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Line × Tester analysis in dual purpose sorghum [*Sorghum bicolor* (L.) Moench)]

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ABSTRACT

Thirty F_1 crosses generated by crossing ten lines with three testers in line x tester mating design and their thirteen parents were evaluated in randomized block design replicated thrice at Agricultural College Farm, Bapatla during *rabi* 2006 -2007. SPV 1782, SPV 1714, SPV 1754 and SPV 1616 among lines and CSV 15 among testers were found to be good general combiners. SPV 1782 x HC 308, SPV 1730 x HC 308 and SPV 1616 x CSH 16 were fond to be good specific combiners. Grain yield and leaf crude protein content were governed by additive gene action. Green forage yield at 50% flowering, 1000 grain weight, grain crude protein content and leaf breadth were under the control of both additive and non additive gene action. Remaining characters were under the control of non additive gene action.

Key words : Combing ability, Dual purpose sorghum, gca, Line x Tester, sca

Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth most important crop in the world and third most important crop in India. It is a major cereal grown as a dual purpose crop for food, feed and fodder adapted to the drought prone semi arid tropic regions of the world. In recent years, the county is facing an acute shortage of livestock feed and fodder. A comprehensive understanding on the genetic architecture of parents, knowledge on the combining ability of parents and relative importance of additive and non additive gene action are essential for implementing systematic crop improvement programme. Combining ability analysis is a powerful and precise tool to discriminate the good as well as poor combiners and for choosing appropriate parental material and crosses. Hence the present investigation was undertaken to estimate combining ability effects and types of gene action through line × tester analysis.

MATERIAL AND METHODS

The experiment was conducted in randomized block design with thirty F_1 crosses generated by crossing ten lines with three testers in line × tester mating design and their thirteen parents replicated thrice at Agricultural College Farm, Bapatla, during *rabi* 2006- 2007. Each entry was sown in 5 rows of 3 m length with a uniform spacing of 45 cm x 15 cm. Recommended package of practices and prophylactic measures were adopted to raise a healthy crop. Observations were recorded on ten randomly selected plants for seventeen characters *viz*., days to 50% flowering, days to maturity, plant height, number of green leaves per plant at harvest, number of dry leaves per plant at harvest, leaf length, leaf breadth, leaf length-breadth ratio, leaf weight, stem weight, leaf stem ratio, green forage yield at 50% flowering, stover yield per plant, grain yield per plant, 1000 grain weight, leaf crude protein content and grain crude protein content.

The mean data on various characters were subjected to combining ability analysis through line × tester method developed by Kempthorne (1957) and detailed by Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

Analysis of variance for line × tester design revealed highly significant mean sum of squares due to genotypes, indicating the presence of considerable amount of genetic variability in the material evaluated for various characters (Table 1). Highly significant mean sum of squares due to parents (line and testers) indicated considerable genetic variability among them. Significant line *Vs* tester mean sum of square for all characters except number of dry leaves per plant at harvest revealed that mean of lines and testers manifested significant differences. Hybrids manifested significant genetic differences among themselves for all attributes which indicated the possibilities of identifying the superior hybrids from the study. Comparison of means of hybrids with mean of parents as a group was found to be highly significant for all characters which suggested the existence of heterosis for all characters and importance of non additive genetic effects in determining these characters.

The analysis of variance for combining ability revealed that variance due to lines were significant for all the characters. It may be due to the fact that lines used in this study had considerable amount of genetic variability for all the characters. Considerable amount of genetic diversity was present among testers for green forage yield at 50% flowering, grain yield per plant and leaf crude protein content as indicated by their corresponding mean sum of squares. Mean sum of squares due to lines were higher than those due to testers for all characters except leaf stem ratio. This indicated larger contribution of lines to total gca effects. In case of leaf stem ratio contribution of testers to total gca effects was more. Mean sum of squares due to line × tester interaction were highly significant for all characters. This suggested lines manifested differential behaviour with different testers or different testers showed markedly different combining ability effects with different lines for all the traits which indicated the presence of inter allelic interaction. The magnitude of mean sum of squares due to interaction were lower for most of the characters except days to 50% flowering and days to maturity indicating both gca and sca effects contributes to the hybrid.

