The Pharma Innovation Journal 2022; 11(5): 2342-2348

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(5): 2342-2348

www.thepharmajournal.com
Received: 16-01-2022
Accepted: 31-04-2022

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Combining ability and gene action for yield and yield contributing traits in greengram (*Vigna radiata* L.)

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Abstract
Ten lines were crossed with four testers in Line × Tester fashion to estimate the combining ability for yield attributing traits in greengram. Preponderance of non-additive gene action was realized from higher values of specific combining ability compared to general combining ability and ratio of variances of GCA to SCA. Parents Pusa 0672, IPM 02-17, ML 1451and CO 7 were considered as superior parents as they recorded high *per se* performance with positive significant effects for seed yield and other yield contributing traits. On the basis of significant *gca* effects of parents and non-significant *sca* effects of hybrids, eight cross combinations *viz.*, Pusa 0672 x CO 7, Pusa 0871 x CO 7, Pusa 0871 x CO 6, MH 565 x CO 7, MH 521 x CO 7, IPM 02-17 x Local TNY, IPM 02-19 x CO 7 and MH 318 x CO7 were found to be suitable for improving various traits through recombination breeding. The best specific combiners based on *per se* performance and *sca* effects were Pusa 0672 x CO 6, IPM 02-3 x VBN 2, IPM 02-19 x CO 6, IPM 02-17 x CO 7, MH 565 x CO 7, MH 521 x Local TNY, ML 1451 x CO 6, and ML 1451 x CO 7 and could be utilized for further improvement of yield in greengram.

Keywords: Greengram, GCA, SCA, combining ability, gene action

Introduction
Greengram (*Vigna radiate* (L.) Wilczek) is an ancient and well known leguminous crop of Asia on account of its nutritional quality and the suitability to cropping system. It is the third most important pulse crop in India covering an area of 4.07 mha with a total production of 1.90 million tonnes and the average productivity of 477 kg /ha (Anonymous, 2018) [1]. Important greengram growing states in India are Orissa, Andhra Pradesh, Maharashtra, Karnataka and Bihar. In Tamil Nadu, greengram occupies an area of 1.85 lakh hectares with a production and productivity of about 0.95 lakh tonnes and 516kg/ha respectively (Anonymous, 2018) [1].

It is an excellent and cheap source of high quality and easily digestible protein and is comparatively rich in lysine. Many biotic and abiotic stresses such as diseases, insects, drought, high temperature, salinity and heavy metals limit greengram yield. Excessive rate of flower shedding and poor seed set on crossing limit its improvement through hybridization. Besides these, greengram is attacked by much number of insect pests and diseases.

For the past few decades, the efforts of plant breeders on yield of greengram has not increased substantially due to lack of sufficient genetic diversity for desirable traits in the germplasm used for improvement (Skrotch and Nienhuis, 1995) [19]. Keeping these views, the present investigation was carried out to estimate the general combining ability (*gca*) effects of parents and specific combining ability (*sca*) effects of crosses for various yield related traits and to find out the nature of gene action in respect of seed yield and its components.

Material and Methods
The experimental material of green gram comprising ten lines *viz.*, Pusa 0672, Pusa 0871, IPM 02-3, IPM 02-19, IPM 02-17, MH 565, KM 2241, MH 318, MH 521 and ML 1451 were crossed with each of four testers *viz.*, VBN 2, CO 6, CO 7 and Local TNY in a Line × Tester mating design. The parents were raised in ridges of four metres length spaced at 30 cm apart. The plant to plant spacing was 30 cm. Staggered sowing of the parents was carried out to have synchronization in flowering. A total of 40 F_1 progenies were produced during Kharif 2012. The parents and hybrids were raised in a Randomized Block Design with three replications during January 2013 at the Department of Plant Breeding and Genetics, Agricultural College and Research Institute, TNAU, Killikulam, Tirunelveli, Tamil Nadu. In this experiment, CO 6 was used as a check variety. The recommended agronomical and plant protection practices were followed to maintain healthy stand of the crop.

From each hybrid and parent, five plants per replication were selected at random and used for recording eleven biometric observations namely, plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, number of seeds per pod, pod length, 100 seed weight and seed yield per plant while the traits days to 50% flowering and days to maturity were recorded on whole row basis. The mean values were worked out (Table 1, 2) and used for statistical analysis.

The data on the hybrids and parents were subjected to L × T analysis. The assumption of null hypothesis was tested for differences among the genotypes as detailed by Panse and Sukhatme (1964). The general combining ability effects of the parents and specific combining ability effects of the crosses were worked out using the mathematical model Xijk= $\mu + \hat{g}i + \hat{g}j + \hat{s}ij + \hat{r}k + \hat{e}ijk$as suggested by Kempthorne (1957) [4].

Table 1: Mean performance of parents for seed yield and its component traits in greengram

