance revealed significant variability among the parents and hybrids for all the nine characters studied. For efficient selection, presence of variability among the genotypes for the traits of interest is a prerequisite. The analysis of variance for combining ability revealed the significant mean square due to general and specific combining ability for all the characters under study (Table 2). This indicates that all the characters contribute much for genetic variability among the parents and hybrids and both additive and none additive gene effects were important for the expression of these traits. However the variance due to specific combining ability was greater than the variance due to general combining ability, which indicated the predominant role of non-additive gene action in the expression of these traits. Predominance of non-additive gene action for these traits in sorghum was observed by Pillai et al. (1995), Badge and Patil (1997), Premlatha et al. (2008), Mohamed and Talib (2008) and Aruna *et al*. (2010).

Harer and Bapat (1982) stated that the *per se* performance of the parents with high general combining ability provide the criteria for the choice of parents for hybridization. On this basis, those parents which performed well for *per se* performance and general combining ability effects can be considered as desirable parents. Further the parents with high gca effects are desirable for obtaining useful segregants in early generations. The potentiality of parents to produce better offspring's with superior genes was evaluated based on their general combining ability effect. To get desirable recombinants in segregation generations, the parents of the hybrids must be good general combiner for the characters to which improvement is sought (Gravois and McNew, 1993). The estimate of general combining ability effects for different diverse parents revealed that none of the nine lines showed desirable significant general combining ability effects for all the traits together indicating that different parent should be used for genetic improvement of different yield components (Table 3). In the present study, different parental lines have been identified with good general combining ability for different yield and yield related traits.

Considering the both general combining ability effects and *per se* performance, the parental lines GJ-39, GFS-5 and CSV-15 with moderate to high *per se* performance and high significant positive general combining effect for grain yield and 100-seed weight indicate that these lines are good for grain yield/plant. While the parental lines SSV 84, GJ-39, SPV 2113 and CSV-15 showed high per se performance and high significant positive general combining effect for dry fodder yield. Apart from grain and fodder yield some parents also registered significant general combining ability effect in desirable direction for other traits like days to 50% flowering and maturity (SPV 2118, SPV 2125 and CSV-15), number of leaves (SPV 2110, GJ-39 and SSV-84), leaf length and width (SPV 2113 and SSV-84) (Table 3). Thus, it would be worthwhile to use above parents in breeding programme for exploiting additive gene effects. Similar results were reported by earlier workers in sorghum (Prakash *et al*., 2010; Mahdy *et al*., 2011).

A perusal of best hybrids on the basis of significant positive specific combining ability effects and standard heterosis for grain and dry fodder yield revealed that hybrid SPV 2110 x GFS-5 exhibits highest magnitude of positive significant specific combining ability effect for grain yield/plant along with the highest magnitude of standard heterosis for grain yield/plant against the popular local check GJ-39 (Table 4). This hybrid also exhibited positive significant specific combining ability effect and standard heterosis for dry fodder yield/plant, 100-grain weight, plant height, number of leaves/plant and leaf length. It was in fact a cross of poor x good general combining ability effect parent for seed yield/plant. A high x high general combining ability effect hybrid GFS-5 x GJ-39 showed significant high positive specific combining ability effects and standard heterosis for grain yield/plant, fodder yield/plant, 100-grain weight, number of leaves/plant, leaf length. Other important hybrids for grain yield/plant was SPV 2113 x CSV-15 and CSV -15 x SSV 84 which exhibited significant high positive specific combining ability effects and standard heterosis for grain yield/plant and 100-seed weight (Table 4). Both the hybrid involved one good combiner and one poor combiner for grain yield. Such occurrence of good hybrids by the combination of one good combiner and one poor combiner may be due to accumulation of favorable genes and partly due to dominance and recessive interaction.

