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Elucidation of Combining Ability and Gene in Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.]

C. J. Patel [a], R. N. Patel [b], R. A. Gami [c*] and B. A. Gameti [a]

[a] Department of Genetics and Plant Breeding, CPCA, S. D. Agricultural University, Sardarkrushinagar- 385 506, Gujarat, India.
[b] Potato Research Station, S.D. Agricultural University, Deesa-385 535, Gujarat, India.
[c] Centre for Millets Research, S.D. Agricultural University, Deesa-385 535, Gujarat, India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors CJP, RNP and RAG equally contributed in the research work and manuscript preparation. BAG helped to performed the statistical analysis and manuscript preparation. All authors read approved the final manuscript.

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ABSTRACT

Aims: To Study combining ability effects and evaluate gene action for fruit yield with associated traits of bottle gourd.
Study Design: Randomized block design.
Place and Duration of Study: The seeds of F_1 hybrids were produced during summer 2021 at Potato Research Station, S. D. Agricultural University, Deesa.
Methodology: The experimental material consisted of twelve parents, their 35 Line × Tester crosses and one standard check (ABGH 1).
Results: The analysis of variance for combining ability revealed that the mean sum of squares due to female (lines) and male (testers) were highly significant for all the traits except fruit girth, average fruit weight, chlorophyll *a,* chlorophyll *b* and total chlorophyll. The gca effects indicated that four male parents ABGS 14-25, ABGS 11-17, ABGS 11-24 and PUNJAB LONG and three female

**Corresponding author: E-mail: ramangami@sdau.edu.in;*

parents DBG 5, NDBG 132 and LOCAL were found good general combiners for fruit yield per plant and its some of the contributing traits. Based on estimates of sca effects, the most promising hybrids for fruit yield per plant were DBG 5 × ABGS 14-27, NDBG 132 × PUNJAB LONG and GPBG 108 × ABGS 11-24. The good general combiners for fruit yield and contributing traits can be utilized in intensive crossing programme and select transgressive segregants for desired characters in segregating generations to develop superior lines.

Conclusion: The ratio of σ^2_{GCA} / $\sigma^2_{SCA}$was less than unity for all the characters under study, which suggested greater role of non-additive genetic variance in the inheritance of these characters. The genetic components of variance revealed that different type of gene action were involved for fruit yield associated with different traits in bottle gourd.

Keywords: Combining ability; fruit yield; gene action; L × T analysis.

1. INTRODUCTION

Bottle gourd [*Lagenaria siceraria* (Mol) Standl.] is one of the most important cucurbitaceous vegetables due to prolific bearing habit, low cost of cultivation and its utility as a cooked vegetable. It is only cultivated species among the six species of *Lagenaria* having a somatic chromosome number 2n = 2x = 22. Considerable genetic diversity exists in this crop, which can be utilized for the exploitation of hybrid vigour. The size of the flower and monoecious condition makes the hybridization easy and convenient in this crop. The fruits being larger in size contain many seeds per fruit. According to Choudhary [1], the amount of cross pollination ranges from 60 to 80 per cent.

Combining ability analysis is a potent tool to identify the parents and sort out promising crosses as per desired traits. It also elucidates the nature of gene action involved in the inheritance of the particular trait. Therefore, combining ability analysis was carried out in the present investigation to obtain information on *gca* effects of parents (lines and testers) and *sca* effects of crosses, which would help in selecting better parents and cross combinations for their future use in a hybrid breeding programme. In addition, this will also provide information regarding the type and magnitude of gene action, which will help to choose the breeding method utilized to improve the yield and related traits. The concept of combining ability as a measure of gene action was proposed by Sprague and Tatum [2]. It is a powerful tool to discriminate between good and poor combiners and select appropriate parental material. It also provides information on the nature of gene action involved in the inheritance of various traits. Thus, it helps plant breeders to develop improved hybrids, high yielding varieties and also helps to identify the best combiner in the breeding procedure. The Line × Tester analysis technique suggested by Kempthorne [3] has been extensively used to compare with the other methods because it provides a more systematic approach to assess the combining ability of parents and crosses for different quantitative characters and contributing characters. Besides, it gives an overall genetic picture of the materials under investigation in a single generation.

2. MATERIALS AND METHODS

The experimental material comprises five females (ABG 1, NDBG 132, GPBG 108, DBG 5 and Local), seven males (ABGS 11-24, ABGS 11-19, ABGS 14-25, ABGS 14-27, Punjab Long, ABGS 11-17, GPBG 109), 35 F_1 hybrids and one standard check ABGH 1. The parents were obtained from Main Vegetables Research Station, AAU, Anand. Parents were crossed in a Line × Tester fashion during summer 2021. Hybridization was carried out through hand pollination. Simultaneously parental genotypes were also maintained through selfing to get pure seeds of parents for the experiment. The experimental materials consisted of 48 entries comprising 35 crosses and 12 parents and one standard check evaluated in Randomized Block Design with four replications during *Kharif,* 2021 at Potato Research Station, SDAU, Deesa. Each genotype was sown in two rows with the plot size 4 m × 5m. The distance between rows and within row was 2 m and 1 m, respectively. Observations on various quantitative as well as qualitative characters were recorded from three randomly selected plants in each genotype in each replication. The average of three plants for each genotype in each replication has been worked out for each character *viz.,* days to first male flower appearance, days to first female flower appearance, node number at which first male flower appearance, node number at which first female flower appearance, number of branch per

plant, fruit length (cm), fruit girth (cm), average fruit weight (g), number of fruit per plant, fruit yield per plant (kg),moisture content (%),total soluble solids (ºBrix), chlorophyll *a* (µg/g F.W.), chlorophyll *b* (µg/g F.W.) and total chlorophyll (µg/g F.W.). The replication-wise mean values for all the characters were subjected to statistical analysis. The analysis of variance was carried out as per the procedure suggested by Panse and Sukhatme [4]. The mean value of 48 genotypes (Parents, their F_1 hybrids and one standard check) were entered in the computer and combining ability analysis was carried out according to the procedure given by Kempthorne [3].