Parents	Days to 50% flowering	Plant height (cm)	No. of branches/ plant	No. of clusters/ plant	No. of pods/ cluster	No. of pods/ plant	No. of seeds/ pod	Days to maturity	Pod length (cm)	100 grain weight (g)	Seed yield per plant (g)
Lines											
Pusa 0672	35.33	39.83	3.00	8.03	5.33	42.83	11.67*	50.33	7.73*	3.90*	18.33*
Pusa 0871	35.33	40.87	4.00	6.30	3.67	23.10	12.77*	50.33	7.20	3.50	11.80
IPM 02-3	36.00	38.67	4.00	8.00	4.33	34.33	12.47*	51.00	7.97*	3.70*	13.13
IPM 02-19	35.00	34.87	3.67	8.27	5.67*	46.27*	9.63	50.00	6.60	3.67	12.70
IPM 02-17	35.00	49.10*	3.33	8.73	4.67	40.60	9.93	50.00	7.40*	3.30	17.60*
MH 565	35.00	35.00	3.67	7.43	5.13	37.67	10.13	50.00	7.12	3.10	12.67
KM 2241	35.00	41.03	4.00	7.33	5.27	38.53	9.00	50.00	7.78	3.30	11.67
MH 318	35.00	36.40	4.00	7.53	4.33	32.60	10.80	50.00	6.87	3.37	14.57
MH 521	35.00	33.27	5.00*	7.33	4.00	29.33	11.00	50.00	7.50*	3.20	10.87
ML 1451	35.00	42.37	3.67	7.93	3.67	28.63	12.73*	50.00	6.60	3.77*	13.97
Overall mean	35.16	39.14	3.83	7.68	4.60	35.38	11.01	50.16	7.27	3.48	13.73
VBN 2	36.00	36.07	4.00	7.67	4.33	33.00	10.50	51.00	7.07	3.30	14.80
CO6	28.33*	47.33*	5.67*	9.33*	6.33*	58.67*	11.00	43.33*	7.20	4.00	25.00*
CO7	35.00	42.23	5.00*	8.20	6.33*	51.73*	10.87	50.00	7.17	3.47	18.00*
Local TNY	36.33	33.33	4.33	8.00	5.33	42.23	9.30	51.33	6.60	3.30	16.33
Overall mean	33.91	39.74	4.75	8.30	5.58	46.40	10.41	48.91	7.01	3.51	18.53
S.E±	0.22	2.32	0.32	0.42	0.30	2.30	0.11	0.22	0.06	0.08	0.61
CD(P=0.5)	0.62	6.45	0.88	1.16	0.83	6.39	0.31	0.62	0.18	0.23	1.70

* Significant at 5% level

Table 2: Mean performance of hybrids for seed yield and its component traits in greengram

Hybrids	Days to 50% flowering	Plant height (cm)	No. of branches/ plant	No. of clusters/ plant	No. of pods/ cluster	No. of pods/ plant	No. of seeds/ pod	Days to maturity	Pod length (cm)	100 grain weight (g)	Seed yield per plant (g)
Pusa 0672 x VBN 2	35.00	50.10*	4.02	8.00	4.67	38.67	11.53*	50.00	7.50	3.47	13.07
Pusa 0672 x CO6	35.33	55.40*	4.90*	8.20	6.00*	45.87*	11.73*	50.33	7.70	3.87*	19.33*
Pusa 0672 x CO7	35.00	29.13	3.77	6.67	5.00	35.33	9.83	50.00	8.33*	3.60	14.37
Pusa 0672 x Local TNY	35.00	24.97	3.77	8.00	4.33	32.67	11.00	50.00	7.00	3.67	16.67
Pusa 0871 x VBN 2	35.33	31.40	4.10	8.43	4.33	36.07	13.27*	50.33	6.88	3.50	15.90
Pusa 0871 x CO6	35.00	39.60	3.50	7.00	4.02	28.07	11.90*	50.00	7.70	3.27	12.47
Pusa 0871 x CO7	35.00	40.83	5.20*	9.00	4.90	44.1*	9.63	50.00	7.88*	3.77*	15.03
Pusa 0871 x Local TNY	35.00	35.27	5.03*	7.67	3.77	28.83	11.80*	50.00	6.87	3.20	13.67
IPM 02-3 x VBN 2	35.00	28.53	3.80	8.67	3.77	32.63	11.17	50.00	6.97	3.50	15.50
IPM 02-3 x CO6	35.00	41.37	4.13	9.03	4.10	37.07	11.20	50.00	7.07	3.20	13.67
IPM 02-3 x CO7	35.00	23.73	4.03	6.33	5.33	34.00	8.33	50.00	7.17	3.37	11.00
IPM 02-3 x Local TNY	36.33	46.35	3.67	5.50	5.20	28.58	9.67	51.33	7.58	3.07	11.80
IPM 02-19 x VBN 2	35.00	32.17	4.00	7.33	5.03	36.98	12.90*	50.00	7.87*	3.27	16.67
IPM 02-19 x CO6	36.00	36.73	4.33	8.33	5.33	44.33*	12.17*	51.00	8.5*	3.97*	22.87*
IPM 02-19 x CO7	35.00	20.73	3.00	7.67	4.17	30.47	9.63	50.00	7.07	3.67	15.87
IPM 02-19 x Local TNY	36.00	37.10	3.67	9.17*	4.03	36.97	10.90	51.00	7.60	3.60	14.73
IPM 02-17 x VBN 2	36.00	41.70	4.00	8.67	4.33	37.67	11.13	51.00	7.90*	3.50	17.40*
IPM 02-17 x CO6	36.00	25.63	4.00	7.40	4.50	33.17	12.50*	51.00	6.97	3.37	18.70*
IPM 02-17 x CO7	34.00*	29.87	4.67	8.50	5.67*	48.00*	12.43*	49.00*	7.97*	3.80*	24.30*
IPM 02-17 x Local TNY	35.00	38.77	3.33	8.80	5.00	44.20*	10.73	50.00	7.58	3.40	19.70*
MH 565 x VBN 2	35.00	34.20	4.00	9.13*	4.00	36.53	10.90	50.00	7.33	3.07	12.30
MH 565 x CO6	35.00	42.17	3.33	8.67	4.00	36.00	9.60	50.00	6.98	3.50	11.10
MH 565 x CO7	32.67*	49.27*	4.67	9.00	4.33	39.00	12.17*	47.67*	8.20*	3.97*	20.60*
MH 565 x Local TNY	35.00	33.37	4.33	8.13	4.33	35.30	11.47	50.00	7.30	3.77*	14.70
KM 2241 x VBN 2	36.33	32.77	3.00	5.50	3.67	20.00	12.77*	51.33	7.97*	3.40	11.50
KM 2241 x CO6	36.00	34.93	3.67	8.67	4.00	34.67	12.90*	51.00	7.40	3.47	16.70
KM 2241 x CO7	36.00	37.50	2.90	8.93	5.67*	50.37*	9.20	51.00	6.90	3.77*	19.50*
KM 2241 x Local TNY	36.00	35.10	3.67	8.00	4.67	37.33	10.00	51.00	7.60	3.37	15.57