On the basis of higher significant positive specific combining ability effect in relation to standard heterosis for dry fodder yield/plant revealed that hybrid SPV 2113 x SPV 1616 recorded the high specific combining ability effects for dry fodder yield/plant. This hybrid also exhibited positive significant specific combining ability effect for plant height, number of leaves/plant, leaf length and leaf width. It was derived from high x low parental combinations for dry fodder yield/plant and exhibited highest positive standard heterosis and per se performance for dry fodder yield/plant. Another important hybrid for dry fodder yield/plant were SPV 21 10 x GJ- 39 and GJ-39 x SSV-84 (Table 4). Both hybrids were a derivative of high x high parental combinations in terms of general combining ability and these hybrids might produce desirable segregants. Hence, these hybrids might be desirable for biparental selection or intermating. These hybrids appeared in the top ranking hybrids with high specific combining ability effects and exhibited highest positive standard heterosis and per se performances for dry fodder yield/plant. High specific combining ability and standard heterosis for grain yield/plant and dry fodder yield and their related traits were observed by Prakash *et al*., (2010) and Mahdy *et al*., (2011).
In general parental lines and all the hybrids possessed good per se performance and combining ability effects for grain and dry fodder yield and other agronomic traits. The result indicated that the heterosis for grain and dry fodder yield can be exploited commercially. It is apparent the good x poor, poor x good and good x good general combiners depicted high specific combining ability effect indicating the role of the dominance gene action. Thus, it can be concluded that both inter and intra allelic interactions were involved in the expression of these traits. The parental lines in this study were having diverse genetic background of their source populations, and hence their hybrids exhibited high specific combining ability effects along high standard heterosis for grain and dry fodder yield/plant.

References

Aruna, C., Audilakshmi, S. and Chandrasekara Reddy, D. 2010. Evaluation of sorghum [*Sorghum biecolor* (L.) Moench] germplasm lines for their yield components. *Indian J. Agric. Sci*., 80: 409-412.

Badge, P.L. and Patil, H.S. 1997. Line x Tester analysis in sorghum [*Sorghum biecolor* (L.) Moench]. *Ann. Agric. Res*., 18: 281-284.

Gravois, K.A. and McNew, W.R. 1993. Genetic relationships and selection for rice yield and yield components. *Crop Sci*., 33: 249-252.

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. *Aust. J. Biol. Sci.,* **9**: 463-493.

Harer, P.N. and Bapat, D.R. 1982. Line x tester analysis of combining ability in grain sorghum. *J. Maharashtra Agric. Univ*., 7: 230-232.

Kumar, A.A., Reddy, B.V.S., Ramaiah, B. and Sharma, R. 2011. Heterosis in white-grained grain mold resistant sorghum hybrids. *SAT J. Agric. Res*., 9: 1-6.

Mahdy, E.E., Ali, M.A. and Mahmoud, A.M. 2011. The Effect of Environment on Combining Ability and Heterosis in Grain Sorghum (*Sorghum bicolor* L. Moench). *Asian J. Crop Sci*., 3: 1-15.

Meredith, W.R. and Bridge, R.R. 1972. Heterosis and gene action in cotton (*Gossypium hirsutum* L.). *Crop. Sci*., 12: 304-310.

Mohamed, M.I. and Talib, N.H. 2008. Heterosis and combining ability for quality traits in sorghum [*Sorghum biecolor*(L.) Moench]. *Aust. J. Basic Appl. Sci.,* **2**: 99-104.

Nagy Z.Z., Tuba, F. Soldos, Z. and Erdei, L. 1995. CO2-Ex- change and Water Relation Responses of Sorghum and Maize during Water and Salt Stress. *J. Plant Physiol*., 145:539-544.

Panse V.G. and Sakhatme, P.V. 1964. Statistical methods for Agricultural workers, 2 nd Edn, ICAR, New Delhi. 361 p.

Pillai M.A., Rangaswamy, P., Nadarajan, N., Vanniarajan, C. and Ramalingam, J. 1995. Combining ability analysis for panicle characters in sorghum. *Indian J. Agric. Res*., **29**: 98-102.

Prakash, R., Ganesamurthy, K., Nirmalakumari, A., Nagarajan, P. 2010. Combining ability for fodder yield and its components in Sorghum (*Sorghum bicolor* L. Moench). *Electron. J. Plant Breed*., 1: 124-128

Premlatha, N., Kumar, N.and Veerabadhiran, P. 2006. Heterosis and combining ability for grain yield and its components in sorghum [*Sorghum biecolor* (L.) Moench]. *Indian J. Genet*., 66: 123-126.

