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Combining ability studies for earliness and yield attributing characters in bottle gourd [*Lagenaria siceraria* (Molina) Standl.]

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Abstract
A combining ability study involving 10 lines and 4 testers namely VRBG-107, VRBG-408, VRBG-1001, VRBG-1003, IC-092467, IC-144389, NDBG-104, DVBG-2, PBOG-40, IC-042345(lines); PSPL, Pusa Naveen, Arka Bahar and Selection-1(testers) mated in line x tester fashion producing hybrids were evaluated at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) during the Spring-Summer 2015. Up on examining the data it was revealed that NDBG-104 the best general combiner among the parents for most of the characters in desired direction, while among the crosses NDBG-104 x PSPL was found to be good specific combiner and also revealed that crosses involving at least one good general combiner can yield a good cross combination. The gca and sca variance ratio showed that both additive and non-additive gene actions were found to govern most of the characters under study.

Keywords: Bottle gourd, combining ability, hybrids, GCA, SCA, earliness, fruit yield

Introduction
Bottle gourd [*Lagenaria siceraria* (Molina) Standl.] is one of the most important nutritious cucurbitaceous vegetables grown throughout the country for its tender fruits. At present main emphasis is being given to develop F1 hybrids in bottle gourd. Identification and selection of potential parents based on their combining ability is very essential for hybrid development. The present study was, therefore, undertaken to identify the genetic architecture of characters related to earliness and yield based on combining ability analysis.

Research Method
Fourteen parental lines of bottle gourd including 10 lines and 4 testers namely VRBG-107, VRBG-408, VRBG-1001, VRBG-1003, IC-092467, IC-144389, NDBG-104, DVBG-2, PBOG-40, IC-042345(lines); PSPL, Pusa Naveen, Arka Bahar and Selection-1(testers) were used to mode crosses in line x tester mating design (Kemptrone, 1957) [5] to produce 40 crosses. Crosses and their parents were grown with plant to plant 0.6 m and row to row 2.0 m at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) during the Spring-Summer 2015. The trial was conducted in Randomized Block Design with three replications. The observations were recorded on ten characters of bottle gourd *viz.*, days to fifty per cent staminate flowering, days to fifty per cent pistillate flowering, node at which first staminate flower appears, node at which first pistillate flower appears, vine length (m), number of primary branches per plant, fruit weight (kg), fruit length (cm), number of fruits per plant and fruit yield per plant (kg). All the cultural operations and plant protection measures were carried out as per schedule of crop. The combining ability analysis was calculated by the method suggested by Griffing (1956) [3].

Results
The analysis of variances among crosses revealed that crosses were highly significant and further partitioning of variance among hybrids in to testers, lines and line x tester revealed that they were all significant for lines, testers and line x tester for all the characters under study indicating the importance of both gca and sca variances for the traits and presented in Table 1. These differences may be due to the differences in the genetic materials studied. Similar findings were reported by Maurya *et al.* (2004) [7].
From the data of gca and sca variances revealed that estimates of sca varinace was found greater than gca variance in days to 50% staminate flowering, days to 50% pistillate

flowering, node at which first pistillate flower appears, vine length, number of primary branches per plant and number of fruits per plant representing the preponderance of dominance variance indicating non-additive gene action. Higher estimates of gca variance, representing additive variance, than sca variance estimates were recorded for node at which first staminate flower appears, fruit weight, fruit length and yield per plant. Similar reports were registered by Rehana and Sharma (2007) [8], Shaik *et al.* (2012) [9] and Kumar *et al*. (2014) [6]. GCA effects of parents for various characters were presented in table 2.

Early maturity is a desirable trait as it results in early supply of the produce without much competition and consequently making the crop more profitable to the farmers. General combining ability effects of parents revealed that the lines NDBG-104, PBOG-40 and IC-042345 were found to be good general combiners for flowering traits. Lines VRBG-107, VRBG-1001 and IC-144389 and tester Selection-1 were good general combiners exhibiting higher negative gca effects for node at which first staminate flower appears while, for node at which first pistillate flower appears, VRBG-1001 and IC-042345 among lines and Pusa Naveen and Selection-1 among testers were reported as good general combiners recording negative significant gca effects. For vine length, lines DVBG-2, VRBG-107 and IC-092467, whereas parents NDBG-104, VRBG-1001 and DVBG-2 for number of primary branches per plant registered significant positive gca effects. For fruit weight, parents VRBG-1003, PSPL and NDBG-104 registered significant positive gca effects, while for fruit length VRBG-1003 and IC-144389; for number of fruits per plant NDBG-104, IC-042345 and VRBG-1001 exhibited positively significant gca effects and for yield per plant parents NDBG-104 and PSPL registered significantly positive gca effects.