Estimates of combining ability effects are useful to predict the relative performance of different parents in hybrid combinations. The magnitude and direction of general combining ability effects provide guidelines for discriminating parents and their utilization. Sprague and Tatum (1942) stated that gca is an intrinsic value of parents due to additive effects of genes.

A perusal of results on gca effects (Table 2) revealed several good combiners for different traits studied but none of the parents recorded significant gca effects for all the characters. Among lines SPV 1782 recorded significant gca effect for 8 characters followed by SPV 1714 for 9 characters, SPV 1754 for 7 characters and SPV 1616 for 5 characters. Among testers CSV 15 recorded significant gca effect for 7 characters. High gca effect for a particular character of a parent indicated the additive gene effects for the characters by the genes in the parent concerned which is fixable component of genetic variation. It would be desirable to develop multiple crosses to select desirable segregants for yield and favourable associated traits in advanced generations, as no parent was a good general combiner for all the traits.

The evaluation of hybrids become necessary to consider whether a hybrid might be used as a commercial hybrid variety or further utilized in breeding programme. The sca effects of the hybrids could be used to evaluate hybrids. The magnitude and sca effects are of vital importance in selecting cross combinations with higher probability of generating desired transgressive segregants.

An overall picture of sca effects (Table 3) revealed that no cross combination was found to be good specific combiners for all the characters studied. SPV 1782 x HC 308 recorded significant sca effect for 9 characters followed by SPV 1730 x HC 308 for 5 characters and SPV 1616 x CSH 16 for 7 characters.

Relationship between sca effects of hybrids and gca effects of parents are helpful to understand the type of interaction between the parents and to understand the breeding procedure to be used. An examination of gca effects of parents and the sca effects of resultant hybrids revealed that it may not be possible to find a definite trend for all the traits in all the hybrids. In general mostly crossed with significant sca effect involved parents with high × low or low × low gca effects indicated the existence of non additive inter allelic interaction. In such crosses selection should be delayed up to F_5 or F_6 segregating generations, by the time heterozygosity would be reduced and additive genes could be stabilized.

The estimates of gca and sca variances are useful to infer the type of gene action and the relative importance of the character in a breeding programme. Variance due to sca was higher than that due to GCA for all characters except grain yield and leaf crude protein content. Ratio of gca variance to sca variance and predictability ratio (Table 4) revealed that grain yield and leaf crude protein content were under the control of additive gene action. Hence significant achievement could be achieved in the segregating generations using simple selection procedures or conventional breeding methods such as pedigree or bulk selection which are useful for accumulation of desirable genes for these characters.

Additive gene action for grain yield in the present study were in accordance with the reports of Sankarapandian *et al.* (2004) and Desai *et al.* (2005) and for leaf crude protein content by Parmer and Tikka (2005).

For grain forage yield at 50% flowering, 1000 grain weight, grain crude protein content and leaf breadth both additive and non additive gene action were of equal magnitude. Hence reciprocal recurrent selection is useful for improvement of these

Table 1. Analysis of variance for linex tester mating design for different characters in sorghum

Source of variations	d.f	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	No. of green leaves $plant^{-1}$ at harvest	No.of dry leaves $plant^{-1}$ at harvest	Leaf length (cm)	Leaf breadth (cm)	Leaf length breadth ratio
Replications	2	0.07	0.14	0.60	0.00	0.95	0.20	0.001	0.01
Genotypes	42	81.87**	85.73**	3223.50**	1.60**	0.58**	114.86**	2.05**	3.13**
Parents	12	51.95**	61.65**	2627.64**	1.01**	0.28**	82.07**	1.16**	3.17**
Parent Vs Crosses	1	1130.32**	1175.74**	8430.05**	22.76	1.98**	1199.32**	14.76**	0.20**
Crosses	29	58.10	58.10**	3290.53**	1.22**	0.65**	91.04	1.98**	3.21**
Line effect	9	52.71	52.71	6879.94**	2.64**	0.54	133.39	3.93**	6.07*
Tester effect	2	41.07	41.07	326.45	0.29	0.14	22.13	2.73	2.37
Line x Tester effect	18	62.69**	62.69**	1825.16**	0.45**	0.76**	77.52**	0.92**	1.88**
Error	58	1.52	1.52	1.24	0.01	0.00	1.03	0.03	0.00

