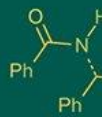


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Generation mean analysis for fruit yield and its components in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

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Abstract

A six-generation biometrical appraisal of four bottle gourd crosses during *Kharif* 2023 at Sardarkrushinagar Dantiwada Agricultural University disclosed substantial exploitable genetic variability for yield, reproductive, and physiological traits.

Inheritance was predominantly regulated by intricate additive, dominance, overdominance, and epistatic gene effects, with non-additive gene action exerting marked influence on yield and fruit quality attributes.

Generation mean analysis elucidated significant additive $\times$ additive, additive $\times$ dominance, and dominance $\times$ dominance interactions, while superior segregating and backcross generations evidenced favourable allelic recombination and introgression potential.

The findings advocate an integrated breeding strategy encompassing pedigree selection, recurrent recombination, biparental mating, and heterosis exploitation for sustained genetic enhancement in bottle gourd.

Keywords: Additive, bottle gourd, dominance, epistasis, generation mean analysis

Introduction

Vegetables constitute an indispensable component of Indian agriculture and nutritional security owing to their short crop duration, high productivity, economic profitability, and rich nutritional composition. India's diverse agro-climatic conditions facilitate year-round cultivation of a wide range of vegetable crops, contributing significantly to agricultural diversification and rural employment generation. During 2024-25, horticultural crops occupied approximately 29.09 million hectares with a production of 367.70 million tonnes, reflecting sustained growth in the sector (Anonymous, 2024) [8]. Vegetables are important dietary sources of vitamins, minerals, proteins, dietary fibre, and bioactive phytochemicals possessing antioxidant and anti-carcinogenic properties. Rapid urbanization, increasing health awareness, changing dietary preferences, and rising per capita income have further accelerated vegetable production and consumption in India.

Among vegetable crops, cucurbits occupy a prominent position due to their adaptability, high yield potential, and economic importance, particularly for small and marginal farmers. The family Cucurbitaceae

comprises nearly 118 genera and 825 species worldwide, of which India harbours considerable diversity with several endemic species. Bottle gourd [*Lagenaria siceraria* (Mol.) Standl; $2n = 2x = 22$] is one of the oldest domesticated cucurbitaceous vegetables and an important monoecious, cross-pollinated crop cultivated extensively throughout tropical and subtropical regions. It is valued not only for its culinary utility but also for its medicinal, nutritional, and industrial significance. The fruits are easily digestible and rich in carbohydrates, minerals, vitamins, and moisture, while different plant parts possess therapeutic properties against several ailments. Dried fruits are also utilized for preparing utensils, containers, and musical instruments.

Despite its economic importance, bottle gourd productivity in many regions of India, including Gujarat, remains constrained due to cultivation of genetically heterogeneous local cultivars with limited yield potential.

Although improved cultivars and hybrids such as Anand Bottle Gourd-1 and Gujarat Anand Bottle Gourd Hybrid-1 have been released, there remains substantial scope for genetic enhancement of yield and quality traits. Bottle gourd exhibits 60-80 percent natural cross-pollination, facilitating extensive variability and providing immense opportunities for exploitation of heterosis in breeding programmes. Owing to its monoecious flowering behaviour, high seed recovery, low seed requirement, and comparatively low inbreeding depression, the crop is highly amenable to hybrid breeding. Improvement of fruit yield in bottle gourd is genetically complex because yield is a quantitative trait governed by polygenic inheritance and influenced by environmental interactions. Therefore, understanding the nature and magnitude of gene effects is essential for devising efficient breeding strategies. Generation mean analysis provides comprehensive information on additive, dominance, and epistatic gene interactions, including additive $\times$ additive, additive $\times$ dominance, and dominance $\times$ dominance effects, thereby enabling precise identification of suitable breeding approaches such as pedigree selection, recurrent selection, or heterosis breeding. Simultaneously, assessment of heterosis and inbreeding depression assists in identifying superior cross combinations and evaluating the extent of non-additive genetic effects governing economically important traits.

Materials and Methods

Plant material

The experimental materials comprised of six basic generations viz., P₁, P₂, F₁, F₂, BC₁ and BC₂ of four Crosses namely ABGS 11-24 $\times$ P. Komal, ABGS 11-17 $\times$ NDBG 132, P. Komal $\times$ P. Long and Local $\times$ P. Long were made between six parents by manual emasculation and pollen transfer. F₁ plants were selfed to obtain seed for the F₂ generation and backcrossed with their respective parents to generate BC₁ and BC₂ generations. Thus, a total of six generations were obtained.

Field Trial

The experimental material consisted of six parental lines, viz., ABGS 11-24, ABGS 11-17, Punjab Komal, NDBG-132, local, Punjab Long and their F₁, F₂, and back crosses (B₁ and B₂). Each family was made up of six generations: P₁, P₂, F₁, F₂, B₁ and B₂. The seed of parents were taken from the Main Vegetable Research Station, Anand. For the generation mean analysis, six basic generations (P₁, P₂, F₁, F₂, B₁, and B₂) were developed following standard breeding procedures in bottle gourd (*Lagenaria siceraria*). The parental lines (P₁ and P₂) were first self-pollinated to maintain genetic purity, and seeds thus obtained were used for hybridization. Fresh F₁ seeds were produced by crossing P₁ and P₂ during the *rabi* 2022-23.

The F₂ generation was obtained by selfing the F₁ plants. Backcross generations were produced during the *kharif* 2023, with B₁ derived from crossing F₁ with P₁, and B₂ from crossing F₁ with P₂. This set of six generations formed the basis for subsequent generation mean analysis to determine the nature of gene action governing the traits under study. Seventeen different characters were studied viz., days to first male flower appearance, days to first female flower appearance, node number at which first male flower appearance, node number at which first female flower appearance, number of branches per plant, vine length (m),

days to first picking, fruit length (cm), fruit girth (cm), number of fruits per plant, average fruit weight (g), yield per plant (kg), chlorophyll-a, chlorophyll-b, total chlorophyll, moisture content (%) and total soluble solids ($^{\circ}$ Brix)

Selfing and crossing technique

In bottle gourd, anthesis takes place from 6 am to 11 am. Thus, the best time for bottle gourd pollination, whether natural or hand-assisted, is typically when the flowers are fully open, which usually occurs in the evening hours. The female and male flower buds likely to open on the next day were enclosed during morning hours with butter paper bags just to protect them from stray pollens. During evening, the bags were removed and female buds having receptive stigma were then pollinated by rubbing the dehiscent anthers from the desired male parent. The pollinated flowers were identified and covered with white paper bags. When the F₁ was available, backcrosses were created using the same methodology. To obtain the parents' and the F₂s' seeds, a few closed buds from the F₁ and parents' plants were selfed.

Statistical analysis

For statistical analysis, the data recorded for each character from the observations made on each representative (tagged) plants of each generation of each family in each replication were used. Statistical analysis was performed for the following traits. The analysis of variance among families (Table 1) indicated significant mean square differences among all the three families (crosses) for all the characters studied. Likewise, the mean squares among progenies within each family revealed that the variations among the six generations were significant for all the characters studied in all the three crosses.

