

ESTIMATION OF COMBINING ABILITY AND GENE ACTION FOR FRUIT YIELD WITH ASSOCIATED TRAITS OF BOTTLE GOURD [*Lagenaria siceraria* (Mol.) Standl.]

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 F₁ 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 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 $\sigma^2_{GCA} / \sigma^2_{SCA}$ 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.

Key words: 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.

In a hybridization programme, selecting the right type of parents is a crucial step for a breeder. Combining ability is a relative ability of an inbred or a clone when crossed to another inbred or clone to transmit desirable traits or a specific trait to its progeny. The concept of combining ability as a measure of gene action was proposed by Sprague and Tatum [13]. 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 \times Tester analysis technique suggested by Kempthorne [5] 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. MATERIAL 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), and 35 F₁ hybrids. Parents were crossed in a Line \times 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 \times 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 ($^{\circ}$ Brix), chlorophyll *a* (μ g/g F.W.), chlorophyll *b* (μ g/g F.W.) and total chlorophyll (μ g/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 [8]. The mean value of 48 genotypes (Parents, their F₁ hybrids and one standard check) were entered in the computer and combining ability analysis was carried out according to the procedure given by Kempthorne [5].

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,

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	Fruit girth
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 x Male (L x 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
$\sigma^2_{GCA} / \sigma^2_{SCA}$		0.01	0.03	0.00	0.04	-	0.15	-

Sources of variation	d.f.	Average fruit weight	Number of fruit per plant	Fruit yield per plant	Moisture content	Total soluble solids	Chlorophyll a	Chlorophyll b	Total Chlorophyll
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 x Male (L x 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
$\sigma^2_{GCA} / \sigma^2_{SCA}$	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.

UNDER PEER REVIEW

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 \times Tester interaction were highly significant for all the traits. This signified the contribution of hybrids for specific combining ability variance components.

The ratio of $\sigma^2_{GCA} / \sigma^2_{SCA}$ 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.* [10], Janaranjani *et al.* [4], Shinde *et al.* [12], Rajkumar *et al.* [11], Hadiya *et al.* [3], Khot *et al.* [7] and Patel and Mehta [9] 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 [2], Janaranjani *et al.* [4], Khot *et al.* [7] for days to first male flower appearance; Gayakawad [2], Janaranjani *et al.* [4], Shinde *et al.* [12], Khot [6], Hadiya *et al.* [3], Khot *et al.* [7], Patel and Mehta [9] for days to first female flower appearance; Gayakawad [2], Janaranjani *et al.* [4] for node number at which first male flower appearance; Gayakawad [2], Janaranjani *et al.* [4], Shinde *et al.* [12], Khot [6], Hadiya *et al.* [3], Khot *et al.* [7] for node number at which first female flower appearance; Gayakawad [2], Khot [6], Khot *et al.* [7] for number of branch per plant; Patel *et al.* [10], Gayakawad [2], Janaranjani *et al.* [4], Shinde *et al.* [12], Khot [6], Khot *et al.* [7], Patel and Mehta [9] for fruit length;

Gayakawad[2], Janaranjani *et al.* [4], Hadiya *et al.* [3], Patel and Mehta [9] for fruit girth; Janaranjani *et al.* [4], Shinde *et al.* [12], Khot [6], Hadiya *et al.* [3], Patel and Mehta [9] for average fruit weight; Gayakawad[2], Janaranjani *et al.* [4], Shinde *et al.* [12], Khot [6], Hadiya *et al.* [3], Patel and Mehta [9] for number of fruit per plant; Gayakawad[2], Janaranjani *et al.* [4], Shinde *et al.* [12], Khot [6], Hadiya *et al.* [3], Khot *et al.* [7], Patel and Mehta [9] for fruit yield per plant; Patel and Mehta [9] for total soluble solids in bottle gourd.

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 for total 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,

UNDER PEER REVIEW

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 <i>a</i>		Chlorophyll <i>b</i>		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*	
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*
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**
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.