Source of variations	d.f	Leaf weight (g)	Stem weight (g)	Leaf stem ratio	Green forage yield at 50% flowering (kg)	Stover yield $plant^{-1}$ (g)	Grain yield $plant^{-1}$(g)	1000 grain weight (g)	Leaf crude protein content (%)	Grain crude protein content (%)
Replications	2	0.02	0.00	0.03	0.09	0.01	0.02	0.00	0.00	0.00
Genotypes	42	181.67**	0.00**	13025.91**	131.75**	8278.54**	354.51**	26.75**	14.60**	18.06**
Parents	12	189.08**	0.00**	8620.45**	129.99**	1540.47**	455.67**	15.36**	10.15**	13.62**
Parent Vs Crosses	1	2124.06**	0.01**	248952.17**	1122.54**	154391.29**	6291.53**	255.12**	57.11**	36.65**
Crosses	29	111.63**	0.00**	6713.47**	98.32**	6028.34**	107.93**	23.59**	14.98**	19.26**
Line effect	9	180.61	12897.29**	0.01	200.04**	10094.76*	183.16**	56.24**	39.25**	47.44**
Tester effect	2	46.11	9541.77	0.01	164.56**	8403.80	436.80**	23.87	16.63**	4.65
Line x Tester effect	18	84.42**	3307.31**	0.00**	40.09**	3731.19**	33.76**	7.23**	2.66**	6.79**
Error	58	1.03	1.02	0.00	0.96	1.03	1.03	0.01	0.00	0.00

Table 2. Estimates of general combining ability (gca) effects of parents for various characters in sorghum

Parents	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	No. of green leaves plant^{-1} at harvest	No.of dry leaves plant^{-1} at harvest	Leaf length (cm)	Leaf breadth (cm)	Leaf length breadth ratio
Lines								
SPV 1616	1.19	1.19	31.42**	0.80**	0.06	4.96**	-0.41**	1.38**
SPV 1753	-2.70**	-2.70**	-9.83**	-0.61**	-0.12**	-4.08**	-0.86**	0.61**
SPV 1750	-3.92**	-3.92**	-10.54**	0.34**	-0.12**	-0.41	0.08	-0.20**
SPH 1467	1.41	1.41	-33.63**	-0.20**	0.20**	-0.08	-0.88**	1.28**
SPV 1714	2.74**	2.74**	11.29**	-0.25**	-0.33**	-7.08**	-0.64**	-0.19**
SPV 1751	-1.70*	-1.70*	2.86**	-0.86**	0.03	-2.74**	0.40**	-0.095**
SPV 1754	-1.14	-1.14	36.71**	0.52**	0.52**	3.94**	0.91**	-0.67**
SPV 1730	0.19	0.19	-22.48**	-0.41**	-0.28**	3.79**	0.43**	-0.12**
SPV 1791	0.08	0.08	-38.60**	0.20**	0.09**	-0.41	0.16	-0.33**
SPV 1782	3.86**	3.86**	32.80**	0.46**	-0.04	2.09**	0.81**	-0.80**
SE gi	0.41	0.41	0.37	0.02	0.02	0.33	0.06	0.01
C D at 5%	0.82	0.82	0.74	0.05	0.04	0.68	0.13	0.03
Testers								
CSH 16	0.56	0.56	-3.77**	0.05	-0.02	0.97	0.35**	-0.32**
CSV 15	0.79	0.79	20.37**	0.06	-0.06	-0.66	-0.16	0.13**
HC 308	-1.34	-1.34	1.40*	-0.11**	0.08*	-0.31	-0.19	0.19**
SE gj	0.23	0.23	0.20	0.01	0.01	0.19	0.03	0.01
CD at 5%	0.45	0.45	0.41	0.03	0.02	0.37	0.07	0.02

