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Combining ability studies in the advanced lines of bottle gourd [*Lagenaria siceraria* (mol.) Standl.] for growth, earliness and yield parameters

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Abstract
The present investigation was carried out with the objective to study the combining ability of parents and hybrids for growth, earliness and yield parameters in bottle gourd. General combining ability effects of parents and sca effects of crosses were highly significant for the characters studied. The parents Bot.G-4, Bot.G-7 and Kolkata Collection are the good general combiners for fruit yield per vine. The line Bot.G-6-2 exhibited significant and maximum gca effects for vine length and number of branches. The line Kolkata Collection showed maximum and significant gca effects for days to first female flower, days to first harvest and sex ratio. Tester Samrat exhibited significant gca effects for vine length, number of branches, nodes up to first female flower, sex ratio and fruit yield per vine. Among crosses, the cross Bot.G-6-2 X Arka Bahar exhibited significant sca effects for vine length and fruit yield per vine. While the cross Bot.G-6-1 X Samrat showed significant sca effects for days to first female flowering and days to first harvest. The cross Bot.G-6 X Samrat exhibited maximum and significant sca effects for nodes up to first female flowering and sex ratio. It is evident that gca or sca effects in parents or hybrids were in desirable for some other traits. Therefore it is important to ascertain the status of parent or hybrid with respective to combining ability effects over a number of component characters.

Keywords: General combining ability, specific combining ability, bottle gourd

Introduction
Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] is one of the important cucurbitaceous vegetable having wide range of uses and it is cultivated largely in the tropics and subtropics for its edible fruits. It is commonly called as calabash gourd, trumpet gourd, white flowered gourd and zucca melon. Bottle gourd is a commonly grown vegetable in India having chromosome number of 2n = 22. The combining ability studies are essential to identify potential parents. Mating designs like line × tester (l×t) analysis which was first developed by Kempthorne (1957) [4] provides information of combining ability and gene action. The general combining ability (gca) effects helps in selection of superior parents whereas, specific combining ability (sca) effects helps in selection of parental combination (hybrids). The information generated in the process will be helpful to know the magnitude of heterosis in F_1 hybrids for commercial exploitation. Hence, the present investigation was undertaken to study the combining ability of parents and hybrids for growth, earliness and yield parameters.

Materials and Methods
The investigation on "Combining ability studies in the advanced lines of bottle gourd [L*agenaria siceraria* (mol.) Standl.] For growth, earliness and yield parameters" was undertaken at the Department of Vegetable Science, K. R. C. College of Horticulture, Arabhavi, Gokak Taluk, Belagavi district of Karnataka state. The experimental material comprised of 10 lines which were collected from the department itself and 3 testers (Arka Bahar, Pusa Naveen and Samrat) collected from different sources and their 30 F_1 hybrids. Each of the 10 lines were crossed with each of the 3 testers to derive 30 F_1 hybrids in line x tester fashion. The experiment was laid out in randomized block design with two replications. Ridges and furrows were opened at a distance of three meters apart. Two to three seeds of each genotype per hill were dibbled at a distance of 90 cm in a row.

Five randomly chosen plants in each replication of all the entries were labelled and used for recording the observations. The mean of five plants was taken for statistical analysis.

Results and Discussions

General combining ability effects of parents and sca effects of crosses were highly significant for the characters studied. The variance due to general combining ability (GCA), specific combining ability (SCA) and GCA to SCA ratio for various characters are presented in Table 1. Ratio of GCA to SCA was low for fruit yield per vine (0.0566), sex ratio (0.0924), days to last harvest (0.0970), days to first flowering (0.1159), vine length (0.1267), number of branches (0.1551), number of leaves (0.1619), nodes up to first female flowering (0.1639), days to first female flower (0.2352) and days to first harvest (0.2645). General combining ability effects and specific combining ability effects for various traits are presented in Tables 2 to 5.

For vine length, three lines exhibited positive and significant gca effects and two testers exhibited positive and significant gca effects. Maximum positive and significant gca effects was observed in the line Bot.G-6-2 (48.74) fallowed by Kolkata Collection (16.80). Tester Arka Bahar exhibited maximum positive and significant gca effects (4.53). Among 30 crosses, 15 crosses showed positively significant sca effects, whereas, 14 crosses showed significantly negative sca effects. Maximum sca effects (49.70) was exhibited by the cross Bot.G-6-2 X Arka Bahar followed by Bot.G-6 X Arka Bahar (36.48).

