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*Research Article*

# Gene Action Study for Fruit Yield and Its Components in Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.] Through Genration Mean Analysis

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**ABSTRACT**

*In the present investigation, nature and magnitude of gene action was analyzed in six generations ($P_1$, $P_2$, $F_1$, $F_2$, $BC_1$ and $BC_2$) of two crosses [Pusa Naveen × DBG 6 (cross 1) and DBG 5 × DBG 6 (cross 2)] of bottle gourd. On the basis of individual scaling tests, additive-dominance model was adequate in cross Pusa Naveen x DBG 6 for number of node bearing first female flower; in cross Pusa Naveen x DBG 6 for number of fruits per plant; and in cross DBG 5 x DBG 6 for fruit yield per plant. For the remaining character-cross combinations, additive-dominance model was found inadequate for description of variation in generation means. The (h) and (l) components had opposite sign in all the crosses for all characters except fruit equatorial diameter in DBG 5 x DBG 6 and for fruit yield per plant Pusa Naveen x DBG 6. Thus, these cross presuming largely complementary type of epistasis. Remaining crosses for all traits presuming largely duplicate type of epistasis. It would be concluded from the present study that fruit yield per plant and its component traits studied in two bottle gourd crosses were governed by additive, dominance, digenic, epistasis and digenic epistasis gene effects along with duplicate type of gene action. When additive as well as non-additive gene effects are involved, a breeding scheme efficient in exploiting both types of gene effects should be employed. Bi-parental mating could be followed which would facilitate exploitation of both types of gene effects simultaneously for genetic improvement of fruit yield and its component traits in bottle gourd.*

***Keywords:*** *Additive, Bottle gourd, Dominance, Epistasis, Generation mean analysis.*

## INTRODUCTION

Bottle gourd (*Lagenaria siceraria* (Mol.) Standl. 2n = 2x = 22), is one of humankind's first domesticated plants. It is an important cucurbitaceous vegetable crop belonging to family *Cucurbitaceae* and subfamily *Cucurbitoidae*. Bottle gourd is commonly grown for vegetable and it has medicinal value to human being. It can be used for making sweets (e.g. halva, kheer, petha and burfi) and pickle.

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A decoction made from the leaf is very good medicine for curing jaundice. The pulp is good for overcoming constipation, cough, night blindness, and as an antidote against certain poisons. The plant extract is used as a cathartic and the seed are used in dropsy. The fruit contain 0.2 per cent protein, 0.1 per cent fat, 2.5 g carbohydrates, 0.5 g mineral matter, 0.3 mg thiamine, 0.01 mg riboflavin, 0.2 mg niacin, 12 k cal energy per 100 g fresh weight and 11 mg of vitamin C per 100 g fresh weight.

Bottle gourd is highly cross pollinated crop. Cross pollination per cent ranges from 60 to 80 per cent, results into large variation in shape and size of fruits varies from very long slender to thick and round.

The information on the nature of gene action would be helpful in predicting the effectiveness of selection from segregating materials. A distinct knowledge of the type of gene action and its magnitude are of fundamental importance to a plant breeder, which helps in formulation of an effective and sound breeding programme. The main purpose of bottle gourd breeding is to increase fruit yield. However, fruit yield is a very complex character which is governed by polygenes and affects many genetic and non-genetic factors. Therefore, the choice of appropriate breeding method for enhancing fruit yield potential through component traits largely depends upon the information on the nature and magnitude of gene effects present in the populations. Although diallel and line × tester analysis have been used the most, but they do not provide the estimates of non-allelic interactions. Generation mean analysis (Mather and Jinks, 1982), besides providing estimates of main gene effects (additive and non-additive), also provide estimates of non-allelic (digenic) interactions *viz*., additive × additive [i], additive × dominance [j] and dominance × dominance [l] cross-wise. This helps in the proper understanding and selection of potential parents or crosses for the pedigree selection or heterosis exploitation.

## MATERIALS AND METHODS

### *Plant material*

The experimental materials comprised of six basic generations *viz*., $P_1$, $P_2$, $F_1$, $F_2$, $BC_1$ and $BC_2$ of two cross namely Pusa Naveen × DBG 6 and DBG 5 × DBG 6 were made between three parents by manual emasculation and pollen transfer. $F_1$ plants were selfed to obtain seed for the $F_2$ generation and backcrossed with their respective parents to generate $BC_1$ and $BC_2$ generations. Thus, a total of six generations were obtained.

### *Field trial*

The six generations ($P_1$, $P_2$, $F_1$, $F_2$, $BC_1$ and $BC_2$) for each population were planted during *kharif* 2019. Six populations were planted in compact family block design (CFBD) with three replications. Each replication was divided in to two compact blocks, each consists of single cross and blocks were consisted of six plots of six basic generation of each cross. The crosses were assigned to each block and six generations of a cross were relegated to individual plot within the block. Each block was comprised of eleven rows consisting single row each of $P_1$, $P_2$ and $F_1$; four rows of $F_2$ and two rows each of $BC_1$ and $BC_2$ generations with 10 plants in each row. Each row spaced 2 m apart and plant to plant distance within row was 1 m. Fertilizers were applied as per recommended doses and other cultural practices were carried out at regular intervals during the course of experimentation. The observations were recorded on five competitive and randomly selected plants from $P_1$, $P_2$ and $F_1$, ten plants from $BC_1$ and $BC_2$ generations and twenty plants from $F_2$ generations in each replication for days to opening first female flower, days to opening first male flower, number of node bearing first female flower, number of node bearing first male flower, vine length (m), days to first picking, fruit length (cm), fruit equatorial diameter (cm), number of fruits per plant, average fruit weight per plant (kg), days to last picking and fruit yield per plant (kg).