Leaf weight (g)	Stem weight (g)	Leaf stem ratio	Green forage yield at 50% flowering (kg)	Stover yield plant^{-1} (g)	Grain yield plant^{-1}(g)	1000 grain weight (g)	Leaf crude protein content(%)	Grain crude protein content (%)
3.94**	-57.58**	0.05**	0.80	-46.76**	5.13**	0.38**	-1.67**	-1.63**
-4.06**	-53.35**	0.01	-1.37**	-50.26**	-4.00**	-3.52**	-1.79**	-2.80**
-1.06	-38.69**	0.02**	5.63**	-28.92**	0.73	0.88**	-1.79**	-1.63**
-6.23**	22.24**	-0.04**	-4.70**	14.41**	-5.60**	-4.45**	-1.96**	-1.92**
5.61**	53.06**	-0.01	4.63**	52.74**	-1.93**	1.58**	3.00**	4.48**
-1.06	14.40**	-0.02**	-3.03**	18.36**	-0.27	1.18**	0.38**	0.41**
3.11**	15.06**	-0.00	7.47**	14.41**	3.73**	2.18**	0.96**	1.87**
2.94**	30.73**	0.02**	-0.37	12.86**	0.07	0.38**	0.09**	-0.47**
-6.73**	-7.94**	-0.03**	-1.70**	-12.92**	-5.60**	-1.89**	3.87**	2.45**
3.55**	22.06**	-0.01	-7.37**	26.08**	7.73**	3.28**	-1.08**	-0.76**
0.34	0.34	0.00	0.33	0.34	0.34	0.03	0.01	0.00
0.68	0.67	0.01	0.65	0.68	0.68	0.07	0.02	0.01
0.62	-9.93**	0.01*	-0.83	-14.44**	0.40	0.27**	0.22**	0.38**
-1.43*	20.59**	-0.02**	2.64**	18.34**	3.60**	0.72**	-0.83**	-0.41**
0.81	-10.66**	0.01	-1.82**	-3.91**	-4.00**	-1.00**	0.61**	0.03**
0.19	0.18	0.00	0.18	0.19	0.19	0.02	0.01	0.00
0.37	0.37	0.00	0.36	0.37	0.37	0.04	0.01	0.00

Table 3. Estimates of specific combining ability (sca) effects for various characters in sorghum

