

Estimation of Gene Action and Heterosis in Bottle Gourd (*Lagenaria siceraria* Mol. Standl.)

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Abstract An experiment was carried out on bottle gourd to estimate exploitation of hybrid vigor and gene action analysis following half diallel mating design i.e. consisting of 9 parents and their 36 F_1 hybrids. Analysis of variance showed mean squares due to parents and hybrids were almost significant for all the ten the characters except for days to 1st pistillate flower anthesis and fruit weight. It indicates the significant differences in sources of variations among parents vs hybrids for most of the traits. The heterosis for days to 1st pistillate flower anthesis was -22.74% (SBBG-32 × HZP-RC-1) over better parent while standard heterosis was -31.52% (Pusa Naveen × SBBG-

31-1). The heterosis for days to 1st fruit harvest was -16.95% (SBBG-32 × HZP-RC-1) over better parent while standard heterosis was -21.12% (Pusa Naveen × SBBG-31-1) and these characters are suitable for earliness. The heterosis for fruit yield/plant was 47.79% (HZP-RC-1 × SBBG-11) over better parent while 21.32% (Pusa Santushti × Pusa Naveen) over standard variety. It exhibited additive and non-additive gene actions with over mean degree of dominance indicated predominant role of non additive gene action in the inheritance of most of the traits. Thus, heterosis breeding method and gene action may be more rewarding for improvement in bottle gourd.

Keywords Heterosis, Gene action, Bottle gourd, Additive and non-additive.

Introduction

Bottle gourd (*Lagenaria siceraria*) ($2n=22$) is herbaceous, annuals and highly cross pollinated vegetable crop [1]. It can be grown in moderately warm and humid climatic condition while in north Indian condition in spring and rainy season. Fruits are globular, bottle shaped of about 80–90 cm in length and its color varies from dark green to whitish green [2]. Bottle gourd being monoecious and cross pollinated nature of crops there is chance of successful exploitation of heterosis or hybrid vigor [3]. It depends on selection of parents and hybridization programme with an objective of producing hybrids of bottle gourd with

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Table 1. Analysis of variance in set of 9 × 9 diallel crosses for ten characters in bottle gourd.

Source of variation	DF	Node number to anthesis of first pistillate flower	Days to anthesis of first pistillate flower	Days to first fruit harvest	Vine length (m)	Vine girth (cm)	Fruit length (cm)	Fruit girth (cm)	Fruits/plant	Average fruit weight (g)	Fruit yield/plant (kg)
Replications	2	0.76	0.29	0.57	0.07	0.004	2.34	0.83	0.74	0.01	0.05
Genotypes	44	10.70**	71.16**	72.14**	0.58**	0.15**	196.05**	5.78**	3.65**	0.05**	2.75**
Parents	8	14.32**	51.38**	38.80**	1.10**	0.03**	377.05**	5.53**	6.50**	0.11**	1.15**
Hybrids	35	10.16**	73.41**	77.96**	0.44**	0.12**	158.32**	5.85**	2.84**	0.10**	2.71**
Parents vs Hybrids	1	0.54	150.84**	135.00**	0.88**	2.04**	68.34*	5.32**	8.31**	0.00**	17.30**
Error	88	0.47	1.81	4.88	0.06	0.00	6.07	1.27	0.48	0.04	0.27

emphasis on earliness and consumer preference including greater fruit number, weight and high yielding [4]. Therefore, the present investigation was conducted to estimate gene action involved in governing the quantitative traits and extent of heterosis for yield or its contributing traits through half diallel mating design. These lines can be used for production of inbred line and producing F_1 desirable hybrids.