***Statistical analysis***

The analysis of variance was performed to test the significance of difference among the genotypes for all the characters following fixed effect model as suggested by Panse and Sukhatme (1985), Individual scaling test will be done as per Mather (1949). Joint scaling test will be done as per Cavalli (1952). Gene effects will be calculated by using model as per Jinks and Jones (1958) and Cavalli (1952).

## RESULTS AND DISCUSSION

The analysis of variance among families (Table 1) indicated significant mean square differences among all the two 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.

***Components of generation means based on additive-dominance model***

To decide the adequacy of additive-dominance model, simple scaling tests given by Mather (1949) and joint scaling test of Cavalli (1952) were applied to test adequacy of three and six-parameter models. Whenever, this additive-dominance model failed to explain the variation in generation means, six-parameter model using weighted least square method was used to estimate main, digenic and linked digenic effects. The results of individual scaling test A, B, C of Mather (1949) and joint scaling test D of Cavalli (1952) showed that additive-dominance model was adequate in cross Pusa Naveen x DBG 6 for number of node bearing first female flower; in cross Pusa Naveen x DBG 6 for number of fruits per plant, and in cross DBG 5 x DBG 6 for fruit yield per plant. Patel (2010) observed adequacy of additive – dominance model in about 22.22 per cent cases of his study for the remaining character-cross combinations, additive-dominance model was found inadequate for description of variation in generation means. it was observed that all the three or two or any of the individual scaling tests A, B or C were significant for these characters in all the three crosses indicating the presence of epistasis. The application of joint scaling test expressed significant chi-square values for these traits further confirming involvement of digenic interaction parameters in the inheritance of all these characters. The failure of additive- dominance model was attributed mainly to the epistasis. Cockerham (1959) postulated that the epistatic gene action is common in the inheritance of quantitative traits and there is no sound biological reason as to why this type of gene action should be less common for quantitative traits.

***Components of generation means based on three parameter model (Cavalli, 1952) as well as Jinks and Jones (1958)***

The results obtained from three parameter model of additive- dominance by Jinks and Jones (1958) as well as Cavalli (1952) revealed that parameter 'm' was found significant in all the crosses in which three parameter model was satisfied for various traits. The significant 'm' suggested that all the generations differed significantly from one another for their performance (Table 2 to 7).

As per three parameter model of Jinks and Jones (1958), additive (d) gene effect was found significant and positive for days to opening first female flower in Pusa Naveen x DBG 6; for number of node bearing first female flower and number of node bearing first male flower in Pusa Naveen x DBG 6 and DBG 5 x DBG 6; for days to first picking in Pusa Naveen x DBG 6; for average fruit weight per plant in DBG 5 x DBG 6; and for days to last picking in Pusa Naveen x DBG 6.

As per three parameter model of Jinks and Jones (1958), dominance (h) gene effect was found significant and positive number of node bearing first male flower in Pusa Naveen x DBG 6; for days to first picking in Pusa Naveen x DBG 6; for fruit equatorial diameter in Pusa Naveen x DBG 6 and DBG 5 x DBG 6; for number of fruits per plant in DBG 5 x DBG 6; and for days to last picking in Pusa Naveen x DBG 6.

As per three parameter model of Cavalli (1952), additive (d) gene effect was found significant and positive for days to opening first female flower in Pusa Naveen x DBG 6 and DBG 5 x DBG 6; for days to opening first male flower in DBG 5 x DBG 6; for number of node bearing first female flower and number of node bearing first male flower in Pusa Naveen x DBG 6 and DBG 5 x DBG 6; for days to first picking in Pusa Naveen x DBG 6; for number of fruits per plant in Pusa Naveen x DBG 6; for average fruit weight per plant in Pusa Naveen x DBG 6 and DBG 5 x DBG 6; for days to last picking in Pusa Naveen x DBG 6.

As per three parameter model of Cavalli (1952), dominance (h) gene effect was found significant and positive for for vine length and fruit length in Pusa Naveen x DBG 6 and DBG 5 x DBG 6 and for number of fruits per plant in Pusa Naveen x DBG 6 and DBG 5 x DBG 6

The magnitude of dominance (h) gene effect was higher than that of additive (d) gene effect for most of the traits in all the crosses evaluated, suggesting greater importance of dominance effect in expression of the characters studied. For the exploitation of dominance effect, non-conventional breeding procedure might be adopted. Wani et al. (2009) and Gautam and Yadav (2017) also observed higher magnitude of dominance effect for most of the traits studied including fruit yield per plant in bottle gourd.

***Components of generation means based on six parameter model (Hayman, 1958)***

When the simple additive model failed to explain the variation among generation means, a six-parameter model involving three digenic interaction parameters ([i], [j] and [l]) was applied on the line of Hayman (1958) and by Cavalli (1952). The results obtained from six parameter model of Hayman (1958) revealed that parameter 'm' was found significant in all the crosses evaluated for various traits.

The results obtained from six parameter model revealed that in addition to the significance of main gene effects m, (d) and (h); all the three digenic interactions *viz*., additive x additive (i), additive x dominance (j) and dominance x dominance (l) were significant for days to opening first female flower in Pusa Naveen x DBG 6 and DBG 5 x DBG 6; for vine length in Pusa Naveen x DBG 6 and for fruit equatorial diameter in Pusa Naveen x DBG 6. The goodness of fit for six parameter model could not be tested in the present study owing to no degrees of freedom left for testing chi-square estimates for various characters. The perfect fit solution of Hayman (1958), therefore, does not provide a general method for testing the adequacy of digenic interaction model. Such a method would require experiment with more number of family means than the minimum number necessary for fitting a full digenic interaction model.

The hybrids showing full digenic interaction had significant and positive dominance (h) component. Also the magnitude of dominance (h) component was higher than that of additive (d) effects for almost all the characters studied in all the crosses, which indicated greater importance of dominance effect in the expression of these characters.

