

Heterosis and Combining Ability Studies for Yield and Quality Traits in Bottle Gourd (*Lagenaria siceraria* (Mol.) Standl.)

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Abstract Eight parental lines and 28 F_1 hybrids of bottle gourd received from half-diallel were examined to analyze the extent of heterosis and combining ability for ten agronomic and five quality characters. Regarding general combining ability the parent PBOG-8 was good combiner for fruit weight, marketable yield, vine length, dry matter and ash content. Pusa Naveen for number of fruit per plant was good combiner. The crosses Punjab Komal \times Punjab Long, PSPL \times Punjab Barkat, Punjab Barkat \times Pusa Naveen, Punjab Long \times Gutka Long, PBOG-7 \times PBOG-8 showed positive significance for specific combining ability for marketable yield. For ascorbic acid content, the best cross combination with highest SCA value was PBOG-7 \times Pusa Naveen and Punjab Long \times Punjab Barkat. Punjab Komal \times PSPL and Gutka Long \times Pusa Naveen showed significantly positive heterosis for fruit weight and marketable yield. For the quality character ascorbic acid, PSPL \times Pusa Naveen, PSPL \times Punjab Barkat and Punjab Barkat \times PBOG-8 showed highly significant positive heterosis.

Keywords Bottle gourd, GCA (General combining ability), Heterosis, SCA (Specific combining ability).

Introduction

Bottle gourd (*Lagenaria siceraria* (Mol.) Standl. $2n = 2x = 22$) is an important cucurbitaceous vegetable crop known as white flower gourd, Ghiakadoo or Lauki belonging to family Cucurbitaceae and subfamily Cucurbitoidae. The *Lagenaria siceraria* is only cultivated species which is annual and monoecious while other species are wild, perennial and dioecious. It thrives well in hot humid weather condition but it can be grown in diverse low temperature condition also (Maurya et al. 1993). Under North-Indian conditions, its cultivation is done in spring-summer and rainy seasons. Its fruit are available from March to November (Anonymous 2015a). In India area and production of bottle gourd was 1.11 million hectares and 18.36 million tonnes and highest area and production was reported in Bihar i.e. 0.04 million hectares and 6.31 million tonnes during 2015-16. In Punjab, bottle gourd was cultivated on an area of about 8.44 thousand hectares with total production 1.27 lakh tonnes during 2015-16 (Anonymous 2015b). Under cucurbits, bottle gourd is gaining importance due to its higher yield potential, steady market prices throughout the season and export potential. Pulp of bottle gourd is used for overcoming constipation, cough, night blindness and as an antidote against certain poisons. Fruit pulp is very good source of fiber-free carbohydrate and fruit pericarp for crude fiber (Singh 2011). Bottle gourd also holds promise for its yet unexploited possible uses of oil and protein contents of seed. The seed kernels contain 52.54% oil, and about 30.72% protein. The oil obtained from seed is clear and pale yellow and is used as cooking oil as well as hair oil (Pradhan et al. 2013).

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Table 1. ANOVA for design of experiment for different characters of bottle gourd. *Significance at 5% level, **Significance at 1% level.

Source of variation	Replication	Genotype	Error
Df	2	35	70
Days to first female flowering	23.35	4.24*	9.69
Node at which the first female flower appears	0.01	0.35	0.6
Days to first fruit harvest	9.68	22.69**	11.89
Fruit length (cm)	20.98	122.10**	1.87
Fruit width (cm)	0.45	3.97**	0.10
Number of fruits per plant	7.56	5.87**	1.30
Fruit weight (g)	1741.78	4271.54**	1633.92
Marketable yield per plant (g)	43.49	2483.21**	200.14
Vine length (m)	3165.78	4769.90**	1125.00
Number of seeds per fruit	2873.67	42318.04**	1879.12
Dry matter (%)	0.02	0.55*	0.07
Ash content (%)	0.10	3.55**	0.20
Ascorbic acid (mg per 100 g)	1.49	36.16**	6.27
Total protein (%)	0.01	0.03	0.00
Fiber (%)	0.01	0.21	0.06

Table 2. Anova for combining ability for different characters of bottle gourd. *Significance at 5% level, **Significance at 1% level.

Source of variation	GCA	SCA	Error
Df	7	28	70
Days to first female flowering	1.13**	1.48	3.23
Node at which the first female flower appears	0.043	0.13	0.021
Days to first fruit harvest	15.72**	5.51**	3.96
Fruit length (cm)	34.94**	42.13**	0.62
Fruit width (cm)	2.43**	1.04**	0.03
Number of fruits per plant	3.48	1.57**	626.3
Fruit weight (g)	2750.8**	1092.1**	544.6
Marketable yield per plant (g)	1566.4**	643.0**	66.71
Vine length (m)	1737.2**	1553.2**	374.9
Number of seeds per fruit	30811.7**	9929.6**	0.63
Dry matter (%)	0.17**	0.19**	0.02
Ash content (%)	2.43**	0.87**	0.06
Ascorbic acid (mg per 100 g)	32.09**	6.2**	0.21
Total protein (%)	0.007	0.01	0.001
Fiber (%)	0.049	0.076	0.021

Diallel mating design proposed by Griffing (1956) is an ideal to produce maximum hybrid combinations from a given number of parents. Diallel cross design is frequently used in plant breeding research to obtain information on genetic effects for a fixed set of parental lines or to estimate general combining ability (GCA), specific combining ability (SCA), variance components and heritability for a population from randomly chosen parental lines. The main advantages of a half diallel design are that each parent is crossed with each other in all possible combinations (excluding the reciprocals). It is better method as compared to line \times tester because in the line \times tester design, each parent does not get equal chance to mate with every other parent, whereas in a diallel cross each parent has equal chance to mate with the every other parent (Ferreira et al. 2002). Heterosis breeding offers an opportunity in bottle gourd due to monoecious nature of flowers, high number of seeds per fruit or per pollination and requirement of less number of plants per unit area. This can be exploited not only for high yield, but for early maturity, uniform size, shape, color, tenderness, longer harvesting span (Khosa and Dhatt 2015).

