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Research Article

Combining ability studies for grain yield and its component traits in cowpea (*Vigna unguiculata* (L.) Walp)

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Abstract
Combining ability analysis was carried out in cowpea for yield and its component traits through Line × Tester design involving 24 hybrids by crossing 10 parents (6 lines and 4 testers). Analysis of variance revealed that non-additive gene action was prevalent for all the traits studied since the magnitude of SCA variances were higher than GCA variances and less magnitude of GCA:SCA ratio further confirmed it. Among the lines, VBN 1 had significant *gca* values for seven traits *viz*., days to 50% flowering, plant height, number of pods per plant, pod length, hundred seed weight, protein content and single plant yield and VBN 2 was the best general combiner for five traits like number of pods per plant, number of seeds per pod, hundred seed weight, protein content and single plant yield. The tester VCP-09-019 was regarded as the best general combiner among the testers for the traits such as plant height, pod length and single plant yield. The cross VBN 1 × VCP-09-013 which showed significant *sca* for six traits *viz*., days to 50% flowering, plant height, number of pods per plant, number of seeds per pod, protein content and single plant yield followed by the hybrid CO 6 × VCP-09-024 was showing best specific combining ability for five traits *viz*., plant height, number of pods per plant, pod length, hundred seed weight and single plant yield.

Key words
Cowpea, combining ability, line×tester hybrids.

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp) is a multiutility, drought tolerant, nitrogen fixing crop and prominent among grain legumes since it is an excellent source of low-cost protein. The cowpea seeds contains 23% protein, 50-67% carbohydrate, 1.0% fat, 3.8% fibre and small percentage of the B-vitamins such as folic acid, thiamine, riboflavin and niacin as well as some micronutrients such as iron and zinc. The protein in cowpea seed is rich in the amino acids *viz.*, lysine and tryptophan compared to cereal grains. Germinated cowpea seeds are good source of vitamin C. So cowpea seed is a best nutritional supplement to cereals. It exhibits maximum genetic diversity in plant type and it offers a unique opportunity for cowpea breeders to develop desirable plant types with high yield. Yield is a complex quantitative character and depends on yield components. Though in world level, India ranks first in terms of area and production of pulses, it is not yet self-sufficient and imports pulses. In India, cowpea grain productivity is comparatively low. In cowpea, research work for its improvement is very limited. But there is a great scope to increase the production by developing high yielding, disease and pest resistant, drought tolerant and improvement in nutritional value by increasing protein value especially.

Developing high yielding hybrid or variety is the ultimate aim of all the crop improvement programmes. Though the latest technologies like genetic engineering and recombinant DNA techniques are being used in the crop improvement programme, yet hybridization method has its own advantage and frequently used in breeding programme aimed to improve the yield. Yield is a complex quantitative character and depends on yield components. For crop improvement, genetics of the yield and its components needs to be thoroughly understood. The objective of hybridization is to combine desirable genes found in two or more different varieties and to produce pure-breeding progeny superior in many respects to the parental types. In a self-pollinating crop like cowpea, variability is often created through hybridization between carefully chosen parents.

The knowledge of combining ability and gene action is the pre-requisite in any plant breeding programme for selection of superior parents and better cross combinations. In this view, the present investigation was carried out to estimate the general combining ability and specific combining ability effects for various traits in cowpea.

Materials and Methods

The study was carried out at Agricultural College and Research Institute, Madurai. The details of parents used for this study are given in Table 1. Crosses were made in line × tester mating design by crossing six lines and four testers. Twenty four hybrids along with ten parents were evaluated in randomized block design with three replications of spacing 45 cm × 25 cm. Recommended agronomic and plant protection measures were followed. Observations were recorded for seven characters namely days to 50% flowering, plant height, number of pods per plant, pod length, number of seeds per pod, hundred seed weight, protein content and single plant yield. Line × Tester analysis was carried out as suggested by Kempthorne (1957).