The (h) and (l) components had opposite sign in all the crosses for all characters except for fruit equatorial diameter in DBG 5 x DBG 6 and for fruit yield per plant Pusa Naveen x DBG 6. Thus, these cross presuming largely complementary type of epistasis. Remaining crosses for all traits presuming largely duplicate type of epistasis.

Estimate of additive (d) and dominance (h) components varied from cross to cross and character to character. The variable expression of gene effect in different crosses might be due to the genetic makeup of a particular cross and the effect of environmental condition on the expression of different traits.

***Components of generation means based on six parameter model (Cavalli (1952*)**

The results obtained from six parameter model on the line of Cavalli (1952) revealed that in addition to the significance of main gene effects m, (d) and (h); and all the three digenic interactions *viz*., additive x additive (i), additive x dominance (j) and dominance x dominance (l) were significant (either positive or negative) in Pusa Naveen x DBG 6 for days to opening first female flower; Pusa Naveen x DBG 6 for vine length and Pusa Naveen x DBG 6 and DBG 5 x DBG 6 for fruit length. These results indicated that six parameter model of Cavalli (1952) was perfect fit and adequate with significance of all the six gene effects.

On the basis of results of adequacy of additive – dominance model and on the basis the results from six parameter model on the line of Cavalli (1952), wherein the three and six parameter model was found to be perfect fit and adequate, the remaining character-cross combinations out of total character-cross combinations, in which any of the additive x additive (i), additive x dominance (j) and dominance x dominance (l) type of interaction was non-significant were reanalyzed after the removal of non-significant effects one-by–one starting with that of lowest magnitude until the remaining inter-allelic interaction became significant. The results of reanalysis revealed the best fitting four or five parameter model on line of Cavalli (1952). In addition to the significance of main gene effects, m, (d) and (h); additive x additive (i) type of interaction was noted significant in Pusa Naveen x DBG 6 for fruit yield per plant; and dominance x dominance (l) type of interaction was found significant in Pusa Naveen x DBG 6 and DBG 5 x DBG 6 for days to first picking and days to last picking. Thus, in these crosses, four parameter model on the line of Cavalli (1952) was found to be perfect fit and adequate.

While, in addition to the significance of main gene effects, m, (d) and (h); additive x additive (i) type of interaction and dominance x dominance (l) type of interaction was noted significant in Pusa Naveen x DBG 6 for days to opening first male flower; in Pusa Naveen x DBG 6 and DBG 5 x DBG 6 for number of node bearing first male flower; in DBG 5 x DBG 6 for vine length; and in Pusa Naveen x DBG 6 for fruit equatorial diameter and additive x additive (i) type of interaction and additive x dominance (j) type of interaction was noted significant in DBG 5 x DBG 6 for fruit equatorial diameter. Thus, in these crosses, five parameter model on the line of Cavalli (1952) was found to be perfect fit and adequate.

Cross Pusa Naveen x DBG 6 for average fruit weight per plant; and DBG 5 x DBG 6 for days to opening first female flower, days to opening first male flower, number of node bearing first female flower, number of fruits per plant and average fruit weight per plant; showing the presence of higher order epistasis and/or linkage.

**Table 1: Analysis of variance (mean squares) between crosses and between generations within cross of six generations for different characters in bottle gourd**

| Source of variation | d.f. | Days to opening first female flower | Days to opening first male flower | No of node bearing first female flower | No of node bearing first male flower | Vine length (m) | Days to first picking |
|---|---|---|---|---|---|---|---|
| **Replications** | **2** | 1.72* | 1.37* | 0.09 | 0.01 | 0.001 | 0.151 |
| **Crosses** | **4** | 1.24* | 1.40* | 1.55* | 0.74* | 0.141** | 0.719** |
| **Error** | **8** | 0.25 | 0.26 | 0.22 | 0.16 | 0.001 | 0.089 |
| $\chi2$ | | NS | NS | NS | NS | S | S |
| **Pusa Naveen x DBG 6** | | | | | | | |
| **Replications** | **2** | 10.13* | 7.28* | 0.48 | 0.54 | 0.017 | 1.350 |
| **Generations** | **5** | 12.82* | 11.68** | 6.69* | 5.12* | 0.209** | 3.332* |
| **Error** | **10** | 2.46 | 1.64 | 1.50 | 1.24 | 0.013 | 0.843 |
| **DBG 5 x DBG 6** | | | | | | | |
| **Replications** | **2** | 2.19 | 1.86 | 2.56 | 1.93 | 0.004 | 0.366 |
| **Generations** | **5** | 7.49** | 3.64* | 4.60* | 3.02* | 0.066** | 2.659** |
| **Error** | **10** | 1.20 | 0.92 | 1.08 | 0.77 | 0.008 | 0.099 |
| **Source of variation** | **d.f.** | **Fruit length (cm)** | **Fruit equatorial diameter (cm)** | **Number of fruits per plant** | **Average fruit weight per plant (kg)** | **Days to last picking** | **Fruit yield per plant (kg)** |
| **Replications** | **2** | 0.09 | 0.003 | 0.02 | 0.0013 | 0.19 | 0.002 |
| **Crosses** | **4** | 47.75** | 0.558** | 0.30** | 0.0062* | 0.72** | 0.018** |
| **Error** | **8** | 0.05 | 0.002 | 0.01 | 0.0011 | 0.06 | 0.001 |
| $\chi2$ | | S | S | NS | S | NS | S |
| **P. Naveen x DBG 6** | | | | | | | |
| **Replications** | **2** | 0.14 | 0.002 | 0.26* | 0.0015* | 0.95 | 0.001 |
| **Generations** | **5** | 27.31** | 0.270** | 0.61** | 0.0042** | 3.01* | 0.077** |
| **Error** | **10** | 0.72 | 0.002 | 0.04 | 0.0003 | 0.84 | 0.003 |
| **DBG 5 x DBG 6** | | | | | | | |
| **Replications** | **2** | 0.14 | 0.025 | 0.09 | 0.0028* | 0.38 | 0.003 |
| **Generations** | **5** | 10.50** | 0.357** | 0.40* | 0.0035** | 2.89** | 0.031** |
| **Error** | **10** | 0.29 | 0.021 | 0.09 | 0.0004 | 0.12 | 0.001 |