MH 318 x VBN 2	36.00	35.80	4.00	8.30	4.33	35.53	10.17	51.00	7.67	3.47	15.93
MH 318 x CO6	36.00	31.43	3.67	7.77	4.53	35.04	9.57	51.00	6.97	3.47	15.97
MH 318 x CO7	36.00	31.77	3.00	7.27	4.33	31.23	11.77*	51.00	7.10	3.50	17.30
MH 318 x Local TNY	36.00	25.23	3.67	7.73	5.33	41.27	10.7	51.00	7.78*	3.67	19.90*
MH 521 x VBN 2	36.00	44.13*	3.67	9.00	5.33	48.00*	7.90	51.00	7.72*	3.47	12.67
MH 521 x CO6	36.00	23.47	3.33	7.70	4.33	33.27	8.00	51.00	7.30	3.70	10.33
MH 521 x CO7	36.00	37.10	4.67	6.53	4.07	26.53	11.00	51.00	7.62	3.50	13.87
MH 521 x Local TNY	36.00	26.77	5.33*	9.00	5.17	46.50	10.80	51.00	8.97*	3.80*	19.80*
ML 1451 x VBN 2	36.00	26.97	3.67	7.00	3.93	27.60	11.00	51.00	7.67	3.30	13.10
ML 1451 x CO6	36.00	31.83	5.33*	9.00	5.00	45.00*	10.73	51.00	7.48	3.90*	20.00*
ML 1451 x CO7	36.00	42.07	5.67*	9.33*	5.00	46.33*	11.77*	51.00	7.98*	4.00*	20.80*
ML 1451 x Local TNY	35.33	33.43	4.00	8.00	4.67	37.33	12.00*	50.33	7.98*	3.27	14.77
Overall mean	35.45	34.96	4.01	8.02	4.60	36.91	10.94	50.45	7.55	3.53	15.97
CD(P=0.5)	0.62	6.45	0.88	1.16	0.83	6.39	0.31	0.62	0.18	0.23	1.70

* Significant at 5% level

Results and Discussion

The analysis of variance for parents and hybrids clearly revealed the presence of significant difference among the genotypes tested for all the characters studied (Table 3).

The results indicated the importance of both additive and non-additive genetic components of variation in the expression of the characters. Similar results were reported by Surashe *et al.* (2017) [21], Latha *et al.* (2018) [8], Nath *et al.* (2018) [15], Samantaray *et al.* (2018) [20], Viraj *et al.* (2019) [22], Mohan and Sheeba (2019) [11] and Lovely and Kumar (2021) [9].

The magnitude of SCA variances was greater than GCA variances for all the eleven biometrical characters and hence the ratio of variance due to general and specific combining ability was less than 1.0 and it ranged from -0.0105 to 0.0448 (Table 3).

This indicated the preponderance of non-additive gene action for all the eleven characters studied**.** These results are in concordance with the findings of Narasimhulu *et al.* (2014) [13], Khaimichho *et al.* (2016) [5], Nath *et al.* (2017) [14], Surashe *et al.* (2017) [21], Kalpana *et al.* (2018) [3], Latha *et al.* (2018) [8], Kakde *et al.* (2019) [2], Viraj *et al.* (2019) [22] and Kohakade *et al.* (2021) [7]. Thus, to exploit the dominant gene action of these traits, hybridization followed by selection in later generations is recommended for the improvement of all these traits in greengram.

The proportion of contribution of the interaction variance (line x tester) to the total genetic variance was high for all the traits studied except for days to 50% flowering and days to maturity (Table 4). Lines contributed more to the total sum square for days to 50% flowering and days to maturity. The contribution of testers was lower as compared to the lines and lines x testers interaction for all traits under study except 100 seed weight where testers contributed more than lines to the total genetic variance. These results showed that the interaction of lines x testers brought much variation in the expression of the traits studied.

Combination of *per se* performance and *gca* effects result in the selection of parents with good reservoir of superior genes. Majumder and Bhowal (1988) [10] reported parallelism between *per se* performance and *gca* effects for the improvement of any character. In the present investigation, Pusa 0672 was the best parent based on both *per se* and *gca* effects for the pod length and hundred seed weight, whereas IPM 02-17 was the best parent for pod length and seed yield per plant. Out of four testers, CO 7 was found to be the best parent for the three traits *viz.,* number of pods per cluster, number of pods per plant and seed yield per plant. Similar findings were reported by Singh *et al.* (2007) [18] and Surashe *et al.* (2018) [21]. Thus, it can be concluded that crosses involving CO 7, Pusa 0672 and IPM 02-17 would result in the identification of superior segregants with favourable genes for yield.

Since *per se* performance is the realized value, it is employed as the first criterion for selecting superior hybrids. In the present study, the hybrid IPM 02-17 x CO 7 recorded high *per se* performance for eight traits, Pusa 0672 x CO 6, MH 565 x CO 7 and ML 1451 x CO7 each for seven different traits, whereas IPM 02-19 x CO 6 was the next best hybrid which showed high mean value for six different traits. All these hybrids were also recorded high seed yield per plant.