Results and Discussion

The analysis of variance showed significant differences for all the traits studied among the parents which indicated wide genetic variability among parents (Table 2). The specific combining ability variance was high indicating non-additive gene action for all the traits. These results were in accordance with Kalubowila (2006), Valarmathi *et al.* (2007), Uma and Kalubowila (2010), Ushakumari *et al.* (2010), Alle (2014) and Pethe *et al.* (2018).Among the lines, VBN 1 had significant *gca*values for seven traits *viz*., days to 50% flowering, plant height, number of pods per plant, pod length, hundred seed weight, protein content and single plant yield. VBN 2 was the best general combiner for five traits like number of pods per plant, number of seeds per pod, hundred seed weight, protein content and single plant yield. VCP-09-019 was regarded as the best general combiner among the testers for the traits such as plant height, pod length and single plant yield. CO 7 has good general combining ability for both hundred seed weight and single plant yield. The parents VCP-09-024 and VCP-12-008 were having good general combining ability for hundred seed weight. The best general combiners for earliness were CO 2, VBN 1 and VCP-09-024. CO 2 was the best general combiner for pod length and CO 4 for number of seeds per pod. VBN 1, VCP-09-013 and VCP-09-019 were regarded as best general combiners for plant height. (Table 3).

The knowledge of combining ability coupled with *per se* performance of parents could be of great value in selecting suitable parents for hybridization programme. According to Sharma and Chauhan (1985), *per se* performance and *gca* effects of the parents were directly related to each other. Hence, it is necessary to consider both *per se* performance and *gca* effects for improvement of any character. Parents with desirable mean and *gca* effects are presented in Table 4. In the present study, based on mean performance and *gca* effects, VBN 1 was best for four traits *viz*., days to 50% flowering, number of pods per plant, hundred seed weight and protein content and VBN 2 had superior mean and *gca* effects for three traits *viz.*, number of pods per plant, protein content and single plant yield.

Among the testers, VCP-09-024 and VCP-12-008 showed superiority in hundred seed weight and VCP-09-019 had high mean and significant gca for single plant yield. The assumption was that parents with high mean *per se* and significant *gca* effects in their hybrid combination could produce superior hybrids with high mean.

The results of the present study indicated that it would be desirable to develop multiple crosses and use them as basic material to select desirable segregants for yield and favourably associated traits in the advanced generations, as none of the parents taken for the study was a good general combiner for all the traits. Several research workers have also reported combining ability effects in cowpea for various traits *viz*., Ushakumari *et al*. (2010) for days to 50% flowering, Valarmathi *et al*. (2007) for plant height, Kalubowila (2010) for number of pods per plant, Kadam et al. (2013) for hundred seed weight and Uma (2010) for single plant yield.

The crossVBN 1 × VCP-09-013 which showed significant *sca* for six traits *viz.,* days to 50% flowering, plant height, number of pods per plant, number of seeds per pod, protein content and single plant yield followed by the hybrid CO 6 × VCP-09-024 was showing best specific combining ability for five traits *viz*., plant height, number of pods per plant, pod length, hundred seed weight and single plant yield. The cross CO 2 × VCP-12-008 was best specific combiner for four traits viz., pod length, number of seeds per pod, hundred seed weight and protein content. The hybrid VBN 2 × VCP-09-019 is best specific combiner for four traits viz., pod length, number of seeds per pod, hundred seed weight and single plant yield.The crosses CO 2 × VCP-09-013 and CO 7 × VCP-12-008 recorded significant *sca* for plant height, number of pods per plant and single plant yield. For single plant yield, eight crosses viz., CO 2 × VCP-09-013, CO 4 × VCP-09-019, CO 4 × VCP-09-024,CO 6 × VCP-09-024, CO 7 × VCP-09-024, CO 7 × VCP-12-008, VBN 1 × VCP-09-013 and VBN 2 × VCP-09-019 were observed as best specific combiners (Table 5).

The crosses which involve parents with high *gca* normally give high *sca* effects (Atanuk Pal and Sabesan, 2009). In the present study, the hybridsCO 7 × VCP-09-024 and VBN 1 × VCP-12-008showed high *sca* effect with the parental combination of superior *gca* effect for hundred seed weight and the hybrid VBN 2 × VCP-09-019 recorded high *sca* with superior *gca* parents for single plant yield. It was observed that all types of *sca* effects were obtained in hybrids with different types (high × high, low × high, high × low, low × low) of parental *gca* combinations.

