

HYBRID SEED PRODUCTION, FRUIT QUALITIES AND SEED STORAGE OF BOTTLE GOURD

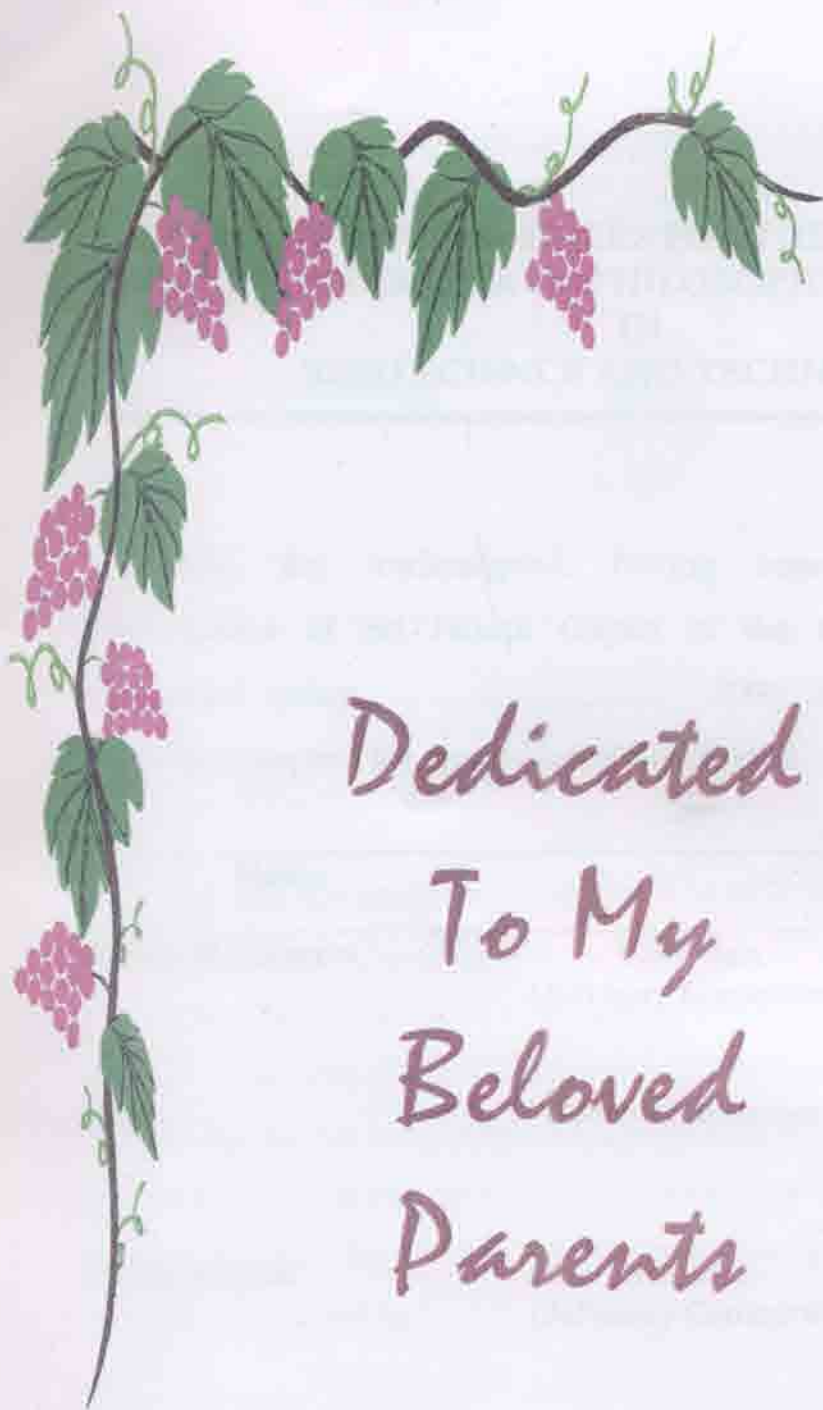
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in
SEED SCIENCE AND TECHNOLOGY

By
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*Dedicated
To My
Beloved
Parents*



