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Combining ability for green pod yield and its components in cowpea [*Vigna unguiculata* (L.) Walp.]

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Abstract

The experiment was conducted with six diverse lines, two each from *Vigna unguiculata* ssp. *unguiculata* (vegetable type), *V. unguiculata* ssp. *unguiculata* (grain type) and *V. unguiculata* ssp. *sesquipedalis* (vegetable type) as female parents and four testers from *unguiculata* ssp. *unguiculata* (three vegetable type and one grain type) as male parents were crossed in line x tester matting design. The ICP-38, ICP-42, Indira Hari and Arka Garima were good general combiner for earliness and ICP-42, ICP-54, Pusa Komal, Arka Garima and Indira Hari for green pod yield. The cross combinations ICP-42 x Arka Garima, ICP-54 x Indira Hari, ICP-26 x Khalleshwari and ICP-49 x Khalleshwari were found best specific combiner for number of pods whereas, crosses ICP-42 x Arka Garima, ICP-42 x Indira Hari, and ICP-54 x Arka Garima were identified as best specific combiner for green pod yield and also expressed high *per se* performance along with high heterosis.

Keywords: Cowpea, general combining ability, specific combining ability

Introduction

Cowpea is a legume vegetable rich in protein having many uses like tender green pods, pulses and fodder. It is one of the most inexpensive source of protein and hardy crop well adapted to rainfed as well as relatively dry conditions. The cultivated cowpea (*Vigna unguiculata* L. Walp.) is divided in three cultigroups at sub-species level ie. *ungiuculata*, *bioflora* and *sesquipedalis*, in which *unguiculata*, the grain types and *sesquipedalis*, the yard long bean (vegetable) type are most commonly cultivated (Marechal *et al*., 1978). The most encountered problem with cultivation of vegetable cowpea is providing space and support for its vigorous growth viny growth habit (Valarmathi *et al*., 2007) and lower protein content. Hence, replacement of yard long bean with bush type vegetable cowpea having either bushy or semi trailing growth habit with incorporation of earliness, more number of seeds per pod and high protein content in green pods will be rewarding . For genetic improvement of any crop the most important prerequisite is selection of suitable parents, which would combine well and produce desirable genotypes in segregating generations in adequate frequency, because the high yielding parent may not necessarily transfer its superiority to the progenies in the cross. It is, therefore, necessary to know the genetic architecture of parents based on genetic contribution for yield and its related characters would help in identifying promising lines and superior crosses in early generation itself. Keeping these views, the above mentioned sub species were subjected to genetical analysis to identify the best general and specific combiners and crosses for future improvement programme.

Materials and Methods

The present experiment was conducted during *Kharif* season of 2011 to 2013 at Department of Horticulture, IGKV, Raipur (C.G.). The experiment comprises of six lines, two each from *Vigna unguiculata* ssp. *unguiculata* (vegetable type) , *Vigna unguiculata* ssp. *unguiculata* (grain type) and *Vigna unguiculata* ssp. *sesquipedalis* (vegetable type) as female parents and four testers from *Vigna unguiculata* ssp. *unguiculata* (three vegetable type and one grain type) as male parents were crossed in line x tester matting design. Genotypes ICP-26 (L_1) and ICP-38 (L_2) as seed type and ICP-45 (L_4) and ICP-49 (L_5) as vegetable type from ssp. *unguiculata* and ICP-42 (L_3) and ICP-54 (L_6) as vegetable type from *sesquipedalis* were selected as lines and four genotypes *viz*., Pusa Komal (T_1), Arka Garima (T_2), Indira Hari (T_3) as vegetable type and Khalleshwari (T_4) as seed type from ssp. *unguiculata* were selected as testers. All the parents along with their 24 F_1s were grown in randomized block

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design with three replications. Each genotype consisted of three rows of 3.15 m long and 7 plants in each row. The spacing given was 60 cm between rows and 45 cm within a row. Observations were recorded on ten randomly tagged competitive plants from each genotype and data were subjected to combining ability analysis as per Kempthorne (1957).