Materials and Methods

The experimental plant material comprised of 8 parental lines (PBOG-7, Punjab Komal, PSPL, Punjab Long, Gutka Long, Punjab Barkat, Pusa Naveen, PBOG-8), 28 F_1 hybrids and one check (Vardan) was sown in polyethene bag on 9th Feb 2016. The transplanting was done in the field on 9th March 2016 in a randomized block design with three replications at Vegetable Research Farm, Punjab Agricultural University, Ludhiana. For the experiments, 10 plants were grown on raised beds of width 2.5 m at plant to plant spacing of 60 cm. Data on five central plants per treatment per replication were recorded excluding the border two plants on each side. The recommended NPK fertilizer doses and cultural practices along with plant protection measures were followed using recommended package of practices (Anonymous 2015b). The general combining ability and the specific combining ability analysis was carried out by Method II (parents and one set of F_1 's were included but not reciprocal F_1 's) and Model I (Fixed effect model) as suggested by Griffing (1956). The experiment was laid out in a randomized complete block design with three replica-

Table 3. Estimation of GCA effects of parents for different characters of bottle gourd. **Significance at 1% level, *Significance at 5% level.

Parents	Days to first female flowering	Node at which the first female flower appears	Days to first fruit harvest	Fruit length (cm)	Fruit width (cm)	Number of fruits per plant	Fruit weight(g)	Marketable yield per plant (g)
PBOG-7	0.49	0.07	0.19	-2.77	0.95**	-0.58**	3.91	-6.04*
Punjab Komal	-0.28	-0.15	-2.45**	0.22	-0.09	-0.64**	-27.4**	-14.71**
PSPL	0.16	0.03	1.52*	1.26**	-0.38**	0.11	9.6	5.41
Punjab Long	0.16	0.03	0.06	0.85**	-0.55**	-0.32	-1.8	-5.82*
Gutka Long	-0.27	0.02	-0.01	-2.10**	0.52**	-0.53**	-17.3*	-13.75*
Punjab Barkat	-0.48	-0.00	-0.70	2.62**	-0.13*	0.63**	-0.38	4.58
Pusa Naveen	-0.10	00	1.47**	-1.26**	-0.22**	0.72**	6.7	7.75**
PBOG-8	0.32	00	-0.08	1.18**	-0.10	0.61**	26.7**	22.58**
CD 5%	1.04	0.11	1.17	0.46	0.10	0.38	13.76	4.81
CD 1%	1.06	0.86	1.55	0.62	0.14	0.51	18.28	6.39

Table 3. Continued.

Parents	Vine length (cm)	Number of seeds per fruit	Dry matter content (%)	Total protein (%)	Ash content (%)	Ascorbic acid (mg/100g)	Fiber content (%)
PBOG-7	-8.25**	-33.51**	-0.05	0.01	-0.72**	-2.02**	-0.02
Punjab Komal	4.36**	96.50**	-0.10	0.05	-0.19*	-2.47**	0.07
PSPL	13.11**	-73.36**	0.02	-0.01	-0.30**	0.76*	0.01
Punjab Long	-27.15**	-35.61**	-0.10	-0.03	-0.31**	-0.25*	0.02
Gutka Long	-0.28**	-5.56**	-0.07	-0.02	0.50**	3.28**	-0.13**
Punjab Barkat	4.68**	62.20**	-0.03	0.01	0.01	0.19	-0.02
Pusa Naveen	-0.52**	-21.56**	0.04	-0.01	0.19*	-0.34	0.09*
PBOG-8	14.45**	10.90**	0.29**	0.00	0.82**	0.85**	-0.02
CD 5%	0.11	0.15	0.08	0.19	0.15	0.11	0.08
CD 1%	0.15	0.20	0.11	0.25	0.20	0.85	0.11

tions and the data were recorded days to first female flowering, node at which first female flower appear, days to first fruit harvest, fruit weight (g), marketable yield per plant, fruit length (cm), fruit width (cm), number of fruits per plant, vine length (cm), number of seeds per fruit, moisture, vitamine-c, total protein, ash content and fiber content.

Results and Discussion

The results of the analysis of variance for the experimental design are presented in the Table 1. The mean square due to replications were non significantly different for all the characters. The mean squares due to genotypes were significantly different for all the characters except node at which first female flower appear, total protein and fiber. The analysis of variance

for combining ability for different yields and quality contributing traits are presented in Table 2. Mean squares due to general combining ability (GCA) for days to first female flowering, days to first fruit harvest, fruit length, fruit width, fruit weight, marketable yield per plant, vine length, dry matter, ash content and ascorbic acid were observed to be significant. Mean squares due to specific combining ability (SCA) for days to first fruit harvest, number of fruit per plant, fruit length, fruit width, fruit weight, marketable yield per plant, vine length, number of seed per fruit, dry matter, ash content and ascorbic acid were observed to be significant.