UNDER PEER REVIEW

Table 4 Top three ranking parents concerning mean performance and gca effects; F₁ hybrids concerning mean performance, scae effects, heterosis over better parent and standard check ABGH1 in bottle gourd

Traits	Best performing parents	Best general combiners	Best performing hybrids	Hybrids with high scae effects	GCA of parents	scae effects	Heterosis over	
							Better parent	Standard check (ABGH1)
Days to first male flower appearance	LOCAL (50.67)	NDBG132	DBG5 × ABGS14-27 (42.00)	DBG5 × ABGS14-27	P × A	-7.03**	-8.53**	-7.70**
	ABGS14-27 (45.92)	ABGS11-17	NDBG 132 × PUNJAB LONG (42.08)	LOCAL × ABGS11-24	A × A	-5.08**	-12.80**	-6.42*
	DBG5 (46.58)	GPBG109	LOCAL × ABGS 11-24 (42.58)	NDBG132 × PUNJAB LONG	G × A	-3.55**	-16.81**	-7.51**
Days to first female flower appearance	NDBG132 (47.08)	NDBG132	NDBG 132 × PUNJAB LONG (42.92)	GPBG108 × GPBG109	P × A	-7.34**	-14.97**	-6.13**
	ABGS14-27 (49.59)	ABGS14-25	LOCAL × ABGS 11-24 (43.00)	LOCAL × ABGS11-24	G × P	-6.88**	-9.31**	-7.38**
	ABGS11-19 (48.18)	PUNJAB LONG	GPBG 108 × GPBG109 (43.58)	ABG1 × ABGS11-19	P × P	-6.29**	1.41	2.86
Node number at which first male flower appears	NDBG132 (11.72)	ABGS14-27	GPBG108 × ABGS 14-27 (8.00)	DBG5 × ABGS11-17	A × P	-4.12**	-23.32**	-21.37**
	ABGS11-19 (10.09)	LOCAL	LOCAL × GPBG 109 (6.58)	GPBG108 × ABGS14-27	P × G	-3.17**	-48.34**	-33.34**
	ABGS11-17 (10.00)	ABGS11-19	NDBG 132 × ABGS11-19 (7.17)	GPBG108 × GPBG109	P × A	-2.54**	-25.58**	-17.95**
Node number at which first female flower appears	ABGS14-27 (11.42)	ABGS14-25	ABG1 × GPBG109 (3.50)	DBG5 × ABGS11-17	P × P	-5.93**	-46.19**	-37.87**
	ABGS11-19 (12.92)	LOCAL	LOCAL × ABGS 14-27 (5.25)	ABG1 × GPBG109	A × G	-5.56**	-73.75**	-69.30**
	NDBG132 (14.66)	ABGS14-27	ABG1 × ABGS14-25 (5.92)	NDBG132 × PUNJAB LONG	G × P	-2.95**	-46.26**	-42.62**
Number of branches per plant	ABGS11-19 (14.50)	ABGS14-27	ABG1 × ABGS14-27 (24.17)	DBG5 × GPBG109	P × P	1.76**	63.51**	94.55**
	GPBG109 (14.17)	GPBG108	ABG1 × ABGS11-19 (23.92)	GPBG108 × PUNJAB LONG	G × P	1.40**	84.23**	95.95**

ABG1(12.92) ABG1 GPBG108x ABGS 11-24(23.75) LOCALxPUNJAB LONG A x P 1.38** 80.93** 92.45**

Value in parenthesis indicated mean data. * and ** indicates significant at 5% and 1% levels of significance, respectively. 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	Hybrid with high sca effects	GCA of parents	sca effects	Heterosis over	
							Better parent	Standard check (ABG H 1)
Fruit length (cm)	NDBG132 (49.25)	ABGS11-19	NDBG132xABGS 11-19 (56.75)	DBG5 xABGS11-17	AxA	12.90**	35.85**	126.39**
	LOCAL(47.25)	NDBG132	DBG5 xABGS11-17 (54.33)	GPBG108 xABGS14-25	PxP	6.80**	6.64	78.48**
	GPBG109(40.17)	LOCAL	NDBG132xABGS 11-24 (56.75)	ABG1xPUNJABLONG	Px A	6.16**	22.78**	96.53**
Fruit girth (cm)	GPBG108(19.58)	-	DBG5 xABGS11-17 (27.67)	DBG5 xABGS11-17	AxA	7.77**	43.70**	28.19**
	LOCAL(19.50)	-	LOCALxPUNJABLONG (23.42)	-	-	-	-	-
	ABGS11-17 (19.25)	-	GPBG108 xPUNJABLONG (21.50)	-	-	-	-	-
Average fruit weight (g)	ABGS11-19 (750.83)	ABGS11-17	LOCAL x ABGS 11-17(826.67)	GPBG108 xGPBG109	Px A	284.83**	66.51**	92.35**
	ABGS14-27 (666.25)	ABGS11-19	LOCALxABGS 11-19 (759.66)	LOCALxABGS11-24	Gx P	231.18**	39.01**	90.31**
	ABGS11-17 (579.58)	LOCAL	GPBG108xGPBG109 (743.75)	DBG5 xABGS14-27	Gx P	190.86**	9.32**	88.37**
Number of fruit per plant	ABGS14-25 (11.58)	ABGS11-17	LOCAL x ABGS 11-17(12.75)	LOCALxABGS11-17	Px G	2.69**	18.60**	7.75**
	ABGS11-17 (10.75)	ABGS11-24	ABG1 xABGS11-24 (12.42)	NDBG132 x ABGS14-27	Gx P	2.23**	17.11**	-8.46**
	DBG5(10.50)	NDBG132	GPBG108xABGS 11-24 (12.08)	ABG1 xGPBG109	Gx G	2.05**	32.72**	0.00
Fruit yield per plant (kg)	DBG5(4.48)	ABGS14-25	NDBG 132 x PUNJAB LONG(5.48)	DBG5 xABGS14-27	Gx P	1.55**	3.63	3.13
	ABGS11-17 (4.35)	ABGS11-17	LOCALxABGS 14-25(5.44)	NDBG132 xPUNJAB LONG	Gx G	1.16**	53.04**	21.64**
	ABGS14-25 (4.26)	PUNJAB LONG	LOCALxABGS 11-17(5.38)	GPBG108 xABGS11-24	Ax G	1.15**	41.15**	13.17**