Results and Discussion

Analysis of variance and *per se* performance

Per se performance of different generations in four bottle gourd crosses revealed the predominance of diverse gene actions for yield and its component traits. F₁ hybrids exhibited overdominance for earliness, vine length, branching, fruit length, average fruit weight, yield per plant, moisture content, and total soluble solids in several crosses, indicating strong heterotic effects and the importance of non-additive gene action. Complete dominance was observed for traits such as node number of flowering, vine length, chlorophyll-b, moisture content, and TSS, whereas incomplete dominance governed fruit girth, fruit number, fruit weight, chlorophyll content, and days to fruit picking, suggesting partial dominance effects. Additive gene action was evident where F₁ means remained at par with mid-parent values for flowering, vegetative, fruit quality, and chlorophyll traits. F₂ generations showed absence of inbreeding depression for several traits including flowering behaviour, branching, fruit number, chlorophyll content, and moisture content, while significant inbreeding depression for fruit length, fruit weight, and yield per plant confirmed the role of dominance effects. Superior F₂ performance over F₁ for certain characters indicated the occurrence of desirable transgressive segregants. The BC₁ and BC₂ generations recorded superior performance for several yield, vegetative, fruit quality, and biochemical traits, demonstrating the accumulation of favourable alleles and suggesting the effectiveness of backcross breeding for improvement of bottle gourd genotypes.

Components of Generation Means Based on Additive-Dominance Model

Generation mean analysis in four bottle gourd crosses, namely Cross I (ABGS 11-24 × P. Komal), Cross II (ABGS 11-17 × NDBG-132), Cross III (P. Komal × P. Long), and Cross IV (Local × Punjab Long), revealed the involvement of both additive and non-additive gene effects for most of the studied traits. Scaling tests and joint χ^2 analysis indicated that the additive-dominance model was adequate for certain traits and crosses, whereas inadequacy in others suggested the presence of non-allelic interactions. Significant additive effects were predominantly observed for days to first male flower appearance, number of branches per plant, chlorophyll-a, chlorophyll-b, total chlorophyll, and moisture content, indicating the importance of fixable gene action and the effectiveness of selection. Dominance effects were more pronounced for fruit length, average fruit weight, yield per plant, and total soluble solids, reflecting the role of heterosis and non-additive gene action in the inheritance of these traits.

Components of Generation Means Based on Six-Parameter Model (Hayman, 1958) ^[43] ^[43]

The six-parameter model of Hayman (1958) ^[43] revealed the presence of significant epistatic interactions governing several quantitative traits in bottle gourd. Along with significant mean (m), additive (d), and dominance (h) effects, epistatic components such as additive × additive (i), additive × dominance (j), and dominance × dominance (l) interactions were detected in different crosses and traits.

Duplicate and complementary types of epistasis were observed for fruit length, yield per plant, chlorophyll-b, total chlorophyll, and total soluble solids, indicating the complex inheritance pattern of these characters. The predominance of dominance and dominance × dominance interactions for yield and fruit traits suggested the importance of non-additive gene action, whereas additive and additive × additive effects for chlorophyll and moisture-related traits indicated scope for effective selection in early generations.

Components of Generation Means Based on Six-Parameter Model (Cavalli, 1952) ^[18]

Cavalli's six-parameter model further confirmed the predominance of digenic interactions with limited higher-order epistasis across the studied bottle gourd crosses. Significant mean (m) effects were recorded for all traits, indicating quantitative inheritance. Additive gene effects played a major role in flowering behaviour, branching, chlorophyll content, and moisture content, whereas dominance effects were important for fruit length, average fruit weight, yield per plant, and total soluble solids. The significance of epistatic components emphasized the contribution of both additive and non-additive gene actions in trait expression. Overall, the results suggested that improvement of economically important traits in bottle gourd can be effectively achieved through suitable breeding approaches such as pedigree selection, biparental mating, recurrent selection, and exploitation of heterosis for accumulation of favourable alleles and development of superior genotypes.

Table 1: Analysis of variance between families and between progenies within family of six generations for different characters in bottle gourd.

Sources	d.f.	Mean sum of squares						
		Days to first male flower appearance	Days to first female flower appearance	Node number at which first male flower appearance	Node number at which first female flower appearance	Number of branches per plant	Vine length	Days to fruit picking
Analysis of variance between families								
Replications	2	0.16	0.15	0.01	0.06	0.01	0.002	0.38
Crosses	3	18.96**	21.91**	15.60**	2.70**	12.43**	0.50**	30.22**
Error	6	0.21	0.20	0.03	0.04	0.03	0.006	0.17
χ^2		HS	HS	NS	NS	NS	HS	HS
Analysis of variance between progenies within family								
Cross I (ABGS 11-24 $\times$ P.Komal)								
Replications	2	0.23	1.11	0.17	0.14	0.14	0.05	0.42
Generations	3	5.69**	12.77**	11.68**	21.70**	1.54**	0.70**	12.61**
Error	6	0.14	0.45	0.22	0.10	0.18	0.01	0.11
Cross II (ABGS11-17 $\times$ NDBG-132)								
Replications	2	0.31	0.94	0.03	0.28	0.12	0.05	0.08
Generations	3	2.45**	27.28**	2.86**	1.71**	80.88**	0.65**	11.41**
Error	6	0.30	0.27	0.14	0.13	0.14	0.01	0.14
Cross III (P.Komal $\times$ P. Long)								
Replications	2	1.99	0.36	0.04	0.53	0.04	0.01	4.38
Generations	3	147.09**	148.40**	28.31**	19.52**	18.65**	1.06**	45.32**
Error	6	0.92	0.64	0.17	0.16	0.23	0.07	1.78
Cross IV (Local $\times$ P. Long)								
Replications	2	2.18	1.403	0.40	0.21	0.22	0.01	0.38
Generations	5	107.2**	110.096**	4.00**	0.67**	2.80	0.21**	31.06**
Error	10	2.64	2.879	0.11	0.09	0.15	0.01	0.10

*, **, Significant at 5% and 1%, levels of significance, respectively;

Chi-square for Bartlett's test of homogeneity of error variances, S = Significant, HS = Highly significant and NS-significant