Crosses	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	No.of green leaves plant^{-1} at harvest	No.of dry leaves plant^{-1} at harvest	Leaf length (cm)	Leaf breadth (cm)	Leaf length breadth ratio	Leaf weight (g)
SPV 1616 X CSH 16	4.11**	4.11**	16.33**	0.31**	-0.33**	-1.14	0.78**	-1.44**	10.71**
SPV 1616 X CSV 15	-5.12**	-5.12**	-10.65**	0.03	-0.01	- 0.91	-0.23*	0.15**	-2.24**
SPV 1616 X HC 308	1.01	1.01	-5.68**	-0.34**	0.33**	2.05**	-0.55**	1.29**	-8.47**
SPV 1753 X CSH 16	2.00**	2.00**	-25.37**	0.12**	0.44**	2.70**	0.32**	-0.16**	-6.29**
SPV 1753 X CSV 15	-0.23	-0.23	21.23**	-0.11*	-0.10**	0.33	-0.18	0.36**	3.76**
SPV 1753 X HC 308	-1.77*	-1.77*	4.13**	-0.01	-0.34**	-3.02**	-0.14	-0.20**	2.53**
SPV 1750 X CSH 16	2.22**	2.22**	7.48**	0.21**	-0.57**	1.02	-0.41**	0.67**	-4.29**
SPV 1750 X CSV 15	-0.01	-0.01	9.31**	-0.11*	0.55**	0.66	-0.31**	0.48**	-0.24
SPV 1750 X HC 308	-2.21**	-2.21**	-16.79**	-0.10*	0.02	-1.69**	0.72**	-1.14**	4.53**
SPH 1467 X CSH 16	1.89*	1.89*	16.34**	-0.46**	0.88**	-0.31	-0.66**	0.98**	2.38**
SPH 1467 X CSV 15	-5.34**	-5.34**	-6.51**	-0.25**	-0.33**	2.33**	0.15	0.12**	0.93
SPH 1467 X HC 308	3.46**	3.46**	-9.83**	-0.22**	-0.56**	-2.02**	0.50**	-1.10**	-3.31**
SPV 1714 X CSH16	-2.44**	-2.44**	9.32**	0.21**	0.44**	1.70**	0.40**	-0.32**	0.04
SPV 1714 X CSV 15	-2.01**	-2.01**	-27.34**	-0.12**	-0.09**	-1.68**	-0.40**	0.35**	-0.91
SPV 1714 X HC 308	4.46**	4.46**	18.02**	-0.10*	-0.36**	-0.02	-0.00	-0.03	0.86
SPV 1751 X CSH 16	-5.67**	-5.67**	33.81**	-0.45**	0.16**	2.36**	0.57**	-0.23**	3.21**
SPV 1751 X CSV 15	10.43**	10.43**	-30.16**	0.47**	0.30**	8.99**	0.51**	0.50**	2.76**
SPV 1751 X HC 308	-4.77**	-4.77**	-3.66**	-0.02	-0.46**	-11.35**	-1.08**	-0.27**	-5.97**
SPV 1754 X CSH 16	-1.22	-1.22	-9.90**	0.17**	-0.04	2.68**	0.06	0.31**	-5.96**
SPV 1754 X CSV 15	4.88**	4.88**	-0.87	0.14**	-0.10**	-5.50**	0.06	-0.80**	0.59
SPV 1754 X HC 308	-3.66**	-3.66**	10.77**	-0.31**	0.14**	2.81**	-0.12	0.49**	5.36**
SPV 1730 X CSH 16	-1.22	-1.22	-48.78**	-0.80**	-0.72**	- 2.57**	-0.28*	0.02	1.71**
SPV 1730 X CSV 15	0.21	0.21	33.99**	0.44**	-0.20**	2.46**	0.20	0.05	-0.24
SPV 1730 X HC 308	1.01	1.01	14.79**	0.36**	0.92**	0.11	0.07	-0.07**	-1.47*
SPV 1791 X CSH 16	1.89*	1.89*	1.21	-0.08	0.05	-0.97	-0.39**	0.37**	0.38
SPV 1791 X CSV 15	-0.01	-0.01	22.91**	-0.17**	-0.08*	-3.34**	0.35**	-0.92**	0.43
SPV 1791 X HC 308	-1.88*	-1.88*	-24.12**	0.24**	0.04	4.31**	0.04**	0.55**	-0.81
SPV 1782 X CSH 16	-1.56*	-1.56*	-0.45	-0.16**	-0.31**	-5.47**	-0.39	-0.20**	-1.90**
SPV 1782 X CSV 15	-2.79**	-2.79**	-11.92**	-0.34**	0.05	-3.34**	-0.16	-0.28**	-4.85**
SPV 1782 X HC 308	4.34**	4.34**	12.38**	0.50**	0.27**	8.81**	0.55**	0.48**	6.75**
SE s_{ij}	0.71	0.71	0.64	0.04	0.03	0.59	0.11	0.03	0.59
CD at 5%	1.43	1.43	1.29	0.08	0.06	1.18	0.29	0.05	1.18

(Table 3. Contd..........)

