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Gene action studies over different environments in sorghum [*Sorghum bicolor* (L.) Moench]

B.H. KALE AND R.T. DESAI[1]

AUTHORS' INFO

Associated Co-author :
[1]Department of Genetics and Plant Breeding, N.M. College of Agriculture, Navsari Agricultural University, NAVSARI (GUJARAT) INDIA

Author for correspondence:
B.H. KALE
Department of Genetics and Plant Breeding, N.M. College of Agriculture, Navsari Agricultural University, NAVSARI (GUJARAT) INDIA
Email: bhushan.kale@nau.in

ABSTRACT : An experiment was conducted to estimate the combining ability using three females [Cytoplasmic-Genetic Male Sterile (CGMS) Lines], 18 males (testers) and their 54 hybrids developed through line x tester mating design in three diverse seasons (environments). Result of analysis of variance for means revealed significant differences for all the twelve characters. Combining ability analysis over environments revealed importance of both additive and non-additive components. Close agreement between GCA and *per se* performance of parents was observed for most of the characters studied. Combination having high *per se* performance also had high SCA effects and involved at least one good general combining parent. The female parents 28A and 86A and among male parents, KR 125, KR 191, KR 196, PMSC-43, GJ 38, GSF 5 and CSV 21F were good general combiners for grain yield and its component traits. While considering the SCA effects and *per se* value, 10 hybrids were best for grain yield and component characters. All these hybrids were combination of parents having either good x good or good x poor GCA for grain yield.

KEY WORDS : Combining ability, Line x tester, Sorghum, *Sorghum bicolor*

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Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth important cereal crop after wheat, maize, rice and barley in the world. It is mainly grown in the Deccan plateau, central and western India apart from a few patches in northern India. Sorghum is one of the major crops among the millets grown in dry land. Sorghum is nutritionally superior to other fine cereals such as rice and wheat and hence it is known as nutritious cereal. It is a multipurpose and bio-energy crop; the grain, stem and glumes are the useful parts.

In India, in the last three decades, productivity has gone up by 84 per cent in case of *Kharif* sorghum and 70 per cent in *Rabi* sorghum. Thus, due to sorghum hybrid technology the individual farm household is made economically viable at micro-level (Seetharama, 2006). An attempt was, therefore, made in the present investigation to know the type of gene action governing grain yield and its component traits in different environments and to identify parents and hybrids which could be exploited in future breeding programme.

RESEARCH PROCEDURE

Three male sterile lines 8A, 28A and 86A of sorghum were crossed with18 testers used as male parents *viz.*, KR 125, KR 126, KR 128, KR 191, KR 196, KR 199, PMSC 43, GJ 38, GJ 39, GJ 42, GSF 5, CSV 21F, SPV

1616, SPV 669, PKV Ashwini, AKSSV 22, PKV 400, PVK 809 in line x tester fashion. The resulting 54 F_1's along with their 21 parents and one check CSH18 were grown in Randomized Block Design with three replications at college farm, N.M. College of Agriculture, Navsari Agricultural University, Navsari during late *Kharif* 2010-11, *Rabi* 2010-11 and summer 2011. Data on five randomly selected plants were recorded for 12 characters (except days to 50 per cent flowering and maturity which were recorded on plot basis) *viz.*, grain yield per plant (g), days to 50 per cent flowering, days to maturity, plant height (cm), number of leaves per plant, panicle length (cm), number of primaries per panicle, panicle weight (g), dry stover yield per plant (g), harvest index (%), 1000-grain weight (g) and protein content (%). The combining ability analysis was carried out by following Kempthorne (1957).

RESEARCH ANALYSIS AND REASONING

The pooled analysis of variance revealed significant differences due to parents, crosses and female x male interaction for all the twelve characters, thereby suggesting that the experimental material possessed considerable variability and that both GCA and SCA were involved in the genetic expression of grain yield and other component traits (Table 1). Khandelwal *et al.* (2006) and Birader *et al.* (2000) also reported similar results. Perusal of σ^2GCA/σ^2SCA ratio revealed preponderance of additive gene action for grain yield per plant, plant height, panicle length, primaries per panicle, panicle weight, harvest index, 1000-grain weight and protein content. The preponderance of non-additive gene action was also recorded for the rest of the characters, suggesting in general, the importance of both additive and non-additive gene action for inheritance of component traits. These results were in agreement with those reported by Patel *et al.* (1984); Giriraj and Goud (1985); Chandak and Nandanwankar (1993); Senthil and Palanasamy (1994); Pillai *et al.* (1995); Nayeem (1996); Sankarapandian *et al.* (1994); Siddiqui and Baig (2001); Bhavsar and Borikar (2002); Gaikwad *et al.* (2002); Desai *et al.* (2005); Iyanar and Fazllullah Khan (2005); Wadikar *et al.*