*, ** = Significant at 5% and 1% levels, respectively
**Chi-square for Bartlett's test of homogeneity of error variances, S= Significant and NS = Non-significant**

**Table 2: Estimates of scaling tests, gene effects and best fitting model for days to opening first female flower and days to opening first male flower of two crosses in bottle gourd**

| Scaling tests/ gene effects | Days to opening first female flower | | Days to opening first male flower | |
|---|---|---|---|---|
| | **Pusa Naveen x DBG 6 (cross 1)** | **DBG 5 x DBG 6 (cross 2)** | **Pusa Naveen x DBG 6 (cross 1)** | **DBG 5 x DBG 6 (cross 2)** |
| | **Individual scaling test** | | | |
| A | 1.20* ± 0.56 | -0.40 ± 0.63 | 0.27 ± 0.68 | 1.33* ± 0.65 |
| B | -3.07** ± 0.57 | -3.33** ± 0.63 | -1.20* ± 0.59 | -2.27** ± 0.57 |
| C | 7.67** ± 1.39 | 9.20** ± 1.68 | 7.87** ± 1.80 | 0.73 ± 1.56 |
| D | 4.77** ± 0.67 | 6.47** ± 0.83 | 4.40** ± 0.89 | 0.83 ± 0.80 |
| | **Gene effects in different models** | | | |
| | **Three parameters model (Jinks and Jones, 1958)** | | | |
| M | 60.56** ± 1.41 | 62.96** ± 1.68 | 55.00** ± 1.79 | 48.80** ± 1.62 |
| (d) | 1.10** ± 0.20 | 0.10 ± 0.18 | -1.00** ± 0.17 | 0.07 ± 0.18 |
| (h) | -24.76** ± 3.06 | -32.10** ± 3.74 | -23.13** ± 3.95 | -6.67 ± 3.66 |
| | **Three parameters model (Cavalli, 1952)** | | | |
| M | 50.82** ± 0.16 | 49.85** ± 0.16 | 46.17** ± 0.16 | 47.09** ± 0.16 |
| (d) | 2.01** ± 0.15 | 0.45** ± 0.16 | -0.81** ± 0.15 | 0.42** ± 0.16 |
| (h) | -3.77** ± 0.29 | -2.62** ± 0.33 | -4.54** ± 0.33 | -2.51** ± 0.29 |
| $\chi2$ | 97.37** | 76.99** | | |
| | **Six parameter model (Hayman, 1958)** | | | |
| M | 51.03** ± 0.32 | 51.08** ± 0.38 | 45.86** ± 0.41 | 46.11** ± 0.36 |
| (d) | 3.23** ± 0.24 | 1.56** ± 0.34 | -0.26 ± 0.35 | 1.86** ± 0.36 |
| (h) | -13.36** ± 1.42 | -15.43** ± 1.71 | -13.40** ± 1.82 | -4.06* ± 1.64 |
| (i) | -9.53** ± 1.39 | -12.93** ± 1.67 | -8.80** ± 1.78 | -1.66 ± 1.61 |
| (j) | 2.13** ± 0.31 | 1.46** ± 0.39 | 0.73** ± 0.39 | 1.80** ± 0.40 |
| (l) | 11.40** ± 1.74 | 16.66** ± 2.18 | 9.73** ± 2.28 | 2.60 ± 2.12 |
| | **Six parameters model (Cavalli, 1952)** | | | |
| M | 60.56** ± 1.41 | 62.96** ± 1.68 | 55.00** ± 1.79 | 48.80** ± 1.62 |
| (d) | 1.10** ± 0.20 | 0.10 ± 0.18 | -1.00** ± 0.17 | 0.07 ± 0.18 |
| (h) | -24.76** ± 3.06 | -32.10** ± 3.74 | -23.13** ± 3.95 | -6.67 ± 3.66 |
| (i) | -9.53** ± 1.39 | -12.93** ± 1.67 | -8.80** ± 1.78 | -1.66 ± 1.61 |
| (j) | 4.26** ± 0.63 | 2.93** ± 0.78 | 1.46 ± 0.78 | 3.60** ± 0.80 |
| (l) | 11.40** ± 1.74 | 16.66** ± 2.18 | 9.73** ± 2.28 | 2.60 ± 2.12 |
| Type of epistasis | **Duplicate** | **Duplicate** | **Duplicate** | **Duplicate** |
| | **Best fitting model (Cavalli, 1952)** | | | |
| M | - | - | 55.28** ± 1.79 | - |
| (d) | - | - | -0.85** ± 0.15 | - |
| (h) | - | - | -23.99** ± 3.92 | - |
| (i) | - | - | -9.11** ± 1.78 | - |
| (j) | - | - | | - |
| (l) | - | - | 10.31** ± 2.26 | - |
| $\chi2$ | - | - | 3.49 | - |