Crosses	Stem weight (g)	Leaf stem ratio	Green forage yield at 50% flowering	Stover yield plant^{-1} (g)	Grain yield plant^{-1} (g)	1000 grain weight (g)	Leaf crude protein content (%)	Grain crude protein content (%)
SPV 1616 X CSH 16	-4.60**	0.05**	-1.94**	12.61**	2.37**	1.16**	-0.22**	-0.38**
SPV 1616 X CSV 15	-9.44**	-0.01	-0.71	-12.18**	0.87	0.21**	0.83**	1.28**
SPV 1616 X HC 308	14.04**	-0.04**	2.65**	-0.43	-3.23**	-1.37**	-0.61**	-0.91**
SPV 1753 X CSH 16	2.09**	-0.03**	0.83	4.11**	-0.50	0.66**	-0.10**	-1.84**
SPV 1753 X CSV 15	-21.17**	-0.03**	-4.64**	-18.68**	-0.40	-0.29**	-0.30**	0.70**
SPV 1753 X HC 308	19.08**	0.00	3.82**	14.57**	0.90	-0.37**	0.39**	1.14**
SPV 1750 X CSH 16	21.68**	-0.04**	0.83	12.77**	0.27	0.86**	-1.35**	-1.26**
SPV 1750 X CSV 15	22.91**	0.02**	-0.64	12.99**	-0.93	-0.29**	0.95**	0.41**
SPV 1750 X HC 308	-44.59**	0.06**	-0.18	-25.76**	0.67	-0.57**	0.39**	0.84**
SPH 1467 X CSH 16	0.27	0.00	-3.84**	9.44**	3.60**	0.19**	0.07**	-0.08**
SPH 1467 X CSV 15	22.24**	0.00	8.69**	15.65**	-1.60**	-0.66**	-0.63**	-1.06**
SPH 1467 X HC 308	-22.51**	-0.00	-4.85**	-25.09**	-2.00**	0.46**	0.56**	1.14**
SPV 1714 X CSH16	39.93**	-0.03**	2.83**	38.11**	-1.07	-3.84**	0.36**	0.50**
SPV 1714 X CSV 15	-3.59**	0.01	-2.64**	-1.68*	1.73**	1.01**	-0.34**	0.41**
SPV 1714 X HC 308	-36.34**	0.03**	-0.18	-36.43**	-0.67	2.83**	-0.03	-0.91**
SPV 1751 X CSH 16	22.59**	-0.01	-2.51**	30.00**	2.27**	0.66**	1.24**	1.08**
SPV 1751 X CSV 15	-11.92**	0.02*	0.02	-7.29**	2.07**	-0.29**	-0.33**	-0.76**
SPV 1751 X HC 308	-10.67**	- 0.01	2.48**	-22.71**	-4.33**	-0.37**	-0.90**	-0.32**
SPV 1754 X CSH 16	-35.07**	- 0.02**	2.99**	-31.56**	1.27*	1.16**	-0.22**	-1.26**
SPV 1754 X CSV 15	53.41**	-0.01*	-4.48**	45.66**	0.07	0.41**	-0.05**	-1.34**
SPV 1754 X HC 308	-18.34**	0.03**	1.48*	-14.09**	-1.33*	-1.57**	0.26**	2.59**
SPV 1730 X CSH 16	-27.74**	0.08**	-0.17	-67.01**	-6.07**	-1.84**	0.66**	1.08**
SPV 1730 X CSV 15	-19.26**	-0.02**	1.36*	4.54**	1.73**	0.91**	0.83**	0.12**
SPV 1730 X HC 308	47.00**	-0.06**	-1.18*	62.46**	4.33**	0.93**	-1.48**	-1.20**
SPV 1791 X CSH 16	2.93**	-0.01	1.16*	9.77**	0.60**	0.93**	-0.51**	2.54**
SPV 1791 X CSV 15	-9.59**	0.01*	0.69	-10.01**	0.40**	0.08	-1.21**	-1.05**
SPV 1791 X HC 308	6.66**	-0.00	-1.85**	0.24	-1.00	-1.00**	1.72**	-1.49**
SPV 1782 X CSH 16	-22.07**	0.00	-0.17	-18.23**	-2.73**	0.06	0.07**	-0.38**
SPV 1782 X CSV 15	-23.59**	0.00	2.36**	-29.01**	-3.93**	-1.10**	0.24**	1.29**
SPV 1782 X HC 308	45.66**	-0.00	-2.18**	47.24**	6.67**	1.03**	-0.32	-0.90**
SE s_{ij}	0.58	0.01	0.57	0.58	0.58	0.06	0.02	0.01
C D at 5%	1.17	0.01	1.13	1.17	1.18	0.12	0.03	0.01