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

alcombiner; A = Average general combiner and P = Poor general combiner.

Table 4 Continued...

Traits	Best performing parents	Best general combiners	Best performing hybrids	Hybrid with high sca effects	GCA of parents	sca effects	Heterosis over	
							Better parent	Standard check (ABGH 1)
Moisture content (%)	ABGS14-27 (94.65)	ABGS11-17	DBG5 x ABGS11-19 (95.84)	DBG5 x ABGS11-19	P x A	4.71**	4.53**	1.72*
	NDBG132 (94.50)	ABGS14-27	LOCAL x PUNJAB LONG (95.53)	LOCAL x PUNJAB LONG	G x P	3.97**	1.26	1.40
	PUNJAB LONG (94.34)	ABGS11-24	LOCAL x ABGS 11-17 (95.33)	ABG1 x PUNJAB LONG	A x P	2.65**	-0.77	-0.64
Total soluble solids (°Brix)	ABGS14-27 (5.45)	DBG5	LOCAL x ABGS 11-17 (5.53)	ABG1 x ABGS11-24	A x A	0.73**	14.00**	12.40**
	ABGS11-19 (5.10)	-	ABG1 x ABGS11-24 (5.52)	ABG1 x PUNJAB LONG	A x A	0.66**	13.43**	11.89*
	GPBG108 (4.89)	-	DBG 5 x PUNJAB LONG (5.51)	LOCAL x PUNJAB LONG	A x A	0.56**	-7.05	-10.70*
Chlorophyll a (µg/g F.W.)	ABGS11-24 (553.09)	GPBG109	ABG1 x GPBG109 (754.88)	ABG1 x GPBG109	G x G	185.47*	59.28**	72.73**
	GPBG109 (529.40)	ABG1	ABG1 x ABGS11-19 (546.82)	GPBG108 x ABGS14-25	G x P	74.90**	19.14**	25.08**
	ABG1 (473.94)	PUNJAB LONG	GPBG108 x ABGS 14-25 (546.63)	DBG5 x PUNJAB LONG	P x G	68.20**	-0.87	20.09**
Chlorophyll b (µg/g F.W.)	ABGS14-27 (104.75)	ABGS14-25	LOCAL x ABGS14-25 (90.13)	ABG1 x PUNJAB LONG	P x G	26.06**	-1.08	-22.98**
	ABGS14-25 (92.42)	LOCAL	-	LOCAL x ABGS14-25	G x G	24.14**	-2.48	9.83*
	GPBG109 (74.33)	NDBG132	-	GPBG108 x ABGS11-19	P x P	12.33**	-51.60**	-57.69**

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

Totalchlorophyll($\mu\text{g/gF.W.}$)	ABGS11-24(606.62)	GPBG109	ABG1xGPBG109(791.84)	ABG1 xGPBG109	Gx G	190.85*	47.07**	52.55**
	PUNJABLONG(593.29)	ABG1	GPBG108x ABGS 14-25(572.55)	DBG5xPUNJABLONG	Px G	60.06**	-6.37**	7.02**
	GPBG109(538.42)	PUNJAB LONG	ABG1xABGS11-19(563.40)	GPBG108 xABGS14-25	Gx G	52.67**	11.97**	10.30**

UNDER PEER REVIEW

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 per se 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 high per se performance, high sca effects, and at least one parent having high gca effects would increase the frequency of favourable 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 $\sigma^2_{GCA} / \sigma^2_{SCA}$ 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 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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