3. RESULTS AND DISCUSSION

The analysis of variance for combining ability and estimates of variance components are given in Table 1. The analysis of variance for combining ability partitioning the total genetic variance into general combining ability, representing the additive type of gene action and specific combining ability as a measure of the non-additive type of gene action was carried out for fifteen characters. The mean squares due to female (lines) and male (testers) were highly significant for the traits *viz.*, days to first male flower appearance, days to first female flower appearance, node number at which first male flower appearance, node number at which first female flower appearance, number of branch per plant, fruit length, number of fruit per plant, fruit yield per plant and moisture content*,* while for total soluble solids it was highly significant for lines only and it was significant for chlorophyll *b* for both lines and testers.. This indicated a significant contribution of both female and male towards general combining ability variance components for days to first male flower appearance, days to first female flower appearance, node number at which first male flower appearance, node number at which first female flower appearance, number of branch per plant, fruit length, number of fruit per plant, fruit yield per plant and moisture content. The mean sum of squares due to males were higher in magnitude for days to first male flower appearance, node number at which first male flower appearance, number of fruit per plant, fruit girth, average fruit weight, moisture content and fruit yield per plant than the female indicated the greater contribution of male toward these traits, while in rest of traits showed more contribution of female. The mean sum of squares due to the Line × Tester interaction were highly significant for all the traits. This signified the contribution of hybrids for specific combining ability variance components.

The ratio of σ^2_{GCA} / σ^2_{SCA} was less than unity for all the characters under study. Which suggested a greater role of non-additive genetic variance in the inheritance of these characters. The predominant role of non-additive gene action was also reported by Patel *et al.* [5], Janaranjani *et al.* [6], Shinde *et al*. [7], Rajkumar *et al*. [8], Hadiya *et al*. [9], Khot *et al*. [10] and Patel and Mehta [11] in bottle gourd.

The magnitude of specific combining ability variance was higher than general combining ability variance for all of the traits *viz.,*days to first male flower appearance, days to first female flower appearance, node number at which first male flower appearance, node number at which first female flower appearance, number of branch per plant, fruit length, fruit girth, average fruit weight , number of fruit per plant, fruit yield per plant, moisture content, total soluble solids, chlorophyll *a*, chlorophyll *b* and total chlorophyll which indicated the importance of non-additive gene effects in the inheritance of these traits, which suggesting exploitation of these traits for improvement of yield through heterosis breeding. The above results were in accordance with the findings of Gayakawad [12], Janaranjani *et al.* [6], Khot *et al*. [10] for days to first male flower appearance; Gayakawad [12], Janaranjani *et al.* [6], Shinde *et al*. [7], Khot [13], Hadiya *et al*. [9], Khot *et al*. [10],Patel and Mehta [11] for days to first female flower appearance; Gayakawad [12], Janaranjani *et al.* [6] for node number at which first male flower appearance; Gayakawad [12], Janaranjani *et al.* [6], Shinde *et al*. [7], Khot [13], Hadiya *et al*. [9], Khot *et al*. [10] for node number at which first female flower appearance; Gayakawad [12], Khot [13], Khot *et al*. [10] for number of branch per plant; Patel *et al.* [5], Gayakawad [12], Janaranjani *et al.* [6], Shinde *et al*. [7], Khot [13], Khot *et al*. [10], Patel and Mehta [11] for fruit length; Gayakawad [12], Janaranjani *et al.* [6], Hadiya *et al*. [9], Patel and Mehta [11] for fruit girth;, Janaranjani *et al.* [6], Shinde *et al*. [7], Khot [13], Hadiya *et al*. [9], Patel and Mehta [11] for average fruit weight; Gayakawad [12], Janaranjani *et al.* [6], Shinde *et al*. [7], Khot [13], Hadiya *et al*. [9], Patel and Mehta [11] for number of fruit per plant; Gayakawad [12], Janaranjani *et al.* [6], Shinde *et al*. [7], Khot [13], Hadiya *et al*. [9], Khot *et al*. [10], Patel and Mehta [11] for fruit yield per plant; Patel and Mehta [9] for total soluble solids in bottle gourd.

Table 1. Analysis of variance (mean square) for combining ability, estimates of components of variance and their ratio for various characters in bottle gourd

Sources of variation	d.f.	Days to first male flower appearance	Days to first female flower appearance	Node number at which first male flower appearance	Node number at which first female flower appearance	Number of branch per plant	Fruit length (cm)	Fruit girth (cm)
Replication	**3**	1.98	0.24 **	1.36	0.22	0.99	9.14	1.62
Hybrid (Crosses)	**34**	53.64**	100.16**	20.64**	38.08**	9.40**	143.09 **	19.68 *
Female in hybrid	**4**	52.36**	135.01**	18.63**	50.17**	5.32**	342.52 **	9.74
Male in hybrid	**6**	59.68**	92.24**	22.89**	38.95**	3.82**	105.25 **	18.54
Female × Male (L × T)	**24**	52.34**	96.34**	20.41**	35.84**	11.48**	119.31 **	21.62 **
Error	**102**	2.76	1.09	0.93	1.15	0.58	6.51	11.57
Components of variance:								
σ^2 Females		0.00	1.38	-	0.51	-	7.97	-
σ^2 Males		0.37	-	0.12	0.16	-	-	-
σ^2_{GCA}		0.15	0.72	0.01	0.36	-	4.36	-
σ^2_{SCA}		12.40	23.81	4.87	8.67	2.72	28.20	2.51
σ^2_{GCA} / σ^2_{SCA}		0.01	0.03	0.00	0.04	-	0.15	-

Sources of variation	d.f.	Average fruit weight (g)	Number of fruit per plant	Fruit yield per plant (kg)	Moisture content (%)	Total soluble solids (ºBrix)	Chlorophyll *a* (µg/g F.W.)	Chlorophyll *b* (µg/g F.W.)	Total Chlorophyll (µg/g F.W.)
Replication	**3**	159.04	0.31	0.05	1.87	0.15	76.39	1.88	54.80
Hybrid (Crosses)	**34**	65607.89**	19.61**	3.83**	27.25**	0.69**	14524.15**	909.94**	13693.55**
Female in hybrid	**4**	47549.11	11.65**	2.26**	24.44**	1.29**	24535.18	1928.11*	19104.94
Male in hybrid	**6**	69034.73	25.66**	5.58**	38.08**	0.22	17084.93	1510.72*	17390.38
Female × Male (L × T)	**24**	67760.98**	19.42**	3.66**	25.02**	0.71**	12215.45**	590.05**	11867.45**
Error	**102**	82.75	0.20	0.03	1.07	0.11	45.34	21.32	60.60

