ADVNACE RESEARCH JOURNAL OF CROP IMPROVEMENT
Volume 1 Issue 2 (December, 2010) Page : 187-193

Received : *November, 2010;* ***Accepted :*** *December, 2010*

Research Paper

Combining ability analysis for green fodder yield and quality attributes in sorghum [*Sorghum bicolor* (L.) Moench] over environments

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ABSTRACT

Sorghum is one of the most important food and fodder crop of dry land agriculture. In order to make forage sorghum as an enterprising and remunerative crop, there is urgent need to develop varieties and hybrids having early maturity, fast growth habit and higher yield coupled with high protein content and safe limit of toxic constituents like HCN for animal. Combining ability analysis is a powerful tool to discriminate good as well as poor combiners and choose appropriate parental material in breeding programme. Combining ability for green fodder yield and quality attributes was studied using three male sterile lines, sixteen male parents and 48 hybrids in RBD with three replications in three environments created by different dates of sowing. Highly significant mean squares for males and females indicated the presence of sufficient variability in the parental material. The ratio of general combining ability to specific combining ability variance indicated the non additive gene action. Parent showed difference in their combining ability effects for same traits under different environments. Indore 9A from female and PB 22, ASF 7, PB 181 and PB 45 from male parents were identified as good combiner for green fodder yield per plant, dry matter yield per plant and majority of yield components. Estimates of specific combining ability effects did not reveal any specific pattern but varied from cross to cross in individual environment. The pooled data showed that Indore 9A x PB 22, 3660 A x Sholapari, 3660 A x PB 45 exhibited positive and significant *sca* effect for green fodder yield per plant and majority of its components in overall environmental conditions. On the basis of *gca* : *sca* ratio preponderance of non-additive gene action for green fodder per plant suggested heterosis breeding programme could be useful for developing superior genotype/hybrids.

Patel, K.V. and Patel, A.D. (2010). Combining ability analysis for green fodder yield and quality attributes in sorghum [*Sorghum bicolor* (L.) Moench] over environments, *Adv. Res. J. Crop Improv.,* **1** (2) : 187-193.

Key words : Sorghum, Combining ability, Environment, Hybrid

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is a major fodder crop among cereal fodder. Green fodder is the cheapest source of feed for milky, meat and draft animals. Therefore, development of fodder resources of the country becomes a high priority national programme. This could be achieved through covering more area under cultivation of high productivity coupled with quality of fodder crop. There is need to improve the crop by identifying good combiner for development of high yielding hybrid. Combining ability analysis is being used in crop plants for identifying the superior parents for obtaining superior hybrid combinations. On the basis *gca/ sca* ratio, also help in characterization of nature and magnitude of gene action for various characters of economic importance.

The concept of general and specific combining ability is an especially useful in testing procedure that involves the study and comparison of the performance of homozygous inbred lines in cross combinations. The knowledge of gene action for characters helps in employing suitable breeding methodology for their improvement. Forage yield is basically a function of many morphological and physiological characters; therefore, breeding for high fodder yield depends on one or more other characters. For improvement of yield basically involved the exploitation of genetic diversity present in population. Development of hybrids provides a good avenue for quicker exploitation of both additive and non-additive genetic variances through such alterations.

MATERIALS AND METHODS

The experiment was laid down at the plant breeding farm, Anand Agricultural University, Anand during *Kharif* 2006 with the objective to study combining ability and nature of gene action for fodder yield and its component characters in individual environment as well as on pooled basis in sorghum. The experiment material comprised with three male sterile lines as a female parent, sixteen male parents and 48 F_1s was planted in RBD with three replications in three different dates of sowing *viz.,* 15th June (E_1), 1st August (E_2) and 15th September (E_3) during *Kharif* 2005. Each net plot had single row of 4.5 m each, the inter row spacing 30 cm apart. Five plants were selected at random from each plot and tagged. Observations for each plant was recorded separately and average value per plot was computed. Observations for various characters *viz.*, days to 50% flowering, plant height, number of tillers per plant, number of leaves per plant, leaf length, leaf width, leaf: stem ratio, number of nodes per plant, stem thickness, green fodder yield, dry matter content, dry matter yield, crude protein content, crude protein yield per plant, hydrocyanic acid (HCN), neutral detergent fiber content (NDF). Estimation of combining effects were made as per Kempthorne (1957). Analysis of variance for combining ability for sixteen characters in all environments calculated as suggested by Arunachalam (1974).