The estimates of general combining ability effects of eight parental lines for all characters are presented in Table 3. Among 8 parents, Punjab Komal

was the best general combiner for 6 traits viz. days to first female flowering, node at which first female flower appear, days to first fruit harvest, number of seeds per fruit, total protein and fiber. PBOG-8 was good combiner for fruit weight, marketable yield, vine length, dry matter and ash content. Pusa Naveen for number of fruit per plant was good combiner. For ascorbic acid content Gutka Long was good combiner. It was studied on five parents and found that Arka Bahar and Pusa Summer Prolific Long expressed significant negative GCA effect indicating their good general combining ability for days to first fruit harvest. All the parents were average combiner except Gutka Long which was poor combiner for fiber content. High GCA effects of a parent is a function of breeding value and hence due to additive gene effect and additive × ad-

ditive interaction effect which represents the fixable components of genetic variance. Clearly, Parents with good GCA effects may be assumed to possess more favorable genes for the concerned traits (Sarkar et al. 2015).

The specific combining ability effects of crosses for all characters are presented in Table 4. Punjab Komal × Punjab Long (50.73), PSPL × Punjab Barkat (37.38), Punjab Barkat × Pusa Naveen (30.91), Punjab Long × Gutka Long (23.62), PBOG-7 × PBOG-8 (21.73) showed positive significance for specific combining ability for marketable yield. Cross combinations, PBOG-7 × PBOG-8, Punjab Long × Gutka Long and PBOG-7 PSPL were positively significant for marketable yield, number of fruit per plant and fruit weight.

Table 4. Estimation of SCA effects of cross combinations for different characters of bottle gourd. *Significance at 5% level, **Significance at 1% level.

Hybrids	Node at which the		Days to first fruit harvest	Fruit length (cm)	Fruit width (cm)	Number of fruits per plant	Fruit weight (g)
	Days to first female flowering	first female flower appears					
PBOG - 7 × Punjab Komal	-0.47	-0.15	0.07	13.96**	-1.21**	1.41**	-6.42
PBOG - 7 × PSPL	0.91	-0.24*	-1.39	-2.53**	-0.19	1.06*	55.22**
PBOG - 7 × Punjab long	0.74	0.25*	2.15	0.21	-0.84**	-0.90	-3.68
PBOG - 7 × Gutka long	-5.65**	-0.23*	0.13	5.70**	0.27	-0.09	32.56
PBOG - 7 × Punjab Barkat	-0.41	-0.29*	-0.68	-10.33**	1.03**	-1.15*	16.87
PBOG - 7 × Pusa Naveen	0.31	-0.01	3.15*	4.76**	-0.56**	-1.74**	-36.86*
PBOG - 7 × PBOG-8	1.08	0.02	0.69	-0.23	-1.04**	1.27*	-63.90**
Punjab Komal × PSPL	1.15	-0.13	-1.25	-1.64*	0.42**	-0.98	-18.39
Punjab Komal × Hybrids Punjab long	-1.78	0.27*	-0.96	-2.57**	1.26**	-0.95	4.16
Punjab Komal × Gutka long	-0.22	-0.02	-1.22	-6.46**	0.60**	-0.94	22.18
Punjab Komal × Punjab Barkat	-1.00	0.01	-0.53	-3.09**	-0.08	-1.60**	-7.49
Punjab Komal × Pusa Naveen	1.61	-0.09	1.29	3.06**	-0.44**	-1.49**	-3.16
Punjab Komal × PBOG-8	-0.14	-0.59**	0.84	7.51**	-0.90**	-0.28	-7.06
PSPL × Punjab long	-1.89	0.47**	-2.27	5.52**	0.20	0.59	1.09
PSPL × Gutka long	-0.66	-0.11	0.20	5.09**	-1.12**	-0.89	71.58**
PSPL × Punjab Barkat	1.22	-0.18	1.88	-2.09**	0.58	0.24	-0.48
PSPL × Pusa Naveen	0.50	-0.32**	-0.07	-0.06	0.12	0.16	-4.61
PSPL × PBOG-8	-0.39	-0.28*	-0.03	-5.69**	0.13	0.06	23.22
Punjab long × Gutka long	0.80	0.08	-1.73	2.21**	-1.26**	1.93**	-61.61**
Punjab long × Punjab Barkat	-0.78	-0.28*	0.94	-4.92**	-0.13	1.17*	2.48
Punjab long × Pusa Naveen	0.16	-0.18	1.88	0.52	-1.01**	-1.51**	12.26
Punjab long × PBOG-8	-0.39	0.01	-2.17	-5.16**	0.46**	-0.70	13.90
Gutka long × Punjab Barkat	0.05	0.43**	0.35	1.61*	-0.67**	-0.91	2.44
Gutka long × Pusa Naveen	0.07	0.13	6.85**	-9.33**	2.69**	-0.70	24.33
Gutka long × PBOG-8	-2.15	-0.07	-3.26*	-9.92	2.08**	1.10*	11.81
Punjab Barkat × Pusa Naveen	-0.71	0.35*	-4.45**	-0.24	0.28	1.23*	22.08
Punjab Barkat × PBOG-8	1.99	-0.74**	2.08	-1.75**	-0.11	1.84**	-6.35
Pusa Naveen × PBOG-8	-2.49	-0.44**	-0.41	-5.21**	0.21	0.26	-24.69
CD (5%)	2.82	0.23	3.13	1.24	0.28	1.03	36.70
CD (1%)	3.75	0.30	4.15	1.64	0.38	1.37	48.76

Table 4. Continued.