Components of variance:								
σ^2 Females	1695.23	-	-	-	0.02	874.64	68.10	680.16
σ^2 Males	3447.60	0.31	0.10	0.65	-	851.98	74.47	866.49
σ^2_{GCA}	2425.38	-	0.01	0.26	0.00	865.20	70.75	757.79
σ^2_{SCA}	16919.56	4.81	0.91	5.99	0.15	3042.53	142.18	2951.71
σ^2_{GCA} / σ^2_{SCA}	0.14	-0.01	0.01	0.04	0.00	0.28	0.50	0.26

** and ** indicate significant at 5% and 1% levels of significance, respectively. Where, '-' indicates -ve estimate*

The general combining ability effects of twelve parents for fifteen traits are depicted in Table 2. The *gca* effects of parents explicated that none of the parents was consistently good general combiner for all the traits under study. The male parent ABGS 11-17 was good general combiner for days to first male flower appearance, average fruit weight, number of fruit per plant, fruit yield per plant and moisture content. The female parent NDBG 132 was good general combiner for days to first male flower appearance, days to first female flower appearance, node number at which first female flower appearance, fruit length, number of fruit per plant, fruit yield per plant, chlorophyll *b* and moisture content. The parent LOCAL was good general combiner for days to first female flower appearance, node number at which first male flower appearance, node number at which first female flower appearance, fruit length, average fruit weight, fruit yield per plant, chlorophyll *b* and moisture content. The male parent ABGS 14-25 was good general combiner for days to first male flower appearance, days to first female flower appearance, node number at which first female flower appearance, number of fruit per plant, fruit yield per plant and chlorophyll *b*. The female DBG 5 was good general combiner for average fruit weight, fruit yield per plant and total soluble solids. The male parent GPBG 109 was good general combiner for days to first male flower appearance, node number at which first female flower appearance, number of fruit per plant, chlorophyll *a* and total chlorophyll. The female parent ABG 1 was good general combiner for node number at which the first male flower appearance, number of branch per plant, number of fruit per plant, chlorophyll *a* and total chlorophyll. The parent GPBG 108 was good general combiner for number of branch per plant. Parent ABGS 11-19 was good general combiner for node number at which the first male flower appearance, number of branch per plant, fruit length and average fruit weight. ABGS 11-24 was found good general combiner for node number at which first male flower appearance, number of fruit per plant, fruit yield per plant and moisture content. The parent ABGS 14-27 was found good general combiner for node number at which first male flower appearance, node number at which first female flower appearance, number of branch per plant and moisture content. PUNJAB LONG was found good general combiner for days to first female flower appearance, number of fruit per plant, fruit yield per plant, chlorophyll *a* and total chlorophyll.

The results based on specific combining ability effects of hybrids revealed that none of the hybrids was consistently superior for all the characters given in Table 3. Considering the performance of the *sca* effects, seventeen hybrids for fruit yield per plant manifested desirable and significant *sca* effects. In the case of other component traits, ten hybrids for days to first male flower appearance, twelve hybrids for days to first female flower appearance, ten hybrids for node number at which first male flower appearance, fourteen hybrids for node number at which first female flower appearance, twelve hybrids for number of branch per plant, ten hybrids for fruit length, one hybrid for fruit girth, thirteen hybrids for average fruit weight, thirteen hybrids for number of fruit per plant, nine hybrids for moisture content, eight hybrids for total soluble solids, thirteen hybrids for chlorophyll *a*, ten hybrids for chlorophyll *b* and thirteen hybrids fortotal Chlorophyll manifested significant and desirable *sca* effects. Based on estimates of *sca* effects, the most promising hybrids for fruit yield per plant were DBG 5 × ABGS 14-27, NDBG 132 × PUNJAB LONG and GPBG 108 × ABGS 11-24. Furthermore, these crosses also exhibited a positive significant sca effects for other contributing traits *viz*. Fruit length, average fruit weight, Number of fruit per plant, and number of branch per plant. As, these hybrids showing significant *sca* effects can directly used for a hybrid breeding programmes.

The best three crosses selected based on sca effects for various traits are depicted in Table 4. A perusal of data implied that none of the crosses had high-ranking sca effects for all the traits. The data revealed that the high-ranking sca for most of the traits were accompanied by high ranking per se performance, which proved the predominant role of non-additive gene effects in the expression of fruit yield per plant. For fruit yield per plant, they seem that hybrids with high sca effects analogue, high heterobeltiosis in some of the yield and component traits suggested that sca performance might be an essential criterion for choosing the best hybrids.

The crosses DBG 5 × ABGS 14-27, NDBG 132 × PUNJAB LONG and GPBG 108 × ABGS 11-24 for fruit yield per plant, recorded the highest SCA effects which were also highest in persent performance which involved good × poor; good × good and average × good parent combinations for fruit yield per plant parent combinations, respectively. Thus, the cross combination with

Table 2. The estimates of general combining ability (*gca*) effects of the parents for various characters in bottle gourd