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Materials and Methods

The experiment was conducted at vegetable research farm, Bihar Agricultural College, Sabour (Bhagalpur) which falls under humid sub-tropical climate. It is located between 24.47° and 26.56° N latitude and 82.12° and 83.98°E longitude at an altitude of 75 m above sea level in the Indo-gangetic plains of Bihar. The experimental material consist of nine diverse parent viz. Rajendra Chamatkar, Pusa Santushti, Pusa Naveen, Narendra Dharidar, SBBG-23, SBBG-31-1, SBBG-32, HZP-RC-1, SBBG-11. The crosses were made in half diallel mating design during August-2012. The flowers were hand emasculated and pollinated to produce

F_1 hybrids excluding reciprocals. The seeds of 9 genotype and 36 hybrids were sown in the field at vegetable research farm. The experiments were laid out in randomized complete block design in three replications with a spacing of 3.0 meters in rows and 0.5 meter plant to plant spacing. Observations were recorded after selection and tagging of five plants for different characters i.e. node no. to first pistillate flower anthesis, days to anthesis of first pistillate flower, days to first fruit harvest, fruit length, fruit girth, vine length, vine girth, number of fruit/plant, average weight of fruit/plant and fruit yield/plant. All cultural practices and plant protection measures are taken as per need of crop. Heterosis was calculated according to method suggested by Hayes et al. [5]. The genetic components of variation were calculated by method given in Theory and analysis of diallel crosses [6, 7].

Results and Discussion

Analysis of variance

The results show that mean squares due to parents, hybrids and parents vs hybrids were almost highly significant for all the ten characters except for days to 1st pistillate flower anthesis and fruit weight indicating significant differences in these sources of varia-

Table 2. Identification of superior crosses based on heterosis.

Characters	Heterosis			Number of superior crosses over			Range of heterosis	
	M.P (Mid parents)	B.P (Better parents)	S.V (Standard variety)	M.P	B.P	S.V	B.P	S.V
1. Node no. to 1 st pistillate flower anthesis	1. SBBG-32 × HZP-RC-1 (-21.58**)	1. Pusa Santushti × SBBG-32 (-38.52**)	1. Pusa Santushti × SBBG-32 (-38.52**)	23	14	32	-38.52 to 38.10%	-38.52 to
	2. Pusa Stantushti × SBBG-32 (-32.11**)	2. SBBG-32 × HZP-RC-1 (-30.00**)	2. Narendra Dharidar × HZP-RC-1 (-38.15**)					
	3. SBBG-32 × SBBG-11 (17.65**)	3. SBBG-32 × SBBG-11 (-30.00**)	3. Pusa Santushti × Narendra Dharidar (-32.96**)					
	4. SBBG-32 × SBBG-11 (-17.40**)	4. Pusa Naveen × SBBG-31-1 (-25.30**)	4. Pusa Santushti × HZP-RC-1 (-32.22**)					
	5. Pusa Santushti × SBBG-31-1 (-15.25**)	5. SBBG-23 × SBBG-11 (-23.92**)	5. Pusa Naveen × SBBG-31-1 (-30.00**)					
2. Days to 1 st pistillate flower anthesis	1. SBBG-32 × HZP-RC-1 (-17.78**)	1. SBBG-32 × HZP-RC-1 (-22.74**)	1. Pusa Naveen × SBBG-31-1 (-31.02)	13	8	17	-22.74 to 18.97%	-31.52 to 8.40%
	2. Pusa Naveen × SBBG-31-1 (-19.23**)	2. Pusa Naveen × SBBG-31-1 (-20.98**)	2. SBBG-32 × HZP-RC-1 (-22.74**)					
	3. SBBG-32 × SBBG-11 (-12.51**)	3. SBBG-32 × SBBG-11 (-14.28**)	3. Pusa Naveen × HZP-RC-1 (-21.29**)					
	4. Pusa Naveen × HZP-RC-1 (-10.17**)	4. Pusa Naveen × SBBG-11 (-13.82**)	4. Pusa Naveen × SBBG-11					
		5. Pusa Naveen × SBBG-11 (-12.07**)	5. Narendra Dharidar × SBBG-23 (-17.56**)					
3. Days to 1 st fruit harvest	1. SBBG-32 × HZP-RC-1 (-12.96**)	1. SBBG-32 × HZP-RC-1 (-16.95**)	1. Pusa Naveen × SBBG-31-1 (-21.12**)	10	6	15	-16.95 to 15.85%	-21.12 to 9.67%
	2. Pusa Naveen × SBBG-31-1 (-11.12**)	2. Pusa Naveen × SBBG-11 (-12.66**)	2. SBBG-11 × HZP-RC-1 (-16.95**)					
	3. Pusa Naveen	3. Pusa Naveen × SBBG-31-1 (-12.03)	3. Pusa Naveen × HZP-RC-1 (-16.90**)					
	4. SBBG-32 × SBBG-11 (-7.50**)	4. Narendra Dharidar × SBBG-32 (-10.94)	4. Narendra Dharidar × SBBG-23 (-15.42**)					
	5. Pusa Naveen × HZP-RC-1 (-6.98**)	5. Pusa Naveen × SBBG-32 (-9.16)	5. Pusa Naveen × SBBG-11 (-15.42**)					
4. Vine length (m)	1. Rajendra Chamatkar × HZP-RC-1 (19.66**)	1. Pusa Santushti × Pusa Naveen (12.79**)		5	2	-	-26.79 to 12.79	-26.95 to 23.65%