For number of branches, only one line (Bot.G-6-2) exhibited positive and significant gca effects (1.15). Similarly one tester (Samrat) exhibited positive and significant gca effects (0.26). Among 30 crosses, three crosses showed positively significant sca effects whereas, nine crosses showed significantly negative sca effects. Maximum sca effects was exhibited by the cross Bot.G-4-1 X Samrat (1.24) followed by Bot.G-6 X Arka Bahar (1.14).

For number of leaves, only one line (Bot.G-6-2) exhibited positive and significant gca effects (11.47). None of the testers exhibited positive and significant gca effects. Among 30 crosses, six crosses showed positively significant sca effects whereas, seven crosses showed significantly negative sca effects. Maximum sca effects was exhibited by the cross Bot.G-6-2 X Arka Bahar (13.13) followed by Bot.G-6 X Arka Bahar (7.63).

For days to first male flowering, four lines exhibited significant gca effects, of which two lines exhibited significant gca effects in negative direction, which is desirable. Maximum negative gca effects was observed in the line Bot.G-2 (-1.37) followed by Kolkata Collection (-1.03). None of the testers showed significant gca effects. Among the crosses, four crosses showed negative and significant sca effects whereas three cross exhibited positive and significant gca effects. Maximum negative sca effects was observed in the cross Bot.G-2 X Arka Bahar (-2.18) followed by Bot.G-6-2 X Samrat (-2.05).

For days to first female flowering, six lines exhibited significant gca effects, of which three lines exhibited significant gca effects in negative direction. Maximum negative gca effects was observed in the line Kolkata Collection (-2.98) followed by Bot.G-2-1 (-1.15). One tester (Samrat) showed significant gca effects (-0.48). Among the crosses, seven crosses showed negative and significant sca effects whereas nine cross exhibited positive and significant gca effects. Maximum negative sca effects was observed in the cross Bot.G-6-1 X Samrat (-3.53) followed by Bot.G-2-1 X Pusa Naveen (-2.35).

For nodes up to first female flowering, none of the lines exhibited significant gca effects in negative direction, which is desirable. Tester Samrat (-0.34) showed significant and negative gca effects. Among the crosses, only one cross (Bot.G-6 X Samrat) showed negative and significant sca effects whereas two cross exhibited positive and significant gca effects (-1.50).

For days to first harvest, only one line (Kolkata Collection) exhibited significant and negative gca effects (-2.72). Among the crosses, the cross (Bot.G-6-1 X Samrat) exhibited significant negative sca effects and one crosses exhibited significant positive sca effects (-3.88).

For days to last harvest, two lines showed significant positive gca effects and one line showed negative and significant gca effects. Maximum and positive gca effects was observed in the line Bot.G-7-1 (3.38) followed by Bot.G-6 (2.88). None of the testers exhibited the significant gca effects. Among the crosses, three crosses exhibited significant positive sca effects. Maximum significant and positive sca effects was observed in the cross Bot.G-2-1 X Arka Bahar (6.92) followed by Bot.G-4-1 X Samrat (6.10) and Bot.G-6-1 X Pusa Naveen (5.15).

For sex ratio, four lines showed negative and significant gca effects. Among the testers, two exhibited significant and negative gca effects and one exhibited significant positive gca effects. The line Kolkata Collection showed maximum and negative gca effects (-1.31) fallowed by Bot.G-7 (-1.00). The tester Samrat showed maximum and negative gca effects (-0.23) fallowed by Arka Bahar (-0.18). Among 30 crosses, 14 crosses exhibited significant sca effects in desirable direction (negative). The highest negative and significant sca effects was observed in the cross Bot.G-6 X Samrat (-2.47) followed by Bot.G-4 X Pusa Naveen (-2.37).

