

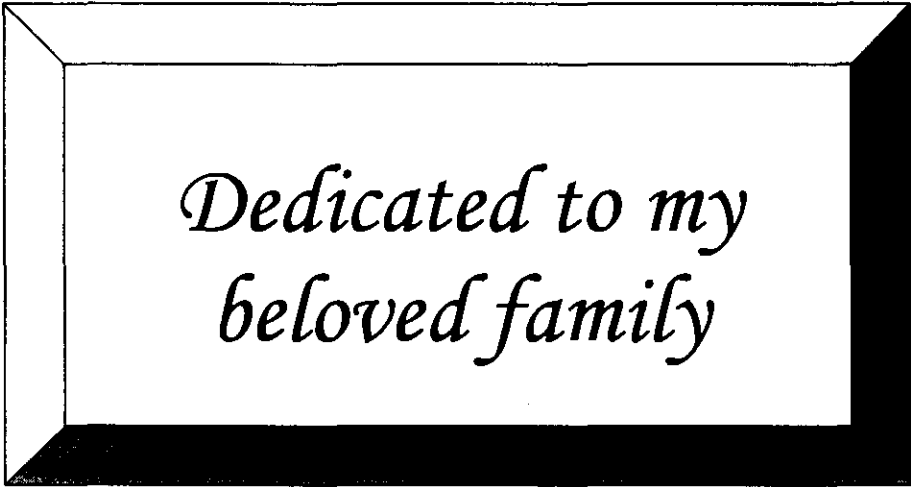
**GENETIC VARIABILITY, YIELD COMPONENTS,  
HETEROSIS AND GENE ACTION IN BOTTLE  
GOURD (*Lagenaria siceraria* (Molina) Standl.)**

*A  
Thesis  
Submitted to the  
Bidhan Chandra Krishi Viswavidyalaya  
in partial fulfillment of the requirements for the award of  
the Degree of Doctor of Philosophy (Horticulture)  
in  
VEGETABLE CROPS*

*By  
Babulal Mahato*



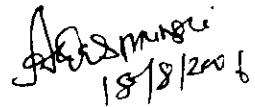
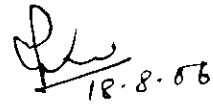
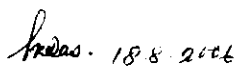
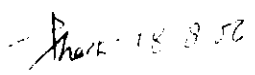
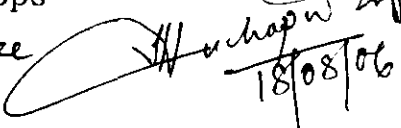
**DEPARTMENT OF VEGETABLE CROPS  
FACULTY OF HORTICULTURE  
BIDHAN CHANDRA KRISHI VISWAVIDYALAYA  
MOHANPUR, NADIA, WEST BENGAL,  
2006**



*Dedicated to my  
beloved family*

# APPROVAL OF EXAMINERS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (HORTICULTURE) IN VEGETABLE CROPS

We, the undersigned, having been satisfied with the performance of **Sri Babulal Mahato**, in the Viva Voce Examination, conducted today the 18<sup>th</sup> of August, 2006, recommend that the thesis be accepted for the award of the **Degree of Doctor of Philosophy (Horticulture) in Vegetable Crops**.

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### CERTIFICATE

This is to certify that the work recorded in the thesis, entitled “**Genetic Variability, Yield Components, Heterosis and Gene Action in Bottle gourd (*Lagenaria siceraria* (Molina) Standl.)**”, submitted by **Shri Babulal Mahato** in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy** (Horticulture) in Vegetable Crops of the Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal is the record of faithful and bonafide research work carried out by Shri Mahato under my direct supervision and guidance. The results of the investigation reported in this thesis have not so far been submitted for any other Degree or Diploma. The assistance and help received during the course of the investigation have been duly acknowledged.

.....  
(M. K. Pandit)

Chairman, Advisory Committee

---

## *Acknowledgement*

I feel pleasure to convey my deepest sense of incessant and humble gratitude to the Chairman of my Advisory Committee, Dr. M. K. Pandit, Reader, Department of Vegetable Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, for selecting the problems and unstinted help, liberal guidance, sustained interest, inexhaustible encouragement and invaluable suggestions throughout the course of investigation. His constant monitoring has made this thesis presentable. I will ever remain grateful to him.

I avail myself of this unique opportunity to express my earnest gratitude to Dr. P. Hazara, Professor, department of Vegetable Crops, for his valuable suggestions, unestimated guidance and incessant support. Although I am aware that these words are no means to measure his contribution and are really insufficient to word off a bit of debt, I have already incurred.

I reiterate my deepest gratitude to Dr. P. K. Das, Professor, Department of Genetics, Dr. P. S. Nath, Professor, Department of Plant Pathology for his valuable suggestion and help to carry out my work more accurately.

I convey my sense of gratefulness from the core of my heart to Dr. T. K. Maity, Professor and Head, Department of Vegetable Crops, Dr. P. Ghanti, Professor, Department of Vegetable Crops, Dr. Umesh Thapa, Reader, Department of Vegetable Crops, Dr. N. C. Paria, Prof. Department of Vegetable Crops, Dr. A. R. Mandal, Reader, Department of Vegetable Crops, Dr. A. Chattopadhyay, Dr. S.B. Chattopadhyay, Lecturer, Department of Vegetable Crops for their support and necessary helps during the course of work.

I am especially indebted to Prof. B. Ghosh, Department of Fruits and Orchard Management and Prof. B. Mandal, Department Agril. Chemistry and Soil Science for their invaluable help during the course of investigation.

I reiterate my deepest gratitude to Samsul, Subratada, Jayanta, Abhijit, Subhankarda, Prasanta, Dibyendu, Sukanta, Gobindada, Aravindada, Tarakda, Alokda, Kesuda, Manojda, Indranilda, Rahul, Nakulda, Subhra Saikat, Snehansu, Shyamu, Panda, Sayanda for their careful guidance, kind cooperation and constant help to complete my thesis work. I wish to express my sincere thanks to the other research workers in the area of my study. Their study, research papers and references helped me a lot in framing and conducting my dissertation.

Words and deeds are really insufficient to repay the unending love and constant inspiration to all my loving friends.

I am very much grateful to Shyamalda for composing and printing of this thesis neatly and grateful to Bishnupriya Copy Centre for binding and colour photography printing.

Devine blessing and taciturn sacrifices of my family have been the strength of my mind to struggle at each and every steps of this entire period.

**Place : Mohanpur**

**Dated : ...16th March..2006.**

*Babulal Mahato.*  
**(Babulal Mahato)**

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## **CHAPTER-1**

# **INTRODUCTION**

# INTRODUCTION

Importance of horticultural crops particularly vegetables in income and employment generation, their expanding role in country's food security strategy and in health benefits has well been documented. Vegetables are integral part of human diet because of their precious nutritional components viz., vitamins, minerals, antioxidants, roughage, a series of micronutrients indispensable for human health and some invaluable phytonutrients. Moreover, vegetable culture, both in developing and developed countries, can be undertaken in small farms with a high rate of human labour and very rapid and diversified rotations with significant returns. Though India is the second largest producer of vegetables in the world after China, per capita availability of vegetables (around 145g per day) is much less than the recommended consumption of 300 g per capita per day (ICMR), as per which manifold augmentation of both productivity and production of vegetable crops.

The vegetables belonging to the fascinatingly diverse family of Cucurbitaceae constitute the largest group of vegetables. There is tremendous genetic diversity with in the family and the range of adaptation for cucurbit species includes tropical and subtropical regions, arid deserts and temperate locations and now been adapted in high altitude areas. The family Cucurbitaceae consists of 117 genera and 825 species and there are approximately 30 species belonging to 9 genera of cucurbits that are used as cultivated plants. Among the different genera belonging to this family, four are of great economic importance: *Cucurbita*, *Cucumis*, *Citrullus* and *Lagenaria*. Bottle gourd or calabash gourd (*Lagenaria siceraria* (Molina.) Standl.) might be the only plant that was known to man in both the New and the Old world from very early prehistoric times ( Alacazer and Gullick, 1983; Zeven and Wet, 1982 and Vavilov, 1949). It is believed to have originated in tropical Africa. The genus

*Lagenaria* has long been considered as a monotypic genus, but Wills (1966) has listed 6 wild species under this genera.

Bottle gourd (*Lagenaria siceraria*) is cultivated widely throughout the tropics and subtropics of the world including India. Its prominent position among the vegetable crops in India is due to its widespread acceptance, high yield per unit area and extensive cultivation in tropical and subtropical parts of the country. The tender fruits of bottle gourd are used for vegetables and also for making sweets. The shell of matured and dry fruits is useful for making containers, floats for fishermen, utensils and musical instruments. In many parts of the country tender shoots with green leaves are used as potherbs. Bottle gourd is a rich source of minerals specially Ca, P, Fe and vitamins like ascorbic acid, thiamine, riboflavin and niacin. It is monoecious in sex form and solitary flowers are borne in axils. Female flowers are borne on small peduncles and can easily be recognized by the small bump at the base of the flower. It is cross-pollinated and entomophilous with the anthesis time from 5 to 8 p.m.

A wide range of variability is available particularly for different fruit characters, yield and maturity in this crop. In spite of its old history and wide range of variability available, comparatively little improvement work has been done in this crop particularly in West Bengal. The advantages of bottle gourd breeding lay on the absence of inbreeding depression. So, selfings can be done to develop uniform and improved lines from heterozygous and heterogeneous open pollinated cultivars. However, characterization of the genetic materials, estimation of variability, heritability and correlation studies among the polygenic characters are necessary to realize the genetic gain from such breeding method.

Bottle gourd, being monoecious, is a cross-pollinated crop, which provides ample scope for utilization of the hybrid vigour. A single fruit gives large number of seeds and the cost of production of  $F_1$  seeds is not high in comparison to other cucurbitaceous vegetables. In fact, bottle gourd hybrids have

gained high importance both in export and domestic markets. Hence, a speedy improvement in this crop can be brought about by assessing the genetic variability and exploitation for heterosis. Hybrids offer opportunities for improvement in production, earliness, uniformity, quality and resistance to pests and diseases. In heterosis breeding, plant breeder is often confronted with problems of choice of the parents. The analysis of combining ability helps to determine the feasibility of its utilization and identification of the best combiners. Knowledge of gene action for yield and its contributing characters are helpful to formulate an appropriate breeding strategy.

Keeping the importance of bottle gourd improvement ~~approaches~~ and availability of wide genetic diversity in West Bengal, the present investigation was outlined with the following objectives-

1. Assemblage, evaluation and characterization of bottle gourd germplasm as per documented descriptors.
2. Determination of genetic variability components for important growth and fruit characters influencing yield as well as interrelationship among the characters and their direct and indirect effects on fruit yield.
3. Development of group constellation and grouping of the genotypes through multivariate analysis.
4. Determination of the nature of gene action for yield and other important attributes with a view to identify good combiners, as well as to frame the breeding approach for the genetic improvement of such characters.
5. Determination of nature and magnitude of heterosis for fruit yield and its components.

## ***CHAPTER-II***

# **REVIEW OF LITERATURE**

## REVIEW OF LITERATURE

The bottle gourd or calabash gourd (*Lagenaria siceraria* (Molina) Standl.) is one of the important vegetables cultivated throughout the warmer regions of the world. The works so far done on genetic variability, combining ability, heterosis and gene action on different characters of bottle gourd are reviewed hereunder.

### 2.1. Genetic variability and its features in quantitative characters

All most all economic characters with which the plant breeder has to deal with are polygenic in inheritance i.e. quantitative characters which are governed by several genes; each gene has small but cumulative effect. These characters are considerably affected by the environment. Such characters show a continuous variation and it is not possible to classify them into distinct classes. If a large number of quantitative characters are plotted in a frequency distribution curve, often a bell-shaped normal curve would be obtained. Inheritance of quantitative characters cannot be studied through classical techniques of genetic analysis applied so successfully to the study of qualitative characters. Therefore, inheritance studies on quantitative characters have to employ statistical procedures. A special branch of <sup>statistics</sup> mathematics, biometry, has developed as a result of construction of special models and procedures to deal with the various aspects and problems of quantitative inheritance. Features of variability in quantitative characters may be outlined hereunder point wise.

1. This variability presumably results from subtle environmental differences within the experimental site.
2. The variability in the  $F_1$  population is comparable in magnitude to that with the two parental populations.
3. Individuals from various parts of the distribution curve of an  $F_2$  population should produce  $F_3$  progenies differing markedly in mean size.

4. Different  $F_2$  individuals should produce  $F_3$  progenies with different variability. The possible range of variability should extend from progenies as variable as the  $F_2$  to ones no more variable than the original parents.
5. Because homozygosity within families should increase with continued self-fertilization, a concomitant decrease in genetic variability is expected in each succeeding generation. It can be seen that the coefficient of variability for the  $F_2$  generation is higher than for any of the  $F_3$  families. In general, the coefficients of variability of  $F_4$  families are lower than those of  $F_3$  families, and a similar trend continues into the  $F_5$  generation.

Such reasoning and observations establish that Mendelian scheme is capable of explaining the inheritance of quantitative characters. This explanation for quantitative inheritance is called the *multiple-factor hypothesis*. The multiple-factor hypothesis views the genotypes for a given quantitative character as simply the sum of the effects of some definite number of gene differences, and do not visualize coordinated genetic systems of the type now regarded as basic to quantitative inheritance, which is one of the most important of all contributions to genetic thought.

## 2.2. Genetic variability and selection

Selection from the available variations is the oldest and most effective breeding procedure. The switch over from mass selection to progeny row breeding may be regarded as the first impact of the science of statistics in plant breeding. Since then, experimental procedure based on randomization and replication has been developed for testing progenies. This in turns has led to a change of emphasis on the part of plant breeders from purification and fixing of strains to the progressive improvement of their mean performance by exploitation of residual genetic variability through continued selection.

More precisely the amount of heritable variability and its genetic component has a close relation on its response to selection, Planning and execution of a breeding programme for the improvement of quantitative

characters depends, to a great extent in the magnitude of genetic variability existing in the germplasm. In practice the difference between qualitative and quantitative characters depends not so much on the magnitude of effect of individual gene as on the relative importance of heredity and environment in producing the final phenotype. It is therefore apparent that the key to progress in the analysis of quantitative characters lies in evaluating the relative contribution of these two casual agents to the variability.

### Concept of heritability

In a strict sense, the question of whether a character is hereditary or environmentally influenced has no meaning because genes cannot cause a character to develop unless they have the proper environment and conversely, no amount of manipulation of the environment will cause a characteristic to develop unless the necessary genes are present. It would therefore be useful to have a quantitative statement of the relative importance of heredity and environment in determining the expression of characters.

In order to develop such a qualitative statement, we must first have a clear idea of the effect of environment on variability and also a class of the effect of genes on variability.

When the genotype completely determine the phenotype, heritability is 100 per cent, If environment also contributes to the variability, the genotypes of the  $F_2$  can no longer represented by histograms but are more accurately portrayed by curves that means heritability now is less than 100%. Heritability, therefore, specifies the proportion of the total variability that is due to genetic causes, or the ratio of the genetic variance to the total variance, this can be expressed quantitatively.

$$H = \frac{\sigma^2 G}{\sigma^2 G + \sigma^2 E}$$

Where,  $\sigma^2 G$  = Genetic variance

$\sigma^2 E$  = Environmental variance

Estimation of heritability in advanced generation.

Too lengthy  
It should be  
strict and  
to the  
point

Heritability in broad sense ( $h^2$ ) in  $F_2$  generation.

$$h^2(F_2) = \frac{S^2(F_2) - \{S^2(P_1) + S^2(P_2) + 2S^2(F_1)\}/4}{S^2(F_2)}$$

Heritability in broad sense ( $h^2$ ) in  $F_3$  generation

$$h^2(F_3) = \frac{S^2(G)}{S^2(G) + S^2(E)/n} \quad \text{where, } S^2(G) = \frac{S^2(L) - S^2(E)}{n}$$

$S^2(L)$  = mean square of “ between  $F_3$  lines”

$S^2(E)$  = mean square of “within  $F_3$  lines”

$n$  = number of plants per line

### Factors affecting phenotypic expression

With Johansen's demonstration of the distinction between genotype and phenotype, and the proof by Nilsson-Ehle and East that quantitative characters were inherited according to Mendel's laws, it became clear that variation arises from the joint action of the genotype and environment. So the phenotypic expression of any particular character, denoted by  $A$ , can be represented as -

$$A = \mu + a + e + ae$$

Where,  $\mu$  = General population mean

$a$  = A genotypic effect

$e$  = An environmental effect

$ae$  = An interaction effect

In practice, these items are usually identified with years and locations. If the analysis is conducted in terms of different locations and different seasons the above equation can be expanded to

$$A = \mu + a + r + l + y + al + ay + ly + aly + e$$

where  $r$ ,  $l$  and  $y$  are the direct effects of replicates, locations and years, respectively, and  $e$  is a composite-error term of the remaining effects. Combinations of symbols indicate interaction between or among these main

factors. For example (al) represents the effect of interaction between a specific genotype and location.

### **Genetic advance under selection**

According to Comstock and Robinson (1952) the essential aspects of most breeding programmes are:

- 1) Selection within a base population of genetically variable individuals or families,
- 2) Utilization of the selected materials for the creation of new populations to be employed either as potential new commercial varieties or as the base for a new cycle of selection.

It is apparent from the two equations on phenotypic expression that genetic advance under selection (as represented by improvement in the genotypic value) in the new population as contrasted to the base population will depend on:

1. The amount of genetic variability, i.e. the magnitude of differences among different individuals (or families) in the base population, and
2. The magnitude of the masking effect of the environmental and interaction components of variability on the genetic variability, that is  $e$  and  $ae$  or  $l$ ,  $y$ ,  $al$  etc.

A third factor, the intensity of the selection will also influence the rate of genetic advance under selection.

Against this background, it is possible to calculate a mean yield ( $A$ ) for each line. If the values of a normally distributed with standard deviation  $\sigma A$ , the frequency distribution of the mean value can be represented by normal bell shaped curve.

It can be shown by the methods of the calculus that the expectation of genetic advance for the selected families is

$$G_s = (K) (\sigma A) (H)$$

Where,  $G_s$  represents the expectation of genetic advance under selection. It measures the difference between the mean genotypic values of the selected lines.  $\sigma_A$  is the phenotypic standard deviation of the mean yields of the original lines.

$H$  is the heritability coefficient, estimated as the ratio formed by dividing the genotypic variance by the phenotypic variance, thus

$$H = \frac{\sigma^2_a}{\sigma^2_A}$$

*Don't mix  
not the same*

$k$  is a selection differential which takes into account the mean phenotypic value of the  $q$  selected families ( $O_s$ ), the mean phenotypic value for all  $n$  families tested, the phenotypic standard deviation ( $\sigma^2_A$ ), and the stringency of the selection  $q/n$ . Since  $k$  is expressed in standard deviation units that is, in terms of a unit normal curve  $k$  does not vary except as the selection intensity,  $q/n$ , is varied. Thus if the highest yielding 1 per cent of the lines are saved,  $k$  can be shown to have the value of 2.64. Other likely selection intensities for plant materials are 2, 5, 10, 20 and 30 per cent of the lines saved, for which selection intensities  $k$  takes the values of 2.42, 2.06, 1.76, 1.40 and 1.16, respectively.

If the heritability is 100 per cent (i.e., if  $\sigma_A = \sigma_a$ ), the phenotype provides a perfect measure of the genotypic value. But even in this event the heritability value is an inadequate measure of the genetic progress that would result from selecting the highest-yielding lines, because the heritability could be 100 per cent when  $\sigma_a$  has a small value or a large value, whereas genetic progress is also expected to be larger with stringent than with moderate selection. Equation is therefore seen to evaluate, relative to one another, the three items that determine the rate of genetic advance expected under directional selection.

### **Genetic variability in bottle gourd**

It is well established that developing an effective plant breeding programme is dependant upon the existing genetic variability as efficiency of

selection largely depends on its magnitude present in the plant population. Research works on the genetic variability parameters like genotypic coefficient of variation, heritability and genetic advance for different characters of bottle gourd are here under reviewed.

**Components of variability for different characters of bottle gourd.**

| Character                           | Components of variability                                                   | Reference(s)                 |
|-------------------------------------|-----------------------------------------------------------------------------|------------------------------|
| Vine length                         | High heritability (76.4%) with high genetic advance                         | Sharma and Dhankhar (1989)   |
|                                     | High heritability (89.50%) with moderate genetic advance (34.73% of mean)   | Janakiram and Sirohi (1994)  |
|                                     | High GCV, PCV and Heritability (82.9%) and low genetic advance (2.82)       | Narayan <i>et.al.</i> (1996) |
| Days to first male flower opening   | High heritability (70.76%) with low genetic advance                         | Sharma <i>et. al.</i> (1983) |
|                                     | High heritability (90.60%) with low genetic advance (14.82)                 | Janakiram and Sirohi (1994)  |
|                                     | Low GCV, PCV with high heritability (75.6%) and low genetic advance (2.78). | Narayan <i>et.al.</i> (1996) |
| Days to first female flower opening | High heritability (93.47%) with high genetic advance                        | Sharma and Dhankhar (1989)   |
|                                     | High heritability (68.57%) with low genetic advance                         | Sharma <i>et. al.</i> (1983) |
|                                     | Low GCV, PCV with high heritability (74.7%) and low genetic advance (3.57). | Narayan <i>et.al.</i> (1996) |
| Fruit shape                         | Moderate heritability (0.36).                                               | Bisognin and Storck (2000)   |
| Fruit length                        | High heritability (99.80%) with very high genetic advance (136.72)          | Janakiram and Sirohi (1994)  |
|                                     | Low GCV, PCV coupled with high heritability (89.8%).                        | Narayan <i>et.al.</i> (1996) |
| Fruit width                         | High heritability (98.30%) with high genetic advance (47.79)                | Janakiram and Sirohi (1994)  |

|                         |                                                                                         |                                 |
|-------------------------|-----------------------------------------------------------------------------------------|---------------------------------|
| Fruits/ plant           | High heritability (71.85%) with high genetic advance                                    | Sharma and Dhankhar (1989)      |
|                         | Moderate heritability (36.15%) with high genetic advance (55.55)                        | Sharma <i>et. al.</i> (1983)    |
|                         | High heritability (88.40%) with moderate genetic advance (36.61)                        | Janakiram and Sirohi (1994)     |
|                         | Low GCV, PCV with high Heritability (82.9%)                                             | Narayan <i>et.al.</i> , (1996)  |
| Fruit weight            | Moderate heritability (37.50%) with low genetic advance (20.25)                         | Sharma <i>et. al.</i> (1983)    |
|                         | High heritability (94.60%) with high genetic advance (49.59)                            | Janakiram and Sirohi, (1994)    |
|                         | Low GCV, PCV with moderate heritability (38.5%) and low genetic advance (7.53% of mean) | Narayan <i>et.al.</i> , (1996)  |
| Fruit yield per plant   | High heritability coupled with high genetic advance                                     | Hawlader <i>et.al.</i> , (1999) |
|                         | High GCV, PCV and heritability                                                          | Narayan <i>et.al.</i> , (1996)  |
|                         | High heritability (92.20) coupled with high genetic advance (62.70)                     | Janakiram and Sirohi,(1994)     |
|                         | High heritability (75.46%) with high genetic advance                                    | Sharma and Dhankhar (1989)      |
|                         | Moderate heritability (39.37%) with high genetic advance (68.75)                        | Sharma <i>et. al.</i> (1983)    |
| No. of primary branches | High GCV, PCV and heritability                                                          | Narayan <i>et.al.</i> , (1996)  |
|                         | Moderate heritability (93.47%) with high genetic advance                                | Sharma and Dhankhar (1989)      |
| Sex ratio               | Very high heritability coupled with high genetic advance                                | Maurya and Singh (1994)         |

|                       |                                                                             |                              |
|-----------------------|-----------------------------------------------------------------------------|------------------------------|
| Days to first harvest | High heritability (98.90%) with moderate genetic advance (24.61)            | Janakiram and Sirohi (1994)  |
|                       | Low GCV, PCV with high heritability (75.4%) and low genetic advance (4.55). | Narayan <i>et.al.</i> (1996) |
| Ascorbic acid content | Low narrow sense heritability                                               | Sit and Sirohi (2000)        |

### 2.3 Character Association

It becomes necessary to estimate correlation (both genotypic and phenotypic) among various traits for selection to be effective among two or more characters taken simultaneously in a breeding programme. It is well known that selection on a particular trait draws correlated response in several other characters. Reports on associationships and direct effects of different characters with fruit yield have been reviewed and presented in the following table.

#### Associationships of different characters with fruit yield.

| Character                           | Character associationship       | Reference                                                                                                                               |
|-------------------------------------|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Vine length                         | Significant and positive        | Kumar and Singh (1998)<br>Prasad and Prasad (1978)<br>Narayan <i>et.al.</i> (1996)                                                      |
|                                     | <del>Strong</del> and positive  | Umamaheswarappa <i>et. al.</i> (2004)                                                                                                   |
|                                     | Negative                        | Kumar <i>et.al.</i> (1998), Badade <i>et.al</i> (2001)                                                                                  |
| Days to first male flower opening   | Significant and negative        | Badade <i>et.al</i> (2001), Kumar <i>et.al.</i> (1998), Kumar and Singh, (1998), Prasad and Prasad (1978), Narayan <i>et.al.</i> (1996) |
| Days to first female flower opening | Significant and negative        | Kumar and Singh, (1998), Badade <i>et. al.</i> (2001), Narayan <i>et .al.</i> (1996)                                                    |
| No. of primary branches             | Significant and positive        | Narayan <i>et. al.</i> (1996), Kumar and Singh (1998)                                                                                   |
| No. of fruits per plant             | Highly significant and positive | Kumar and Singh, (1998), Srivastava and Srivastava, (1976), Narayan <i>et.al.</i> (1996)                                                |

|                       |                          |                                                               |
|-----------------------|--------------------------|---------------------------------------------------------------|
| Average fruit weight  | Significant and positive | Narayan <i>et.al.</i> (1996)                                  |
| Fruit yield per plant | Significant and positive | Kumar and Singh, (1998),<br>Srivastava and Srivastava, (1976) |
| Days to first harvest | Direct and positive      | Narayan <i>et.al.</i> (1996),<br>Prasad and Prasad (1978)     |
|                       | Significant and negative | Kumar and Singh, 1998                                         |

## 2.4. Manifestation of heterosis for different characters

The phenomenon heterosis has been exploited commercially in developing  $F_1$  hybrids in bottle gourd. In bottle gourd heterosis is manifested in several economic traits, which ultimately influence in favourable direction. The review works in this regard <sup>are</sup> presented below showing extent and magnitude of heterosis for different characters.

### Heterosis in bottle gourd for different characters.

| Parental combinations and extent of heterosis                                                                                                                                                                                        | Reference                   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| $F_1$ hybrid Pusa Meghdoot (PSPL X SI-2) showed 16 per cent early yield and 75 per cent total increased yield than better parent PSPL.                                                                                               | Chaudhury and Singh, (1971) |
| $F_1$ hybrid Pusa Manjari (PSPRXSI-11) showed 36 per cent higher early yield than SI-11 and 106 per cent increased yield than better parent PSPL.                                                                                    | Chaudhury and Singh, (1971) |
| Among the 45 $F_1$ crosses of 10 parents, 3 best $F_1$ hybrids showed 84.5, 80 and 80 per cent heterosis (S46 X S54, S10 X S52-7 and S 54 X S52-7) over best parent S41 and S46 X S54 gave a 148.97 per cent higher yield than PSPL. | Janakiram and Sirohi (1989) |
| Crosses involving long and round fruited inbreds showed significant heterosis over the better parent for different characters of which S-36-1 $\times$ NC-59812-1 and S-39-1 $\times$ S-1-3 were the best hybrids.                   | Janakiram and Sirohi (1995) |

|                                                                                                                                                                                                                                            |                                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| Among 11 line X 3 tester crosses, the cross Summer Long Green Sel 2 X Faizabadi Long had highest heterosis over PSPL for number of fruits 106.63 per cent and total yield per plant by 110.33 per cent.                                    | Sharma <i>et. al.</i> , (1993) |
| In general bottle gourd shows 80 to 200 increased yield over parents.                                                                                                                                                                      | Peter (1998)                   |
| Highest heterobeltiosis for yield was recorded in cross PSPL x NDBG-1 (106.68%) followed by in the crosses L12 x T2 (27.07%) and L9 x T1 (20.68%).                                                                                         | Kumar <i>et al.</i> (1998)     |
| Combining ability analysis revealed high sca effect in the cross NDBG-1 x NDBG-20 for all the characters.                                                                                                                                  | Maurya and Singh (1998)        |
| Among 28 F <sub>1</sub> , 14 showed heterosis for early and other hybrids for late flowering and of these 22 hybrids gave better yield over better parent.                                                                                 | Singh <i>et.al.</i> (1998)     |
| Among the crosses between 13 lines with 3 testers, heterosis over the mid parent of the five best crosses for yield per plant ranged from 32.54 to 117.26 per cent while heterosis over the top parent varied from 1.68 to 13.80 per cent. | Kumar <i>et. al.</i> (1999)    |
| Among the crosses between 13 lines with 3 testers, heterobeltiosis for yield per plant ranged from -67.36 to 106.85 per cent, while standard heterosis varied from -56.02 to 27.07 per cent.                                               | Kumar <i>et. al.</i> (1999)    |
| From a 10 line x 2 tester crosses, PBOG-22 x Punjab Komal, PBOG-62 x Punjab Komal, PSPL x Punjab Komal and PBOG-62 x BGL2-1 emerged as the promising hybrids for fruit yield per plant.                                                    | Kumar <i>et. al.</i> (1999)    |
| From 10 line x 2 tester crosses, the 20 F <sub>1</sub> hybrids revealed significant heterosis for almost all the traits.                                                                                                                   | Kumar <i>et. at.</i> (1999)    |

|                                                                                                                                                                                                                                                                                                                   |                                |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| Combining ability analysis showed the highest sca effect in the cross ARBGH-7 × LC-2-1 for fruit yield per vine                                                                                                                                                                                                   | Singh <i>et. al.</i> (1999)    |
| The hybrids BL-1 X IC 92374, BL-1 X Pusa Naveen, and IC 92374 X PSPL were superior and exhibited significant economic heterosis for fruit yield per plant and yield components such as number of fruits and female flowers per plant. Most of the heterotic crosses were also heterobeltiotic.                    | Samadia and Khandelwala (2001) |
| In a study involving 45 F <sub>1</sub> crosses, maximum heterosis for yield and yield components over the top parent was recorded in the crosses PSPL × NDBG - 58, Pusa Naveen × NDBG 56 and PSPL × S <sub>8</sub> . Heterosis was also recorded for vitamin C, phosphorous, calcium and iron contents of fruits. | Sit and Sirohi (2002)          |
| High heterosis in terms of fruit diameter and length was recorded in BOG-68 × BOG-40 and NDBG-1 × BOG-13                                                                                                                                                                                                          | Kushwaha and Ram (2002)        |
| The best hybrids revealing significant sca effects for yield and some other related attributes were GH-10 × G2, GH-9 × PSPL and GH-13 × G2.                                                                                                                                                                       | Sharma <i>et al.</i> (2002)    |
| A combining ability analysis in 10 × 3 mating design showed significant sca effects in the crosses GH-10 × G-2, GH-9 × PSPL and GH-9 × G-2.                                                                                                                                                                       | Sharma <i>et. al.</i> (2002)   |
| Significant and positive heterosis over the better plant was observed for fruit yield per plant in the hybrid PBOG-22 × BGL-2-1. Heterosis for fruit yield per plant was due to heterosis the node number, first female flower, number of fruits per plant and fruit weight.                                      | Singh <i>et al</i> (2002)      |
| Highest standard heterosis for early fruit yield per plant was recorded in Pusa Naveen × PBOG-61 (59.9%) followed by in PBOG-40 × PBOG-91 (20.47%).                                                                                                                                                               | Maurya <i>et al</i> (2004)     |

|                                                                                                                                                                                                                                                                                                                                                                                                             |                              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| The cross Sel. 16 × PSPL showed significant heterosis over better parent and two standard varieties for number of primary branches/ plant and length of lateral shoot.                                                                                                                                                                                                                                      | Pandey <i>et. al.</i> (2003) |
| Significant positive sca effect for high early fruit yield per plant was recoeded in PBOG - 40 × PBOG -91, Pusa Naveen × PBOG-61, PBOG-84 × PBOG-54, DVBG -2 × PBOG-91, Punjab Kamal × PBOG-54 and PBOG-15 × PBOG-61.                                                                                                                                                                                       | Maurya <i>et al</i> (2004)   |
| The cross UR-2 × UR-4 revealed the highest sca effect and heterosis for fruit yield.                                                                                                                                                                                                                                                                                                                        | Dubey and Maurya (2004)      |
| Of the thirty F <sub>1</sub> hybrids of 10 line× 3 tester mating design, significant heterobeltiosis was recorded in Gh-9 × PSPL for days to first female flowering, GH-13× G-2 for days to first picking, fruit diameter and early yield, KBG-16 × G-2 for fruit length , G-22 × PSPL for average fruit weight, KBG-16 × Pusa Naveen for total yield per vine and GH-16 × Pusa Naveen for fruits per vine. | Sharma <i>et. al.</i> (2004) |
| 30 hybrids under line × tester analysis indicated manifestation of positive heterosis mostly for fruit characters and yield. The crosses IC-92362 × Pusa Naveen and IC- 92462 × Pusa Naveen exhibited high heterosis for yield and other yield components.                                                                                                                                                  | Pal <i>et. al</i> (2005)     |

## 2.5. Gene action for different characters

Knowledge about the gene action governing a trait is very much essential in a breeding programme so as to proceed with the right breeding technique. Since most of the characters in which heterosis is manifested are governed by polygenes, the study of inheritance of these characters is important in ascertaining the genetic basis of heterosis. Studies on gene action reveal the genetic mechanism and the inheritance of quantitative characters, particularly in

respect to gene actions including epistasis and additive gene effect, the order of dominance in the parents, degree of dominance, distribution of positive and negative alleles and their linkage and the estimation of general and specific combining ability of the parental lines involved.