On examination of all the traits under study an inference can be made that NDBG-104 was observed as the best general combiner among the parents for most of the characters in desired direction. Similar results were also reported by Sharma *et al.* (2002) [10], Sharma *et al*. (2007) [11], Janaranjani *et al*. (2016) [4] and Gayakawad *et al*. (2016a) [2].

While observing at sca effects of crosses VRBG-1003 × Pusa Naveen and NDBG-104 × Arka Bahar exhibited highest negative sca estimates for the flowering traits, while crosses IC-144389 × PSPL and VRBG-107 × Pusa Naveen recorded higher negative sca effects for node at which first staminate flower appears and NDBG-104 × Pusa Naveen, IC-042345 × Selection-1 and VRBG-107 × PSPL recorded higher negative sca effects for node at which first pistillate flower appears representing good specific combining ability of the crosses. Crosses VRBG-1003 × Pusa Naveen, PBOG-40 × Selection-1 and VRBG-408 × Arka Bahar; PBOG-40 × PSPL, IC-144389 × Selection-1 and NDBG-104 × PSPL for number of primary branches per plant recorded higher positive significant sca for vine length. For fruit length hybrids VRBG-1003 × Arka Bahar, VRBG-1003 × Selection-1 and IC-144389 × PSPL, while for number of fruits per plant crosses NDBG-104 × PSPL, DVBG-2 × Arka Bahar and IC-042345 × Pusa Naveen crosses expressed significant positive sca effects. Similarly, cross combinations NDBG-104 × PSPL, DVBG-2 × Arka Bahar and IC-042345 × Pusa Naveen were good specific combiners and recorded higher positively significant sca estimates for yield per plant. Similar results were also reported by Sharma *et al.* (2002) [10], Sharma *et al*. (2007) [11], Janaranjani *et al*. (2016) [4] and Gayakawad *et al*. (2016a) [2]. SCA effects of parents for various characters were presented in table 3a. and 3b.

The data fairly showed that none of the parents were good general combiners and also none of the crosses were observed as specific combiners for all the traits.

Very few crosses reportedly had significantly superior sca effects for yield per vine. Superior crosses involving both good general combiners NDBG-104 and PSPL might had been governed by additive x additive gene action and early generation selections can be taken up, as GCA is controlled by genetic material, is heritable and can be transmitted to the offspring. From these studies, it is evident that sca effects of certain crosses were related with gca of their parents as the best cross combination for most of the characters involved at least one parent with high or average gca effects for particular traits. The above crosses had one or both the parents in common. The variance due to gca was slightly higher than variance due to sca, indicating the importance of both additive and non-additive gene action governing the yield per plant trait.

The importance of additive and non-additive types gene action for different characters have also been reported previously by Maurya *et al.* (2004) [7] and Sit and Sirohi (2008) [12]. The results were confirmed by Wani *et al.* (2008) [14], Vegad *et al.* (2011) [13] and Adarsh *et al*. (2017) [1].

Table 1: ANOVA for combining ability for various yield traits in bottle gourd

Source of Variation	df	Mean Sum of Squares									
		D50SF	D50PF	NFSF	NFPF	VL (m)	NPB	FW (g)	FL (cm)	No. FRTS	YPP (kg)
Replicates	2	0.76	2.71	0.08	0.10	0.19	0.32	5145.07	6.96	1.09	1.14
Crosses	39	45.35**	43.42**	1.59**	4.63**	4.28**	10.92**	70738.69**	169.13**	5.66**	6.26**
Lines in hybrids	9	90.81**	84.59**	3.74**	3.90**	14.22**	31.26**	219588.57**	600.45**	14.44**	14.46**
Testers in hybrids	3	43.49**	31.92**	4.96**	27.84**	0.64**	8.82**	151456.44**	95.06**	7.10**	11.88**
(Line x Tester) in hybrids	27	30.41**	30.97**	0.50**	2.29**	1.36**	4.37**	12153.43**	33.59**	2.57**	2.90*
Error	78	1.37	1.38	0.08	0.14	0.07	0.19	5634.14	6.28	1.26	1.75
σ^2 gca	-	1.75	1.30	0.18	0.65	0.29	0.75	8255.67	14.96	0.39	0.49
σ^2 sca	-	9.68	9.87	0.14	0.72	0.43	1.39	2173.10	9.11	0.44	0.38