Table 1: Analysis of variance (Mean squares) and variance estimates for combining ability pooled over environments

Source	d.f.	Grain yield per plant	Days to 50 % flower	Days to maturity	Plant height	Leaves per plant	Panicle length	Primaries Per Panicle	Panicle Weight	Dry stover yield per plant	Harvest Index	1000-grain weight	Protein content
Environment	2	5971.11**	262.39**	325.55**	2147.93**	2.09**	20.09**	11922.3**	6774.05**	1495.90**	608.68**	86.34**	1.37**
Rep./Env.	6	409.55	47.69	104.22	3387.04	5.55	55.92	964.74	545.99	1464.56	174.78	7.58	6.02
Females (F)	2	26816.9**	630.36**	663.52**	343856**	85.01**	1431.17**	6242.88**	28042.1**	37863.8**	1432.35**	5304.13**	115.18**
Males (M)	17	4850.65**	587.99**	632.08**	41679**	50.82**	252.58**	1535.41**	4890.66**	5667.69**	406.34**	310.90*	118.51**
F x M	34	1213.91**	87.33**	84.12**	11844.3**	10.69**	73.83**	404.43**	1276.48**	2174.94**	82.16**	150.72**	7.40**
F x Env.	4	270.48	18.37	4.23	207.76	1.38	9.09	67.40	191.56	56.23	40.73	5.93**	0.44
M x Env.	34	152.59	6.78	7.72	347.94	1.23	5.54	153.02	154.57	66.66	20.14	1.42	0.33
(F x M) x Env	68	174.96**	12.12**	16.47**	524.93**	2.34**	6.51**	128.14**	179.14	117.03**	23.11**	1.52**	0.31*
Pooled Error	318	15.00	1.88	3.86	124.51	0.20	2.07	35.46	19.75	53.12	6.325	0.27	0.21
σ^2 Env.	-	26.47**	1.15**	1.46**	8.99*	0.0084	0.080	3.94	30.01**	6.41**	2.67**	0.38**	0.0051
σ^2 Females	-	157.45**	3.31**	3.65**	2051.41**	0.46**	8.36**	36.41**	165.14**	220.67**	8.22**	31.78**	0.66**
σ^2 Males	-	135.52**	21.70**	20.61**	1111.55**	1.5276**	6.65**	40.96**	131.76**	131.22**	12.11**	5.11**	4.11**
σ^2 GCA	-	136.59**	5.48**	5.54**	1917.14**	0.5478**	8.11*	37.06**	144.50**	207.89**	7.60*	27.97**	1.15**
σ^2 SCA	-	115.43**	9.49**	7.51**	1257.71**	0.92**	7.47**	30.69**	121.92**	228.65**	6.56**	16.57**	0.78**
σ^2 GCA/σ^2SCA	-	1.18	0.57	0.73	1.52	0.58	1.08	1.20	1.18	0.90	1.15	1.68	1.4
σ^2 F x Env.	-	4.73	0.31	0.007	1.54	0.0219	0.13	0.59	3.18	0.0577	0.63	0.104**	0.0043
σ^2 M x Env.	-	15.29	0.54	0.42	24.82	0.1145	0.38	13.06	14.98	1.50	1.53	0.12	0.0128
σ^2 GCA x Env	-	6.24	0.34	0.067	4.86	0.035	0.16	2.37	4.86	0.26	0.76	0.10	0.0055
σ^2 SCA x Env.	-	53.31**	3.41**	4.20**	133.47**	0.715**	1.48**	30.89**	53.13**	21.30**	5.59**	0.41**	0.031*

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 2 : Estimates of general combining ability (GCA) of parents pooled over environments