RESULTS AND DISCUSSION

The mean sum of squares due

Table 1 : Analysis of variance for combining ability over environment for different character of forage sorghum

Sources	d.f.	Days to 50% flowering	Plant height	Number of tillers per plant	Number of leaves per plant	Leaf length	Leaf width	Leaf: stem ratio	Number of nodes per plant	Stem thickness	Green fodder yield per plant	Dry matter content	Dry matter yield per plant	Crude protein content	Crude protein yield per plant	HCN content	NDF content
Environment	2	19888.10**	11856.80**	0.3230**	215.90**	18552.50**	7558.08**	1.668**	212.14**	1.924**	196303**	244.83**	19537.10**	124.83**	2622.11**	15246.30**	1940.47**
Replication/ Environment	6	30.74	268.51**	0.0383	0.84	14.79	14.15	0.006	0.10	0.001	357.99	5.92*	38.77	0.19	4.29	400.26**	32.203*
Female	2	126.49	9288.44**	0.0469	4.61	49.28	288.08	0.053	0.73	0.103*	1866.52	13.04	72.236	2.42	26.47	2268.83	245.02
Male	15	580.54**	3279.3	0.0613	12.87**	273.27**	255.04*	0.082	9.44**	0.053*	6697.00	62.48	691.03	7.44**	64.99	2249.43	209.25
Female x Male	30	43.78**	1667.66**	0.0499**	3.38**	96.38**	119.32**	0.064**	1.90**	0.032	6088.72**	31.84**	475.44**	1.72**	52.57**	2066.17**	152.26**
Female x Environment	4	9.044	283.22	0.0294	3.34	9.72	117.22	0.087	2.06	0.052	4256.15	0.81	349.72	4.16	37.80	782.77	97.71
Male x Environment	30	151.91**	615.81	0.0954*	3.61	154.40**	135.75	0.064	2.58	0.051**	4513.61	14.03**	405.34	7.55**	48.11	3004.08**	60.08
F x M x Environment	60	43.035**	1011.81**	0.0537**	2.91**	55.34**	115.13**	0.046**	1.87**	0.025	5293.81**	6.91**	437.96**	2.19**	47.5**	1181.74**	46.54**
Error	282	14.6	81.89	0.0246	1.20	8.99	9.58	0.008	0.13	0.028	374.05	2.56	36.42	0.17	3.45	112.49	12.52
σ^2f		0.81	57.98	0.00	0.01	0.01	1.16	0.00	0.01	0.00	22.11	0.09	2.19	0.01	0.11	4.18	0.29
σ^2m		15.85	74.36	0.00	0.33	2.77	4.26	0.00	0.25	0.00	51.43	0.87	9.19	0.01	0.44	60.71	1.61
σ^2fm		0.25	218.62	0.00	0.16	13.68	1.40	0.01	0.01	0.00	264.97	8.31	12.49	0.15	1.67	294.81	35.24
σ^2f x e		0.71	15.18	0.00	0.01	0.95	0.04	0.00	0.00	0.00	21.62	0.13	1.84	0.04	0.20	8.31	1.07
σ^2m x e		12.10	44.00	0.00	0.08	11.34	2.29	0.00	0.08	0.00	86.69	0.79	3.62	0.60	0.06	202.48	1.50
σ^2fm x e		9.48	309.97	0.01	0.57	15.45	35.18	0.01	0.58	0.01	1639.92	1.45	133.85	0.67	14.71	356.42	11.34
σ^2gca		3.186	60.56	0.00005	0.0560	0.429	1.65	0.0003	0.03	0.0002	10.50	0.06	0.39	0.005	0.026	6.06	0.49
σ^2sca		0.25	218.62	0.00	0.16	13.68	1.40	0.01	0.01	0.00	264.97	8.31	12.49	0.15	1.67	294.81	35.24
σ^2gca/σ^2sca		12.744	0.27701	0.00	0.35	0.031	1.176	0.030	3.200	0.00	0.04	0.008	0.031	0.04	0.02	0.021	0.014