The average performance of specific cross combination expressed as deviation from the population mean defines specific combining ability. According to Sprague and Tatum (1942), the specific combining ability is controlled by non-additive gene action. For days to 50 per cent flowering, significant negative *sca* effect is considered as desirable as it indicates earliness. The *sca* effects for days to 50% flowering ranged from -1.36 (MH 565 x CO 7) to 0.89 (IPM-02-3 x Local TNY). The crosses IPM 02-3 x CO 6, IPM 02-19 x VBN 2, IPM 02-17 x CO 7, MH 565 x CO 7 and ML 1451 x Local TNY had highly significant negative *sca* effects and IPM 02-3 x VBN 2 had negative significant effects (Table 6).

For the trait plant height, the *sca* values fell between -13.60 and 14.21. Of these, nine hybrids *viz.*, Pusa 0672 x VBN 2,Pusa 0672 x CO 6, IPM 02-3 x Local TNY, IPM 02-19 x Local TNY, IPM 02-17 x VBN 2, IPM 02-17 x Local TNY, MH 565 x CO7, MH 521 x VBN 2 and ML 1451 x CO 7 showed highly significant positive *sca* effects and three crosses Pusa 0871 x CO 7, IPM 02-3 x CO 6 and MH 521 x CO 7 recorded significant and positive *sca* effects. For number of branches per plant, hybrids had the lowest and the highest *sca* effects of -0.97 and 1.05 respectively. The *sca* effects were highly significant and positive for the hybrids namely Pusa 0672 x CO 7, MH 521 x Local TNY and ML 1451 x CO 7, whereas crosses Pusa 0871 x CO 7, Pusa 0871 x Local TNY, IPM 02-19 x CO 6, MH 318 x VBN 2 and ML 1451 x CO 6 showed significant positive *sca* effects for this trait.

The *sca* effects for number of clusters per plant ranged from -2.25 to 1.50 and were highly significant and positive for the hybrids Pusa 0871 x CO 7, IPM 02-3 x VBN 2, IPM 02-3 x CO 6, IPM 02-19 x Local TNY, KM 2241 x CO 7 and ML 1451 x CO 7. The significant and positive *sca* effects were shown by two crosses MH 521 x VBN 2 and MH 521 x Local TNY. The hybrids had the lowest and the highest *sca* effects of -0.90 (MH 521 x CO 7) and 1.02 (Pusa 0672 x CO 6) for the trait number of pods per cluster. Hybrids Pusa 0672 x CO 6, KM 2241 x CO 7 and MH 521 x VBN 2 showed highly significant positive effects. For number of pods per plant, the *sca* effects varied from -13.67 to 13.15. Highly significant and positive *sca* effects were reported by Pusa 0672 x CO 6, PUSA 0871 x CO 7, IPM 02-19 x CO 6, KM 2241 x CO 7, MH 521 x VBN 2 and MH 521 x Local TNY, whereas significant and positive *sca* effects were shown by the hybrids IPM 02-17 x CO 7, MH 318 x Local TNY, ML 1451 x CO 6 and ML 1451 x CO 7.

The *sca* effects for seeds per pod ranged from -1.85 (MH 521 x VBN 2) to 1.94 (MH 521 x CO 7). Seventeen crosses showed highly significant and positive effects and three hybrid *viz*., Pusa 0672 x VBN 2, Pusa 0871 x Local TNY and MH 318 x Local TNY recorded positive significant *sca* effects for the trait. The minimum and maximum *sca* effects for days to maturity were recorded in MH 565 x CO 7 (-1.36) and IPM 02-3 x Local TNY (0.89) hybrids. With this trait, the hybrids IPM 02-17 x CO 7, IPM-02-19 x VBN 2, IPM 02-3 x CO 7, MH 565 x CO 7 and ML 1451x Local TNY had shown highly significant negative *sca* effects and IPU 02-3 x VBN 2 showed significant negative *sca* effects.

For pod length, the *sca* effects varied from -0.76 (IPM 02-19 x CO 7) to 0.99 (MH 521 x Local TNY) and 13 crosses showed highly significant and positive effects whereas three hybrids were with significant positive effects. The minimum and maximum *sca* effects recorded for 100 seed weight were -0.37 (MH 565 x VBN 2) and 0.36 (IPM 02-3 x VBN 2). The hybrids IPM 02-3 x VBN 2, IPM 02-19 x CO 6, MH 565 x CO 7, MH 565 x Local TNY, MH 521 x Local TNY, ML 1451 x CO 6 recorded highly significant positive *sca* effects and the crosses Pusa 0672 x CO 6, Pusa 0871 x VBN 2, Pusa 0871 x CO 7, MH 318 x Local TNY, ML 1451 x CO 7 showed significant positive *sca* effects.

For seed yield per plant**,** the *sca* effects ranged from -3.97 (MH 521 x CO 6) to 5.48 (MH 521 x Local TNY) and 11 hybrids namely Pusa 0672 x CO 6, Pusa 0871 x VBN 2, IPM 02-3 x VBN 2, IPM 02-19 x CO 6, IPM 02-17 x CO 7, MH 565 x CO 7, KM 2241 x CO 7, MH 318 x Local TNY, MH 521 x Local TNY, ML 1451 x CO 6 and ML 1451 x CO 7 showed highly significant positive *sca* effects for this trait.

On the basis of *sca* effects of hybrids for seed yield and yield contributing traits, the hybrids Pusa 0672 x CO 6 and ML 1451 x CO7 recorded high *sca* effects for eight traits, IPM 02-19 x CO 6, MH 565 x CO 7 and MH 521 x Local TNY for seven characters followed by the hybrids IPM 02-3 x VBN 2, IPM 02-17 x CO 7 and MH 318 x Local TNY for six traits and KM 2241 x CO 7 and ML 1451 x CO 6 for four traits each. These hybrids were identified as superior hybrids and can be effectively utilized for hybrid breeding programme.