For fruit yield per vine, three lines exhibited significant and positive gca effects and the highest was observed in the line Kolkata Collection (0.24) followed by Bot.G-4 (0.19), Bot.G-7 (0.16). Among the testers, Samrat (0.08) exhibited significantly and positive gca effects. Among crosses, 11 crosses exhibited positively significant sca effects. Maximum and positively significant sca effects was observed in the cross Bot.G-6-2 X Arka Bahar (0.75) followed by Bot.G-6-1 X Samrat (0.60), Bot.G-4 X Pusa Naveen (0.53).

Among lines, the line Bot.G-6-2 exhibited significant and maximum gca effects for vine length and number of branches. Similar results were also made by Vegad *et al*. (2011) [14] and Gayakawad (2014) [2] for vine length, Singh *et al*. (1995) and Dubey and Maurya (2006) [1] for number of branches. The line Bot.G-2 exhibited maximum and significant gca effects for days to first male in desirable (negative) direction. Significant gca effects was also reported by Vegad *et al*. (2011) [14] for days to first male flower in bottle gourd. The line Kolkata Collection showed maximum and significant gca effects for days to first female flower, days to first harvest, sex ratio and fruit yield per vine. Significant gca effects was also reported by Mourya *et al.* (2004) for days to first female flower and days to first harvest, Sreevani (2005) [13] for sex ratio and Singh *et al*. (1995) for fruit yield per vine in bottle gourd. The line Bot.G-7-1 showed maximum and significant gca effects for days to last harvest. Significant gca effects was also noticed by Mourya *et al.* (2004) for days to last harvest.

Among testers, Arka Bahar exhibited maximum and significant gca effects for vine length and sex ratio. Tester Pusa Naveen exhibited significant gca effects for days to first

female flower. Tester Samrat exhibited significant gca effects for vine length, number of branches, nodes up to first female flower, sex ratio and fruit yield per vine. Significant gca effects for these characters were reported by Sreevani (2005) [13] and Singh *et al*. (2006) in bottle gourd.

For exploitation of heterosis the information of gca should be supplemented with sca and hybrid performance. Estimation of sca effects for 30 crosses has resulted in identification of good specific combiners for various traits. Among crosses, the cross Bot.G-6-2 X Arka Bahar exhibited significant sca effects for vine length and fruit yield per vine. Similar observations were also noticed by Maurya *et al*. (1993) [6], Sharma *et al*. (2007) [10] and Kumar *et al*. (2014) [5] for vine length, Shinde *et al*. (2016) [11] for fruit yield per vine in bottle gourd. The cross Bot.G-4-1 X Samrat exhibited significant sca effects for number of branches. Significant sca effects were also reported by Maurya *et al*. (2004) [7] and Ray *et al*. (2015) [8] for number of branches in bottle gourd.

The cross Bot.G-2 X Arka Bahar exhibited significant sca effects for days to first male flower. Janakiram and Sirohi (1992) [3], Maurya *et al.* (1993) [6] and Ray *et al*. (2015) [8] also reported significant sca effects for days to first male flower in bottle gourd. While the cross Bot.G-6-1 X Samrat showed significant sca effects for days to first female flowering and days to first harvest. Similar results were also found by Janakiram and Sirohi (1992) [3], Maurya *et al.* (1993) [6] and Ray *et al*. (2015) [8] for days to first female flowering, Samadia and Khandelwal (2002) [9] for days to first harvest in bottle gourd.

The cross Bot.G-6 X Samrat exhibited maximum and significant sca effects for nodes upto first female flowering and sex ratio. Singh *et al*. (2012b) [12] also reported significant sca effects for sex ratio and Shinde *et al*. (2016) [11] for nodes to first female flowering in bottle gourd. The cross Bot.G-2-1 X Pusa Naveen exhibited maximum and significant sca effects for days to last harvest. Vegad *et al*. (2011) [14] also reported significant sca effects for days to last harvest in bottle gourd.