to *gca* were found significant for plant height, stem thickness in female over environments. The mean sum of squares due to male were significant for days to 50% flowering, number of leaves per plant, leaf length, leaf width, numberof nodes per plant, stem thickness and crude protein content on pooled basis. The mean sum of square due to female x male was significant for all the characters except for stem thickness. Among the components of source of variation of combining ability analysis with environment interaction, female x environment interaction was non significant for all the characters under study. It means the female performed consistently over range of environment. The mean square due to male x environment were significant for days to 50% flowering, number of tillers per plant, leaf length, stem thickness, dry matter content, crude protein and HCN content which revealed that performance of the male were vulnerable to change in different environmental condition for these characters. Mean sum of squares due to female x male x environment were significant for all the traits except stem thickness. Analysis of variance for combining ability presented in Table 1 shows that the magnitude of *sca* variances were higher than *gca* variance for all the characters except days to 50% flowering, leaf width, number of nodes per plant and stem thickness on individual as well as pooled basis indicating pre dominance of non-additive gene action for these characters. From overall, we can say both additive non-additive genetic variances were important for the inheritance of various traits under study. Higher magnitude of *sca*

Table 2: Estimates of general combining ability effects (*gca*) for different characters over environment

Parents		Days to 50 % flowering	Plant height (cm)	No. of tillers per plant	No of leaves per plant	Leaf length	Leaf Width	Leaf stem ratio	Number of nodes per plant	Stem thickness	GFY per plant	Dry matter content	DMY per plant	Crude protein content	CPY per plant	HCN content	NDF content
Females (Lines)																	
Indore 9A	(P_1)	0.30	2.41	0.00	0.19**	0.43*	1.57**	0.00	0.08**	0.00	3.49	0.35	0.59	0.08	0.42**	3.52*	1.79**
AKMS 14 A	(P_2)	1.05**	6.55**	0.02	0.16**	0.23	0.38	0.02	0.03*	0.03**	3.70	0.19	0.78	0.15	0.44**	4.30*	0.93
3660 A	(P_3)	0.75**	8.96**	0.02	0.04	0.66**	1.18**	0.02	0.06**	0.03**	0.21	0.16	0.19	0.07	0.02	0.78	0.56
S.E. (g_i)		0.22	0.52	0.01	0.06	0.17	0.18	0.01	0.02	0.00	1.11	0.09	0.35	0.02	0.11	0.61	0.20
Males (Testers)																	
S 1049	(P_4)	1.04	1.63	0.02	0.26	2.24**	0.94	0.07	0.14	0.07**	2.47	0.05	1.21	0.28**	0.76*	2.03	2.06**
ASFS 7	(P_5)	1.26*	17.24**	0.02	0.22	3.12**	0.64	0.06	0.34**	0.03**	6.39*	1.71**	0.07	0.14*	1.04**	10.05**	0.83
SSG 59 3	(P_6)	8.70**	1.66	0.05*	0.98**	0.93	7.33**	0.09	0.86**	0.06**	18.43**	2.67**	7.57**	0.59**	1.05**	1.56	3.72**