The criteria for selection of hybrids for recombination breeding is based on the parents having significant *gca* effect and corresponding hybrids with non-significant *sca* effects. The segregation of such hybrids likely to throw desirable recombinants possessing favourable additive genes from both the parents (Nadarajan, 1986, Khorgade *et al.*, 1989) [12, 6]. For days to 50% flowering, *gca* effects were positive and highly significant in lines Pusa 0672, Pusa 0871, IPM 02-17 and MH 565 and tester CO 7 (Table 7). Among the crosses involving above mentioned parents, Pusa 0672 x CO 7 and Pusa 0871 x CO 7 expressed non-significant *sca* effects, Hence these hybrids were identified for recombination breeding. For number of pods per clusters, the hybrid Pusa 0672 x CO 7 was reported for the recombination breeding.

The parents Pusa 0871, IPM 02-19, IPM 02-17, KM 2241 and ML 1451 in lines, and VBN 2 and CO 6 in testers showed positive and highly significant *gca* effects for number of seeds per pod. Among the possible cross combinations, only two crosses *viz.,* Pusa 0672 x Local TNY and Pusa 0871 x CO 6 had non-significant *sca* effects and thus can be recommended for improvement of number of seeds per pod. For days to maturity, *gca* effects were positive and highly significant in lines Pusa 0672, Pusa 0871, IPM 02-17 and MH 565 and in tester CO 7 and non-significant *sca* effects in crosses Pusa 0672 x CO 7 and Pusa 0871 x CO 7. Hybrid IPM 02-19 x CO 7 for 100 seed weight and hybrids IPM 02-17 x Local TNY, IPM 02-19 x CO 7 and MH 521 x CO7 for pod length were identified for recombination breeding. Parents IPM 02-19, MH 318 and CO7 were found to be suitable for future use in breeding programs, hybrids of these parents showed negative and non-significant *sca* effects.

Table 3: Analysis of combining ability and estimates of genetic variances for seed yield and its component traits in greengram

Source	df	Mean square										
		Days to 50% flowering	**Plant height (cm)**	**No. of branches/ plant**	**No. of clusters/ plant**	**No. of pods/ cluster**	**No. of pods/ plant**	**No. of seeds/ pod**	**Days to maturity**	**Pod length (cm)**	**100 grain weight (g)**	**Seed yield per plant (g)**
Replication	2	0.19	8.65	0.31	1.01	0.47	25.34	0.06	0.19	0.01	0.01	0.62
Parents	13	11.06**	72.40 **	1.50**	1.52**	2.33**	272.51**	4.46**	11.06**	0.59**	0.22**	42.10**
Crosses	39	1.53**	183.22 **	1.38**	2.87 **	1.05**	138.22**	5.30**	1.53**	0.70**	0.17 **	34.83**
Lines	9	3.39**	111.80**	1.94**	1.79**	0.76**	64.80**	6.32**	3.39**	0.59**	0.14**	51.67**
Testers	3	2.07**	46.81*	0.57*	0.34	1.31**	65.30**	2.52**	2.07**	0.31**	0.49**	41.73**
L X T	27	0.85**	222.19**	1.29**	3.52**	1.12**	170.79**	5.27**	0.85**	0.78**	0.15**	28.45**
Error	78	0.10	15.34	0.21	0.45	0.24	17.60	0.02	0.10	0.008	0.02	1.06
σ^2gca		0.0112	-0.6396	0.0015	-0.0106	-0.0011	-0.5347	0.0005	0.0112	-0.0013	0.0004	0.1047
σ^2sca		0.2501	68.9499	0.3592	1.0246	0.2942	51.0642	1.7508	0.2501	0.2588	0.0431	9.1305
σ^2gca/σ^2sca		0.0448	-0.0093	0.0042	-0.0103	-0.0037	-0.0105	0.0003	0.0448	-0.0050	0.0093	0.0115

*, ** Significant at 5% and 1% levels, respectively

Table 4: Proportion of contribution of lines, testers and line x tester to total genetic variance for seed yield and its component traits in greengram

Character	Days to 50% flowering	Plant height (cm)	No. of branches/ plant	No. of clusters/ plant	No. of pods/ cluster	No. of pods/ plant	No. of seeds/ pod	Days to maturity	Pod length (cm)	100 grain weight (g)	Seed yield per plant (g)
Lines	51.08	14.08	32.29	14.36	16.69	10.82	27.50	51.08	19.47	19.34	34.23
Testers	10.41	1.97	3.16	0.92	9.54	3.63	3.66	10.41	3.44	21.40	9.21
L x T	38.51	83.95	64.54	84.72	73.77	85.55	68.85	38.51	77.09	59.26	56.55

Table 5: General combining ability effects of parents for seed yield and its component traits in greengram