Reddy, B.V.S., Ramesh, S., Reddy, P.S. and Kumar, A.A. 2009. Genetic Enhancement for Drought Tolerance in Sorghum. *Plant Breed. Rev*., 31:189-222.

Table 1. Origin and pedigree of sorghum genotypes used for the diallel cross

Cultivar	Origin	Pedigree
SPV 2113	DSR (AVU) Hyderabad (Andra Pradesh)	HC 260 x B 35
SPV 2125	AICSIP Akola(Maharastra)	SPV 775 x S 35
SPV 1616	DSR Hyderabad (Andra Pradesh)	SPV 946 x Kh 89-246
SPV 2118	AICSIP Udaipur (Rajasthan)	SPV 946 x SPV 1474
SPV 2110	AICSIP Palam (Andra Pradesh)	Palem 2 x IS 48592
GFS 5	AICSIP GAU (Gujarat)	SPV 1087 x GSSV-148
GJ 39	AICSIP GAU (Gujarat)	M-49 x M-51
CSV 15	DSR Hyderabad (Andra Pradesh)	SPV 475 x SPV 462
SSV 84	AICSIP Rahuri (Maharastra)	Selection from Zera-Zera (IS 23568)

Table 2. Analysis of variance for combining ability in diallel crosses for nine characters in sorghum

Source of Variation	DF	Days to 50 % Flowering	Days to Maturity	Plant height	No of Leaves	Leaf length	Leaf Width	Seed yield/ plant	Fodder yield/plant	100- Seed weight
gca	8	24.50**	32.02**	2195.69**	5.35**	460.87**	6.99**	371.15**	15940.91**	0.20**
sca	36	20.04**	28.48**	2278.51**	5.44**	181.87**	4.39**	332.84**	12995.36**	0.12**
Error	88	0.44	1.08	77.02	0.08	1.50	0.05	3.31	12.57	0.00
σ^2 gca		0.40	0.32	-	-	25.36	0.23	3.48	267.77	0.01
σ^2 sca		19.60	27.40	2201.49	5.36	180.37	4.34	329.53	12982.79	0.12
σ^2gca/ σ^2sca		0.02	0.01	-	-	0.14	0.05	0.01	0.02	0.06

*, ** Significant at 5 % and 1% level respectively; Negative values of gca variances are not indicated in Table

Table 3. Estimates of general combining ability effects (gca) and *per se* (P) performance of parents for nine characters

Characters		Days to 50 % Flowering	Days to Maturity	Plant height	No of Leaves/plant	Leaf length	Leaf Width	Seed yield/plant	Fodder yield /plant	100- Seed weight
SPV 2113	gca	0.58**	-0.653**	-4.943**	-0.02	7.89**	0.89**	-2.80**	19.88**	0.02
	P	70.00	111.00	173.00	11.73	81.57	7.63	42.33	258.00	3.07
SPV 2125	gca	-1.02**	-1.13**	-10.39**	-0.19	-3.86**	0.01	-6.41**	-26.47**	-0.08**
	P	69.00	105.00	163.00	10.17	76.67	7.10	45.00	205.00	2.97
SPV 1616	gca	0.22	0.92**	5.81**	-0.36*	-0.97**	-0.53**	0.20	-4.75**	-0.04*
	P	71.00	107.00	188.00	9.27	66.83	6.73	52.00	195.00	3.03
SPV 2118	gca	-1.17**	-1.04**	4.96**	-0.14	0.67**	-0.36**	-0.67	-35.17**	0.01
	P	70.00	106.00	202.00	11.30	85.53	6.28	53.67	127.00	3.13
SPV 2110	gca	0.13	0.34*	2.66**	0.35*	2.30**	-0.32*	-0.26	4.88**	0.10**
	P	70.00	106.00	204.00	12.23	86.30	7.35	15.60	173.00	3.10
GFS 5	gca	0.82**	0.95**	-13.91**	-0.68**	-3.78**	-0.11	3.45**	-0.05	0.05*
	P	71.00	106.00	174.00	10.23	71.70	7.10	54.33	264.00	2.87
CSV 15	gca	-0.77**	-1.02**	2.12**	0.070	-3.33**	-0.02	3.07**	-10.53**	0.05*
	P	71.00	106.00	174.00	10.23	71.70	7.10	54.33	264.00	2.87
SSV 84	gca	1.34**	1.40**	2.24**	0.56**	1.46**	0.58**	-0.84*	28.27**	-0.11**
	P	76.00	112.00	174.00	11.30	80.90	8.10	54.00	287.00	2.87
GJ 39 (c)	gca	-0.14	0.22	11.45**	0.42**	-0.39**	-0.12	4.27**	23.94**	0.10**
	P	68.00	105.00	215.00	11.23	65.50	6.38	55.67	255.00	3.07
SE G(I)		0.10	0.17	1.44	0.04	0.20	0.03	0.29	0.58	0.01
SE G(I)-G(J)		0.16	0.25	2.16	0.07	0.30	0.05	0.44	0.87	0.01