For example, high *sca* effect was produced byhigh × high, low × high or high × low or, low × low combinations of parental *gca* effects for days to 50% flowering in CO 7 × VCP-09-024 (L×H), for plant height in CO 4 × VCP-09-013 (L×H), for number of pods per plant in VBN 1 × VCP-09-013 (H×L), for pod length in VBN 2 × VCP-09-019 (L×H), for number of seeds per pod in VBN 1 × VCP-09-013 (L×L), for hundred seed weight in CO 2 × VCP-12-008 (L×H), VBN 2 × VCP-09-013 (H×L) for protein content and for single plant yield in VBN 2 × VCP-09-019 (H×H). The interaction of recessive alleles from poor combiners with dominant alleles from good combiner would have resulted in superior crosses from good × poor parental combiners (Dubey, 1975).Similarly the involvement of two poor combiners also produced potential crosses as reported by Hazem*et al*. (2013).

For the trait single plant yield, the parents with significant *gca* were CO 7, VBN 1, VBN 2, VCP-09-019 and the hybrids with significant *sca* were CO 2× VCP-09-013 (L×L), CO 4 × VCP-09-019 (L×H), CO 4 × VCP-09-024 (L×L), CO 6 × VCP-09-024 (L×L), CO 7 × VCP-09-024 (H×L), CO 7 × VCP-12-008 (H×L), VBN 1 × VCP-09-013 (H×L) and VBN 2 × VCP-09-019 (H×H) which indicates the significant *sca* in hybrids from all different types of combinations of *gca* in parents. It was observed that the parents with high *gca* were not always the best specific combiners for all the traits under study. The results further showed that, certain parents were 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 also observed by Ushakumari *et al.* (2010), Bhavesh*et al.* (2013) and Anitha *et al*. (2017) in cowpea genotypes.

To sum up, the parents *viz*., VBN 1 and VBN 2 from lines and VCP-12-008 and VCP-09-019 in testers can be used in multiple crossing programmes to identify segregants with high seed yield and high protein content.

Finally it is concluded that the hybrids VBN 1 × VCP-09-013, CO 6 × VCP-09-024, and CO 2 × VCP-12-008 and VBN 2 × VCP-09-019 are suitable for heterosis breeding. But cowpea as a self-pollinated crop, it is important to choose the hybrids for recombination breeding. The hybrids CO 2 × VCP-09-019, CO 4 × VCP-09-024, CO 4 × VCP-12-008, CO 6 × VCP-09-024, CO 7 × VCP-09-024 and CO 7 × VCP-12-008 were selected based on non significant *sca* effects with significant *gca* effects of parents for recombination.

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Table 1. Details of information of parents involved in the study

Genotype	Parentage	Source	Distinct features
LINES			
CO 2	C521×C49	Department of Pulses, TNAU, Coimbatore, TN	Vegetable type. Seeds reddish brown with irregular patches
CO 4	Selection from Russian giant	Department of Pulses, TNAU, Coimbatore, TN	Clusters are projected above canopy. Suited to rainfed and irrigated conditions. Slate coloured seeds.
CO 6	Ms9804×C152	Department of Pulses, TNAU, Coimbatore, TN	Dwarf and suited to rainfed conditions
CO 7	Gamma mutant of CO 4	Department of Pulses, TNAU, Coimbatore, TN	Grain type, Square, dull brown seeds
VBN 1	Pureline selection from IT 85-F2020	NPRC, Vamban, TN.	White grain type and suited to rainfed condition throughout Tamil Nadu
VBN 2	Selection from IT-81-D-1228-10 (Culture VCP 6)	NPRC, Vamban, TN.	Vegetable type, Ivory coloured seeds and suited for all seasons
TESTERS			
VCP-09-013	TLS 38 × VCP 16-1(Released as VBN 3 in 2018)	NPRC, Vamban, TN.	Determinate plant type, synchronized maturity, multiple resistance to Bean common mosaic virus, rust and anthracnose diseases.
VCP-09-019		NPRC, Vamban, TN.	High yielding, Determinate plant type and synchronized maturity
VCP-09-024		NPRC, Vamban, TN.	High yielding, Determinate plant type and synchronized maturity.
VCP-12-008		NPRC, Vamban, TN.	Vegetable type, Long pods and bold seeds.