Parents	Days to 50% flowering	Plant height (cm)	No. of branches/ plant	No. of clusters/ plant	No. of pods/ cluster	No. of pods/ plant	No. of seeds/ pod	Days to maturity	Pod length (cm)	100 grain weight (g)	Seed yield per plant (g)
Lines											
Pusa 0672	-0.38**	4.93**	0.10	-0.31	0.40**	1.22	0.08	-0.38 **	0.08**	0.12**	-0.12
Pusa 0871	-0.38**	1.81	0.45 **	-0.00	-0.35*	-2.65*	0.70**	-0.38 **	-0.22**	-0.10*	-1.71 **
IPM 02-3	-0.13	0.03	-0.10	-0.64 **	-0.00	-3.84**	-0.85**	-0.13	-0.35**	-0.25**	-2.99 **
IPM 02-19	0.04	-3.28**	-0.26	0.10	0.04	0.27	0.45**	0.04	0.21**	0.09*	1.56 **
IPM 02-17	-0.21*	-0.98	-0.01	0.32	0.27	3.85**	0.75**	-0.21 *	0.05*	-0.02	4.05 **
MH 565	-1.04**	4.78**	0.07	0.71 **	-0.44**	-0.20	0.09	-1.04 **	-0.10**	0.04	-1.30 **
KM 2241	0.63**	0.11	-0.70 **	-0.25	-0.10	-1.32	0.27**	0.63 **	-0.08**	-0.03	-0.16
MH 318	0.54**	-3.91**	-0.43 **	-0.26	0.03	-1.14	-0.40**	0.54 **	-0.17**	-0.01	1.30 **
MH 521	0.54**	-2.10	0.24	0.03	0.12	1.66	-1.52**	0.54 **	0.35**	0.08	-1.81 **
ML 1451	0.38**	-1.39	0.65 **	0.31	0.05	2.15	0.43**	0.38 **	0.23**	0.08	1.19 **
S.E±	0.09	1.13	0.13	0.19	0.14	1.21	0.04	0.09	0.02	0.04	0.29
Testers											
VBN 2	0.11	0.81	-0.19*	-0.02	-0.26 **	-1.94 *	0.33**	0.11	0.00	-0.14**	-1.57 **
CO 6	0.17**	1.29	0.01	0.15	-0.02	0.34	0.08**	0.17 **	-0.14**	0.04	0.14
CO 7	-0.39**	-0.77	0.14	-0.10	0.24 **	1.62*	-0.37**	-0.39 **	0.07**	0.16**	1.29 **
Local TNY	0.11	-1.33	0.03	-0.03	0.05	-0.01	-0.04	0.11	0.08**	-0.05	0.15
S.E±	0.05	0.71	0.05	0.12	0.09	0.76	0.02	0.05	0.01	0.02	0.18

*, ** Significant at 5% and 1% levels, respectively

Table 6: Specific combining ability effects of hybrids for seed yield and its component traits in greengram

Hybrids	Days to 50% flowering	Plant height (cm)	No. of branches/ plant	No. of clusters/ plant	No. of pods/ cluster	No. of pods/ plant	No. of seeds/ pod	Days to maturity	Pod length (cm)	100 grain weight (g)	Seed yield per plant (g)
Pusa 0672 x VBN 2	-0.19	9.39**	0.09	0.31	-0.07	2.48	0.18*	-0.19	-0.13*	-0.04	-1.22 *
Pusa 0672 x CO 6	0.08	14.21**	0.78 **	0.33	1.02 **	7.40 **	0.62**	0.08	0.21**	0.18*	3.34 **
Pusa 0672 x CO 7	0.31	-10.00**	-0.49	-0.95 *	-0.24	-4.42	-0.82**	0.31	0.63**	-0.21*	-2.78 **
Pusa 0672 x Local TNY	-0.19	-13.60**	-0.38	0.31	-0.71 *	-5.45 *	0.01	-0.19	-0.71**	0.07	0.66
Pusa 0871 x VBN 2	0.14	-6.18**	-0.17	0.43	0.34	3.74	1.29**	0.14	-0.45**	0.21*	3.21 **
Pusa 0871 x CO 6	-0.26	1.54	-0.97**	-1.18 **	-0.21	-6.54 **	0.17	-0.26	0.51**	-0.20*	-1.94 **
Pusa 0871 x CO 7	0.31	4.83*	0.60 *	1.08 **	0.40	8.21 **	-1.65**	0.31	0.48**	0.17*	-0.52
Pusa 0871 x Local TNY	-0.19	-0.18	0.54 *	-0.33	-0.53	-5.42 *	0.19*	-0.19	-0.54**	-0.18*	-0.75
IPM 02-3 x VBN 2	-0.44*	-7.27**	0.08	1.31 **	-0.57 *	1.51	0.75**	-0.44 *	-0.23**	0.36**	4.08 **
IPM 02-3 x CO 6	-0.51**	5.08*	0.22	1.50 **	-0.48	3.67	1.02**	-0.51 **	0.01	-0.12	0.54
IPM 02-3 x CO 7	0.06	-10.50**	-0.02	-0.95 *	0.49	-0.70	-1.39**	0.06	-0.10	-0.08	-3.28 **
IPM 02-3 x Local TNY	0.89**	12.69**	-0.28	-1.86 **	0.55	-4.47	-0.38**	0.89 **	0.31**	-0.16	-1.34*
IPM 02-19 x VBN 2	-0.61**	-0.33	0.44	-0.77 *	0.66 *	1.74	1.17**	-0.61 **	0.11*	-0.22*	0.71
IPM 02-19 x CO 6	0.32	3.76	0.58 *	0.06	0.71 *	6.81 **	0.68**	0.32	0.89**	0.31**	5.20 **
IPM 02-19 x CO 7	-0.11	-10.18**	-0.89 **	-0.36	-0.72 *	-8.34 **	-1.4**	-0.11	-0.76**	-0.12	-2.95 **
IPM 02-19 x Local TNY	0.39*	6.75**	-0.12	1.07 **	-0.65 *	-0.21	-0.46**	0.39 *	-0.23**	0.03	-2.95 **
IPM 02-17 x VBN 2	0.64**	6.90**	0.19	0.35	-0.28	-1.15	-0.89**	0.64 **	0.3**	0.12	-1.05
IPM 02-17 x CO 6	0.57**	-9.65**	-0.01	-1.09**	-0.35	-7.93 **	0.72**	0.57 **	-0.49**	-0.19*	-1.46 *
IPM 02-17 x CO 7	-0.86**	-3.36	0.52	0.26	0.55	5.62 *	1.1**	-0.86 **	0.29**	0.12	2.99 **
IPM 02-17 x Local TNY	-0.36	6.11**	-0.70*	0.48	0.08	3.46	-0.93**	-0.36	-0.10	-0.06	-0.48
MH 565 x VBN 2	0.47*	-6.36**	0.10	0.42	0.10	1.77	-0.46**	0.47 *	-0.12*	-0.37**	-0.80
MH 565 x CO 6	0.41*	1.13	-0.76 **	-0.22	-0.14	-1.04	-1.52**	0.41 *	-0.33**	-0.11	-3.71 **
MH 565 x CO 7	-1.36**	10.28**	0.44	0.37	-0.08	0.67	1.5**	-1.36 **	0.67**	0.23**	4.64 **
MH 565 x Local TNY	0.47*	-5.05*	0.22	-0.57	0.12	-1.39	0.47**	0.47 *	-0.23**	0.25**	-0.13
KM 2241 x VBN 2	0.14	-3.12	-0.12	-2.25 **	-0.57 *	-13.65 **	1.22**	0.14	0.50**	0.04	-2.74 **
KM 2241 x CO 6	-0.26	-1.43	0.35	0.74	-0.48	-1.26	1.6**	-0.26	0.08	-0.07	0.75
KM 2241 x CO 7	0.31	3.19	-0.55 *	1.26 **	0.92 **	13.15 **	-1.65**	0.31	-0.64**	0.11	2.40 **
KM 2241 x Local TNY	-0.19	1.36	0.32	0.25	0.12	1.76	-1.18**	-0.19	0.06	-0.08	-0.40
MH 318 x VBN 2	-0.11	3.93	0.60 *	0.56	-0.04	1.71	-0.71**	-0.11	0.29**	0.08	0.23
MH 318 x CO 6	-0.18	-0.91	0.08	-0.15	-0.08	-1.06	-1.07**	-0.18	-0.27**	-0.09	-1.44 *