Table 2. Continued.

Characters	Heterosis		S.V (Standard variety)	Number of superior crosses over			Range of heterosis	
	M.P (Mid parents)	B.P (Better parents)		M.P	B.P	S.V	B.P	S.V
	2. Pusa Santushti × Pusa Naveen (13.00**)	2. Rajendra Chamatkar × HZP-RC-1 (10.42**)						
	3. Narendra Dharidar × HZP-RC-1 (10.06**)							
	4. Narendra Dharidar × SBBG-23 (9.97**)							
5. Vine girth (cm)	1. SBBG-23 × SBBG-31-1 (26.21**)	1. HZP-RC-1 × SBBG-11 (23.05**)	1. HZP-RC-1 × SBBG-11 (22.47**)	26	13	25	-8.13 to 23.05%	-9.65 to 94.94%
	2. HZP-RC-1 × SBBG-11 (24.97**)	2. Pusa Naveen × SBBG-11 (22.80**)	2. SBBG-23 × SBBG-31-1 (20.94**)					
	3. Pusa Naveen × SBBG-11 (23.79**)	3. Pusa Naveen × SBBG-32 (21.97**)	3. Pusa Naveen × SBBG-32 (18.71**)					
	4. Pusa Naveen × SBBG-32 (23.27**)	4. SBBG-23 × SBBG-31-1 (20.94**)	4. SBBG-32 × HZP-RC-1 (18.59**)					
	5. SBBG-32 × HZP-RC-1 (20.29**)		5. Pusa Naveen × SBBG-11 (18.47**)					
6. Fruit length (m)	1. Narendra Dharidar × SBBG-32 (26.52**)	1. Pusa Santushti × Pusa Naveen (17.68**)		5	5	–	-33.20 to 17.68	-45.29 to -3.84%
	2. Pusa Naveen × SBBG-31-1 (27.44**)	2. Pusa Naveen × Narendra Dharidar (16.39**)						
	3. Pusa Naveen × SBBG-32 (39.75**)	3. Pusa Naveen × SBBG-31-1 (15.83**)						
	4. Pusa Santushti × SBBG-23 (15.40**)	4. Pusa Naveen × SBBG-32 (15.40**)						
	5. Pusa Santushti × Pusa Naveen (24.47**)	5. Narendra Dharidar × SBBG-32 (9.00**)						
7. Fruit girth (cm)	1. Rajendra Chamatkar × Pusa Naveen (15.79**)	1. Rajendra Chamatkar × Pusa Naveen (11.93)		2	1	–	-17.59 to 11.93%	-21.47 to 0.46%
8. No. of fruits/plants	1. Rajendra Chamatkar × Narendra Dharidar (69.23**)	1. Pusa Santushti × SBBG-23 (57.14)		7	5	–	-36.00 to 57.14%	-56.00 to 16.00%

Table 2. Identification of superior crosses based on heterosis.