Table 2. Analysis of variance for combining ability for yield and yield components in cowpea (*Vigna unguiculata* (L.)

Source of variation	d.f	DFF	PH	NPP	PL	NSP	HSW	PC	SPY
Replication	2	0.35	0.86	0.45	0.77	0.92	0.28	0.82	0.01
Crosses	23	13.99**	109.93**	25.65**	9.57**	4.04**	6.75**	10.66**	67.56**
Line Effect	5	36.92**	222.68**	101.22**	20.06**	4.53**	21.43**	44.09**	233.40**
Tester Effect	3	5.37**	215.86**	2.22**	4.58**	1.06	2.93**	0.46	5.91**
L*T effect	15	8.07**	51.17**	5.15**	7.07**	4.47**	2.62**	1.55**	24.60**
Error	46	0.54	0.58	0.46	0.54	0.47	0.04	0.31	0.08

*Significant at 5% level, **Significance at 1% level.

DFF: Days to 50% flowering, PH: Plant height (cm), NPP: Number of pods per plant, PL: Pod length (cm), NSP: Number of seeds per pod, HSW: Hundred seed weight (g), PC: Protein content (%) and SPY: Single plant yield (g).

Table 3. General combining ability effects of parents for different traits in cowpea

Parents	Days to 50% flowering	Plant height (cm)	No. of pods/ plant	Pod length (cm)	No. of seeds/ pod	Hundred seed weight (g)	Protein content (%)	Single plant yield (g)
CO 2	-2.89**	0.39	-2.37**	1.96**	-0.60**	-1.03**	-0.96**	-4.53**
CO 4	0.61**	0.16	-2.63**	0.22	0.73**	-1.88**	-0.96**	-3.23**
CO 6	0.61**	-3.40**	-1.78**	-1.40**	-0.83**	-0.27**	-1.50**	-2.97**
CO 7	1.19**	-4.82**	0.14	-1.49**	-0.08	1.57**	-1.43**	0.54**
VBN 1	-1.31**	7.60**	1.83**	0.48*	0.33	1.31**	2.91**	3.47**
VBN 2	1.78**	0.07	4.81**	0.22	0.45*	0.31**	1.94**	6.72**
VCP-09-013	-0.22	4.37**	0.21	0.12	0.05	-0.21**	-0.17	-0.48**
VCP-09-019	0.39*	1.16**	0.04	0.67**	0.25	-0.46**	-0.08	0.82**
VCP-09-024	-0.67**	-2.39**	-0.51**	-0.41*	0.04	0.32**	0.04	-0.29**
VCP-12-008	0.50**	-3.14**	0.25	-0.37*	-0.34*	0.35**	0.20	-0.05

*Significant at 5% level, **Significance at 1% level.

Table 4. Parents chosen based on *per se* performance and *gca* effects

S. No	Characters	*Per se* performance	*gca* effects	*Per se* performance and *gca* effects
1.	Days to 50% flowering	CO 2,CO 6, CO 7, VBN 1, VBN 2	CO 2, VBN 1, VCP-09-024	CO 2, VBN 1
2.	Plant height	CO 4, VBN 2	VCP-09-013, VCP-09-019	-
3.	Number of pods per plant	CO 7, VBN 1, VBN 2, VCP-09-013	VBN 1, VBN 2,	VBN 1, VBN 2
4.	Pod length	CO 2, VBN 2, VCP-12-008	CO 2, VBN 1	CO 2
5.	Number of seeds per pod	CO 2, CO 4, VCP-09-019, VCP-12-008	CO 4, VBN 2	CO 4
6.	Hundred seed weight	VBN 1, VCP-09-019, VCP-09-024, VCP-12-008	CO 7, VBN 1, VBN 2, VCP-09-024, VCP-12-008	VBN 1, VCP-09-024, VCP-12-008
7.	Protein content	VBN 1, VBN 2, VCP-09-013, VCP-09-024, VCP-12-008	VBN 1, VBN 2	VBN 1, VBN 2
8.	Single plant yield	VBN 2, VCP-09-013, VCP-09-019	CO 7, VBN 1, VBN 2, VCP-09-019	VBN 2, VCP-09-019
	Overall effects	**VBN 2, VBN 1, VCP-12-008,VCP-09-019**	**VBN 1, VBN 2, CO 7**	**VBN 1, VBN 2, VCP-12-008,VCP-09-019**