Sources	d.f.	Mean sum of squares									
		Fruit Length	Fruit girth	Number of fruits per plant	Average fruit weight	yield per plant	Chloro phyll a	Chloro phyll b	Total chlorpphyll	Moisture content	Total soluble solids (°Brix)
Analysis of variance between families											
Replications	2	1.10	3.75	0.05	0.001	0.01	6.2	0.27	4.88	0.01	0.002
Crosses	4	33.67**	210.81**	5.01**	0.134**	0.50**	3847.08**	1.60**	4489.52**	4.54**	0.042
Error	8	0.88	6.07	0.02	0.001	0.01	2.5	0.08	2.51	0.14	0.001
χ^2		HS	NS	HS	HS	S	S	NS	HS	HS	HS
Analysis of variance between progenies within family											
Cross I (ABGS 11-24 ×P. Komal)											
Replications	2	0.32	36.81	0.12	0.01	0.01	21.18	1.56	11.97	0.24	0.002
Generations	5	0.94**	596.033**	7.37**	0.12**	0.15**	652.87**	5.46**	7 65.055**	0.68**	0.15**
Error	10	0.82	29.57	0.09	0.01	0.004	5.58	0.54	5.65	0.11	0.003
Cross II (ABGS 11-17 × NDBG-132)											
Replications	2	9.35	47.72	0.01	0.002	0.08	19.47	0.43	25.24	0.18	0.022
Generations	5	44.97*	73.65*	0.82**	0.005**	0.90**	25.56**	12.54**	292.65**	0.76**	0.12**
Error	10	11.70	18.92	0.07	0.001	0.02	24.74	0.24	27.78	0.07	0.012
Cross III (Local × P. Long)											
Replications	2	11.68	46.18	0.34	0.001	0.005	13.87	0.65	8.69	0.03	0.0001
Generations	5	100.90**	1081.84**	15.39**	0.01**	1.241**	361.062**	3.50**	433.84**	0.22**	0.007**
Error	10	8.00	15.46	0.11	0.001	0.01	3.82	0.23	3.20	0.04	0.0000
Cross IV (P. Komal × P. Long)											
Replications	2	1.06	1.02	0.23	0.004	0.08	27.19	0.43	28.53	2.14	0.001
Generations	5	7.25**	75.49**	17.93**	0.006**	0.50**	2140.05**	211.50**	3461.01**	20.86**	0.01**
Error	10	1.07	9.17	0.18	0.001	0.023	9.33	0.11	9.55	0.60	0.0003

*, **, Significant at 5% and 1%, levels of significance, respectively;

Chi-square for Bartlett's test of homogeneity of error variances, S = Significant, HS = Highly significant and NS-significant

Table 2: Estimation of scaling tests and gene effects for days to first male flower appearance in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Days to first male flower appearance								
Scaling Tests (Mather, 1949) ^[61]								
A	3.60**	±0.72	1.87**	±0.81	-27.60**	±1.26	-3.87**	±1.17
B	2.80**	±0.73	-2.07**	±0.80	16.00**	±1.39	5.73**	±1.79
C	10.00**	±1.26	-0.67	±1.29	4.33	±2.95	0.47	±3.09
D	1.80**	±0.50	-0.23	±0.56	7.97**	±1.40	-0.70	±1.62
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	45.69**	±0.20	48.55**	±0.23	41.41**	±0.35	42.77**	±0.40
(d)	-0.46*	±0.18	-0.25	±0.22	3.16**	±0.33	-8.32**	±0.38
(h)	-0.69	±0.43	-2.12**	±0.47	-1.60*	±0.73	-0.20	±0.71
χ^2	63.17**		18.14**		871.89**		25.56**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	46.27**	±0.19	47.23**	±0.21	43.62**	±0.61	43.02**	±0.68
(d)	-0.53**	±0.33	0.97*	±0.39	-13.40**	±0.68	-12.07**	±0.88
(h)	-5.93**	±1.12	-1.00	±1.23	-14.87**	±2.93	1.47	±3.32
(i)	-3.60**	±1.01	0.47	±1.12	-15.93**	±2.81	1.40	±3.24
(j)	0.40**	±0.41	1.97**	±0.50	-21.80**	±0.78	-4.80**	±0.99
(l)	-2.80**	±1.82	-0.27	±2.01	27.53**	±4.03	-3.27	±4.70
Best fitting model								
(m)	-	-	48.07**	±0.26	-	-	42.99**	0.40
(d)	-	-	-1.04**	±0.29	-	-	-7.28**	0.44
(h)	-	-	-1.50**	±0.49	-	-	0.17**	0.72
(i)	-	-	-	-	-	-	-	-
(j)	-	-	4.07**	±0.96	-	-	-8.93**	1.79
(l)	-	-	-	-	-	-	-	-
χ^2	-	-	0.31(at d.f 2)		-	-	0.67 (at d.f. 1)	
Type of epistasis	-	-	Duplicate		-	-	Duplicate	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively;