Sr. No.	Parents	Days to first male flower appearance		Days to first female flower appearance		Node number at which first male flower appearance		Node number at which first female flower appearance		Number of branch per plant		Fruit length		Fruit girth	
Female Parents (Lines)															
1	ABG 1	0.14	(A)	1.87**	(P)	-0.42*	(G)	-0.19	(A)	0.41**	(G)	-1.16*	(P)	-0.68	(A)
2	DBG 5	1.26**	(P)	0.75**	(P)	0.21	(A)	1.11**	(P)	-0.36*	(P)	0.00	(A)	0.80	(A)
3	GPBG 108	1.13**	(P)	1.52**	(P)	1.24**	(P)	1.61**	(P)	0.43**	(G)	-4.95**	(P)	-0.05	(P)
4	NDBG 132	-2.10**	(G)	-3.54**	(G)	-0.09	(A)	-1.05**	(G)	-0.52**	(P)	4.54**	(G)	-0.41	(A)
5	LOCAL	-0.44	(A)	-0.60**	(G)	-0.94**	(G)	-1.48**	(G)	0.04	(A)	1.57**	(G)	0.34	(A)
S. Em. ±		**0.31**		**0.20**		**0.18**		**0.20**		**0.14**		**0.48**		**0.64**	
Male Parents (Testers)															
1	ABGS 11-17	-2.06**	(G)	1.33**	(P)	2.01**	(P)	1.99**	(P)	-0.24	(A)	-1.03	(A)	0.06	(A)
2	ABGS 11-19	3.22**	(P)	2.69**	(P)	-0.73**	(G)	-0.15	(A)	0.40*	(G)	4.95**	(G)	0.39	(A)
3	ABGS 11-24	0.62	(A)	1.01**	(P)	-0.51*	(G)	1.35**	(P)	0.26	(A)	0.25	(A)	-1.99**	(A)
4	ABGS 14-25	-1.14**	(G)	-3.32**	(G)	-0.14	(A)	-1.75**	(G)	-0.10	(A)	-1.48**	(P)	0.01	(A)
5	ABGS 14-27	0.29	(A)	0.80**	(P)	-1.15**	(G)	-1.41**	(G)	0.61**	(G)	-0.60	(A)	0.48	(A)
6	GPBG 109	-1.19**	(G)	-0.07	(A)	-0.27	(A)	-0.66**	(G)	-0.34*	(P)	-1.81**	(P)	-0.06	(A)
7	PUNJAB LONG	0.26	(A)	-2.44**	(G)	0.79**	(P)	0.63**	(P)	-0.60**	(P)	-0.29	(A)	1.10	(A)
S. Em. ±		**0.37**		**0.23**		**0.22**		**0.24**		**0.17**		**0.57**		**0.76**	

Sr. No.	Parents	Average fruit weight		Number of fruit per plant		Fruit yield per plant		Moisture content		Total soluble solids		Chlorophyll *a*		Chlorophyll *b*		Total Chlorophyll	
Female parents (Lines)																	
1	ABG 1	-23.09**	(P)	0.18*	(G)	-0.48**	(P)	-0.05	(A)	-0.04	(A)	47.25**	(G)	-6.65**	(P)	40.60**	(G)
2	DBG 5	34.47**	(G)	-0.67**	(P)	0.08*	(G)	-1.58**	(P)	0.30**	(G)	-26.44**	(P)	-4.96**	(P)	-31.40**	(P)
3	GPBG 108	-47.91**	(P)	-0.18*	(P)	-0.01	(A)	0.30	(A)	-0.04	(A)	9.22**	(G)	-5.72**	(P)	3.50**	(G)
4	NDBG 132	-14.22**	(P)	1.02**	(G)	0.21**	(G)	0.78**	(G)	-0.29**	(P)	-10.68**	(P)	5.20**	(G)	-5.48**	(P)
5	LOCAL	50.74**	(G)	-0.35**	(P)	0.21**	(G)	0.55**	(G)	0.07	(A)	-19.35**	(P)	12.12**	(G)	-7.22**	(P)
S. Em. ±		**1.72**		**0.10**		**0.03**		**0.20**		**0.06**		**1.27**		**1.00**		**1.47**	
Male parents (Testers)																	
1	ABGS 11-17	85.95**	(G)	1.10**	(G)	0.45**	(G)	1.33**	(G)	0.05	(A)	-34.05**	(P)	-8.66**	(P)	-42.71**	(P)
2	ABGS 11-19	69.72**	(G)	-1.40**	(P)	-0.61**	(P)	0.13	(A)	-0.18*	(P)	12.12**	(G)	-12.67**	(P)	-0.56	(A)
3	ABGS 11-24	-56.55**	(P)	1.08**	(G)	0.26**	(G)	0.81**	(G)	-0.07	(A)	-27.38**	(P)	3.41**	(G)	-23.97***	(P)
4	ABGS 14-25	-18.30**	(P)	0.23*	(G)	0.52**	(G)	-2.26**	(P)	0.14	(A)	-7.18**	(P)	13.08**	(G)	5.90**	(G)
5	ABGS 14-27	-7.47**	(P)	-1.74**	(P)	-0.70**	(P)	1.13**	(G)	0.04	(A)	-9.33**	(P)	4.39**	(G)	-4.94**	(P)
6	GPBG 109	-3.63	(A)	0.28**	(G)	-0.33**	(P)	0.41	(A)	0.05	(A)	52.47**	(G)	-2.56*	(P)	49.91**	(G)
7	PUNJAB LONG	-69.72**	(P)	0.45**	(G)	0.41**	(G)	-1.56**	(P)	-0.03	(A)	13.36**	(G)	3.01**	(G)	16.37**	(G)
S. Em. ±		**2.03**		**0.10**		**0.04**		**0.23**		**0.07**		**1.51**		**1.03**		**1.74**	

** and ** indicate significant at 5% and 1% levels of significance, respectively. The letters in parenthesis showed the status of parents, where: G = Good general combiner; A = Average general combiner and P = Poor general combiner*

Table 3. The estimates of specific combining ability (*sca*) effects of the crosses for various characters in bottle gourd