#### Gene action for different characters in bottle gourd.

| Character                           | Nature of gene action                                   | Reference(s)                                                                                                                   |
|-------------------------------------|---------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Vine length                         | Dominance                                               | Singh <i>et.al.</i> , (2000).                                                                                                  |
|                                     | Additive                                                | Sharma <i>et.al.</i> , (1983), Sirohi <i>et.al.</i> , (1986), Sirohi <i>et.al.</i> , (1988).<br>Janakiram and Sirohi (1987)    |
|                                     | Non-additive                                            | Sharma <i>et.al.</i> , (1983), Sirohi <i>et.al.</i> , (1986), Sirohi <i>et. al.</i> , (1988),<br>Sharma <i>et. al.</i> , 2002. |
| Days to first male flower opening   | Over-dominance                                          | Janakiram and Sirohi (1987),<br>Janakiram and Sirohi (1995).                                                                   |
|                                     | Additive                                                | Sharma <i>et.al.</i> (1983), Maurya and Singh (1994)                                                                           |
| Days to first female flower opening | Dominance                                               | Sirohi <i>et. al.</i> (1988), Singh <i>et. al.</i> , (2000)                                                                    |
|                                     | Additive                                                | Maurya and Singh (1994), Sharma <i>et.al.</i> (1983).                                                                          |
|                                     | Non-additive                                            | Singh <i>et. al.</i> (2000)                                                                                                    |
| Sex ratio                           | Dominance                                               | Maurya and Singh (1994)                                                                                                        |
| Fruit colour                        | Monogenically inherited with green dominant over white. | Peter (1998)                                                                                                                   |
| Fruit shape                         | Monogenically inherited with long dominant over round.  | Peter (1998)                                                                                                                   |
| Number of fruits per vine           | Additive                                                | Singh <i>et.al.</i> (2000).                                                                                                    |
|                                     | Non-additive                                            | Sirohi <i>et.at.</i> (1988).                                                                                                   |
|                                     | Additive and non-additive                               | Sharma <i>et.al.</i> (1983), Sirohi <i>et.al.</i> (1986), Janakiram and Sirohi (1987).                                         |
| Fruit length                        | Non-additive                                            | Sirohi <i>et. Al.</i> (1988)                                                                                                   |
| Primary branches per vine           | Non-additive                                            | Sharma <i>et.al.</i> (2002)                                                                                                    |
| Fruit yield/plant                   | Non-additive                                            | Sirohi <i>et. al.</i> (1988)                                                                                                   |
| Ascorbic acid                       | Non-additive                                            | Sit and Sirohi (2002)                                                                                                          |

|                      |                           |                                                                                                                     |
|----------------------|---------------------------|---------------------------------------------------------------------------------------------------------------------|
| Day to first harvest | Additive                  | Singh <i>et.al.</i> (2000).                                                                                         |
|                      | Additive and non additive | Sharma <i>et.al.</i> (1983), Sirohi <i>et.al.</i> (1986), Sirohi <i>et.al.</i> (1988). Janakiram and Sirohi (1987). |
|                      | Dominance                 | Janakiram and Sirohi (1990), Janakiram and Sirohi (1991)                                                            |
| Fruit length         | Dominance                 | Janakiram and Sirohi (1991)                                                                                         |
|                      | Additive and non-additive | Kishwaha and Ram (1998)                                                                                             |
| Single fruit weight  | Additive                  | Singh <i>et.al.</i> , (2000).                                                                                       |
|                      | Non-additive              | Munshi and Sirohi (1994)<br>Khattra <i>et al.</i> (2004)<br>Mohanty (2001)<br>Mohanty and Prusti (2002)             |
|                      | Additive and non-additive | Sharma <i>et.al.</i> (1983), Sirohi <i>et.al.</i> (1986), Sirohi <i>et.al.</i> (1988). Janakiram and Sirohi (1987). |
| Fruit length         | Additive                  | Munshi and Sirohi (1994)                                                                                            |
|                      | Non-additive              | <del>Munshi and Sirohi (1994)</del> ?<br>Khattra (2004)                                                             |
| Fruit diameter       | Additive                  | Hormuzdi and More (1989)                                                                                            |
|                      | Non- additive             | Munshi and Sirohi (1994)<br>Khattra (2004)                                                                          |
| Flesh thickness      | Additive                  | Munshi and Sirohi (1994)                                                                                            |
|                      | <del>Non-additive</del>   | <del>Munshi (1991)</del><br><del>Munshi and Sirohi (1994)</del>                                                     |
|                      | Additive and non-additive | Sirohi and Ghorui (1992)<br>Mohanty (2001)                                                                          |
| 100 seed weight      | Additive and non-additive | Gopalakrishnan (1986)                                                                                               |
| Yield per vine       | Additive                  | Tasdighi and Baker (1981)<br>Pal <i>et al.</i> (1983)<br>Richard Kennedy (1994)<br>Kabilar (1999)                   |
|                      | Non-additive              | Sirohi <i>et al.</i> (1988)<br>Munshi and Sirohi (1994)<br>Khattra (2004)                                           |
|                      | Additive and non-additive | Sirohi and Ghorui (1992)<br>Mohanty (2001)                                                                          |

*CHAPTER-III*

# **MATERIALS AND METHODS**

## MATERIALS AND METHODS

Field experiments of the present investigation “Genetic variability, yield components, heterosis and gene action in bottle gourd (*Lagenaria siceraria* (Molina) Standl.)” were conducted during September 2002 to March, 2005.

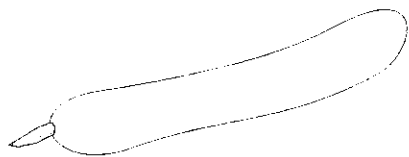
### 3.1 Experimental site

The field trials were carried out at the Central Research Farm, Gayeshpur, Bidhan Chandra Krishi Viswavidyalaya lying at 22°57' N latitude, 89° E longitude and with average altitude of 9.75 m above mean sea level during autumn-winter season. Topographic situation of the experimental site comes under Gangetic new alluvial plains of West Bengal. Estimation of proximate compositions of fruit was done in the vegetable breeding laboratory of the Department of Vegetable Crops. The meteorological data of the experimental site during the period of investigation have been presented in the Annexure I. The soil texture of the farm is fine loamy, slightly acidic and sandy loam. The characteristic features of the soil have been presented in the Annexure II.

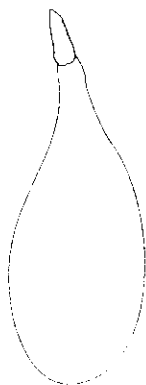
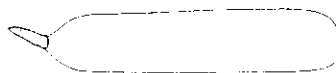
### 3.2. Assemblage of genotypes and determination of genetic variability

Bottle gourd is one of the most popular vegetables grown all over India including West Bengal on a commercial scale. In other states of India, bottle gourd is mostly cultivated as a summer crop whereas in West Bengal it is commercially cultivated as <sup>(7) winter</sup> both autumn-spring (sowing in September) and summer-rainy crop (sowing in March-April). Widely divergent genotypes comprising of 15 open pollinated cultivars were collected from major bottle gourd growing areas of Hoogly, 24-Parganas (N) and Birbhum under a research project “Exploration and utilization of biodiversity of some vegetable crops in West Bengal”. One year selfed progenies of these open pollinated cultivars have been utilized in the present investigation.

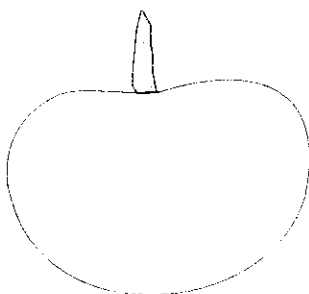
## FRUIT SHAPES IN BOTTLE GOURD



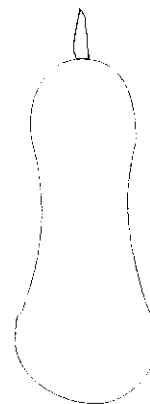
ELONGATE



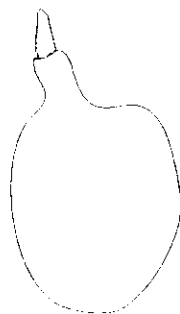
CLUB



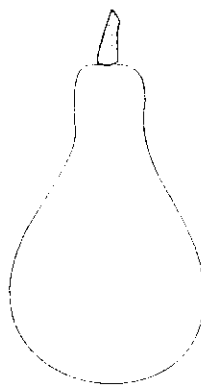
GLOBULAR



DUMBELL



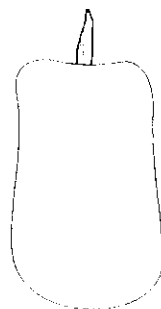
KAMANDAL



PYRIFORM



ELLIPTICAL  
or OVAL



OBLONG

**Table-1: Characteristic features of different bottle gourd genotypes used as experimental materials.**

| Genotypes | Place of Collection                        | Characteristic features                                | Geographical Location  |
|-----------|--------------------------------------------|--------------------------------------------------------|------------------------|
| BCBG-1    | Gadamara Market, Barasat, 24- Parganas (N) | Fruits greenish white and globular in shape.           | La-22°48'N, Lo-88°30'E |
| BCBG-3    | Suri Market, Birbhum                       | Fruits white and globular.                             | La-23°55'N, Lo-87°32'  |
| BCBG-4    | Suri Market, Birbhum                       | Fruits white and oval or elliptical.                   | La-23°55'N, Lo-87°32'  |
| BCBG-6    | Gadamara Market, Barasat, 24- Parganas (N) | Fruits patchy green and oblong.                        | La-22°48'N, Lo-88°30'E |
| BCBG-7    | Gadamara Market, Barasat, 24- Parganas (N) | Fruits white and pyriform.                             | La-22°48'N, Lo-88°30'E |
| BCBG-15   | Suri Market, Birbhum                       | Fruits white and pyriform.                             | La-23°55'N, Lo-87°32'  |
| BCBG-16   | Nilgang, Barrackpore, 24-Parganas (N)      | Fruits greenish white and oval or elliptical.          | La-22°40'N, Lo-88°26'E |
| BCBG-17   | Seoraphuli Market, Hoogly                  | Fruits patchy green and oval or elliptical.            | La-22°08'N, Lo-88°18'E |
| BCBG-19   | Nilgang, Barrackpore, 24- Parganas         | Fruits greenish in colour and kamandal in shape.       | La-22°40'N, Lo-88°26'E |
| BCBG-20   | Suri Market, Birbhum                       | Fruits white and oval or elliptical.                   | La-23°55'N, Lo-87°32'  |
| BCBG-22   | Seoraphuli Market, Hoogly                  | Fruits white and pyriform.                             | La-22°08'N, Lo-88°18'E |
| BCBG-33   | Seoraphuli Market, Hoogly                  | Fruits white and globular.                             | La-22°08'N, Lo-88°18'E |
| BCBG-34   | Seoraphuli Market, Hoogly                  | Fruits white and pyriform.                             | La-22°08'N, Lo-88°18'E |
| BCBG-38   | Gadamara Market, Barasat, 24- Parganas (N) | Fruits white and globular.                             | La-22°48'N, Lo-88°30'E |
| BCBG-40   | Gadamara Market, Barasat, 24- Parganas (N) | Fruits greenish white in colour and elongate in shape. | La-22°48'N, Lo-88°30'E |



**FIRST YEAR**

**SECOND YEAR**



**THIRD YEAR**

**PLATE 1. YEARWISE FIELD VIEW**

At the start of this investigation in 2002-03, 10 plants of each of the 15 genotypes were grown in the autumn-winter season. The selfed seeds of the genotypes were grown in the next year for further evaluation.

#### Details of the replicated field trial with the inbreds of bottle gourd

|                                    |                                               |
|------------------------------------|-----------------------------------------------|
| Design of the experiment           | : Randomized Block Design                     |
| Genotypes                          | : Inbreds                                     |
| Number of replication              | : 3                                           |
| Genotypes for variability analysis | : 15                                          |
| Number of plots                    | : 45                                          |
| Spacing                            | : 3mX1.5m                                     |
| Number of plant per mound          | : 1                                           |
| Number of plants per plot          | : 8                                           |
| Fertilizer application/ mound      | : Suphala @ 250g thrice + mustard cake @ 500g |
| System of irrigation               | : Furrow                                      |
| Date of sowing in three years      | : 30.09.2002; 25.09.2003; 23.09.2004          |

### 3.3. Crop husbandry

**Preparation of land:** The selected land of the experimental site was thoroughly prepared by repeated ploughings with power tiller followed by harrowing. The soil was then pulverized to make it loose and friable condition. All the weeds and stubbles were removed. The field was properly leveled and divided by the irrigation channels into several plots as per lay out.

**Fertilizer application:** Inorganic fertilizer (N, P, K) was applied to the all plots. Three doses of Suphala @ 250 g + Mustard cake @ 500 g/ mound were applied.

**Sowing:** Mixing of farmyard manure with the soil just at the top of the irrigation channel made the mounds in the plot. Seeds were sown in two rows of mounds in a plot, each spaced at 1.5 m and rows 3m apart.

**Irrigation:** Initial light irrigation after sowing ensured proper and uniform germination. Next irrigation at four-leaf stage of the seedlings and subsequently at 10-12 days interval met the water requirement satisfactorily.

**Weed control:** Initially power tiller in between the rows of crop controlled weeds, and later hand weedings were opted to control the weeds.

**Plant protection:** At 2-4 leaf stage, Metacide @ 1.5 ml / ~~lit~~<sup>sq m</sup> was sprayed two times to control the red pumpkin beetles. Later, Blitox @ 3 g/~~lit~~<sup>sq m</sup> was sprayed three times to control fruit rot disease.

**Harvesting:** Harvesting of fruits at tender stages was started from first week of December in both the years.

### 3.4. Observations recorded

Three plants per replication (plot) were selected for recording observations on qualitative characters and data on quantitative characters.

#### **Vine length**

The length of the vine was measured with a metre scale from the first cotyledonary node to the vine tip at the time of final harvest and expressed in metres.

#### **Number of primary branches**

Number of primary branches were counted at the final stage of the crop and expressed as number.

#### **Days to first female flower appearance**

The number of days taken for production of first female flower were counted from the date of sowing and expressed in number of days.

#### **Days to first male flower appearance**

The number of days taken for production of first male flower were counted from the date of sowing and expressed in number of days.

**Days to first harvest**

The number of days taken for the first harvest of the fruits at the optimum vegetable maturity stage at which the fruits are tender. They were counted from the date of sowing to the date of first harvest and expressed in number of days.

**Number of fruits per plant**

The number of fruits harvested per vine upto the final harvest were recorded from each genotype and expressed as number per plant.

**Average fruit weight (unit ?)**

The weight of single fruit was obtained by taking individual fruit weight per genotype per replication and the weight was expressed in kg at tender stage.

**Fruit length**

The length of the fruit at the optimum maturity stage was recorded from the fruit stalk to the tip and expressed in centimeters.

**Fruit width**

Fruits used for measuring the length were longitudinally cut into two halves and the width was measured at the broadest portion and the mean value was expressed in centimeters.

**Fruit yield per plant**

The fruits at vegetable maturity stage were harvested periodically and the cumulative weights were recorded upto the end of the crop. The total yield by weight for the individual plant was calculated and expressed in kilograms.

**Sex ratio**

Sex ratios were worked out at the full growth stage of the crop dividing total male flowers by total female flowers.

**Seed number per fruit**

Seeds were extracted from fully ripe and hard bottle gourd fruits and counted.

**100 seed weight**

Randomly selected 100 seeds from the ripe fruits per genotype per replication were accurately weighed in an electronic balance and expressed in grams.

**3.5. Laboratory analysis**

Proximate compositions of the composite pulp of the three sampled tender fruits per replication were estimated following standard methods (Sadasivam and Manickam, 1996; Rangana, 1990) in the laboratory of the Dept. of Vegetable crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya. Procedural details are given below.

**Total soluble solids of the pulp**

Individual fruit was crushed in a mortar with a pestle and the pulp was used to measure T.S.S. T.S.S. was determined by ERMA Hand Refractometer and recorded in °Brix.

**Total sugar content of the pulp**

Total sugar was determined following Lane and Eynon method.

**Materials required:** i) Fehling A ii) Fehling B iii) Methylene blue indicator iv) Concentrated HCL v) Concentrated NaOH solution.

**Procedure :** 10 g sample was taken, crushed with little amount of distilled water. It was taken in a beaker and 1 ml of concentrated HCl was added. Then it was boiled for few minutes. After cooling the mixture was neutralized with concentrated NaOH, which was judged by a small piece of litmus paper. The juice was strained and 100 ml volume make up was done using distilled water. Burette was filled with this solution. In a conical flask, 2 ml each of Fehling A and Fehling B was taken and 50 ml distilled water was added. It was heated to boil and 1 drop methylene blue was added to it. When hot, it was titrated against the juice till the end point came. End point was judged by brick red colour with reddish precipitation. The burette reading was recorded.

**Calculation :** % of total sugar in juice =  $\frac{20}{X}$  (where, X = burette reading)

**Ascorbic acid content of the pulp**

The ascorbic acid content of the fruits was estimated at their edible maturity stage by adopting the method as suggested by Ranganna (1990) and expressed as mg per 100 g. of edible portion in the following manner.

**Reagents**

- a) 3% of metaphosphoric acid ( $\text{HPO}_3$ ).
- b) Ascorbic Acid (standard).

100 mg of ascorbic acid was dissolved in 3% metaphosphoric acid and the volume was made upto 100 ml. 10 ml of this solution was then made upto 100 ml with 3% metaphosphoric acid (1 ml = 0.1 mg of ascorbic acid).

**Dye solution**

50 mg of sodium salt of 2-6 dichlorophenol indophenol was dissolved in approximately 150 ml of hot distilled water containing 42 mg of  $\text{NaHCO}_3$  solution; then cooled and diluted with distilled water upto 200 ml.

**Standardization of dye**

5 ml of standard ascorbic acid and 5 ml of metaphosphoric acid was taken into a beaker and titrated with dye solution to a faint pink colour, by factor ( i.e. mg of ascorbic acid per ml of dye) was determined by dye factor = 0.5/ litre.

**Preparation of sample**

A randomly chosen fruit at edible maturity stage was taken. It was peeled and cut into small pieces and made homogenized. 10g of fruit material was blended with 3% metaphosphoric acid and filtered. Volume of the filtrate was made upto 100 ml with 3% metaphosphoric acid.

**Assay of the extract**

10 ml of the metaphosphoric acid extract of the sample was titrated with the dye to a pink end point.

$$\text{mg of ascorbic acid per 100 g of fresh fruit} = \frac{\text{Titre} \times \text{dye factor} \times \text{volume made up to} \times 100}{\text{Aliquot of extract} \times \text{weight of sample taken for extraction}}$$

### 3.6. Heterosis and gene action for fruit yield and its components

**Materials:** Thirteen inbreds were selected on the basis of performance and diversity for important characters to raise thirty cross combinations in 10 x 3 line X tester mating design in 2<sup>nd</sup> year (2003 – 04).

|                                         |                                                                                                                                                                                                                                                                                       |
|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Lines used in mating design             | : (L <sub>1</sub> - BCBG-1), (L <sub>2</sub> -BCBG-4), (L <sub>3</sub> - BCBG-6), (L <sub>4</sub> - BCBG-7), (L <sub>5</sub> - BCBG-15), (L <sub>6</sub> - BCBG-16), (L <sub>7</sub> - BCBG-17), (L <sub>8</sub> - BCBG-22), (L <sub>9</sub> - BCBG-34), (L <sub>10</sub> - BCBG-38). |
| Tester used in mating design            | : (T <sub>1</sub> - BCBG-3), (T <sub>2</sub> - BCBG-20), (T <sub>3</sub> - BCBG-33).                                                                                                                                                                                                  |
| Commercial check for standard heterosis | : Warad (MGH-4) of Mahyco Vegetable Seeds Ltd.                                                                                                                                                                                                                                        |

#### Crossing technique:

**a) Protection of the male and female flowers:** A day prior to anthesis the female and male flowers in the intended male and female parents , respectively were covered by butter paper bags.

**b) Pollen collection:** The male flowers of the intended male parents, which have already opened within the bag, were collected next day between 11:30 AM to 1:30 PM. These male flowers were as such used for self-pollination.

**c) Self and cross pollination:** Cross pollination operations were completed within 1:30 PM. by gentle touching the pollen laden androecia of the male flowers to the sticky stigma head after removing the bag ~~did~~ self pollinations. Care was taken so that self-pollinations could be done as gently as possible



**MALE FLOWER BUD**



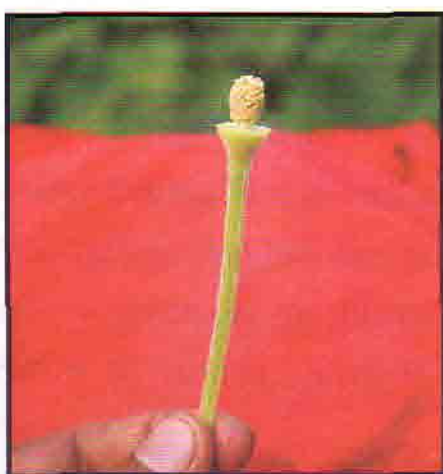
**FEMALE FLOWER BUD**



**BAGGING OF  
MALE FLOWER BUD**



**BAGGING OF  
FEMALE FLOWER BUD**



**MALE FLOWER BUD  
PREPARATION**



**HAND POLLINATION**

because of highly sensitive nature of the stigma of the female flower. Rebagging of the female flowers for one day was done to avoid the contamination of alien pollens. Paper tags in the peduncle of all self-pollinated female flowers identified the selfed fruits. Selfing of the parents were also done by sibmating. The seeds were thoroughly washed to remove the mucilaginous coating, dried and stored in paper covers after labeling.

### **Raising of the F<sub>1</sub>s, lines and testers**

Thirty hybrids, their thirteen parents along with the commercial hybrid, 'Warad' as check were grown with 3 replications in autumn-spring season of 2004-05. A inter row spacing of 3 m and intra row spacing of 1.5 m was adopted and the vines were trained to bower. Five seeds per pit were sown and finally one plant per pit was allowed to grow. Uniform standard recommended cultural practices and plant protection measures were followed to raise a successful crop.

The hybrids and their parents were evaluated for the eighteen characters as described earlier. Five plants per replication were randomly selected and the mean values of them were subjected to statistical analysis.

## **3.7. Statistical analysis**

### **Analysis of variance**

The data were subjected to the analysis of variance for randomized block design as suggested by Panse and Sukhatme (1978). Partitioning the total variance into that due to replications and treatments represents the expectations of the variance and the appropriate degrees of freedom in each case. Differences between genotypes for different characters were tested for significance using analysis of variance. Analysis of variance was done by using the following model

$$Y_{ij} = \mu + g_i + r_j + e_{ij}$$

Where  $Y_i$  = phenotypic observation in i-th genotype and j-th replication.

$\mu$  = general mean,  $g_i$  = effect of i-th genotype

$e_{ij}$  = random error effect associated with i-th genotype and j-th replication.

ANOVA TABLE

| Source       | d.f.         | M.S.   | Expected M.S.                               | F               |
|--------------|--------------|--------|---------------------------------------------|-----------------|
| Genotypes    | (t - 1)      | Mt 1.1 | $R^2e \text{ 1.1} + r\sigma^2g \text{ 1.1}$ | Mt 1.1 / Mc 1.1 |
| Replications | (r - 1)      | Mr 1.1 |                                             |                 |
| Error        | (r-1) (t -1) | Mc 1.1 | $\sigma^2e \text{ 1.1}$                     |                 |

Where t = number of genotypes, r = number of replications

Standard error (S.E.), standard error of difference between two means (S.Ed.) and critical difference (C.D.) were calculated by the following formula.

$$S.E. = (MS_e/r)^{1/2}$$

$$S.Ed. = (2 MS_e/r)^{1/2}$$

Where,  $MS_e$  = Error mean sum of square, r = number of replications.

And C.D. = S. Ed x t

(Distribution of t probability at error degrees of freedom)

Co-efficient of variance (CV %) was calculated as follows :

$$C.V. (\%) = \frac{MS_e}{\bar{X}} \times 100$$

Where  $MS_e$  = Environmental variance,  $\bar{X}$  = General mean for the character.

### Component of Variance

Considering that all the genotypes tested were uniform genetically, the expected mean sum of squares for error ( $MS_e$ ) will be partly a random environmental variance.

$$\text{i.e. Error variance} = \sigma_e^2 \text{ 1.1} = MS_e \text{ 1.1}$$

$$\text{So, Genotype variance} = \sigma_g^2 \text{ 1.1} = (Mt \text{ 1.1} - Me \text{ 1.1})/r$$

The phenotypic variance will consist of variation among genotypes and environmental variation among the individuals of each genotype.

$$\text{Phenotypic variance} = \sigma_p^2 \text{ 1.1} = (\sigma_g^2 \text{ 1.1} + \sigma_e^2 \text{ 1.1})$$

Where,  $M_t$  1.1 and  $M_e$  1.1 stand for mean sum of squares due to genotype and error respectively.

The genotype (G.C.V) and phenotypic (P.C.V) co-efficient of variation were calculated by the following formula given by Burton (1952).

$$G.C.V. = \frac{\text{Genotypic standard variation}}{\text{Grand mean}} \times 100$$

$$P.C.V. = \frac{\text{Phenotypic standard variation}}{\text{Grand mean}} \times 100$$

Heritability in broad sense (H) was estimated by the formula given by Hanson *et al.* (1956) –

$$H (\%) = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

The expected genetic advance (GA) was calculated by the formula as suggested by Johnson *et al.*, (1955) and Lush (1949).

$$GA = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times \kappa \times \sigma_p$$

$$= H \times \kappa \times \sigma_p$$

Where, H = Heritability in broad sense,

$\sigma_p$  = Phenotypic standard deviation,

$\kappa$  = Selection differential, a constant value is 2.06 for 5% selection intensity.

### Analysis of Co-variance

Co-variance components were estimated from co-variance analysis in an analogous manner to the variance components computed from the analysis of variance. The structure of co-variance table was as follows :

ANCOV Table

| Source       | d.f.          | M.P.   | Expected M.P.                 | F               |
|--------------|---------------|--------|-------------------------------|-----------------|
| Genotypes    | (t - 1)       | Mt 1.2 | $\sigma_e 1.2 + \sigma_g 1.2$ | Mt 1.2 / Mc 1.2 |
| Replications | (r - 1)       | Mr 1.2 |                               |                 |
| Error        | (T-1) (r - 1) | Me 1.2 | $\sigma_e 1.2$                |                 |

Where, t = number of genotypes,

r = number of replications.

Genotypic co-variance =  $\sigma_g 1.2 = (Mt 1.2 - Me 1.2)/r$

Phenotypic co-variance =  $\sigma_p 1.2 = (\sigma_g 1.2 + \sigma_e 1.2)$

Genetic correlation were computed from the genetic variance and co-variance by the following formula:

$$r(xy) = \frac{\text{Cov.}(xy)}{\sqrt{\text{Var.}(x) \times \text{Var.}(y)}}$$

Where, r (xy) is the correlation between characters x and y.

Cov. (xy) is the co-variance between x and y.

Var. (x) is the variance of x

Var. (y) is the variance of y

### Associationship Analysis

The association between hybrid and its component traits and among themselves was computed based on *per se* performance of parents and hybrids as genotypic and phenotypic correlation co-efficient (Goulden, 1952). For each trait, analysis of variance was computed and the mean square expectations from which the estimates of variance components obtained were given below (Al-Jibouri *et al.*, 1958).

### Genotypic correlation coefficient

$$r_g(xy) = \frac{\text{Cov.}(xy)}{\sqrt{\sigma^2_{g_x} \times \sigma^2_{g_y}}}$$

Where,

$r_g(xy)$  = Genotypic correlation coefficient between the traits x and y

$Cov\ g(xy)$  = Genotypic covariance between the traits 'x' and 'y'

$\sigma^2\ g_x$  = Genotypic variance of the trait - 'x'

$\sigma^2\ g_y$  = Genotypic variance of the trait 'y'

### Phenotypic correlation coefficient

$$r_p(x, y) = \frac{Cov. p(xy)}{\sqrt{\sigma^2 p_x \times \sigma^2 p_y}}$$

Where,

$r_p(xy)$  = Phenotypic correlation coefficient between the traits x and y

$Cov\ p(xy)$  = Phenotypic covariance between the traits 'x' and 'y'

$\sigma^2\ p_x$  = Phenotypic variance of the trait - 'x'

$\sigma^2\ p_y$  = Phenotypic variance of the trait 'y'

Significance of correlation was tested using 't' statistic at (n-2) degrees of freedom as given

$$t = \frac{R}{\sqrt{(1-r)^2}} \times \sqrt{(n-2)}$$

Where,

'r' is estimate obtained from 'n' pairs.

### Path coefficient analysis

Path coefficient analysis as suggested by Dewey and Lu (1959) was used to partition the genotypic correlation into components of direct and indirect effects. By keeping yield as dependent variable and other traits as independent variables, simultaneous equations, which express the basic relationship between

path co-efficients, were solved to estimate the direct and indirect effects. The simple correlation coefficients already estimated at genotypic level were utilized for this purpose.

#### **D<sup>2</sup> statistic (Mahalanobis, 1936)**

D<sup>2</sup> statistic was used for assessing the genetic divergence between populations. The generalized distance between any two populations was defined by –

$D^2 = (\lambda_{ij})^{-1} \delta_i \delta_j$  where,  $\lambda_{ij}$  was the reciprocal matrix to the common dispersion matrix and  $\delta_i$  was the difference between the mean values of the two populations for the  $i^{th}$  character. This quantity was estimated by the D<sup>2</sup> statistic (Majumder and Rao, 1958) as –

$D^2 = (S_{ij})^{-1} d_i d_j$  where,  $S_{ij}$  was the sample estimate of  $(\lambda_{ij})$  and  $d_i$  of  $\delta_i$ . Since the formula for computation required the inversion of the matrix, transformation of the original correlated, unstandardized character means to standardized uncorrelated variables was done to simplify the computational procedure. This transformation was effectuated by pivotal condensation method (Rao, 1952). The grouping of the populations was done by using Tocher's method as described by Rao, 1952. The criterion used in clustering by this method was that any two entries belonging to the same cluster should at least, on an average have shown a smaller D<sup>2</sup> value than those belonging to different clusters.

#### **Combining ability analysis**

Since significant differences were found among genotypes in ANOVA, the combining ability analysis was undertaken. The combining ability analysis was done using the line x tester method described by Kempthorne (1957). The data of all biometrical traits, which were subjected to analysis of variance, was also appropriate for L x T design.

The mean squares due to different sources of variation as well as their genetic expectations were estimated as follows.

### Analysis of variance of combining ability

| Source of variance        | df             | MS             | Expectation of mean squares                                                |
|---------------------------|----------------|----------------|----------------------------------------------------------------------------|
| Replication               | (r-1)          |                |                                                                            |
| Hybrids                   | (lt-1)         |                |                                                                            |
| Lines                     | (l-1)          | M <sub>1</sub> | $\sigma^2_e + r (\text{Cov F.S.} - 2 \text{Cov. H.S.}) + r$                |
| Testers                   | (t-1)          | M <sub>2</sub> | $\sigma^2_e + r (\text{Cov F.S.} - 2 \text{Cov H.S.}) + r l$<br>(Cov.H.S.) |
| Line x Tester interaction | (l-1) (t-1)    | M <sub>3</sub> | $\sigma^2_e + r (\text{Cov F.S.} - 2 \text{Cov.H.S.})$                     |
| Error                     | (r-1) (lt - 1) | M <sub>4</sub> | $\sigma^2_e$                                                               |
| Total                     | (ltr-1)        |                |                                                                            |

Where,

r = number of replications

l = number of lines

t = number of testers

The variance (mean squares) due to GCA and SCA are expressed in terms of covariance of full sibs (Cov. F.S.) and half sibs (Cov. H.S.).

From the genetic expectations of the mean squares, the covariance of full sibs (Cov. F.S.) and half sibs (Cov. H.S.) were estimated as follows:

$$\text{Cov. H.S.} = \frac{(M_1 - M_3) + (M_2 - M_3)}{r(l+t)}$$

$$\text{Cov. H.S.} = \frac{(M_1 - M_4) + (M_2 - M_4) + (M_3 - M_4)}{3r} - \frac{6r (\text{Cov.H.S.}) - r(l+t) \text{Cov. H.S.}}{3r}$$

From the covariance values, general and specific combining ability variances were computed as follows.