Characters	Heterosis		S.V (Standard variety)	Number of superior crosses over			Range of heterosis	
	M.P (Mid parents)	B.P (Better parents)		M.P	B.P	S.V	B.P	S.V
9. Average fruit weight (g)	2. Rajendra Chamatkar × SBBG-31-1 (69.23**)	2. Rajendra Chamatkar × SBBG-31-1 (37.57**)						
	3. Pusa Santushti × SBBG-23 (62.96**)	3. Rajendra Chamatkar × Narendra Dharidar (37.50**)						
	4. Rajendra Chamatkar × SBBG-32 (48.15**)	4. Pusa Santushti × HZP-RC-1 (33.33**)						
	5. Rajendra Chamatkar × SBBG-23 (47.83**)	5. Rajendra Chamatkar × SBBG-23 (30.77**)						
	1. Narendra Dharidar × Narendra Dharidar (50.37**)	1. Narendra Dharidar × HZP-RC-1 (33.88**)		9	5	-	-46.19 to 33.88%	-46.19 to -3.10%
	2. Narendra Dharidar × SBBG-11 (44.59**)	2. Pusa Naveen × Narendra Dharidar (32.57**)						
	3. Narendra Dharidar × HZP-RC-1 (39.62**)	3. Narendra Dharidar × SBBG-11 (29.61**)						
	4. Narendra Dharidar × SBBG-32 (35.74**)	4. SBBG-32 × HZP-RC-1 (26.52**)						
	5. SBBG-32 × HZP-RC-1 (33.46**)	5. Pusa Santushti × Pusa Naveen (19.38**)						
	10. Average fruit yields/plants (kg)	1. HZP-RC-1 × SBBG-11 (52.30**)	1. HZP-RC-1 × SBBG-11 (47.79**)	1. Pusa Santushti × Pusa Naveen (21.32**)	15	5	4	-20.43 to 47.79
2. SBBG-31-1 × HZP-RC-1 (47.43**)		2. SBBG-31-1 × HZP-RC-10	2 Pusa Naveen × Narendra Dharidar (19.02**)					
3. Narendra Dharidar × SBBG-32 (42.62**)		3. Pusa Santushti × SBBG-32	3. Rajendra Chamatkar × Pusa Naveen (14.11**)					
4. Pusa Santushti × SBBG-32 (42.62**)		4. SBBG-32 × HZP-RC-1						
5. SBBG-23 × HZP-RC-1 (36.60**)		5. SBBG-23 × HZP-RC-1						

tions for the given traits (Table 1) under study as similar reported by Ray et al. [8] and Yadav and Kumar [2]. These significant differences due to effect of heterosis and observance of sufficient amount of genetic variability among the parents and their hybrids [9]. Heterosis varies in positive or negative direction with its magnitude. Negative heterosis is desirable for characters like node number to 1st pistillate flower anthesis, days to 1st pistillate flower anthesis and days to 1st fruit maturity while rest of the character is desirable for positive heterosis [10].

Degree of dominance and heritability

The results of genetic component analysis revealed that dominance components were significant for all the ten characters while additive components were significant for most of the characters (Table 2) except for days to first pistillate flower anthesis, days to first fruit harvest and average fruit weight which indicates both additive and dominance gene action were responsible for expression of these characters. These results are in agreement with finding of Kathiria et al. [11] and Singh [1]. However, additive (D) component was lower in magnitude than dominance components for all traits except for fruit girth (cm) which revealed preponderance of dominance component of variance in the expression of these traits. The magnitude of additive components was higher than dominance components for all the characters except days to first fruit harvest and fruit length. These results are in agreement of finding of Quamruzzaman and Ahmad [12]. The positive values of F were significant for all the traits showed that there is an excess of dominance gene in the inheritance of these traits among the parents. The net dominance effect in heterozygous condition was non-significant for all the traits except vine length and fruit yield/plant which shows that there is contribution of additive effect for all the traits except vine length and fruit yield/plant. The environmental component was non significant for all the traits which confers effect of environment on the expression of trait however the magnitude of E was lower than the values of additive (D) and (H) dominance component of variation for all characters which indicate that there was little or negligible influence of genotype on the environment [12]. The average de-