*** and** Significant at 5 and 1 per cent levels, respectively**

**Table 3: Estimates of scaling tests, gene effects and best fitting model for number of node bearing first female flower and number of node bearing first male flower of two crosses in bottle gourd**

| Scaling tests/ gene effects | Number of node bearing first female flower | | Number of node bearing first male flower | |
|---|---|---|---|---|
| | Pusa Naveen x DBG 6 (cross 1) | DBG 5 x DBG 6 (cross 2) | Pusa Naveen x DBG 6 (cross 1) | DBG 5 x DBG 6 (cross 2) |
| | **Individual scaling test** | | | |
| A | -0.93 ± 0.68 | 0.33 ± 0.85 | 0.00 ± 0.61 | -0.27 ± 0.67 |
| B | 0.13 ± 0.87 | -1.93* ± 0.72 | -1.27 ± 0.75 | -1.87* ± 0.78 |
| C | 2.07 ± 1.32 | 0.67 ± 1.26 | 3.07** ± 1.11 | 1.87 ± 1.08 |
| D | 1.43 ± 0.78 | 1.13 ± 0.75 | 2.17** ± 0.59 | 2.00** ± 0.63 |
| | **Gene effects in different models** | | | |
| | **Three parameters model (Jinks and Jones, 1958)** | | | |
| M | 17.00** ± 1.58 | 16.00** ± 1.51 | 15.93** ± 1.19 | 15.50** ± 1.28 |
| (d) | 2.13** ± 0.19 | 1.40** ± 0.19 | 1.60** ± 0.16 | 1.10** ± 0.19 |
| (h) | -7.33 ± 3.90 | -6.66 ± 3.79 | -10.40** ± 3.02 | -10.43** ± 3.30 |
| | **Three parameters model (Cavalli, 1952)** | | | |
| M | 14.14** ± 0.18 | 13.61** ± 0.17 | 11.62** ± 0.15 | 11.46** ± 0.17 |
| (d) | 2.03** ± 0.18 | 1.58** ± 0.17 | 1.64** ± 0.15 | 1.20** ± 0.17 |
| (h) | -0.80** ± 0.26 | -0.50 ± 0.29 | -0.28 ± 0.31 | -0.26 ± 0.30 |
| $\chi 2$ | 5.12 | 8.60* | 15.36** | 11.72** |
| | **Six parameter model (Hayman, 1958)** | | | |
| M | - | 13.63** ± 0.27 | 12.13** ± 0.21 | 11.81** ± 0.22 |
| (d) | - | 2.53** ± 0.50 | 2.23** ± 0.40 | 1.90** ± 0.45 |
| (h) | - | -2.80 ± 1.52 | -4.80** ± 1.23 | -4.30** ± 1.30 |
| (i) | - | -2.26 ± 1.50 | -4.33** ± 1.18 | -4.00** ± 1.27 |
| (j) | - | 1.13* ± 0.53 | 0.63 ± 0.43 | 0.80 ± 0.48 |
| (l) | - | 3.86 ± 2.37 | 5.60** ± 1.95 | 6.13** ± 2.10 |
| | **Six parameters model (Cavalli, 1952)** | | | |
| M | - | 16.00** ± 1.51 | 15.93** ± 1.19 | 15.50** ± 1.28 |
| (d) | - | 1.40** ± 0.19 | 1.60** ± 0.16 | 1.10** ± 0.19 |
| (h) | - | -6.66 ± 3.79 | -10.40** ± 3.02 | -10.43** ± 3.30 |
| (i) | - | -2.26 ± 1.50 | -4.33** ± 1.18 | -4.00** ± 1.27 |
| (j) | - | 2.26* ± 1.07 | 1.26 ± 0.86 | 1.60 ± 0.97 |
| (l) | - | 3.86 ± 2.37 | 5.60** ± 1.95 | 6.13** ± 2.10 |
| Type of epistasis | - | **Duplicate** | **Duplicate** | **Duplicate** |
| | **Best fitting model (Cavalli, 1952)** | | | |
| M | - | - | 15.65** ± 1.17 | 15.26** ± 1.27 |
| (d) | - | - | 1.69** ± 0.15 | 1.22** ± 0.17 |
| (h) | - | - | -9.56** ± 2.96 | -9.72** ± 3.27 |
| (i) | - | - | -4.09** ± 1.17 | -3.80** ± 1.26 |
| (j) | - | - | - | - |
| (l) | - | - | 5.04** ± 1.91 | 5.66** ± 2.08 |
| $\chi 2$ | - | - | 2.14 | 2.67 |

*** and** Significant at 5 and 1 per cent levels, respectively**

**Table 4: Estimates of scaling tests, gene effects and best fitting model for vine length (m) and days to first picking of two crosses in bottle gourd**