Hybrids	Marketable yield per plant (g)	Vine length (m)	Number of seeds per fruit	Dry matter content (%)	Total protein (%)	Ash content (%)	Ascorbic acid (mg/100g)	Fiber content (%)
PBOG - 7 × Punjab Komal	9.76	-43.52**	-113.11**	0.66**	-0.03	0.62	-2.22	-0.31**
PBOG - 7 × PSPL	14.26*	-4.95	50.75*	0.77**	0.02	0.74	-0.97	0.24*
PBOG - 7 × Punjab long	-5.12	45.30**	72.98**	-0.17	-0.00	-0.74	-5.35**	-0.49**
PBOG - 7 × Gutka long	-12.71	-91.55**	126.28**	0.18	0.06*	0.50	0.34	0.05
PBOG - 7 × Punjab Barkat	-11.05	-2.85	-11.14	-0.22	0.12**	-0.69	1.87	-0.23*
PBOG - 7 × Pusa Naveen	-3.06	0.76	-92.37**	-0.72**	-0.03	-1.04	4.59**	-0.01
PBOG - 7 × PBOG-8	-21.73**	40.77*	64.82**	-0.51**	0.04	0.27	-0.05	0.02
Punjab Komal × PSPL	-12.12	37.10*	-27.57	-0.44**	-0.08**	-0.74	0.04	-0.07
Punjab Komal × Punjab long	50.73**	21.04	-212.01**	-0.15	-0.01	1.26**	-3.17**	0.07
Punjab Komal × Gutka long	-30.54**	22.50	-42.04	0.54**	0.02	0.55**	-0.46	0.49**
Punjab Komal × Punjab Barkat	-35.53**	55.54**	133.18**	-0.32**	0.24**	-0.03	2.04	0.22*
Punjab Komal × Pusa Naveen	-39.31**	-8.26	-50.04	-0.38**	-0.09**	-0.68	-0.99	-0.34**
Punjab Komal × PBOG-8	-15.21*	6.50	29.82	-17.12	-0.23**	0.63	1.53	-0.30*
PSPL × Punjab long	16.53*	33.94*	183.85**	-0.00	0.08**	-0.67	0.74	-0.42**
PSPL × Gutka long	12.17	38.74*	48.82	0.44	0.01	1.62	-0.44	-0.33**
PSPL × Punjab Barkat	37.38**	-29.22	-44.94	-0.01	0.08**	0.58**	-1.27	0.01
PSPL × Pusa Naveen	2.48	37.30*	-113.17**	-0.15	-0.07**	-0.91	-3.23**	-0.15
PSPL × PBOG-8	-7.24	-68.92**	94.97**	0.33**	-0.07**	-0.15	-0.14	-0.01
Punjab long × Gutka long	23.62**	-10.65	50.05*	0.22	-0.03	-0.61	-1.09	0.38**
Punjab long × Punjab Barkat	18.54**	2.37	-73.04**	0.06	-0.13**	-0.66	2.78*	0.21
Punjab long × Pusa Naveen	-20.04**	28.57	109.38**	0.29*	0.01	0.39	1.00	0.14
Punjab long × PBOG-8	-32.70**	-38.32*	68.58**	0.53**	0.01	1.45**	-2.78*	0.17
Gutka long × Punjab Barkat	-16.45*	-19.49	54.58	-0.17	-0.23**	-0.96	0.86	-0.38**
Gutka long × Pusa Naveen	9.44	40.37**	-26.64	-0.02	0.02	0.28	-0.76	0.02
Gutka long × PBOG-8	12.55	36.47*	-114.44**	-0.15	0.14**	0.05	2.22	0.12
Punjab Barkat × Pusa Naveen	30.91**	-2.26	95.92**	0.69**	-0.05	1.04**	-0.41	-0.07
Punjab Barkat × PBOG-8	21.54**	16.17	-30.87	-0.53**	-0.03	-1.04	-0.14	-0.13
Pusa Naveen × PBOG-8	-13.39*	-41.62**	98.88**	-0.14	0.12**	-1.74	-4.23**	0.23*
CD (5%)	12.74	30.11	39.21	0.23	0.05	0.41	2.27	0.22
CD (1%)	17.06	40.22	52.11	0.31	0.06	0.54	3.02	0.30

PBOG-7 × PSPL (0.77), Punjab Barkat × Pusa Naveen (0.69), PBOG-7 × Punjab Komal (0.66) were best cross combinations for dry matter content. Punjab long × PBOG-8 (1.45), Punjab Komal × Punjab long (1.26), Punjab Barkat × Pusa Naveen (1.04), PSPL × Punjab Barkat (0.58) were showed good specific combiners for ash content. For ascorbic acid content, the best cross combination with highest SCA value was PBOG-7 × Pusa Naveen (4.59) and Punjab Long × Punjab Barkat (2.78). Out of 28 cross combinations, five crosses exhibited positive SCA value i.e. Punjab Komal × Gutka Long (0.47), Punjab Long × Gutka Long (0.38), PBOG-7 × PSPL (0.24), Pusa Naveen × PBOG-8 (0.23) and Punjab Komal × Punjab Barkat (0.22) for fiber content.

The data w.r.t. SCA effects pertained that the per-

formance of the hybrids for majority of the traits was higher when the parents were of high × low or low × low GCA status. The parental combinations with high × low GCA resulted in the higher frequency of significant heterosis for different traits. The data computed on the estimates of heterosis over better parent and standard check (Vardan) was evaluated for all the characters under study. The heterotic effects determined as per cent increase or decrease over the better parent and standard checks of respective F₁ hybrid have been presented in Table 5. In summer season 13 hybrids over Vardan showed significantly positive heterosis among 28 cross combinations for marketable yield. Top five best cross combinations were Punjab Komal × PSPL (41.32%), Punjab Long × Gutka Long (40.94%), Punjab Komal × Punjab Barkat (26.99%), Gutka Long × Pusa Naveen (25.07%)

and PSPL × Pusa Naveen (22.32%). Punjab Komal × PSPL and Gutka Long × Pusa Naveen showed significantly positive heterosis for fruit weight and marketable yield. Heterosis over better parent and standard checks for fruit yield was also reported by Singh et al. (2011), Singh et al. (2012) and Sharma et al. (2012). Heterosis in the negative direction is desirable for days to first female flowering. Among 28 crosses only one cross showed significant negative heterosis over better parent, three crosses over Vardan viz. Punjab Komal × Punjab Barkat (-4.83%), Punjab Komal × PBOG-8 (-4.60%) and PSPL × Pusa Naveen (-4.25). Genotypes showed significant differences among themselves for number of nodes bearing first female flower. Magnitude of heterosis was significant in both the directions. The magnitude of heterosis ranged from -26.09% (PSPL × Gutka Long) to 30.43% (PSPL ×