Variance due to general combining ability ( $\sigma^2 GCA$ ) = Cov H.S.

Variance due to specific combining ability ( $\sigma^2 SCA$ ) = Cov F.S. – 2 Cov H.S.

From the variance of GCA and SCA, the gene action was calculated as follows.

Additive genetic variance  $\frac{1}{4} \sigma^2 A = \sigma^2 GCA (F = 0)$

Non-additive genetic variance  $\sigma^2 D = \sigma^2 SCA (F = 0)$

Where, F = Inbreeding coefficient.

#### Estimation of combining ability effects

Both the *gca* and *sca* effect of an  $ijk^{\text{th}}$  observation was derived by using the mathematical model given below

$$X_{ijk} = \mu + \hat{g}_i + \hat{g}_j + \hat{s}_{ij} + \hat{l}_{ijk}$$

The general combining ability effect of parents and specific combining ability effect of hybrids were estimated as follows.

$$\mu = \frac{X_{...}}{rlt}$$

#### *gca* effects of lines

$$\text{gca effect of lines } (g_i) = \frac{X_{i..}}{rt} - \frac{X_{...}}{rlt}$$

#### *gca* effects of testers

$$\text{gca effect of testers } (g_j) = \frac{X_{.j.}}{rl} - \frac{X_{...}}{rlt}$$

**sca effects of hybrids**

$$sca \text{ effects of hybrid } (s_{ij}) = \frac{X_{ij.}}{r} - \frac{X_{i..}}{rt} - \frac{X_{.j.}}{rl} + \frac{X_{...}}{rlt}$$

Where,

$x_{...}$  = Total of hybrids over 'r' number of replication

$x_{i..}$  = Total of  $i^{th}$  line over 'l' testers and 'r' replications

$x_{.j.}$  = Total of  $j^{th}$  tester over 'l' lines and 'r' replications

$sx_{ij.}$  = Total of the hybrids between  $i^{th}$  line and  $j^{th}$  tester over 'r' replications.

**Test of significance of combining ability effects**

The standard error pertaining to *gca* effects of lines and testers and *sca* effects of different hybrids were calculated as follows

$$S.E. \text{ of } gca \text{ of lines} = \sqrt{\frac{EMS}{rt}}$$

$$S.E. \text{ of } gca \text{ of testers} = \sqrt{\frac{EMS}{rl}}$$

$$S.E. \text{ of } sca \text{ of hybrids} = \sqrt{\frac{EMS}{r}}$$

Where,

SE = Standard error

EMS = Error mean square

$$\text{Calculated } t = \frac{\text{Parameter}}{S.E.}$$

The calculated 't' value was compared with table 't' value at error degrees of freedom to test the significance.

### Estimation of heterosis

The mean values of hybrids were used for the calculation of heterosis. Magnitude of heterosis for all the hybrids was estimated over mid parent, better parent and standard parent as given below and all the three types of heterosis were expressed as percentage.

#### Relative heterosis ( $d_i$ )

The deviation of F1 over mid-parental value was estimated as follows.

$$d_i = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where,

$\overline{F_1}$  = Mean value of hybrid

$\overline{MP}$  = Value of mid parent

#### Heterobeltiosis ( $d_{ii}$ )

The deviation of F1 over better parent was estimated as follows :

$$d_{ii} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{BP}$  = Mean value of better parent

#### Standard heterosis ( $d_{iii}$ )

The deviation of F1 over the standard variety was estimated as follows

$$d_{iii} = \frac{\overline{F_1} - \overline{SP}}{\overline{SP}} \times 100$$

Where,

$\overline{SP}$  = Mean value of standard variety

### Test of significance for heterosis

Significance for heterosis was tested by using error mean square as suggested by Turner (1953).

$$t' \text{ for relative heterosis} = \frac{\overline{F_1} - \overline{MP}}{\sqrt{\frac{Me}{r} \times \frac{3}{2}}}$$

$$t' \text{ for heterobeltiosis} = \frac{\overline{F_1} - \overline{BP}}{\sqrt{\frac{Me}{r} \times 2}}$$

$$t' \text{ for standard heterosis} = \frac{\overline{F_1} - \overline{SP}}{\sqrt{\frac{Me}{r} \times 2}}$$

Where,

Me = Error variance

r = Number of replications

The calculated 't' value was compared with the table value of 't' at error degrees of freedom to assess the significance.

## ***CHAPTER-IV***

# **RESULTS AND DISCUSSION**

## RESULTS AND DISCUSSION

In the present investigation 15 inbred lines developed from assembled eco diversity of bottle gourd from different bottle gourd growing areas have been employed to study (a) Genetic variability for different morpho-physiological, fruit yield and fruit quality characters. (b) Character associationship and their effect on fruit yield/plant. (c) Genetic diversity of the inbred lines by multivariate analysis and (d) Gene action for fruit yield, yield components and fruit quality characters through line  $\times$  tester analysis. The results are presented and discussed below.

### 4.1. Genetic variability

**Mean performance:** Mean of the 16 different characters of the inbreds recorded in two consecutive years along with the pooled data have been presented in the Table-2. The data for different characters viz. vine length, days to first male and female flower opening, fruit length, fruit width, average fruit weight, number of seeds/fruit, 100 seed weight and ascorbic acid content showed quite a high range of variation among the inbreds, in both the years, showing the suitability of the genotypes for ~~carrying out~~<sup>conducting</sup> the study of genetic variability for these characters. However, not much variation could be recorded among the genotypes for other characters namely number of primary branches/plant, number of fruits/plant, days to first harvest, sex ratio, fruit yield/plant and total sugar and total soluble solid content of the fruits indicating comparatively lesser weightage of these characters for such genetic variability study.

**Measures of variation:** Variation in the characters can arise from both genotypic (i.e. real heritable difference) and environmental factors (non heritable factors). All the statistical calculations related to genetic variability parameters were based on pooled data for all the sixteen characters. However, the measures of variations of inbreds and replications were done in both the years and were also pooled, separately.

**Table-2: Mean performances of different genotypes for fruit yield and other traits**

| Geno-<br>types | Vine Length (m)      |                      |        | No. of primary branches |                      |        | Days to 1 <sup>st</sup> male flower opening |                      |        | Days to 1 <sup>st</sup> female flower opening |                      |        |
|----------------|----------------------|----------------------|--------|-------------------------|----------------------|--------|---------------------------------------------|----------------------|--------|-----------------------------------------------|----------------------|--------|
|                | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled | 1 <sup>st</sup> year    | 2 <sup>nd</sup> year | Pooled | 1 <sup>st</sup> year                        | 2 <sup>nd</sup> year | Pooled | 1 <sup>st</sup> year                          | 2 <sup>nd</sup> year | Pooled |
| BCBG-1         | 4.63                 | 4.58                 | 4.60   | 12.73                   | 12.65                | 12.70  | 53.33                                       | 55.33                | 54.33  | 62.33                                         | 61.33                | 61.83  |
| BCBG-3         | 5.43                 | 5.40                 | 5.41   | 12.67                   | 12.53                | 12.60  | 54.67                                       | 53.67                | 54.17  | 61.33                                         | 59.67                | 60.50  |
| BCBG-4         | 5.20                 | 5.10                 | 5.15   | 11.87                   | 11.80                | 11.83  | 56.67                                       | 55.67                | 66.17  | 62.00                                         | 61.00                | 61.50  |
| BCBG-6         | 5.18                 | 5.28                 | 5.23   | 12.07                   | 11.93                | 12.00  | 50.00                                       | 49.33                | 49.67* | 54.00*                                        | 53.00*               | 53.50* |
| BCBG-7         | 5.91                 | 5.85                 | 5.88   | 12.00                   | 11.80                | 11.90  | 53.33                                       | 52.00                | 52.67  | 60.33                                         | 58.33                | 59.33  |
| BCBG-15        | 4.92                 | 4.79                 | 4.85   | 12.27                   | 12.47                | 12.30  | 53.00                                       | 51.67                | 52.33  | 59.00                                         | 58.00                | 58.50  |
| BCBG-16        | 5.60                 | 5.50                 | 5.55   | 12.87                   | 13.07                | 12.97  | 51.33                                       | 50.33                | 50.83  | 57.33                                         | 56.33                | 56.80  |
| BCBG-17        | 7.37*                | 7.25*                | 7.31*  | 14.07                   | 13.69                | 13.87* | 45.33*                                      | 44.33*               | 44.83* | 52.00*                                        | 50.33*               | 51.17* |
| BCBG-19        | 6.26                 | 6.19                 | 6.22   | 11.53                   | 11.29                | 11.40  | 55.33                                       | 54.33                | 54.83  | 60.67                                         | 59.00                | 59.83  |
| BCBG-20        | 6.49                 | 6.42                 | 6.46   | 14.80*                  | 14.67*               | 14.73* | 52.67                                       | 52.67                | 52.67  | 58.67                                         | 57.33                | 58.00  |
| BCBG-22        | 6.76*                | 6.78*                | 6.77*  | 15.80*                  | 15.55*               | 15.23* | 50.67                                       | 49.33                | 50.00  | 56.67                                         | 55.33                | 56.00* |
| BCBG-33        | 7.44*                | 7.39*                | 7.41*  | 12.53                   | 12.00                | 12.17  | 52.33                                       | 41.33*               | 51.83  | 58.33                                         | 57.33                | 57.83  |
| BCBG-34        | 6.89*                | 6.81*                | 6.85*  | 15.87*                  | 16.40*               | 16.13* | 50.67                                       | 51.67                | 51.17  | 56.33                                         | 57.67                | 57.00  |
| BCBG-38        | 6.80*                | 7.00*                | 6.90*  | 12.13                   | 12.00                | 12.07  | 52.00                                       | 50.67                | 51.33  | 56.33                                         | 55.67                | 56.00* |
| BCBG- 40       | 6.87*                | 6.80*                | 6.84*  | 14.60*                  | 14.33*               | 14.47* | 53.00                                       | 51.33                | 52.17  | 56.33                                         | 54.67*               | 55.50* |
| Mean           | 6.11                 | 6.08                 | 6.09   | 13.12                   | 13.06                | 13.09  | 52.28                                       | 51.57                | 51.90  | 58.11                                         | 57.00                | 57.55  |
| C.D. at 5%     | 0.68                 | 0.66                 | 0.47   | 0.99                    | 0.84                 | 0.64   | 3.26                                        | 2.68                 | 2.07   | 2.72                                          | 1.78                 | 1.53   |

**Table-2 (Contd.)**

| Geno-<br>types | Fruit length (cm)    |                      |        | Fruit width (cm)     |                      |        | Average fruit weight (kg) |                      |        | No. of fruits/plant  |                      |        |
|----------------|----------------------|----------------------|--------|----------------------|----------------------|--------|---------------------------|----------------------|--------|----------------------|----------------------|--------|
|                | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled | 1 <sup>st</sup> year      | 2 <sup>nd</sup> year | Pooled | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled |
| BCBG-1         | 14.17                | 14.71                | 14.41  | 10.57                | 11.44                | 10.95  | 1.90                      | 1.84                 | 1.87   | 4.80                 | 4.67                 | 4.73*  |
| BCBG-3         | 19.13                | 18.81                | 18.91  | 15.46                | 16.71                | 16.08  | 1.65                      | 1.77                 | 1.71   | 4.67                 | 4.53                 | 4.60   |
| BCBG-4         | 18.53                | 17.62                | 18.07  | 12.89                | 14.01                | 13.45  | 1.71                      | 1.62                 | 1.68   | 4.27                 | 4.40                 | 4.33   |
| BCBG-6         | 27.23                | 26.01                | 26.73* | 11.20                | 16.60                | 13.90  | 1.91                      | 1.78*                | 1.87   | 4.67                 | 4.53                 | 4.60   |
| BCBG-7         | 29.37*               | 29.33*               | 29.33* | 16.99                | 18.89*               | 17.79  | 2.49*                     | 2.30                 | 2.43*  | 4.13                 | 3.93                 | 4.03   |
| BCBG-15        | 23.87                | 24.78                | 24.32  | 16.00                | 17.54                | 16.73  | 2.06                      | 2.03                 | 2.01   | 4.20                 | 4.47                 | 4.33   |
| BCBG-16        | 26.75                | 26.13                | 26.25* | 18.23                | 16.51                | 17.36  | 1.97                      | 1.91                 | 1.95   | 4.20                 | 4.40                 | 4.30   |
| BCBG-17        | 32.00*               | 30.62*               | 31.33* | 21.36*               | 19.60*               | 20.65* | 2.55*                     | 2.48*                | 2.54*  | 4.47                 | 4.27                 | 4.37   |
| BCBG-19        | 30.00*               | 32.40*               | 31.10* | 20.22*               | 18.93*               | 19.59* | 2.27                      | 2.12                 | 2.18*  | 4.60                 | 4.47                 | 4.53   |
| BCBG-20        | 20.11                | 19.09                | 19.52  | 13.86                | 15.42                | 14.56  | 1.82                      | 2.02                 | 1.87   | 4.73                 | 4.60                 | 4.67*  |
| BCBG-22        | 29.47*               | 28.32*               | 28.82* | 20.65*               | 18.17*               | 19.38* | 1.82                      | 1.75                 | 1.78   | 5.33*                | 5.47*                | 5.40*  |
| BCBG-33        | 28.68*               | 27.64*               | 28.26* | 20.63*               | 19.73*               | 20.10  | 2.78*                     | 2.64*                | 2.71*  | 4.00                 | 3.73                 | 3.87   |
| BCBG-34        | 30.11*               | 28.77*               | 29.44* | 16.95                | 15.38                | 16.10  | 2.59*                     | 2.48*                | 2.53*  | 3.53                 | 3.73                 | 3.63   |
| BCBG-38        | 26.40                | 25.96                | 26.16  | 18.30                | 19.89*               | 19.07* | 2.43*                     | 2.29                 | 2.34*  | 4.13                 | 3.93                 | 4.03   |
| BCBG- 40       | 23.86                | 22.71                | 23.22  | 18.27                | 17.02                | 17.65  | 1.85                      | 1.98                 | 1.92   | 5.40*                | 5.20*                | 5.30*  |
| Mean           | 25.31                | 24.86                | 25.05  | 16.77                | 17.05                | 16.88  | 2.12                      | 2.06                 | 2.09   | 4.47                 | 4.42                 | 4.44   |
| C.D. at 5%     | 2.15                 | 1.42                 | 1.14   | 2.65                 | 0.95                 | 1.33   | 0.17                      | 0.29                 | 0.09   | 0.36                 | 0.28                 | 0.22   |

Table-2 (Contd.)

| Geno-<br>types | Days to 1 <sup>st</sup> harvest |                      |        | Sex ratio            |                      |         | No. of seeds/fruit   |                      |         | 100 seed weight (g)  |                      |        |
|----------------|---------------------------------|----------------------|--------|----------------------|----------------------|---------|----------------------|----------------------|---------|----------------------|----------------------|--------|
|                | 1 <sup>st</sup> year            | 2 <sup>nd</sup> year | Pooled | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled  | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled  | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled |
| BCBG-1         | 76.00                           | 77.73                | 76.87  | 7.94:1               | 7.43:1               | 7.69:1  | 378.67               | 373.80               | 376.23  | 14.53                | 14.36                | 14.45  |
| BCBG-3         | 75.00                           | 76.07                | 75.53  | 8.78:1               | 8.42:1               | 8.63:1  | 422.00               | 417.67               | 419.83  | 15.92                | 15.75                | 15.83  |
| BCBG-4         | 69.67*                          | 70.87                | 70.27  | 12.93:1              | 11.23:1              | 12.20:1 | 420.47               | 416.50               | 418.48  | 14.99                | 14.86                | 14.92  |
| BCBG-6         | 70.33                           | 68.73*               | 69.53* | 9.00:1               | 8.56:1               | 8.75:1  | 452.00               | 448.40               | 450.20  | 15.88                | 15.71                | 15.79  |
| BCBG-7         | 74.67                           | 73.93                | 74.30  | 7.35:1               | 6.65:1*              | 6.94:1  | 557.23*              | 554.60*              | 555.92  | 16.45                | 15.40                | 16.43  |
| BCBG-15        | 75.33                           | 74.00                | 74.67  | 8.98:1               | 8.50:1               | 8.78:1  | 436.00               | 435.67               | 435.83  | 16.47                | 15.36                | 16.42  |
| BCBG-16        | 71.00                           | 71.93                | 71.47  | 7.73:1               | 7.55:1               | 7.67:1  | 423.83               | 418.40               | 421.12  | 16.60                | 16.46                | 16.53  |
| BCBG-17        | 70.00                           | 70.73                | 70.37  | 6.77:1*              | 6.33:1*              | 6.52:1* | 657.87*              | 673.60*              | 665.73* | 19.76*               | 19.55*               | 19.66* |
| BCBG-19        | 76.67                           | 74.27                | 75.47  | 8.28:1               | 7.42:1               | 7.85:1  | 496.10               | 488.30               | 492.20  | 18.64*               | 18.50*               | 18.57* |
| BCBG-20        | 74.00                           | 72.33                | 73.17  | 8.93:1               | 8.46:1               | 8.69:1  | 545.20*              | 538.43*              | 541.82  | 18.56                | 18.56*               | 18.56* |
| BCBG-22        | 71.67                           | 70.47                | 71.07  | 6.85:1*              | 6.69:1*              | 6.73:1* | 488.13               | 483.53               | 485.83  | 18.86*               | 18.82*               | 18.84* |
| BCBG-33        | 74.00                           | 72.00                | 73.00  | 6.59:1*              | 6.11:1*              | 6.35:1* | 597.80*              | 594.33*              | 596.07  | 17.85                | 17.79                | 17.82  |
| BCBG-34        | 73.67                           | 72.67                | 73.17  | 7.89:1               | 7.55:1               | 7.70:1  | 523.93               | 516.53*              | 520.23  | 21.43*               | 21.55*               | 21.49* |
| BCBG-38        | 74.33                           | 71.33                | 72.83  | 8.51:1               | 7.58:1               | 8.05:1  | 479.07               | 441.13               | 460.10  | 19.48*               | 19.38*               | 19.43* |
| BCBG- 40       | 71.67                           | 69.87                | 70.77  | 7.10:1*              | 6.37:1*              | 6.67:1* | 515.53               | 510.30               | 512.92  | 18.69*               | 18.51*               | 18.60* |
| Mean           | 73.20                           | 72.46                | 72.83  | 8.28:1               | 7.65:1               | 7.94:1  | 492.92               | 487.41               | 590.16  | 17.60                | 17.50                | 17.55  |
| C.D. at 5%     | 3.45                            | 2.87                 | 2.20   | 0.63                 | 0.76                 | 0.41    | 37.66                | 24.15                | 21.95   | 0.82                 | 0.84                 | 0.58   |

Table-2 (Contd.)

| Geno-<br>types | Ascorbic acid (mg)   |                      |        | TSS (°Brix)          |                      |        | Total sugar (%)      |                      |        | Fruit yield/plant    |                      |        |
|----------------|----------------------|----------------------|--------|----------------------|----------------------|--------|----------------------|----------------------|--------|----------------------|----------------------|--------|
|                | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled | 1 <sup>st</sup> year | 2 <sup>nd</sup> year | Pooled |
| BCBG-1         | 6.82                 | 6.76*                | 6.79*  | 3.20                 | 3.35*                | 3.27*  | 1.78                 | 1.62                 | 1.70   | 9.12                 | 8.57                 | 8.85   |
| BCBG-3         | 6.49                 | 6.52                 | 6.51   | 3.80*                | 3.67*                | 3.73*  | 2.31                 | 2.10                 | 2.21*  | 7.71                 | 8.05                 | 7.90   |
| BCBG-4         | 6.75                 | 6.62                 | 6.69*  | 3.07                 | 3.27*                | 3.17   | 1.88                 | 1.75                 | 1.82   | 7.29                 | 7.45                 | 7.36   |
| BCBG-6         | 5.04                 | 4.96                 | 5.00   | 2.47                 | 2.73                 | 2.60   | 2.02                 | 1.69                 | 1.85   | 8.90                 | 8.52                 | 8.70   |
| BCBG-7         | 7.85*                | 7.70*                | 7.78*  | 2.93                 | 2.83                 | 2.88   | 2.38*                | 2.33*                | 2.36*  | 10.30*               | 9.43                 | 9.86*  |
| BCBG-15        | 7.19*                | 7.01*                | 7.10*  | 2.73                 | 2.67                 | 2.70   | 1.65                 | 1.84                 | 1.74   | 8.65                 | 8.79                 | 8.72   |
| BCBG-16        | 4.21                 | 4.01                 | 4.11   | 3.67*                | 3.43*                | 3.55*  | 2.12                 | 1.81                 | 1.95   | 8.28                 | 8.47                 | 8.39   |
| BCBG-17        | 7.66*                | 7.38*                | 7.52*  | 2.53                 | 2.43                 | 2.48   | 1.95                 | 2.14                 | 2.04   | 11.37*               | 10.97*               | 11.16* |
| BCBG-19        | 5.28                 | 5.13                 | 5.21   | 3.53*                | 3.27*                | 3.40*  | 2.07                 | 2.19                 | 2.13   | 10.46*               | 9.22                 | 9.83*  |
| BCBG-20        | 7.89*                | 7.71*                | 7.80*  | 2.67                 | 2.60                 | 2.63   | 1.58                 | 1.50                 | 1.54   | 8.59                 | 8.82                 | 8.74   |
| BCBG-22        | 5.45                 | 5.29                 | 5.35   | 3.47*                | 3.27*                | 3.37*  | 2.25                 | 2.10                 | 2.17*  | 9.70                 | 9.43                 | 9.58   |
| BCBG-33        | 6.64                 | 6.42                 | 6.53   | 2.60                 | 2.43                 | 2.52   | 2.04                 | 2.24*                | 2.14   | 11.10*               | 10.12*               | 10.53* |
| BCBG-34        | 8.36*                | 8.10*                | 8.23*  | 2.67                 | 2.40                 | 2.53   | 2.02                 | 2.00                 | 2.01   | 9.14                 | 9.40                 | 9.28   |
| BCBG-38        | 5.06                 | 4.84                 | 4.95   | 3.33                 | 3.26*                | 3.30*  | 2.08                 | 1.94                 | 2.01   | 10.03                | 8.97                 | 9.50   |
| BCBG- 40       | 5.60                 | 5.44                 | 5.52   | 3.00                 | 2.73                 | 2.87   | 1.76                 | 1.60                 | 1.68   | 9.99                 | 10.22*               | 10.13* |
| Mean           | 6.42                 | 6.26                 | 6.34   | 3.04                 | 2.95                 | 2.99   | 1.99                 | 1.92                 | 1.95   | 9.37                 | 9.09                 | 9.23   |
| C.D. at 5%     | 0.41                 | 0.41                 | 0.29   | 0.36                 | 0.22                 | 0.21   | 0.33                 | 0.27                 | 0.21   | 0.88                 | 0.58                 | 0.44   |



**BCBG-3**



**BCBG-1**



**BCBG-7**



**WARAD**



**BCBG-19**



**BCBG-40**

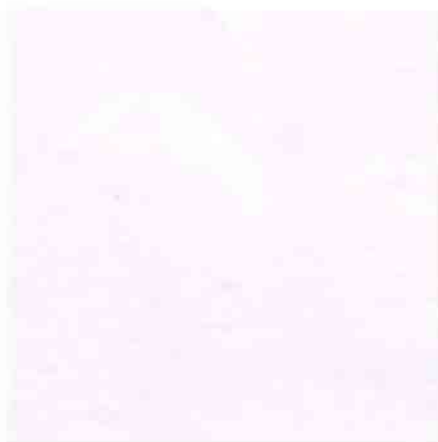
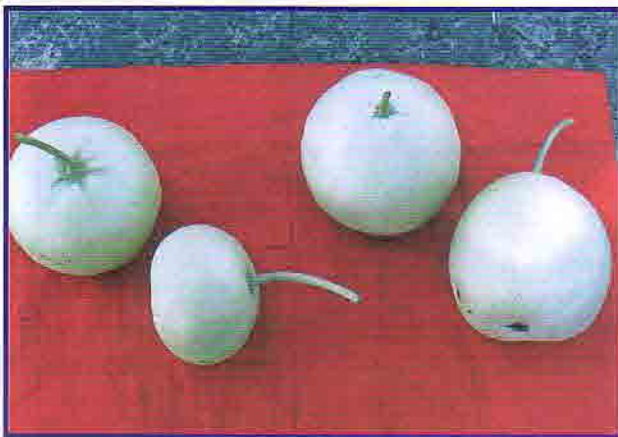
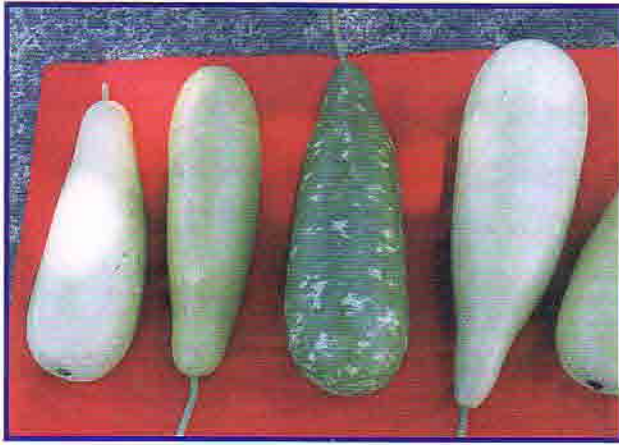
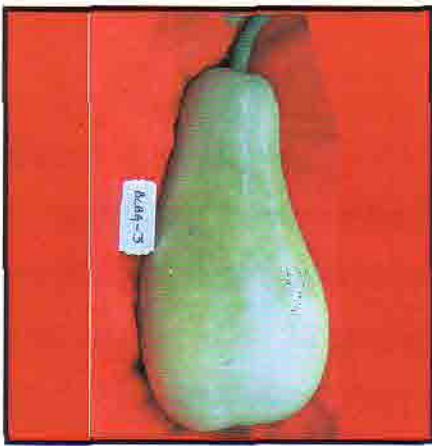


**PLATE 4. DIVERSITY IN FRUIT SHAPE OF PARENTAL LINES**



Please write the name of the genotype

PLATE 5. DIVERSITY IN FRUIT SHAPE OF PARENTAL LINES

**Variance:**

Analysis of variance for <sup>sixteen</sup> ~~16~~ characters has been computed separately for <sup>two</sup> ~~2~~ years along with the pooled data. Mean sum of squares, presented in Table-3 clearly suggested significant differences in the inbred lines for vine length, primary branches/plant, days to first male and female flower opening, fruit length, fruit width, days to first harvest, seeds/fruit, 100 seed weight, fruit yield/plant, sex ratio and ascorbic acid content of fruit even at 1% level of significance in both the years and also in pooled data, which clearly endorse the justification of studying genetic variability of these characters employing these genotypes. However, non-significant<sup>t</sup> difference for two important yield components namely, fruit number/plant and fruit weight among the inbred lines suggested the need of widening the present genetic base of bottle gourd for studying genetic variability of these characters. In this context, collection of genotypes across different geographical locations of the country is needed to develop wide germplasm pool of bottle gourd.

**Range of characters:** The range, which apparently indicates the phenotypic variation, was moderately high for different characters. However, it was markedly high for vine length (4.60-7.31 m), fruit length (14.42-31.33 cm), fruit width (10.95-20.65 cm), seeds/fruit (376.23-665.73), 100 seed weight (14.42-21.49 g) and ascorbic acid content of fruit (4.11-8.23 mg/100 g fresh). Wide range of ascorbic acid content of the fruit pulp in the genotypes indicated the worth of keeping these fruit quality parameters in the genetic variability study.

**Coefficient of variation:** Coefficient of variation is expressed as percentage ratio of the standard deviation to the corresponding mean of the concerned characters. Coefficient of variation for all the sixteen characters was low, ranging from 2.30 to 9.15, which indicated lesser influence of environment for the expression of these characters under study.

Table-3: Analysis of variance of different characters.

| Characters                            | Mean sum of squares  |                      |           |                      |                      |        |                      |                      |        |
|---------------------------------------|----------------------|----------------------|-----------|----------------------|----------------------|--------|----------------------|----------------------|--------|
|                                       | Genotypes            |                      |           | Replication          |                      |        | Error                |                      |        |
|                                       | 1 <sup>st</sup> Year | 2 <sup>nd</sup> Year | Pooled    | 1 <sup>st</sup> Year | 2 <sup>nd</sup> Year | Pooled | 1 <sup>st</sup> Year | 2 <sup>nd</sup> Year | Pooled |
| df                                    | 14                   | 14                   | 56        | 2                    | 2                    | 2      | 28                   | 28                   | 56     |
| Vine length (m)                       | 2.50                 | 2.57*                | 5.05**    | 0.04                 | 0.12                 | 0.15   | 0.17                 | 0.16                 | 0.16   |
| Primary branches/plant                | 5.72**               | 6.77**               | 12.39**   | 0.08                 | 0.09                 | 0.022  | 0.35                 | 0.26                 | 0.306  |
| Days to 1 <sup>st</sup> male flower   | 20.85**              | 23.40**              | 42.78**   | 5.48                 | 1.75                 | 1.23   | 3.79                 | 2.57                 | 3.18   |
| Days to 1 <sup>st</sup> female flower | 26.22**              | 25.76**              | 51.09**   | 10.55                | 0.87                 | 2.88   | 2.65                 | 1.13                 | 1.75   |
| Fruit length (cm)                     | 81.71**              | 81.24**              | 161.88**  | 9.08                 | 0.86                 | 5.98   | 1.65                 | 0.72                 | 0.97   |
| Fruit width (cm)                      | 35.36**              | 16.49**              | 45.89**   | 3.90                 | 0.18                 | 2.05   | 2.51                 | 0.32                 | 1.306  |
| Fruit weight (kg)                     | 0.39                 | 0.29                 | 0.68      | 0.03                 | 0.14                 | 0.016  | 0.01                 | 0.029                | 0.007  |
| Fruits/plant                          | 0.73                 | 0.70                 | 1.38      | 0.003                | 0.006                | 0.008  | 0.05                 | 0.03                 | 0.036  |
| Days to 1 <sup>st</sup> harvest       | 15.66**              | 17.26**              | 29.60**   | 2.46                 | 2.21                 | 2.64   | 4.25                 | 2.93                 | 3.59   |
| Seed no. /fruit                       | 17099**              | 18965.8**            | 35897.8** | 701.00               | 333.0                | 925.0  | 506.36               | 208.3                | 357.09 |
| 100 seed weight (g)                   | 11.44**              | 11.95**              | 23.38**   | 0.041                | 0.014                | 0.009  | 0.24                 | 0.25                 | 0.25   |
| Ascorbic acid content (mg)            | 4.70**               | 4.60**               | 9.29**    | 0.14                 | 0.024                | 0.101  | 0.06                 | 0.06                 | 0.06   |
| TSS (° brix)                          | 0.57                 | 0.52                 | 1.05      | 0.03                 | 0.006                | 0.019  | 0.05                 | 0.017                | 0.031  |
| Total sugar (%)                       | 0.16                 | 0.20                 | 0.31      | 0.03                 | 0.053                | 0.073  | 0.04                 | 0.026                | 0.032  |
| Sex ratio                             | 7.15**               | 5.02**               | 12.60**   | 0.18                 | 0.065                | 0.03   | 0.14                 | 0.205                | 0.127  |
| Fruit yield/plant (kg)                | 4.22**               | 2.39*                | 6.04**    | 0.44                 | 0.212                | 0.25   | 0.28                 | 0.120                | 0.144  |

\* P=0.05, \*\*P=0.01

**Genetic components of variation:**

Different variability parameters like genotypic coefficient of variation, heritability and genetic advance essential for initiating an efficient breeding programme is presented in table-4.

**Genotypic coefficient of variation (G.C.V.):** The genotypic coefficient of variations (GCV) helps to measure the range of variability in the programme and provides a measure to compare the genetic variability presenting various characters. However, with the help of GCV alone the heritable variation cannot be measured. In this investigation, the estimates of genotypic and phenotypic coefficient of variation corresponded well, suggesting lesser influence of environment for the expression of all the characters under study. It is to be mentioned here that such inference could also be drawn from the low magnitude of coefficient of variation for all the characters. In this investigation highest GCV was recorded in fruit length (20.63) followed by ascorbic acid content of the fruit pulp (19.62), and sex ratio (18.10). These findings were supported by several earlier works on genetic variability studies in bottle gourd (viz. Sharma and Dhankhar, 1990; Janakiram and Sirohi, 1994; Narayan *et al.*, 1996; Sharma *et al.*, 1983; Bisognin and Storck, 2000; Maurya and Singh, 1994; Hawlader *et al.*, 1999).