MH 318 x CO 7	0.39*	1.48	-0.73 **	-0.40	-0.54	-6.16 *	1.59**	0.39 *	-0.35**	-0.18*	-1.26 *
MH 318 x Local TNY	-0.11	-4.49*	0.05	-0.01	0.65 *	5.51 *	0.19*	-0.11	0.33**	0.20*	2.47 **
MH 521 x VBN 2	-0.11	10.46**	-0.40	0.96 *	0.87 **	11.37 **	-1.85**	-0.11	-0.18**	-0.01	0.07
MH 521 x CO 6	-0.18	-10.69**	-0.92**	-0.51	-0.37	-5.64 *	-1.51**	-0.18	-0.46**	0.05	-3.97 **
MH 521 x CO 7	0.39*	5.00*	0.27	-1.42 **	-0.90 **	-13.67 **	1.94**	0.39 *	-0.35**	-0.28**	-1.59 **
MH 521 x Local TNY	-0.11	-4.77*	1.05 **	0.97 *	0.40	7.94 **	1.41**	-0.11	0.99**	0.24**	5.48 **
ML 1451 x VBN 2	0.06	-7.42**	-0.81 **	-1.31 **	-0.45	-9.52 **	-0.7**	0.06	-0.11*	-0.18*	-2.49 **
ML 1451 x CO 6	-0.01	-3.03	0.66 *	0.52	0.37	5.60 *	-0.72**	-0.01	-0.15**	0.25**	2.70 **
ML 1451 x CO 7	0.56**	9.26**	0.86 **	1.10 **	0.11	5.64 *	0.76**	0.56 **	0.13*	0.22*	2.35 **
ML 1451 x Local TNY	-0.61**	1.19	-0.70 *	-0.31	-0.03	-1.72	0.66**	-0.61 **	0.13*	-0.30**	-2.55 **
S.E±	0.18	2.26	0.26	0.38	0.28	2.42	0.09	0.18	0.05	0.08	0.59

*, ** Significant at 5% and 1% levels respectively

Table 7: Promising hybrids based on *gca* effects of parents for recombination breeding in greengram

S. No.	Characters	Significant *gca* effects		Cross combinations	Selected hybrids for recombination breeding
		Lines	Testers		
1.	Days to 50% flowering	Pusa 0672, Pusa 0871, IPM 02-17, MH 565	CO 7	Pusa 0672 x CO 7, Pusa 0871 x CO 7, IPM 02-17 x CO 7, MH 565 x CO 7	Pusa 0672 x CO 7, Pusa 0871 x CO 7
2.	Plant height (cm)	Pusa 0672, MH 565	-	-	-
3.	No. of branches per plant	Pusa 0871, ML 1451	-	-	-
4.	No. of clusters per plant	MH 565	-	-	-
5.	No. of pods per cluster	Pusa 0672	CO 7	Pusa 0672 x CO 7	Pusa 0672 x CO 7
6.	No. of pods per plant	IPM 02-17	CO 7	IPM 02-17 x CO 7	-
7.	No. of seeds per pod	Pusa 0871, IPM 02-19, IPM 02-17, KM 2241, ML 1451	VBN 2, CO 6	Pusa 0871 x VBN 2, Pusa 0871 x CO 6, IPM 02-19 x VBN2, IPM 02-19 x CO 6, IPM 02-17 x VBN 2, IPM 02-17 x CO 6, KM 2241 x VBN 2, KM 2241 x CO 6, ML 1451 x VBN 2, ML 1451 x CO 6	Pusa 0871 x CO 6
8.	Days to maturity	Pusa 0672, Pusa 0871, IPM 02-17, MH 565	CO 7	Pusa 0672 x CO 7, Pusa 0871 x CO 7, IPM 02-17 x CO 7, MH 565 x CO 7	Pusa 0672 x CO 7, Pusa 0871 x CO 7
9.	Pod length (cm)	Pusa 0672, IPM 02-19, IPM 02-17, MH 521, ML 1451	CO 7, Local TNY	Pusa 0672 x CO 7, IPM 02-19 x CO 7, IPM 02-17 x CO 7, MH 521 x CO 7, ML 1451 x CO 7, Pusa 0672 x Local TNY, IPM 02-19 x Local TNY, IPM 02-17 x Local TNY, MH 521 x Local TNY, ML 1451 x Local TNY.	IPM 02-19 x CO 7, IPM 02-17 x Local TNY, MH 521 x CO 7
10.	100 seed weight(g)	Pusa 0672, IPM 02-19	CO 7	Pusa 0672 x CO 7, IPM 02-19 x CO 7	IPM 02-19 x CO 7
11.	Seed yield per plant (g)	IPM 02-19, IPM 02-17, MH 318, ML 1451	CO 7	IPM 02-19 x CO 7, IPM 02-17 x CO 7, MH 318 x CO 7, ML 1451x CO 7.	IPM 02-19 x CO 7, MH 318 x CO 7

