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Combining ability analysis to identify dual purpose genotypes in cowpea

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Abstract
A study was carried out to know the pattern of inheritance of fodder yield, seed yield and their related traits among 15 F_1 hybrids derived from eight selected cowpea genotypes. Five lines (fodder types) and three testers (grain types) were crossed in L × T mating design. The analysis of variance revealed significant variation among crosses for all the characters. Most of the characters exhibited significantly higher SCA variances than the GCA variances, indicating preponderance of non-additive genetic components for all the characters except for days to maturity, dry matter content and crude protein content. Based on general combining ability effects, the parents MFC-09-12, MFC-08-14 and PL-3 were identified as good general combiners. The most promising specific combiners for green fodder and grain yield as well as its components identified were MFC-09-12 × PGCP-12 and MFC-08-14 × PL-3. These crosses would provide scope for further selection of dual purpose genotypes in cowpea.

Keywords: Combining ability, Dual purpose cowpea, Line × tester analysis

Introduction
Cowpea (*Vigna unguiculata* (L.) Walp.) is an important *kharif* food legume belonging to the tribe Phaseoleae of family *Fabaceae* and forms an integral part of traditional cropping systems for the semi-arid regions of the tropics where other food legumes may not perform well. The use of cowpea as a dual-purpose crop, providing both grain and fodder, is attractive in mixed crop/livestock systems where land and feed are becoming increasingly scarce (Tarawali *et al*., 1997) especially in the dry season. Though it gives high grain and fodder yields, the haulms of improved dual-purpose (UPC-625) have crude protein content (17-18%) and dry matter digestibility (64-71%) compared to the local varieties. Efforts at global level (IITA and ILRI) focused systematic programme to develop medium-maturing (85-95 days), semi-erect, dual purp-ose varieties with higher grain and fodder yields with enhanced fodder quality. Similarly, the emphasis on the development of dual purpose types in other crops also was reported by Pal and Kumar (2009) in barley and Sah *et al*. (2016) in maize.

A greater understanding of combining ability and gene action would provide a useful platform to develop high yielding dual purpose cowpea varieties. 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, high *sca* (specific combining ability) values refer to dominance gene effects and higher *gca* (general combining ability) 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 actions through this technique could be useful in determining the possibility of commercial exploitation of heterosis and isolation of pure lines among the progenies of good hybrids (Stuber, 1994). With this background, an attempt was made to study the combining ability effects for dual purpose both for green fodder yield and grain yield in cowpea.

Materials and Methods
Plant materials: The released varieties were evaluated for dual purpose traits like green fodder yield and grain yield. Eight parents (5 lines as fodder types and 3 testers as grain types) were selected. Fifteen hybrids were obtained by crossing them in line × tester mating design during *rabi* summer 2016.The hybrids along with their parents and checks (MFC-08-14 and MFC-09-1) were sown and evaluated in a randomized block design with

two replications during *kharif* 2016 at Southern Regional Research Station, ICAR-IGFRI, Dharwad. The row to row and plant to plant spacing was 45 and 15 cm, respectively. All recommended package of practices were followed to raise a good crop.

Observations: At first flowering stage, plants were harvested for green fodder yield leaving three nodes from base of the plant. Morphological traits like plant height, days to first flowering, number of primary branches per plant, number of secondary branches per plant, green fodder yield per plant and leaf to stem ratio, were recorded prior to harvest on five randomly selected plants from each plot. Dry matter content as well as crude protein content estimated after harvesting fodder. Grain related characteristics, *viz*., days to 50% flowering, days to maturity, number of pods per plant, number of seeds per pod, pod length and seed yield per plant were recorded from five randomly selected and tagged plants left uncut.

Statistical analysis: The mean values were computed based on observations recorded on five randomly selected plants in each genotype. The mean data were analysed by using line × tester method suggested by Kempthorne (1957).

Results and Discussion

Analysis of variance: The values with high significance for the variance of parents *vs* hybrids for all the characters except plant height, number of primary branches per plant, days to fifty per cent flowering, number of seeds per pod, green fodder yield per plant and crude protein content revealed the presence of average heterosis in the hybrids. The variance due to line × tester interaction was significant for all the characters studied except days to first flowering, days to fifty per cent flowering, days to maturity and dry matter content indicating the importance of both additive and non-additive variances. The proportion of additive and dominance genetic variance was higher in magnitude than the additive genetic variance for all the traits *viz*., for plant height (cm), number of primary branches per plant, number of secondary branches per plant, leaf to stem ratio, days to first flowering, days to fifty per cent flowering, number of pods per plant, number of seeds per pod, pod length (cm), seed yield per plant (g) and green fodder yield per plant (g) indicating predominance of non-additive gene action in controlling these traits (Table 1).