**Heritability in broad sense:** Heritability is a primary measure of a value of selection for particular character in various types of progeny and as an index of transmissibility of characters from parents to off springs (Hayes *et al* 1955). So the concept of heritability is important to evaluate the relative magnitude of the effects of genes and environments on total phenotypic variability. Burton (1952) suggested that genetic variability along with heritability should be considered for assessing maximum and accurate affect of selection. In this investigation broad sense heritability estimates were very high (above 80%) for all the characters excepting days to first male flower opening, days to first harvest and total sugar content for which moderate heritability ranging from 54.9 to 68.4% was revealed. The overall scenario of broad sense heritability estimate of different characters indicated higher efficiency of selection for different fruit

Table-4: Genetic variability parameters for different characters.

| Components of variation Characters    | Mean   | Range         | Coefficient of variation (C.V.) | Genetic coefficient of variation (G.C.V.) | Phenotypic coefficient of variation (P.C.V.) | Heritability (%) (H) | Genetic Advance (GA) | Genetic Advance (GA) % of Mean |
|---------------------------------------|--------|---------------|---------------------------------|-------------------------------------------|----------------------------------------------|----------------------|----------------------|--------------------------------|
| Vine length (m)                       | 6.10   | 4.60-7.31     | 6.58                            | 15.04                                     | 16.41                                        | 83.90                | 1.73                 | 28.36                          |
| Primary branches/plant                | 13.10  | 11.40-16.13   | 4.22                            | 10.93                                     | 11.72                                        | 87.00                | 2.75                 | 20.99                          |
| Days to 1 <sup>st</sup> male flower   | 51.93  | 44.83-56.17   | 3.44                            | 5.05                                      | 6.11                                         | 68.40                | 4.47                 | 8.61                           |
| Days to 1 <sup>st</sup> female flower | 57.56  | 51.17-61.83   | 2.30                            | 5.03                                      | 5.52                                         | 82.70                | 5.42                 | 9.42                           |
| Fruit length (cm)                     | 25.06  | 14.42-31.33   | 3.93                            | 20.63                                     | 21.00                                        | 96.50                | 10.46                | 41.74                          |
| Fruit width (cm)                      | 16.89  | 10.95-20.65   | 6.77                            | 15.20                                     | 16.64                                        | 83.50                | 4.83                 | 28.60                          |
| Fruit weight (kg)                     | 2.09   | 1.68-2.54     | 3.93                            | 15.86                                     | 16.34                                        | 94.20                | 0.66                 | 31.58                          |
| Fruits/plant                          | 4.45   | 3.63-5.40     | 4.28                            | 10.58                                     | 11.41                                        | 85.90                | 0.90                 | 20.22                          |
| Days to 1 <sup>st</sup> harvest       | 72.83  | 69.53-76.87   | 2.60                            | 2.87                                      | 3.88                                         | 54.90                | 3.20                 | 4.39                           |
| Seed no. /fruit                       | 490.17 | 376.23-665.73 | 3.86                            | 15.74                                     | 16.21                                        | 94.30                | 154.41               | 31.50                          |
| 100 seed weight (g)                   | 17.56  | 14.45-21.49   | 2.83                            | 11.24                                     | 11.59                                        | 94.10                | 3.94                 | 22.44                          |
| Ascorbic acid content (mg)            | 6.34   | 4.11-8.23     | 3.88                            | 19.62                                     | 20.00                                        | 96.20                | 2.51                 | 39.59                          |
| TSS (° brix)                          | 3.00   | 2.48-3.73     | 5.91                            | 13.68                                     | 14.91                                        | 84.30                | 0.78                 | 26.00                          |
| Total sugar (%)                       | 1.96   | 1.68-2.36     | 9.15                            | 10.80                                     | 14.16                                        | 58.20                | 0.33                 | 16.84                          |
| Sex ratio                             | 7.95:1 | 6.35-12.20:1  | 4.48                            | 18.10                                     | 18.65                                        | 94.20                | 2.88                 | 36.23                          |
| Fruit yield/plant (kg)                | 9.23   | 7.36-11.16    | 4.11                            | 10.41                                     | 11.19                                        | 86.50                | 1.84                 | 19.93                          |

characters including ascorbic acid content of fruit. However, this broad sense heritability values are likely to be overestimated as in this calculation it was not possible to exclude variation due to different <sup>(7) or Environ. components</sup> genetic components. For this reason such broad sense heritability estimates may present some exaggerated picture for the transmissibility of characters from parents to off springs.

**Genetic advance:** Genetic advance is important in the performance of selected lines over the original population. However, it is not necessarily true that high heritability always exhibit high genetic advance. Johnson *et al.* (1955) for this reason suggested that heritability in combination with genetic advance would be more reliable for predicting the effect of selection because genetic advance depends on the amount of genetic variability, the magnitude of masking effect of genetic expression (environmental influence) and the intensity of selection. In the present investigation, genetic advance as percentage of mean was moderate for fruit length (41.74), ascorbic acid content of fruit (39.59) and sex ratio (36.23), average fruit weight (31.58) and seeds/fruit (31.50) and moderately low, ranging from 16.84 to 28.36 for total sugar content of the pulp, fruits/plant, 100 seed weight, fruit yield/plant, vine length and primary branches /plant and very low (4.39 to 9.42) for days to fruit harvest, days to first male and female flower opening.

**Joint consideration of GCV, heritability and genetic advance:** It is important to consider the magnitude of genetic variability (GCV), the degree to which the progenies are likely to resemble parents (heritability) and the expected genetic progress possible through selection (genetic advance), should be considered together to identify the most important character for indirect selection.

In the present investigation high GCV coupled with high broad sense heritability and high genetic advance could not be recorded for any characters. Such combination of genetic variability parameters is important because according to Panse (1957), such situation may arise due to additive gene action controlling the characters. So, no character in the present investigation can be improved by early generation selection.

High heritability coupled with moderate genetic advance was recorded for fruit length, ascorbic acid content of the fruit pulp, sex ratio, fruit weight and seed number/fruit indicating that these characters could be improved by rigid selection in early generation. However, deferred selection would be helpful to realize high genetic gain through indirect selection. Several characters namely vine length, primary branches /plant, fruit number/plant, 100 seed weight and fruit yield /plant showed high heritability coupled with low genetic advance which indicated limited possibility for improvement by selection. However, stringent selection over several generations may be followed to improve these characters.

Moderate heritability with low genetic advance was recorded for days to first male and female flower opening, days to first harvest and total sugar content of the pulp. These characters would response least to selection because such association of genetic parameters may be attributed to non additive gene action (Liang and Walter, 1968). These findings were supported by several early works in bottle gourd (Janakiram and Sirohi, 1994; Narayan *et al.*, 1996; Sit and Sirohi, 2000; Sharma and Dhankhar, 1990; Sharma *et al.*, 1983).

## 4.2 Character associationship

Information generated from the studies of character association serve as the most important indicator i.e. plant character that should be considered in the selection programme. Such studies would also help us to know the suitability of multiple characters for indirect selection because selection for one or more traits results in correlated response in several other traits (Searle, 1965).

### Correlation coefficient:

The intensity and direction of association among the characters can conveniently be measured by genotypic and phenotypic correlation coefficient. In fact knowledge of genotypic interaction between characters is also of theoretical interest because genotypic correlation may be derived from genetic linkage, pleiotropy or developmentally induced relationship between

component characters, which are only indirectly the consequence of gene action (Adams, 1967). The intensity and direction of association between the characters can be measured by genotypic and phenotypic correlation coefficient.

In the present study (Table-5) the magnitude of genotypic correlation coefficient was higher than phenotypic correlation coefficient in most of the pair characters under study. However, the gap between the two estimates correlation coefficient was not very wide indicating the lesser influence of environment on correlated response on the pair of characters. Falconer (1981) put forward such proposition of environmental influence on correlated response on the expression of characters. In the situation of high environmental influence on the expression of characters there is always possibility of underestimation of the genotypic correlation coefficient.

However, phenotypic correlation coefficient between different pair of characters has been employed to study the character associationship.

In the present investigation most of the characters did not register significant phenotypic correlation among themselves for which the following assumptions could be put forward-

1. Lack of adequate genetic diversity among the inbred lines for different characters. This proposition did find support from the study of genetic variability in present investigation.
2. Simultaneous vegetative growth and reproductive expression in the plant over a long period of time.
3. Internal balancing and mutual cancellation during expression of different characters.

In the present investigation fruit yield was significantly and positively correlated (Table 5) with vine length ( $r_p = 0.66$ ), fruit length ( $r_p = 0.64$ ), fruit width ( $r_p = 0.67$ ), fruit weight ( $r_p = 0.72$ ), seed number/fruit ( $r_p = 0.77$ ) and 100 seed weight ( $r_p = 0.56$ ). These findings on correlation of different characters with fruit yield find support from several earlier reports (Kumar and Singh,

Table-5: Genotypic (G), phenotypic (P) and environmental (E) correlation coefficients among pair of characters.

| Characters                  |   | 1     | 2     | 3      | 4       | 5       | 6       | 7       | 8      |
|-----------------------------|---|-------|-------|--------|---------|---------|---------|---------|--------|
| 1. (Vine length)            | P | 1.000 | 0.392 | -0.443 | -0.481  | 0.568*  | 0.676** | 0.583*  | -0.124 |
|                             | G | 1.000 | 0.452 | -0.518 | -0.565  | 0.612   | 0.803   | 0.649   | -0.111 |
|                             | E | 1.000 | 0.043 | -0.224 | -0.061  | 0.230   | 0.027   | 0.058   | -0.195 |
| 2. (Primary branch / plant) | P |       | 1.000 | -0.333 | -0.330  | 0.093   | -0.012  | 0.022   | 0.194  |
|                             | G |       | 1.000 | -0.396 | -0.370  | 0.095   | 0.057   | 0.021   | 0.222  |
|                             | E |       | 1.000 | -0.136 | -0.108  | 0.084   | -0.412  | 0.030   | 0.023  |
| 3. (Days to male flower)    | P |       |       | 1.000  | 0.863** | -0.489  | -0.387  | -0.363  | 0.009  |
|                             | G |       |       | 1.000  | 0.941   | -0.603  | -0.534  | -0.438  | 0.014  |
|                             | E |       |       | 1.000  | 0.663   | 0.004   | 0.074   | -0.083  | -0.005 |
| 4. (Days to female flower)  | P |       |       |        | 1.000   | -0.542* | -0.409  | -0.322  | -0.048 |
|                             | G |       |       |        | 1.000   | -0.599  | -0.519  | -0.335  | -0.098 |
|                             | E |       |       |        | 1.000   | -0.088  | 0.133   | -0.265  | 0.221  |
| 5. (Fruit length)           | P |       |       |        |         | 1.000   | 0.789** | 0.659** | -0.276 |
|                             | G |       |       |        |         | 1.000   | 0.867   | 0.692   | -0.289 |
|                             | E |       |       |        |         | 1.000   | 0.140   | -0.011  | -0.189 |
| 6. (Fruit width)            | P |       |       |        |         |         | 1.000   | 0.574*  | -0.109 |
|                             | G |       |       |        |         |         | 1.000   | 0.641   | -0.102 |
|                             | E |       |       |        |         |         | 1.000   | 0.056   | 0.150  |
| 7. (Fruitweight)            | P |       |       |        |         |         |         | 1.000   | -0.677 |
|                             | G |       |       |        |         |         |         | 1.000   | -0.711 |
|                             | E |       |       |        |         |         |         | 1.000   | -0.410 |
| 8. (Fruit no. / plant)      | P |       |       |        |         |         |         |         | 1.000  |
|                             | G |       |       |        |         |         |         |         | 1.000  |
|                             | E |       |       |        |         |         |         |         | 1.000  |

\* Significant at 5% level. \*\* Significant at 1% level.

Table-5 (contd.)

| Characters                  |   | 9      | 10      | 11      | 12     | 13     | 14     | 15       | 16      |
|-----------------------------|---|--------|---------|---------|--------|--------|--------|----------|---------|
| 1. (Vine length)            | P | -0.266 | 0.715** | 0.769** | 0.090  | -0.293 | 0.220  | -0.533   | 0.667** |
|                             | G | -0.335 | 0.805   | 0.850   | 0.070  | -0.370 | 0.321  | -0.591   | 0.797   |
|                             | E | -0.142 | -0.014  | 0.143   | 0.353  | 0.111  | -0.016 | -0.078   | -0.078  |
| 2. (Primary branch / plant) | P | -0.107 | 0.254   | 0.558*  | 0.276  | -0.229 | -0.165 | -0.284   | 0.161   |
|                             | G | -0.255 | 0.289   | 0.635   | 0.313  | -0.277 | -0.213 | -0.326   | 0.179   |
|                             | E | 0.289  | -0.094  | -0.182  | -0.150 | 0.062  | -0.058 | 0.123    | 0.042   |
| 3. (Days to male flower)    | P | 0.345  | -0.503  | -0.383  | 0.001  | 0.368  | -0.056 | 0.473    | -0.497  |
|                             | G | 0.544  | -0.616  | -0.501  | 0.004  | 0.464  | -0.149 | 0.558    | -0.643  |
|                             | E | 0.030  | -0.058  | 0.136   | -0.023 | 0.073  | 0.105  | 0.189    | -0.011  |
| 4. (Days to female flower)  | P | 0.489  | -0.507  | -0.449  | 0.155  | 0.402  | -0.001 | 0.412    | -0.506  |
|                             | G | 0.742  | -0.565  | -0.550  | 0.180  | 0.491  | -0.019 | 0.459    | -0.604  |
|                             | E | -0.040 | -0.079  | 0.357   | -0.069 | -0.053 | 0.046  | 0.069    | 0.032   |
| 5. (Fruit length)           | P | -0.193 | 0.611*  | 0.604*  | -0.100 | -0.273 | 0.467  | -0.524*  | 0.641** |
|                             | G | -0.300 | 0.632   | 0.635   | -0.110 | -0.314 | 0.635  | -0.546   | 0.712   |
|                             | E | 0.202  | 0.178   | -0.031  | 0.176  | 0.135  | -0.073 | -0.071   | -0.258  |
| 6. (Fruit width)            | P | -0.218 | 0.616*  | 0.604   | -0.166 | -0.111 | 0.515* | -0.580** | 0.677** |
|                             | G | -0.201 | 0.704   | 0.664   | -0.204 | -0.143 | 0.746  | -0.634   | 0.814   |
|                             | E | -0.300 | -0.087  | 0.151   | 0.210  | 0.056  | -0.020 | -0.181   | -0.092  |
| 7. (Fruit weight)           | P | 0.054  | 0.687** | 0.520*  | 0.313  | -0.472 | 0.416  | -0.520*  | 0.724** |
|                             | G | 0.042  | 0.730   | 0.573   | 0.321  | -0.550 | 0.498  | -0.568   | 0.749   |
|                             | E | 0.146  | -0.029  | -0.320  | 0.144  | 0.191  | 0.304  | 0.271    | 0.543   |
| 8. (Fruit no. / plant)      | P | -0.186 | -0.194  | -0.130  | -0.362 | 0.224  | -0.255 | -0.111   | 0.000   |
|                             | G | -0.203 | -0.223  | -0.174  | -0.366 | 0.329  | -0.321 | -0.096   | -0.071  |
|                             | E | -0.183 | 0.082   | 0.292   | -0.392 | -0.376 | -0.117 | -0.281   | 0.444   |

\* Significant at 5% level. \*\* Significant at 1% level.

Table-5 (contd.)

| Characters                 |   | 9     | 10     | 11     | 12     | 13     | 14     | 15      | 16       |
|----------------------------|---|-------|--------|--------|--------|--------|--------|---------|----------|
| 9. (Days to first harvest) | P | 1.000 | -0.217 | -0.191 | 0.206  | 0.232  | 0.203  | -0.028  | -0.102   |
|                            | G | 1.000 | -0.306 | -0.209 | 0.298  | 0.318  | 0.178  | -0.109  | -0.152   |
|                            | E | 1.000 | 0.020  | 0.248  | -0.081 | 0.059  | 0.236  | 0.310   | 0.012    |
| 10. (Seed no. /fruit)      | P |       | 1.000  | 0.579* | 0.388  | -0.616 | 0.171  | -0.539* | 0.774**  |
|                            | G |       | 1.000  | 0.621  | 0.415  | -0.668 | 0.293  | -0.558  | 0.846    |
|                            | E |       | 1.000  | -0.108 | -0.151 | -0.218 | -0.299 | -0.224  | 0.105    |
| 11. (100 seed weight)      | P |       |        | 1.000  | 0.144  | -0.328 | 0.123  | -0.459  | 0.565*   |
|                            | G |       |        | 1.000  | 0.150  | -0.357 | 0.167  | -0.477  | 0.624    |
|                            | E |       |        | 1.000  | 0.041  | -0.100 | -0.003 | -0.168  | 0.033    |
| 12. (Vitamin C content)    | P |       |        |        | 1.000  | -0.507 | -0.030 | 0.036   | 0.080    |
|                            | G |       |        |        | 1.000  | -0.564 | -0.049 | 0.041   | 0.105    |
|                            | E |       |        |        | 1.000  | 0.011  | 0.055  | 0.046   | -0.222   |
| 13. (TSS)                  | P |       |        |        |        | 1.000  | 0.267  | 0.189   | -0.441   |
|                            | G |       |        |        |        | 1.000  | 0.311  | 0.203   | -0.488   |
|                            | E |       |        |        |        | 1.000  | 0.192  | 0.088   | -0.168   |
| 14. (Total sugar)          | P |       |        |        |        |        | 1.000  | -0.260  | 0.333    |
|                            | G |       |        |        |        |        | 1.000  | -0.393  | 0.394    |
|                            | E |       |        |        |        |        | 1.000  | 0.196   | 0.226    |
| 15. (Sex ratio)            | P |       |        |        |        |        |        | 1.000   | -0.787** |
|                            | G |       |        |        |        |        |        | 1.000   | -0.879   |
|                            | E |       |        |        |        |        |        | 1.000   | 0.074    |
| 16. (Fruit yield /plant)   | P |       |        |        |        |        |        |         | 1.000    |
|                            | G |       |        |        |        |        |        |         | 1.000    |
|                            | E |       |        |        |        |        |        |         | 1.000    |

\* Significant at 5% level. \*\* Significant at 1% level.

1998; Umamaheswarappa *et al.*, 2004). The correlated response of different characters with yield suggested selection of long viny genotypes, which produced oblong- cylindrical fruits (high length and width) of higher weight and having higher number of heavier seeds, which would be better for developing high yielding genotypes.

Fruit weight showed significant positive correlation with seed number/fruit and 100 seed weight. Fruit length registered significant positive correlation with fruit width and fruit weight, suggesting the possibility of increases of fruit weight through enhancement of fruit length and width. Interestingly fruit number/plant did not registered significant correlation with any character, which might have happened due to lack of genetic variability for fruit number in the genotypes under study. Of the fruit quality characters only total sugar content of fruits was significantly correlated with fruit width.

From the study of correlation the characters namely vine length, fruit length, fruit width and fruit weight emerged as the most important characters influencing fruit yield and fruit quality.

#### **Path coefficient:**

Linear correlation between any two characters may present a confusing picture because any character may exert simultaneous influence on many characters of the plants. Path coefficient technique is more useful in establishing direct and indirect relationship among any character, which is more realistic interpretation regarding influence of a character on a particular trait. The path coefficient analysis using phenotypic correlation coefficient among pair of characters have been presented in Table-6. The perusal of data showed direct affects of different characters on fruit yield/plant in low magnitude indicating lack of specificity of identification of important fruit yield influencing character from this analysis. However, vine length had the highest positive direct affect on yield (0.106) followed by days to first harvest (0.063), total sugar content (0.056), primary branches per plant (0.040), days to first female flower opening (0.036),

Table-6: Phenotypic path coefficient analysis for yield/plant.

| Compo-<br>nents | Direct and indirect effect via |        |        |        |        |        |        |        |        |        |        |        |        |        |        | Phenotypic<br>Correlation<br>with yield<br>/ plant |
|-----------------|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|----------------------------------------------------|
|                 | 1                              | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      | 10     | 11     | 12     | 13     | 14     | 15     |                                                    |
| 1               | 0.106                          | 0.056  | -0.007 | -0.043 | -0.001 | 0.031  | -0.019 | -0.053 | 0.682  | -0.103 | -0.008 | -0.004 | 0.005  | 0.012  | 0.013  | 0.667                                              |
| 2               | 0.038                          | 0.040  | -0.003 | -0.108 | -0.001 | 0.021  | -0.003 | 0.001  | 0.025  | 0.163  | -0.003 | -0.011 | 0.004  | -0.009 | 0.007  | 0.161                                              |
| 3               | -0.075                         | -0.028 | 0.003  | 0.036  | 0.003  | -0.055 | 0.016  | 0.030  | -0.425 | 0.008  | 0.010  | 0.000  | -0.007 | -0.003 | -0.012 | -0.497                                             |
| 4               | -0.075                         | -0.032 | 0.003  | 0.036  | 0.003  | -0.064 | 0.018  | 0.032  | -0.377 | -0.040 | 0.015  | -0.006 | -0.007 | 0.000  | -0.010 | -0.506                                             |
| 5               | 0.091                          | 0.044  | -0.004 | -0.010 | -0.001 | 0.035  | -0.033 | -0.062 | 0.772  | -0.231 | -0.006 | 0.004  | 0.005  | 0.026  | 0.013  | 0.641                                              |
| 6               | 0.091                          | 0.044  | -0.005 | 0.001  | -0.001 | 0.026  | -0.026 | -0.078 | 0.671  | -0.091 | -0.007 | 0.007  | 0.002  | 0.029  | 0.014  | 0.677                                              |
| 7               | 0.102                          | 0.038  | -0.004 | -0.002 | -0.001 | 0.021  | -0.022 | -0.045 | 1.170  | -0.567 | 0.002  | -0.012 | 0.009  | 0.023  | 0.013  | 0.724                                              |
| 8               | -0.029                         | -0.009 | 0.001  | -0.021 | 0.000  | 0.003  | 0.009  | 0.009  | -0.792 | 0.837  | -0.006 | 0.014  | -0.004 | -0.014 | 0.003  | 0.000                                              |
| 9               | -0.032                         | -0.014 | 0.002  | 0.012  | 0.001  | -0.031 | 0.006  | 0.017  | 0.063  | -0.156 | 0.030  | -0.008 | -0.004 | 0.011  | 0.001  | -0.102                                             |
| 10              | 0.148                          | 0.042  | -0.005 | -0.028 | -0.001 | 0.033  | -0.020 | -0.048 | 0.804  | -0.162 | -0.007 | -0.016 | 0.011  | 0.010  | 0.013  | 0.774                                              |
| 11              | 0.086                          | 0.072  | -0.005 | -0.061 | -0.001 | 0.029  | -0.020 | -0.047 | 0.609  | -0.109 | -0.006 | -0.006 | 0.006  | 0.007  | 0.011  | 0.565                                              |
| 12              | 0.058                          | 0.010  | -0.001 | -0.030 | 0.000  | -0.010 | 0.003  | 0.013  | 0.366  | 0.303  | 0.006  | -0.040 | 0.009  | -0.002 | -0.001 | 0.080                                              |
| 13              | -0.091                         | -0.024 | 0.002  | 0.025  | 0.001  | -0.026 | 0.009  | 0.009  | -0.553 | 0.187  | 0.007  | 0.020  | -0.018 | 0.015  | -0.005 | -0.441                                             |
| 14              | 0.025                          | 0.009  | -0.002 | 0.018  | 0.000  | 0.000  | -0.015 | -0.040 | 0.487  | -0.214 | 0.006  | 0.001  | -0.005 | 0.056  | 0.007  | 0.333                                              |
| 15              | -0.080                         | -0.033 | 0.004  | 0.031  | 0.001  | -0.027 | 0.017  | 0.045  | -0.608 | -0.093 | -0.001 | -0.001 | -0.003 | -0.015 | -0.025 | -0.787                                             |

Residual effect = 0.023 ; List of characters as per given in table- 2. Bold diagonal values indicate direct effects.

fruit width (0.026). The direct and indirect effects of different characters suggested that a long viny genotype, which flowers late and bears heavy and long fruits with increased sugar content would be a high yielding genotype. *What about the residual effect?*

#### **Selection indices for yield and quality:**

Straight forward selection of important fruit yield and quality components for indirect selection became difficult in this investigation owing to lack of appreciable genetic variability for different characters among the inbred lines and non registration of high direct effect of different characters for fruit yield/plant. However, from the present study of genetic variability and character association, the characters namely vine length, fruit length, fruit weight, days to first female flower opening, days to first harvest and total sugar content of fruit emerged as important components, which should be given due weightage during selection of high yielding genotypes having high quality fruits.

#### **4.3 Genetic diversity of the inbreds through multivariate analysis**

Multivariate analysis (Mahalanobis, 1936) is a powerful tool in quantifying the degree of divergence between biological populations (genetic distance) and to assess the relative contribution of different components to the total divergence. India is endowed with the huge wealth of bottle gourd germplasms comprising of both wild and cultivated forms. In West Bengal, bottle gourd is cultivated widely and due to continuous cultivation of the cross-pollinated crop, large variation in different characters is expected to have occurred in the genotypes through cultivation. On the other hand, continuous cultivation of similar types in a particular locality may not produce high variation because of sharing a common gene pool during sexual reproduction. Genetic divergence of bottle gourd using Mahalanobis's  $D^2$  statistic was also studied earlier (Mathew *et al.*, 2001).

The present study aimed to understanding the genetic divergence of 15 inbreds of bottle gourd in two years/ separately, employing 16 <sup>quality traits</sup> characters

quantitatively namely, vine length, number of primary branches/plant, days to first male and female flower opening, fruit length, fruit width, average fruit weight, number of fruits/plant, days to first harvest, number of seeds/fruit, 100 seed weight, ascorbic acid content of the fresh fruit, total soluble solids, total sugar content, sex ratio and fruit yield/plant. Although Mahalanobis's general distance as a measure of genetic distance occupy a unique place in plant breeding. Yet, as it happens in biology, several problems under the influence of random unpredictable environmental problems, evade the direct grip of the concept well proven in more exact field like Mathematical components. It suggests determining the genetic distance of the biological population through multivariate analysis over environment or years to fortify its reliability.

#### Range and significance of $D^2$ values:

The range of  $D^2$  values (129.02 to 1708.58) in the first year Table-7 and in second year (146.15 to 3068.91) indicated the degree of divergence among 15 inbreds of bottle gourd consistently in both the years Table 8. Each  $D^2$  value is analogous to  $\chi^2$  (p.d.f., where, p is the number of characters). All the 105  $D^2$  values in both the years were greater than  $\chi^2$  (15 d.f. at 5% level, 25.00) and thereby significantly different from zero. Considerable difference in bottle gourd accession for all the characters was also recorded earlier (Mathew *et al.*, 2001).

**Divergence of Inbreds:** As per average mean  $D^2$  values ( $\overline{D_7^2}$ ) the inbreds BCBG-34, BCBG-4 and BCBG-16 (with average  $D^2 = 904.50, 838.77, 627.16$  respectively) were on an average maximum divergent from all the inbreds in the first year. Although, all the other inbreds in this year also showed considerably high  $D^2$  values. As per average values ( $\overline{D_2^2}$ ) the inbreds BCBG-1, BCBG-17 and BCBG-4 (with  $\overline{D^2} = 2205.55, 2057.44, 2004.34$  respectively) were on an average maximum divergent among all the inbreds.

Average divergence values of the inbreds markedly changed with the environment, which also indicated the utility of determining genetic divergence over the years or environments. Arunachalam (1981) indicated this

Table-7: Divergence ( $D^2$  values) among 15 genotypes in first year.

| Geno-<br>types   | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8       | 9      | 10      | 11     | 12      | 13      | 14     | 15     |
|------------------|--------|--------|--------|--------|--------|--------|--------|---------|--------|---------|--------|---------|---------|--------|--------|
| 1                | 000.00 | 202.41 | 488.47 | 469.64 | 480.28 | 159.65 | 546.99 | 951.12  | 484.87 | 597.06  | 609.14 | 734.82  | 1324.70 | 614.80 | 499.28 |
| 2                |        | 000.00 | 262.59 | 581.71 | 518.55 | 245.27 | 599.48 | 725.12  | 471.56 | 290.53  | 279.54 | 764.36  | 1126.22 | 577.07 | 221.38 |
| 3                |        |        | 000.00 | 707.60 | 973.60 | 455.84 | 887.64 | 1222.94 | 785.75 | 575.61  | 784.32 | 1323.58 | 1708.58 | 902.26 | 663.96 |
| 4                |        |        |        | 000.00 | 488.83 | 234.59 | 129.02 | 893.81  | 212.34 | 1118.69 | 588.59 | 594.29  | 1327.74 | 295.16 | 670.88 |
| 5                |        |        |        |        | 000.00 | 207.92 | 601.31 | 253.63  | 329.80 | 602.31  | 432.30 | 167.81  | 461.61  | 413.09 | 525.22 |
| 6                |        |        |        |        |        | 000.00 | 352.44 | 507.69  | 207.37 | 483.03  | 369.55 | 401.06  | 812.20  | 299.29 | 379.20 |
| 7                |        |        |        |        |        |        | 000.00 | 983.21  | 145.20 | 1245.45 | 523.87 | 542.08  | 1384.15 | 200.59 | 638.87 |
| 8                |        |        |        |        |        |        |        | 000.00  | 565.26 | 415.63  | 334.47 | 294.80  | 251.74  | 555.41 | 389.91 |
| 9                |        |        |        |        |        |        |        |         | 000.00 | 849.09  | 349.64 | 282.52  | 928.89  | 70.17  | 419.14 |
| 10               |        |        |        |        |        |        |        |         |        | 000.00  | 401.99 | 806.06  | 668.99  | 853.37 | 244.93 |
| 11               |        |        |        |        |        |        |        |         |        |         | 000.00 | 469.47  | 715.86  | 403.12 | 72.25  |
| 12               |        |        |        |        |        |        |        |         |        |         |        | 000.00  | 419.11  | 231.83 | 520.54 |
| 13               |        |        |        |        |        |        |        |         |        |         |        |         | 000.00  | 753.09 | 780.17 |
| 14               |        |        |        |        |        |        |        |         |        |         |        |         |         | 000.00 | 433.44 |
| 15               |        |        |        |        |        |        |        |         |        |         |        |         |         |        | 000.00 |
| $\overline{D_2}$ | 583.09 | 490.41 | 838.77 | 593.78 | 461.16 | 365.36 | 627.16 | 596.05  | 435.83 | 653.77  | 452.44 | 539.45  | 904.50  | 471.62 | 461.37 |

\*All  $D^2$  values are significant at 5% level.

Table-8: Divergence ( $D^2$  values) among 15 genotypes in second year.

| Geno-<br>types   | 1       | 2       | 3       | 4       | 5       | 6       | 7       | 8       | 9       | 10      | 11      | 12      | 13      | 14      | 15      |
|------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1                | 000.00  | 549.80  | 481.53  | 1588.17 | 2088.17 | 1428.80 | 1471.75 | 5252.88 | 2830.51 | 1334.97 | 2654.77 | 3281.55 | 2576.10 | 2863.99 | 2474.67 |
| 2                |         | 000.00  | 477.45  | 759.39  | 928.93  | 465.62  | 793.58  | 3131.72 | 1591.91 | 492.62  | 1372.01 | 1650.91 | 1589.30 | 1270.04 | 1203.99 |
| 3                |         |         | 000.00  | 1157.81 | 1955.00 | 1100.23 | 1393.11 | 4863.90 | 2605.90 | 1022.20 | 2498.26 | 3068.91 | 2387.59 | 2595.18 | 2453.69 |
| 4                |         |         |         | 000.00  | 708.46  | 369.49  | 146.15  | 2318.39 | 538.44  | 1081.30 | 594.61  | 1304.99 | 951.17  | 685.98  | 896.50  |
| 5                |         |         |         |         | 000.00  | 297.26  | 815.52  | 1045.43 | 444.60  | 845.56  | 547.17  | 433.32  | 567.81  | 627.39  | 560.09  |
| 6                |         |         |         |         |         | 000.00  | 606.16  | 1681.58 | 659.52  | 501.51  | 593.07  | 862.05  | 707.69  | 665.85  | 570.08  |
| 7                |         |         |         |         |         |         | 000.00  | 2627.52 | 511.14  | 1373.40 | 592.24  | 1440.53 | 1042.28 | 685.81  | 1000.77 |
| 8                |         |         |         |         |         |         |         | 000.00  | 1351.83 | 1924.67 | 1182.38 | 477.40  | 1096.89 | 1086.90 | 762.62  |
| 9                |         |         |         |         |         |         |         |         | 000.00  | 1730.79 | 230.88  | 910.84  | 731.50  | 577.27  | 728.87  |
| 10               |         |         |         |         |         |         |         |         |         | 000.00  | 1328.99 | 1000.80 | 933.00  | 1127.71 | 704.50  |
| 11               |         |         |         |         |         |         |         |         |         |         | 000.00  | 900.39  | 652.04  | 543.73  | 375.21  |
| 12               |         |         |         |         |         |         |         |         |         |         |         | 000.00  | 714.69  | 390.02  | 387.30  |
| 13               |         |         |         |         |         |         |         |         |         |         |         |         | 000.00  | 783.09  | 630.79  |
| 14               |         |         |         |         |         |         |         |         |         |         |         |         |         | 000.00  | 385.74  |
| 15               |         |         |         |         |         |         |         |         |         |         |         |         |         |         | 000.00  |
| $\overline{D^2}$ | 2205.55 | 1162.66 | 2004.34 | 935.78  | 847.48  | 750.64  | 1035.71 | 2057.44 | 1103.14 | 1100.14 | 1004.70 | 1201.69 | 1097.42 | 1020.62 | 938.20  |

\*All  $D^2$  values are significant at 5% level.

unpredictable changes in genetic divergence due to environmental influence on the expression of different quantitative characters, which somewhat reduced the grip on this concept of biological distance among different populations.