Results and Discussion

The analysis of variance for combining ability in respect of 19 characters is depicted in table 1. Partitioning of variance due to crosses into interaction components was significant for all the characters. Thus the significance of mean squares due to lines and testers were tested for all the characters whereas, crosses also showed significant differences for all the characters except number of nodes, percent pod set, days to final picking and number of seeds per pod. The mean square due to lines were recorded higher for plant height, percent pod set, days to final picking, pod length, pod weight, fruiting duration and number of pickings indicating the greater diversity among the lines as compared to the testers whereas, in rest of the characters testers had higher diversity as compared to the lines. Similar views were also expressed by Pal *et al*. (2002).

The estimates of general combining ability effects of lines and testers are presented in table 2 and best general combiners for different characters are shown in Table 3. The line ICP-42 had recorded significant gca values in desirable direction for most of the characters. The lines ICP-26, ICP-38 and ICP-54 had significant negative gca effect that can contribute to develop bushy or semi trailing type genotype, whereas, ICP-42 and ICP-45 had significant positive gca effect for plant height. High and significant gca estimates was observed in ICP-38, ICP-54 and Khalleshwari for number of branches per plant, while parents ICP-26 and Pusa Komal and Indira Hari for number of nodes per plant. Early flowering is desirable character therefore, negative gca effect value is important for this character. The parents ICP-38, ICP-42, Indira Hari and Arka Garima were good general combiner for days to first flowering, days to 50 % flowering and days to first picking. These results are in close conformity with the findings of Tiwari *et al.* (1993), Patel *et al.* (1994) and Pal *et al.* (2002) for earliness and Pal *et al.* (2002) for number of branches per plant.

High gca estimate was recorded in ICP-26, ICP-38 and Arka Garima for number of flowers per cluster, Arka Garima and Khalleshwari for number of pods per cluster, ICP-42, ICP-54 and Khalleshwari for per cent pod set and ICP-42, ICP-45 and Indira Hari for days to final picking. Parents ICP-42, ICP-54, Pusa Komal, Arka Garima and Indira Hari were identified as good general combiner for pod length and pod weight, whereas, ICP-38 and ICP-54 for number of pods per plant. The significant and high estimate of gca was found in ICP-38, ICP-42 and Indira Hari for number of seeds per pod, ICP-42, ICP-45, ICP-49 and Indira Hari for fruiting duration, Khalleshwari for per cent protein content in green pods, ICP-38, ICP-42, ICP-49, ICP-54, Pusa Komal, Arka Garima and Indira Hari for 100-seed weight and ICP-42, ICP-54, Pusa Komal, Arka Garima and Indira Hari for green pod yield per plant. Similar results

Table 1: Analysis of variance for combining ability analysis for green pod yield and its component characters in cowpea

S. No.	Character	df	Replications	Lines	Testers	Lines x Testers	Error
			02	05	03	15	46
1.	Plant height (cm)		25.08	22945.02*	946.76*	227.00*	379.00
2.	Number of branches per plant		0.46	19.47*	21.80*	1.58*	0.38
3.	Nodes per plant		26.75	84.94*	514.03*	5.34	4.99
4.	Days to first flower		6.09	64.88*	213.22*	12.68 *	2.74
5.	Days to 50% flowering		11.26	114.54*	252.38*	14.00*	3.16
6.	Number of flowers /cluster		0.67	5.69*	6.05*	1.51*	0.13
7.	Number of pods/ cluster		0.35	0.57*	2.11*	0.77*	0.02
8.	Per cent pod set		16.68	752.64*	88.95*	18.37	15.14
9.	Days first picking		14.53	18.23*	159.42*	37.41*	4.26
10.	Days final picking		7.24	833.25*	115.66*	13.15	20.97
11.	Pod length (cm)		12.15	295.14*	143.45*	221.92*	5.11
12.	Pod weight (g)		0.93	32.45*	17.52*	36.70*	0.37
13.	Number of pods /plant		20.22	8.96*	17.53*	37.99*	5.34
14.	Number of seeds / pod		0.30	23.43*	28.31*	1.03	2.64
15.	Fruiting duration (days)		13.45	673.95*	523.41*	81.55*	17.66
16.	Protein con. in green pods (%)		0.01	0.23*	1.03*	0.43*	0.03
17.	100-seed weight (g)		0.62	14.14*	16.65*	7.83*	0.31
18.	Number of pickings		0.24	21.47*	16.65*	12.39*	0.44
19.	Green pod yield /plant (g)		214.23*	8452.11*	10366.87*	31636.71*	411.42*