Sr. No.	Hybrids	Days to first male flower appearance	Days to first female flower appearance	Node number at which first male flower appearance	Node number at which first female flower appearance	Number of branch per plant
1	ABG 1 × ABGS 11-17	1.86*	0.74	0.84	2.12**	0.72
2	ABG 1 × ABGS 11-19	-3.18**	-6.29**	-0.84	-2.08**	1.01**
3	ABG 1 × ABGS 11-24	-2.07*	0.64	-0.56	-1.91**	-0.36
4	ABG 1 × ABGS 14-25	-1.48	0.14	-1.60**	-2.06**	0.42
5	ABG 1 × ABGS 14-27	0.26	7.61**	3.99**	5.93**	1.04**
6	ABG 1 × GPBG 109	-0.26	-4.27**	-1.63**	-5.56**	-2.84**
7	ABG 1 × PUNJAB LONG	4.87**	1.43**	-0.20	3.56**	0.01
8	DBG 5 × ABGS 11-17	0.15	-3.06**	-4.12**	-5.93**	1.16**
9	DBG 5 × ABGS 11-19	0.04	3.16**	1.45**	3.71**	0.70
10	DBG 5 × ABGS 11-24	3.56**	6.76**	1.23*	0.87	0.66
11	DBG 5 × ABGS 14-25	1.74*	-1.07*	1.69**	1.64**	1.11**
12	DBG 5 × ABGS 14-27	-7.03**	-3.19**	-0.83	-1.94**	-2.10**
13	DBG 5 × GPBG 109	4.04**	0.68	1.33**	1.89**	1.76**
14	DBG 5 × PUNJAB LONG	-2.49**	-3.29**	-0.74	-0.24	-3.30**
15	GPBG 108 × ABGS 11-17	-1.80*	2.93**	-0.58	0.07	-3.22**
16	GPBG 108 × ABGS 11-19	6.09**	6.57**	1.64**	0.62	-1.10**
17	GPBG 108 × ABGS 11-24	3.35**	-0.83	1.19*	-0.13	0.95*
18	GPBG 108 × ABGS 14-25	0.12	0.25	0.99*	-1.28*	0.57
19	GPBG 108 × ABGS 14-27	-3.06**	0.72	-3.17**	-1.11*	0.43
20	GPBG 108 × GPBG 109	-3.16**	-7.34**	-2.54**	1.06*	0.97*
21	GPBG 108 × PUNJAB LONG	-1.53	-2.3**	2.47**	0.76	1.40**
22	NDBG 132 × ABGS 11-17	0.51	-2.84	1.17*	1.31*	0.57
23	NDBG 132 × ABGS 11-19	-0.85	0.21	-1.59**	-2.38**	-0.81*
24	NDBG 132 × ABGS 11-24	0.24	0.31	-1.40**	2.70**	-2.10**
25	NDBG 132 × ABGS 14-25	0.59	2.64**	-2.01**	-0.78	0.69
26	NDBG 132 × ABGS 14-27	2.99**	0.36	-0.42	-1.11*	-0.03
27	NDBG 132 × GPBG 109	0.06	-0.11	4.62**	3.22**	1.17**
28	NDBG 132 × PUNJAB LONG	-3.55**	-0.58	-0.36	-2.95**	0.52
29	LOCAL × ABGS 11-17	-0.73	2.22**	2.69**	2.42**	0.76*

Sr. No.	Hybrids		Days to first male flower appearance	Days to first female flower appearance	Node number at which first male flower appearance	Node number at which first female flower appearance	Number of branch per plant
30	LOCAL × ABGS 11-19		-2.09*	-3.65**	-0.65	0.13	0.21
31	LOCAL × ABGS 11-24		-5.08**	-6.88**	-0.46	-1.53**	0.84*
32	LOCAL × ABGS 14-25		-0.98	-1.97**	0.93	2.48**	-2.79**
33	LOCAL × ABGS 14-27		6.84**	-5.50**	0.43	-1.77**	0.66
34	LOCAL × GPBG 109		-0.68	11.04**	-1.77**	-0.60	-1.06**
35	LOCAL × PUNJAB LONG		2.71**	4.74**	-1.17*	-1.14*	1.38**
S.Em.±			0.83	0.52	0.48	0.54	0.38
Range		**Minimum**	-7.03	-7.34	-4.12	-5.93	-3.30
		Maximum	6.84	11.04	4.62	5.93	1.76
Significant *sca* effects			20	22	22	26	21
No. of +ve significant			10	10	12	12	12
No. of –ve significant			10	12	10	14	09

** and ** indicate significant at 5% and 1% levels of significance, respectively.*

Table 3 Continued…

Sr. No.	Hybrids	Fruit length	Fruit girth	Average fruit weight	Number of fruit per plant	Fruit yield per plant
1	ABG 1 × ABGS 11-17	-1.10	-0.50	-7.08	1.15**	0.75**
2	ABG 1 × ABGS 11-19	0.67	0.25	-13.76**	0.24	-0.28**
3	ABG 1 × ABGS 11-24	2.28	1.55	-41.25**	1.83**	0.81**
4	ABG 1 × ABGS 14-25	-4.99**	-0.95	76.34**	-1.14**	-0.17*
5	ABG 1 × ABGS 14-27	0.63	-0.33	3.84	-0.68**	-0.06
6	ABG 1 × GPBG 109	-3.65**	-0.72	17.92**	2.05**	0.83**
7	ABG 1 × PUNJAB LONG	6.16**	0.71	-36.00**	-3.45**	-1.89**
8	DBG 5 × ABGS 11-17	12.90**	7.77**	-80.89**	0.75**	-0.05
9	DBG 5 × ABGS 11-19	-2.67*	-0.32	40.77**	0.49*	0.30**
10	DBG 5 × ABGS 11-24	-5.39**	-2.10	-116.31**	-2.15**	-1.42**
11	DBG 5 × ABGS 14-25	-3.99**	-1.35	40.86**	-1.46**	-0.94**
12	DBG 5 × ABGS 14-27	4.63**	-0.48	190.86**	2.00**	1.55**
13	DBG 5 × GPBG 109	2.68*	-0.62	-145.89**	-1.02**	0.20*