#### Group constellation of the inbreds:

Based on the degree of divergence ( $D^2$  values) between any two genotypes, a logical grouping of the genotypes with low  $D^2$  value could be arrived at by Tocher's method (Rao, 1952).

**Table-9: Clustering pattern of 15 inbreds in first year.**

| Cluster | Inbreds                               | Place of collection                                                                      | Geographical location                                                                               |
|---------|---------------------------------------|------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| 1       | BCBG-19<br>BCBG-38                    | Nilganj, 24-Pgs. (N)<br>Gadamara, 24-Pgs. (N)                                            | La-22°40'N, Lo-88°26'E<br>La-22°48'N, Lo-88°30'E                                                    |
| 2       | BCBG-22<br>BCBG-40                    | Seoraphuli, Hoogly<br>Gadamara, 24-Pgs. (N)                                              | La-22°48'N, Lo-88°30'E<br>La-22°48'N, Lo-88°30'E                                                    |
| 3       | BCBG-1<br>BCBG-3<br>BCBG-6<br>BCBG-16 | Gadamara, 24-Pgs. (N)<br>Suri, Birbhum,<br>Gadamara, 24-Pgs. (N)<br>Nilganj, 24-Pgs. (N) | La-22°48'N, Lo-88°30'E<br>La-23°55'N, Lo-87°32'<br>La-22°48'N, Lo-88°30'E<br>La-22°40'N, Lo-88°26'E |
| 4       | BCBG-7<br>BCBG-33                     | Gadamara, 24-Pgs. (N)<br>Seoraphuli, Hoogly                                              | La-22°48'N, Lo-88°30'E<br>La-22°48'N, Lo-88°30'E                                                    |
| 5       | BCBG-17<br>BCBG-34                    | Seoraphuli, Hoogly<br>Seoraphuli, Hoogly                                                 | La-22°48'N, Lo-88°30'E<br>La-22°48'N, Lo-88°30'E                                                    |
| 6       | BCBG-4<br>BCBG-15<br>BCBG-20          | Suri, Birbhum<br>Suri, Birbhum<br>Suri, Birbhum                                          | La-23°55'N, Lo-87°32'<br>La-23°55'N, Lo-87°32'<br>La-23°55'N, Lo-87°32'                             |

Based on the determination of divergence in first year the 15 inbreds could be grouped into 6 clusters (Table-9). Cluster 3 contained the maximum of 4 inbreds while cluster 1, 2, 4 and 5 contained 2 inbreds each. Cluster 6 contained 3 inbreds. In the second year the inbred were clustered in 7 groups (Table-10)

**Table-10: Clustering pattern of 15 inbreds in second year.**

| Cluster | Inbreds | Place of collection  | Geographical location   |
|---------|---------|----------------------|-------------------------|
| 1       | BCBG-6  | Gadamara, 24-Pgs.(N) | La-22°48'N, Lo-88°30'E  |
|         | BCBG-16 | Nilganj, 24-Pgs.(N)  | La-22°40'N, Lo-88°26'E  |
| 2       | BCBG-19 | Nilganj, 24-Pgs.(N)  | La-22°40'N, Lo-88°26'E  |
|         | BCBG-22 | Seoraphuli, Hoogly   | La-22°084'N, Lo-88°18'E |
| 3       | BCBG-7  | Gadamara, 24-Pgs.(N) | La-22°48'N, Lo-88°30'E  |
|         | BCBG-15 | Suri, Birbhum        | La-23°55'N, Lo-87°32'E  |
| 4       | BCBG-38 | Gadamara, 24-Pgs.(N) | La-22°48'N, Lo-88°30'E  |
|         | BCBG-40 | Gadamara, 24-Pgs.(N) |                         |
| 5       | BCBG-17 | Seoraphuli, Hoogly   | La-22°084'N, Lo-88°18'E |
|         | BCBG-33 | Seoraphuli, Hoogly   |                         |
| 6       | BCBG-1  | Gadamara, 24-Pgs.(N) | La-22°48'N, Lo-88°30'E  |
|         | BCBG-3  | Suri, Birbhum        | La-23°55'N, Lo-87°32'E  |
|         | BCBG-4  | Suri, Birbhum        | La-23°55'N, Lo-87°32'E  |
|         | BCBG-20 | Suri, Birbhum        | La-23°55'N, Lo-87°32'E  |
| 7       | BCBG-34 | Seoraphuli, Hoogly.  | La-22°084'N, Lo-88°18'E |

**Table-11: Stable diverse inbreds.**

| Number | Inbred lines      | Clusters                                                        |
|--------|-------------------|-----------------------------------------------------------------|
| 1      | BCBG-6<br>BCBG-16 | Cluster 1 in first year and cluster 3 in second years together. |
| 2      | BCBG-1<br>BCBG-3  | Cluster 6 in first year and cluster 3 in second years together. |
| 3      | BCBG-4<br>BCBG-20 | Cluster 6 in both the year.                                     |

with cluster 6 containing maximum of 4 inbreds and cluster 7 had only 1 inbred. As expected, environment influenced clustering pattern, which could be demonstrated by examining the composition of different clusters in both the years. Environmental influence on the composition of cluster also recorded earlier in different crops like pearl millet (Upadhyay and Murthi, 1970), tomato (Peter and Roy, 1976), wheat (Dasgupta and Das, 1984), cowpea (Hazra *et al.*, 1983) and pumkin (Mandal, 2005).

#### **Identification of stable diverge genotypes:**

The concept of stable diverse genotypes refers to those genotypes, which clustered in the same group or in combination with the other in different group consistently both the years (Table-11). The present study indicated that BCBG-6 (fruit oblong and patchy green in colour), BCBG-16 (fruits oval or elliptical and greenish white in colour), BCBG-1 (fruits globular in shape and greenish white in colour), BCBG-3 (fruits globular and white in colour), BCBG-4 (fruits oval or elliptical shape and white in colour) and BCBG-20 (fruits oval or elliptical and white in colour) could be identified as stable diverse genotypes. Mean of different characters of the stable diverse genotypes has been presented in Table-12.

#### **Intra and inter cluster divergence:**

Intra cluster divergence represents the average of the  $D^2$  values between all possible pair of genotypes entered in the cluster concern. In the first year highest intra cluster divergence was recorded in cluster 6 (504.82) and lowest of 70.17 was recorded in cluster 1 (Table-13). In the second year also highest intra cluster divergence (726.43) was recorded in cluster 6 and lowest of 146.15 was recorded in cluster 1 (Table-14). High intra cluster divergence suggested the heterogeneity of inbreds as far as expression of characters are concerned.

The inter cluster divergence was calculated by averaging all possible  $D^2$  values among all the genotypes belonging to different clusters concerned, divided by the number of pairs involved. On the basis of inter cluster divergence in the first year the inbreds belonging to cluster 3 and cluster 5 were most

Table-12: Mean of different characters in stable diverse inbreds.

| Charac-<br>ters<br>Inbreds | 1    | 2     | 3     | 4     | 5     | 6     | 7    | 8    | 9     | 10      | 11     | 12    | 13   | 14   | 15   | 16    |
|----------------------------|------|-------|-------|-------|-------|-------|------|------|-------|---------|--------|-------|------|------|------|-------|
| 1                          | 4.60 | 12.70 | 54.33 | 61.83 | 14.41 | 10.95 | 1.87 | 4.73 | 76.87 | 7.69:1  | 376.23 | 14.45 | 6.79 | 3.27 | 1.70 | 8.85  |
| 2                          | 5.41 | 12.60 | 54.17 | 60.50 | 18.91 | 16.08 | 1.71 | 4.60 | 75.53 | 8.63:1  | 419.83 | 15.83 | 6.51 | 3.73 | 2.21 | 7.90  |
| 3                          | 5.15 | 11.83 | 66.17 | 61.50 | 18.07 | 13.45 | 1.68 | 4.33 | 70.27 | 12.20:1 | 418.48 | 14.92 | 6.69 | 3.17 | 1.82 | 7.36  |
| 4                          | 5.23 | 12.00 | 49.67 | 53.50 | 26.73 | 13.90 | 1.87 | 4.60 | 69.53 | 8.75:1  | 450.20 | 15.79 | 5.00 | 2.60 | 1.85 | 8.70  |
| 5                          | 5.88 | 11.90 | 52.67 | 59.33 | 29.33 | 17.79 | 2.43 | 4.03 | 74.30 | 6.94:1  | 555.92 | 16.43 | 7.78 | 2.88 | 2.36 | 9.86  |
| 6                          | 4.85 | 12.30 | 52.33 | 58.50 | 24.32 | 16.73 | 2.01 | 4.33 | 74.67 | 8.78:1  | 435.83 | 16.42 | 7.10 | 2.70 | 1.74 | 8.72  |
| 7                          | 5.55 | 12.97 | 50.83 | 56.80 | 26.25 | 17.36 | 1.95 | 4.30 | 71.47 | 7.67:1  | 421.12 | 16.53 | 4.11 | 3.55 | 1.95 | 8.39  |
| 8                          | 7.31 | 13.87 | 44.83 | 51.17 | 31.33 | 20.65 | 2.54 | 4.37 | 70.37 | 6.52:1  | 665.73 | 19.66 | 7.52 | 2.48 | 2.04 | 11.16 |
| 9                          | 6.22 | 11.40 | 54.83 | 59.83 | 31.10 | 19.59 | 2.18 | 4.53 | 75.47 | 7.85:1  | 492.20 | 18.57 | 5.21 | 3.40 | 2.13 | 9.83  |
| 10                         | 6.46 | 14.73 | 52.67 | 58.00 | 19.52 | 14.56 | 1.87 | 4.67 | 73.17 | 8.69:1  | 541.82 | 18.56 | 7.80 | 2.63 | 1.54 | 8.74  |
| 11                         | 6.77 | 15.23 | 50.00 | 56.00 | 28.82 | 19.38 | 1.78 | 5.40 | 71.07 | 6.73:1  | 485.83 | 18.84 | 5.35 | 3.37 | 2.17 | 9.58  |
| 12                         | 7.41 | 12.17 | 51.83 | 57.83 | 28.26 | 20.10 | 2.71 | 3.87 | 73.00 | 6.35:1  | 596.07 | 17.82 | 6.53 | 2.52 | 2.14 | 10.53 |
| 13                         | 6.85 | 16.13 | 51.17 | 57.00 | 29.44 | 16.10 | 2.53 | 3.63 | 73.17 | 7.70:1  | 520.23 | 21.49 | 8.23 | 2.53 | 2.01 | 9.28  |
| 14                         | 6.90 | 12.07 | 51.33 | 56.00 | 26.16 | 19.07 | 2.34 | 4.03 | 72.83 | 8.05:1  | 460.10 | 19.43 | 4.95 | 3.30 | 2.01 | 9.50  |
| 15                         | 6.84 | 14.47 | 52.17 | 55.50 | 23.22 | 17.65 | 1.92 | 5.30 | 70.77 | 6.67:1  | 512.92 | 18.60 | 5.52 | 2.87 | 1.68 | 10.13 |

Characters as given in table-2.

**Table-13: Intra and inter cluster D<sup>2</sup> values recorded in first year.**

| Cluster | 1            | 2            | 3             | 4             | 5             | 6             |
|---------|--------------|--------------|---------------|---------------|---------------|---------------|
| 1       | <b>70.17</b> | 401.33       | 375.20        | 314.31        | 700.66        | 649.52        |
| 2       |              | <b>72.25</b> | 503.95        | 486.88        | 555.10        | 478.49        |
| 3       |              |              | <b>421.54</b> | 590.57        | 1089.51       | 549.15        |
| 4       |              |              |               | <b>167.81</b> | 357.29        | 719.09        |
| 5       |              |              |               |               | <b>251.74</b> | 889.51        |
| 6       |              |              |               |               |               | <b>504.82</b> |

The value printed in bold indicates intra cluster D<sup>2</sup> values.

**Table-14: Intra and inter cluster D<sup>2</sup> values recorded in second year.**

| Cluster | 1             | 2             | 3             | 4             | 5             | 6             | 7           |
|---------|---------------|---------------|---------------|---------------|---------------|---------------|-------------|
| 1       | <b>146.15</b> | 559.12        | 625.17        | 817.26        | 1922.86       | 1202.31       | 996.73      |
| 2       |               | <b>230.88</b> | 561.09        | 556.27        | 1086.36       | 2076.71       | 691.77      |
| 3       |               |               | <b>297.26</b> | 605.85        | 1005.59       | 1164.23       | 637.75      |
| 4       |               |               |               | <b>385.74</b> | 656.71        | 1836.72       | 706.94      |
| 5       |               |               |               |               | <b>477.39</b> | 3022.67       | 905.84      |
| 6       |               |               |               |               |               | <b>726.43</b> | 1871.50     |
| 7       |               |               |               |               |               |               | <b>0.00</b> |

The value printed in bold indicates intra cluster D<sup>2</sup> values.

divergent (BCBG-1, BCBG-3, BCBG-6 and BCBG-16) from BCBG-17 and BCBG-34). Based on the inter cluster divergence recorded in the second year the inbreds belonging to cluster 5 and cluster 6 were most divergent (BCBG-17 and BCBG-33 from BCBG-1, BCBG-3, BCBG-4 and BCBG-20).

**Contribution of characters to divergence:**

It refers to the forces a character exerts at genotypic level to differentiate to population.

**Rank method:** In this method lowest Rank Total for the character meant its highest contribution towards divergence and vice-versa (Table-15). The top five characters contributed to the divergence of the inbreds in the first year were sex ratio, fruit yield/plant, total soluble solids, 100 seed weight and ascorbic acid content of the fruits, while the top five divergence contributory characters in the second year were ascorbic acid content in the fruit, fruit length, fruit yield/plant, fruit width and total soluble solids.

It is interesting to note that though average divergence of the inbreds and cluster constellation differed in the year, yet the set of characters contributed maximum to the divergence of inbreds emerged more or less consistently both the years. This finding suggested the stability in relative expression of these characters at genotypic level.

**Per cent contribution method:** Contribution of different characters to divergence of the inbreds was also determined through their per cent contribution up to 10<sup>th</sup> rank in each of the pair comparison (Table-15). Although both these rankings matched well, some differences were also apparent.

Considering both these methods of determining the contribution of characters to the divergence of the inbreds the top 6 characters emerged were-

1. Fruit yield /plant
2. Ascorbic acid content of fruit
3. Fruit length
4. Total soluble solid of the fruit
5. Sex ratio
6. Fruit width

Table-15: Contribution of the characters to total divergence of the genotypes.

| No. | Rank Method                                          |                                                     | Per cent contribution              |                               |
|-----|------------------------------------------------------|-----------------------------------------------------|------------------------------------|-------------------------------|
|     | 1 <sup>st</sup> year                                 | 2 <sup>nd</sup> year                                | 1 <sup>st</sup> year               | 2 <sup>nd</sup> year          |
| 1.  | Sex ratio (583)                                      | Ascorbic acid content (595)                         | Fruit yield / plant (46.67)        | Fruit yield / plant (55.24)   |
| 2.  | Fruit yield / plant (591)                            | Fruit length (662)                                  | Ascorbic acid content (23.81)      | Ascorbic acid content (18.09) |
| 3.  | Total soluble solids (601)                           | Fruit yield / plant (699)                           | Sex ratio (20.00)                  | Total soluble solids (9.52)   |
| 4.  | 100 seed weight (710)                                | Fruit width (740)                                   | Fruit length (3.81)                | Fruit length (8.57)           |
| 5.  | Ascorbic acid content (728)                          | Total soluble solids (772)                          | Total soluble solids (2.86)        | Average fruit weight (3.81)   |
| 6.  | No. of fruits / plant (796)                          | No. of fruits / plant (783)                         | Days to male flower opening (1.90) | Fruit width (2.86)            |
| 7.  | Fruit width (853)                                    | No. of seeds / fruit (859)                          | Days to first harvest (0.95)       | Sex ratio (0.95)              |
| 8.  | No. of seeds / fruit (880)                           | Days to 1 <sup>st</sup> female flower opening (917) |                                    | Vine length (0.95)            |
| 9.  | Days to first harvest (919)                          | Sex ratio (962)                                     |                                    |                               |
| 10. | Fruit length (961)                                   | 100 seed weight (1008)                              |                                    |                               |
| 11. | No. of primary branches (981)                        | Total sugar (1045)                                  |                                    |                               |
| 12. | Days to 1 <sup>st</sup> male flower opening (997)    | No. of primary branches (1096)                      |                                    |                               |
| 13. | Total sugar (1080)                                   | Average fruit weight (1130)                         |                                    |                               |
| 14. | Average fruit weight (1113)                          | Days to 1 <sup>st</sup> male flower opening (1483)  |                                    |                               |
| 15. | Vine length (1195)                                   | Days to first harvest (1497)                        |                                    |                               |
| 16. | Days to 1 <sup>st</sup> female flower opening (1292) | Vine length (1519)                                  |                                    |                               |

Values in parentheses indicate per cent contribution

In an earlier study, the characters like fruits/plant, seeds/fruit, fruit length, fruit weight, vine length and fruit set percentage contributed maximum to the genetic divergence of bottle gourd (Mathew *et al.*, 2001).

#### **Genetic verses Geographical diversity:**

In the present study no close correspondence was evident between geographical distribution and genetic divergence of the inbreds, which agreed well to the same findings in bottle gourd (Mathew *et al.*, 2001) and bitter melon (Wahab and Gopalakrishnan, 1993).

This showed that geographic diversity was not adequate as an index of genetic diversity. However, in some cases the inbreds developed from the open pollinated cultivars of the same places cluster together (example cluster 5 and 6 in first year, cluster 4 in second year). This suggested that although geographical was not sole criteria of genetic diversity its importance would be traced.

#### **4.4 Selection of parents on the basis of divergence for development of hybrids:**

The expression of heterosis over mid parent (H) depends on the difference in allele frequency (y) of the parents and dominance affect (d) at various loci i.e.  $H = dy^2$  (Falconer, 1981). Therefore, some level of dominance and genetic diversity are necessary for expression of heterosis. The hybrids produced involving the parents selected on the basis of high genetic divergence may likely to produce transgressive segregates in advanced generations. Therefore, the choice of diverse genotypes with good combining ability is the prerequisite for efficient hybridization programme. However, this seems an optimum level of diversity beyond which heterosis does not increase and it may even decrease due to unfavourable interaction of co-adapted gene complexes, epistasis or physiological incompatibility (Dhilon *et al.*, 2004).

Keeping the relationship between genetic diversity and manifestation of heterosis in view four groups of inbreds have been selected on the basis of inter cluster divergence and average divergence of the inbreds determined in 2 years.

Group 1: BCBG-1

Group 2: BCBG-15

Group 3: BCBG-17

Group 4: BCBG-34

Inter group crossing of the inbred line is expected to produce desirable and heterotic hybrid however final selection of the divergent parental inbreds should be made on the basis of combining abilities and manifestation of specific characters.

Desirable transgressive segregates is also expected through advancement of the hybrids developed through involvement of these parental inbred lines.

### Gene action for different characters

The present study has been undertaken to determine the gene action for <sup>Sixteen</sup> ~~16~~ growth, fruit characters, yield and fruit quality characters employing 10 x 3 line x tester analysis, which allows for testing of additive and dominance genetic variations.

### Analysis of variance for parents and hybrids

Mean for different characters manifested in the parents and hybrids are given in table-16 and table-17. The parents were significantly different for all the characters excepting vine length, total soluble solids and sugar contents of fruits (Table-18). Among the parents, the lines were significantly different for 13 characters and the testers, for 10 characters. Significant divergence among the lines satisfied their choice in such genetic analysis. The parental selections ensured the likelihood of getting variable hybrids. The variance due to parents vs. hybrids under single degree of freedom comparison reflected considerable average heterosis in the hybrids for most of the characters excepting vine length, sex ratio, fruit weight, fruit/plant, ascorbic acid, TSS and sugar contents of fruits. These observation indicate the need of inclusion more divergent parents compared to those employed in the present study to get highly heterotic hybrids. It was mentioned earlier that expression of heterosis over mid parent

Table-16: Mean performance of parents.

| Parents               | 1                     | 2    | 3     | 4     | 5     | 6       | 7     | 8     | 9     | 10   | 11   | 12    | 13     | 14    | 15   | 16   |      |
|-----------------------|-----------------------|------|-------|-------|-------|---------|-------|-------|-------|------|------|-------|--------|-------|------|------|------|
| Lines                 | BCBG-1                | 4.55 | 12.67 | 55.33 | 61.33 | 9.47:1  | 81.00 | 14.67 | 11.40 | 1.83 | 4.68 | 8.20  | 371.97 | 14.10 | 6.76 | 3.35 | 1.62 |
|                       | BCBG-4                | 5.13 | 11.77 | 55.67 | 61.33 | 11.47:1 | 78.47 | 17.61 | 13.97 | 1.66 | 4.46 | 7.42  | 420.00 | 14.83 | 6.62 | 3.27 | 1.75 |
|                       | BCBG-6                | 5.49 | 13.44 | 49.33 | 55.00 | 8.49:1  | 73.87 | 23.09 | 16.36 | 1.83 | 4.65 | 8.50  | 448.40 | 15.65 | 4.96 | 2.73 | 1.69 |
|                       | BCBG-7                | 5.76 | 11.80 | 52.00 | 58.33 | 6.51:1  | 76.00 | 29.30 | 18.51 | 2.24 | 4.23 | 9.42  | 554.33 | 16.22 | 7.70 | 2.83 | 2.33 |
|                       | BCBG-15               | 4.68 | 12.43 | 51.67 | 58.00 | 8.56:1  | 75.67 | 24.78 | 17.40 | 1.95 | 4.51 | 8.79  | 436.30 | 16.21 | 7.01 | 2.67 | 1.84 |
|                       | BCBG-16               | 5.79 | 13.07 | 50.33 | 56.33 | 7.68:1  | 74.67 | 25.75 | 16.53 | 1.95 | 4.34 | 8.49  | 418.67 | 16.22 | 4.01 | 3.43 | 1.81 |
|                       | BCBG-17               | 6.09 | 14.66 | 48.00 | 53.00 | 6.86:1  | 72.00 | 26.33 | 17.63 | 2.04 | 4.26 | 9.10  | 606.77 | 14.53 | 6.46 | 3.21 | 1.98 |
|                       | BCBG-22               | 6.71 | 15.33 | 49.33 | 55.33 | 6.57:1  | 75.67 | 26.30 | 18.11 | 1.74 | 5.39 | 9.46  | 484.30 | 18.83 | 5.29 | 3.27 | 2.10 |
|                       | BCBG-34               | 6.79 | 15.99 | 51.67 | 58.33 | 7.47:1  | 76.33 | 28.77 | 15.07 | 2.53 | 3.70 | 9.36  | 517.60 | 20.37 | 8.10 | 2.40 | 2.00 |
|                       | BCBG-38               | 6.88 | 12.00 | 50.67 | 56.67 | 7.60:1  | 72.33 | 24.92 | 19.83 | 2.26 | 4.00 | 8.97  | 444.03 | 20.13 | 4.84 | 3.26 | 1.94 |
| S.E.(g <sub>i</sub> ) | 0.05                  | 0.11 | 0.32  | 0.27  | 0.02  | 0.34    | 0.27  | 0.24  | 0.03  | 0.05 | 0.08 | 11.52 | 0.05   | 0.06  | 0.04 | 0.03 |      |
| Tester                | BCBG-3                | 5.47 | 12.50 | 53.67 | 60.33 | 8.48:1  | 76.07 | 18.88 | 16.57 | 1.77 | 4.58 | 8.09  | 417.57 | 15.61 | 6.52 | 3.67 | 2.10 |
|                       | BCBG-20               | 5.90 | 13.25 | 52.67 | 61.00 | 8.33:1  | 73.00 | 19.84 | 15.23 | 1.75 | 4.26 | 8.22  | 505.73 | 17.23 | 7.71 | 2.60 | 1.50 |
|                       | BCBG-33               | 6.24 | 12.00 | 51.33 | 57.67 | 6.36:1  | 75.33 | 25.36 | 19.57 | 2.37 | 4.21 | 9.96  | 594.93 | 27.55 | 6.42 | 2.43 | 2.24 |
|                       | S.E.(g <sub>i</sub> ) | 0.02 | 0.05  | 0.15  | 0.13  | 0.01    | 0.16  | 0.13  | 0.11  | 0.01 | 0.03 | 0.04  | 5.43   | 0.02  | 0.03 | 0.02 | 0.01 |

Characters denote 1= Vine length (m) ; 2 = No. of primary branches; 3= Days to male flower opening; 4= Days to female flower opening  
 5= Sex ratio; 6= Days to first harvest; 7= Fruit length (cm); 8= Fruit width (cm); 9= Average fruit weight (kg); 10= No. of fruits per plant;  
 11=Fruit yield/plant ; 12=No. of seeds/fruit ; 13= 100 seed weight (g); 14= Ascorbic acid content (mg/100 g fresh); 15= Total soluble  
 solids (°Brix) ; 16= Total sugar content (%).

Table-17: Mean performance of the hybrids.

| Hybrids                         | 1    | 2     | 3     | 4     | 5    | 6     | 7     | 8     | 9    | 10   | 11    | 12     | 13    | 14   | 15   | 16   |
|---------------------------------|------|-------|-------|-------|------|-------|-------|-------|------|------|-------|--------|-------|------|------|------|
| L <sub>1</sub> X T <sub>1</sub> | 6.68 | 13.97 | 51.33 | 58.00 | 7.32 | 75.67 | 16.72 | 17.80 | 1.67 | 4.45 | 7.36  | 445.40 | 15.30 | 6.96 | 3.40 | 2.05 |
| L <sub>1</sub> X T <sub>2</sub> | 6.87 | 15.28 | 53.00 | 59.67 | 7.33 | 75.67 | 17.52 | 15.92 | 2.63 | 3.58 | 9.40  | 511.27 | 21.30 | 7.24 | 2.90 | 1.86 |
| L <sub>1</sub> X T <sub>3</sub> | 6.53 | 12.43 | 54.33 | 59.67 | 6.43 | 76.00 | 24.25 | 19.53 | 1.74 | 5.45 | 9.50  | 556.73 | 22.40 | 6.53 | 2.13 | 1.95 |
| L <sub>2</sub> X T <sub>1</sub> | 5.76 | 14.44 | 52.33 | 59.00 | 8.40 | 74.67 | 24.40 | 19.21 | 1.90 | 4.32 | 8.12  | 419.53 | 15.37 | 6.25 | 2.77 | 1.60 |
| L <sub>2</sub> X T <sub>2</sub> | 6.34 | 15.38 | 51.67 | 57.67 | 7.82 | 75.00 | 19.18 | 17.33 | 1.99 | 4.39 | 8.93  | 509.23 | 20.15 | 7.62 | 2.50 | 1.70 |
| L <sub>2</sub> X T <sub>3</sub> | 5.35 | 12.14 | 52.00 | 57.67 | 6.43 | 75.67 | 25.14 | 21.30 | 2.26 | 5.83 | 13.20 | 495.60 | 21.43 | 6.37 | 2.00 | 1.64 |
| L <sub>3</sub> X T <sub>1</sub> | 6.25 | 14.27 | 51.00 | 57.67 | 8.05 | 75.67 | 24.65 | 17.87 | 1.83 | 5.07 | 9.26  | 422.53 | 16.11 | 6.96 | 2.40 | 1.76 |
| L <sub>3</sub> X T <sub>2</sub> | 5.56 | 15.24 | 51.00 | 56.00 | 8.20 | 73.33 | 24.93 | 17.37 | 2.14 | 3.89 | 8.32  | 516.53 | 21.81 | 7.15 | 2.73 | 1.89 |
| L <sub>3</sub> X T <sub>3</sub> | 5.81 | 13.44 | 50.00 | 55.00 | 6.84 | 72.00 | 26.30 | 18.73 | 2.24 | 3.60 | 8.10  | 454.00 | 28.32 | 8.09 | 2.60 | 1.99 |
| L <sub>4</sub> X T <sub>1</sub> | 5.76 | 14.71 | 52.67 | 58.00 | 7.37 | 77.33 | 28.00 | 14.10 | 2.79 | 4.73 | 13.20 | 487.70 | 16.65 | 7.37 | 1.90 | 1.80 |
| L <sub>4</sub> X T <sub>2</sub> | 6.28 | 15.20 | 53.00 | 59.67 | 8.20 | 77.33 | 30.53 | 14.00 | 2.07 | 5.33 | 11.06 | 511.87 | 19.76 | 8.13 | 3.03 | 2.14 |
| L <sub>4</sub> X T <sub>3</sub> | 5.50 | 13.80 | 51.00 | 56.00 | 6.58 | 74.33 | 29.55 | 15.54 | 2.30 | 5.45 | 11.73 | 516.67 | 19.54 | 7.13 | 2.57 | 2.14 |
| L <sub>5</sub> X T <sub>1</sub> | 6.24 | 14.22 | 52.00 | 57.00 | 8.19 | 76.33 | 28.50 | 17.24 | 2.32 | 5.17 | 12.02 | 461.26 | 16.54 | 6.77 | 2.73 | 1.74 |
| L <sub>5</sub> X T <sub>2</sub> | 6.22 | 15.20 | 52.33 | 57.00 | 7.98 | 75.00 | 29.42 | 18.10 | 2.45 | 4.52 | 11.03 | 515.53 | 20.30 | 7.97 | 3.47 | 1.70 |
| L <sub>5</sub> X T <sub>3</sub> | 6.88 | 13.54 | 51.33 | 55.67 | 6.44 | 73.33 | 25.61 | 15.62 | 2.56 | 4.15 | 10.55 | 446.47 | 18.52 | 6.85 | 2.87 | 2.10 |

Table-17 (contd.)

| Hybrid<br>s                      | 1    | 2     | 3     | 4     | 5    | 6     | 7     | 8     | 9    | 10   | 11    | 12     | 13    | 14   | 15   | 16   |
|----------------------------------|------|-------|-------|-------|------|-------|-------|-------|------|------|-------|--------|-------|------|------|------|
| L <sub>6</sub> X T <sub>1</sub>  | 5.81 | 13.63 | 51.00 | 56.33 | 7.78 | 74.67 | 25.50 | 18.00 | 2.11 | 3.54 | 7.47  | 446.37 | 16.55 | 6.68 | 2.53 | 2.35 |
| L <sub>6</sub> X T <sub>2</sub>  | 6.40 | 15.37 | 50.00 | 55.67 | 7.80 | 73.67 | 25.23 | 20.33 | 2.17 | 4.04 | 8.78  | 497.07 | 16.31 | 6.76 | 2.50 | 2.28 |
| L <sub>6</sub> X T <sub>3</sub>  | 6.56 | 12.78 | 49.00 | 55.00 | 7.67 | 73.33 | 26.63 | 20.53 | 2.18 | 3.55 | 7.74  | 422.83 | 27.81 | 6.82 | 2.37 | 1.96 |
| L <sub>7</sub> X T <sub>1</sub>  | 7.41 | 20.33 | 47.00 | 56.67 | 6.20 | 74.67 | 32.37 | 19.63 | 2.48 | 5.47 | 13.57 | 647.57 | 25.33 | 7.27 | 2.53 | 2.00 |
| L <sub>7</sub> X T <sub>2</sub>  | 7.71 | 18.40 | 48.00 | 54.00 | 6.30 | 73.00 | 29.40 | 15.61 | 1.98 | 6.15 | 12.17 | 655.50 | 25.55 | 7.82 | 3.60 | 1.95 |
| L <sub>7</sub> X T <sub>3</sub>  | 6.57 | 15.01 | 48.00 | 54.00 | 6.50 | 73.00 | 28.73 | 18.15 | 2.31 | 5.14 | 11.84 | 543.17 | 28.47 | 6.68 | 3.37 | 2.67 |
| L <sub>8</sub> X T <sub>1</sub>  | 6.56 | 15.55 | 54.00 | 59.00 | 6.59 | 77.33 | 27.70 | 18.63 | 1.93 | 5.09 | 9.80  | 315.50 | 19.47 | 7.58 | 3.13 | 1.62 |
| L <sub>8</sub> X T <sub>2</sub>  | 6.49 | 15.89 | 52.00 | 57.67 | 6.34 | 77.33 | 25.37 | 17.70 | 2.16 | 4.52 | 9.77  | 551.07 | 25.50 | 7.49 | 2.70 | 1.82 |
| L <sub>8</sub> X T <sub>3</sub>  | 6.34 | 15.59 | 50.33 | 56.00 | 6.46 | 75.33 | 26.29 | 19.53 | 2.03 | 4.89 | 9.90  | 556.50 | 28.53 | 6.31 | 2.47 | 1.49 |
| L <sub>9</sub> X T <sub>1</sub>  | 7.23 | 16.23 | 52.33 | 57.00 | 7.47 | 75.67 | 26.74 | 16.53 | 2.25 | 4.50 | 10.10 | 530.47 | 21.82 | 7.24 | 2.77 | 1.86 |
| L <sub>9</sub> X T <sub>2</sub>  | 7.34 | 17.53 | 53.33 | 58.33 | 7.20 | 77.00 | 25.71 | 17.60 | 2.13 | 4.94 | 10.43 | 612.73 | 25.47 | 9.41 | 2.30 | 1.60 |
| L <sub>9</sub> X T <sub>3</sub>  | 6.30 | 16.45 | 49.00 | 56.67 | 7.58 | 75.33 | 29.70 | 18.72 | 2.80 | 4.85 | 13.60 | 497.07 | 25.50 | 8.27 | 3.53 | 2.10 |
| L <sub>10</sub> X T <sub>1</sub> | 6.46 | 13.54 | 50.00 | 56.00 | 7.26 | 74.00 | 26.27 | 18.50 | 2.23 | 4.07 | 8.98  | 456.57 | 18.94 | 7.45 | 2.20 | 2.29 |
| L <sub>10</sub> X T <sub>2</sub> | 6.84 | 13.14 | 52.00 | 57.67 | 7.42 | 75.33 | 24.03 | 19.33 | 2.43 | 3.93 | 9.60  | 560.37 | 19.66 | 6.25 | 2.50 | 2.08 |
| L <sub>10</sub> X T <sub>3</sub> | 6.45 | 12.33 | 48.33 | 55.67 | 7.24 | 74.67 | 26.40 | 20.18 | 2.29 | 4.29 | 9.77  | 489.60 | 28.52 | 6.27 | 2.60 | 1.89 |
| S.E.(s <sub>ij</sub> )           | 0.07 | 0.16  | 0.46  | 0.38  | 0.03 | 0.48  | 0.38  | 0.34  | 0.04 | 0.08 | 0.11  | 16.30  | 0.07  | 0.08 | 0.05 | 0.04 |

Characters are given as table-16.