Table 4: Estimates of genetic components of variance, degree of dominance and proportional contribution of lines, testers and interaction to total variance

	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	No. of green leaves per plant at harvest	No.of green leaves per plant at harvest	Leaf length (cm)	Leaf breadth (cm)	Leaf length breadth ratio	Leaf weight (g)
σ^2gca	-0.8101	-0.8101	91.1814**	0.0522**	-0.0219	0.0124	0.1233**	0.1202**	1.4842*
σ^2sca	20.3908**	20.3908**	607.9747**	0.1490**	0.2555**	25.4958**	0.2978**	0.6272**	27.7943**
σ^2gca/σ^2sca	-0.0397	-0.0397	0.15	0.35	-0.08	0.0005	0.4138	0.1917	0.0534
Degree of dominance	3.55	3.55	1.83	1.20	2.41	32.09	1.09	1.62	3.06
Predictability ratio	0.073	0.073	0.234	0.41	0.14	0.0009	0.452	0.27	0.096
Contribution of									
Line (%)	28.1556	28.1556	64.89	73.19	25.7063	45.47	61.4424	58.5902	50.2119
Tester (%)	4.8753	4.8753	0.6842	1.79	1.4836	1.6768	9.5014	5.095	2.8489
Line x tester (%)	6.6969	6.6969	34.4279	25.02	72.81	52.85	29.0562	36.3148	46.9393

	Stem weight (g)	Leaf stem ratio	Green forage yield at 50% flowering plant $^{-1}$ (kg)	Stover yield plant^{-1} (g)	Grain yield plant^{-1} (g)	1000 grain weight (g)	Leaf crude protein content (%)	Grain crude protein content (%)
σ^2gca	405.755**	0.0001*	7.2930**	282.9788**	14.165**	1.6835**	1.2967**	0.9876**
σ^2sca	1102. 097**1	0.0014**	13.0427**	1243.3881**	10.91**	2.4058**	0.8852**	2.2637**
σ^2gca/σ^2sca	0.3682	0.0714	0.5592	0.2276	1.2984	0.6998	1.465	0.4363
Degree of dominance	1.17	2.40	0.95	1.48	0.62	0.85	0.58	1.07
Predictability ratio	0.42	0.125	0.527	0.312	0.72	0.58	0.74	0.46
Contribution of								
Line (%)	59.62	32.9229*	63.1462	51.9688	52.66	74.00	81.3357	76.44
Tester (%)	9.80	11.7494	11.5436	9.6141	27.91	6.9788	7.6569	1.66
Line x tester (%)	30.5775	55.3278	25.3102	38.4171	19.41	19.01	11.0074	21.8856

* and ** significant at P = 0.05 and P = 0.01 respectively

characters since it exploits both the components of genetic variance. Both gene actions for the above characters in the present study were in accordance with the earlier reports of Pahuja *et al.* (2003) for green forage yield and Biradar *et al.* (2000) for 1000 grain weight.

For the remaining characters non additive gene action was observed. Non additive gene action was earlier reported by Premalatha *et al.* (2006) for days to 50% flowering, Vikas Kulkarni *et al.*(2005) for days to maturity, Yadav and Pahuja (2007) for plant height, Jhansi Rani (2004) for number of dry leaves per plant at harvest, Yadav and Pahuja (2007) for leaf length, Iyanar *et al.* (2001) for leaf length breadth ratio and Patel *et al.* (2006) for stover yield. Hence heterosis breeding or modified breeding methods such as biparental mating or triple test cross or any other form of recurrent selection methods in early generations which is more useful for exploitation of non additive gene action in order to recover transgressive segregants.

Estimates of degree of dominance indicated partial dominance for leaf crude protein content and grain yield per plant, complete dominance for green forage yield, 1000 grain weight, grain crude protein content and leaf breadth and over dominance for the remaining characters.

Interaction of genes from both the parents played a major role in the expression of number of dry leaves per plant at harvest, leaf length and leaf stem ratio. For the remaining characters involvement of genes from female parents played a major role in the expression.

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