gree of dominance was more than 1, suggesting over dominance hypothesis was responsible expression for all the traits in bottle gourd. This suggested that heterosis breeding might be advantageous for improvement of yield and its component traits in bottle gourd. The proportion of genes ($H_2/4H_1$) in the parents was less than 0.18 for all the traits which showed asymmetrical distribution of dominant and recessive alleles in the parent. The ratio of $(4DH_1) 1/2 + F/(4DH_1) 1/2$ estimates the proportion of dominant and recessive alleles in the parents. It indicates that ratio was greater than 1 for all the characters except days to first fruit harvest and suggests that there is excess of dominant genes among the parental strains (Table 3). The ratio of h^2/H_2 was lesser than 1, provides information about groups of gene exhibiting that major genes mainly governed the characters except fruit length which may be due to concealing effects of dominant gene with positive and negative effect or non-isodirectional distribution of polygene which nullify the effects of each other. Heritability (h^2) was higher for all the characters indicates these traits was highly heritable and epistasis for the traits indicated differential sensitivity of the genes to the environment. The results are in agreement with findings of Quamruzzaman and Ahmad [12] and Singh et al. [13] whereas Sit and Sirohi [14] reported that predominance of non-additive gene action for all studied traits except fruit length emphasize that the heterosis breeding has prime importance to acquire high-yielding bottle gourd hybrid.

Heterobeltiosis and standard heterosis

The range of parents and hybrids mean values over parents and hybrids and grand mean over parents and hybrids (Table 2). The heterosis for node number to first pistillate flower anthesis was -38.52% (Pusa Santushti × SBBG-32) over better parent while 38.52% (Pusa Santushti × SBBG-31-1) for standard variety. For node number to 1st pistillate flower anthesis there are 23 superior crosses over mid parent, 14 over better parent and 32 over standard variety. The heterosis for days to 1st pistillate flower anthesis was -22.74% (SBBG-32 × HZP-RC-1) over better parent while -31.52% (Pusa Naveen × SBBG-31-1) for standard variety. The heterosis for days to 1st fruit harvest was -

16.95% (SBBG-32 × HZP-RC-1) over better parent while for standard variety it was -21.12% (Pusa Naveen × SBBG-31-1). Above three characters are important for earliness [15]. The heterosis for vine length was 12.79% (Pusa Santushti × Pusa Naveen) over better parent and no crosses were superior over standard variety. For vine length five crosses were superior over mid parent while two over better parent. The heterosis for vine girth was 23.05% (HZP-RC-1 × SBBG-11) over better parent while 22.47% (HZP-RC-1 × SBBG-11) over standard variety. There are 13 superior crosses for vine girth over better parents and 25

over standard variety. This increase in vine length and vine girth due to heterotic effect of the crosses [9, 15]. This vegetative growth is essential for high fruit yield [16]. The heterosis for fruit length was 17.68% (Pusa Santushti × Pusa Naveen) over better parent. There are 5 superior crosses over better parent. There are 5 superior crosses for fruit length over better parent. The heterosis for fruit girth was 11.93% (Rajendra Chamatkar × Pusa Naveen) over better parents while no other crosses were superior over standard variety. There is 1 superior cross for fruit girth over better parent. The fruit girth and fruit length were

Table 3. Genetic components of variation and their related statistics for ten characters in half diallel cross of bottle gourd.

Components of variation and related statistics	Node No. to first pistilate flower	Days to first pistilate flower anthesis	Days to first fruit harvest	Vine length (m)	Vine girth (cm)
\hat{D} (Additive effect)	4.62* ± 1.49	16.53 ± 8.89	11.4 ± 7.06	0.35**±0.074	0.007 ± 0.016
\hat{H}_1 (Dominance effect)	18.04** ± 3.28	85.86** ± 19.60	77.46** ± 15.58	0.73** ± 0.16	0.19** ± 0.04
\hat{H}_2 (Dominance indicating asymmetry of +/-effect of genes)	13.07** ± 2.82	68.73** ± 16.85	65.32** ± 13.40	0.53**±0.141	0.17** ± 0.03
\hat{F} (Mean Fr over arrays)	8.66* ± 3.47	15.82 ± 20.71	3.29 ± 16.47	0.46* ± 0.173	0.09* ± 0.037
\hat{h}^2	0.02 ± 1.90	21.84 ± 11.29	19.12 ± 8.97	0.120 ± 0.094	0.30** ± 0.02
\hat{E} (Environmental component)	0.16 ± 0.47	0.59 ± 2.81	1.59 ± 2.23	0.021 ± 0.23	0.001 ± 0.005
$(\hat{H}_1/\hat{D})^{1/2}$ (Mean degree of dominance)	1.98	2.28	2.61	1.45	5.02
$\hat{H}_2/4\hat{H}_1$ (Proportion of genes with +/-effects in parents)	0.18	0.20	0.21	0.182	0.03
$(4\hat{D}\hat{H}_1)^{1/2} + \hat{F} / (4\hat{D}\hat{H}_1)^{1/2} - \hat{F}$ (Proportion of dominant and recessive genes in parents)	2.81	1.53	1.11	2.69	1.28
\hat{h}^2/\hat{H}_2 (Number of gene groups)	0.001	0.318	0.293	0.227	1.74
r (Correlation coefficient)	0.28	-0.037	-0.064	0.182	0.10
t^2	0.075	0.610	1.303	0.033	4.78