Table 3: Estimation of scaling tests and gene effects for days to first female flower appearance in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Days to first female flower appearance								
Scaling Tests (Mather, 1949) ^[61]								
A	1.87*	±0.70	-1.67*	±0.74	-10.67	±1.29	-3.87	±1.17
B	-2.93**	±0.85	-5.00**	±1.44	-0.80	±1.36	5.40	±1.75
C	-1.60	±1.16	-1.40	±1.23	4.47	±2.94	0.13	±3.07
D	-0.27	±0.56	2.63**	±0.82	7.97	±1.40	-0.70	±1.62
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	41.44**	±0.23	47.60**	±0.25	41.03**	±0.37	42.77	±0.36
(d)	4.37**	±0.22	1.97**	±0.25	-9.97**	±0.35	-8.32	±0.35
(h)	-0.95*	±0.43	-0.95*	±0.46	0.06	±0.74	-0.20	±0.68
χ^2	26.20**		16.03**		92.15**		24.79**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	40.72**	±0.19	47.23**	±0.20	43.62**	±0.61	43.02**	±0.68
(d)	6.03**	±0.42	3.83**	±0.71	-13.40**	±0.68	-12.07**	±0.88
(h)	-0.37	±1.21	-6.17**	±1.69	-14.80**	±2.92	1.30	±3.32
(i)	0.53	±1.12	-5.27**	±1.63	-15.93**	±2.81	1.40	±3.24
(j)	2.40**	±0.50	1.67*	±0.77	-4.93**	±0.79	-4.63**	±0.97
(l)	0.53	±2.03	11.93**	±3.09	27.40**	±4.02	-2.93	±4.68
Best fitting model								
(m)	41.38**	±0.23	-	-	-	-	43.12**	±0.36
(d)	3.634**	±0.27	-	-	-	-	-7.42**	±0.39
(h)	-1.02*	±0.43	-	-	-	-	0.00	±0.69
(i)	-	-	-	-	-	-	-	-
(j)	4.76**	±0.96	-	-	-	-	-8.72**	±1.77
(l)	-	-	-	-	-	-	-	-
χ^2	1.93 (at d.f.2)		-		-		0.48(at d.f.2)	
Type of epistasis	-		Duplicate		Duplicate		-	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 4: Estimation of scaling tests and gene effects for node number at which first male flower appearance in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Node number at which first male flower appearance								
Scaling Tests (Mather, 1949) ^[61]								
A	6.40**	±0.76	4.87**	±0.53	4.20	±0.59	-4.27**	±0.58
B	1.80*	±0.82	4.87**	±0.60	10.80	±0.57	-1.73**	±0.53
C	8.13**	±1.04	9.53**	±0.93	13.87	±0.99	-3.40**	±0.79
D	-0.03	±0.51	-0.10	±0.40	-0.57	±0.46	1.30**	±0.38
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	15.47**	±0.20	13.96**	±0.19	15.89**	0.16	13.08**	0.15
(d)	-3.32**	±0.19	-0.03	±0.17	2.85**	0.16	1.02**	0.15
(h)	5.03**	±0.40	2.79**	±0.35	1.25**	0.33	-0.47	0.30
χ^2	148.04**		22.60**		160.40**		19.82**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	18.38**	±0.13	15.90**	±0.15	17.43**	±0.17	12.80**	±0.12
(d)	-1.40**	±0.43	-0.17	±0.26	0.37	±0.30	0.03	±0.30
(h)	3.23**	±1.11	2.77**	±0.88	0.00	±0.98	-2.43**	±0.83
(i)	0.07	±1.01	0.20	±0.80	1.13	±0.92	-2.60**	±0.77
(j)	2.30**	±0.49	0.00	±0.35	-3.30**	±0.36	-1.27**	±0.35
(l)	-8.27**	±2.03	-9.93**	±1.40	-16.13**	±1.56	8.60**	±1.45
Best fitting model								
(m)	14.76**	±0.22	12.23**	±0.24	14.53**	±0.19	-	-
(d)	-3.70**	±0.22	-0.16	±0.17	3.67**	±0.19	-	-
(h)	11.32**	±0.89	12.22**	±0.86	13.37**	±0.78	-	-
(i)	4.60**	±0.98	-	-	-	-	-	-
(j)	-	±1.01	-	-	-6.61**	±0.71	-	-
(l)	-8.15**	±0.22	-9.65**	±0.80	-14.51**	±0.84	-	-
χ^2	0.003 (at d.f. 2)		0.06 (at d.f. 2)		1.52 (at d.f. 1)		-	
Type of epistasis	Duplicate		Duplicate		Duplicate		Duplicate	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 5: Estimation of scaling tests and gene effects for node number at which first female flower appearance in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Node number at which first female flower appearance								
Scaling Tests (Mather, 1949) ^[61]								
A	0.33	±0.62	1.93**	±0.50	6.13**	±0.53	1.27*	±0.56
B	6.40**	±0.56	1.73**	±0.46	0.20	±0.53	0.87	±0.49
C	8.13**	±1.33	2.73**	±0.78	7.40**	±0.93	3.87**	±0.87
D	0.70	±0.67	-0.47	±0.34	0.53	±0.37	0.87*	±0.40
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	8.18**	±0.17	11.38**	±0.13	8.82**	±0.17	11.14**	±0.16
(d)	2.39**	±0.16	-0.27*	±0.13	-1.70**	±0.15	0.00	±0.15
(h)	4.45**	±0.31	1.67**	±0.27	4.21**	±0.34	0.73*	±0.31
χ^2	148.04**		22.60**		160.40**		19.82**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	11.43**	±0.29	12.28**	±0.12	11.35**	±0.14	11.95**	±0.15
(d)	0.03	±0.33	-0.37	±0.24	-0.03	±0.24	0.10	±0.26
(h)	2.20	±1.38	2.00**	±0.74	2.20**	±0.82	-1.30	±0.86
(i)	-1.40	±1.34	0.93	±0.67	-1.07	±0.74	-1.73*	±0.79
(j)	-3.03**	±0.38	0.10**	±0.28	2.97**	±0.31	0.20	±0.33
(l)	-5.33**	±1.87	-4.60	±1.23	-5.27**	±1.32	-0.40	±1.37
Best fitting model								
(m)	7.60**	±0.19	11.09**	±0.15	7.87**	±0.19	12.71**	±0.39
(d)	3.07**	±0.19	-0.43**	±0.13	-3.00**	±0.19	-0.03	±0.15
(h)	10.66**	±0.84	4.21**	±0.62	10.03**	±0.75	-1.49*	±0.59
(i)	-	-	-	-	-	-	-1.92**	±0.44
(j)	-6.03**	±0.75	-3.17**	±0.70	5.88**	±0.61	-	-
(l)	-7.06**	±0.85	-	-	-6.77**	±0.82	-	-
χ^2	1.09 (at d.f. 1)		2.13 (at d.f. 1)		2.08 (at d.f. 1)		0.42 (at d.f. 2)	
Type of epistasis	Duplicate		Duplicate		Duplicate		Duplicate	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 6: Estimation of scaling tests and gene effects for number of branches per plant in four crosses of bottle gourd.

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Number of branches per plant								
Scaling Tests (Mather, 1949) ^[61]								
A	-1.53	±0.79	8.07**	±0.46	5.47**	±0.61	-2.87**	±0.49
B	-3.73**	±0.82	1.07	±0.57	6.20**	±0.60	-1.47**	±0.59
C	3.00*	±1.26	18.47**	±0.81	10.53**	±1.03	1.07	±1.05
D	4.13**	±0.55	4.67**	±0.38	-0.57	±0.46	2.70**	±0.56
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	13.67**	±0.21	13.43**	±0.17	13.65**	±0.17	12.52**	±0.15
(d)	0.63**	±0.20	2.16**	±0.17	0.64**	±0.15	0.21	±0.15
(h)	0.26	±0.44	10.85**	±0.28	6.45**	±0.34	2.08**	±0.25
χ ²	60.10**		718.14**		158.76**		45.90**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	14.67**	±0.18	21.17**	±0.14	17.43**	±0.17	14.17**	±0.23
(d)	1.53**	±0.41	4.93**	±0.26	0.37	±0.30	-0.23	±0.32
(h)	-7.83**	±1.21	1.57	±0.81	5.27**	±0.10	-3.33**	±1.15
(i)	-8.27**	±1.10	-9.33**	±0.76	1.13	±0.92	-5.40**	±1.12
(j)	1.10*	±0.47	3.50**	±0.34	-0.37	±0.35	-0.70	±0.36
(l)	13.53**	±2.06	0.20	±1.31	-12.80**	±1.59	9.73**	±1.65
Best fitting model								
(m)	-	-	20.32**	±0.33	12.73**	±0.18	18.55**	±1.13
(d)	-	-	1.44**	±0.22	0.64**	±0.15	0.30	±0.15
(h)	-	-	1.67**	±0.47	15.32**	±0.79	-13.91**	±2.68
(i)	-	-	-9.23**	±0.40			-5.67	±1.11
(j)	-	-	6.98**	±0.67	-	-	-	-
(l)	-	-	-	-	-11.18**	±0.89	10.30**	±1.62
χ ²	-		0.02 (at d.f. 1)		2.63 (at d.f. 2)		3.69 (at d.f. 1)	
Type of epistasis	-		Duplicate		Duplicate		Duplicate	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 7: Estimation of scaling tests and gene effects for vine length in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Vine length								
Scaling Tests (Mather, 1949) ^[61]								
A	0.03	±0.26	-0.01	±0.26	0.68**	±0.23	-0.56**	±0.21
B	1.23**	±0.22	0.25	±0.27	0.99**	±0.19	0.17	±0.21
C	0.92*	±0.46	-0.03	±0.44	1.67**	±0.33	0.37	±0.30
D	-0.17	±0.16	-0.14	±0.22	0.00	±0.18	0.38*	±0.17
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	3.77**	±0.07	3.26**	±0.07	3.11**	±0.03	3.26**	±0.04
(d)	0.37**	±0.06	0.34**	±0.06	0.21**	±0.03	0.35**	±0.04
(h)	1.25**	±0.14	1.04**	±0.14	1.84**	±0.08	0.17	±0.09
χ^2	40.68**		1.17		40.57**		13.15**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	4.38**	±0.07	-	-	4.20**	±0.06	3.44**	±0.06
(d)	-0.02	±0.09	-	-	0.04	±0.13	0.03	±0.12
(h)	0.97*	±0.38	-	-	1.44**	±0.37	-0.64	±0.35
(i)	0.34**	±0.33	-	-	0.00	±0.36	-0.76*	±0.34
(j)	-0.60	±0.12	-	-	-0.15	±0.13	-0.37**	±0.13
(l)	-1.60**	±0.59	-	-	-1.66**	±0.61	1.16	±0.58
Best fitting model								
(m)	3.30**	±0.34	-	-	3.06**	±0.03	3.43**	±0.14
(d)	0.32**	±0.06	-	-	0.18**	±0.03	0.38**	±0.05
(h)	3.16**	±0.82	-	-	3.16**	±0.23	-0.06	±0.20
(i)	0.36	±0.33	-	-	-	-	-0.15	±0.14
(j)	-	-	-	-	-	-	-0.74**	±0.27
(l)	-1.99**	±0.58	-	-	-1.71**	±0.27	-	-
χ^2	24.14** (at d.f. 1)		-		1.33 (at d.f. 2)		3.91 (at d.f. 1)	
Type of epistasis	Duplicate		-		Duplicate		Duplicate	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17× NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 8: Estimation of scaling tests and gene effects for days to fruit picking in four crosses of bottle gourd.