GFS 4	(P_7)	4.15**	14.60**	0.01	0.91**	0.46	0.16	0.03	0.93**	0.01	5.01	0.03	2.10*	0.64**	1.07**	1.59	0.80
GFS 5	(P_8)	3.07**	22.37**	0.00	0.82**	2.61**	0.30	0.04	0.71**	0.02*	16.09**	1.41**	5.69**	0.84**	0.62*	4.53**	0.69
Sholapuri	(P_9)	3.85**	0.71	0.03	0.54**	0.31	1.90**	0.04	0.45**	0.00	7.52*	1.03**	1.35	0.66**	1.49**	4.95**	1.94**
HC 171	(P_{10})	1.70**	5.62**	0.06**	0.05	2.06**	0.41	0.06	0.01	0.02*	12.90**	0.01	3.41**	0.09	1.25**	5.92**	1.54**
HC 308	(P_{11})	3.00**	7.52**	0.07**	0.75**	2.28**	0.10	0.03	0.80**	0.04**	3.13	2.41**	2.21*	0.19**	0.09	10.46**	0.31
IS 21475	(P_{12})	6.33**	3.77*	0.04*	0.97**	4.38**	0.93	0.06	0.82**	0.08**	27.03**	1.28**	6.47**	0.38**	2.04**	0.89	1.57**
PB 45	(P_{13})	5.44**	7.74**	0.13**	0.40*	5.34**	4.21**	0.10	0.40**	0.08**	20.24**	1.67**	7.71**	0.28**	2.28**	3.49*	0.69
IS 2472	(P_{14})	1.19*	5.12**	0.03	0.54**	0.10	3.50**	0.05	0.63**	0.01	0.16	0.47	0.08	0.30**	0.34	2.50	2.06**
IS 3260	(P_{15})	6.44**	15.29**	0.00	0.28	6.07**	0.84	0.02	0.19**	0.04**	29.76**	0.20	8.21**	0.15*	2.78**	8.20**	0.28
DSIS 8315	(P_{16})	1.78**	1.18	0.01	0.02	2.36**	1.30**	0.04	0.02	0.02*	12.98**	1.09**	2.46*	0.33**	0.99**	22.09**	0.57
PB 78	(P_{17})	0.07	10.68**	0.02	0.35*	1.95**	0.36	0.00	0.33**	0.03**	14.60**	0.39	4.20**	0.02	1.39**	10.81**	3.31**
PB 181	(P_{18})	3.30**	14.00**	0.04*	0.51**	3.87**	2.91**	0.06	0.54**	0.01	1.06	1.40**	1.60	1.24**	1.48**	10.88**	5.91**
PB 22	(P_{19})	8.00**	8.43**	0.02	1.36**	3.28**	6.38**	0.01	0.71**	0.04**	20.21**	2.79**	8.66**	0.31**	2.39**	11.84**	6.06**
S.E. (g_i)		0.60	1.43	0.02	0.17	0.47	0.49	0.01	0.06	0.01	3.05	0.25	0.95	0.06	0.29	1.67	0.56

variances, which is important for green fodder yield per plant. Same results were reported by Agarwal *et al.* (2005) and Sumalini *et al.* (2005).

The information regarding *gca* effects of the parents is a prime importance as this would help in identification of suitable parental line, the parental line have been identified on the basis of high per se performance and desirable *gca* effects with respect to different characters. Parents showed differences in their general combining ability effects for the same traits under different environments (Table 2). Indore 9A from female, and PB 22, ASFS 7, PB 78, DSIS 8315, PB 181 and PB 45 from male were good general combiner for green fodder yield per plant, dry matter yield per plant and majority of yield components.

Indore 9A from female showed significantly negative *gca* effects for HCN content NDF content, among the male parents GSF 5 and HC 308 showed negating *gca* effect for HCN and NDF content on pooled basis for these two characters negative *gca* affects is desirable one in crop improvement. Similar results were observed earlier by Boora and Lodhi (1982) and Grewal et *al.* (1994).