Pusa Naveen) over Vardan. However, the magnitude of heterosis over better parent, it ranged from -37.14% (Punjab Long × PBOG-8) to 20% (PSPL × Pusa Naveen).

Out of 28 hybrids, 17 hybrids showed significant negative heterosis over better parent, one hybrid over Vardan. Shaikh et al. (2011) reported that cross Punjab Long × DBG-5 showed standard heterosis only for this trait during summer season among 50 crosses. Among 28 hybrids, 4 crosses showed negative significant heterosis over Vardan for days to first fruit harvest. The magnitude of heterosis varied from 14.78% (Gutka Long × Pusa Naveen) to -26.96% (Punjab Komal × Pusa Naveen) over Vardan and respective better parent for number of fruits per plant varied from 1.04% (Punjab Komal × PSPL) to -42.61%

Table 5. Estimation of heterosis (%) over the respective better parents and standard check Vardan for different characters of bottle gourd. *Significance at 5% level, **Significance at 1% level.

Hybrids	Days to first female flowering		Node at which the first female flower appears		Days to first fruit harvest	
	BP	SC	BP	SC	BP	SC
PBOG-7 × Punjab Komal	0.70	-1.15	0.00	13.04	-13.35	-2.63
PBOG-7 × PSPL	-1.05	-2.01	-15.38	-4.35	-13.93	-3.29
PBOG-7 × Punjab long	2.45	1.15	-17.86	0.00	-10.89	0.0
PBOG-7 × Gutka long	-1.36	0.86	7.69	21.74*	-8.55	2.76
PBOG-7 × Punjab Barkat	-1.05	-2.30	-11.54	0.00	-11.01	0.0
PBOG-7 × Pusa Naveen	-0.70	-2.24	7.69	21.74*	-12.76	-1.91
PBOG-7 × PBOG-8	-2.03	-0.34	-28.57	8.70	-5.74	5.92**
Punjab Komal × PSPL	5.36	1.72	1.33	10.14	2.68	0.62
Punjab Komal × Punjab long	-0.90	-1.78	-10.71	8.70	0.00	-5.70**
Punjab Komal × Gutka long	-2.72	0.23	-8.33	-4.35	-4.55	-3.29
Punjab Komal × Punjab Barkat	-1.79	-4.83*	8.33	13.04	-3.36	-4.82*
Punjab Komal × Pusa Naveen	3.70	-2.87	-4.17	0.00	0.00	-5.26**
Punjab Komal × PBOG-8	-6.95	-4.60*	-34.29	0.00	-6.49	-5.26**
PSPL × Punjab long	2.32	0.57	-21.43	-4.35	2.01	0.0
PSPL × Gutka long	-3.40	-1.72	-32.00	-26.09**	-3.90	-2.63
PSBL × Punjab Barkat	2.32	-1.72	4.00	13.04	7.65	5.55**
PSPL × Pusa Naveen	-0.36	-4.25*	20.00	30.43**	0.00	-1.32
PSPL × PBOG-8	-2.37	-2.87*	-31.43	4.35	0.52	1.84
Punjab long × Gutka long	-1.70	0.0	-17.86	0.00	1.82	3.16
Punjab long × Punjab Barkat	2.87	-0.57	0.00	21.74*	5.50	3.42
Punjab long × Pusa Naveen	2.69	-1.38	-21.43	-4.35	7.08	1.45
Punjab long × PBOG-8	-0.85	1.72*	-37.14	-4.35	-0.13	1.18
Gutka long × Punjab Barkat	-2.21	-0.34	8.33	13.04	-3.90	-2.63
Gutka long × Pusa Naveen	-4.25	-3.45	10.00	-4.35	-1.30	0.0
Gutka long × PBOG-8	-3.05	-1.15	-34.29	0.00	2.73	4.08*
Punjab Barkat × Pusa Naveen	2.51	-1.38	4.17	8.70	-1.34	-3.29
Punjab Barkat × PBOG-8	-1.53	0.0	-31.43	4.35	-2.60	-1.37
Pusa Naveen × PBOG-8	-3.56	-2.93	-17.14	26.09**	-2.60	-0.88
CD (5%)		2.36		0.41		2.58
CD (1%)		4.51		0.51		3.98

Table 5. Continued.