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Days to fruit picking								
Scaling Tests (Mather, 1949) ^[61]								
A	6.53**	±0.78	-3.40**	±1.17	-2.93	±5.45	-0.87	±0.55
B	3.40**	±0.78	1.53	±1.06	-8.53**	±0.99	-9.47**	±0.60
C	9.20**	±1.18	-6.33**	±1.67	-13.40**	±1.27	-8.33**	±0.73
D	-0.37	±0.60	-2.23**	±0.83	-0.97	±2.79	1.00*	±0.41
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	50.47**	±0.22	60.32**	±0.26	55.42**	±0.24	56.71	±0.14
(d)	-2.13**	±0.21	1.65**	±0.25	-4.52**	±0.26	-3.44	±0.15
(h)	1.77**	±0.40	-4.25**	±0.54	-2.03**	±0.41	-4.30	±0.27
χ^2	98.51**		31.17**		146.66**		308.75**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	52.12**	±0.21	57.30**	±0.27	52.73**	±0.24	53.87**	±0.12
(d)	-0.73	±0.43	-0.43	±0.62	-2.37	±2.75	0.33	±0.34
(h)	1.50	±1.27	1.23	±1.78	0.03	±5.60	-5.23**	±0.87
(i)	0.73	±1.20	4.47**	±1.66	1.93	±5.58	-2.00*	±0.83
(j)	1.57**	±0.50	-2.47**	±0.68	2.80	±2.76	4.30**	±0.38
(l)	-10.67**	±2.09	-2.60	±3.01	9.53	±11.1	12.33**	±1.54
Best fitting model								
(m)	49.43**	±0.24	57.32**	±0.79	55.42**	0.24	-	-
(d)	-2.30**	±0.25	2.02**	±0.28	-4.52**	0.26	-	-
(h)	10.32**	±1.01	0.13	±1.24	-2.03**	0.40	-	-
(i)	-	-	3.22**	±0.83	-	-	-	-
(j)	3.10**	±0.10	-5.10**	±1.35	-	-	-	-
(l)	-9.56**	±1.03	-	-	-	-	-	-
χ^2	0.37(at d.f. 1)		0.75 (at d.f. 2)		146.66 (at d.f. 3)		-	
Type of epistasis	Duplicate		Duplicate		Duplicate		-	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17× NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 9: Estimation of scaling tests and gene effects for fruit length in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Fruit length								
Scaling Tests (Mather, 1949) ^[61]								
A	-2.26	±2.27	-6.64*	±3.05	15.50**	±3.14	-2.03	±1.67
B	-1.00	±2.77	7.63**	±4.00	4.92	±3.84	-3.25	±2.21
C	-0.66	±4.05	-6.05	±4.58	19.67**	±4.36	3.29	±3.05
D	1.30	±1.89	-8.52**	±2.75	-0.38	±2.10	4.28**	±1.23
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	17.93**	±0.52	26.92**	±0.80	24.44**	±0.69	25.09**	±0.68
(d)	1.23*	±0.50	1.09	±0.81	-7.45**	±0.72	-1.84**	±0.62
(h)	7.80**	±1.20	1.68	±1.49	-4.33**	±1.05	1.66	±1.19
χ^2	1.23		28.07**		39.21**		30.37**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	-	-	26.94**	±0.85	25.44**	±0.96	27.01**	±0.45
(d)	-	-	-9.13**	±2.16	-2.60	±2.31	-1.19	±0.84
(h)	-	-	17.50**	±5.70	-3.50	±6.08	-7.01**	±2.75
(i)	-	-	17.04**	±5.49	0.75	±5.99	-8.57*	±2.47
(j)	-	-	-12.14**	±2.37	5.29*	±2.43	0.61	±1.28
(l)	-	-	-28.03**	±9.77	-21.17*	±10.20	13.85**	±4.53
Best fitting model								
(m)	-	-	-	-	22.66**	±10.76	33.68**	±2.58
(d)	-	-	-	-	-7.89**	±0.76	-1.46*	±0.63
(h)	-	-	-	-	15.72**	±3.79	-19.99**	±6.64
(i)	-	-	-	-	-	-	-8.38**	±2.44
(j)	-	-	-	-	10.67*	±4.80		
(l)	-	-	-	-	-19.97**	±3.61	13.27**	±4.37
χ^2	-		-		0.02 (at d.f. 1)		0.23(at d.f. 1)	
Type of epistasis	-		-		Duplicate		Duplicate	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17× NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 10: Estimation of scaling tests and gene effects for fruit girth in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Fruit girth								
Scaling Tests (Mather, 1949) ^[61]								
A	-3.33	±4.84	4.26	±5.71	-44.53	±6.61	4.20	±8.46
B	-11.47	±8.93	16.39*	±6.32	-4.87	±5.03	6.07	±5.85
C	35.47**	±12.60	14.34	±11.90	52.80	±13.12	-18.80	±10.02
D	25.13**	±6.87	-3.15	±6.42	51.10	±6.27	-14.53**	±5.28
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	83.39**	±1.34	60.49**	±1.39	65.33**	±1.90	53.15**	±1.75
(d)	-31.20**	±1.33	5.53**	±1.39	13.49**	±1.81	3.76*	±1.70
(h)	-19.99**	±2.76	-2.94	±2.63	-6.27*	±3.16	5.11	±3.54
χ ²	13.88**		30.79**		97.84**		10.54**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	81.73**	±2.65	60.52**	±2.64	81.20**	±2.80	51.70**	±1.63
(d)	-26.80**	±4.36	0.47	±3.64	4.50	±2.81	4.13	±4.15
(h)	-70.67**	±14.15	1.92	±13.13	-115.53**	±12.1	35.60**	±11.22
(i)	-50.27**	±13.74	6.30	±12.84	-102.20**	±12.53	29.07**	±10.56
(j)	4.07	±4.58	-6.06	±3.94	-19.83**	±3.87	-0.93	±4.62
(l)	65.07**	±21.52	-26.95	±18.82	151.60**	±17.29	-39.33*	±19.38
Best fitting model								
(m)	128.18**	±12.52	60.49**	±1.39	-	-	23.18*	±9.82
(d)	-30.48**	±1.34	5.53**	±1.39	-	-	4.89**	±1.82
(h)	-120.27**	±29.30	-2.94	±2.63	-	-	77.60**	±25.77
(i)	-45.41**	±12.60	-	-	-	-	30.02**	±9.44
(j)	-	-	-	-	-	-	-	-
(l)	54.76**	±18.11	-	-	-	-	-41.11*	±17.27
χ ²	0.79 (at d.f. 1)		7.24 (at d.f. 3)		-		0.04 (at d.f. 1)	
Type of epistasis	Duplicate		Duplicate		-		Duplicate	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17× NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 11: Estimation of scaling tests and gene effects for number of fruits per plant in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Number of fruits per plant								
Scaling Tests (Mather, 1949) ^[61]								
A	-0.13	±0.62	1.60**	±0.54	3.27**	±0.58	0.33	±0.43
B	0.80	±0.79	-1.27*	±0.55	-0.20	±0.44	-3.13**	±0.58
C	9.67**	±0.76	0.20	±0.86	3.27*	±1.49	7.67**	±2.38
D	4.50**	±0.47	-0.07	±0.40	0.10	±0.74	5.23**	±1.19
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	10.26**	±0.18	10.75**	±0.14	8.41**	±0.15	8.06**	±0.15
(d)	-1.76**	±0.20	-0.35*	±0.14	3.04**	±0.14	2.75**	±0.14
(h)	-0.91**	±0.31	-0.15	±0.29	-2.00**	±0.28	2.62**	±0.27
χ^2	221.38**		19.27**		36.64**		44.57**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	10.83**	±0.11	10.73**	±0.14	7.87**	±0.34	11.40**	±0.58
(d)	-2.10**	±0.42	0.73*	±0.28	4.30**	±0.27	4.10**	±0.28
(h)	-9.83**	±0.10	-0.30	±0.86	-2.30	±1.51	-7.70**	±2.40
(i)	-9.00**	±0.95	0.13	±0.79	-0.20	±1.48	-10.47**	±2.38
(j)	-0.47	±0.48	1.43**	±0.33	1.73**	±0.32	1.73**	±0.33
(l)	8.33**	±1.85	-0.47	±1.43	-2.87	±1.85	13.27**	±2.63
Best fitting model								
(m)	18.10**	±0.23	10.93**	±0.15	8.39**	±0.15	-	-
(d)	-1.74**	±0.23	-0.71**	±0.16	2.64**	±0.17	-	-
(h)	-18.96**	±0.81	-0.39	±0.30	-1.80**	±0.28	-	-
(i)	-9.29**	±0.91	-	-	-	-	-	-
(j)	-	±0.74	2.87**	±0.66	2.80**	±0.61	-	-
(l)	8.87**	±0.23	-	-	-	-	-	-
χ^2	0.93 (at d.f. 1)		0.14 (at d.f. 2)		15.89 (at d.f. 2)		-	
Type of epistasis	Duplicate		Duplicate		Duplicate		-	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 12: Estimation of scaling tests and gene effects for average fruit weight per plant in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Average fruit weight								
Scaling Tests (Mather, 1949) ^[61]								
A	-0.04	±0.11	0.03	±0.15	-0.17	±0.13	-0.06	±0.13
B	-0.38**	±0.14	-0.14	±0.16	0.13	±0.13	-0.10	±0.12
C	0.44	±0.24	-0.11	±0.24	0.13	±0.24	-0.13	±0.15
D	0.43**	±0.14	0.00	±0.13	0.09	±0.14	0.02	±0.09
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	0.85**	±0.03	0.91**	±0.05	1.09*	±0.03	0.64**	±0.03
(d)	-0.22**	±0.03	0.06	±0.05	0.03	±0.03	0.05	±0.04
(h)	-0.25**	±0.04	0.02	±0.07	0.06	±0.05	-0.01	±0.05
χ ²	12.16**		0.78		3.11		1.26	
Six parameter model (Hayman, 1958) ^[43]								
(m)	0.84**	±0.05	-	-	-	-	-	-
(d)	-0.07	±0.08	-	-	-	-	-	-
(h)	-1.11**	±0.28	-	-	-	-	-	-
(i)	-0.86	±0.27	-	-	-	-	-	-
(j)	0.17**	±0.09	-	-	-	-	-	-
(l)	1.28**	±0.40	-	-	-	-	-	-
Best fitting model								
(m)	1.62**	±0.27	-	-	-	-	-	-
(d)	-0.21**	±0.03	-	-	-	-	-	-
(h)	-2.12**	±0.65	-	-	-	-	-	-
(i)	-0.77**	±0.27	-	-	-	-	-	-
(j)	-	-	-	-	-	-	-	-
(l)	1.10**	±0.39	-	-	-	-	-	-
χ ²	3.82 (at d.f 1)		-		-		-	