* Significant at P = 0.05 level

Table 2: General combining ability (GCA) effects of lines and testers for green pod yield and its components

Parents	Characters																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Lines																			
ICP-26	-19.59*	-0.49*	5.25*	3.28*	2.74*	0.12*	-0.20*	-4.42*	2.97*	-7.26*	-3.99*	-3.09*	-2.41*	-0.03	-10.24*	0.10	-1.76*	-2.78*	-82.47*
ICP-38	-52.62*	2.10*	-0.45	-3.47*	-4.68*	1.05*	0.05	-6.11*	-3.78*	-12.43*	0.82	-0.07	1.42*	1.14*	-8.65*	0.01	0.40*	0.31*	4.07
ICP-42	65.66*	-1.15*	-1.96*	-1.64*	-2.51*	-0.55*	0.10*	6.24*	-1.19*	6.49*	5.80*	3.68*	1.18	1.72*	7.68*	-0.07	0.72*	1.09*	94.30*
ICP-45	38.61*	-1.27*	-0.08	1.03*	0.99	0.01	0.08	0.44	0.56	9.82*	-2.16*	-0.84*	-0.83	-0.03	9.26*	0.02	-0.51*	-0.32*	-27.33*
ICP-49	-9.26	0.08	-1.24*	0.11	0.15	-0.15*	-0.09	-1.17	0.47	2.57	-4.38*	-0.21	-2.75*	-0.78	2.10*	-0.02	0.30*	-0.23	-31.38*
ICP-54	-22.80*	0.73*	-1.51*	0.69	3.32*	-0.50*	0.06	5.01*	0.97	0.82	3.90*	0.53*	3.39*	-2.03*	-0.15	-0.03	0.86*	1.92*	42.81*
Testers																			
Pusa Komal	-1.24	-0.61*	3.02*	-0.44	0.79	-0.15*	-0.44*	-5.54*	-0.08	0.68	3.87*	1.07*	0.87	0.69	0.76	-0.25*	0.70*	0.99*	33.03*
Arka Garima	10.38	-1.01*	-3.82*	-1.11*	-0.65	1.08*	0.56*	0.05	-1.25*	0.35	3.43*	2.00*	0.71	-0.92*	1.60	-0.25*	0.92*	1.00*	46.80*
Indira Hari	-6.41	0.14	5.95*	-3.28*	-4.60*	-0.88*	-0.58*	-1.26	-3.58*	1.96*	5.24*	0.87*	0.41	1.19*	5.54*	-0.15*	1.03*	0.63*	21.00*
Khalleshwari	-2.73	1.49*	-5.15*	4.83*	4.46*	-0.05	0.46*	6.75*	4.92*	-2.99*	-12.55*	-3.94*	-1.99*	-0.97*	-7.90*	0.65*	-2.65*	-2.62*	-100.82*
SE (Lines)	4.31	0.14	0.49	0.37	0.39	0.04	0.04	0.66	0.40	0.64	0.50	0.10	0.47	0.31	0.67	0.04	0.08	0.12	4.64
SE (Testers)	3.34	0.11	0.38	0.28	0.30	0.03	0.03	0.51	0.31	0.50	0.39	0.08	0.37	0.24	0.52	0.03	0.06	0.10	3.60

1. Plant Height (cm) 2. No. of branches/ plant 3. No. of nodes/ plant 4. Days to first flower
5. Days to 50% flowering 6. No. of flowers/cluster 7. No. of pods/cluster 8. Per cent pod set
9. Days to first picking 10. Days to final picking 11. Pod length (cm) 12. Pod weight (g)
13. No. of pods /plant 14. No. of seeds/pod 15. Fruiting duration (days) 16. Protein cont. in green pods (%)
17. 100-seed weight (g) 18. No. of pickings 19. Green pod yield/ plant (g)

was also reported by Hazra *et al.*(1996), Umaharan *et al.* (1997), Kumar and Sangwan (2005) and Pal *et al.* (2002).