Table 5. Specific combining ability effects of hybrids for different traits

Hybrids	Days to 50% flowering	Plant height (cm)	No. of pods/ plant	Pod length (cm)	No. of seeds/ pod	Hundred seed weight (g)	Protein content (%)	Single plant yield (g)
CO 2 × VCP-09-013	-0.61	1.41**	1.70**	-1.67**	-1.09**	-0.77**	-1.39**	0.72**
CO 2 × VCP-09-019	-0.22	-0.25	-0.50	-0.12	0.05	0.29*	-0.17	-0.98**
CO 2 × VCP-09-024	1.50**	1.30**	-0.73	-0.59	0.13	-0.37**	0.82*	0.27
CO 2 × VCP-12-008	-0.67	-2.46**	-0.47	2.37**	0.91*	0.84**	0.74*	-0.01
CO 4 × VCP-09-013	-0.44	5.11**	-0.41	0.23	-0.07	0.80**	0.41	-2.01**
CO 4 × VCP-09-019	-1.06*	-2.62**	0.50	-0.64	0.11	-0.04	-0.53	0.88**
CO 4 × VCP-09-024	2.33**	-0.30	-0.54	0.36	0.37	-0.27*	-0.04	0.97**
CO 4 × VCP-12-008	-0.83	-2.19**	0.46	0.05	-0.41	-0.49**	0.16	0.15
CO 6 × VCP-09-013	0.89*	-3.80**	-1.73**	0.43	-0.25	0.62**	0.02	-2.72**
CO 6 × VCP-09-019	0.28	-2.46**	0.15	-0.15	0.18	-1.73**	0.16	0.26
CO 6 × VCP-09-024	-0.67	1.06*	1.74**	1.27**	-0.10	0.70**	-0.08	2.54**
CO 6 × VCP-12-008	-0.50	5.20**	-0.15	-1.55**	0.17	0.41**	-0.10	-0.08
CO 7 × VCP-09-013	0.64	-4.24**	-1.46**	0.68	-0.19	-1.12**	-0.59	-1.85**
CO 7 × VCP-09-019	-0.97*	-0.94*	-0.70	-0.97	-0.98*	0.46**	0.86*	-2.18**
CO 7 × VCP-09-024	-0.92*	2.39**	0.36	0.54	2.12**	0.48**	0.28	2.45**
CO 7 × VCP-12-008	1.25**	2.78**	1.81**	-0.26	-0.95*	0.18	-0.56	1.58**
VBN 1 × VCP-09-013	-1.19**	2.07**	2.15**	0.58	1.45**	-0.80**	0.85*	5.89**
VBN 1 × VCP-09-019	0.19	7.54**	0.31	-1.52**	-1.43**	0.68**	0.31	-2.48**
VBN 1 × VCP-09-024	1.58**	-3.07**	-1.48**	0.43	-1.11**	-0.28*	-0.63	-3.71**
VBN 1 × VCP-12-008	-0.58	-6.53**	-0.98*	0.51	1.09**	0.40**	-0.53	0.29
VBN 2 × VCP-09-013	0.72	-0.54	-0.24	-0.26	0.16	1.26**	0.70*	-0.03
VBN 2 × VCP-09-019	1.78**	-1.27**	0.24	3.39**	2.06**	0.34**	-0.63	4.50**
VBN 2 × VCP-09-024	-3.83**	-1.38**	0.65	-2.02**	-1.42**	-0.26*	-0.35	-2.53**
VBN 2 × VCP-12-008	1.33**	3.19**	-0.66	-1.12*	-0.80*	-1.34**	0.28	-1.93**

Significant at 5% level, **Significance at 1% level.