The estimates of *sca* effects for green fodder yield ranged from –35.69 to 55.25. Among the cross combination P_1 x P_{19}, P_2 x P_{14}, P_3 x P_{13}, P_1 x P_7 and P_3 x P_9 on pooled basis gave superior performance for *sca* effect for green fodder yield per plant and majority of yield components. Hybrids showed differences in their specific combining ability effects for the

Table 3 : Classification of parents with respect to general combining ability effects (pooled) for various traits

Parents	Days to 50% flowering	Plant height	Number of tillers per plant	Number of leaves per plant	Leaf length	Leaf width	Leaf: stem ratio	Number of nodes per plant	Stem thickness	Green fodder yield per plant	Dry matter content	Dry matter yield per plant	Crude protein content	Crude protein yield per plant	HCN content	NDF content
Females																
Indore 9A	P	A	P	P	G	P	P	P	A	A	P	A	A	G	P	P
AKMS 14A	G	G	P	G	A	A	G	G	G	P	A	P	P	P	A	A
3660 A	P	P	A	A	P	G	P	G	P	A	A	A	A	A	P	A
Males																
S 1049	G	A	P	P	G	P	G	P	P	A	A	A	G	G	A	G
ASFS 7	A	G	P	A	G	P	P	G	G	G	P	A	G	G	P	A
SSG 59-3	G	A	P	P	P	P	G	P	P	P	P	P	G	P	A	P
GFS 4	G	G	A	P	A	P	A	P	P	A	A	G	P	P	A	P
GFS 5	G	P	P	P	P	P	G	P	P	P	P	P	G	P	P	P
Sholapuri	G	A	P	P	P	P	G	P	P	P	G	P	P	P	G	P
HC 171	A	P	G	A	P	P	P	P	P	G	P	G	A	G	G	P
HC 308	P	G	G	G	G	P	P	G	G	A	P	P	P	A	P	P
IS 21475	G	P	P	P	P	P	G	P	P	P	G	P	G	P	A	G
PB 45	P	P	G	G	G	G	P	G	G	G	G	G	G	G	G	P
IS 2472	A	G	P	G	A	P	G	G	P	P	A	A	G	A	A	G
IS 3260	P	P	P	A	P	A	P	G	G	P	A	P	P	P	P	A
DSIS 8315	A	A	P	A	P	G	P	P	G	G	P	G	P	G	G	P
PB 78	A	G	P	G	P	A	P	G	G	G	A	G	P	G	P	G
PB 181	P	P	P	G	G	G	P	G	P	A	G	A	P	P	G	P
PB 22	P	G	P	G	G	G	A	G	G	G	G	G	G	G	P	G

* G = Good, A = Average, P = Poor

Table 4 : Estimates of specific combining ability (*sca*) effects of hybrids for various traits