Table 3. Continued.

Components of variation and related statistics	Fruit length (cm)	Fruit girth (cm)	No. of fruit/plants	Average fruit weight (kg)	Fruit yield (kg)
\hat{D} (Additive effect)	123.69** \pm 22.24	1.42** \pm 0.32	2.004** \pm 0.42	0.03 \pm 0.02	0.06** \pm 0.01
\hat{H}_1 (Dominance effect)	229.34** \pm 49.09	6.92** \pm 0.72	4.96** \pm 0.92	0.16** \pm 0.03	2.91** \pm 0.37
\hat{H}_2 (Dominance indicating asymmetry of +/-effect of genes)	174.40** \pm 42.20	6.06** \pm 0.62	3.33** \pm 0.79	0.10* \pm 0.03	2.79** \pm 0.32
\hat{F} (Mean Fr over arrays)	137.05* \pm 51.89	1.58 \pm 0.76	3.10* \pm 0.97	0.08 \pm 0.04	-0.10 \pm 0.39
\hat{h}^2	9.21 \pm 28.27	0.61 \pm 0.41	1.15 \pm 0.53	-0.01 \pm 0.02	2.50* \pm 0.21
\hat{E} (Environmental component)	2.00 \pm 7.03	0.42 \pm 0.10	0.16 \pm 0.13	0.002 \pm 0.005	0.09 \pm 0.05
$(\hat{H}_1/\hat{D})^{1/2}$ (Mean degree of dominance)	1.26	2.20	1.57	2.18	3.15
$\hat{H}_2/4\hat{H}_1$ (Proportion of genes with +/-effects in parents)	0.19	0.22	0.17	0.16	0.24
$(4\hat{D}\hat{H}_1)^{1/2} + \hat{F}/(4\hat{D}\hat{H}_1)^{1/2} - \hat{F}$ (Proportion of dominant and recessive genes in parents)	2.37	1.67	2.93	3.19	0.90
\hat{h}^2/\hat{H}_2 (Number of gene groups)	0.05	0.10	0.35	-0.008	0.894
R (Correlation coefficient)	-0.03	0.84	0.52	-0.056	0.18
t^2	0.006	0.62	0.05	0.383	0.021

directly or indirectly related to fruit yield while these both are directly related to fruit yield [17]. The heterosis for number of fruit/plant was 57.14% (Pusa Santushti \times SBBG-23) over better parent while no other crosses were superior over standard variety. There are 5 superior crosses over better parent. The heterosis for average number of fruit/plant was 33.88% (Narendra Dharidar \times HZP-RC-1) while no other crosses was superior over standard variety. There are 5 superior crosses over better parent. The heterosis for fruit yield/plant was 47.79% (HZP-RC-1 \times SBBG-11) over better parent while 21.32% (Pusa Santushti \times Pusa Naveen) over standard variety.

There are 5 superior crosses over better parent and 4 over standard variety. Fruit yield was important character for hybrid vigor due to heterotic effect of crosses [10].

Conclusion

Heterosis breeding approach could be advantageous rather than selection to produce superior hybrids for high fruit yield in bottle gourd. Thus, these F_1 hybrids could be recommended for commercial exploitation of heterosis. This should be tested over other environment or different season and years to further

confirm its worth. Future prospects of bottle gourd breeding helps in development of region and season specific varieties.

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