Sr. No.	Hybrids		Fruit length	Fruit girth	Average fruit weight	Number of fruit per plant	Fruit yield per plant
14	DBG 5 × PUNJAB LONG		-8.17**	-2.90	70.61**	1.40**	0.35**
15	GPBG 108 × ABGS 11-17		-4.40**	-1.13	-78.51**	-3.99**	-0.94**
16	GPBG 108 × ABGS 11-19		1.03	0.54	-59.36**	0.43	-0.55**
17	GPBG 108 × ABGS 11-24		-0.18	0.00	-11.01*	1.86**	1.15**
18	GPBG 108 × ABGS 14-25		6.80**	0.25	-52.17**	-0.23	0.01
19	GPBG 108 × ABGS 14-27		0.42	-0.55	-56.34**	1.35**	-0.32**
20	GPBG 108 × GPBG 109		2.88*	-0.51	284.83**	-0.42	0.23**
21	GPBG 108 × PUNJAB LONG		-6.55**	1.41	-27.44**	0.99**	0.42**
22	NDBG 132 × ABGS 11-17		-4.72**	-2.61	-13.03**	-0.60**	-0.77**
23	NDBG 132 × ABGS 11-19		4.79**	-0.03	-96.38**	-1.43**	0.24**
24	NDBG 132 × ABGS 11-24		5.49**	-0.47	-62.62**	-2.75**	-0.76**
25	NDBG 132 × ABGS 14-25		1.06	1.44	103.30**	0.86**	0.09
26	NDBG 132 × ABGS 14-27		-6.73**	1.22	25.80**	2.23**	0.24**
27	NDBG 132 × GPBG 109		-3.02*	2.59	-44.70**	1.05**	-0.20*
28	NDBG 132 × PUNJAB LONG		3.13*	-2.15	87.64**	0.63**	1.16**
29	LOCAL × ABGS 11-17		-2.67*	-3.52*	179.52**	2.69**	1.01**
30	LOCAL × ABGS 11-19		-3.82**	-0.44	128.74**	0.27	0.28**
31	LOCAL × ABGS 11-24		-2.20	1.02	231.18**	1.20**	0.22*
32	LOCAL × ABGS 14-25		1.11	0.61	-168.32**	1.98**	1.01**
33	LOCAL × ABGS 14-27		1.06	0.14	-164.15**	-4.90**	-1.41**
34	LOCAL × GPBG 109		1.11	-0.74	-112.15**	-1.67**	-1.06**
35	LOCAL × PUNJAB LONG		5.43**	2.93	-94.81**	0.42	-0.04
S.Em.±			1.28	1.70	4.55	0.22	0.09
Range		**Minimum**	-8.17	-3.52	-168.32	-4.90	-1.89
		Maximum	12.90	7.77	284.83	2.69	1.55
Significant *sca* effects			23	02	33	33	30
No. of +ve significant			10	01	13	13	17
No. of –ve significant			13	01	20	20	13

** and ** indicate significant at 5% and 1% levels of significance, respectively.*

Table 3 Continued…

Sr. No.	Hybrids	Moisture content	Total soluble solids	Chlorophyll *a*	Chlorophyll *b*	Total Chlorophyll
1	ABG 1 × ABGS 11-17	0.41	-0.43*	-21.32**	-9.65**	-30.97**
2	ABG 1 × ABGS 11-19	-2.72**	-0.21	17.76**	-4.88*	12.89**
3	ABG 1 × ABGS 11-24	0.58	0.73**	-56.46**	0.77	-55.69**
4	ABG 1 × ABGS 14-25	-1.81**	-0.52**	-46.60**	-13.98**	-60.58**
5	ABG 1 × ABGS 14-27	-1.40**	0.22	-32.48**	-3.70	-36.18**
6	ABG 1 × GPBG 109	2.28**	-0.45**	185.47**	5.38*	190.85**
7	ABG 1 × PUNJAB LONG	2.65**	0.66**	-46.38**	26.06**	-20.32**
8	DBG 5 × ABGS 11-17	-1.29*	0.16	-43.25**	3.73	-39.52**
9	DBG 5 × ABGS 11-19	4.71**	-0.13	-2.71	-8.94**	-11.65**
10	DBG 5 × ABGS 11-24	2.61**	-0.25	-1.03	2.00	0.97
11	DBG 5 × ABGS 14-25	0.06	0.05	-23.94**	10.22**	-13.72**
12	DBG 5 × ABGS 14-27	0.36	-0.33*	33.76**	1.18	34.93**
13	DBG 5 × GPBG 109	-3.36**	0.14	-31.03**	-0.04	-31.08**
14	DBG 5 × PUNJAB LONG	-3.09**	0.34*	68.20**	-8.14**	60.06**
15	GPBG 108 × ABGS 11-17	-0.25	0.36*	20.00**	7.84**	27.84**
16	GPBG 108 × ABGS 11-19	2.29**	0.02	-17.11**	12.33**	-4.78
17	GPBG 108 × ABGS 11-24	-3.20**	-0.34*	14.20**	-1.28	12.92**
18	GPBG 108 × ABGS 14-25	1.52**	0.37*	74.90**	-22.23**	52.67**
19	GPBG 108 × ABGS 14-27	0.07	0.13	-4.50	0.71	-3.79
20	GPBG 108 × GPBG 109	1.18*	-0.20	-70.09**	-4.04	-74.12**
21	GPBG 108 × PUNJAB LONG	-1.59**	-0.33*	-17.41**	6.66**	-10.75**
22	NDBG 132 × ABGS 11-17	0.25	-0.61**	41.14**	1.92	43.05**
23	NDBG 132 × ABGS 11-19	1.05*	0.14	-9.47**	7.57**	-1.90
24	NDBG 132 × ABGS 11-24	0.14	-0.08	32.75**	-8.42**	24.32**
25	NDBG 132 × ABGS 14-25	-0.28	0.52**	10.19**	1.85	12.04**
26	NDBG 132 × ABGS 14-27	0.36	-0.07	-25.48**	11.94**	-13.54**
27	NDBG 132 × GPBG 109	0.40	0.20	-38.97**	3.27	-35.70**
28	NDBG 132 × PUNJAB LONG	-1.94**	-0.11	-10.15**	-18.13**	-28.28**
29	LOCAL × ABGS 11-17	0.87	0.51**	3.43	-3.84	-0.41
30	LOCAL × ABGS 11-19	-5.34**	0.17	11.53**	-6.08**	5.45
31	LOCAL × ABGS 11-24	-0.14	-0.07	10.53**	6.93**	17.47**

Sr. No.	Hybrids		Moisture content	Total soluble solids	Chlorophyll *a*	Chlorophyll *b*	Total Chlorophyll
32	LOCAL × ABGS 14-25		0.50	-0.42*	-14.55**	24.14**	9.59*
33	LOCAL × ABGS 14-27		0.62	0.05	28.70**	-10.12**	18.59**
34	LOCAL × GPBG 109		-0.50	0.31	-45.38**	-4.57	-49.96**
35	LOCAL × PUNJAB LONG		3.97**	0.56**	5.74	-6.46**	-0.72
S.Em.±			0.52	0.17	3.38	2.31	3.89
Range		**Minimum**	-5.34	-0.61	-70.09	-22.23	-74.12
		Maximum	4.71	0.73	185.47	26.06	190.85
Significant *sca* effects			19	16	30	21	28
No. of +ve significant			09	08	13	10	13
No. of –ve significant			10	08	17	11	15