Hybrids	Fruit length (cm)		Fruit width (cm)		Number of fruits per plant	
	BP	SC	BP	SC	BP	SC
PBOG-7 × Punjab Komal	-2.84*	-40.93**	2.11**	75.01*	-23.96	-15.36*
PBOG-7 × PSPL	-9.82**	39.92**	-39.09**	4.40**	-7.03	-0.29
PBOG-7 × Punjab long	-17.77**	-15.00**	-30.49**	19.14**	-18.18	4.35
PBOG-7 × Gutka long	-12.51**	-6.64	-40.17**	2.54**	-42.61	-23.48**
PBOG-7 × Punjab Barkat	0.37	2.31	-14.57**	46.43*	-38.72	-16.52*
PBOG-7 × Pusa Naveen	-22.90**	-37.91**	-13.29**	48.62*	-27.00	-15.36*
PBOG-7 × PBOG-8	-29.31**	1.96	-32.97**	14.89**	-13.92	-21.16**
Punjab Komal × PSPL	-40.13**	-7.10	-33.40**	7.63**	1.04	12.46**
Punjab Komal × Punjab long	-21.00**	-18.33**	-31.24**	11.12**	-21.82	-0.29
Punjab Komal × Gutka long	-7.45**	-1.24	-31.70**	10.38**	-40.00	-20.00**
Punjab Komal × Punjab Barkat	-7.78**	-6.00	-23.33**	23.90**	-28.51	-2.61**
Punjab Komal × Pusa Naveen	-13.56**	-30.38**	-18.27**	32.09**	-37.00	-26.96**
Punjab Komal × PBOG-8	-31.74**	-1.54	-34.78**	5.40**	-29.17	-21.16**
PSPL × Punjab long	-31.35**	6.52	-12.64**	-3.64**	-36.36	-18.84**
PSPL × Gutka long	-15.54**	31.05**	-14.57**	-10.53**	-29.57	-6.09
PSPL × Punjab Barkat	-28.51**	10.92**	-2.74**	-5.11**	-27.66	-1.45
PSPL × Pusa Naveen	-18.38**	26.65**	-11.26**	-2.92**	-12.00	2.03
PSPL × PBOG-8	-26.19**	14.53**	-7.42**	-8.16**	-23.24	-17.68**
Punjab long × Gutka long	-0.84	5.81	2.47**	13.03**	-18.26	8.99
Punjab long × Punjab Barkat	-4.07**	-0.83	-7.48**	2.06**	-20.00	8.99
Punjab long × Pusa Naveen	-15.03**	-12.16**	-5.18**	4.60**	-16.36	6.67
Punjab long × PBOG-8	-21.67**	12.99**	-6.91**	2.69**	-36.36	-18.84**
Gutka long × Punjab Barkat	-3.60**	2.87**	-18.22**	-14.35**	-19.15	10.14
Gutka long × Pusa Naveen	-11.62**	-5.69	-12.79**	-4.59**	-13.91	14.78*
Gutka long × PBOG-8	-30.80**	-0.18	-27.45**	-24.01**	-36.52	-15.36*
Punjab Barkat × Pusa Naveen	-13.36**	-11.68**	-1.48**	7.78**	-31.91	-7.25
Punjab Barkat × PBOG-8	-27.80**	4.15	7.38**	6.53**	-35.32	-11.88
Pusa Naveen × PBOG-8	-25.83**	6.99	-3.11**	6.00**	-24.00	-11.88
CD (5%)		2.19		0.50		1.04
CD (1%)		2.83		0.63		1.57

Table 5. Continued.

Hybrids	Fruit weight (g)		Marketable yield per plant (g)		Vine length (cm)	
	BP	SC	BP	SC	BP	SC
PBOG-7 × Punjab Komal	-2.39	2.55	-19.61	-19.61**	8.64	-6.44
PBOG-7 × PSPL	-10.29	-7.39	-7.68	-15.72**	-2.77	-16.27
PBOG-7 × Punjab long	9.18	16.60**	-13.00	-3.76	6.38	-8.38
PBOG-7 × Gutka long	-5.02	-0.51	-28.16	-18.63**	8.32	-6.72
PBOG-7 × Punjab Barkat	0.10	4.56	-29.78	-26.17**	-12.96	-25.04
PBOG-7 × Pusa Naveen	1.56	4.85	-14.61	-16.46*	5.16	-9.44
PBOG-7 × PBOG-8	-21.63	-6.48	-22.39	-11.04**	4.84	-9.72
Punjab Komal × PSPL	-12.61	-8.18	16.05	16.05**	15.41	-0.61
Punjab Komal × Punjab long	-17.12	-11.49*	-16.05	-7.13	-0.71	-14.49
Punjab Komal × Gutka long	-13.29	-8.91*	-30.06	-20.78**	16.96	0.72
Punjab Komal × Punjab Barkat	-10.74	-6.22	-0.83	4.28	6.06	-8.66
Punjab Komal × Pusa Naveen	-10.14	-5.59	-10.71	-10.71*	11.54	-3.94
Punjab Komal × PBOG-8	-23.48	-8.69*	-41.17	-32.56**	18.89	2.39
PSPL × Punjab long	-11.90	-5.91	-39.30	-32.85**	5.54	-9.11
PSPL × Gutka long	-6.45	-2.00	-24.03	-13.95**	11.22	-4.22
PSPL × Punjab Barkat	-14.73	-10.93*	-24.43	-20.53**	7.22	-7.66
PSPL × Pusa Naveen	0.02	2.04	2.66	0.44	10.25	-5.05

Table 5. Continued.

