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Research Note

Combining ability analysis for yield and quality traits in fodder cowpea (*Vigna unguiculata* (L.) Walp.)

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Abstract
A study was carried out to determine combining ability analysis among crosses derived from 15 selected fodder cowpea genotypes. Three lines and twelve testers were crossed in L × T fashion and 36 hybrids were synthesized. The analysis of variance revealed significant variation among the genotypes for all the characters. All the characters exhibited significant SCA variance that was higher than the GCA variance, indicating preponderance of non-additive genetic component for all the characters. Based on general combining ability effects, the parents FD 2288, IFC 95101 and CO 5 were identified as good general combiners. The most promising specific combiners for yield and yield components were CO (FC) 8 × FD 2288,CO (FC) 8 × UPC 9103, CO (FC) 8 × FD 2295, TNFC 0924 × FD 2307, CO 5 × CL 88 and CO 5 × FD 2288.

Key words
Fodder cowpea, combining ability, line × tester analysis, hybrids

Cowpea (*Vigna unguiculata* (L.) Walp.) is the most widely cultivated food legume. Cowpea grains are consumed as food and the haulms, are fed to livestock as a nutritious fodder. The average protein content of cowpea fodder is 21 per cent with 60 per cent dry-matter degradability. This compares with 4 to 7.5 per cent protein in cereal stovers with less than 50 per cent degradability (Powell, 1986; Tarawali *et al*., 1996). The cowpea fodder is usually better than other forage legumes in terms of both quantity and quality in semi-arid areas (Tarawali *et al*., 1996). Cowpea haulms can provide adequate protein and energy to sustain ruminant production during an extended dry season. Dry matter digestibility is about 65-70 per cent (Karachi and Lefofe, 2004; Savadogo *et al*., 2000) and differs greatly between leaves (60-75 %) and stems (50-60 %). Development of high yielding fodder cowpea genotypes would be helpful to the farmers for sustainable livestock farming. A greater understanding of combining ability and gene action, would provide a useful platform to develop high yielding fodder cowpea genotypes. Combining ability describes the breeding value of parental lines to produce hybrids. It helps to select the parents and utilize them in the breeding programmes for production of superior hybrids. The concept of combining ability was first proposed by Sprague and Tatum (1942) in maize. Based on combining ability analysis of different characters, higher *sca* values refers to dominance gene effects and higher *gca* effects indicate a greater role of additive gene effects controlling these characters. If both *gca* and *sca* values are not significant, epistatic gene effect may play an important role in determining these characters (Fehr, 1993). The estimation of additive and non-additive gene action through this technique could be useful in determining the possibility of commercial exploitation of heterosis and isolation of pure lines among the progenies of the good hybrids (Stuber, 1994). Thus knowledge of gene action for different characters helps in employing suitable breeding methodology for their improvement.

The present study on combining ability of forage yield and it's component traits in fodder cowpea was carried out with 15 parents (3 lines and 12 testers) and 36 hybrids, obtained by crossing themselves in line × tester mating design. The experimental materials were sown during rabi, 2014 in the experimental fields of Vanavarayar Institute of Agriculture, Pollachi. Each genotype including parents and hybrids were sown in single rows, each of 1.5 m length, adopting randomized block design, replicated twice. The row to row and plant to plant spacing was 30 and 15 cm, respectively. All the recommended agronomic and plant protection measures were carried out. Observations were recorded on five plants chosen randomly in each replication at the flowering stage, for ten characters namely, days to 50 per cent flowering, plant height, number of branches per plant, number of leaves per plant, leaf: stem ratio, green fodder yield, dry fodder yield, crude protein content, crude fibre content and crude fat content. The mean data were analysed by using line × tester method suggested by Kempthrone (1957).