D50SF: days to50 % staminate flowering; D50PF: days to 50 % pistillate flowering; NFSF: node at which first staminate flower appears; NFPF: node at which first pistillate flower appears; VL: vine length; NPB: number of primary branches per plant; FW: fruit weight; FL: fruit length; No.FRTS: number of fruits per plant; YPP: yield per plant

Table 2: Estimates of general combining ability effects of parents for earliness and yield traits in bottle gourd

	D50SF	D50PF	NFSF	NFPF	VL (m)	NPB	FW (g)	FL (cm)	No. FRTS	YPP (kg)
LINES										
VRBG-107	1.73**	1.68**	-0.63**	-0.84**	1.18**	-2.79**	31.84	-0.74	-0.11	0.16
VRBG-408	2.98**	4.18**	0.45**	-0.06	-1.14**	-1.30**	3.56	1.68*	-1.14**	-1.13**
VRBG-1001	-0.43	-0.23	-0.58**	-0.78**	-0.49**	1.57**	-62.95**	-1.84*	0.16	-0.21
VRBG-1003	0.65	0.85*	1.15**	1.09**	-0.84**	-0.52**	344.34**	16.51**	-1.86**	-0.03
IC-092467	1.90**	1.10**	-0.4**	0.39**	0.78**	-0.38**	-28.17	-4.61**	-0.94**	-1.15**
IC-144389	-1.68**	-0.23	-0.42**	-0.01	0.21**	0.49**	-38.17	5.47**	0.08	-0.19
NDBG-104	-5.35**	-5.15**	0.10	0.16	0.43**	2.66**	44.08*	-3.03**	1.73**	2.45**
DVBG-2	3.73**	2.18**	-0.05	-0.15	1.78**	1.15**	-41.67	0.63	1.21**	0.94*
PBOG-40	-2.18**	-2.48**	0.43**	0.42**	-1.72**	0.58**	-166.67**	-9.43**	0.04	-1.10**
IC-042345	-1.35**	-1.90**	-0.03	-0.21	-0.19*	-1.45**	-86.17**	-4.62**	0.84*	0.28
Std Error	0.34	0.34	0.08	0.11	0.08	0.13	21.67	0.72	0.32	0.51
TESTERS										
PSPL	1.60**	1.15**	0.37**	-0.19**	-0.18**	-0.32**	103.68**	-1.89**	-0.04	0.69**
Pusanaveen	-1.23**	-0.98**	-0.34**	-0.72**	0.07	0.06	-55.73**	-0.13	0.70**	0.36
Arkabahar	0.13	0.58**	0.34**	1.41**	-0.04	-0.48**	-15.63	-0.38	-0.32	-0.42
Selection-1	-0.50*	-0.75**	-0.37**	-0.50**	0.16**	0.74**	-32.33*	2.40**	-0.34	-0.63*
Std Error	0.21	0.21	0.05	0.07	0.05	0.08	13.70	0.46	0.21	0.32

* Significant at p= 0.05, ** Significant at p= 0.01

D50SF: days to50 % staminate flowering; D50PF: days to 50 % pistillate flowering; NFSF: node at which first staminate flower appears; NFPF: node at which first pistillate flower appears; VL: vine length; NPB: number of primary branches per plant; FW: fruit weight; FL: fruit length; No.FRTS: number of fruits per plant; YPP: yield per plant

Table 3a: Estimates of specific combining ability effects of crosses for earliness and yield traits in bottle gourd