Best specific combiners for different characters were identified on the basis of estimates of specific combining ability and mean performance of crosses (Table 3). The best specific combiners identified were ICP-42 x Indira Hari, ICP-45 x Arka Garima, ICP-38 x Arka Garima, ICP-26 x Khalleshwari and ICP-49 x Khalleshwari for plant height, ICP-49 x Khalleshwari, ICP-38 x Pusa Komal and ICP-38 x Arka Garima for number of branches per plant, ICP-26 x Arka Garima and ICP-45 x Indira Hari for number of nodes per plant, ICP-38 x Indira Hari, ICP-38 x Pusa Komal, ICP-54 x Pusa Komal, ICP-26 x Arka Garima and ICP-26 x Indira Hari for number of flowers per cluster. Among the twenty four crosses, ICP-38 x Indira Hari, ICP-42 x Khalleshwari and ICP-45 x Arka Garima combined well to produce earliness being desirable for both days to first flower and days to 50% flowering. These results are similar to the findings of Mishra *et al.* (1987), Tiwari *et al.* (1993), Patel *et al.* (1994), Chaudhary *et al.* (1998) and Singh *et al.* (2004).

Among the twenty four crosses, ICP-42 x Indira Hari, ICP-26 x Khalleshwari, ICP-49 x Pusa Komal, ICP-54 x Indira Hari, ICP-38 x Arka Garima and ICP-26 x Arka Garima for number of pods per cluster and ICP-42 x Indira Hari, ICP-54 x Indira Hari, ICP-38 x Arka Garima, ICP-49 x Pusa Komal, ICP-26 x Khalleshwari and ICP-26 x Pusa Komal for per cent pod set were recognize as best specific combiners. Pod length is one of the deciding factors for the success of a variety as a vegetable cowpea. The best specific combiners identified were ICP-42 x Indira Hari, ICP- 26 x Khalleshwari, ICP-49 x Khalleshwari and ICP-38 x Arka Garima for pod length. Among these only ICP-42 x Indira Hari and ICP-38 x Arka Garima showed high mean and gca performance shown by one of the parent that attributed to importance of additive gene action and possibility of getting better transgressive segeregants for early generation selection. The crosses ICP-26 x Khalleshwari, ICP-42 x Indira Hari, ICP-42 x Arka Garima, ICP-54 x Arka Garima, ICP-54 x Pusa Komal, ICP-45 x Khalleshwari and ICP-49 x Pusa Komal for pod weight and four crosses *viz.*, ICP-42 x Arka Garima, ICP-54 x Indira Hari, ICP-26 x Khalleshwari and ICP-49 x Khalleshwari were recognized as best combiner for number of pods per plant and these crosses can be exploited for Heterosis breeding. These results are in confirmation with Tiwari *et al.* (1993), Hazara *et al.* (1996), Yadav *et al.* (2004) and Kumar and Sangwan (2005).