The analysis of variance revealed significant variation among the parents and crosses for all the traits. Highly significant values for the variance of parents *vs* hybrids for all the characters revealed the presence of significant level of average heterosis in the hybrids. The variance due to lines, testers and line x tester interaction was significant for all the characters studied indicating the existence of genetic differences among the lines and testers. The proportion of additive and dominance variances revealed that the dominance genetic variance was higher in magnitude than the additive genetic variance for all the traits *viz.*, days to 50 % flowering, plant height, number of branches per plant, number of leaves per plant, leaf: stem ratio, green fodder yield, dry fodder yield, crude protein content, crude fibre content and crude fat content (Table 1). Selection of parents based on *per se* performance and *gca* effects is of great importance in breeding programme, as it provides useful information on the choice of parents in terms of expected performances of hybrids and progenies. Evaluation of parents based on *per se* performance and *gca* effects separately might lead to contradiction in selection of promising parents, since *per se* performance of the parents was not always associated with high *gca* effects (Singh and Singh, 1985). Combination of both *per se* performance and *gca* effects will result in the selection of parents with good reservoir of superior genes. Therefore, the parents were evaluated for high *per se* performance coupled with high *gca* effects.

Based on *per se* performance and *gca* effects, the genotypes FD 2288, IFC 95101 and CO 5 were identified as good general combiners for fodder yield and it's components (Table 2). The line CO (FC) 8 was found to be the best general combiner for plant height, number of branches per plant, crude protein content and crude fat content. CO (FC) 8 was released by Tamil Nadu Agricultural University, Coimbatore for commercial cultivation. It is resistant to yellow mosaic virus and suitable for inter cropping systems. The tester, FD 2288 exhibited good general combining ability for plant height, number of branches per plant, number of leaves per plant, green fodder yield, dry fodder yield, crude protein content and crude fat content. UPC 9103 was another tester, with good general combining ability for plant height, number of branches per plant, number of leaves per plant, crude fibre content and crude fat content. One more tester, CL 88 exhibited good general combining ability for days to 50 per cent flowering, leaf : stem ratio and crude fibre content. The above mentioned genotypes can be utilised in the breeding programme for improving the green fodder yield as well as quality in fodder cowpea.

The genetic worth of the parents is decided on the basis of their combining ability and to produce better effects in F_1 hybrids. Therefore, the second important criterion for the evaluation of hybrids is specific combining ability effects (*sca*). The *sca* effects of hybrids have been attributed to the combination of positive favourable genes from different parents.

The estimate of *sca* of 36 crosses for the ten characters are presented in table 3. The cross combinations CO (FC) 8 × FD 2288, CO (FC) 8 × UPC 9103, CO (FC) 8 × FD 2295, TNFC 0924 × FD 2307, CO 5 × CL 88 and CO 5 × FD 2288 were identified as good specific combiners for most of yield and yield contributing characters. The cross combination TNFC 0924 × UPC 9103 was the best specific combiner for days to 50 % flowering and crude protein content. This hybrid resulted from the combination of high × low general combiners. The cross CO 5 × FD 2288, originated from high × high general combiners, was the good specific combiner for plant height and number of leaves per plant. CO (FC) 8 × FD 2288, resulted from low × high general combiners, was found to be a good specific combiner for number of branches per plant, leaf: stem ratio, green fodder yield and crude fibre content, whereas, the hybrid CO (FC) 8 × UPC 9103 obtained from low × high general combiners, recorded high *sca* effects for number of leaves per plant, green fodder yield and dry fodder yield. The hybrid TNFC 0924 × FD 2307 registered best *sca* effects for number of leaves per plant, green fodder yield, dry fodder yield, crude protein content and crude fat content. This hybrid was derived from low × high general combiners. High *sca* effects for number of leaves per plant and number of branches per plant was shown by the hybrid CO 5 × CL 88, which originated from the combination of high × high *gca* effects. Another hybrid CO (FC) 8 × FD 2295 recorded higher values of *sca* for leaf : stem ratio and crude fat content. This hybrid was derived from low × high general combiners.

All type of parental combination for combining ability, produced hybrids with positive and significant *sca* for green fodder yield. The present investigation also indicated that, the best parents with high *gca* were not always the best specific combiners. The results further showed that, the best parents were the best general combiners for a particular trait, but none of the parents or the specific crosses was the best for all the characters. Similar results were observed by Thiyagarajan (1992), Ushakumari *et al.* (2010) and Bhavesh *et al.* (2013) in cowpea genotypes.