*, ** Significant at 5 % and 1% level of significance respectively

Table 4. Estimates of specific combining ability effects (sca), standard heterosis (SH) and per se performance (P) for various traits

Crosses		Seed yield/plant	Fodder yield/plant	100- Seed weight	Days to 50 % flowering	Days to maturity	Plant height	No of leaves/plant	Leaf length	Leaf width
SPV 2110 x GFS 5	sca	18.71**	135.84**	0.298**	-2.05**	0.38	34.61**	2.74**	3.51**	0.12
	SH	34.72**	36.08**	16.29**	-	-	4.65**	15.76**	19.69**	12.07**
	P	75.00	347.00	3.57	69.00	112.00	225.00	13.00	78.40	7.15
GFS 5 x GJ 39	sca	11.17**	86.12**	0.370**	4.89**	6.83**	8.82	1.42**	2.27**	-0.98**
	SH	28.74**	23.92**	18.24**	10.29**	-	-	13.71**	13.69**	-
	P	71.67	316.00	3.63	75.00	119.00	208.00	12.77	74.47	6.25
SPV 2113 x CSV 15	sca	13.97**	-111.67**	0.116**	0.43	-0.31	-10.81*	-0.39*	0.99	-0.72**
	SH	4.78**	-	4.23*	-	-	-	-	25.08	19.59**
	P	58.33	104.00	3.20	70.00	109.00	188.00	11.27	81.93	7.63
CSV 15 x SSV 84	sca	12.01**	42.60**	0.485**	0.01	1.62**	26.01**	3.89**	6.89**	2.09**
	SH	4.78	4.31*	11.73**	-	-	7.91**	43.63**	24.27**	58.78**
	P	58.33	266.00	3.43	71.00	113.00	232.00	16.13	81.40	10.13
SPV 2113 x SPV 1616	sca	-6.50**	145.87**	0.04	-0.56	-1.25*	17.82**	1.84**	2.94**	1.79**
	SH	-	43.92**	-	-	-	2.33	16.38**	31.65**	50.94**
	P	35.00	367.00	3.13	70.00	110.00	220.00	13.07	86.23	9.63
SPV 2110 x GJ 39	sca	1.06	82.84**	-0.048	2.58**	1.11*	35.91**	0.84**	-1.88**	-0.39**
	SH	-	24.71**	6.51**	-	6.67*	16.74**	17.81**	16.64**	-
	P	49.17	318.00	3.27	70.00	112.00	251.00	13.23	76.40	6.63
GJ 39 x SSV 84	sca	-2.53	68.12**	-0.266**	-5.29**	-4.62**	7.34	-2.36**	13.85**	2.29**
	SH	-	27.84**	-	-2.94**	-	-	-	39.39**	60.34**
	P	15.00	326.00	2.83	66.00	108.00	222.00	10.23	91.30	10.23
Check										
GJ-39 (Check)	P	55.67	255.00	3.07	68.00	105.00	215.00	11.23	65.50	6.38

*, ** Significant at 5 % and 1% level of significance respectively