Type of epistasis	Duplicate		-		-		-	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 13: Estimation of scaling tests and gene effects for yield per plant in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Yield per plant								
Scaling Tests (Mather, 1949) ^[61]								
A	0.55**	±0.11	-0.56	±0.30	1.62**	±0.18	-0.78*	±0.33
B	0.10**	±0.12	0.99**	±0.25	1.23**	±0.22	-0.44	±0.29
C	1.03	±0.21	1.02*	±0.43	2.52**	±0.33	-0.09	±0.43
D	0.19*	±0.09	0.29	±0.24	-0.16	±0.14	0.56*	±0.25
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	2.89**	±0.04	3.39**	±0.04	3.16**	±0.05	3.44**	±0.09
(d)	0.06	±0.03	0.78**	±0.04	-0.24**	±0.05	0.34**	±0.10
(h)	0.41**	±0.07	-0.20	±0.11	1.85	±0.11	0.92**	±0.10
χ^2	32.46**		26.42*		11.14*		8.05*	
Six parameter model (Hayman, 1958) ^[43]								
(m)	3.19**	±0.04	3.43**	±0.09	-	-	3.95**	±0.09
(d)	0.14*	±0.05	0.05	±0.17	-	-	0.23	±0.19
(h)	0.03	±0.20	-0.99	±0.50	-	-	-0.33	±0.53
(i)	-0.39*	±0.18	-0.58	±0.49	-	-	-1.12*	±0.51
(j)	0.23**	±0.07	-0.77**	±0.18	-	-	-0.17	±0.22
(l)	-0.26	±0.30	0.15	±0.81	-	-	2.34**	±0.86
Best fitting model								
(m)	3.26**	±0.09	3.40**	±0.04	-	-	4.67**	±0.52
(d)	-0.08	±0.05	0.83**	±0.05	-	-	0.35**	±0.10
(h)	-0.10	±0.13	-0.27*	±0.11	-	-	-2.58	±1.36
(i)	-0.52**	±0.10	-	-	-	-	-1.10*	±0.51
(j)	0.47**	±0.14	-1.58**	±0.35	-	-	-	-
(l)	-	-	-	-	-	-	2.28**	±0.86
χ^2	0.81(at d.f. 1)		5.54 (at d.f. 2)		-		0.59 (at d.f.1)	
Type of epistasis	Duplicate		Duplicate		-		Duplicate	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17× NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 14: Estimation of scaling tests and gene effects for chlorophyll-a in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Chlorophyll-a								
Scaling Tests (Mather, 1949) ^[61]								
A	-22.23*	±10.28	33.52**	±8.16	3.08	±10.3	3.22	±6.50
B	0.43	±11.82	10.50	±8.05	-16.2	±8.08	-36.19*	±14.17
C	-41.29*	±16.77	4.24	±14.66	32.01**	±8.99	-39.28*	±17.06
D	-9.74	±8.77	-19.88**	±5.73	22.56**	±6.01	-3.16	±10.31
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	521.02**	±3.24	444.73**	±1.12	523.21	±2.15	492.47	±1.51
(d)	19.60**	±3.27	-8.97**	±1.09	-7.37	±2.52	-35.61	±1.50
(h)	-2.39	±5.56	12.27**	±3.26	11.18	±3.56	-28.56	±3.51
χ^2	9.34**		24.32*		11.14*		8.05*	
Six parameter model (Hayman, 1958) ^[43]								
(m)	514.29**	±3.12	446.50**	±2.14	531.98**	±1.18	470.30**	±3.72
(d)	10.35	±6.16	1.44	±3.81	-3.35	±5.52	-17.05*	±7.13
(h)	18.66	±18.41	42.71**	±12.91	-29.61*	±12.61	-19.90	±21.04
(i)	19.48	±17.53	39.77**	±11.46	-45.11**	±12.01	6.31	±20.63
(j)	-11.33	±7.30	11.51**	±3.98	9.63	±6.36	19.71**	±7.30
(l)	2.32	±29.82	-83.78**	±21.14	58.21*	±23.84	26.65	±33.25
Best fitting model								
(m)	521.02**	±3.24	-	-	564.67**	±12.22	492.23**	1.51
(d)	19.60**	±3.27	-	-	-10.61**	±2.74	-36.52**	1.56
(h)	-2.39	±5.56	-	-	-97.82**	±35.17	-31.34**	3.71
(i)	-	-	-	-	-	-	-	-
(j)	-	-	-	-	-	-	24.54**	10.76
(l)	-	-	-	-	64.88**	±23.43	-	-
χ^2	9.34(at d.f. 3)		-		2.21 (at d.f 1)		7.47 (at d.f 2)	
Type of epistasis	Duplicate		-		Duplicate		Duplicate	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17× NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 15: Estimation of scaling tests and gene effects for Chlorophyll-b in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Chlorophyll-b								
Scaling Tests (Mather, 1949) ^[61]								
A	-3.94**	±1.43	2.39	±1.40	1.24	±1.12	-0.17	±0.73
B	0.09	±1.18	9.33	±2.14	-1.73	±1.17	13.43**	±1.08
C	-0.25	±2.11	9.32	±2.77	1.89	±1.43	-16.96**	±1.46
D	1.80	±1.11	-1.20	±1.69	1.19	±0.83	-15.11**	±0.81
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	51.59**	±0.41	44.21**	±0.33	51.81**	±0.28	53.43**	±0.24
(d)	1.32**	±0.42	-0.89**	±0.33	-1.07**	±0.29	-9.70**	±0.24
(h)	0.84	±0.61	1.58**	±0.61	1.30*	±0.50	-6.90**	±0.42
χ^2	8.13*		26.91**		5.48		382.68**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	52.27**	±0.42	46.39**	±0.61	-	-	46.05**	±0.30
(d)	-0.03	±0.73	-3.81**	±1.17	-	-	-15.73**	±0.54
(h)	-3.07	±2.31	3.37	±3.45	-	-	23.40**	±1.67
(i)	-3.60	±2.22	2.40	±3.39	-	-	30.22**	±1.61
(j)	-2.01*	±0.89	-3.47**	±1.22	-	-	-6.80**	±0.61
(l)	7.45*	±3.59	-14.13*	±5.43	-	-	-43.48**	±2.63
Best fitting model								
(m)	52.07**	±0.52	43.57**	±0.35	-	-	-	-
(d)	1.98**	±0.52	-0.34	±0.35	-	-	-	-
(h)	-1.79	±1.94	11.55**	±2.06	-	-	-	-
(i)	-	-	-	-	-	-	-	-
(j)	-3.73*	±1.77	-6.47**	±2.35	-	-	-	-
(l)	2.32	±1.68	-10.58**	±2.12	-	-	-	-
χ^2	2.62 (at d.f. 1)		0.50 (at d.f. 1)		-		-	
Type of epistasis	Duplicate		Duplicate		-		-	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 16: Estimation of scaling tests and gene effects for total chlorophyll in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Total chlorophyll								
Scaling Tests (Mather, 1949) ^[61]								
A	-26.17*	±10.44	35.91**	±9.06	4.32	±11.00	3.05	±6.92
B	0.51	±12.93	19.83*	±9.08	-17.91*	±8.52	-22.75	±14.69
C	-41.54*	±17.67	13.57	±16.05	33.91**	±9.71	-56.23**	±17.07
D	-7.94	±9.11	-21.09**	±6.46	23.75**	±6.30	-18.27	±10.33
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	572.66**	±3.49	488.37**	±1.23	575.41**	±2.33	545.99**	±1.68
(d)	20.85**	±3.50	-9.54**	±1.21	-8.05**	±2.73	-44.47**	±1.67
(h)	-2.36	±6.01	16.95**	±3.63	12.19**	±3.91	-36.37**	±3.82
χ^2	9.91*		20.20**		24.09**		15.06**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	566.56**	±3.21	492.89**	±2.37	584.68**	±1.22	516.35**	±3.62
(d)	10.33	±6.46	-2.37	±4.40	-3.29	±5.81	-32.79**	±7.36
(h)	15.59	±19.20	46.08**	±14.46	-30.54*	±13.28	3.49	±21.15
(i)	15.88	±18.22	42.17**	±12.93	-47.49**	±12.60	36.53	±20.66
(j)	-13.34	±7.71	8.04	±4.58	11.12	±6.75	12.90	±7.57
(l)	9.77	±31.30	-97.91**	±23.82	61.08**	±25.18	-16.83	±34.04
Best fitting model								
(m)	-	-	445.06**	±12.99	619.33**	±12.83	-	-
(d)	-	-	-9.80**	±1.21	-11.51**	±2.96	-	-
(h)	-	-	144.92**	±33.32	-103.95**	±36.97	-	-
(i)	-	-	42.75**	±12.93	-49.81**	±12.53	-	-
(j)	-	-	-	-	-	-	-	-
(l)	-	-	-98.53**	±23.82	69.30**	±24.68	-	-
χ^2	-		3.09 (at d.f. 1)		2.71(at d.f. 1)		-	
Type of epistasis	-		Duplicate		Duplicate		-	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 17: Estimation of scaling tests and gene effects for moisture content in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Moisture content								
Scaling Tests (Mather, 1949) ^[61]								
A	-0.21	±0.55	0.53	±0.54	-0.10	±0.50	3.05	±6.92
B	0.73	±0.65	0.09	±0.45	-0.12	±0.32	-22.75	±14.69
C	88.30	±51.54	81.25	±47.16	97.92	±57.37	-56.23**	±17.07
D	43.89	±25.77	40.32	±23.58	49.07	±28.69	-18.27	±10.33
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	95.04**	±0.20	94.08**	±0.16	94.52**	±0.14	91.23**	±0.41
(d)	0.35	±0.18	-0.52**	±0.14	-0.22	±0.12	-3.48**	±0.41
(h)	0.67	±0.37	0.75**	±0.29	0.56*	±0.24	3.96**	±0.46
χ^2	4.65		3.91		3.09		14.97**	
Six parameter model (Hayman, 1958) ^[43]								
(m)	-	-	-	-	-	-	113.14**	±12.15
(d)	-	-	-	-	-	-	-3.80**	±1.02
(h)	-	-	-	-	-	-	-82.75	±48.67
(i)	-	-	-	-	-	-	-86.21	±48.66
(j)	-	-	-	-	-	-	-0.87	±1.13
(l)	-	-	-	-	-	-	94.08	±48.80
Best fitting model								
(m)	-	-	-	-	-	-	-	-
(d)	-	-	-	-	-	-	-	-
(h)	-	-	-	-	-	-	-	-
(i)	-	-	-	-	-	-	-	-
(j)	-	-	-	-	-	-	-	-
(l)	-	-	-	-	-	-	-	-
χ^2	-	-	-	-	-	-	-	-
Type of epistasis	-	-	-	-	-	-	-	-