| Scaling tests/ gene effects | Vine length (m) | | Days to first picking | |
|---|---|---|---|---|
| | **Pusa Naveen x DBG 6 (cross 1)** | **DBG 5 x DBG 6 (cross 2)** | **Pusa Naveen x DBG 6 (cross 1)** | **DBG 5 x DBG 6 (cross 2)** |
| | **Individual scaling test** | | | |
| A | -0.47** ± 0.03 | -0.25* ± 0.11 | 3.27** ± 0.59 | 1.93* ± 0.86 |
| B | -0.11** ± 0.03 | -0.07 ± 0.03 | 2.53* ± 0.95 | 2.73** ± 0.90 |
| C | 0.49** ± 0.10 | 0.20 ± 0.15 | 3.87* ± 1.63 | 4.27** ± 1.50 |
| D | 0.53** ± 0.05 | 0.26** ± 0.05 | -0.97 ± 0.74 | -0.20 ± 0.80 |
| | **Gene effects in different models** | | | |
| | **Three parameters model (Jinks and Jones, 1958)** | | | |
| M | 4.61** ± 0.11 | 4.17** ± 0.11 | 58.70** ± 1.51 | 58.50** ± 1.64 |
| (d) | -0.25** ± 0.01 | -0.15* ± 0.05 | 0.96** ± 0.32 | -0.76* ± 0.34 |
| (h) | -2.35** ± 0.23 | -1.15** ± 0.28 | 8.56* ± 3.55 | 6.10 ± 4.05 |
| | **Three parameters model (Cavalli, 1952)** | | | |
| M | 3.45** ± 0.01 | 3.56** ± 0.01 | 61.20** ± 0.26 | 59.73** ± 0.26 |
| (d) | -0.33** ± 0.01 | -0.23** ± 0.01 | 1.14** ± 0.23 | -1.16** ± 0.27 |
| (h) | 0.40** ± 0.01 | 0.27** ± 0.02 | -0.13 ± 0.46 | 0.15 ± 0.38 |
| $\chi2$ | 233.99** | 28.17** | 32.04** | 16.07** |
| | **Six parameter model (Hayman, 1958)** | | | |
| M | 3.84** ± 0.02 | 3.80** ± 0.02 | 61.05** ± 0.32 | 60.28** ± 0.31 |
| (d) | -0.43** ± 0.01 | -0.24** ± 0.02 | 1.33** ± 0.37 | -1.16* ± 0.49 |
| (h) | -0.71** ± 0.11 | -0.32** ± 0.11 | 0.83 ± 1.56 | 1.03 ± 1.66 |
| (i) | -1.06** ± 0.10 | -0.51** ± 0.10 | 1.93 ± 1.48 | 0.40 ± 1.61 |
| (j) | -0.17** ± 0.02 | -0.09 ± 0.06 | 0.36 ± 0.49 | -0.40 ± 0.60 |
| (l) | 1.64** ± 0.13 | 0.83** ± 0.17 | -7.73** ± 2.20 | -5.06* ± 2.50 |
| | **Six parameters model (Cavalli, 1952)** | | | |
| M | 4.61** ± 0.11 | 4.17** ± 0.11 | 58.70** ± 1.51 | 58.50** ± 1.64 |
| (d) | -0.25** ± 0.01 | -0.15** ± 0.05 | 0.96** ± 0.32 | -0.76* ± 0.34 |
| (h) | -2.35** ± 0.23 | -1.15** ± 0.28 | 8.56* ± 3.55 | 6.10 ± 4.05 |
| (i) | -1.06** ± 0.10 | -0.51** ± 0.10 | 1.93 ± 1.48 | 0.40 ± 1.61 |
| (j) | -0.35** ± 0.04 | -0.18 ± 0.11 | 0.73 ± 0.98 | -0.80 ± 1.20 |
| (l) | 1.64** ± 0.13 | 0.83** ± 0.17 | -7.73** ± 2.20 | -5.06* ± 2.50 |
| Type of epistasis | **Duplicate** | **Duplicate** | **Duplicate** | **Duplicate** |
| | **Best fitting model (Cavalli, 1952)** | | | |
| M | - | 4.09** ± 0.10 | 6.49** ± 0.29 | 58.95** ± 0.33 |
| (d) | - | -0.23** ± 0.02 | 1.19** ± 0.23 | -0.89** ± 0.28 |
| (h) | - | -0.91** ± 0.23 | 4.89** ± 1.04 | 5.03** ± 1.29 |
| (i) | - | -0.50** ± 0.10 | - | - |
| (j) | - | | - | - |
| (l) | - | 0.67** ± 0.13 | -5.86** ± 1.08 | -4.45** ± 1.12 |
| $\chi2$ | - | 1.99 | 2.84 | 0.52 |

*** and** Significant at 5 and 1 per cent levels, respectively**

**Table 5: Estimates of scaling tests, gene effects and best fitting model for fruit length (cm) and fruit equatorial diameter (cm) of two crosses in bottle gourd**