** and ** indicate significant at 5% and 1% levels of significance, respectively.*

Table 4. Top three ranking parents concerning mean performance and *gca* effects; F_1 hybrids concerning mean performance, *sca* effects, heterosis over better parent and standard check ABGH 1 in bottle gourd

Traits	Best performing parents	Best general combiners	Best performing hybrids	Hybrids with high *sca* effects	GCA of parents	*sca* effects	Heterosis over	
							Better parent	Standard check (ABGH 1)
Days to first male flower appearance	LOCAL (50.67)	NDBG 132	DBG 5 × ABGS 14-27 (42.00)	DBG 5 × ABGS 14-27	P × A	-7.03**	-8.53**	-7.70**
	ABGS 14-27 (45.92)	ABGS 11-17	NDBG 132 × PUNJAB LONG (42.08)	LOCAL × ABGS 11-24	A × A	-5.08**	-12.80**	-6.42*
	DBG 5 (46.58)	GPBG 109	LOCAL × ABGS 11-24 (42.58)	NDBG 132 × PUNJAB LONG	G × A	-3.55**	-16.81**	-7.51**
Days to first female flower appearance	NDBG 132 (47.08)	NDBG 132	NDBG 132 × PUNJAB LONG (42.92)	GPBG 108 × GPBG 109	P × A	-7.34**	-14.97**	-6.13**
	ABGS 14-27 (49.59)	ABGS 14-25	LOCAL × ABGS 11-24 (43.00)	LOCAL × ABGS 11-24	G × P	-6.88**	-9.31**	-7.38**
	ABGS 11-19 (48.18)	PUNJAB LONG	GPBG 108 × GPBG 109 (43.58)	ABG 1 × ABGS 11-19	P × P	-6.29**	1.41	2.86
Node number at which first male flower	NDBG 132 (11.72)	ABGS 14-27	GPBG 108 × ABGS 14-27 (8.00)	DBG 5 × ABGS 11-17	A × P	-4.12**	-23.32**	-21.37**
	ABGS 11-19	LOCAL	LOCAL × GPBG 109	GPBG 108 × ABGS 14-	P × G	-3.17**	-48.34**	-33.34**

Traits	Best performing parents	Best general combiners	Best performing hybrids	Hybrids with high *sca* effects	GCA of parents	*sca* effects	Heterosis over	
							Better parent	Standard check (ABGH 1)
appearance	(10.09)		(6.58)	27				
	ABGS 11-17 (10.00)	ABGS 11-19	NDBG 132 × ABGS 11-19 (7.17)	GPBG 108 × GPBG 109	P × A	-2.54**	-25.58**	-17.95**
Node number at which first female flower appearance	ABGS 14-27 (11.42)	ABGS 14-25	ABG 1 × GPBG 109 (3.50)	DBG 5 × ABGS 11-17	P × P	-5.93**	-46.19**	-37.87**
	ABGS 11-19 (12.92)	LOCAL	LOCAL × ABGS 14-27 (5.25)	ABG 1 × GPBG 109	A × G	-5.56**	-73.75**	-69.30**
	NDBG 132 (14.66)	ABGS 14-27	ABG 1 × ABGS 14-25 (5.92)	NDBG 132 × PUNJAB LONG	G × P	-2.95**	-46.26**	-42.62**
Number of branch per plant	ABGS 11-19 (14.50)	ABGS 14-27	ABG 1 × ABGS 14-27 (24.17)	DBG 5 × GPBG 109	P× P	1.76**	63.51**	94.55**
	GPBG 109 (14.17)	GPBG 108	ABG 1 × ABGS 11-19 (23.92)	GPBG 108 × PUNJAB LONG	G × P	1.40**	84.23**	95.95**
	ABG 1(12.92)	ABG 1	GPBG 108 × ABGS 11-24 (23.75)	LOCAL × PUNJAB LONG	A × P	1.38**	80.93**	92.45**

*Value in parenthesis indicated mean data. * and ** indicate significant at 5% and 1% levels of significance, respective. Where: G = Good general combiner; A = Average general combiner and P = Poor general combiner*

Table 4 Continued…

Traits	Best performing parents	Best general combiners	Best performing hybrids	Hybrids with high *sca* effects	GCA of parents	*sca* effects	Heterosis over	
							Better parent	Standard check (ABGH 1)
Fruit length (cm)	NDBG 132 (49.25)	ABGS 11-19	NDBG 132 × ABGS 11-19 (56.75)	DBG 5 × ABGS 11-17	A × A	12.90**	35.85**	126.39**
	LOCAL (47.25)	NDBG 132	DBG 5 × ABGS 11-17 (54.33)	GPBG 108 × ABGS 14-25	P × P	6.80**	6.64	78.48**
	GPBG 109 (40.17)	LOCAL	NDBG 132 × ABGS 11-24 (56.75)	ABG 1 × PUNJAB LONG	P × A	6.16**	22.78**	96.53**
Fruit girth (cm)	GPBG 108 (19.58)	-	DBG 5 × ABGS 11-17 (27.67)	DBG 5 × ABGS 11-17	A × A	7.77**	43.70**	28.19**
	LOCAL (19.50)	-	LOCAL × PUNJAB	-	-	-	-	-