Table 1. Analysis of variance for combining ability effects of different characters in cowpea

Sources of variation	d.f.	Mean Squares						
		Plant height	No. of primary branches	No. of secondary branches	Leaf: stem ratio	Days to first flowering	Days to 50% flowering	Days to maturity
Replications	1	128.96	0.34	0.09	0.04	0.83	0.03	1.20
Crosses	14	625.03**	0.627**	0.704*	0.02**	89.06*	83.17*	150.48*
Lines	4	1225.01	0.35	0.67	0.04	60.72	50.45	107.12
Testers	2	156.41	0.20	0.20	0.03	193.63	196.23	552.10*
L × T	8	442.20**	0.87**	0.84*	0.018*	77.09	71.28	71.77
Error	14	97.30	0.15	0.21	0.01	30.69	27.03	42.91
Variance GCA		62.13	0.15	0.10	0.00	12.52	13.02	64.46
Variance SCA		180.23	0.30	0.32	0.01	26.36	24.54	16.29
Var. GCA/ Var. SCA		0.34	0.49	0.32	0.63	0.48	0.53	3.96

Sources of variation	d.f.	Mean Squares						
		No. of pods /plant	No. of seeds / pod	Pod length	Seed yield/ plant	Green fodder yield/plant (g)	Dry matter content	Crude protein
Replications	1	2.35	7.60	1.44	2.59	150.44	0.67	1.90
Crosses	14	16.73*	3.62**	1.40*	13.55**	1112.13**	1.87*	2.21**
Lines	4	9.48	0.82	0.82	17.21	1449.06	1.47	1.87
Testers	2	34.87	7.57	1.86	1.36	1686.40	5.40*	7.84*
L × T	8	15.82*	4.03**	1.58*	14.76**	800.11*	1.20	0.99*
Error	14	5.28	0.88	0.48	3.07	285.87	0.74	0.35
Variance GCA		1.59	0.04	0.06	1.37	191.90	0.56	0.97
Variance SCA		6.04	1.42	0.40	6.23	295.99	0.22	0.27
Var. GCA/ Var. SCA		0.26	0.03	0.15	0.22	0.65	2.49	3.54

*(P<0.05), **(P<0.01); d.f.: defrees of freedom

Table 2. Mean performance of parents and crosses for different characters in cowpea

Genotypes	Days to first flowering	Days to 50% flowering	Days to maturity	No. of secondary branches	Leaf: stem ratio	No. of pods/ plant	No. of seeds/ pod	Pod length (cm)	Seed yield/ plant (g)	Green fodder yield/ plant (g)	Crude protein (%)
Lines											
EC-4216	56.67	65.17	91.83	4.18	0.74	20.60	14.76	15.80	18.33	268.00	20.59
MFC-09-12	53.33	59.00	84.17	2.58	1.02	24.90	14.65	15.25	23.45	237.00	22.45
MFC-08-14	66.50	76.00	106.30	2.15	1.07	23.50	14.78	15.21	22.90	232.00	20.70
MFC-09-1	63.50	73.00	101.80	2.50	0.97	22.40	15.45	16.41	22.15	215.00	20.84
UPC-622	50.66	58.50	91.16	1.90	0.67	19.30	14.40	14.68	17.85	207.50	22.04
Testers											
PGCP-12	43.00	48.57	81.23	0.90	0.91	18.93	13.43	16.28	21.10	147.00	23.46
PL-1	49.20	56.17	84.54	0.70	1.02	17.25	13.20	13.96	13.63	176.00	22.32
PL-3	53.73	60.67	89.83	1.30	1.16	18.75	11.75	12.88	22.25	189.00	23.15
Crosses											
EC-4216 × PGCP-12	56.50	61.50	91.00	2.90	0.84	23.90	13.25	14.49	24.40	208.83	21.55
EC-4216 × PL-1	59.50	65.00	104.50	4.00	0.81	24.90	13.55	14.49	28.20	231.50	20.93
EC-4216 × PL-3	52.00	58.00	93.50	2.80	0.76	22.50	14.85	14.04	20.16	245.17	22.68
MFC-09-12 × PGCP-12	51.50	57.50	89.00	4.10	0.94	28.10	15.40	14.63	26.40	247.34	23.52
MFC-09-12 × PL-1	65.00	70.00	111.00	2.70	0.73	20.90	12.20	14.14	26.82	204.33	21.82
MFC-09-12 × PL-3	55.00	59.50	85.50	3.60	0.72	30.10	14.45	15.31	28.90	218.50	25.10
MFC-08-14 × PGCP-12	69.00	74.50	105.50	2.30	0.91	25.30	13.30	14.15	25.75	192.00	21.64
MFC-08-14 × PL-1	60.00	63.50	102.00	4.10	0.89	24.50	15.80	15.75	26.87	212.75	22.35
MFC-08-14 × PL-3	55.50	62.50	92.50	3.20	1.10	31.50	14.05	14.48	27.10	257.58	23.25
MFC-09-1 × PGCP-12	63.00	68.50	99.50	2.90	1.05	25.90	14.05	14.18	24.90	183.75	23.43
MFC-09-1 × PL-1	57.00	64.50	107.00	2.70	0.88	24.20	12.45	13.81	20.45	186.00	22.19
MFC-09-1 × PL-3	58.00	62.00	101.50	2.90	0.81	28.00	14.80	14.81	24.30	221.17	24.05
UPC-622 × PGCP-12	51.00	58.00	93.00	2.50	0.81	23.40	12.65	12.85	26.77	202.50	23.19
UPC-622 × PL-1	65.50	71.50	102.00	2.60	0.80	27.40	11.50	12.98	22.20	187.00	21.02
UPC-622 × PL-3	43.00	49.00	80.50	2.80	0.74	27.80	15.95	15.77	25.89	197.50	24.43
Checks											
MFC-08-14	66.50	76.00	106.30	2.15	1.07	23.50	14.78	15.21	22.90	232.00	20.70
MFC-09-1	63.50	73.00	101.80	2.50	0.97	22.40	15.45	16.41	22.15	215.00	20.84