Table-18: Analysis of variance for parents and hybrids for different traits.

| Source of variation | d.f. | Mean sum of squares |         |         |        |        |        |        |        |         |        |        |          |         |        |        |       |
|---------------------|------|---------------------|---------|---------|--------|--------|--------|--------|--------|---------|--------|--------|----------|---------|--------|--------|-------|
|                     |      | 1                   | 2       | 3       | 4      | 5      | 6      | 7      | 8      | 9       | 10     | 11     | 12       | 13      | 14     | 15     | 16    |
| Replication         | 2    | 0.103               | 0.163   | 0.376   | 0.488  | 0.013  | 4.333  | 0.895  | 0.293  | 0.0008  | 0.100  | 0.192  | 1496.3   | 0.096   | 0.009  | 0.028  | 0.100 |
| Parents             | 12   | 1.683               | 5.682*  | 15.444* | 20.63* | 5.969* | 18.05* | 59.31* | 16.29* | 0.2259* | 0.477* | 1.464  | 12487.1* | 39.34*  | 4.560* | 0.514* | 0.177 |
| Line (female)       | 9    | 2.138*              | 6.900*  | 18.652* | 21.37* | 6.939* | 21.86* | 64.91* | 18.11* | 0.217   | 0.606* | 1.229  | 15102.9* | 15.49*  | 5.356* | 0.370* | 0.132 |
| Tester (male)       | 2    | 0.451               | 1.194   | 4.111*  | 9.333* | 4.172* | 7.691* | 36.75* | 14.80* | 0.3724  | 0.121  | 3.256* | 6937.7*  | 125.86* | 1.530  | 1.348* | 0.464 |
| Line vs. tester     | 1    | 0.050               | 3.698   | 9.238*  | 36.62* | 0.831  | 4.441* | 53.98* | 2.856  | 0.0124  | 0.037  | 0.001  | 43.00*   | 80.943* | 3.454  | 0.140  | 0.012 |
| Hybrids             | 29   | 0.981               | 9.725*  | 10.192* | 7.378* | 1.407  | 6.209* | 36.39* | 9.998* | 0.2313  | 0.148  | 10.01* | 14629.8* | 57.024* | 1.559  | 0.593* | 0.204 |
| Parents vs. hybrids | 1    | 10.18*              | 77.489* | 8.414*  | 23.01* | 15.01* | 3.547  | 172.5* | 47.82* | 1.331   | 1.373  | 53.92* | 26443.0* | 449.62* | 19.64* | 2.533* | 0.010 |
| Error               | 84   | 0.028               | 0.149   | 1.285   | 1.107  | 0.024  | 1.806  | 0.789  | 0.599  | 0.0089  | 0.033  | 0.069  | 1331.66  | 0.1327  | 0.051  | 0.019  | 0.016 |

\*Significant at 5% level. Characters denotes as mean of parents table -16.

depends on the difference in allele frequency of the parents i.e. genetic diversity of the parents and dominance effects at various loci (Falconer, 1981). In the present investigation somewhat limited scope is provided to select superior hybrids.

### Combining ability variances and gene effects

The general and specific combining ability are the main criteria of rapid genetic assaying of test genotypes under line x tester analysis. The variance due to line, tester and line x tester were highly significant for most of the characters excepting vine length, fruit weight, fruits/plant, total soluble solids and sugar content of fruits (Table-19). Variances due to sca were considerably higher than that of gca for all the characters. For fruit weight, fruits/plant, TSS and total sugar contents of fruit, both gca and sca variances and concomitantly additive and dominance variances were very low in magnitude. This might have been due to the absence of genetic divergence among the parents involved in the crossing programme for the concerned characters or ~~cancellation of~~ <sup>masking of</sup> gene effects.

The relative importance of gca and sca in determining the progeny performance is better assessed by the predictability ratio which is the proportion of additive genetic variance with respect to total genetic variance. The overwhelming presence of dominance genetic component for all the characters (Table-20) determined in this investigation was in agreement with Sharma *et al.* (1983), Sirohi *et al.* (1986), Sirohi *et al.* (1988), Sharma *et al.* (2002) and Singh *et al.* (2000) for vine length, Janakiram and Sirohi (1995), Sirohi *et al.* (1988) and Singh *et al.* (2000) for day to first male and female flower opening, Maurya and Singh (1994) for sex ratio, Sirohi *et al.* (1988) for fruits/plant, fruit length and fruit yield/plant. Khattra *et al.* (2004), Mohanty (2001) and Mohanty and Prusti (2002) for fruit weight, Sit and Sirohi (2002) for ascorbic acid content of fruits.

Table-19: Analysis of variance for combining ability analysis for different traits.

| Source of variation | d.f. | Mean sum of squares |       |       |       |       |       |       |       |       |       |        |         |        |       |       |       |
|---------------------|------|---------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|---------|--------|-------|-------|-------|
|                     |      | 1                   | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11     | 12      | 13     | 14    | 15    | 16    |
| Replication         | 2    | 0.107               | 0.340 | 0.044 | 0.811 | 0.016 | 3.017 | 0.409 | 0.448 | 0.002 | 0.136 | 0.259  | 2017.77 | 0.018  | 0.004 | 0.028 | 0.078 |
| Line (female)       | 9    | 2.084               | 20.20 | 21.28 | 14.24 | 2.184 | 11.36 | 86.75 | 19.63 | 0.251 | 2.658 | 21.389 | 20750.5 | 70.94  | 2.168 | 0.624 | 0.359 |
| Tester (male)       | 2    | 1.079               | 28.83 | 14.15 | 16.18 | 4.174 | 13.68 | 22.47 | 16.81 | 0.114 | 0.271 | 3.927  | 48531.6 | 336.44 | 3.618 | 0.325 | 0.077 |
| Line vs. tester     | 18   | 0.418               | 2.363 | 4.206 | 2.967 | 0.710 | 2.801 | 12.75 | 4.424 | 0.234 | 1.019 | 4.988  | 7802.66 | 19.019 | 1.026 | 0.608 | 0.140 |
| Error               | 58   | 0.034               | 0.182 | 1.504 | 1.041 | 0.006 | 1.632 | 1.024 | 0.832 | 0.012 | 0.043 | 0.093  | 1903.33 | 0.035  | 0.049 | 0.205 | 0.014 |

Characters denotes as mean of parents table -16.

Table-20: Estimates of combining ability variances.

| Characters                          | Combining ability variances |             |               |               | Genetic components of variance    |                                   | Predictability ratio $(\sigma^2A)/(\sigma^2A) + (\sigma^2D)$ |
|-------------------------------------|-----------------------------|-------------|---------------|---------------|-----------------------------------|-----------------------------------|--------------------------------------------------------------|
|                                     | Cov. (H.S.)                 | Cov. (F.S.) | $\sigma^2GCA$ | $\sigma^2SCA$ | Additive variance ( $\sigma^2A$ ) | Dominant variance ( $\sigma^2D$ ) |                                                              |
| Vine length (m)                     | 0.059                       | 0.247       | 0.059         | 0.51          | 0.24                              | 0.51                              | 0.320                                                        |
| No. of primary branches             | 1.136                       | 2.999       | 1.136         | 2.91          | 4.54                              | 2.91                              | 0.609                                                        |
| Days to first male flower opening   | 0.693                       | 2.286       | 0.693         | 3.60          | 2.77                              | 3.60                              | 0.435                                                        |
| Days to first female flower opening | 0.628                       | 1.898       | 0.628         | 2.57          | 2.51                              | 2.57                              | 0.494                                                        |
| Fruit length (cm)                   | 2.147                       | 8.203       | 2.147         | 15.64         | 8.59                              | 15.64                             | 0.355                                                        |
| Fruit width (cm)                    | 0.708                       | 2.612       | 0.708         | 4.79          | 2.83                              | 4.79                              | 0.371                                                        |
| Average fruit weight (kg)           | 0.003                       | 0.069       | 0.003         | 0.30          | 0.01                              | 0.30                              | 0.034                                                        |
| No. of fruits/plant                 | 0.023                       | 0.371       | 0.023         | 1.30          | 0.09                              | 1.30                              | 0.065                                                        |
| Days to first harvest               | 0.498                       | 1.387       | 0.498         | 1.56          | 1.99                              | 1.56                              | 0.561                                                        |
| No. of seeds per fruit              | 1376.33                     | 4719.10     | 1376.33       | 7865.78       | 5505.31                           | 7865.78                           | 0.412                                                        |
| 100 seed weight (g)                 | 9.47                        | 25.27       | 9.47          | 25.31         | 37.88                             | 25.31                             | 0.599                                                        |
| Vitamin C (mg/100 g fresh)          | 0.096                       | 0.517       | 0.096         | 1.30          | 0.38                              | 1.30                              | 0.226                                                        |
| TSS ° Brix                          | 0.007                       | 0.182       | 0.007         | 0.78          | 0.03                              | 0.78                              | 0.040                                                        |
| Total sugar (%)                     | 0.004                       | 0.050       | 0.004         | 0.17          | 0.02                              | 0.17                              | 0.105                                                        |
| Sex ratio                           | 0.127                       | 0.488       | 0.127         | 0.94          | 0.51                              | 0.94                              | 0.352                                                        |
| Fruit yield /plant (kg)             | 0.393                       | 2.418       | 0.393         | 6.53          | 1.57                              | 6.53                              | 0.194                                                        |

### General combining ability effects of the parents and specific combining ability effects of the hybrids

It was quite expected in view of over whelming dominance effect for all the characters that the parents would reveal comparatively low gca effect because it is the function of additive gene action. Among the lines BCBG 34 and BCBG-7 emerged as the outstanding parent registering significantly positive gca effect for nine and seven characters, respectively including fruit yield/plant.

Among the tester parents, BCBG-20 could be regarded as most promising, which showed significant gca effect for four characters (Table-21).

Magnitudes of sca effects in the hybrids were in general low for all the characters. This was predicted earlier due to revelation of low difference among parents and hybrids for some important characters like vine length, sex ratio, fruit weight, fruits/plant, ascorbic acid, sugar and TSS contents of fruit (Table-22). Any way, the hybrids that registered somewhat higher sca effects were BCBG-4  $\times$  BCG-33, BCBG-7  $\times$  BCBG-3, BCBG-16  $\times$  BCBG-20 and BCBG 34  $\times$  BCBG-33. Among these promising hybrids, outstanding general combiners were involved in three hybrids, BCBG-7  $\times$  BCBG-3, BCBG-16  $\times$  BCBG-20 and BCBG-34  $\times$  BCBG-33. From such crosses in which one of the parents involved were high general combiners for good number of characters, promising segregates may be expected in the advanced generations.

### **Breeding strategy**

Combining ability analysis clearly suggested the overwhelming importance of dominance gene action for all the 16 characters of the crop. Thus the methods, which exploit additive gene action such as pedigree selection method, will not at all be effective. If combination breeding programme, if at all, is to be resorted to, the segregating population should preferably be derived from multiple crosses, which help to bring together co-adapted gene complexes. The four groups of inbred lines (Group 1: BCBG-1; Group 2: BCBG-15; Group 3: BCBG-17; and Group 4: BCBG-34) identified earlier from multivariate analysis will be suitable for such breeding approach.

However, heterosis breeding will be the best strategy to achieve high yielding ability along with improved fruit quality characters. In the recent years, major breakthrough in fruit yield improvement and other quality traits like earliness, fruit shape, etc. could be brought about in all the cucurbits including bottle gourd through hybrid technology. Hybrid seed production in bottle gourd is commercially feasible by bagging of staminate and pistillate flowers and hand

Table-21: *Per se* performance of the parents (bold values) and their GCA effects

| Parents | 1                     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12     | 13      | 14    | 15    | 16    |       |
|---------|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|---------|-------|-------|-------|-------|
| Lines   | BCBG-1                | 4.55  | 12.67 | 55.33 | 61.33 | 9.47  | 81.00 | 14.67 | 11.40 | 1.83  | 4.68  | 8.20   | 371.97  | 14.10 | 6.76  | 3.35  | 1.62  |
|         |                       | 0.27* | -0.94 | 1.78* | 2.13* | -0.22 | 0.72  | -6.53 | -0.20 | -0.20 | -0.14 | -1.42  | 4.81    | -1.90 | -0.28 | 0.11* | 0.02  |
|         | BCBG-4                | 5.13  | 11.77 | 55.67 | 61.33 | 11.47 | 78.47 | 17.61 | 13.97 | 1.66  | 4.46  | 7.42   | 420.00  | 14.83 | 6.62  | 3.27  | 1.75  |
|         |                       | -0.60 | -0.85 | 0.89* | 1.13* | 0.30* | 0.06  | -3.12 | 1.33* | -0.16 | 0.22* | -0.09  | -27.20  | -2.58 | -0.44 | -0.28 | -0.29 |
|         | BCBG-6                | 5.49  | 13.44 | 49.33 | 55.00 | 8.49  | 73.87 | 23.09 | 16.36 | 1.83  | 4.65  | 8.50   | 448.40  | 15.65 | 4.96  | 2.73  | 1.69  |
|         |                       | -0.54 | -0.52 | -0.44 | -0.76 | 0.45* | -1.39 | -0.73 | 0.03  | -0.14 | -0.44 | -1.62  | -37.63  | 0.52* | 0.21* | -0.13 | -0.05 |
|         | BCBG-7                | 5.76  | 11.80 | 52.00 | 58.33 | 6.51  | 76.00 | 29.30 | 18.51 | 2.24  | 4.23  | 9.42   | 554.33  | 16.22 | 7.70  | 2.83  | 2.33  |
|         |                       | -0.57 | -0.27 | 1.11* | 0.91* | 0.13* | 1.28* | 3.33* | -3.41 | 0.17* | 0.54* | 1.82*  | 3.42    | -2.91 | 0.35  | -0.20 | 0.09* |
|         | BCBG-15               | 4.68  | 12.43 | 51.67 | 58.00 | 8.56  | 75.67 | 24.78 | 17.40 | 1.95  | 4.51  | 8.79   | 436.30  | 16.21 | 7.01  | 2.67  | 1.84  |
|         |                       | 0.03  | -0.51 | 0.78* | -0.42 | 0.29* | -0.17 | 1.82* | -0.97 | 0.24* | -0.02 | 1.02*  | -27.58  | -3.11 | 0.01  | 0.32* | -0.09 |
|         | BCBG-16               | 5.79  | 13.07 | 50.33 | 56.33 | 7.68  | 74.67 | 25.75 | 16.53 | 1.95  | 4.34  | 8.49   | 418.67  | 16.22 | 4.01  | 3.43  | 1.81  |
|         |                       | -0.16 | -0.91 | -1.11 | -1.31 | 0.50* | -1.17 | -0.24 | 1.67* | -0.06 | -0.92 | -2.18  | -46.57  | -1.34 | -0.44 | -0.24 | 0.26* |
|         | BCBG-17               | 6.09  | 14.66 | 48.00 | 53.00 | 6.86  | 72.00 | 26.33 | 17.63 | 2.04  | 4.26  | 9.10   | 606.77  | 14.53 | 6.46  | 3.21  | 1.98  |
|         |                       | 0.81* | 3.08* | -3.44 | -2.09 | -0.91 | -1.50 | 4.14* | -0.16 | 0.04  | 0.96* | 2.35*  | 113.42* | 4.89* | 0.07  | 0.46* | 0.27  |
|         | BCBG-22               | 6.71  | 15.33 | 49.33 | 55.33 | 6.57  | 75.67 | 26.30 | 18.11 | 1.74  | 5.39  | 9.46   | 484.30  | 18.83 | 5.29  | 3.27  | 2.10  |
|         |                       | 0.04  | 0.84* | 1.00* | 0.58  | -0.79 | 1.61* | 0.43  | 0.67* | -0.18 | 0.20* | -0.36  | -27.63  | 2.94* | -0.07 | 0.06  | -0.29 |
| BCBG-34 | 6.79                  | 15.99 | 51.67 | 58.33 | 7.47  | 76.33 | 28.77 | 15.07 | 2.53  | 3.70  | 9.36  | 517.60 | 20.37   | 8.10  | 2.40  | 2.00  |       |
|         | 0.55*                 | 1.90* | 0.44  | 0.36  | 0.17* | 0.94* | 1.36* | -0.34 | 0.18* | 0.13* | 1.20* | 44.77* | 2.70*   | 1.11* | 0.16* | -0.08 |       |
| BCBG-38 | 6.88                  | 12.00 | 50.67 | 56.67 | 7.60  | 72.33 | 24.92 | 19.83 | 2.26  | 4.00  | 8.97  | 444.03 | 20.13   | 4.84  | 3.26  | 1.94  |       |
|         | 0.17*                 | -1.83 | -1.00 | -0.53 | 0.06* | -0.39 | -0.46 | 1.38* | 0.11* | -0.54 | -0.72 | 0.19   | 0.81*   | -0.53 | -0.27 | 0.15* |       |
| Tester  | S.E.(g <sub>i</sub> ) | 0.05  | 0.11  | 0.32  | 0.27  | 0.02  | 0.34  | 0.27  | 0.24  | 0.03  | 0.05  | 0.08   | 11.52   | 0.05  | 0.06  | 0.04  | 0.03  |
|         | BCBG-3                | 5.47  | 12.50 | 53.67 | 60.33 | 8.48  | 76.07 | 18.88 | 16.57 | 1.77  | 4.58  | 8.09   | 417.57  | 15.61 | 6.52  | 3.67  | 2.10  |
|         |                       | 0.00  | 0.25* | 0.26  | 0.49* | 0.22* | 0.54* | 0.03  | -0.20 | -0.06 | 0.01  | -0.19  | -38.00  | -3.36 | -0.14 | -0.07 | -0.03 |
|         | BCBG-20               | 5.90  | 13.25 | 52.67 | 61.00 | 8.33  | 73.00 | 19.84 | 15.23 | 1.75  | 4.26  | 8.22   | 505.73  | 17.23 | 7.71  | 2.60  | 1.50  |
|         |                       | 0.19* | 0.83* | 0.52* | 0.36* | 0.21* | 0.21  | -0.89 | -0.63 | 0.00  | -0.10 | -0.23  | 42.13*  | 0.02  | 0.39* | 0.12* | -0.03 |
|         | BCBG-33               | 6.24  | 12.00 | 51.33 | 57.67 | 6.36  | 75.33 | 25.36 | 19.57 | 2.37  | 4.21  | 9.96   | 594.93  | 27.55 | 6.42  | 2.43  | 2.24  |
|         |                       | -0.19 | -1.08 | -0.78 | -0.84 | -0.43 | -0.76 | 0.83* | 0.83* | 0.06* | 0.09* | 0.42*  | -4.13   | 3.34* | -0.26 | -0.05 | 0.06* |
|         | S.E.(g <sub>j</sub> ) | 0.02  | 0.05  | 0.15  | 0.13  | 0.01  | 0.16  | 0.13  | 0.11  | 0.01  | 0.03  | 0.04   | 5.43    | 0.02  | 0.03  | 0.02  | 0.01  |

Characters denotes as mean of parents table -16. \* Denotes significant at 5% level.

Table-22: *Per se* performance of the hybrids (bold values) and their SCA effects.

| Hybrids          | 1           | 2            | 3            | 4            | 5           | 6            | 7            | 8            | 9           | 10          | 11           | 12            | 13           | 14          | 15          | 16          |
|------------------|-------------|--------------|--------------|--------------|-------------|--------------|--------------|--------------|-------------|-------------|--------------|---------------|--------------|-------------|-------------|-------------|
| $L_1 \times T_1$ | <b>6.68</b> | <b>13.97</b> | <b>51.33</b> | <b>58.00</b> | <b>7.32</b> | <b>75.67</b> | <b>16.72</b> | <b>17.80</b> | <b>1.67</b> | <b>4.45</b> | <b>7.36</b>  | <b>445.40</b> | <b>15.30</b> | <b>6.96</b> | <b>3.40</b> | <b>2.05</b> |
|                  | -0.01       | -0.18        | -1.81        | -1.60        | 0.08        | -0.66        | -2.84        | 0.25         | -0.28       | -0.06       | -1.20        | -16.40        | -1.01        | 0.19        | 0.66*       | 0.12*       |
| $L_1 \times T_2$ | <b>6.87</b> | <b>15.28</b> | <b>53.00</b> | <b>59.67</b> | <b>7.33</b> | <b>75.67</b> | <b>17.52</b> | <b>15.92</b> | <b>2.63</b> | <b>3.58</b> | <b>9.40</b>  | <b>511.27</b> | <b>21.30</b> | <b>7.24</b> | <b>2.90</b> | <b>1.86</b> |
|                  | -0.02       | 0.56*        | -0.41        | 0.20         | 0.09        | -0.32        | -1.08        | -1.20        | 0.62*       | -0.81       | 0.87*        | -37.66        | 1.62*        | -0.07       | -0.03       | -0.06       |
| $L_1 \times T_3$ | <b>6.53</b> | <b>12.43</b> | <b>54.33</b> | <b>59.67</b> | <b>6.43</b> | <b>76.00</b> | <b>24.25</b> | <b>19.53</b> | <b>1.74</b> | <b>5.45</b> | <b>9.50</b>  | <b>556.73</b> | <b>22.40</b> | <b>6.53</b> | <b>2.13</b> | <b>1.95</b> |
|                  | 0.03        | -0.38        | 2.22*        | 1.40*        | -0.17*      | 0.98         | 3.92*        | 0.95*        | -0.33       | 0.87*       | 0.33*        | 54.04*        | -0.61        | -0.12       | -0.62       | -0.06       |
| $L_2 \times T_1$ | <b>5.76</b> | <b>14.44</b> | <b>52.33</b> | <b>59.00</b> | <b>8.40</b> | <b>74.67</b> | <b>24.40</b> | <b>19.21</b> | <b>1.90</b> | <b>4.32</b> | <b>8.12</b>  | <b>419.53</b> | <b>15.37</b> | <b>6.25</b> | <b>2.77</b> | <b>1.60</b> |
|                  | -0.06       | 0.20         | 0.08         | 0.40         | 0.63        | 0.99*        | 1.43*        | 0.13         | -0.09       | -0.54       | -1.77        | -17.25        | -0.26        | -0.36       | 0.41*       | -0.02       |
| $L_2 \times T_2$ | <b>6.34</b> | <b>15.38</b> | <b>51.67</b> | <b>57.67</b> | <b>7.82</b> | <b>75.00</b> | <b>19.18</b> | <b>17.33</b> | <b>1.99</b> | <b>4.39</b> | <b>8.93</b>  | <b>509.23</b> | <b>20.15</b> | <b>7.62</b> | <b>2.50</b> | <b>1.70</b> |
|                  | 0.33*       | 0.57*        | -0.86        | -0.80        | 0.06        | -0.32        | -2.83        | -1.32        | -0.07       | -0.36       | -0.93        | -7.68         | 1.15*        | 0.48*       | -0.04       | 0.08        |
| $L_2 \times T_3$ | <b>5.35</b> | <b>12.14</b> | <b>52.00</b> | <b>57.67</b> | <b>6.43</b> | <b>75.67</b> | <b>25.14</b> | <b>21.30</b> | <b>2.26</b> | <b>5.83</b> | <b>13.20</b> | <b>495.60</b> | <b>21.43</b> | <b>6.37</b> | <b>2.00</b> | <b>1.64</b> |
|                  | 0.28*       | -0.77        | 0.78         | 0.40         | -0.69*      | 1.31*        | 1.40*        | 1.19*        | 0.15*       | 0.90*       | 2.70*        | 24.94         | -0.89        | -0.12       | -0.37       | -0.07       |
| $L_3 \times T_1$ | <b>6.25</b> | <b>14.27</b> | <b>51.00</b> | <b>57.67</b> | <b>8.05</b> | <b>75.67</b> | <b>24.65</b> | <b>17.87</b> | <b>1.83</b> | <b>5.07</b> | <b>9.26</b>  | <b>422.53</b> | <b>16.11</b> | <b>6.96</b> | <b>2.40</b> | <b>1.76</b> |
|                  | 0.38*       | -0.30        | 0.08         | 0.96*        | 0.14        | 1.46*        | -0.70        | 0.08         | -0.18       | 0.87*       | 0.89*        | -3.82         | -2.62        | -0.31       | -0.11       | -0.09       |
| $L_3 \times T_2$ | <b>5.56</b> | <b>15.24</b> | <b>51.00</b> | <b>56.00</b> | <b>8.20</b> | <b>73.33</b> | <b>24.93</b> | <b>17.37</b> | <b>2.14</b> | <b>3.89</b> | <b>8.32</b>  | <b>516.53</b> | <b>21.81</b> | <b>7.15</b> | <b>2.73</b> | <b>1.89</b> |
|                  | -0.51       | 0.09         | -0.19        | -0.58        | 0.29        | -0.54        | 0.53         | 0.00         | 0.06        | -0.20       | -0.01        | 10.05         | -0.29        | -0.64       | 0.04        | 0.04        |
| $L_3 \times T_3$ | <b>5.81</b> | <b>13.44</b> | <b>50.00</b> | <b>55.00</b> | <b>6.84</b> | <b>72.00</b> | <b>26.30</b> | <b>18.73</b> | <b>2.24</b> | <b>3.60</b> | <b>8.10</b>  | <b>454.00</b> | <b>28.32</b> | <b>8.09</b> | <b>2.60</b> | <b>1.99</b> |
|                  | 0.13        | 0.21         | 0.11         | -0.38        | -0.43*      | -0.91        | 0.17         | 0.08         | 0.12*       | -0.68       | -0.87        | -6.23         | 2.90*        | 0.95*       | 0.08        | 0.05        |
| $L_4 \times T_1$ | <b>5.76</b> | <b>14.71</b> | <b>52.67</b> | <b>58.00</b> | <b>7.37</b> | <b>77.33</b> | <b>28.00</b> | <b>14.10</b> | <b>2.79</b> | <b>4.73</b> | <b>13.20</b> | <b>487.70</b> | <b>16.65</b> | <b>7.37</b> | <b>1.90</b> | <b>1.80</b> |
|                  | -0.09       | -0.11        | 0.19         | -0.38        | -0.23*      | 0.46         | -1.42        | -0.24        | 0.47*       | -0.45       | 1.39*        | 20.29         | 1.36*        | -0.03       | -0.53       | -0.20       |
| $L_4 \times T_2$ | <b>6.28</b> | <b>15.20</b> | <b>53.00</b> | <b>59.67</b> | <b>8.20</b> | <b>77.33</b> | <b>30.53</b> | <b>14.00</b> | <b>2.07</b> | <b>5.33</b> | <b>11.06</b> | <b>511.87</b> | <b>19.76</b> | <b>8.13</b> | <b>3.03</b> | <b>2.14</b> |
|                  | 0.24*       | -0.20        | 0.26         | 1.42*        | 0.61        | 0.79         | 2.06*        | 0.08         | -0.32       | 0.26*       | -0.71        | -35.67        | 1.09*        | 0.19        | 0.41*       | 0.14*       |
| $L_4 \times T_3$ | <b>5.50</b> | <b>13.80</b> | <b>51.00</b> | <b>56.00</b> | <b>6.58</b> | <b>74.33</b> | <b>29.55</b> | <b>15.54</b> | <b>2.30</b> | <b>5.45</b> | <b>11.73</b> | <b>516.67</b> | <b>19.54</b> | <b>7.13</b> | <b>2.57</b> | <b>2.14</b> |
|                  | -0.16       | 0.31         | -0.44        | -1.04        | -0.37*      | -1.24        | -0.64        | 0.16         | -0.15       | 0.19        | -0.68        | 15.38         | -2.45        | -0.16       | 0.12*       | 0.05        |
| $L_5 \times T_1$ | <b>6.24</b> | <b>14.22</b> | <b>52.00</b> | <b>57.00</b> | <b>8.19</b> | <b>76.33</b> | <b>28.50</b> | <b>17.24</b> | <b>2.32</b> | <b>5.17</b> | <b>12.02</b> | <b>461.26</b> | <b>16.54</b> | <b>6.77</b> | <b>2.73</b> | <b>1.74</b> |
|                  | -0.20       | -0.35        | -0.14        | -0.04        | 0.44        | 0.90*        | 0.60         | 0.46         | -0.06       | 0.55*       | 1.01*        | 24.82         | 1.44*        | -0.29       | -0.22       | -0.08       |

Characters denotes as mean of parents table -16. \* Significant at 5% level..