Only three crosses *viz.*, ICP-42 x Khalleshwari, ICP-26 x Indira Hari and ICP-45 x Pusa Komal expressed good specific combining ability for fruiting duration and ICP-26 x Khalleshwari, ICP-42 x Arka Garima, ICP-38 x Indira Hari and ICP-38 x Khalleshwari for 100-seed weight. Particularly in legume vegetables moderate protein content is more desirable than very high or low, an increase in protein content reducing green pod yield. Therefore, positive estimate of GCA and SCA effects would be measured as desirable. Five crosses *viz.*, ICP-26 x Khalleshwari, ICP-42 x Arka Garima, ICP-42 x Indira Hari, ICP-49 x Khalleshwari, ICP-54 x Arka Garima, ICP-54 x Pusa Komal and ICP-45 x Khalleshwari were found best specific combiner for green pod yield per plant,

High specific combining ability coupled with high *per*

Table 3: Best general combiners and specific combiners for different characters

S. No.	Characters	Best general combiners		Best specific combiners
		Lines	Testers	
1.	Plant height (cm)	ICP-38, ICP-54 and ICP-26	-	ICP-42/ Indira Hari, ICP-45/ Arka Garima, ICP-38/ Arka Garima, ICP-26/ Khalleshwari, ICP-49/ Khalleshwari
2.	No. of branches/plant	ICP-38, ICP-54	Khalleshwari	ICP-49/ Khalleshwari, ICP-38/ Pusa Komal, ICP-38/ Arka Garima.
3.	Number of nodes/plant	ICP-26,	Pusa Komal	ICP-26/ Arka Garima, ICP-45/ Indira Hari
4.	Days to first flower	ICP-38, ICP-42	Arka Garima, Indira Hari	ICP-26/ Indira Hari, ICP-49/ Khalleshwari, ICP-42/ Khalleshwari, ICP-38/ Khalleshwari, ICP-45/ Pusa Komal, ICP-45/ Arka Garima, ICP-38/ Indira Hari
5.	Days to 50% flowering	ICP-38, ICP-42	Indira Hari	ICP-38/ Indira Hari, ICP-54/ Arka Garima, ICP-42/ Indira Hari, ICP-42/ Khalleshwari, ICP-45/ Arka Garima
6.	Number of flowers/ cluster	ICP-26, ICP-38	Pusa Komal, Indira Hari	ICP-38/ Indira Hari, ICP-38/ Pusa Komal, ICP-54/ Pusa Komal, ICP-26/ Arka Garima, ICP-26/ Indira Hari
7.	Number of pods/ cluster	ICP-42	Arka Garima, Khalleshwari	ICP-42/ Indira Hari, ICP-26/ Khalleshwari, ICP-49/ Pusa Komal, ICP-54/ Indira Hari, ICP-38/ Arka Garima and ICP-26/ Arka Garima
8.	Per cent pod set	ICP-42, ICP-54	Khalleshwari	ICP-42/Indira Hari, ICP-54/ Indira Hari, ICP-38/ Arka Garima, ICP-49/ Pusa Komal, ICP-26/ Khalleshwari, ICP-26/ Pusa Komal
9.	Days to first picking	ICP-38, ICP-42	Khalleshwari	ICP-45/ Pusa Komal, ICP-26/ Indira Hari, ICP-38/ Indira Hari, ICP-42/ Khalleshwari, ICP-49/ Khalleshwari
10.	Days to final picking	ICP-42, ICP-45	Indira Hari	ICP-42/ Khalleshwari, ICP-26/ Indira Hari and ICP-38/ Arka Garima
11.	Pod length (cm)	ICP-42, ICP-54	Pusa Komal, Arka Garima, Indira Hari	ICP-42/ Indira Hari, ICP- 26/ Khalleshwari, ICP-49/ Khalleshwari, ICP-38/ Arka Garima
12.	Pod weight (g)	ICP-42, ICP-54	Pusa Komal, Arka Garima, Indira Hari	ICP-26/ Khalleshwari, ICP-42/ Indira Hari, ICP-42/ Arka Garima, ICP-54/ Arka Garima, ICP-54/ Pusa Komal, ICP-45/ Khalleshwari and ICP-49/ Pusa Komal
13.	Number of pods/plant	ICP-42, ICP-54	Pusa Komal	ICP-42/ Arka Garima, ICP-54/ Indira Hari, ICP-26/ Khalleshwari, ICP-49/ Khalleshwari
14.	Number of seeds/pod	ICP-38, ICP-42	Indira Hari	-
15.	Fruiting duration	ICP-42, ICP-45, ICP-49	Indira Hari	ICP-42/ Khalleshwari, ICP-26/ Indira Hari, ICP-45/ Pusa Komal
16.	Protein content in green pod (%)	-	Khalleshwari	-
17.	100-seed weight (g)	ICP-38, ICP-42, ICP-49, ICP-54	Pusa Komal, Arka Garima, Indira Hari	ICP-26/ Khalleshwari, ICP-42/ Arka Garima, ICP-38/ Indira Hari, ICP-38/ Khalleshwari
18	Number of pickings	ICP-38, ICP-42, ICP-54	Pusa Komal, Arka Garima, Indira Hari	ICP-26/ Khalleshwari, ICP-42/ Arka Garima, ICP-42/ Indira Hari
19.	Green pod yield/ plant (g)	ICP-42, ICP-54	Pusa Komal, Arka Garima, Indira Hari	ICP-26/ Khalleshwari, ICP-42/ Arka Garima, ICP-42/ Indira Hari, ICP-49/ Khalleshwari, ICP-54/ Arka Garima, ICP-54/ Pusa Komal, ICP-45/ Khalleshwari