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Table 18: Estimation of scaling tests and gene effects for total soluble solids in four crosses of bottle gourd

Scales/Components	Cross-I		Cross-II		Cross-III		Cross-IV	
Total soluble solids								
Scaling Tests (Mather, 1949) ^[61]								
A	0.34**	±0.10	-0.28**	±0.08	-0.15*	±0.06	0.09	±0.06
B	-0.83**	±0.14	0.56**	±0.09	0.14*	±0.06	-0.04	±0.06
C	-0.22	±0.19	-0.69**	±0.1	0.14	±0.09	0.15	±0.10
D	0.13	±0.10	-0.49**	±0.03	0.07	±0.05	0.05	±0.04
Gene effects in different models								
Three parameter model (Cavalli, 1952) ^[18]								
(m)	4.36**	±0.04	4.48**	±0.03	4.65**	±0.02	4.56	±0.02
(d)	-0.06	±0.04	-0.32**	±0.02	-0.04	±0.02	-0.03	±0.02
(h)	0.39**	±0.05	-0.34**	±0.06	-0.05*	±0.03	0.14	±0.04
χ ²	49.89**		319.26**		15.36**		6.04	
Six parameter model (Hayman, 1958) ^[43]								
(m)	4.54**	±0.04	4.20**	±0.01	4.65**	±0.02	-	-
(d)	0.35**	±0.07	-0.50**	±0.02	-0.11**	±0.03	-	-
(h)	0.07	±0.21	0.85**	±0.09	-0.20*	±0.10	-	-
(i)	-0.26	±0.21	0.97**	±0.06	-0.15	±0.09	-	-
(j)	0.58**	±0.08	-0.42**	±0.04	-0.14*	±0.04	-	-
(l)	0.74*	±0.34	-1.25**	±0.17	0.16	±0.16	-	-
Best fitting model								
(m)	4.44**	±0.04	-	-	4.66**	±0.02	-	-
(d)	-0.23**	±0.04	-	-	0.04	±0.03	-	-
(h)	-0.04	±0.17	-	-	-0.07**	±0.03	-	-
(i)	-	-	-	-	-	-	-	-
(j)	1.13**	±0.16	-	-	-0.31**	±0.09	-	-
(l)	0.36*	±0.15	-	-	-	-	-	-
χ ²	1.55(at d.f. 1)		-		3.10(at d.f. 2)		-	
Type of epistasis	Duplicate		-		Duplicate		-	