Table 1: Variance due to general combining ability and specific combining ability for different characters in bottle gourd

Sl. No.	Character	GCA	SCA	GCA:SCA
1	Vine length	122.2960	965.3446	0.1267
2	Number of leaves	5.5182	34.0917	0.1619
3	Number of branches	0.0834	0.5373	0.1551
4	Days to first flowering	0.1814	1.5647	0.1159
5	Days to first female flower	0.6748	2.8683	0.2352
6	Nodes up to first female flowering	0.0637	0.3884	0.1639
7	Days to first harvest	0.4274	1.6158	0.2645
8	Days to last harvest	1.3240	13.6489	0.0970
9	Sex ratio (M:F)	0.2881	3.1175	0.0924
10	Fruit yield per vine	0.0231	0.2111	0.1094

Table 2: General combining ability effects for growth and earliness parameter in bottle gourd

Sl. No.	Parent/Lines	Vine length	No. of branches	No. of leaves	DFMF	DFFF
1	Bot.G-2	-9.41**	-0.25*	-0.40	-1.37**	0.85**
2	Bot.G-2-1	-1.09	-0.36**	2.11	0.30	-1.15**
3	Bot.G-4	-16.62**	-0.50**	-2.62**	-0.20	-0.32
4	Bot.G-4-1	-2.04**	0.18	0.99	-0.03	0.52
5	Bot.G-6	-3.04**	-0.02	-0.55	0.47	1.35**
6	Bot.G-6-1	1.91*	-0.02	-1.36	-0.20	-0.82*
7	Bot.G-6-2	48.74**	1.15**	11.47**	-0.70	0.52
8	Bot.G-7	-28.23**	-0.39**	-6.33**	1.47**	0.02
9	Bot.G-7-1	-7.01**	0.15	-2.80*	1.30**	2.02**
10	KC	16.80**	0.06	-0.50	-1.03**	-2.98**
	S.Em±	1.44	0.08	0.80	0.24	0.19
	C.D. at 5%	1.52	0.24	2.31	0.70	0.55
	C.D. at 1%	2.04	0.32	3.11	0.94	0.74
Testers						
1	AB	4.53**	-0.14*	0.44	0.02	0.62**
2	PN	-6.05**	-0.12	-1.37*	-0.23	-0.48*
3	S	1.52**	0.26**	0.93	0.22	-0.13
	S.Em±	0.29	0.04	0.44	0.13	0.10
	C.D at 5%	0.83	0.13	1.26	0.38	0.30
	C.D at 1%	1.12	0.17	1.70	0.52	0.40

*and ** indicate significance of values at p=0.05 and 0.01, respectively. KC-Kolkata collection, AB = Arka Bahar, PN = Pusa Naveen, S-Samrat, DFMF = Days to first male flowering and DFFF = Days to first female flowering.

Table 3: Specific combining ability effects for growth and earliness parameter in bottle gourd

Sl. No	Crosses	Vine length	No. of branches	No. of leaves	DFMF	DFFF
1	Bot.G-2 X AB	-39.90**	-0.43*	-7.42**	-2.18**	0.55
2	Bot.G-2 X PN	15.74**	0.39	4.48*	0.57	1.65*
3	Bot.G-2 X S	24.16**	0.04	2.94	1.62**	-2.20**
4	Bot.G-2-1 X AB	24.33**	0.18	-1.79	1.15	2.05**
5	Bot.G-2-1 X PN	12.02**	0.30	6.52**	-0.10	-2.35**
6	Bot.G-2-1 X S	-36.36**	-0.48*	-4.73*	-1.05	0.30