Hybrids	Days to 50% flowering	Plant height	Number of tillers per plant	Number of leaves per plant	Leaf length	Leaf width	Leaf: stem ratio	Number of nodes per plant
P_1 x P_4	0.26	10.04**	-0.04	0.48*	-1.59*	-4.89**	-0.07**	0.34**
P_1 x P_5	0.70	8.18**	-0.04	0.43	0.08	0.29	-0.03*	0.41**
P_1 x P_6	5.04**	-10.37**	0.00	0.43	-0.53	-0.59	-0.04*	0.47**
P_1 x P_7	0.93	18.62**	0.02	0.47*	0.59	-1.16	-0.04*	0.33**
P_1 x P_8	1.63	7.32**	-0.05*	0.11	3.84**	3.77**	-0.05**	0.13
P_1 x P_9	-0.04	10.55**	-0.02	-0.45	-0.55	3.67**	-0.04*	-0.62**
P_1 x P_{10}	-2.04*	-3.18	0.16**	0.47*	-0.95	1.08	0.00	0.27**
P_1 x P_{11}	-2.33**	-4.11*	-0.12**	-0.26	0.73	1.02	0.12**	-0.16*
P_1 x P_{12}	0.67	-3.11	0.02	0.00	2.92**	-0.69	0.11**	-0.01
P_1 x P_{13}	0.67	1.10	0.18**	0.05	-0.22	0.62	-0.05**	0.07
P_1 x P_{14}	-2.37**	-3.21	-0.02	0.02	2.22**	1.47	-0.03*	0.10
P_1 x P_{15}	-1.00	-35.93**	-0.05*	-0.95**	-7.23**	-1.81	0.03*	-0.86**
P_1 x P_{16}	-1.67	-4.22*	0.00	-0.01	3.12*	-3.60**	-0.01	-0.12
P_1 x P_{17}	-1.26	-0.92	-0.01	0.28	-1.72*	-2.61**	0.03*	0.24**
P_1 x P_{18}	-0.07	1.18	0.01	0.02	0.11	-2.32**	0.08**	-0.15*
P_1 x P_{19}	0.89	8.06**	-0.03	-1.11**	-0.83	5.76**	-0.01	-0.45**
P_2 x P_4	1.27	0.12	0.00	-0.45	4.77**	2.40**	0.00	-0.19*
P_2 x P_5	-1.62	-0.49	0.07*	-0.52	2.24**	-3.46**	0.10**	-0.36**
P_2 x P_6	-1.95*	12.84**	0.02	-0.28	1.69*	3.97**	0.03*	-0.10
P_2 x P_7	-0.73	-21.08**	-0.05*	-0.73**	-0.70	-2.87**	0.07**	-0.76**
P_2 x P_8	-1.91*	-8.31**	-0.01	-0.51	-4.87**	-3.00**	0.08**	-0.38**
P_2 x P_9	-3.58**	-19.70**	0.00	-0.18	-4.88**	-7.46**	0.11**	-0.11
P_2 x P_{10}	3.64**	12.25**	-0.07**	-0.06	-0.93	2.56**	-0.01	0.06
P_2 x P_{11}	0.68	2.92	0.03	-0.23	-1.20	-0.82	-0.09**	-0.22**
P_2 x P_{12}	-0.10	2.28	0.01	0.32	-1.74*	-1.90**	-0.09**	0.42**
P_2 x P_{13}	0.79	-4.09*	-0.16**	-0.17	-0.39	1.76*	0.07**	-0.11
P_2 x P_{14}	1.64	4.38*	0.06*	0.54	-2.33**	0.85	0.05*	0.63**
P_2 x P_{15}	0.13	9.08**	0.05*	0.57*	4.32**	1.44*	-0.02	0.52**
P_2 x P_{16}	-0.76	21.05**	-0.03	-0.17	2.79**	5.13**	-0.03*	-0.05
P_2 x P_{17}	2.53**	-8.29**	0.00	-0.12	-0.76	2.04**	-0.21**	-0.02
P_2 x P_{18}	0.94	1.79	0.00	0.18	0.96	3.35**	-0.05**	0.21**
P_2 x P_{19}	-0.99	-4.77*	0.08**	1.81**	1.02	-3.99**	-0.01	0.44**
P_3 x P_4	-1.53	-10.16**	0.03	-0.04	-3.18**	2.49**	0.07**	-0.15*
P_3 x P_5	0.91	-7.69**	-0.03	0.09	-2.33**	3.17**	-0.07**	-0.06
P_3 x P_6	-3.09**	-2.47	-0.02	-0.16	-1.16	-3.38**	0.01	-0.37**
P_3 x P_7	-0.20	2.46	0.03	0.26	0.11	4.03**	-0.03*	0.43**
P_3 x P_8	0.28	0.98	0.06*	0.39	1.03	-0.77	-0.03*	0.26**
P_3 x P_9	3.62**	9.15**	0.03	0.63**	5.44**	3.79**	-0.07**	0.73**
P_3 x P_{10}	-1.61	-9.08**	-0.09**	-0.41	1.88**	-3.64**	0.01	-0.33**
P_3 x P_{11}	1.65	1.19	0.10**	0.49*	0.47	-0.20	-0.02	0.37**
P_3 x P_{12}	-0.57	0.84	-0.03	-0.32	-1.18	2.59**	-0.01	-0.41**
P_3 x P_{13}	-1.46	2.98	-0.02	0.13	0.61	-2.37**	-0.02	0.04
P_3 x P_{14}	0.73	-1.17	-0.04	-0.56*	0.12	-2.32**	-0.02	-0.73**
P_3 x P_{15}	0.88	26.84**	0.00	0.38	2.91**	0.37	-0.01	0.34**
P_3 x P_{16}	2.43**	-16.83**	0.03	0.18	-5.91**	-1.53*	0.04*	0.17*
P_3 x P_{17}	-1.27	9.21**	0.01	-0.16	2.47**	0.57	0.18**	-0.23**
P_3 x P_{18}	-0.87	-2.96	-0.01	-0.21	-1.08	-1.03	-0.03*	-0.06
P_3 x P_{19}	0.10	-3.28	-0.05*	-0.70**	-0.19	-1.77*	0.01	0.01
S.E.(Sij)	0.85	2.02	0.03	0.24	0.67	0.69	0.02	0.08