se performance expressed by the top five high green pod yielding crosses along with gca effects of parents and heterosis of respective crosses and two most important trait for vegetable cowpea is presented in table 4. ICP-42 x Arka Garima, ICP-42 x Indira Hari and ICP-54 x Arka Garima expressed high *per se* performance and high SCA effect with high heterosis had proved as good combiners for yield. So these crosses were ideal to produce desirable segregants in segregating generation for high green pod yield with long and tender pods.

It is clear from the results that majority of the crosses had good sca effects. Most of the crosses included Good x Good, Good x Poor, Poor x Poor and Poor x Good type of general combiners. The desirable cross combination with Average x Average type and Poor x Poor type of general combiners were also obtained, which may be due to complimentary gene effects. The crosses involving with good gca effects can be exploited effectively by conventional breeding like pedigree method. However, The crosses involving one good combiner and another poor or average combiner could

Table 4: Pod length, tenderness, *per se* performance, *sca* effects, heterosis of F_1 crosses and *gca* effects of the parents for total green pod yield per plant in cowpea.

Hybrids	Pod length (cm)	Tenderness	*Per se* performance green pod yield per plant (g)	sca effects	gca effect of female	gca effect of male	Heterosis (%)		
							RH	HB	SH
ICP-42 x Arka Garima	37.43	Very tender	380.32	51.81*	94.30*	46.80*	86.71**	76.95**	93.52**
ICP-42 x Indira Hari	43.20	Very tender	342.68	39.98*	94.30*	21.00*	89.96**	59.44**	74.37**
ICP- 42 x Pusa Komal	36.10	Very tender	298.51	-16.23*	94.30*	33.03*	45.10**	38.89**	51.89**
ICP-54 x Arka Garima	33.07	Very tender	298.73	21.71*	42.81*	46.80*	48.40**	42.15**	52.00**
ICP-54 x Pusa Komal,	33.67	Very tender	279.15	15.90	42.81*	33.03*	37.29**	32.83**	42.04**

*, ** Significant at P= 0.05 and 0.001 levels respectively; RH = Relative heterosis, HB = Heterobeltiosis, SH = Standard heterosis

produce desirable transgressive segregants when additive gene action was working in good combining parents and epistatic effects also act in same direction. Similar results were also reported by Patel *et al*. (1994), Hazra *et al*. (1996) and Pal *et al*. (2002.).