7	Bot.G-4 X AB	-9.64**	0.02	-0.12	0.65	-1.28**
8	Bot.G-4 X PN	4.77**	0.07	-0.50	-0.10	-0.18
9	Bot.G-4 X S	4.87**	-0.09	0.62	-0.55	1.47*
10	Bot.G-4-1 X AB	-27.22**	-0.76**	-4.29*	-0.52	-0.12
11	Bot.G-4-1 X PN	-2.98**	-0.48*	-0.43	0.23	-1.52**
12	Bot.G-4-1 X S	30.20**	1.24**	4.72*	0.28	1.63**
13	Bot.G-6 X AB	36.48**	1.14**	7.63**	-0.52	-1.45**
14	Bot.G-6 X PN	-23.13**	-0.48*	-3.97	-0.27	0.15
15	Bot.G-6 X S	-13.36**	-0.66**	-3.66	0.78	1.30**
16	Bot.G-6-1 X AB	20.13**	0.14	1.31	0.65	1.22*
17	Bot.G-6-1 X PN	-21.88**	-0.48*	-4.36*	-1.10	2.32**
18	Bot.G-6-1 X S	1.75	0.34	3.05	0.45	-3.53**
19	Bot.G-6-2 X AB	49.70**	1.08	13.13**	0.15	-0.62
20	Bot.G-6-2 X PN	-15.21**	0.05	-4.71*	1.90**	0.48
21	Bot.G-6-2 X S	-34.49**	-1.13**	-8.42**	-2.05**	0.13
22	Bot.G-7 X AB	14.77**	0.31	2.26	0.98	-0.62
23	Bot.G-7 X PN	-7.50**	0.09	-0.79	-1.77**	0.98*
24	Bot.G-7 X S	-7.27**	-0.40	-1.47	0.78	-0.37
25	Bot.G-7-1 X AB	-23.25**	-0.92**	-3.62	1.15	0.38
26	Bot.G-7-1 X PN	9.84**	0.15	0.48	-1.10	-1.52*
27	Bot.G-7-1 X S	13.41**	0.77**	3.14	-0.05	1.13*
28	KC X AB	-45.41**	-0.74**	-7.08**	-1.52**	-0.12
29	KC X PN	28.33**	0.39	3.28	1.73**	-0.02
30	KC X S	17.08**	0.36	3.80	-0.22	0.13
	S.Em±	0.63	0.14	1.38	0.42	0.33
	C.D. @ 5%	1.80	0.41	3.99	1.21	0.95
	C.D. @ 1%	2.40	0.55	5.39	1.63	1.28

*and ** indicate significance of values at p = 0.05 and 0.01, respectively. KC-Kolkata collection, AB = Arka Bahar, PN = Pusa Naveen, S-Samrat, DFMF = Days to first male flowering and DFFF = Days to first female flowering.

Table 4: General combining ability effects for earliness parameters and fruit yield per vine in bottle gourd

Sl. No.	Parent Lines	NFFF	DFH	DLH	SR	FYPV
1	Bot.G-2	-0.26	0.78	2.05	0.53**	-0.09
2	Bot.G-2-1	-0.13	-1.05	-1.62	0.45**	0.02
3	Bot.G-4	0.48*	0.95	-1.12	-0.49**	0.19*
4	Bot.G-4-1	-0.30	0.28	1.05	-0.86**	0.09
5	Bot.G-6	-0.20	0.78	2.88*	0.81**	0.10
6	Bot.G-6-1	0.35	-0.72	-0.45	-0.21	0.09
7	Bot.G-6-2	-0.22	0.62	1.55	0.36*	-0.20**
8	Bot.G-7	-0.28	-0.55	-1.95	-1.00**	0.16*
9	Bot.G-7-1	0.33	1.62	3.38*	1.72**	-0.60**
10	KC	0.22	-2.72**	-5.78**	-1.31**	0.24**
	S.Em±	0.16	0.64	0.96	0.11	0.05
	C.D. at 5%	0.47	1.86	2.77	0.32	0.15
	C.D. at 1%	0.63	2.50	3.74	0.44	0.20
Testers						
1	AB	0.16	0.48	0.58	-0.18*	0.04
2	PN	0.18	-0.87	-0.82	0.41**	-0.12**
3	S	-0.34**	0.38	0.23	-0.23*	0.08*
	S.Em±	0.09	0.35	0.53	0.06	0.03
	C.D at 5%	0.26	1.06	1.52	0.18	0.08
	C.D at 1%	0.34	1.37	2.05	0.24	0.11

*and** indicate significance of values at p = 0.05 and p = 0.01, respectively. KC- Kolkata collection, AB = Arka Bahar, PN-Pusa Naveen, S-Samrat, NFFF = Nodes up to first female flowering, DFH = Days to first harvesting, DLH- Days to last harvesting, SR = Sex Ratio, FYPV- Fruit yield per vine.