Crosses	D50SF	D50PF	NFSF	NFPF	VL (m)
VRBG -107× PSPL	1.57*	0.52	-0.10	-0.77**	0.36*
VRBG -107× PUSA NAVEEN	0.40	1.65*	-0.40*	-0.38	-0.79**
VRBG -107× ARKA BAHAR	-1.30	-2.25**	0.19	1.09**	0.02
VRBG -107× SELECTION-1	-0.67	0.08	0.30	0.06	0.42**
VRBG-408× PSPL	-3.68**	-2.98**	0.02	-0.09	0.58**
VRBG-408× PUSA NAVEEN	-1.85**	-2.85**	-0.22	1.24**	-0.77**
VRBG-408× ARKA BAHAR	3.45**	3.25**	-0.36*	-0.63**	0.74**
VRBG-408× SELECTION-1	2.08**	2.58**	0.55**	-0.52*	-0.56**
VRBG-1001× PSPL	1.40*	0.10	0.39*	-0.38	0.43**
VRBG-1001× PUSA NAVEEN	2.23**	2.23**	-0.18	0.09	0.28
VRBG-1001× ARKA BAHAR	-3.13**	-3.33**	-0.06	0.96**	0.69**
VRBG-1001× SELECTION-1	-0.50	1.00	-0.15	-0.67**	-1.41**
VRBG-1003× PSPL	-3.68**	-3.98**	0.38*	-0.18	-0.52**
VRBG-1003× PUSA NAVEEN	-6.85**	-5.85**	0.28	0.82**	0.83**
VRBG-1003× ARKA BAHAR	5.12**	4.92**	-0.59**	-1.84**	0.54**
VRBG-1003× SELECTION-1	5.42**	4.92**	-0.08	1.20**	-0.86**
IC-092467× PSPL	1.07	0.77	-0.07	0.46*	-0.84**
IC-092467× PUSA NAVEEN	3.23**	2.23**	-0.10	-0.28	0.21
IC-092467× ARKA BAHAR	-3.47**	-1.67*	0.43*	-0.27	0.32*
IC-092467× SELECTION-1	-0.83	-1.33	-0.27	0.10	0.32*
IC-144389× PSPL	-1.35*	0.10	-0.98**	0.13	0.33*
IC-144389× PUSA NAVEEN	-2.52**	-2.77**	0.05	-0.28	-0.62**
IC-144389× ARKA BAHAR	2.12**	0.67	0.51**	0.86**	0.09
IC-144389× SELECTION-1	1.75*	2.00**	0.42*	-0.70**	0.19
NDBG-104× PSPL	3.65**	5.35**	0.50**	0.56*	0.01
NDBG-104× PUSA NAVEEN	2.15**	1.15	0.20	-1.32**	0.06
NDBG-104× ARKA BAHAR	-4.22**	-4.42**	-0.14	-0.64**	-0.73**
NDBG-104× SELECTION-1	-1.58*	-2.08**	-0.57**	1.40**	0.67**
DVBG-2× PSPL	-0.43	-0.98	-0.35*	-0.61**	-0.04
DVBG-2× PUSA NAVEEN	1.07	0.82	0.22	0.58**	0.51**
DVBG-2× ARKA BAHAR	-0.30	0.25	0.21	0.39	-0.58**
DVBG-2× SELECTION-1	-0.33	-0.08	-0.08	-0.37	0.12
PBOG-40× PSPL	1.15	0.35	0.10	0.49*	0.06
PBOG-40× PUSA NAVEEN	-0.02	0.48	-0.27	-0.45*	-0.09
PBOG-40× ARKA BAHAR	1.62*	2.92**	0.06	-0.51*	-0.78**
PBOG-40× SELECTION-1	-2.75**	-3.75**	0.10	0.47*	0.82**
IC042345× PSPL	0.32	0.77	0.10	0.39	-0.37*
IC042345× PUSA NAVEEN	2.15**	2.90**	0.40*	-0.02	0.38*
IC042345× ARKA BAHAR	0.12	-0.33	-0.27	0.59**	-0.31*
IC042345× SELECTION-1	-2.58**	-3.33**	-0.23	-0.97**	0.29
Std Error	0.68	0.68	0.16	0.22	0.15

D50SF: days to50 % staminate flowering; D50PF: days to 50 % pistillate flowering; NFSF: node at which first staminate flower appears; NFPF: node at which first pistillate flower appears; VL: vine length;

Table 3b: Estimates of specific combining ability effects of crosses for various yield traits in bottle gourd