Table-22 (Contd.).

| Hybrids                         | 1     | 2     | 3     | 4     | 5      | 6     | 7     | 8     | 9     | 10    | 11    | 12      | 13    | 14    | 15    | 16    |
|---------------------------------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|-------|---------|-------|-------|-------|-------|
| L <sub>5</sub> X T <sub>2</sub> | 6.22  | 15.20 | 52.33 | 57.00 | 7.98   | 75.00 | 29.42 | 18.10 | 2.45  | 4.52  | 11.03 | 515.53  | 20.30 | 7.97  | 3.47  | 1.70  |
|                                 | -0.42 | 0.05  | -0.08 | 0.09  | 0.23   | -0.10 | 2.47* | 1.74  | 0.00  | 0.01  | 0.06  | -1.01   | 1.83* | 0.38* | 0.32* | -0.12 |
| L <sub>5</sub> X T <sub>3</sub> | 6.88  | 13.54 | 51.33 | 55.67 | 6.44   | 73.33 | 25.61 | 15.62 | 2.56  | 4.15  | 10.55 | 446.47  | 18.52 | 6.85  | 2.87  | 2.10  |
|                                 | 0.62* | 0.30  | 0.22  | -0.04 | -0.67* | -0.80 | -3.07 | -2.20 | 0.06  | -0.56 | -1.07 | -23.82  | -3.27 | -0.09 | -0.10 | 0.19* |
| L <sub>6</sub> X T <sub>1</sub> | 5.81  | 13.63 | 51.00 | 56.33 | 7.78   | 74.67 | 25.50 | 18.00 | 2.11  | 3.54  | 7.47  | 446.37  | 16.55 | 6.68  | 2.53  | 2.35  |
|                                 | -0.45 | -0.55 | 0.74  | 0.18  | -0.14* | 0.23  | -0.35 | -1.42 | 0.02  | -0.18 | -0.34 | 28.95   | -0.32 | 0.07  | 0.13* | 0.18* |
| L <sub>6</sub> X T <sub>2</sub> | 6.40  | 15.37 | 50.00 | 55.67 | 7.80   | 73.67 | 25.23 | 20.33 | 2.17  | 4.04  | 8.78  | 497.07  | 16.31 | 6.76  | 2.50  | 2.28  |
|                                 | -0.04 | 0.61  | -0.54 | -0.36 | -0.16* | -0.43 | 0.34  | 1.34  | 0.02  | 0.43* | 1.01* | -0.48   | -3.93 | -0.39 | -0.09 | 0.12* |
| L <sub>6</sub> X T <sub>3</sub> | 6.56  | 12.78 | 49.00 | 55.00 | 7.67   | 73.33 | 26.63 | 20.53 | 2.18  | 3.55  | 7.74  | 422.83  | 27.81 | 6.82  | 2.37  | 1.96  |
|                                 | 0.49* | -0.05 | -0.22 | 0.18  | 0.35   | 0.20  | 0.01  | 0.08  | -0.03 | -0.25 | -0.67 | -28.46  | 4.25* | 0.32* | -0.05 | -0.30 |
| L <sub>7</sub> X T <sub>1</sub> | 7.41  | 20.33 | 47.00 | 56.67 | 6.20   | 74.67 | 32.37 | 19.63 | 2.48  | 5.47  | 13.57 | 647.57  | 25.33 | 7.27  | 2.53  | 2.00  |
|                                 | 0.18* | 2.16* | -0.92 | 1.29* | -0.35* | 0.57  | 2.14* | 2.04  | 0.28* | -0.13 | 1.23* | 70.16*  | 2.23* | 0.15  | -0.57 | -0.18 |
| L <sub>7</sub> X T <sub>2</sub> | 7.71  | 18.40 | 48.00 | 54.00 | 6.30   | 73.00 | 29.40 | 15.61 | 1.98  | 6.15  | 12.17 | 655.50  | 25.55 | 7.82  | 3.60  | 1.95  |
|                                 | 0.29* | -0.34 | -0.19 | -1.24 | -0.25* | -0.77 | 0.13  | -1.56 | -0.28 | 0.67  | -0.13 | -2.04   | -0.91 | 0.17  | 0.31* | -0.23 |
| L <sub>7</sub> X T <sub>3</sub> | 6.57  | 15.01 | 48.00 | 54.00 | 6.50   | 73.00 | 28.73 | 18.15 | 2.31  | 5.14  | 11.84 | 543.17  | 28.47 | 6.68  | 3.37  | 2.67  |
|                                 | -0.47 | -1.82 | 1.11* | -0.04 | 0.60   | 0.20  | -2.27 | -0.48 | -0.01 | -0.54 | -1.10 | -68.12  | -1.32 | -0.32 | 0.25* | 0.40* |
| L <sub>8</sub> X T <sub>1</sub> | 6.56  | 15.55 | 54.00 | 59.00 | 6.59   | 77.33 | 27.70 | 18.63 | 1.93  | 5.09  | 9.80  | 315.50  | 19.47 | 7.58  | 3.13  | 1.62  |
|                                 | 0.10  | -0.38 | 1.63* | 0.96* | -0.09* | 0.12  | 1.19* | 0.22  | -0.05 | 0.24* | 0.16* | -120.85 | -1.67 | 0.59  | 0.43* | 0.00  |
| L <sub>8</sub> X T <sub>2</sub> | 6.49  | 15.89 | 52.00 | 57.67 | 6.34   | 77.33 | 25.37 | 17.70 | 2.16  | 4.52  | 9.77  | 551.07  | 25.50 | 7.49  | 2.70  | 1.82  |
|                                 | -0.17 | -0.62 | -0.63 | -0.24 | -0.34* | 0.46  | -0.19 | -0.30 | 0.12* | -0.21 | 0.17  | 34.58   | 0.98* | -0.03 | -0.19 | 0.21* |
| L <sub>8</sub> X T <sub>3</sub> | 6.34  | 15.59 | 50.33 | 56.00 | 6.46   | 75.33 | 26.29 | 19.53 | 2.03  | 4.89  | 9.90  | 556.50  | 28.53 | 6.31  | 2.47  | 1.49  |
|                                 | 0.07  | 1.00* | -1.00 | -0.71 | 0.43   | -0.58 | -1.00 | 0.08  | -0.07 | -0.03 | -0.34 | 86.27*  | 0.69* | 0.56  | -0.25 | -0.21 |
| L <sub>9</sub> X T <sub>1</sub> | 7.23  | 16.23 | 52.33 | 57.00 | 7.47   | 75.67 | 26.74 | 16.53 | 2.25  | 4.50  | 10.10 | 530.47  | 21.82 | 7.24  | 2.77  | 1.86  |
|                                 | 0.26* | -0.76 | 0.52  | -0.82 | -0.16* | -0.88 | -0.70 | -0.88 | -0.08 | -0.28 | -1.09 | 21.71   | 0.91* | -0.93 | -0.03 | 0.03  |
| L <sub>9</sub> X T <sub>2</sub> | 7.34  | 17.53 | 53.33 | 58.33 | 7.20   | 77.00 | 25.71 | 17.60 | 2.13  | 4.94  | 10.43 | 612.73  | 25.47 | 9.41  | 2.30  | 1.60  |
|                                 | 0.22* | -0.03 | 1.26* | 0.64  | -0.43* | 0.79  | -0.78 | 0.61  | -0.27 | 0.28* | -0.72 | 23.85   | 1.19* | 0.71* | -0.69 | -0.22 |

Characters denotes as mean of parents table -16. \* Significant at 5% level..

Table-22 (contd.)

| Hybrids                          | 1     | 2     | 3     | 4     | 5      | 6     | 7     | 8     | 9     | 10    | 11    | 12     | 13    | 14    | 15    | 16    |
|----------------------------------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|
| L <sub>9</sub> X T <sub>3</sub>  | 6.30  | 16.45 | 49.00 | 56.67 | 7.58   | 75.33 | 29.70 | 18.72 | 2.80  | 4.85  | 13.60 | 497.07 | 25.50 | 8.27  | 3.53  | 2.10  |
|                                  | -0.48 | 0.79* | -1.78 | 0.18  | 0.59   | 0.09  | 1.48* | 0.27  | 0.35* | 0.00  | 1.80* | -45.56 | -2.10 | 0.22* | 0.72* | 0.19* |
| L <sub>10</sub> X T <sub>1</sub> | 6.46  | 13.54 | 50.00 | 56.00 | 7.26   | 74.00 | 26.27 | 18.50 | 2.23  | 4.07  | 8.98  | 456.57 | 18.94 | 7.45  | 2.20  | 2.29  |
|                                  | -0.12 | 0.28  | -0.37 | -0.93 | 0.26   | -1.21 | 0.64  | -0.64 | -0.02 | -0.04 | -0.29 | -7.61  | -0.07 | 0.93* | -0.17 | 0.23* |
| L <sub>10</sub> X T <sub>2</sub> | 6.84  | 13.14 | 52.00 | 57.67 | 7.42   | 75.33 | 24.03 | 19.33 | 2.43  | 3.93  | 9.60  | 560.37 | 19.66 | 6.25  | 2.50  | 2.08  |
|                                  | 0.07  | -0.69 | 1.37* | 0.87* | -0.10* | 0.46  | -0.64 | 0.62  | 0.11* | -0.06 | 0.38* | 16.06  | -2.73 | -0.80 | -0.05 | 0.03  |
| L <sub>10</sub> X T <sub>3</sub> | 6.45  | 12.33 | 48.33 | 55.67 | 7.24   | 74.67 | 26.40 | 20.18 | 2.29  | 4.29  | 9.77  | 489.60 | 28.52 | 6.27  | 2.60  | 1.89  |
|                                  | 0.05  | 0.41* | -1.00 | 0.07  | 0.36   | 0.79  | 0.00  | 0.02  | -0.09 | 0.10  | -0.09 | -8.45  | 2.81* | -0.13 | 0.22* | -0.26 |
| S.E.(s <sub>ij</sub> )           | 0.07  | 0.16  | 0.46  | 0.38  | 0.03   | 0.48  | 0.38  | 0.34  | 0.04  | 0.08  | 0.11  | 16.30  | 0.07  | 0.08  | 0.05  | 0.04  |

Characters denotes as mean of parents table -16. \* Significant at 5% level..

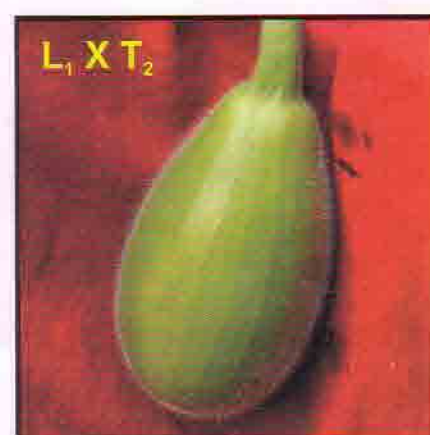
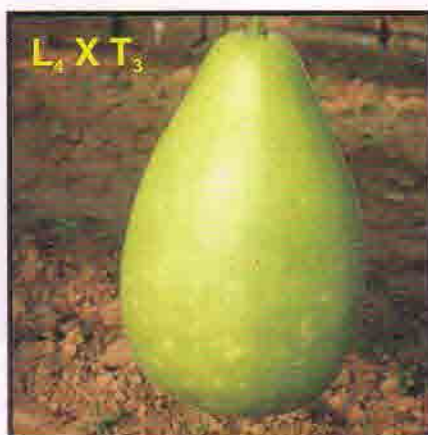
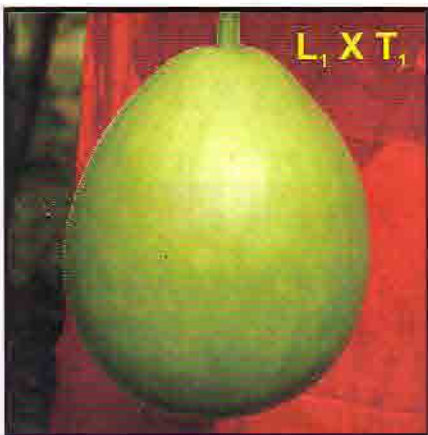
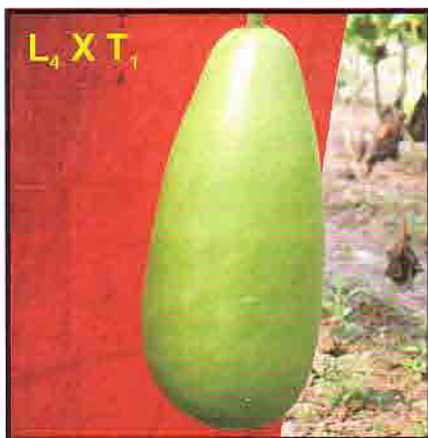


PLATE 6. FRUIT SHAPE AND SIZE OF DIFFERENT HYBRIDS



$L_5 \times T_3$



$L_5 \times T_1$



$L_6 \times T_1$



$L_6 \times T_2$



$L_6 \times T_3$



$L_8 \times T_1$

PLATE 7. FRUIT SHAPE AND SIZE OF DIFFERENT HYBRIDS



PLATE 8. FRUIT SHAPE AND SIZE OF DIFFERENT HYBRIDS

pollination method because of conspicuous flower size, good crossability and high seed number per fruit. Assemblage of wide parental diversity and existence of desired flowering and fruit characters in the parental lines are mandatory to achieve success in hybrid breeding at commercial scale.

### **Manifestation of heterosis**

Variance recorded for the hybrids in the analysis of variance for parents and hybrids (Table-19) suggested the manifestation of considerable average heterosis for most of the characters. Average heterosis though has high implication from quantitative genetics point of view yet bears no value from the angle of commercial utilization of the hybrids. For this reason manifestation of heterosis in the hybrids was determined over mid parent (average heterosis), better parent (heterobeltiosis) and over commercial check hybrid 'Warad' (standard heterosis) for all the sixteen growth, fruit characters, fruit yield and fruit quality parameters (Table-23). Manifestation of heterosis for different characters is discussed on the basis of only heterobeltiosis and standard heterosis.

**Vine length:** Most of the hybrids registered significant heterobeltiosis and standard heterosis for this character.

**Primary branches/plant:** Interestingly, 17 out of 30 hybrid showed significant heterobeltiosis for primary branches/plant but all the hybrid<sup>s</sup> registered significantly high heterotic depression (-15.5 to -33.3%) with respect to the commercial hybrid 'Ward'. It was clear from the observation that the parental combination of 'Warad' was chosen with the objective of increasing the primary branches in the hybrid in view because of its high contribution towards fruit number and ultimately fruit yield.

**Days to first male flower:** Significant negative heterosis, which is desirable, was recorded only in one hybrid with respect to its better (i.e. early flowering) parent. All the hybrids flowered significantly later than the commercial hybrid.

Table-23: Manifestation of heterosis over mid-parent, better parent and commercial check for different characters

| Hybrids                          | Vine length |        |       | Primary branches/plant |        |       | Days to first male flower |        |      |
|----------------------------------|-------------|--------|-------|------------------------|--------|-------|---------------------------|--------|------|
|                                  | MP          | BP     | CC    | MP                     | BP     | CC    | MP                        | BP     | CC   |
| L <sub>1</sub> X T <sub>1</sub>  | 31.38       | 22.12  | 21.0  | 11.01                  | 10.26  | -23.2 | -5.81                     | -4.35  | 16.1 |
| L <sub>1</sub> X T <sub>2</sub>  | 31.42       | 16.32  | 24.5  | 17.86                  | 15.27  | -16.0 | -1.85*                    | 0.63*  | 19.9 |
| L <sub>1</sub> X T <sub>3</sub>  | 21.04       | 4.59   | 18.3  | 0.77*                  | -1.89* | -31.7 | 1.88*                     | 5.84   | 22.9 |
| L <sub>2</sub> X T <sub>1</sub>  | 8.68        | 5.30   | 4.3*  | 18.97                  | 15.49  | -20.7 | -4.27                     | -2.48* | 18.4 |
| L <sub>2</sub> X T <sub>2</sub>  | 14.92       | 14.31  | 14.9  | 22.94                  | 16.07  | -15.5 | -4.62                     | -1.90* | 16.9 |
| L <sub>2</sub> X T <sub>3</sub>  | -5.92       | 4.29   | -3.1* | 2.12*                  | 1.14*  | -33.3 | -2.80*                    | 1.30*  | 17.6 |
| L <sub>3</sub> X T <sub>1</sub>  | 14.02       | 13.77  | 13.2  | 10.05                  | 6.20   | -21.6 | -0.97*                    | 3.38*  | 15.4 |
| L <sub>3</sub> X T <sub>2</sub>  | -2.49*      | 1.15*  | 0.7*  | 14.16                  | 13.34  | -16.3 | 0.00*                     | 3.38*  | 15.4 |
| L <sub>3</sub> X T <sub>3</sub>  | -0.94*      | 5.83*  | 5.3   | 5.69                   | 0.02*  | -26.2 | -0.66*                    | 1.35*  | 13.1 |
| L <sub>4</sub> X T <sub>1</sub>  | 2.58*       | 0.00*  | 4.3*  | 21.07                  | 17.69  | -19.2 | -0.32*                    | 1.28*  | 19.2 |
| L <sub>4</sub> X T <sub>2</sub>  | 7.69        | 6.38   | 13.8  | 21.34                  | 14.69  | -16.5 | 1.27*                     | 1.92*  | 19.9 |
| L <sub>4</sub> X T <sub>3</sub>  | -8.38       | -4.51  | -0.4* | 15.94                  | 14.97  | -24.2 | -1.29*                    | -0.65* | 15.4 |
| L <sub>5</sub> X T <sub>1</sub>  | 22.92       | 14.08  | 13.0  | 14.08                  | 13.76  | -21.9 | -1.27*                    | 0.65*  | 17.6 |
| L <sub>5</sub> X T <sub>2</sub>  | 17.44       | 5.31   | 12.7  | 18.36                  | 14.69  | -16.5 | 0.32*                     | 1.29*  | 18.4 |
| L <sub>5</sub> X T <sub>3</sub>  | 25.87       | 10.14  | 24.6  | 10.89                  | 8.93   | -25.6 | -0.32*                    | 0.00*  | 16.1 |
| L <sub>6</sub> X T <sub>1</sub>  | 3.14*       | 0.29*  | 5.3   | 6.60                   | 4.29*  | -25.1 | -1.92*                    | 1.32*  | 15.4 |
| L <sub>6</sub> X T <sub>2</sub>  | 9.52        | 8.47   | 15.9  | 16.77                  | 15.94  | -15.5 | -2.91                     | -0.66* | 13.1 |
| L <sub>6</sub> X T <sub>3</sub>  | 9.09        | 5.13   | 18.8  | 1.99*                  | -2.16* | -29.8 | -3.61                     | -2.65* | 10.9 |
| L <sub>7</sub> X T <sub>1</sub>  | 28.26       | 21.73  | 34.2  | 49.72                  | 38.72  | 11.7  | -7.54                     | -2.08* | 6.3  |
| L <sub>7</sub> X T <sub>2</sub>  | 28.57       | 26.60  | 39.7  | 31.85                  | 25.54  | 1.1*  | -4.64                     | 0.00*  | 8.6  |
| L <sub>7</sub> X T <sub>3</sub>  | 6.54        | 5.25   | 19.0  | 12.64                  | 2.42*  | -17.5 | -3.36                     | 0.00*  | 8.6  |
| L <sub>8</sub> X T <sub>1</sub>  | 7.75        | -2.19* | 18.8  | 11.74                  | 1.41*  | -14.6 | 4.84                      | 0.62*  | 22.2 |
| L <sub>8</sub> X T <sub>2</sub>  | 2.88*       | -3.28* | 17.6  | 11.15                  | 3.61*  | -12.7 | 1.96*                     | 5.41   | 17.6 |
| L <sub>8</sub> X T <sub>3</sub>  | -2.08*      | -5.47  | 14.9  | 14.10                  | 1.70*  | -14.3 | 0.00*                     | 2.03*  | 13.9 |
| L <sub>9</sub> X T <sub>1</sub>  | 18.00       | 6.53   | 31.0  | 13.97                  | 1.54*  | -10.8 | -0.63*                    | 1.29*  | 18.4 |
| L <sub>9</sub> X T <sub>2</sub>  | 16.33       | 8.74   | 33.7  | 19.90                  | 9.65   | -3.7* | 2.24                      | 3.23*  | 20.7 |
| L <sub>9</sub> X T <sub>3</sub>  | -3.32*      | -7.22  | 14.1  | 17.54                  | 2.88*  | -9.6  | -4.85                     | -4.55  | 10.9 |
| L <sub>10</sub> X T <sub>1</sub> | 4.67*       | -6.06  | 17.0  | 10.53                  | 8.32   | -25.6 | -4.15                     | -1.32* | 13.1 |
| L <sub>10</sub> X T <sub>2</sub> | 7.07        | -0.53* | 23.9  | 4.07*                  | -0.86* | -27.8 | 0.65*                     | 2.63   | 17.6 |
| L <sub>10</sub> X T <sub>3</sub> | -1.70*      | -6.25  | 16.8  | 2.78*                  | 2.78*  | -32.3 | -5.23                     | -4.61  | 9.3  |
| CD (P=0.05)                      | 0.23        | 0.27   | 0.27  | 0.54                   | 0.62   | 0.62  | 1.60                      | 1.84   | 1.84 |

\* Denotes only non-significant values at 5% level

Table-23 (Contd.)

| Hybrids                          | Days to first female flower |        |       | Sex ratio |        |       | Days to first harvest |        |      |
|----------------------------------|-----------------------------|--------|-------|-----------|--------|-------|-----------------------|--------|------|
|                                  | MP                          | BP     | CC    | MP        | BP     | CC    | MP                    | BP     | CC   |
| L <sub>1</sub> X T <sub>1</sub>  | -4.66                       | -3.87  | 10.69 | -18.41    | -3.65  | 14.4  | -3.65                 | -0.53* | 11.0 |
| L <sub>1</sub> X T <sub>2</sub>  | -2.45                       | -2.19* | 13.87 | -17.61    | -11.97 | 14.5  | -1.73*                | 3.65   | 11.0 |
| L <sub>1</sub> X T <sub>3</sub>  | 0.28*                       | 3.47   | 13.87 | -18.80    | 1.00*  | 0.5*  | -2.77                 | 0.88*  | 11.4 |
| L <sub>2</sub> X T <sub>1</sub>  | -3.01                       | -2.21* | 12.60 | -15.79    | -0.90* | 31.3  | -3.36                 | -1.84* | 9.5  |
| L <sub>2</sub> X T <sub>2</sub>  | -5.72                       | -5.98  | 10.06 | -21.01    | -6.08  | 22.2  | -0.97*                | 2.74*  | 10.0 |
| L <sub>2</sub> X T <sub>3</sub>  | -3.08                       | 0.00*  | 10.06 | -27.94    | 1.00*  | 0.5*  | -1.60*                | 0.44*  | 11.0 |
| L <sub>3</sub> X T <sub>1</sub>  | 0.00*                       | 4.85   | 10.06 | -5.09     | -4.99  | 25.8  | 0.93*                 | 2.44*  | 11.0 |
| L <sub>3</sub> X T <sub>2</sub>  | -3.45                       | 1.82*  | 6.87  | -2.50*    | -1.52* | 28.1  | -0.14*                | 0.46*  | 7.5  |
| L <sub>3</sub> X T <sub>3</sub>  | -2.37*                      | 0.00*  | 4.96  | -7.96     | 7.44   | 6.9   | -3.49                 | -2.53* | 5.6  |
| L <sub>4</sub> X T <sub>1</sub>  | -2.24*                      | 0.57*  | 10.69 | -1.69*    | 13.16  | 15.2  | 1.71*                 | 1.75*  | 13.4 |
| L <sub>4</sub> X T <sub>2</sub>  | 0.00*                       | 2.29*  | 13.87 | 10.54     | 25.96  | 28.1  | 3.80                  | 5.94   | 13.4 |
| L <sub>4</sub> X T <sub>3</sub>  | -3.45                       | -2.89* | 6.87  | 2.18*     | 3.35*  | 2.8*  | -1.76*                | -1.33* | 9.0  |
| L <sub>5</sub> X T <sub>1</sub>  | -3.66                       | -1.72* | 8.78  | -3.83     | -3.34* | 28.0  | 0.62*                 | 0.88*  | 11.9 |
| L <sub>5</sub> X T <sub>2</sub>  | -4.20                       | -1.72* | 8.78  | -5.45     | -4.12  | 24.7  | 0.90*                 | 2.74*  | 10.0 |
| L <sub>5</sub> X T <sub>3</sub>  | -3.75                       | -3.47  | 6.24  | -13.65    | 1.26*  | 0.6*  | -2.87                 | -2.65* | 7.5  |
| L <sub>6</sub> X T <sub>1</sub>  | -3.43                       | -0.00* | 7.50  | -3.63     | 1.39*  | 21.6  | -0.93*                | 0.00*  | 9.5  |
| L <sub>6</sub> X T <sub>2</sub>  | -5.11                       | -1.18* | 6.24  | -2.48*    | 1.65*  | 21.9  | -0.23*                | 0.91*  | 8.0  |
| L <sub>6</sub> X T <sub>3</sub>  | -3.51                       | -2.37* | 4.96  | 9.21      | 20.48  | 19.8  | -0.22*                | -1.79* | 7.5  |
| L <sub>7</sub> X T <sub>1</sub>  | 0.00*                       | 6.92   | 8.15  | -19.17    | -9.66  | -3.1* | 0.86*                 | 3.70   | 9.5  |
| L <sub>7</sub> X T <sub>2</sub>  | -5.26                       | 1.89*  | 3.05  | -17.05    | -8.22  | -1.6* | 0.69*                 | 1.39*  | 7.0  |
| L <sub>7</sub> X T <sub>3</sub>  | -2.41*                      | 1.89*  | 3.05  | -1.71*    | 2.15*  | 1.6*  | -0.90*                | 1.39*  | 7.0  |
| L <sub>8</sub> X T <sub>1</sub>  | 2.02*                       | 6.63   | 12.60 | -12.47    | 0.20*  | 3.0*  | 1.93*                 | 2.20*  | 13.4 |
| L <sub>8</sub> X T <sub>2</sub>  | -0.86*                      | 4.22   | 10.06 | -14.94    | -3.60  | -0.9* | 4.04                  | 5.94   | 13.4 |
| L <sub>8</sub> X T <sub>3</sub>  | -0.88*                      | 1.20*  | 6.87  | -0.13*    | 1.53*  | 0.9*  | -0.22*                | 0.00*  | 10.5 |
| L <sub>9</sub> X T <sub>1</sub>  | -3.93                       | -2.29* | 8.78  | -6.35     | -0.04* | 16.7  | -0.70*                | -0.53* | 11.0 |
| L <sub>9</sub> X T <sub>2</sub>  | -2.23*                      | 0.00*  | 11.32 | -8.84     | -3.61  | 12.5  | 3.12                  | 5.48   | 12.9 |
| L <sub>9</sub> X T <sub>3</sub>  | -2.30*                      | -1.73* | 8.15  | 9.54      | 1.43*  | 18.4  | -0.66*                | 0.00*  | 10.5 |
| L <sub>10</sub> X T <sub>1</sub> | -4.27                       | -1.18* | 6.87  | -9.64     | -4.43  | 13.4  | -0.27*                | 2.30*  | 8.5  |
| L <sub>10</sub> X T <sub>2</sub> | -1.98*                      | 1.78*  | 10.06 | -6.78     | -2.32* | 15.9  | 3.67                  | 4.15   | 10.5 |
| L <sub>10</sub> X T <sub>3</sub> | -2.62                       | -1.76* | 6.24  | 3.70      | 13.78  | 13.1  | 1.13*                 | 3.23   | 9.5  |
| CD (P=0.05)                      | 1.48                        | 1.71   | 1.71  | 0.22      | 0.25   | 0.25  | 0.19                  | 0.21   | 0.21 |

\* Denotes only non-significant values at 5% level

Table-23 (Contd.)

| Hybrids                          | Fruit length |        |       | Fruit width |        |       | Average fruit weight |        |       |
|----------------------------------|--------------|--------|-------|-------------|--------|-------|----------------------|--------|-------|
|                                  | MP           | BP     | CC    | MP          | BP     | CC    | MP                   | BP     | CC    |
| L <sub>1</sub> X T <sub>1</sub>  | 0.32*        | -11.4  | -56.2 | 27.29       | 7.44*  | 74.5  | -6.99                | -8.52  | 33.6  |
| L <sub>1</sub> X T <sub>2</sub>  | 1.56*        | -11.68 | -54.1 | 19.55       | 4.51*  | 56.1  | 47.39                | 44.16  | 110.4 |
| L <sub>1</sub> X T <sub>3</sub>  | 21.16        | -4.39* | -36.5 | 26.12       | -0.20* | 91.5  | -16.83               | -26.34 | 39.2  |
| L <sub>2</sub> X T <sub>1</sub>  | 33.75        | 29.24  | -36.1 | 25.83       | 15.96  | 88.3  | 10.90                | 7.66   | 52.0  |
| L <sub>2</sub> X T <sub>2</sub>  | 2.45*        | -3.31* | -49.8 | 18.70       | 13.76  | 69.9  | 16.42                | 13.65  | 59.2  |
| L <sub>2</sub> X T <sub>3</sub>  | 17.01        | -0.88* | -34.2 | 27.03       | 8.84   | 108.8 | 12.32                | -4.37* | 80.8  |
| L <sub>3</sub> X T <sub>1</sub>  | 17.46        | 6.76   | -35.5 | 8.53        | 7.85   | 75.2  | 1.58*                | -0.18* | 46.4  |
| L <sub>3</sub> X T <sub>2</sub>  | 16.17        | 7.98   | -34.7 | 9.95        | 6.17*  | 70.3  | 19.48                | 16.76  | 71.2  |
| L <sub>3</sub> X T <sub>3</sub>  | 8.56         | 3.69   | -31.2 | 4.29*       | -4.28* | 83.6  | 7.23                 | -4.93* | 80.0  |
| L <sub>4</sub> X T <sub>1</sub>  | 16.22        | -4.45* | -26.7 | -19.60      | -14.89 | 38.2  | 39.20                | 24.41  | 123.2 |
| L <sub>4</sub> X T <sub>2</sub>  | 24.26        | 4.19*  | -20.1 | -17.20      | -24.37 | 37.3  | 4.01*                | -7.50  | 65.6  |
| L <sub>4</sub> X T <sub>3</sub>  | 8.11         | 0.84*  | -22.6 | -18.36      | -20.59 | 52.4  | -0.22*               | -2.82* | 84.0  |
| L <sub>5</sub> X T <sub>1</sub>  | 30.54        | 15.00  | -25.4 | 1.51*       | -0.92* | 69.0  | 25.22                | 19.43  | 85.6  |
| L <sub>5</sub> X T <sub>2</sub>  | 31.87        | 18.71  | -23.0 | 10.93       | 4.02*  | 77.5  | 32.67                | 25.86  | 96.0  |
| L <sub>5</sub> X T <sub>3</sub>  | 2.14*        | 0.97*  | -33.0 | -15.50      | -20.18 | 53.1  | 19.30                | 8.72   | 105.6 |
| L <sub>6</sub> X T <sub>1</sub>  | 14.27        | -3.97  | -33.2 | 8.76        | 8.65   | 76.5  | 13.54                | 8.21   | 68.8  |
| L <sub>6</sub> X T <sub>2</sub>  | 10.70        | -2.01* | -34.0 | 28.02       | 22.98  | 99.3  | 17.58                | 11.45  | 73.6  |
| L <sub>6</sub> X T <sub>3</sub>  | 4.21*        | 3.43*  | -30.3 | 13.75       | 4.92*  | 101.3 | 1.16*                | -7.75  | 74.4  |
| L <sub>7</sub> X T <sub>1</sub>  | 43.17        | 22.91  | -15.3 | 14.80       | 11.32  | 92.5  | 30.18                | 21.39  | 98.4  |
| L <sub>7</sub> X T <sub>2</sub>  | 27.36        | 11.65  | -23.0 | -5.01*      | -11.47 | 53.0  | 4.59*                | -3.00* | 58.4  |
| L <sub>7</sub> X T <sub>3</sub>  | 11.16        | 9.11   | -24.8 | -2.43*      | -7.26  | 77.9  | 4.90*                | -2.27* | 84.8  |
| L <sub>8</sub> X T <sub>1</sub>  | 22.62        | 5.32   | -27.5 | 7.47        | 2.89*  | 82.6  | 9.99                 | 9.06   | 54.4  |
| L <sub>8</sub> X T <sub>2</sub>  | 9.96         | -3.55* | -33.6 | 6.17*       | -2.26* | 73.5  | 24.02                | 23.66  | 72.8  |
| L <sub>8</sub> X T <sub>3</sub>  | 1.77*        | -0.04* | -31.2 | 3.68*       | -0.19* | 91.5  | -1.22*               | -14.37 | 62.4  |
| L <sub>9</sub> X T <sub>1</sub>  | 12.23        | -7.07  | -30.0 | 4.51*       | 0.22*  | 62.1  | 4.58*                | -11.15 | 80.0  |
| L <sub>9</sub> X T <sub>2</sub>  | 5.78         | -10.65 | -32.7 | 16.17       | 15.54  | 72.5  | -0.45*               | -15.82 | 70.4  |
| L <sub>9</sub> X T <sub>3</sub>  | 9.72         | 3.22*  | -22.3 | 8.09        | -4.34* | 83.5  | 14.56                | 10.94  | 124.0 |
| L <sub>10</sub> X T <sub>1</sub> | 19.95        | 5.42*  | -31.2 | 1.65*       | -6.72  | 81.4  | 11.02                | -1.03* | 78.4  |
| L <sub>10</sub> X T <sub>2</sub> | 7.40         | -3.55* | -37.1 | 10.27       | -2.52* | 89.5  | 21.57                | 7.83   | 94.4  |
| L <sub>10</sub> X T <sub>3</sub> | 5.01         | 4.09*  | -30.9 | 2.44*       | 1.76*  | 97.8  | -0.94*               | -0.08* | 83.2  |
| CD<br>(P=0.05)                   | 1.35         | 1.45   | 1.45  | 1.09        | 1.26   | 1.26  | 0.14                 | 0.15   | 0.15  |

\* Denotes only non-significant values at 5% level

Table-23 (Contd.)

| Hybrids                          | No. of fruits/plant |        |       | Fruit yield/plant |        |       |
|----------------------------------|---------------------|--------|-------|-------------------|--------|-------|
|                                  | MP                  | BP     | CC    | BP                | MP     | CC    |
| L <sub>1</sub> X T <sub>1</sub>  | -3.89*              | -4.91* | -57.0 | -9.65             | -9.06  | -43.2 |
| L <sub>1</sub> X T <sub>2</sub>  | -19.84              | -23.43 | -65.4 | 14.43             | 14.27  | -27.4 |
| L <sub>1</sub> X T <sub>3</sub>  | 22.68               | 16.52  | -47.4 | 4.58*             | -4.66  | -26.6 |
| L <sub>2</sub> X T <sub>1</sub>  | -4.32*              | -5.60* | -58.3 | 4.71*             | 0.35*  | -37.3 |
| L <sub>2</sub> X T <sub>2</sub>  | 0.65*               | -1.57* | -57.6 | 14.11             | 8.53   | -31.0 |
| L <sub>2</sub> X T <sub>3</sub>  | 34.62               | 30.89  | -43.7 | 51.96             | 33.58  | 1.9*  |
| L <sub>3</sub> X T <sub>1</sub>  | 9.97                | 9.18   | -51.1 | 11.58             | 8.90   | -28.5 |
| L <sub>3</sub> X T <sub>2</sub>  | -12.57              | -16.21 | -62.5 | -0.56*            | -2.20* | -35.8 |
| L <sub>3</sub> X T <sub>3</sub>  | -18.71              | -22.53 | -65.3 | -12.22            | -18.64 | -37.5 |
| L <sub>4</sub> X T <sub>1</sub>  | 7.45                | 3.35*  | -54.3 | 50.76             | 40.16  | 1.9*  |
| L <sub>4</sub> X T <sub>2</sub>  | 25.64               | 25.20  | -48.6 | 25.38             | 17.43  | -14.6 |
| L <sub>4</sub> X T <sub>3</sub>  | 29.07               | 28.76  | -47.4 | 21.07             | 17.78  | -9.4  |
| L <sub>5</sub> X T <sub>1</sub>  | 13.78               | 12.95  | -50.1 | 42.35             | 35.68  | -7.2  |
| L <sub>5</sub> X T <sub>2</sub>  | 3.12*               | 0.22*  | -56.4 | 29.57             | 25.37  | -14.8 |
| L <sub>5</sub> X T <sub>3</sub>  | -4.93*              | -8.12  | -59.9 | 12.50             | 5.90   | -18.5 |
| L <sub>6</sub> X T <sub>1</sub>  | -20.58              | -22.63 | -65.8 | -9.95             | -12.05 | -42.3 |
| L <sub>6</sub> X T <sub>2</sub>  | -6.08               | -6.98  | -61.0 | 5.07              | 3.42*  | -32.2 |
| L <sub>6</sub> X T <sub>3</sub>  | -16.99              | -18.27 | -65.7 | -16.13            | -22.32 | -40.2 |
| L <sub>7</sub> X T <sub>1</sub>  | 23.78               | 19.51  | -47.2 | 57.80             | 49.08  | 4.8   |
| L <sub>7</sub> X T <sub>2</sub>  | 44.39               | 44.33  | -40.6 | 40.50             | 33.74  | -6.0  |
| L <sub>7</sub> X T <sub>3</sub>  | 21.29               | 20.49  | -50.4 | 24.28             | 18.91  | -8.6  |
| L <sub>8</sub> X T <sub>1</sub>  | 2.07*               | -5.57  | -50.9 | 11.60             | 3.55*  | -24.3 |
| L <sub>8</sub> X T <sub>2</sub>  | -6.36               | -16.15 | -56.4 | 10.45             | 3.23*  | -24.6 |
| L <sub>8</sub> X T <sub>3</sub>  | 1.91*               | -9.22  | -52.8 | 1.95*             | -0.61* | -23.6 |
| L <sub>9</sub> X T <sub>1</sub>  | 8.57                | -1.82* | -56.6 | 15.78             | 7.97   | -22.0 |
| L <sub>9</sub> X T <sub>2</sub>  | 24.07               | 15.96  | -52.3 | 18.69             | 11.50  | -19.5 |
| L <sub>9</sub> X T <sub>3</sub>  | 22.58               | 15.20  | -53.2 | 40.76             | 36.50  | 5.0   |
| L <sub>10</sub> X T <sub>1</sub> | -5.24*              | -11.21 | -60.7 | 5.22              | 0.09*  | -30.7 |
| L <sub>10</sub> X T <sub>2</sub> | -4.80*              | -7.67  | -62.1 | 11.72             | 7.08   | -25.9 |
| L <sub>10</sub> X T <sub>3</sub> | 4.38*               | 1.82*  | -58.6 | 3.27              | -1.87* | -24.6 |
| CD<br>(P=0.05)                   | 0.26                | 0.30   | 0.30  | 0.37              | 0.42   | 0.42  |