Parents	Grain yield per plant	Days to 50 % flower	Days to maturity	Plant height	Leaves per plant	Panicle length	Primaries per paricle	Panicle weight	Dry stover yield per plant	Harvest index	1000-grain weight	Protein content
Females												
8A	-14.79**	1.00**	1.18**	-51.98**	-0.35**	-3.20**	-6.97**	-15.1**	-17.54**	-3.30**	-6.12**	-0.86**
28A	8.59**	-1.93**	-2.15**	16.20**	-0.41**	2.66**	4.90**	8.20**	7.05**	2.46**	0.90**	0.82**
86A	6.19**	0.92**	0.96**	35.78**	0.76**	0.54**	2.07**	6.96**	10.48**	0.83**	5.21**	0.03
S.E.(g)	0.30	0.10	0.15	0.87	0.03	0.11	0.46	0.34	0.57	0.19	0.04	0.03
S.E.(g.g_j)	0.43	0.15	0.21	1.23	0.04	0.15	0.66	0.49	0.80	0.27	0.05	0.05
Males												
KR 125	1.74*	-0.88**	-1.35**	-42.14**	0.96**	1.14**	2.43*	2.12*	3.87**	0.40	0.21*	-3.39**
KR 126	-0.32	-2.06**	-1.72**	-21.70**	1.41**	3.80**	-5.64**	0.34	-10.41**	1.58**	-2.87**	-0.94**
KR 128	-8.68**	4.67**	3.20**	23.65**	1.42**	-2.08**	-5.85**	-8.21**	-1.49	--3.77**	-0.47**	-2.48**
KR 191	7.78**	-1.73**	-2.12**	-43.24**	0.05	4.37**	-3.41**	8.25**	-9.25**	5.11**	-1.22**	0.34**
KR 196	8.61**	-2.10**	-1.68**	-17.56**	-0.51**	-1.98**	-4.13**	8.85**	1.39	3.38**	-1.56**	-1.78**
KR 199	-3.32**	-10.99**	-11.05**	-55.12**	-0.56**	-0.08	1.04	-4.53**	-17.98**	2.87**	-3.47**	0.49**
PMSC-43	11.34**	-1.65**	-1.61**	40.28**	0.95**	0.86**	10.67**	12.03**	12.03**	2.33**	5.08**	2.74**
GJ 38	14.35**	-1.77**	-1.46**	-32.41**	-1.23**	3.46**	11.58**	14.14**	14.94**	2.92**	-1.28**	2.27**
GJ 39	-7.45**	4.00**	3.42**	-41.36**	-0.15	1.62**	-8.10**	-9.67**	-12.13**	-0.84	-1.93**	2.10**
GJ 42	-7.36**	-1.73**	-1.50**	-1.96	-1.87**	2.67**	-8.91**	-8.21**	-8.36**	-1.94**	-4.46**	1.80**
GSF 5	7.55**	8.86**	10.64**	86.37**	2.47**	-4.90**	10.67**	9.70**	36.29**	-2.67**	6.67**	1.88**
CSV 21F	3.91**	9.15**	9.23**	53.61**	2.25**	-5.81**	7.96**	6.02**	26.45**	-2.41**	4.73**	1.07**
SPV 1616	-5.51**	0.04	-0.50	-18.65**	-1.54**	-4.43**	8.00**	-636**	-12.15**	-0.33	-4.24**	1.95**
SPV 669	-1.54*	-0.80**	-0.61	35.86**	-1.86**	1.50**	-8.73**	-0.34	6.78**	-2.54**	0.29**	-2.57**
PKV Ashwini	-3.59**	-4.28**	-5.20**	35.15**	-1.57**	-1.29**	8.33**	-2.57**	-8.73**	-0.55	-1.78**	-2.75**
AKSSV 22	-5.74**	0.63*	0.97*	-20.57**	0.68**	1.63**	-5.10**	-7.12**	-9.13**	-1.10*	3.74**	-2.69**
PKV 400	-11.11**	-1.69**	-1.09**	8.14**	-0.55**	-2.37**	-5.31**	-12.6**	-5.13**	-3.52**	0.88**	0.67**
PVK 809	-0.65	2.34**	2.46**	11.66**	-0.34**	1.88**	-5.48**	-1.49	-6.98**	1.10*	1.72**	1.26**
S.E.(g)	0.74	0.26	0.37	2.14	0.08	0.27	1.14	0.85	1.40	0.48	0.10	0.09
S.E.(g_i-g_j)	1.05	0.37	0.53	3.03	0.12	0.39	1.62	1.20	1.98	0.68	0.14	0.12

* and ** indicate significance of values at P=0.05 and 0.01, respectively

(2006); Premalatha *et al.* (2006); Udutha (2008) and Mohammed (2009).This shows the possibilities of improvement of the traits through heterosis breeding. The low interaction of GCA variance with environments as compared to those of SCA variance indicated that general effects were more stable over seasons compared to specific effects. Kambal and Webster (1965) studying general and specific effects in grain sorghum reported similar results.