Contd... Table 4

Table 4 contd..

P_1 x P_4	0.03**	-5.90	-0.67	-2.73*	0.58**	-0.01	0.91	-1.03
P_1 x P_5	0.05**	8.95*	3.22**	5.81**	0.14	0.98*	1.39	-2.69**
P_1 x P_6	-0.09**	-9.20*	-0.46	-2.77*	-0.33**	-1.08**	20.43**	7.08**
P_1 x P_7	0.01	33.66**	0.53	10.85**	-0.08	1.86**	-5.93*	-1.18
P_1 x P_8	0.00	-3.37	1.12**	-0.20	-0.40**	-0.71	-6.68**	2.60**
P_1 x P_9	0.03**	0.73	1.28**	1.79	0.35**	0.16	5.88*	-2.69**
P_1 x P_{10}	0.01	-26.69**	1.67**	-5.74**	0.63**	-1.65**	4.44	-0.21
P_1 x P_{11}	-0.05**	-10.57*	0.17	-2.52	-0.28	-1.40**	-8.48**	-1.44
P_1 x P_{12}	-0.07**	-5.25	1.59**	0.39	-0.08	-0.39	16.39**	-4.88**
P_1 x P_{13}	-0.06**	-32.34**	1.67**	-8.16**	-0.30**	-3.61**	2.22	0.94
P_1 x P_{14}	0.06**	-7.27	-1.82**	-3.73**	0.40**	-0.17	4.78*	-1.25
P_1 x P_{15}	0.03**	-17.79**	-0.76	-5.37**	-0.12	-1.53**	2.08	-0.92
P_1 x P_{16}	0.02**	4.47	-0.59	-0.08	0.65**	1.32**	-24.99**	3.16**
P_1 x P_{17}	0.00	19.48**	-1.45**	3.71**	-0.47**	1.43**	-4.86*	1.94*
P_1 x P_{18}	0.03**	-4.16	-3.44**	-4.85**	-0.53**	-0.97*	-3.98	-1.18
P_1 x P_{19}	0.00	55.25**	-2.06**	13.60**	-0.16	5.77**	-3.60	1.75*
P_2 x P_4	0.03**	-0.38	0.84*	0.73	0.05	-0.43	3.66	-2.12**
P_2 x P_5	-0.02*	-15.41**	-2.45**	-6.80**	-0.40**	-1.97**	13.75**	-5.01**
P_2 x P_6	0.07**	7.70	0.51	2.51	0.18*	0.85*	-15.07**	-6.56**
P_2 x P_7	-0.10**	-28.39**	1.07**	-7.06**	-0.23**	-2.27**	13.43**	-0.16
P_2 x P_8	-0.03**	-13.38**	-1.20**	-4.48**	0.43**	-10.2**	5.86*	-4.82**
P_2 x P_9	-0.06**	-27.88**	0.90*	-7.11**	-0.37**	-2.35**	-11.77**	-1.12
P_2 x P_{10}	0.03**	-4.59	-1.04**	-2.60	0.28**	-0.29	-14.89**	-2.19**
P_2 x P_{11}	0.02*	20.85**	0.47	5.78**	0.22*	2.41**	-1.35	2.47**
P_2 x P_{12}	0.06**	0.57	-0.08	-.31	0.00	-0.09	0.90	1.59*
P_2 x P_{13}	-0.02	-1.82	-0.34	-0.35	0.08	0.16	6.24**	4.18**
P_2 x P_{14}	-0.05**	40.59**	0.10	11.69**	-0.40**	3.23**	-11.95**	2.77**
P_2 x P_{15}	-0.07**	13.51**	-2.32**	1.64	0.01	1.09**	0.18	2.22**
P_2 x P_{16}	0.06**	31.22**	2.13**	11.40**	-0.35**	2.20**	41.47**	1.07