The crosses that originated from high general combining parents, reflecting high *sca* effects are expected to produce useful transgressive segregants, which can be identified following simple conventional breeding techniques like pedigree method of selection. The high *sca* effects of such crosses might be attributed to additive × additive type of gene action and the high yield potential of these crosses can be fixed in subsequent generations.

On the other hand, high *sca* effects of the crosses that resulted from high × low combining parents are attributed to additive × dominance type of gene action. The high yield from such crosses would be unfixable in subsequent generations and therefore, cannot be exploited by standard selection procedure. However, desirable transgressive segregants could be identified in these crosses in later generations with some modifications in the conventional breeding methods to capitalize on both additive and non-additive genetic effects (Chakraborty *et al*., 2009).

With the foregoing discussion, the genotypes *viz.,* FD 2288, IFC 95101 and CO 5 were found to be good general combiners for fodder yield and yield contributing characters. The most promising specific combiners for yield and yield components were CO (FC) 8 × FD 2288, CO (FC) 8 × UPC 9103, CO (FC) 8 × FD 2295, TNFC 0924 × FD 2307, CO 5 × CL 88 and CO 5 × FD 2288. Fodder cowpea being a self pollinated crop, heterosis breeding may not be a practicable solution for immediate genetic improvement. Bi-parental mating in the early segregating generations could be practiced to utilize both additive and non-additive gene action, to get desirable segregants for yield and quality in fodder cowpea.

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Table 1. Analysis of variance for combining ability for different biometrical traits

Source	D.F	Mean Squares									
		Days to 50 % flowering	Plant height (cm)	Number of branches/ plant	Number of leaves/ plant	Leaf : stem ratio	Green fodder yield (g)	Dry fodder yield (g)	Crude protein content (%)	Crude fibre content (%)	Crude fat content (%)
Replication	1	0.88	1.85	0.011	0.001	0.001	79.88	3.40	0.0001	0.2006	0.0001
Crosses	35	12.67**	838.41**	1.62**	181.68**	0.14**	4026.70**	121.19**	6.17**	45.59**	1.63**
Lines	2	76.63**	1123.83**	1.50**	467.58**	0.58**	1230.86**	33.22**	14.86**	551.05**	1.02**
Testers	11	14.41**	1648.26**	1.35**	246.25**	0.21**	3888.25**	217.05**	5.61**	23.31**	1.41**
Line × tester interaction	22	5.99**	407.54**	1.77**	123.41**	0.11**	4350.09**	81.26**	5.66**	10.79**	1.79**
Error	35	2.20	10.16	0.034	2.54	0.01	44.42	1.73	0.006	0.57	0.0001
GCA	14	0.16	10.18	0.003	1.38	0.0007	0.64	0.94	0.01	0.82	0.003
SCA	35	1.89	198.69	0.87	60.43	0.05	2152.83	39.76	2.80	5.11	0.89
GCA/SCA	1	0.083	0.051	0.0039	0.022	0.014	0.0035	0.024	0.0042	0.16	0.0043

*, ** significant at 5 and 1 per cent level, respectively

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Table 2. General combining ability effects of parents for different traits