Conclusion

The parents IPM 02-17, ML 1451and CO 7 were the best general combiners for different traits since they exhibited high positive *gca* effects for many of the yield attributing character. With respect to *sca* effects the hybrids ML 1451 x CO 7 excelled others by registering high *sca* effects for eight characters including seed yield. Hence, these parents and hybrid can be economically utilized for the hybridization program for the improvement of seed yield in green gram and considered as ideal for further studies.

References

1. Anonymous. Ministry of Agriculture. Selected state wise area, production and productivity of greengram, Govt. of India, 2018. In: http://www.indiastat.com.
2. Kakde SS, Gawate AB, Mandge SV. Estimation of combining ability effect in mungbean [*Vigna radiata* (L.) Wilczek]. Int. J Curr. Microbiol. App. Sci. 2019;8:1668-1674.
3. Kalpana S, Naidu NV, Reddy DM. Combining Ability Studies for Yield, Yield Components and Nutritional Traits in Greengram (*Vigna radiata* (L.) Wilczek). Int. J Curr. Microbiol. App. Sci. 2018;7(11):1771-1779.
4. Kempthorne O. An introduction to genetic statistics. The IOWA State University Press (Eds.). John Wiley and Sons, Inc., New York, 1957, 545.
5. Khaimichho EB, Lakshmi H, Sarkar KK, Mukherjee S. Estimation of combining ability and heterosis for yield related characters with protein content in seed of mungbean. Electronic J Plant Breed. 2016;7:849-856.
6. Khorgade PW, Deshmukh AV, Narkhede MN, Rant SK. Combining abilityfor yield and its components in sesame. J Maharashtra Agric. Univ. 1989;14(2):164-166.
7. Kohakade SN, Kute NS, Karvar SH, Shinde GC. Estimation of combining ability effect in mungbean (*Vigna radiata* (L.) Wilczek.) Int. J Chemical studies. 2021;9(1):101-104.
8. Latha VS, Eswari KB, Kumar SS. Combining ability analysis for seed yield and its component characters in greengram (*Vigna radiata* (L.) Wilczek.). International J Chemical Studies. 2018;6(2):237-242.
9. Lovely B, Kumar V. Gene action and combining ability of yield related characters in genetically diverse lines in yard long bean (*Vigna unguiculata* ssp. Sesquipedalis (L.) Electronic J Plant Breeding. 2021;12(1):82-85.
10. Majumder PK, Bhowal JB. Combining ability in a few varieties of *T. aestivum*, *T. compactum* and *T. sphaercoccum*. Indian J Genet. 1988;48(1):43-48.
11. Mohan S, Sheeba A. Heterosis and combining ability studies for yield and yield related traits in greengram (*Vigna radiata* L.). Electronic J Plant Breeding. 2019;10(3):1255-1261.
12. Nadarajan N. Genetic analysis of fibre characters in cotton (*Gossypium hirsutum* L.). Ph.D. Thesis, TNAU,

Coimbatore, 1986.
13. Narasimhulu R., Naidu NV, Reddy KHP, Naidu GN. Combining ability for yield attributes in greengram [*Vigna radiata* (L.) Wilczeck]. Bioscan. 2014;9:1667-1671.
14. Nath Anamika Maloo SR, Baudh Bharti Dubey RB, Verma Rajani. Combining ability analysis in mungbean [*Vigna radiata* (L.) Wilczek]. Legume Res. 2017;40:1-7.
15. Nath Anamika, Maloo SR, Nath S, Chakma A, Verma R, Yadav GS. Genetical studies on assessment of combining ability for grain yield and yield attributing traits in green gram (*Vigna radiata* (L.) Wilczek). J Pharmacognosy and Phytochemistry. 2018;7(2):2562-2566.
16. Panse VG, Shukatme PV. Statistical Methods for Agricultural workers. ICAR, New Delhi, 1964.
17. Singh RS, Singh ON, Chaudhary RK. Combining ability for yield in Indian mustard. Indian J Agric. Sci. 1985;55:240-242.
18. Singh VK, Tyagi K, Tamer AK, Singh MN, Nandanl R. Gene action for yield and yield attributing traits in mungbean (*Vigna radiata* (L.) Wilczek). Legume Res. 2007;30(1):29-32.
19. Skrotch P, Nienhuis J. Qualitative and quantitative characterization of RAPD variation among snap bean (*Phaseolus lunatus* L.) genotypes. Theor. Appl. Genet. 1995;91:1086-1091.
20. Samantaray J, Das TR, Baisakh B. Combining ability and gene action for yield traits in greengram [*Vigna radiata* (L.) wilczek]. Electronic J Plant Breeding. 2018;9(2):583-588. DOI: 10.5958/0975-928X.2018.00071.6.
21. Surashe SM, Patil DK, Gite VK. Combining Ability for Yield and Yield Attributes Characters in Greengram (*Vigna radiata* L. Wilczek). International J Current Microbio. Appl. Sci. 2017;6(11):3552-3558.
22. Viraj R, Pithia MS, Solanki HV. Combining ability analysis for yield and yield components in mungbean [*Vigna radiata* (L.) Wilczek]. Legume Research, 2019. Print ISSN:0250-5371 / Online ISSN:0976-0571. DOI: 10.18805/LR-4063.