Table 3. General combining ability (g_i) effects for different characters in cowpea

Parents	Days to first flowering	Days to 50% flowering	Days to maturity	No. of secondary branches	Leaf: stem ratio	No. of pods/ plant	No. of seeds/ pod	Pod length	Seed yield/ plant	Green fodder yield/ plant	Crude protein
Lines											
EC-4216	-1.43	-1.53	-0.87	0.16	0.05	-2.12*	0.04	-0.05	-1.02	15.43*	-0.62*
MFC-09-12	-0.27	-0.70	-2.03	0.39*	0.06*	1.97*	0.13	0.30	2.10**	13.32*	0.83**
MFC-08-14	4.07	3.80	2.80	0.13	0.11**	1.21	0.50	0.40	1.30	4.72	-0.38
MFC-09-1	1.90	1.97	5.47	0.24	0.07**	0.14	-0.12	-0.13	-2.05**	16.09*	0.13
UPC-622	-4.27	-3.53	-5.37	-0.44*	-0.07*	0.31	-0.52	-0.53	-0.32	-17.39*	0.04
SE±	2.02	1.92	2.56	0.18	0.03	0.79	0.45	0.36	0.62	5.89	0.27
C.D. 5% GCA (Line)	4.32	4.13	5.48	0.39	0.06	1.70	0.96	0.78	1.33	12.63	0.58
C.D. 1% GCA (Line)	6.00	5.73	7.61	0.54	0.09	2.35	1.33	1.08	1.84	17.53	0.81
Testers											
PGCP-12	0.77	0.97	-1.60	-0.13	0.06*	-0.57	-0.15	-0.33	0.37	-6.18	-0.45*
PL-1	3.96*	3.867*	8.10**	0.15	-0.03	-1.51*	-0.78*	-0.16	-0.64	-8.74	-0.56*
PL-3	-4.73**	-4.83**	-6.50**	-0.01	0.03	2.08**	0.93*	0.49	1.25*	14.92**	1.02**
SE±	1.56	1.49	1.98	0.14	0.02	0.61	0.34	0.28	0.48	4.56	0.21
C.D. 5% GCA (Tester)	3.35	3.20	4.25	0.30	0.05	1.31	0.74	0.60	1.03	9.79	0.45
C.D. 1% GCA (Tester)	4.65	4.44	5.89	0.42	0.07	1.82	1.03	0.84	1.43	13.58	0.63

*(P<0.05), **(P<0.01)

Table 4. Specific combining ability (s_{ij}) effects of crosses for different characters in cowpea