S. No	Traits/ Parents	Days to 50 % flowering	Plant height (cm)	Number of branches/ plant	Number of leaves/ plant	Leaf : stem ratio	Green fodder yield (g)	Dry fodder yield (g)	Crude protein content (%)	Crude fibre content (%)	Crude fat content (%)
1.	CO (FC) 8	1.96**	7.22**	-0.25**	2.13**	0.00	-3.53*	0.53	0.91**	-5.23**	0.15**
2.	TNFC 0924	-1.54**	-6.38**	0.01	-5.07**	0.05**	-4.71**	-1.35**	-0.45**	1.04**	-0.23**
3.	CO 5	-0.42	-0.84	0.25**	2.95**	-0.05**	8.24**	0.82**	-0.46**	4.19**	0.09**
4.	TNFC 0926	0.08	-9.82**	-0.45**	-9.31**	-0.12**	-27.84**	-3.07**	-1.48**	1.15**	0.10**
5.	CL 88	-3.42**	-13.26**	-0.00	-6.56**	0.29**	-35.70**	-6.03**	1.65**	-2.66**	-0.35**
6.	FD 2295	0.58	-9.72**	-0.70**	-7.08**	0.10**	-3.99	-3.07**	-0.24*	-3.13**	0.43**
7.	FD 2307	1.42*	14.78**	-0.02	7.99**	-0.36**	29.19**	5.35**	0.94**	1.35**	1.07**
8.	FD 2288	2.75**	6.71**	0.40**	9.43**	-0.15**	40.07**	9.56**	0.81**	-0.05	0.26**
9.	FD 2303	-1.58*	-18.69**	1.05**	1.89**	0.03	-4.71	-2.00**	0.52**	-1.20**	-0.11**
10.	UPC 953	0.25	18.34**	-0.42**	1.24	0.09**	-5.70*	-2.27**	0.03	-0.21	-0.40**
11.	IFC 8401	-0.75	-11.70**	-0.25**	-6.96**	-0.07*	-38.13**	-7.99**	-0.54**	-0.26	-0.08**
12.	UPC 9103	0.42	36.83**	0.43**	6.07**	0.02	26.20**	11.48**	-1.12**	-0.98**	0.09**
13.	CS 98	1.08	5.38**	-0.25**	4.50**	-0.17**	-2.24	2.47**	-1.19**	3.54**	0.09**
14.	IFC 95101	-0.42	-11.17**	0.05	-2.53**	0.26**	19.93**	-3.20**	0.71**	-0.30	-0.19**
15.	UPC 219	-0.42	-7.68**	0.20*	1.34*	0.07*	2.93	-1.20*	-0.07	2.75**	-0.91**

*, ** significant at 5 and 1 per cent level, respectively

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Table 3. Specific combining ability effects of hybrids for different traits