Traits	Best performing parents	Best general combiners	Best performing hybrids	Hybrids with high *sca* effects	GCA of parents	*sca* effects	Heterosis over	
							Better parent	Standard check (ABGH 1)
			LONG (23.42)					
	ABGS 11-17 (19.25)	-	GPBG 108 × PUNJAB LONG (21.50)	-	-	-	-	-
Average fruit weight (g)	ABGS 11-19 (750.83)	ABGS 11-17	LOCAL × ABGS 11-17 (826.67)	GPBG 108 × GPBG 109	P × A	284.83**	66.51**	92.35**
	ABGS 14-27 (666.25)	ABGS 11-19	LOCAL × ABGS 11-19 (759.66)	LOCAL × ABGS 11-24	G × P	231.18**	39.01**	90.31**
	ABGS 11-17 (579.58)	LOCAL	GPBG 108 × GPBG 109 (743.75)	DBG 5 × ABGS 14-27	G × P	190.86**	9.32**	88.37**
Number of fruit per plant	ABGS 14-25 (11.58)	ABGS 11-17	LOCAL × ABGS 11-17 (12.75)	LOCAL × ABGS 11-17	P × G	2.69**	18.60**	7.75**
	ABGS 11-17 (10.75)	ABGS 11-24	ABG 1 × ABGS 11-24 (12.42)	NDBG 132 × ABGS 14-27	G × P	2.23**	17.11**	-8.46**
	DBG 5 (10.50)	NDBG 132	GPBG 108 × ABGS 11-24 (12.08)	ABG 1 × GPBG 109	G × G	2.05**	32.72**	0.00
Fruit yield per plant (kg)	DBG 5 (4.48)	ABGS 14-25	NDBG 132 × PUNJAB LONG (5.48)	DBG 5 × ABGS 14-27	G × P	1.55**	3.63	3.13
	ABGS 11-17 (4.35)	ABGS 11-17	LOCAL × ABGS 14-25 (5.44)	NDBG 132 × PUNJAB LONG	G × G	1.16**	53.04**	21.64**
	ABGS 14-25 (4.26)	PUNJAB LONG	LOCAL × ABGS 11-17 (5.38)	GPBG 108 × ABGS 11-24	A × G	1.15**	41.15**	13.17**

*Value in parenthesis indicated mean data. * and ** indicate significant at 5% and 1% levels of significance, respective. Where: G = Good general combiner; A = Average general combiner and P = Poor general combiner*

Table 4 Continued…

Traits	Best performing parents	Best general combiners	Best performing hybrids	Hybrids with high *sca* effects	GCA of parents	*sca* effects	Heterosis over	
							Better parent	Standard check (ABGH 1)
Moisture content (%)	ABGS 14-27 (94.65)	ABGS 11-17	DBG 5 × ABGS 11-19 (95.84)	DBG 5 × ABGS 11-19	P × A	4.71**	4.53**	1.72*
	NDBG 132 (94.50)	ABGS 14-27	LOCAL × PUNJAB LONG (95.53)	LOCAL × PUNJAB LONG	G × P	3.97**	1.26	1.40
	PUNJAB LONG (94.34)	ABGS 11-24	LOCAL × ABGS 11-17 (95.33)	ABG 1 × PUNJAB LONG	A × P	2.65**	-0.77	-0.64
Total soluble solids (ºBrix)	ABGS 14-27 (5.45)	DBG 5	LOCAL × ABGS 11-17 (5.53)	ABG 1 × ABGS 11-24	A × A	0.73**	14.00**	12.40**
	ABGS 11-19 (5.10)	-	ABG 1 × ABGS 11-24 (5.52)	ABG 1 × PUNJAB LONG	A × A	0.66**	13.43**	11.89*
	GPBG 108 (4.89)	-	DBG 5 × PUNJAB LONG (5.51)	LOCAL × PUNJAB LONG	A × A	0.56**	-7.05	-10.70*
Chlorophyll *a* (µg/g F.W.)	ABGS 11-24(553.09)	GPBG 109	ABG 1 × GPBG 109 (754.88)	ABG 1 × GPBG 109	G × G	185.47**	59.28**	72.73**
	GPBG 109 (529.40)	ABG 1	ABG 1× ABGS 11-19 (546.82)	GPBG 108 × ABGS 14-25	G × P	74.90**	19.14**	25.08**
	ABG 1 (473.94)	PUNJAB LONG	GPBG 108 × ABGS 14-25 (546.63)	DBG 5 × PUNJAB LONG	P× G	68.20**	-0.87	20.09**
Chlorophyll *b* (µg/g F.W.)	ABGS 14-27 (104.75)	ABGS 14-25	LOCAL × ABGS 14-25 (90.13)	ABG 1 × PUNJAB LONG	P × G	26.06**	-1.08	-22.98**
	ABGS 14-25 (92.42)	LOCAL	-	LOCAL × ABGS 14-25	G × G	24.14**	-2.48	9.83*
	GPBG 109 (74.33)	NDBG 132	-	GPBG 108 × ABGS 11-19	P × P	12.33**	-51.60**	-57.69**
Total chlorophyll (µg/g F.W.)	ABGS 11-24(606.62)	GPBG 109	ABG 1 × GPBG 109 (791.84)	ABG 1 × GPBG 109	G × G	190.85**	47.07**	52.55**
	PUNJAB LONG (593.29)	ABG 1	GPBG 108 × ABGS 14-25 (572.55)	DBG 5 × PUNJAB LONG	P × G	60.06**	-6.37**	7.02**

Traits	Best performing parents	Best general combiners	Best performing hybrids	Hybrids with high *sca* effects	GCA of parents	*sca* effects	Heterosis over	
							Better parent	Standard check (ABGH 1)
	GPBG 109 (538.42)	PUNJAB LONG	ABG 1 × ABGS 11-19 (563.40)	GPBG 108 × ABGS 14-25	G × G	52.67**	11.97**	10.30**

*Value in parenthesis indicated mean data. * and ** indicate significant at 5% and 1% levels of significance, respective. Where: G = Good general combiner; A = Average general combiner and P = Poor general combiner*

high per se performance, high SCA effects, and at least one parent having high GCA effects would increase the frequency of favorable alleles.

4. CONCLUSION

The analysis of variance for combining ability revealed that the mean sum of squares due to female (lines) and male (testers) were highly significant for all the traits except fruit girth, average fruit weight, chlorophyll *a*, chlorophyll *b* and total chlorophyll. The ratio of σ^2_{GCA} / σ^2_{SCA} was less than unity for all the characters under study. Which suggested greater role of non-additive genetic variance in the inheritance of these characters.The *gca* effects indicated that four male parents *viz.,* ABGS 14-25, ABGS 11-17, ABGS 11-24 and PUNJAB LONG and three female parents *viz.,* DBG 5, NDBG 132 and LOCAL were found good general combiners for fruit yield per plant and its contributing traits. These good general combiners can be utilized in intensive crossing programmes and subsequently select transgressive segregants for desired yield traits in segregating generations to develop superior lines. The most promising hybrids for fruit yield per plant were DBG 5 × ABGS 14-27, NDBG 132 × PUNJAB LONG and GPBG 108 × ABGS 11-24.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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