Table 5: Specific combining ability effects for earliness parameters and fruit yield per vine in bottle gourd

Sl. No.	Crosses	NFFF	DFH	DLH	SR	FYPV
1	Bot.G-2 X AB	-0.06	0.02	4.25	-0.43**	0.43**
2	Bot.G-2 X PN	0.45	1.87	0.15	-0.30**	-0.42**
3	Bot.G-2 X S	-0.39	-1.88	-4.40	0.73**	-0.01
4	Bot.G-2-1 X AB	-0.16	1.85	6.92**	-1.09**	0.41**
5	Bot.G-2-1 X PN	0.32	-1.80	-5.18*	1.21**	-0.43**
6	Bot.G-2-1 X S	-0.16	-0.05	-1.73	-0.12	0.02
7	Bot.G-4 X AB	-0.83	-2.65	-3.08	1.83**	-0.03
8	Bot.G-4 X PN	-0.14	-0.30	-0.68	-2.37**	0.53**
9	Bot.G-4 X S	0.97	2.95	3.77	0.54**	-0.49**

10	Bot.G-4-1 X AB	0.46	-1.48	-1.75	0.21*	0.44**
11	Bot.G-4-1 X PN	-0.66	-0.63	-4.35	-1.09**	0.13
12	Bot.G-4-1 X S	0.20	2.12	6.10*	0.88**	-0.57**
13	Bot.G-6 X AB	1.46**	-0.98	-2.08	3.47**	-0.96**
14	Bot.G-6 X PN	0.04	0.37	-1.68	-0.99**	0.49**
15	Bot.G-6 X S	-1.50**	0.62	3.77	-2.47**	0.47**
16	Bot.G-6-1 X AB	-0.09	0.52	0.75	-0.27**	0.12
17	Bot.G-6-1 X PN	-0.31	3.37*	5.15*	0.77**	-0.73**
18	Bot.G-6-1 X S	0.40	-3.88*	-5.90*	-0.51**	0.60**
19	Bot.G-6-2 X AB	-0.33	0.18	0.75	-1.70**	0.75**
20	Bot.G-6-2 X PN	-0.44	0.03	3.15	0.32**	0.09
21	Bot.G-6-2 X S	0.77	-0.22	-3.90	1.37**	-0.84**
22	Bot.G-7 X AB	-0.56	0.35	-1.75*	-1.56**	0.02
23	Bot.G-7 X PN	0.92*	-0.30	3.15	0.89**	0.01
24	Bot.G-7 X S	-0.36	-0.05	-1.40	0.67**	-0.02
25	Bot.G-7-1 X AB	-0.03	1.68	-2.08	1.59**	-0.86**
26	Bot.G-7-1 X PN	0.11	-0.97	-1.18	-0.90**	0.48**
27	Bot.G-7-1 X S	-0.08	-0.72	3.27	-0.69**	0.38**
28	KC X AB	0.14	0.52	-1.92	-2.05**	-0.31*
29	KC X PN	-0.28	-1.63	1.48	2.45**	-0.15
30	KC X S	0.14	1.12	0.43	-0.40**	0.46**
	S.Em±	0.28	1.11	1.66	0.19	0.09
	C.D. @ 5%	0.81	3.21	4.80	0.18	0.26
	C.D. @ 1%	1.09	4.33	6.47	0.24	0.35

*and** indicate significance of values at p = 0.05 and p = 0.01, respectively. KC- Kolkata collection, AB = Arka Bahar, PN - Pusa Naveen, S - Samrat, NFFF = Nodes up to first female flowering, DFH = Days to first harvesting, DLH - Days to last harvesting, SR = Sex Ratio, FYPV - Fruit yield per vine

Conclusion

The parents Bot.G-4, Bot.G-7 and Kolkata Collection are the good general combiners for fruit yield per vine. These can be used for identifying superior heterotic combinations. However, the parents Bot.G-6-1, Bot-G-6-2, Kolkata Collection, Arka Bahar and Samrat also shows good general combining ability for many characters and these can be subjected to recurrent selection for improvement of genetic stock. The characters for fruit yield per vine, sex ratio, days to last harvest, days to first flowering, vine length, number of branches, number of leaves, nodes up to first female flowering, fruit days to first female flower and days to first harvest are predominantly controlled by non-additive gene action and heterosis breeding or recurrent selection can be employed for improvement of these characters.

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