P_2 x P_{17}	0.05**	3.71	-0.06	1.18	0.52**	0.99*	-16.75**	3.18**
P_2 x P_{18}	-0.02**	1.14	1.08**	1.31	0.30**	0.51	-3.95	0.40
P_2 x P_{19}	0.03**	-27.45**	0.38	-7.52**	-0.32**	-3.01**	-9.76**	4.10**
P_3 x P_4	-0.06**	6.28	-0.17	2.00	-0.62**	0.44	-4.57	3.15**
P_3 x P_5	-0.03**	6.46	-0.77*	0.99	0.26**	1.00*	-15.14**	7.70**
P_3 x P_6	0.02**	1.50	-0.05	0.26	0.16	0.23	-5.36*	-0.52
P_3 x P_7	0.10**	-5.27	-1.60**	-3.79**	0.31**	0.42	-7.50**	1.33
P_3 x P_8	0.02**	16.74**	0.08	4.68**	-0.04	1.73**	0.82	2.22**
P_3 x P_9	0.03**	27.15**	-2.18**	5.32**	0.03	2.20**	5.90*	3.81**
P_3 x P_{10}	-0.03**	31.28**	-0.63	8.34**	-0.91**	1.94**	10.45**	2.41**
P_3 x P_{11}	0.03**	-10.28*	-0.64	-3.27*	0.06	-1.02*	9.83**	-1.04
P_3 x P_{12}	0.00	4.68	-1.51**	-0.08	0.08	0.48	-17.29**	3.29**
P_3 x P_{13}	0.08**	34.16**	-1.33**	8.51**	0.22*	3.45**	-8.46**	-5.11**
P_3 x P_{14}	-0.02**	-33.32**	1.72**	-7.95**	0.00	-3.05**	7.17**	-1.52
P_3 x P_{15}	0.04**	4.28	3.07**	3.73**	0.12	0.44	-2.25	-1.30
P_3 x P_{16}	-0.08**	-35.69**	-1.54**	-11.32**	-0.30**	-3.52**	-16.48**	-4.22**
P_3 x P_{17}	-0.06**	-23.19**	1.51**	-4.89**	-0.05	-2.42**	21.61**	-5.11**
P_3 x P_{18}	-0.01	3.02	2.36**	3.54**	0.23**	0.46	7.93**	0.78
P_3 x P_{19}	-0.03**	-27.80**	1.68**	-6.08**	0.48**	-2.76**	13.35**	-5.85**
S.E.(Sij)	0.01	4.31	0.36	1.35	0.09	0.41	2.37	0.79

same traits under different environments (Table 4). Similar results were observed by Patil and Mistry (1997), Katiyar *et al.* (1999) and Agrawal *et al* (2005).

In combining ability analysis, significant *gca* and *sca* variance on pooled basis denotes importance of both additive and non additive gene action for characters studied. Preponderance of non additive gene action for green fodder yield per plant suggested heterosis breeding programme could be useful for developing superior genotypes for green fodder yield.

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