S. No.	Traits/ Parents	Days to 50 % flowering	Plant height (cm)	No. of branches/ plant	No. of leaves/ plant	Leaf : stem ratio	Green fodder yield (g)	Dry fodder yield (g)	Crude protein content (%)	Crude fibre content (%)	Crude fat content (%)
1.	CO (FC) 8 × TNFC 0926	0.87	-5.91*	-0.05	-4.98**	-0.01	12.80**	4.11**	1.00**	0.84	1.50**
2.	CO (FC) 8 × CL 88	-2.63*	-0.42	-0.15	-4.18**	-0.30**	8.65	-0.01	-2.13**	0.01	-0.55**
3.	CO (FC) 8 × FD 2295	-0.13	-0.96	-0.15	4.79**	0.29**	29.67**	2.67**	0.23	-1.62**	1.28**
4.	CO (FC) 8 × FD 2307	1.54	10.09**	-0.13	-0.73	0.22**	8.51	7.21**	-0.95**	-0.96	-0.59**
5.	CO (FC) 8 × FD 2288	1.21	-2.69	0.80**	4.96**	0.32**	57.62**	4.59**	0.18	-3.76**	0.43**
6.	CO (FC) 8 × FD 2303	1.04	-1.34	-1.00**	-6.53**	-0.15*	-51.20**	-8.84**	-1.33**	-0.71	0.88**
7.	CO (FC) 8 × UPC 953	2.21*	9.73**	-0.73**	-7.43**	-0.05	-64.22**	-5.48**	0.06	-3.14**	-0.32**
8.	CO (FC) 8 × IFC 8401	-1.79	-3.57	0.65**	3.47**	0.14*	10.61*	0.68	2.43**	2.01**	-0.15**
9.	CO (FC) 8 × UPC 9103	0.04	5.69*	0.77**	13.39**	-0.10	57.23**	5.25**	-1.49**	1.08	-0.92**
10.	CO (FC) 8 × CS 98	-2.13*	-28.61**	1.50**	7.96**	-0.03	0.72	-2.24*	-0.12	0.56	-0.92**
11.	CO (FC) 8 × IFC 95101	-0.63	3.29	-0.50**	-4.41**	-0.08	-6.80	-4.19**	1.68**	4.49**	-0.44**
12.	CO (FC) 8 × UPC 219	0.37	14.70**	-1.05**	-6.33**	-0.25**	-63.60**	-3.74**	0.45*	1.19*	-0.22**
13.	TNFC 0924 × TNFC 0926	-0.63	8.05**	-0.21	2.77*	0.11	10.85*	-0.59	0.03	-0.47	-0.54**
14.	TNFC 0924 × CL 88	1.38	3.63	-1.01**	-4.48**	0.09	-27.80**	-4.09**	2.49**	1.69**	0.01
15.	TNFC 0924 × FD 2295	1.38	-3.20	0.64**	0.44	-0.28**	19.04**	1.00	1.23**	-1.24*	-0.87**
16.	TNFC 0924 × FD 2307	-0.96	-21.00**	0.56**	9.17**	0.01	58.22**	6.13**	1.30**	-1.42*	1.09**
17.	TNFC 0924 × FD 2288	0.21	-10.93**	-1.21**	-13.42**	-0.16**	-83.61**	-6.09**	-1.07**	3.18**	-1.10**
18.	TNFC 0924 × FD 2303	-0.96	1.02	1.49**	4.57**	0.39**	24.47**	5.88**	1.02**	-0.07	-0.33**
19.	TNFC 0924 × UPC 953	-0.79	22.68**	0.51**	6.42**	-0.08	13.16**	4.05**	-1.11**	2.34**	0.06**
20.	TNFC 0924 × IFC 8401	0.21	-0.67	0.29*	2.59*	-0.18**	-9.76*	1.37	-2.02**	-0.81	-0.16**
21.	TNFC 0924 × UPC 9103	-2.46*	0.00	0.11	-3.61**	0.21**	-34.84**	-12.28**	2.77**	1.16*	-0.33**
22.	TNFC 0924 × CS 98	2.88**	11.70**	-1.01**	-5.39**	-0.10	0.89	1.45	-1.17**	-0.06	1.77**
23.	TNFC 0924 × IFC 95101	-0.63	-1.45	-0.26	-1.51	0.07	-15.83**	3.98**	-2.47**	-2.62**	-0.05**
24.	TNFC 0924 × UPC 219	0.37	-9.84**	0.09	2.42*	-0.07	45.22**	-0.82	-1.02**	-1.67**	0.47**
25.	CO 5 × TNFC 0926	-0.25	-2.14	0.25	2.20	-0.09	-23.64**	-3.52**	-1.02**	-0.37	-0.96**
26.	CO 5 × CL 88	1.25	-3.21	1.15**	8.65**	0.21**	19.15**	4.10**	-0.36*	-1.70**	0.54**
27.	CO 5 × FD 2295	-1.25	4.16	-0.50**	-5.23**	-0.01	-48.71**	-3.67**	-1.46**	2.86**	-0.41**
28.	CO 5 × FD 2307	-0.58	10.91**	-0.43**	-8.45**	-0.23**	-66.73**	-13.34**	-0.35*	2.38**	-0.50**
29.	CO 5 × FD 2288	-1.42	13.62**	0.40**	8.46**	-0.17**	25.99**	1.50	0.89**	0.58	0.67**
30.	CO 5 × FD 2303	-0.08	0.33	-0.50**	1.95	-0.24**	26.74**	2.96**	0.31	0.78	-0.55**
31.	CO 5 × UPC 953	-1.42	-32.41**	0.22	1.00	0.13*	51.06**	1.43	1.06**	0.80	0.26**
32.	CO 5 × IFC 8401	1.58	4.24	-0.95**	-6.06**	0.04	-0.85	-2.05*	-0.41*	-1.20*	0.32**
33.	CO 5 × UPC 9103	2.42*	-5.69*	-0.88**	-9.78**	-0.11	-22.39**	7.03**	-1.28**	-2.24**	1.25**
34.	CO 5 × CS 98	-0.75	16.91**	-0.50**	-2.56*	0.13*	-1.61	0.79	1.29**	-0.50	-0.85**
35.	CO 5 × IFC 95101	1.25	-1.84	0.75**	5.92**	0.01	22.63**	0.21	0.79**	-1.87**	-0.49**
36.	CO 5 × UPC 219	-0.75	-4.86*	0.95**	3.90**	0.33**	18.38**	4.56**	0.56**	0.48	-0.25**

*, ** significant at 5 and 1 per cent level, respectively