Crosses	Days to first flowering	Days to 50% flowering	Days to maturity	No. of primary branches	No. of secondary branches	Leaf: stem ratio	No. of pods/ plant	No. of seeds/ pod	Pod length	Seed yield/ plant	Green fodder yield/ plant	Crude protein
EC-4216 × PGCP-12	-0.27	-0.97	-3.73	-0.76	-0.20	-0.02	0.71	-0.48	0.48	-1.22	-13.49	-0.05
EC-4216 × PL-1	-0.47	-0.37	0.07	0.01	0.62	0.04	2.65	0.45	0.31	4.31**	11.74	-0.06
EC-4216 × PL-3	0.73	1.33	3.67	0.76	-0.42	-0.02	-3.35*	0.03	-0.79	-4.09**	1.74	0.11
MFC-09-12 × PGCP-12	-6.43	-5.80	-4.57	0.20	0.76*	0.12*	3.30*	1.54	0.27	2.34*	30.12*	-0.19
MFC-09-12 × PL-1	3.87	3.80	7.73	0.07	-0.91*	-0.04	-3.95*	-1.03	-0.39	-1.19	-10.31	0.41
MFC-09-12 × PL-3	2.57	2.00	-3.17	-0.28	0.15	-0.05	1.65	-0.50	0.13	1.53	-19.81	-0.22
MFC-08-14 × PGCP-12	6.73	6.70	7.10	-0.23	-0.76*	-0.12*	-1.23	-0.93	-0.31	-1.19	-22.60*	0.30
MFC-08-14 × PL-1	-5.47	-7.20*	-6.10	-0.21	0.75*	-0.04	-1.09	2.20*	1.12	0.66	0.72	-0.18
MFC-08-14 × PL-3	-1.27	0.50	-1.00	0.88*	0.01	0.16**	2.98*	1.27	-0.81	2.53*	21.88 *	-0.12
MFC-09-1× PGCP-12	2.90	2.53	-1.57	0.80*	0.20	0.08	0.44	0.44	0.24	1.31	-7.04	0.52
MFC-09-1× PL-1	-6.30	-4.37	-3.77	0.27	-0.28	-0.01	-0.32	-0.53	-0.30	-2.40*	-2.23	0.45
MFC-09-1× PL-3	3.40	1.83	5.33	-1.07*	0.08	0.08	2.71	0.10	0.06	1.09	9.27	-0.97
UPC-622 × PGCP-12	-2.93	-2.47	2.77	-0.02	0.00	-0.03	-2.23	-0.56	-0.68	0.45	13.01	-0.57
UPC-622 × PL-1	8.36*	8.13*	2.07	-0.15	-0.18	0.05	-0.12	-1.08	-0.73	-2.38*	0.08	-0.62
UPC-622 × PL-3	-5.43	-5.67	-4.83	0.17	0.18	-0.02	-0.49	1.65	1.41*	0.94	-13.09	1.19*
SE±	3.49	3.33	4.43	0.36	0.31	0.05	1.37	0.77	0.63	1.07	10.20	0.47
C.D. 5%	7.49	7.15	9.50	0.78	0.68	0.11	2.92	1.65	1.35	2.30	21.88	1.01
C.D. 1%	10.39	9.92	13.18	1.09	0.94	0.15	4.07	2.30	1.87	3.19	30.37	1.40

*(P<0.05), **(P<0.01)

***General combining ability effects*:** 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 *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 MFC-09-12, MFC-09-1 and PL-3 were identified as good general combiners for green fodder yield, seed yield and its components (Table 2-3). The line MFC-09-12 found to be best general combiner for number of secondary branches per plant, number of pods per plant, seed yield per plant, green fodder yield per plant, leaf to stem ratio and crude protein content. MFC-09-1 was good general combiner for the characters such as green fodder yield per plant, leaf to stem ratio. The tester PL-3 exhibited good general combining ability for days to first flowering, days to fifty per cent flowering, days to maturity, number pods per plant, number of seeds per plant, seed yield per plant, green fodder yield per plant and crude protein content. The above mentioned genotypes can be utilized in the breeding programmes for improving the green fodder yield, seed yield as well as quality in dual purpose cowpea.

***Specific combining ability effects*:** 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. The *sca* effects of hybrids have been attributed to the combination of positive favourable genes from different parents. The estimates of *sca* of 15 F_1 hybrids for fourteen characters were recorded (Table 4). The cross combinations of MFC-09-12 × PGCP-12, MFC-08-14 × PL-3, UPC-622 × PL-3, MFC-09-1 × PL-3 and MFC-08-14 × PL-1, were identified as good specific combiners for most of green fodder yield and seed yield and its contributing characters.

The cross combination MFC-09-12 × PGCP-12 was best specific combiner for number of secondary branches per plant, number of pods per plant, seed yield per plant, leaf: stem ratio and green fodder yield per plant. This hybrid resulted from the combination of high × low general combiners. The cross MFC-08-14 × PL-3, resulted from low × high general combiners, was best specific combiner for number of primary branches per plant, number of pods per plant, seed yield per plant, leaf to stem ratio and green fodder yield per plant. 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 Sathish *et al*. (2017), Anitha *et al*. (2017) and Ushakumari *et al*. (2010) in cowpea.

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).

Conclusion

With the foregoing discussion, genotypes MFC-09-12, MFC-09-1 and PL-3 were found to be good general combiners for fodder yield and seed yield contributing characters. The most promising specific combiners for yield and yield components were MFC-09-1 × PGCP-12 and MFC-08-14 × PL-3. 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 dual purpose cowpea.

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