सारांश

लोबिया में 6 विविध लाइनों जिनमें प्रत्येक 2 को विग्ना अन्गुईकुलाटा उप प्रजाति अन्गुईकुलाटा (सब्जी वाली), विग्ना अन्गुईकुलाटा उप प्रजाति अन्गुईकुलाटा (बीज वाली) तथा विग्ना अन्गुईकुलाटा उप प्रजाति सेस्क्वीपेडालिस (सब्जी वाली) को मादा पित्र रूप में तथा चार टेस्टर्स जो विग्ना अन्गुईकुलाटा उप प्रजाति अन्गुईकुलाटा (3 सब्जी वाली एवं 1 बीज वाली) को नर पित्र के रूप में समाहित कर लाईन × टेस्टर प्रजनन विधि से संकरण कराया गया। प्रजाति आईसीपी–38, आईसीपी–42, इन्दिरा हरी तथा अर्का गरीमा अगेतीपन तथा आईसीपी–42, आईसीपी–54, पूसा कोमल, अर्का गरीमा तथा इन्दिरा हरी फली उपज/पौध के लिए उत्तम सामान्य संयोजक पाये गये। संकरण मेल आईसीपी–42 × अर्का गरीमा, आईसीपी–54 × इन्दिरा हरी, आईसीपी–26 × खालेश्वरी एवं आईसीपी–49 × खालेश्वरी फली/पौध के लिए जबकि संकरण मेल आईसीपी–42 × अर्का गरीमा, आईसीपी–42 × इन्दिरा हरी एवं आईसीपी–54 × अर्का गरीमा को हरी फली उपज/पौध के लिए सबसे विशिष्ट संयोजक पाया गया तथा इसके साथ ही दरअसल उच्च ओज के लिए भी उत्तम प्रदर्शन किए।

References

Chaudhary FP, Thaker DN, Tikka SBS and Patel ID (1998) Genetic architecture of yield and its components in cowpea (*Vigna unguiculata* L. Walp), Gujarat Agric Uni Res J 24: 30-35.

Hazra P, Som MG and Das PK (1996) Combining ability for pod yield and seed protein in cowpea (*Vigna unguiculata* (L.) Walp.). Indian J. Genet. 56(4): 553-555.

Kempthorne O (1957) An Introduction to Genetic Statistics, John Wiley and Sons, Inc., New York, pp. 468-471.

Kumar Deepak and Sangwan VP (2005) Combining ability studies for yield and architectural traits in cowpea [*Vigna unguiculata* (L.) Walp.]. Annals of Biology, 21(1): 47-49.

Marechal R, Mascherpa JM and Stainer F (1978) Etude taxonomique d'um group complexe d' especes des genres *Phaseolus* et *Vigna* (Papilionaceae) sur la base de donnees morphologiques et polliniques, traitees par I'analyse informaque. *Boissiera*, 28:1

Mishra SN, Verma JS and Rastogi R (1987) Combining ability for flowering and seed yield in cowpea. Ann. Agric. Res. 8: 268-272.

Pal AK, Ram D, Maurya AN and Rajput CBS (2002) Combining ability for green pod yield and its traits in cowpea. Indian J Horticulture, 59(4): 395-401.

Patel RN, Godhani PR and Fougat RS (1994) Combining ability in cowpea, (*Vigna unguiculata* L. Walp). Gujarat Agri Univ. Res. J. 20: 70-74.

Singh SP, Kumar R, Joshi AK and Singh B (2004) Genetic architecture of yield traits in cowpea [*Vigna unguiculata* (L.) Walp.]. Advances Plant Sci 17(2): 495-502.

Tiwari DS, Singh V and Shukla PS (1993) Combining ability studies in mungbean (*Vigna radiate* L. Wilczek). Indian J. Genet. 53: 395-398.

Umaharan P, Ariyanayangani RP and Haque SQ (1997) Genetic analysis of pod quality characteristics in vegetable cowpea (*Vigna unguiculata* L. Walp). Scientia Hort. 70: 281-292.

Valarmathi G, Surendran C and Muthaih AR (2007) Studies on combining ability for yield and yield traits in inter subspecies crosses of cowpea (*Vigna unguiculata* ssp. *unguiculata* and *Vigna unguiculata* ssp. *sesquipedalis*). Legume Res 30(3): 173-179.

Yadav KS, Yadava HS and Naik ML (2004) Gene action governing the inheritance of pod yield in cowpea. Legume Res 27(1): 66-69.