Cross I	:	ABGS 11-24 × P. Komal	Cross III	:	P. Komal × P. Long
Cross II	:	ABGS-11-17 × NDBG-132	Cross IV	:	Local × P. Long

*, ** Significant at 5% and 1%, levels of significance, respectively

Conclusion

the present investigation on generation mean analysis in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] was undertaken to understand the genetic control of yield, earliness, and fruit quality traits using six generations (P₁, P₂, F₁, F₂, BC₁, and BC₂) derived from four crosses. Significant variability among generations indicated ample genetic diversity for selection. Per se performance of F₁s exhibited substantial heterosis for vine length, branches per plant, fruit length, average fruit weight, and yield per plant, while reduced F₂ performance for several traits confirmed inbreeding depression and the role of non-additive gene action. Scaling tests revealed the inadequacy of the additive-dominance model for most traits, indicating the involvement of epistatic interactions. Generation mean analysis demonstrated the importance of additive, dominance, and digenic epistatic effects in the inheritance of flowering, yield, and quality traits. Additive gene action coupled with high heritability and genetic advance was predominant for earliness traits, suggesting the effectiveness of direct selection, whereas dominance and overdominance effects were more important for yield and associated traits, indicating the potential of heterosis breeding. The occurrence of additive × additive and dominance × dominance interactions suggested the usefulness of biparental mating and recurrent selection, while superior BC₁ and BC₂ performance indicated the effectiveness of backcross breeding for accumulation of favourable alleles and genetic improvement in bottle gourd.

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