| Scaling tests/ gene effects | Fruit length (cm) | | Fruit equatorial diameter (cm) | |
|---|---|---|---|---|
| | Pusa Naveen x DBG 6 (cross 1) | DBG 5 x DBG 6 (cross 2) | Pusa Naveen x DBG 6 (cross 1) | DBG 5 x DBG 6 (cross 2) |
| | **Individual scaling test** | | | |
| A | -4.47** ± 0.90 | -3.60** ± 0.87 | 0.19 ± 0.16 | -0.83** ± 0.19 |
| B | 0.47 ± 0.48 | -1.13 ± 0.80 | -0.34* ± 0.13 | -0.31* ± 0.14 |
| C | 3.13 ± 1.60 | 1.33 ± 1.72 | -2.71** ± 0.27 | -2.14** ± 0.31 |
| D | 3.57** ± 0.87 | 3.03** ± 0.93 | -1.28** ± 0.02 | -0.50** ± 0.01 |
| | **Gene effects in different models** | | | |
| | **Three parameters model (Jinks and Jones, 1958)** | | | |
| M | 40.50** ± 1.75 | 40.93** ± 1.88 | 4.18** ± 0.06 | 5.48** ± 0.07 |
| (d) | -3.03** ± 0.17 | -1.46** ± 0.20 | 0.02 ± 0.04 | -0.22** ± 0.06 |
| (h) | -14.43** ± 4.06 | -13.40** ± 4.45 | 5.31** ± 0.23 | 1.44** ± 0.25 |
| | **Three parameters model (Cavalli, 1952)** | | | |
| M | 33.39** ± 0.15 | 34.67** ± 0.19 | 6.37** ± 0.02 | 6.32** ± 0.01 |
| (d) | -3.28** ± 0.15 | -1.61** ± 0.19 | -0.34** ± 0.01 | -0.38** ± 0.01 |
| (h) | 3.76** ± 0.28 | 3.28** ± 0.34 | -0.07 ± 0.03 | 0.03 ± 0.03 |
| $\chi 2$ | 32.07** | 20.76** | 2453. 54** | 987.99** |
| | **Six parameter model (Hayman, 1958)** | | | |
| M | 36.06** ± 0.37 | 36.93** ± 0.39 | 6.23** ± 0.01 | 6.24** ± 0.01 |
| (d) | -5.50** ± 0.45 | -2.70** ± 0.51 | 0.28** ± 0.03 | -0.48** ± 0.01 |
| (h) | -3.30 ± 1.76 | -2.60 ± 1.91 | 2.90** ± 0.15 | 1.58** ± 0.16 |
| (i) | -7.13** ± 1.74 | -6.06** ± 1.87 | 2.55** ± 0.05 | 1.00** ± 0.03 |
| (j) | -2.46** ± 0.48 | -1.23** ± 0.55 | 0.26** ± 0.05 | -0.26** ± 0.06 |
| (l) | 11.13** ± 2.41 | 10.80** ± 2.68 | -2.40** ± 0.29 | 0.14 ± 0.32 |
| | **Six parameters model (Cavalli, 1952)** | | | |
| M | 40.50** ± 1.75 | 40.93** ± 1.88 | 4.18** ± 0.06 | 5.48** ± 0.07 |
| (d) | -3.03** ± 0.17 | -1.46** ± 0.20 | 0.02 ± 0.04 | -0.22** ± 0.06 |
| (h) | -14.43** ± 4.06 | -13.40** ± 4.45 | 5.31** ± 0.23 | 1.44** ± 0.25 |
| (i) | -7.13** ± 1.74 | -6.06** ± 1.87 | 2.55** ± 0.05 | 1.00** ± 0.03 |
| (j) | -4.93** ± 0.96 | -2.46* ± 1.10 | 0.52** ± 0.09 | -0.52** ± 0.12 |
| (l) | 11.13** ± 2.41 | 10.80** ± 2.68 | -2.40** ± 0.28 | 0.14 ± 0.31 |
| Type of epistasis | **Duplicate** | **Duplicate** | **Duplicate** | **Complementary** |
| | **Best fitting model (Cavalli, 1952)** | | | |
| M | - | - | 4.46** ± 0.04 | 5.47** ± 0.06 |
| (d) | - | - | 0.22** ± 0.02 | -0.23** ± 0.05 |
| (h) | - | - | 4.48** ± 0.18 | 1.54** ± 0.12 |
| (i) | - | - | 2.47** ± 0.05 | 1.00** ± 0.03 |
| (j) | - | - | | 0.50** ± 0.12 |
| (l) | - | - | -1.85** ± 0.27 | |
| $\chi 2$ | - | - | 28.10** | 0.20 |

*** and** Significant at 5 and 1 per cent levels, respectively**

**Table 6: Estimates of scaling tests, gene effects and best fitting model for number of fruits per plant and average fruit weight per plant (kg) of two crosses in bottle gourd**

| Scaling tests/ gene effects | Number of fruits per plant | | Average fruit weight per plant (kg) | |
|---|---|---|---|---|
| | Pusa Naveen x DBG 6 (cross 1) | DBG 5 x DBG 6 (cross 2) | Pusa Naveen x DBG 6 (cross 1) | DBG 5 x DBG 6 (cross 2) |
| | **Individual scaling test** | | | |
| A | 0.03 ± 0.74 | 0.43 ± 0.54 | -0.14** ± 0.04 | -0.08** ± 0.03 |
| B | -1.17 ± 0.66 | 0.43 ± 0.62 | -0.13** ± 0.03 | -0.08** ± 0.02 |
| C | 0.07 ± 1.10 | -1.60 ± 0.87 | -0.23** ± 0.07 | -0.21** ± 0.05 |
| D | 0.60 ± 0.59 | -1.23** ± 0.40 | 0.02 ± 0.01 | -0.02** ± 0.01 |
| | **Gene effects in different models** | | | |
| | **Three parameters model (Jinks and Jones, 1958)** | | | |
| M | 6.10** ± 1.21 | 1.96* ± 0.83 | 0.67** ± 0.03 | 0.60** ± 0.02 |
| (d) | 0.30 ± 0.20 | 0.10 ± 0.22 | 0.02 ± 0.01 | 0.02* ± 0.01 |
| (h) | -2.80 ± 3.09 | 6.53** ± 2.20 | -0.28** ± 0.09 | -0.01 ± 0.07 |
| | **Three parameters model (Cavalli, 1952)** | | | |
| M | 4.81** ± 0.18 | 4.35** ± 0.18 | 0.63** ± 0.01 | 0.62** ± 0.01 |
| (d) | 0.44* ± 0.18 | 0.14 ± 0.17 | 0.02* ± 0.01 | 0.02** ± 0.01 |
| (h) | 0.70* ± 0.33 | 0.71* ± 0.33 | -0.05* ± 0.02 | 0.01 ± 0.01 |
| $\chi 2$ | 3.58 | 9.70* | 12.18** | 15.41** |
| | **Six parameter model (Hayman, 1958)** | | | |
| M | -- | 4.40** ± 0.13 | 0.60** ± 0.01 | 0.62** ± 0.01 |
| (d) | - | 0.10 ± 0.29 | 0.01 ± 0.01 | 0.02** ± 0.01 |
| (h) | - | 3.20** ± 0.87 | 0.01 ± 0.05 | 0.11** ± 0.04 |
| (i) | - | 2.46** ± 0.80 | -0.03 ± 0.03 | 0.04 ± 0.03 |
| (j) | - | 0.01 ± 0.37 | -0.01 ± 0.01 | -0.01 ± 0.01 |
| (l) | - | -3.33* ± 1.47 | 0.29** ± 0.08 | 0.12 ± 0.06 |
| | **Six parameters model (Cavalli, 1952)** | | | |
| M | - | 1.96* ± 0.83 | 0.67** ± 0.03 | 0.60** ± 0.02 |
| (d) | - | 0.10 ± 0.22 | 0.02 ± 0.01 | 0.02* ± 0.01 |
| (h) | - | 6.53** ± 2.20 | -0.28** ± 0.01 | -0.01 ± 0.07 |
| (i) | - | 2.46** ± 0.80 | -0.03 ± 0.03 | 0.04 ± 0.02 |
| (j) | - | 0.01 ± 0.74 | -0.01 ± 0.03 | -0.01 ± 0.02 |
| (l) | - | -3.33* ± 1.47 | 0.30** ± 0.08 | 0.12 ± 0.06 |
| Type of epistasis | - | **Duplicate** | **Duplicate** | **Duplicate** |