Crosses	NPB	FW (g)	FL (cm)	No. FRTS	YPV (kg)
VRBG -107× PSPL	0.18	6.06	-0.25	-1.04	-1.15
VRBG -107× PUSA NAVEEN	-0.59*	-10.56	2.22	0.08	0.03
VRBG -107× ARKA BAHAR	1.15**	-39.60	-2.37	1.17	0.98
VRBG -107× SELECTION-1	-0.74**	44.10	0.39	-0.21	0.14
VRBG-408× PSPL	-0.51*	9.37	3.01*	-0.27	-0.32
VRBG-408× PUSA NAVEEN	-0.15	-21.28	-1.09	0.05	-0.09
VRBG-408× ARKA BAHAR	-0.11	19.61	2.08	0.34	0.45
VRBG-408× SELECTION-1	0.77**	-7.69	-4.00**	-0.11	-0.04
VRBG-1001× PSPL	-0.52*	-114.16**	-0.77	0.76	-0.06
VRBG-1001× PUSA NAVEEN	-0.09	27.22	-2.00	-0.85	-0.64
VRBG-1001× ARKA BAHAR	0.15	55.12	0.97	-0.57	-0.21
VRBG-1001× SELECTION-1	0.46	31.82	1.80	0.65	0.91
VRBG-1003× PSPL	-1.32**	-41.41	-10.54**	-0.02	-0.42
VRBG-1003× PUSA NAVEEN	0.07	-82.03	0.95	-0.44	-0.74
VRBG-1003× ARKA BAHAR	0.74**	-19.13	5.46**	0.45	0.44
VRBG-1003× SELECTION-1	0.52*	142.57**	4.13**	0.00	0.72
IC-092467× PSPL	-0.40	91.07*	1.37	-0.67	-0.25
IC-092467× PUSA NAVEEN	-0.04	-25.52	-0.59	-0.02	-0.14
IC-092467× ARKA BAHAR	0.06	9.38	-0.86	0.14	0.17
IC-092467× SELECTION-1	0.38	-74.92	0.09	0.56	0.22
IC-144389× PSPL	-0.90**	64.07	3.13*	-0.49	-0.07
IC-144389× PUSA NAVEEN	-0.61*	-27.52	2.30	-0.10	-0.32
IC-144389× ARKA BAHAR	-0.84**	63.38	-1.06	-0.01	0.46
IC-144389× SELECTION-1	2.34**	-99.92*	-4.37**	0.61	-0.06
NDBG-104× PSPL	1.80**	13.82	2.87*	2.00**	2.65**
NDBG-104× PUSA NAVEEN	0.52*	63.23	0.01	0.25	0.63
NDBG-104× ARKA BAHAR	-1.44**	-51.87	-4.90**	-1.27	-1.87*
NDBG-104× SELECTION-1	-0.89**	-25.17	2.01	-0.98	-1.40
DVBG-2× PSPL	-0.89**	54.57	-0.04	-1.29*	-0.85
DVBG-2× PUSA NAVEEN	0.73**	1.98	-1.11	0.77	0.69
DVBG-2× ARKA BAHAR	1.84**	-16.12	-0.55	1.32*	1.20
DVBG-2× SELECTION-1	-1.68**	-40.42	1.71	-0.80	-1.04
PBOG-40× PSPL	2.74**	-84.43	0.52	1.55*	0.87
PBOG-40× PUSA NAVEEN	-0.40	46.98	0.72	-0.67	-0.43
PBOG-40× ARKA BAHAR	-0.86**	2.88	-1.26	-0.72	-0.60
PBOG-40× SELECTION-1	-1.48**	34.58	0.02	-0.16	0.15
IC042345× PSPL	-0.19	1.07	0.71	-0.52	-0.40
IC042345× PUSA NAVEEN	0.57*	27.48	-1.41	0.93	1.01
IC042345× ARKA BAHAR	-0.69**	-23.62	2.48	-0.85	-1.02
IC042345× SELECTION-1	0.32	-4.92	-1.78	0.44	0.40
Std Error	0.25	61.29	1.45	0.65	1.02

NPB: number of primary branches per plant; FW: fruit weight; FL: fruit length; No. FRTS: number of fruits per plant; YPP: yield per plant

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