\* Denotes only non-significant values at 5% level

Table-23 (Contd.)

| Hybrids                          | No. of seeds /fruit |        |       | 100 seed weight |        |       |
|----------------------------------|---------------------|--------|-------|-----------------|--------|-------|
|                                  | MP                  | BP     | CC    | MP              | BP     | CC    |
| L <sub>1</sub> X T <sub>1</sub>  | 14.60               | 8.34*  | 2.3*  | 3.01*           | -1.96* | -31.7 |
| L <sub>1</sub> X T <sub>2</sub>  | 16.50               | 1.09*  | 15.6  | 35.98           | 23.62  | -4.9  |
| L <sub>1</sub> X T <sub>3</sub>  | 28.44               | 12.49  | 25.9  | 7.56            | -18.69 | 0.0*  |
| L <sub>2</sub> X T <sub>1</sub>  | 0.18*               | -0.11* | -5.1* | 0.96*           | -1.54* | -31.4 |
| L <sub>2</sub> X T <sub>2</sub>  | 10.02*              | 0.69*  | 15.2  | 25.70           | 16.94  | -10.0 |
| L <sub>2</sub> X T <sub>3</sub>  | 8.34*               | 0.13*  | 12.1  | 1.14*           | -22.20 | -4.3  |
| L <sub>3</sub> X T <sub>1</sub>  | -2.41*              | -5.77* | -4.4* | 3.06*           | 2.92*  | -28.1 |
| L <sub>3</sub> X T <sub>2</sub>  | 8.27*               | 2.14*  | 16.8  | 32.65           | 26.56  | -2.6* |
| L <sub>3</sub> X T <sub>3</sub>  | -3.75*              | -8.27* | 2.7*  | 31.13           | 2.81*  | 26.4  |
| L <sub>4</sub> X T <sub>1</sub>  | 0.36*               | -12.02 | 10.3  | 4.64            | 2.65*  | -25.7 |
| L <sub>4</sub> X T <sub>2</sub>  | -3.43*              | -7.66* | 15.8  | 18.10           | 14.64  | -11.8 |
| L <sub>4</sub> X T <sub>3</sub>  | -1.52*              | -6.79* | 16.8  | -10.71          | -29.06 | -12.8 |
| L <sub>5</sub> X T <sub>1</sub>  | 8.03*               | 5.71*  | 4.3*  | 3.94            | 1.99*  | -26.2 |
| L <sub>5</sub> X T <sub>2</sub>  | 9.45*               | 1.94*  | 16.6  | 21.37           | 17.78  | -9.4  |
| L <sub>5</sub> X T <sub>3</sub>  | -4.11*              | -9.79* | 1.0*  | -15.38          | -32.79 | -17.3 |
| L <sub>6</sub> X T <sub>1</sub>  | 6.76*               | 6.62*  | 0.9*  | 4.01*           | 2.03*  | -26.1 |
| L <sub>6</sub> X T <sub>2</sub>  | 7.54*               | -1.71* | 12.4  | -2.48*          | -5.34  | -27.2 |
| L <sub>6</sub> X T <sub>3</sub>  | -7.44*              | -14.57 | -4.4  | 27.08           | 0.96*  | 24.2  |
| L <sub>7</sub> X T <sub>1</sub>  | 26.44               | 6.72*  | 46.4  | 68.06           | 62.28  | 13.1  |
| L <sub>7</sub> X T <sub>2</sub>  | 17.84               | 8.03*  | 48.2  | 60.88           | 48.28  | 14.1  |
| L <sub>7</sub> X T <sub>3</sub>  | -1.39*              | -10.48 | 22.8  | 35.32           | 3.35   | 27.1  |
| L <sub>8</sub> X T <sub>1</sub>  | -30.03              | -34.85 | -28.7 | 13.09           | 3.40   | -13.1 |
| L <sub>8</sub> X T <sub>2</sub>  | 11.32               | 8.96*  | 24.6  | 41.42           | 35.42  | 13.8  |
| L <sub>8</sub> X T <sub>3</sub>  | 13.66               | 12.44  | 25.8  | 23.03           | 3.57   | 27.4  |
| L <sub>9</sub> X T <sub>1</sub>  | 13.45               | 2.49*  | 20.0  | 21.31           | 7.14   | -2.6* |
| L <sub>9</sub> X T <sub>2</sub>  | 19.75               | 21.16  | 38.6  | 35.46           | 25.04  | 13.7  |
| L <sub>9</sub> X T <sub>3</sub>  | -1.82*              | -3.97* | 12.4  | 6.43            | -7.44  | 13.8  |
| L <sub>10</sub> X T <sub>1</sub> | 5.98*               | 2.82*  | 3.2*  | 6.00            | -5.91  | -15.4 |
| L <sub>10</sub> X T <sub>2</sub> | 18.00               | 10.80  | 26.7  | 5.22            | -2.35  | -12.2 |
| L <sub>10</sub> X T <sub>3</sub> | 4.28*               | -1.08* | 10.7  | 19.62           | 3.51   | 27.3  |
| CD<br>(P=0.05)                   | 51.60               | 59.40  | 59.40 | 0.51            | 0.59   | 0.59  |

\* Denotes only non-significant values at 5% level

Table-23 (Contd.)

| Hybrids                          | Ascorbic acid content |        |       | TSS    |        |       | Total sugar |        |       |
|----------------------------------|-----------------------|--------|-------|--------|--------|-------|-------------|--------|-------|
|                                  | MP                    | BP     | CC    | MP     | BP     | CC    | MP          | BP     | CC    |
| L <sub>1</sub> X T <sub>1</sub>  | 4.79                  | 2.91*  | -11.5 | -3.04* | -7.27  | 6.2   | 10.22       | -2.38* | 0.0*  |
| L <sub>1</sub> X T <sub>2</sub>  | 0.06*                 | -6.05  | -7.9  | -2.47* | -13.35 | -9.4  | 19.23       | 14.81  | -9.3  |
| L <sub>1</sub> X T <sub>3</sub>  | -0.92*                | -3.43* | -16.9 | -26.14 | -36.25 | -33.4 | 1.04*       | -12.95 | -4.9* |
| L <sub>2</sub> X T <sub>1</sub>  | -4.82                 | -5.53  | -20.5 | -20.19 | -24.55 | -13.4 | -16.88      | -23.81 | -22.0 |
| L <sub>2</sub> X T <sub>2</sub>  | 6.45                  | -1.05* | -3.1  | -14.77 | -23.47 | -21.9 | 4.62*       | -2.86* | -17.1 |
| L <sub>2</sub> X T <sub>3</sub>  | -2.28*                | -3.75* | -19.0 | -29.78 | -38.78 | -37.5 | -17.79      | -6.29* | -20.0 |
| L <sub>3</sub> X T <sub>1</sub>  | 21.19                 | 6.68   | -11.5 | -25.00 | -34.55 | -25.0 | -6.95       | -16.03 | -14.1 |
| L <sub>3</sub> X T <sub>2</sub>  | 12.93                 | -7.19  | -9.0  | 2.50*  | 0.00*  | -14.7 | 18.70       | 12.03  | -7.8* |
| L <sub>3</sub> X T <sub>3</sub>  | 42.14                 | 25.96  | 2.9   | 0.71*  | -4.88  | -18.8 | 1.10*       | -11.31 | -2.9* |
| L <sub>4</sub> X T <sub>1</sub>  | 3.65*                 | -4.31* | -6.2  | -41.51 | -48.18 | -40.6 | -18.67      | -22.64 | -12.2 |
| L <sub>4</sub> X T <sub>2</sub>  | 5.51                  | 5.50   | 3.4   | 11.72  | 7.18*  | -5.3  | 11.85       | -8.02* | 4.4*  |
| L <sub>4</sub> X T <sub>3</sub>  | 0.94*                 | -7.46  | -9.3  | -2.41  | -9.31* | -19.7 | -6.28*      | -8.02* | 4.4*  |
| L <sub>5</sub> X T <sub>1</sub>  | 0.03*                 | -3.43* | -13.9 | -13.73 | -25.45 | -14.7 | -11.68      | -17.15 | -15.1 |
| L <sub>5</sub> X T <sub>2</sub>  | 8.34                  | 3.43   | 1.4   | 31.56  | 29.84  | 8.4   | 1.80*       | -7.61* | -17.1 |
| L <sub>5</sub> X T <sub>3</sub>  | 1.97*                 | -2.28* | -12.8 | 12.42  | 7.37   | -10.3 | 2.94*       | -6.25* | 2.4*  |
| L <sub>6</sub> X T <sub>1</sub>  | 26.81                 | 2.43   | -15.0 | -28.60 | -30.91 | -20.9 | 20.14       | 11.75  | 14.6  |
| L <sub>6</sub> X T <sub>2</sub>  | 15.33                 | -12.30 | -14.0 | -17.08 | -27.11 | -21.9 | 38.10       | 26.38  | 11.2  |
| L <sub>6</sub> X T <sub>3</sub>  | 30.64                 | 6.15   | -13.2 | -19.23 | -31.00 | -25.9 | -3.29*      | -12.65 | -4.4* |
| L <sub>7</sub> X T <sub>1</sub>  | 11.97                 | 11.47  | -7.5  | -26.30 | -30.91 | -20.9 | -1.88*      | -4.76* | -2.4* |
| L <sub>7</sub> X T <sub>2</sub>  | 10.42                 | 1.52*  | -0.5* | 23.92  | 12.15  | 12.5  | 12.18       | -1.35* | -4.9* |
| L <sub>7</sub> X T <sub>3</sub>  | 3.75*                 | 3.41*  | -15.0 | 19.39  | 4.88*  | 5.3*  | 26.64       | 19.20  | 30.2  |
| L <sub>8</sub> X T <sub>1</sub>  | 28.28                 | 16.19  | -3.6* | -9.62  | -14.55 | -2.2* | -23.02      | -23.02 | -21.0 |
| L <sub>8</sub> X T <sub>2</sub>  | 15.17                 | -2.86* | -4.7  | -7.95  | -17.35 | -15.6 | 0.93*       | -13.49 | -11.2 |
| L <sub>8</sub> X T <sub>3</sub>  | 7.70                  | -1.77* | -19.7 | -13.40 | -24.49 | -22.8 | -31.34      | -33.48 | -27.3 |
| L <sub>9</sub> X T <sub>1</sub>  | -1.04*                | -10.69 | -7.9  | -8.79  | -24.55 | -13.4 | -9.27       | -11.43 | -9.3  |
| L <sub>9</sub> X T <sub>2</sub>  | 19.08                 | 16.19  | 19.7  | -8.00  | -11.54 | -28.1 | -8.57*      | -20.00 | -22.0 |
| L <sub>9</sub> X T <sub>3</sub>  | 13.84                 | 2.05*  | 5.2   | 46.31  | 45.40  | 10.3  | -0.94*      | -6.25* | 2.4*  |
| L <sub>10</sub> X T <sub>1</sub> | 31.14                 | 14.25  | -5.2  | -36.48 | -40.00 | -31.3 | 13.29       | 8.89*  | 11.7  |
| L <sub>10</sub> X T <sub>2</sub> | -0.40*                | -18.91 | -20.5 | -18.68 | -23.31 | -21.9 | 21.05       | 7.40*  | 1.5*  |
| L <sub>10</sub> X T <sub>3</sub> | 11.25                 | -2.43* | -20.2 | -8.60  | -20.25 | -18.8 | -9.66       | -15.77 | -7.8  |
| CD<br>(P=0.05)                   | 0.31                  | 0.37   | 0.37  | 0.19   | 0.22   | 0.22  | 0.17        | 0.20   | 0.20  |

\* Denotes only non-significant values at 5% level

**Days to first female flower:** In this case also pistillate flowers came significantly earlier than the respective better parents <sup>in</sup> only two hybrids. All the hybrids were significantly late flowering compared to the commercial hybrids.

**Sex ratio:** Significantly lower sex ratio, as revealed by significantly negative heterobeltiosis, was recorded in 8 hybrids indicating the possibility of increasing fruit number through increasing the number of female flowers in the vine. However, no hybrid could surpass the commercial hybrid in this respect.

**Days to first harvest:** The character, earliness can be implied by with respect to early flowering and early harvest of fruits. As expected, no hybrid showed early harvest character with respect to both respective better parent and commercial hybrid.

**Fruit length:** The hybrids produced fruits of significantly higher length compared to their respective better parents. On the other hand, all the hybrid showed heterotic depression compared to the commercial hybrid because this was basically a long fruited hybrid.

**Fruit width:** Only seven hybrid recorded significant heterobeltiosis however, all the hybrid surpassed the commercial hybrid for fruit width.

**Average fruit weight:** As high as 14 hybrids produced heavier fruits compared to their respective better parents indicating the possibility of increasing fruit yield in the hybrid through enhancing fruit weight. All the hybrids outclassed the commercial hybrid because this popular hybrid was small, long and high fruited one.

**Fruits/plant:** It is the most important yield contributing character and only 11 hybrids proved to be significantly better over their respective better parents in this respect. All the hybrids produced significantly lower fruit number compared to the commercial hybrid.

**Fruit yield/plant:** Possibility of developing high yielding hybrid by heterosis breeding has been proved through registration of significant heterobeltiosis in 17 hybrids. Only two hybrids surpassed the commercial hybrid marginally.

**Seed characters:** No hybrid produced lower number of seeds in the fruit, a desirable character compared to their respective better parents and the commercial hybrid. However, comparative heavier seeds were produced in most of the hybrids.

**Fruit quality characters:** Most of the hybrids fell short in achieving the fruit quality traits in them compared to their respective better parents and the commercial hybrid. Only 6 hybrids had fruits with significantly higher ascorbic acid content over their respective better parents. On the other hand 5 other hybrids surpassed their better parents for sugar content in the fruits. This observation also indicated less likelihood of developing both ascorbic acid and sugar content in the hybrids.

Observation emanated from the present investigation on manifestation of heterosis find ample support from several earlier works in this respect (Janakram and Sirohi, 1989; Janakiram and Sirohi, 1992; Singh *et al.*, 1998; Kumar *et al.*, 1999; Samadia and Khandelwala (2001); Sit and Sirohi, 2002; Sharma *et al.*, 2002; Pandey *et al.*, 2003; Dubey and Maurya, 2004; Pal *et al.*, 2005).

Of the 6 promising hybrids, BCBG 4 x BCBG -33 , BCBG 7 x BCBG - 3, BCBG-15 x BCBG-3, BCBG-17 x BCBG-3, BCBG-17 x BCBG-20 and BCBG-34 x BCBG-33 showing considerable heterobeltiosis for fruit yield and important yield components, two hybrids, BCBG-17 x BCBG-3 and BCBG-34 x BCBG-33 were outstanding because of their superiority, though marginally, over the commercial hybrid for fruit yield.

## ***CHAPTER-V***

# **SUMMARY AND CONCLUSION**

## SUMMARY AND CONCLUSION

In the present investigation 15 inbred lines developed from assembled eco diversity of bottle gourd from different bottle gourd growing areas have been employed to study (a) Genetic variability for different morpho-physiological, fruit yield and fruit quality characters. (b) Character associationship and their effect on fruit yield/plant. (c) Genetic diversity of the inbred lines by multivariate analysis and (d) Gene action for fruit yield, yield components and fruit quality characters through line  $\times$  tester analysis. Summary of the results and conclusion drawn are presented below.

### Genetic variability

Variance analysis clearly suggested significant differences in the inbred lines for vine length, primary branches/plant, days to first male and female flower opening, fruit length, fruit width, days to first harvest, seeds/fruit, 100 seed weight, fruit yield/plant, sex ratio and ascorbic acid content of fruit. However, nonsignificant difference for two important yield components namely, fruits number/plant and fruit weight among the inbred lines under study suggested the need of widening the present genetic base of bottle gourd for studying genetic variability of these characters. Joint consideration of GCV, heritability and genetic advance for different characters revealed high heritability coupled with moderate genetic advance for fruit length, ascorbic acid content of the fruit pulp, sex ratio, fruit weight and seeds number/fruit indicating that these characters could be improved by rigid selection in early generation. However, deferred selection would be helpful to realize high genetic gain through indirect selection. Several characters namely vine length, primary branches /plant, fruit number/plant, 100 seed weight and fruit yield /plant showed high heritability coupled with low genetic advance, which indicated limited possibility for improvement by selection. However, stringent selection over several generations may be followed to improve these characters. Moderate

heritability with low genetic advance was recorded for days to first male and female flower opening, days to first harvest and total sugar content of the pulp. These characters would response least to selection because such association of genetic parameters may be attributed to non additive gene action.

### **Character associationship**

#### **Correlation coefficient**

The magnitude of genotypic correlation coefficient was higher than phenotypic correlation coefficient in most of the pair characters under study. However, the gap between the two estimates correlation coefficient was not very wide indicating the lesser influence of environment on correlated response on the pair of characters. In the present investigation most of the characters did not register significant phenotypic correlation among themselves for which the following assumptions could be put forward-

1. Lack of adequate genetic diversity among the inbred lines for different characters. This proposition did find support from the study of genetic variability in present investigation.
2. Simultaneous vegetative growth and reproductive expression in the plant over a long period of time.
3. Internal balancing and mutual cancellation during expression of different characters.

Fruit yield was significantly and positively correlated with vine length ( $r_p = 0.66$ ), fruit length ( $r_p = 0.64$ ), fruit width ( $r_p = 0.67$ ), fruit weight ( $r_p = 0.72$ ), seed number/fruit ( $r_p = 0.77$ ) and 100 seed weight ( $r_p = 0.56$ ). The correlated response of different characters with yield suggested selection of long viny genotypes, which produced oblong- cylindrical fruits (high length and width) of higher weight and having higher number of heavier seeds which would be better for developing high yielding genotypes. Fruit weight showed significant positive correlation with seed number/fruit and 100 seed weight. Fruit length registered significant positive correlation with fruit width and fruit weight,

suggesting the possibility of increase in fruit weight through enhancement of fruit length and width. Interestingly, fruit number/plant did not registered significant correlation with any character, which might have happened due to lack of genetic variability for fruit number in the genotypes under study. Of the fruit quality characters, only total sugar content of fruits was significantly correlated with fruit width.

From the study of correlation, the characters namely, vine length, fruit length, fruit width and fruit weight emerged as the most important characters influencing fruit yield and fruit quality.

#### **Path coefficient**

The perusal of data showed direct effects of different characters on fruit yield/plant in low magnitude indicating lack of specificity of identification of important fruit yield influencing character from this analysis. However, vine length had the highest positive direct effect on yield (0.106) followed by days to first harvest (0.063), total sugar content (0.056), primary branches per plant (0.040), days to first female flower opening (0.036), fruit width (0.026). The direct and indirect affects of different characters suggested that a long viny genotype, which flowers late and bears heavy and long fruits and having increased sugar content would be a high yielding genotype.

#### **Selection indices for yield and quality**

From the present study of genetic variability and character associationship, the characters namely, vine length, fruit length, fruit weight, days to first female flower opening, days to first harvest and total sugar content of fruit emerged as important components, which should be given due weightage during selection of high yielding genotypes having high quality fruits.

### **Genetic diversity of the inbreds through multivariate analysis**

The range of  $D^2$  values (129.02 to 1708.58) in the first year and in second year (146.15 to 3068.91) indicated the degree of divergence among 15 inbreds of bottle gourd consistently in both the years..

Based on the determination of divergence in first year the 15 inbreds could be grouped into 6 clusters. Cluster 3 contained the maximum of 4 inbreds while cluster 1, 2, 4 and 5 contained 2 inbreds each. Cluster 6 contained 3 inbreds. In the second year, the inbreds were clustered in 7 groups with cluster 6 containing a maximum of 4 inbreds and cluster 7 had only 1 inbred. As expected, environment influenced clustering pattern, which could be demonstrated by examining the composition of different clusters in both the years. Environmental influence on the composition of clusters also recorded earlier in different crops. The concept of stable diverse genotypes refers to those genotypes, which clustered in the same group or in combination with the other in different groups consistently both the years. The present study indicated that BCBG-6 (fruit oblong and patchy green in colour), BCBG-16 (fruits oval or elliptical and greenish white in colour), BCBG-1 (fruits globular and greenish white in colour), BCBG-3 (fruits globular and white in colour), BCBG-4 (fruits oval or elliptical shape and white in colour) and BCBG-20 (fruits oval or elliptical and white in colour) could be identified as stable diverse genotypes.

Considering both rank and per cent contribution methods of determining the contribution of characters to the divergence of the inbreds the top 6 characters emerged, were fruit yield/plant, ascorbic acid content of fruit, fruit length, total soluble solids of fruit, sex ratio and fruit width.

### **Selection of parents on the basis of divergence for development of hybrids:**

Keeping in view, the relationship between genetic diversity and manifestation of heterosis, four groups of inbreds have been selected on the basis of inter cluster divergence and average divergence of the inbreds determined in 2 years.

Group 1: BCBG- 1, Group- 2: BCBG- 15, Group- 3: BCBG- 17, Group 4: BCBG- 34.

Inter group crossing of the inbred lines is expected to produce desirable and heterotic hybrids, however, final selection of the divergent parental inbreds should be made on the basis of combining abilities and manifestation of specific characters.

Desirable transgressive segregates is also expected through advancement of the hybrids developed through involvement of these parental inbred lines.

#### **Gene action for different characters**

The present study has been undertaken to determine the gene action for 16 growth, fruit characters, yield and fruit quality characters employing 10 x 3 line x tester analysis, which allows the scope of testing of additive and dominance genetic variations.

#### **Analysis of variance for parents and hybrids**

The parents were significantly different for all the characters excepting vine length, total soluble solids and sugar content of fruits. Among the parents, the lines were significantly different for 13 characters and in the testers, for 10 characters. Significant divergence among the lines satisfied their choice in such genetic analysis.

#### **Combining ability variances and gene effects**

The general and specific combining ability are the main criteria of rapid genetic assessment to test genotypes under line x tester analysis. Variances due to sca were considerably higher than that of gca for all the characters. For fruit weight, fruits/plant, TSS and total sugar contents of fruit, both gca and sca variances and concomitant additive and dominance variances were very low in magnitude. This might have been due to the absence of genetic<sup>17</sup> among the parents involved in the crossing programme for the concerned characters or cancellation of gene effects. The overwhelming presence of dominance genetic component for all the characters determined in this investigation was in agreement with several earlier works.

### **Combining ability effects**

Among the lines BCBG-34 and BCBG-7 emerged as the outstanding parent registering significantly positive gca effect for nine and seven characters, respectively including fruit yield/plant. Among the tester parents, BCBG-20 could be regarded as most promising, which showed significant gca effect for four characters.

Magnitudes of sca effects in the hybrids were in general, low for all the characters. However, the hybrids that registered somewhat higher sca effects were BCBG-4 x BCG-33, BCBG-7 x BCBG-3, BCBG-16 x BCBG-20 and BCBG 34 x BCBG-33. Among these promising hybrids, outstanding general combiners were involved in three hybrids, BCBG-7 x BCBG-3, BCBG-16 x BCBG-20 and BCBG-34 x BCBG-33. From such crosses in which one of the parents involved was a high general combiner for a good number of characters, promising segregates may be expected in the advanced generations.

### **Breeding strategy**

Combining ability analysis clearly suggested the overwhelming importance of dominance gene action for all the 16 characters of bottle gourd under study. Thus the methods, which exploit additive gene action such as pedigree selection method, will not at all be effective. In combination breeding programme, if at all, to be resorted to, the segregating population should preferably be derived from multiple crosses, which help to bring together co-adapted gene complexes. The four groups of inbred lines identified earlier from multivariate analysis will be suitable for such breeding approach.

However, heterosis breeding will be the best strategy to achieve high yielding ability along with improved fruit quality characters. In the recent years, major breakthrough in fruit yield improvement and other quality traits like earliness, fruit shape, etc. could be brought about in all the cucurbits including bottle gourd through hybrid technology. Hybrid seed production in bottle gourd is commercially feasible by bagging of staminate and pistillate flowers and hand

pollination method because of conspicuous flower size, good crossability and high seed number per fruit. Assemblage of wide parental diversity and existence of desired flowering and fruit characters in the parental lines are mandatory to achieve success in hybrid breeding at commercial scale.

### **Manifestation of heterosis**

Variance recorded for the hybrids in the analysis of variance for parents and hybrids suggested the manifestation of considerable average heterosis for most of the characters. Average heterosis, though has high implication from quantitative genetics point of view, yet bears no value from the angle of commercial utilization of the hybrids. For this reason manifestation of heterosis in the hybrids was determined over mid parent (average heterosis), better parent (heterobeltiosis) and over commercial check hybrid 'Warad' (standard heterosis) for all the 16 growth, fruit characters, fruit yield and fruit quality parameters .

Of the 6 promising hybrids, BCBG-4 x BCBG-33, BCBG-7 x BCBG-3, BCBG-15 x BCBG-3, BCBG-17 x BCBG-3, BCBG-17 x BCBG-20 and BCBG-34 x BCBG-33 showing considerable heterobeltiosis for fruit yield and important yield components, two hybrids, BCBG-17 x BCBG-3 and BCBG-34 x BCBG-33 were outstanding because of their superiority, though marginally, over the commercial hybrid for fruit yield.

## ***CHAPTER-VI***

# **FUTURE SCOPE OF RESEARCH**

## FUTURE SCOPE OF RESEARCH

Considerable information on different breeding approaches of bottle gourd could be generated from the present investigation. However, research works on some important aspects need to be carried out in future to achieve a breakthrough in bottle gourd breeding.

1. Widening of the assemblage of the genotypes to increase the diversity of the germplasm, particularly for some important characters like, high branching habit, fruit number/plant, earliness in flowering and fruiting, small cylindrical or oblong fruits.
2. Characterization of the genotypes based on morphological characters and molecular markers.
3. Development of wide range of hybrids employing parents with specific characters.
4. Evaluation of the assembled genotypes for mineral contents of fruit.
5. Utilization of the good general combiners emerged from the present investigation in future hybrid breeding programme.

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# ANNEXURE

**Table-1: Meteorological observations during the period of experiments.**

| Month     |   | Rainfall<br>(mm) | Temperature<br>(°C) |       | Relative Humidity<br>(%) |       | Bright<br>sunshine<br>hour |
|-----------|---|------------------|---------------------|-------|--------------------------|-------|----------------------------|
|           |   |                  | Max.                | Min.  | Max.                     | Min.  |                            |
| Year 2002 |   |                  |                     |       |                          |       |                            |
| September | : | 148.3            | 32.01               | 25.11 | 98.33                    | 78.27 | 5.45                       |
| October   | : | 25.65            | 32.4                | 22.12 | 96.81                    | 67.71 | 6.27                       |
| November  | : | 38.7             | 29.89               | 17.6  | 98.5                     | 61.33 | 8.32                       |
| December  | : | 0                | 27.41               | 12.44 | 99.77                    | 54.65 | 6.19                       |
| Year 2003 |   |                  |                     |       |                          |       |                            |
| January   | : | 0.0              | 23.7                | 9.2   | 99.65                    | 57.52 | 7.27                       |
| February  | : | 0.8              | 29.2                | 15.9  | 98.04                    | 52.93 | 7.96                       |
| March     | : | 61.8             | 32.0                | 19.4  | 95.10                    | 52.29 | 8.64                       |
| April     | : | 6.0              | 36.5                | 24.7  | 92.03                    | 53.33 | 12.26                      |
| May       | : | 81.4             | 36.5                | 24.9  | 91.23                    | 57.71 | 9.17                       |
| June      | : | 361.3            | 34.8                | 24.9  | 93.43                    | 73.87 | 5.17                       |
| July      | : | 292.2            | 33.4                | 25.0  | 97.35                    | 76.16 | 5.23                       |
| August    | : | 155.7            | 33.4                | 25.0  | 97.65                    | 78.26 | 6.39                       |
| September | : | 162.0            | 33.4                | 25.6  | 98.53                    | 80.47 | 5.29                       |
| October   | : | 197.9            | 31.87               | 23.87 | 99.03                    | 79.52 | 5.17                       |
| November  | : | 22.6             | 30.54               | 16.69 | 99.00                    | 55.57 | 8.79                       |
| December  | : | 20.2             | 26.2                | 13.17 | 99.19                    | 56.74 | 6.99                       |
| Year 2004 |   |                  |                     |       |                          |       |                            |
| January   | : | 0.0              | 24.23               | 11.49 | 98.58                    | 56.81 | 6.86                       |
| February  | : | 0.0              | 29.61               | 14.31 | 96.55                    | 39.76 | 9.13                       |
| March     | : | 1.8              | 35.31               | 20.69 | 94.00                    | 42.94 | 8.58                       |
| April     | : | 112.0            | 36.18               | 24.00 | 93.70                    | 58.73 | 9.13                       |
| May       | : | 104.6            | 37.67               | 25.73 | 89.26                    | 54.74 | 9.02                       |
| June      | : | 320.5            | 34.67               | 25.77 | 95.33                    | 73.50 | 5.27                       |
| July      | : | 229.9            | 33.45               | 25.69 | 90.13                    | 79.39 | 4.74                       |
| August    | : | 293.5            | 32.93               | 25.66 | 98.52                    | 83.71 | 5.25                       |
| September | : | 425.3            | 32.75               | 24.83 | 98.07                    | 79.10 | 4.88                       |
| October   | : | 206.3            | 32.02               | 21.78 | 97.74                    | 67.32 | 7.71                       |
| November  | : | 0.0              | 30.53               | 16.64 | 98.33                    | 50.97 | 8.69                       |
| December  | : | 0.0              | 27.66               | 13.92 | 98.87                    | 52.58 | 7.75                       |
| Year 2005 |   |                  |                     |       |                          |       |                            |
| January   | : | 20.2             | 32.89               | 12.05 | 98.77                    | 55.16 | 6.48                       |
| February  | : | 1.2              | 30.26               | 16.15 | 95.46                    | 46.07 | 8.79                       |
| March     | : | 121.6            | 33.74               | 21.18 | 94.97                    | 50.68 | 8.15                       |
| April     | : | 8.4              | 35.99               | 24.33 | 93.23                    | 51.93 | 9.26                       |
| May       | : | 37.6             | 37.16               | 25.66 | 92.16                    | 56.81 | 6.88                       |
| June      | : | 239.9            | 36.88               | 26.83 | 93.03                    | 62.40 | 6.48                       |

**Source: Department of Agro-meteorology and Physics, BCKV.**

**Table 2 : Physico-chemical properties of the experimental soil.**

| Constituents                            |   | Content      |
|-----------------------------------------|---|--------------|
| Textural class                          | : | Sandy loam   |
| Sand                                    | : | 51.7%        |
| Silt                                    | : | 31.4%        |
| Clay                                    | : | 16.9%        |
| Total N                                 | : | 0.059%       |
| Available P <sub>2</sub> O <sub>5</sub> | : | 52.00 kg/ha  |
| Available K <sub>2</sub> O              | : | 207.48 kg/ha |
| pH                                      | : | 7.2          |

**Source: Status Report NAZ, Nadia, West Bengal.**