Genotypes with significant GCA effects in desired direction are expected to transmit genes with desirable effects to their progeny. It was observed that none of the parent was good general combiner for all the characters studied except male parent PMSC-43 (Table 2). Among female parents, 28A was found to be good general combiner for all the traits except leaves per plant, while, good general combining ability for all the characters was manifested by 86A (except days to 50 per cent flowering, days to maturity and protein content). Among male parents, KR 125, KR191, KR 196, PMSC-43, GJ 38, GSF 5 and CSV 21F were found to be good general combiners for grain yield per plant as well as dry stover yield per plant, thereby classifying these parents as good sources of favourable genes for increasing production of grain and stover yield. These male parents also exhibited good general combining ability for two or more important yield contributing traits. The male parents, KR 125, KR 126, KR 191, KR 196, KR 199, PMSC-43, GJ 38, GJ 42, PKV Ashwini, and PKV 400 registered good general combining ability for days to 50 per cent flowering as well as days to maturity, signifying that these parents are good source of genes for earliness. Even though, only one parent was good combiner for all the attributes, obviously, these lines may be used in conventional breeding programmes employing simple pedigree method or more potent methods like recurrent selection using biparental or diallel selective matting to concentrate more additive genes thereby enhancing the performance.

The estimates of SCA effects revealed that none of the crosses showed consistently significant and desirable SCA effects for all the characters. Considering the overall performance of the hybrids over the environments, in respect of grain yield per plant as well as dry stover yield per plant, 18 and 16 hybrids, respectively manifested significant and positive SCA effects. For various yield components across the environments, significant and desirable SCA effects were noticed in several hybrids for days to 50 per cent flowering (21), days to maturity (18), plant height (18), leaves per plant (17), panicle length (32), primaries per panicle (13), panicle weight (19), harvest index (14), 1000-grain weight (25) and protein content (20). Among the hybrids, 28A × PMSC-43, 28A × GJ 38 and 28A × KR-191 were the best specific combinations for grain yield and its components and they exhibited desired significant SCA effects for maximum number of traits with high yield and involving parents having good x good GCA (Table 3). Yield ranking indicated that hybrids with significant positive SCA effects were also among the best in *per se* performance. However, the hybrid 86A × GJ 38, which was the high yielder in the material, showed non-significant negative SCA effects suggesting that it might be attributed to the high interaction with environments.Similar results also reported by Mohammed (2009). The hybrids 28A × PVK 809, 86A × KR 196, 28A × PKV Ashwini, 86A × GJ 39, 86A × KR126 and 8A × GSF 5 are important as they showed

Table 3 : Hybrid combinations with desired significant SCA effects for gain yield together with *per se* performance in L x T analysis in sorghum

Crosses	Grain yield per plant (g)	SCA effects for grain yield	GCA effects of parents	Type of combination on the basis of GCA
28A × PMSC-43	78.99	10.99**	28A = 8.59** PMSC-43= 11.34**	Good x good
28A × GJ 38	78.93	7.91**	28A = 8.59** GJ 38= 14.35**	Good x good
28A × KR-191	78.18	13.73**	28A = 8.59** KR-191= 7.78**	Good x good
28A × PVK 809	70.66	14.66**	28A = 8.59** PVK 809= -0.65	Good x poor
86A × KR 196	70.53	7.66**	86A = 6.19** KR 196= 8.61**	Good x good
86A × GJ 38	66.72	-1.88	86A = 6.19** GJ 38= 14.35**	Good x good
28A × PKV Ashwini	65.49	12.43**	28A = 8.59** PVK Ashwini = -3.59**	Good x poor
86A × GJ 39	64.05	17.25**	86A = 6.19** GJ 39= -7.45**	Good x poor
86A × KR126	63.09	9.16**	86A = 6.19** KR126= -0.32	Good x poor
8A × GSF 5	62.96	22.13**	8A = -14.79** GSF 5= 7.55**	Good x poor

* and ** indicate significance of values at P=0.05 and 0.01, respectively

significant desired SCA effects for grain yield, stover yield and at least for one yield contributing component. These hybrids also involved parents having good x good and good x poor GCA for grain yield. These results indicated that the hybrids with superior SCA effects involving parents having good GCA could be exploited to yield positive heterosis in higher frequencies. The same results were reported earlier by Iyanar *et al.* (2001). Hybrids involving parents having good x good GCA effects for grain yield along with one or the other component trait indicates presence of additive x additive type of gene action between favourable allele contributed by the two parents, which is fixable. These results are in conformity with the findings of Khandelwal *et al.* (2006).

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