*** and** Significant at 5 and 1 per cent levels, respectively**

**Table 7: Estimates of scaling tests, gene effects and best fitting model for days to last picking and fruit yield per plant (kg) of two crosses in bottle gourd**

| Scaling tests/ gene effects | Days to last picking | | fruit yield per plant (kg) | |
|---|---|---|---|---|
| | **Pusa Naveen x DBG 6 (cross 1)** | **DBG 5 x DBG 6 (cross 2)** | **Pusa Naveen x DBG 6 (cross 1)** | **DBG 5 x DBG 6 (cross 2)** |
| | **Individual scaling test** | | | |
| A | 2.93** ± 0.64 | 1.87* ± 0.85 | -0.28 ± 0.17 | -0.23 ± 0.13 |
| B | 2.47* ± 0.96 | 2.73** ± 0.90 | -0.24 ± 0.16 | -0.23 ± 0.12 |
| C | 3.60* ± 1.69 | 5.40** ± 1.49 | -0.97** ± 0.33 | -0.50 ± 0.25 |
| D | -0.90 ± 0.77 | 0.40 ± 0.79 | -0.23* ± 0.10 | -0.02 ± 0.05 |
| | **Gene effects in different models** | | | |
| | **Three parameters model (Jinks and Jones, 1958)** | | | |
| M | 118.83** ± 1.58 | 119.70** ± 1.62 | 2.83** ± 0.21 | 3.44** ± 0.11 |
| (d) | 0.96** ± 0.32 | -0.76* ± 0.34 | -0.05** ± 0.01 | 0.03 ± 0.02 |
| (h) | 7.96* ± 3.71 | 3.63 ± 4.01 | 0.76 ± 0.53 | -0.13 ± 0.29 |
| | **Three parameters model (Cavalli, 1952)** | | | |
| M | 121.15** ± 0.26 | 119.81** ± 0.26 | 3.28** ± 0.01 | 3.47** ± 0.02 |
| (d) | 0.98** ± 0.24 | -1.18** ± 0.27 | -0.05** ± 0.01 | 0.03 ± 0.01 |
| (h) | -0.27 ± 0.47 | 0.11 ± 0.38 | 0.08 ± 0.05 | 0.04 ± 0.05 |
| $\chi2$ | 22.49** | 19.31** | 11.03** | 3.87 |
| | **Six parameter model (Hayman, 1958)** | | | |
| M | 121.01** ± 0.33 | 120.56** ± 0.31 | 3.23** ± 0.04 | - |
| (d) | 1.20** ± 0.39 | -1.20* ± 0.49 | -0.07 ± 0.06 | - |
| (h) | 0.76 ± 1.63 | -0.16 ± 1.64 | 0.82** ± 0.25 | - |
| (i) | 1.80 ± 1.55 | -0.80 ± 1.59 | 0.45* ± 0.21 | - |
| (j) | 0.23 ± 0.50 | -0.43 ± 0.59 | -0.02 ± 0.06 | - |
| (l) | -7.20** ± 2.30 | -3.80 ± 2.47 | 0.06 ± 0.41 | - |
| | **Six parameters model (Cavalli, 1952)** | | | |
| M | 118.83** ± 1.5 | 119.70** ± 1.62 | 2.83** ± 0.21 | - |
| (d) | 0.96** ± 0.3 | -0.76* ± 0.34 | -0.05** ± 0.01 | - |
| (h) | 7.96* ± 3.7 | 3.63 ± 4.01 | 0.76 ± 0.53 | - |
| (i) | 1.80 ± 1.5 | -0.80 ± 1.59 | 0.45* ± 0.21 | - |
| (j) | 0.46 ± 1.0 | -0.86 ± 1.19 | -0.03 ± 0.13 | - |
| (l) | -7.20** ± 2.3 | -3.80 ± 2.47 | 0.06 ± 0.41 | - |
| Type of epistasis | **Duplicate** | **Duplicate** | **Complementary** | |
| | **Best fitting model (Cavalli, 1952)** | | | |
| M | 120.55** ± 0.29 | 118.95** ± 0.33 | 2.80** ± 0.15 | - |
| (d) | 1.10** ± 0.24 | -0.90** ± 0.28 | -0.06** ± 0.01 | - |
| (h) | 4.28** ± 1.10 | 5.41** ± 0.33 | 0.83** ± 0.25 | - |
| (i) | | - | 0.47** ± 0.15 | - |
| (j) | | - | | - |
| (l) | -5.23** ± 1.15 | -4.83** ± 1.12 | | - |
| $\chi2$ | 1.78 | 0.74 | 0.10 | - |

*** and** Significant at 5 and 1 per cent levels, respectively**

## CONCLUSION

It would be concluded from the present study that fruit yield and its component traits studied in two bottle gourd crosses were governed by additive, dominance, digenic, epistasis and digenic epistasis gene effects along with duplicate type of gene action. When additive as well as non-additive gene effects are involved, a breeding scheme efficient in exploiting both types of gene effects should be employed. Bi-parental mating could be followed which would facilitate exploitation of both additive and non-additive gene effects simultaneously for genetic improvement of fruit yield and its component traits in bottle gourd.

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