Hybrids	Fruit weight (g)		Marketable yield per plant (g)		Vine length (cm)	
	BP	SC	BP	SC	BP	SC
PSPL × PBOG-8	-3.27	15.42**	-18.23	-6.27	16.38	0.22
Punjab long × Gutka long	-4.47	2.02	2.18	15.74**	4.19	-10.27
Punjab long × Punjab Barkat	-3.80	2.75	-9.22	0.41	16.05	-0.06
Punjab long × Pusa Naveen	7.09	14.37**	-9.87	-0.31	-1.68	-15.32
Punjab long × PBOG-8	-13.86	2.79	-37.67	-28.55**	-12.06	-24.26
Gutka long × Punjab Barkat	-23.37	-19.73**	-19.14	-8.41	-0.97	-14.71
Gutka long × Pusa Naveen	-4.59	-0.05	-9.33	2.70	2.51	-11.72
Gutka long × PBOG-8	-12.81	4.05	-29.49	-19.18**	6.58	-8.22
Punjab Barkat × Pusa Naveen	4.65	9.31*	-22.13	-18.12**	-3.55	-16.94
Punjab Barkat × PBOG-8	-33.84	-21.05**	-33.06	-23.27**	4.71	-9.83
Pusa Naveen × PBOG-8	-19.39	-3.80	-32.67	-22.82**	0.71	-13.27
CD (5%)		35.35			54.02	
CD (1%)		54.19			69.58	

Table 5. Continued.

Hybrids	Number of seeds per fruit		Dry matter (%)		Ash content (%)	
	BP	SC	BP	SC	BP	SC
PBOG-7 × Punjab Komal	-17.53	-17.76*	-3.95	-2.41	-22.27	-3.65
PBOG-7 × PSPL	-23.87	0.75	6.46	11.60**	-10.87	6.77*
PBOG-7 × Punjab long	-35.29	-0.93	0.89	17.11**	-12.77	6.77*
PBOG-7 × Gutka long	-8.49	15.89	-6.63	-7.81	-23.91	-8.85**
PBOG-7 × Punjab Barkat	39.64	39.25**	-4.95	1.49	-11.76	12.60**
PBOG-7 × Pusa Naveen	-14.20	19.72*	-10.58	-6.89	-20.87	-5.21
PBOG-7 × PBOG-8	-37.67	-26.54**	-31.37	-17.11**	-28.11	-6.77*
Punjab Komal × PSPL	-4.31	26.64**	-10.73	-6.43	-8.40	13.54**
Punjab Komal × Punjab long	36.14	108.41**	-15.73	-2.18	-21.43	-2.60
Punjab Komal × Gutka long	-10.33	13.55**	-13.67	-12.28*	-21.85	-3.12
Punjab Komal × Punjab Barkat	-27.30	-27.57**	-14.41	-8.61*	-7.76	17.71**
Punjab Komal × Pusa Naveen	-7.90	28.50**	4.08	8.38	-4.20	18.75**
Punjab Komal × PBOG-8	66.85*	96.64**	-25.86	-10.45*	-17.27	7.29**
PSPL × Punjab long	-20.45	21.78*	-22.85	-10.45*	-16.17	2.60
PSPL × Gutka long	15.82	53.27**	-4.49	0.11	3.51	22.92**
PSPL × Punjab Barkat	-44.63	-26.73**	-15.38	-9.64	-20.82	1.04
PSPL × Pusa Naveen	-2.68	35.79**	-6.68	-2.18	-18.86	-3.65
PSPL × PBOG-8	-19.63	6.36	-9.60	9.18	-0.80	28.65**
Punjab long × Gutka long	-35.29	-0.93	-14.14	-0.34	-8.09	12.50**
Punjab long × Punjab Barkat	-63.13	-43.55**	-15.63	-2.07	-22.45	-1.04
Punjab long × Pusa Naveen	-53.85	-29.35**	-1.29	14.58**	-7.23	13.54**
Punjab long × PBOG-8	-56.35	-33.18**	-28.80	-14.01**	-22.09	1.04
Gutka long × Punjab Barkat	-7.38	17.29*	-5.59	0.80	-17.55	5.21
Gutka long × Pusa Naveen	-27.06	1.78	-5.62	-1.72	-7.28	-0.52
Gutka long × PBOG-8	2.21	29.44**	-13.02	5.05	-13.25	12.50**
Punjab Barkat × Pusa Naveen	-8.91	27.10**	8.71	16.07**	2.04	30.21**
Punjab Barkat × PBOG-8	-16.73	-1.87	-29.85	-15.27**	-13.25	12.50**
Pusa Naveen × PBOG-8	4.62	45.98**	-22.24	-6.08	-19.28	4.69
CD (5%)		60.74		0.42		0.64
CD (1%)		81.13		0.51		0.83

Table 5. Continued.

Hybrids	Ascorbic acid (mg per 100 g)		Total protein (%)		Fiber (%)	
	BP	SC	BP	SC	BP	SC
PBOG-7 × Punjab Komal	-24.25	-0.26	-18.75	4.00	9.19	6.07
PBOG-7 × PSPL	-25.41	-12.27	1.03	17.20*	-10.33	-8.59
PBOG-7 × Punjab long	-12.59	2.81	3.57	16.00*	5.42	3.29
PBOG-7 × Gutka long	-28.02	-15.34*	-1.79	10.00*	-12.14	-14.66**
PBOG-7 × Punjab Barkat	-1.66	15.67*	3.45	20.00*	-9.32	-4.89
PBOG-7 × Pusa Naveen	-6.08	10.48	1.56	30.00*	-13.65	-8.85
PBOG-7 × PBOG-8	-3.50	17.80**	-5.17	10.00*	2.08	-0.84
Punjab Komal × PSPL	-19.37	6.17	-6.25	20.00*	-4.38	-2.53
Punjab Komal × Punjab long	-24.70	-0.85	7.81	38.00**	6.79	4.63
Punjab Komal × Gutka long	-20.46	4.73	-15.63	8.00	0.52	-2.44
Punjab Komal × Punjab Barkat	-31.29	-9.52	-10.31	14.80*	-2.73	2.02
Punjab Komal × Pusa Naveen	-15.34	11.47	-6.56	19.60*	3.03	8.76
Punjab Komal × PBOG-8	-16.81	9.53	18.13	51.20**	8.25	5.05
PSPL × Punjab long	-10.07	-2.50	-6.90	8.00	-8.43	-6.66
PSPL × Gutka long	-2.95	10.00	-20.00	-7.20	-10.00	-8.26
PSPL × Punjab Barkat	8.28	24.34**	-3.45	12.00*	1.69	6.66
PSPL × Pusa Naveen	12.35	14.54*	-7.81	18.00*	-17.24	-12.64**
PSPL × PBOG-8	0.27	22.40**	-5.17	10.00*	-16.03	-14.41**
Punjab long × Gutka long	-3.62	9.24	10.83	22.80*	-0.43	-2.44
Punjab long × Punjab Barkat	-12.17	0.86	-12.07	2.00	-8.59	-4.13
Punjab long × Pusa Naveen	6.33	15.28*	-18.75	4.00	-8.30	-3.20
Punjab long × PBOG-8	-0.21	21.81**	-6.21	8.80	-0.34	-2.36
Gutka long × Punjab Barkat	1.71	16.79**	-11.38	2.80	-0.48	4.38
Gutka long × Pusa Naveen	5.41	19.47**	-26.88	-6.40	-2.23	3.20
Gutka long × PBOG-8	-8.53	11.66	-6.21	8.80	8.52	4.04
Punjab Barkat × Pusa Naveen	-10.36	2.94	-13.75	10.40*	-3.19	2.19
Punjab Barkat × PBOG-8	7.49	31.21**	-6.90	8.00	-17.83	-13.82**
Pusa Naveen × PBOG-8	2.31	24.89**	-34.38	-16.00*	-20.03	-15.59**
CD (5%)		4.04		0.09		0.40
CD (1%)		5.19		0.3		0.51

(PBOG-7×Gutka Long) for the trait number of fruits per plant. For fruit weight, ten crosses were significantly positive over Vardan and top three hybrids were PBOG-7 × Punjab long (16.60%), PSPL × PBOG-8 (15.42%) and Punjab Long × Pusa Naveen (14.37%).

For the quality character ascorbic acid, PSPL × Pusa Naveen, PSPL × Punjab Barkat and Punjab Barkat × PBOG-8 showed highly significant positive heterosis. Heterosis over respective better parent for fiber content ranged from 9.31% (PBOG-7 × Punjab Komal) to -20.03% (Pusa Naveen × PBOG-8). 7 crosses showed best heterosis over respective better parent. Magnitude of heterosis for the trait ash content over Vardan 30.21 to -8.85% and significantly positive heterosis was showed by 14 crosses. Punjab Komal × Punjab Barkat, Punjab Komal × Punjab Long and

Punjab Long × Gutka Long were recorded 51.20%, 38.00% and 22.80% significant heterosis over Vardan respectively for total protein

From this investigation, it is concluded that there is tremendous scope for the development of F_1 hybrids in bottle gourd. Hybrids with significant heterosis in desirable direction for yield, its attributing traits and quality should be further evaluated and can be exploitation for commercial cultivation. The crosses Punjab Komal × Punjab Long, PSPL × Punjab Barkat, Punjab Barkat × Pusa Naveen, Punjab Long × Gutka Long, PBOG-7 × PBOG-8 showed positive significance for specific combining ability for marketable yield. Punjab Komal × PSPL and Gutka Long × Pusa Naveen showed significantly positive heterosis for fruit weight and marketable yield.

References

- Anonymous (2015a) Area and production of bottle gourd in India. <http://www.indiastat.com>.
- Anonymous (2015b) Package of practices for cultivation of vegetables. Punjab Agricultural University, Ludhiana, pp 1–2.
- Ferreira FM, Ribeiro Junior JI, Pacheco CAP, Silva CHO, Martins Filho S (2002) Genetic components of combining ability in a complete diallel. *Crop Breed Appl Biotech* 4 : 338–343.
- Griffing B (1956) Concept of general and specific combining abilities in relation to diallel crossing system. *Aust J Biol Sci* 9 : 463–493.
- Khosa JS, Dhatt AS (2015) Bottle gourd. Chapter. In : Peter KV, Hazra Pranab (eds). Book : Handbook of Vegetables Vol. III Publisher : Studium Press LLC, pp 49–78.
- Maurya IB, Singh SP, Singh NK (1993) Heterosis and combining ability in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). *Veg Sci* 20 : 77–81.
- Pradhan RC, Said PP, Singh S (2013) Physical properties of bottle gourd seeds. *Agric Eng Int CIGR J* 15 : 106–113.
- Sarkar M, Singh DK, Lohani M, Das AK, Ojha S (2015) Exploitation of heterosis and combining ability for earliness and vegetative traits in ridge gourd (*Luffa acutangula* (Roxb.) L.). *Int J Agric Envt Biotech* 8 (1) : 153–161.
- Shaika JA, Kathiria KB, Acharya RR (2011) Heterosis and combining ability for fruit yield and its component traits in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). *Veg Sci* 38 : 169–175.
- Sharma DR, Choudhary MR, Jakhar ML, Dadheech (2012) Heterosis in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). *Int J Life Sci* 1 : 212–216.
- Singh D (2011) Vegetable Science. New Vishal Publication, New Delhi, pp 242.
- Singh PP, Singh SP, Pandey S (2011) Heterosis in bottle gourd (*Lagenaria siceraria*) over two varied seasons. *Veg Sci* 38 : 39–43.
- Singh SK, Upadhyay AK, Pandey J, Pandey AK (2012) Studies on heterosis and combining ability in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.) for yield traits. *Annals Hort* 5 : 246–251.