**APPROVAL OF EXAMINERS FOR THE AWARD OF THE
DEGREE OF DOCTOR OF PHILOSOPHY (AGRICULTURE)
IN
SEED SCIENCE AND TECHNOLOGY**

We, the undersigned, having been satisfied with the performance of Sri Nikhil Gayen in the viva-voce examination conducted today, ... 2006, recommended that the thesis be accepted for the award of the Degree

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CERTIFICATE

This is to certify that the work recorded in the thesis entitled **"Hybrid Seed Production, Fruit Qualities and Seed Storage of Bottle Gourd"** submitted by **Shri Nikhil Gayen** for award of the Degree of Doctor of Philosophy (Agriculture) in Seed Science and Technology of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, is a faithful and bona fide research work carried out under my personal supervision and guidance. The results of the investigation reported in the 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.


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ABSTRACT

Bottle gourd is monoecious and cross pollinated crop. It provides ample scope for exploiting its hybrid vigour. For enhancing production, boron and ethrel were applied particularly for changing sex ratio.

Bottle gourd is propagated commercially through seed. So seed quality comprising high viability and high vigour is essential for better crop production. The basic reasons of low productivity attribute to non-availability of quality seed, lack of production technology and environmental factors.

Based on the mean performances, *gca*, *sca*, gene action and heterotic effects (estimated by line x tester analysis), the following conclusions could be drawn : (i) The L_5 line was the best as it exhibited good *per se* performance for fruit yield per plant and other fourteen important characters. (ii) Among the testers, T_3 ranked first as it registered superior *per se* performance for fruit yield per plant along with thirteen traits. (iii) The hybrid, $L_5 \times T_1$ was the best as it produced highest fruit yield per plant along with nine important characters. It also had best heterotic manifestation over both, better and mid parent with respect to fruit yield per plant. (iv) High heritability coupled with high genetic advance was recorded for fruit length, TSS, 100-seed weight and number seeds per fruit indicating that such characters are under the control of additive gene action. This information provides a scope of selecting plants with desirable improved traits. (v) The traits like sex ratio, fruit yield per plant had high heritability with average to below average GA and above average heritability coupled with low GA was recorded for node number of first female flower, number of days to first fruit harvest. These characters are under the influence of non-additive gene action leaving no scope of selection. (vi) Among the parents, L_3 , L_4 , L_5 , L_6 and T_3 were the best general combiners. These parents also exhibit desirable *per se* performance. (vii) The hybrid, $L_6 \times T_3$ was the best for *sca* effects for twelve characters. L_6 and T_3 parents had positive and significant *gca* effect. So there is a possibility of selection for fruit yield per plant in advance generation. (viii) The analysis of additive and dominant variance and the ratio of σ^2_{GCA} and σ^2_{SCA} revealed that two characters ascorbic acid and seed length under the control of additive gene action while the rest of traits are under the control of non-additive gene action. (ix) Based on *per se* performance, *sca* effects and heterosis over better parent, the hybrids $L_5 \times T_1$, $L_2 \times T_3$ and $L_3 \times T_1$ were superior for fruit yield per plant while $L_6 \times T_3$ was superior for fruit yield per plant as well as quality. These four hybrids can be used commercially.

Among the storage containers, desiccator was the best showing better germinability and vigour of the seeds during storage followed by glass bottle, polyethylene packet, earthen pot and cloth bag. The rate of reduction in germination percentage and vigour index with the advancement of storage period were more in V_2 (hybrid) than that in the V_1 irrespective of container.

Natural pollination had better performance over hand pollination. At the same time, planting in 4 : 2 row ratio (4 female : 2 male) produced enhanced performance. The natural pollination in 4 : 2 row ratio sowing, might be recommended for general cultivation.

The doses of 10 ppm boron and 300 ppm ethrel induced more yield as number of fruits set per plant was more. Thus, the doses of 10 ppm boron and 300 ppm ethrel were more effective in increasing female flowers and modifying sex ratio thereby increasing number of fruits per plant in bottle gourd. The 10 ppm boron and 300 ppm ethrel doses might be suggested for wide use.

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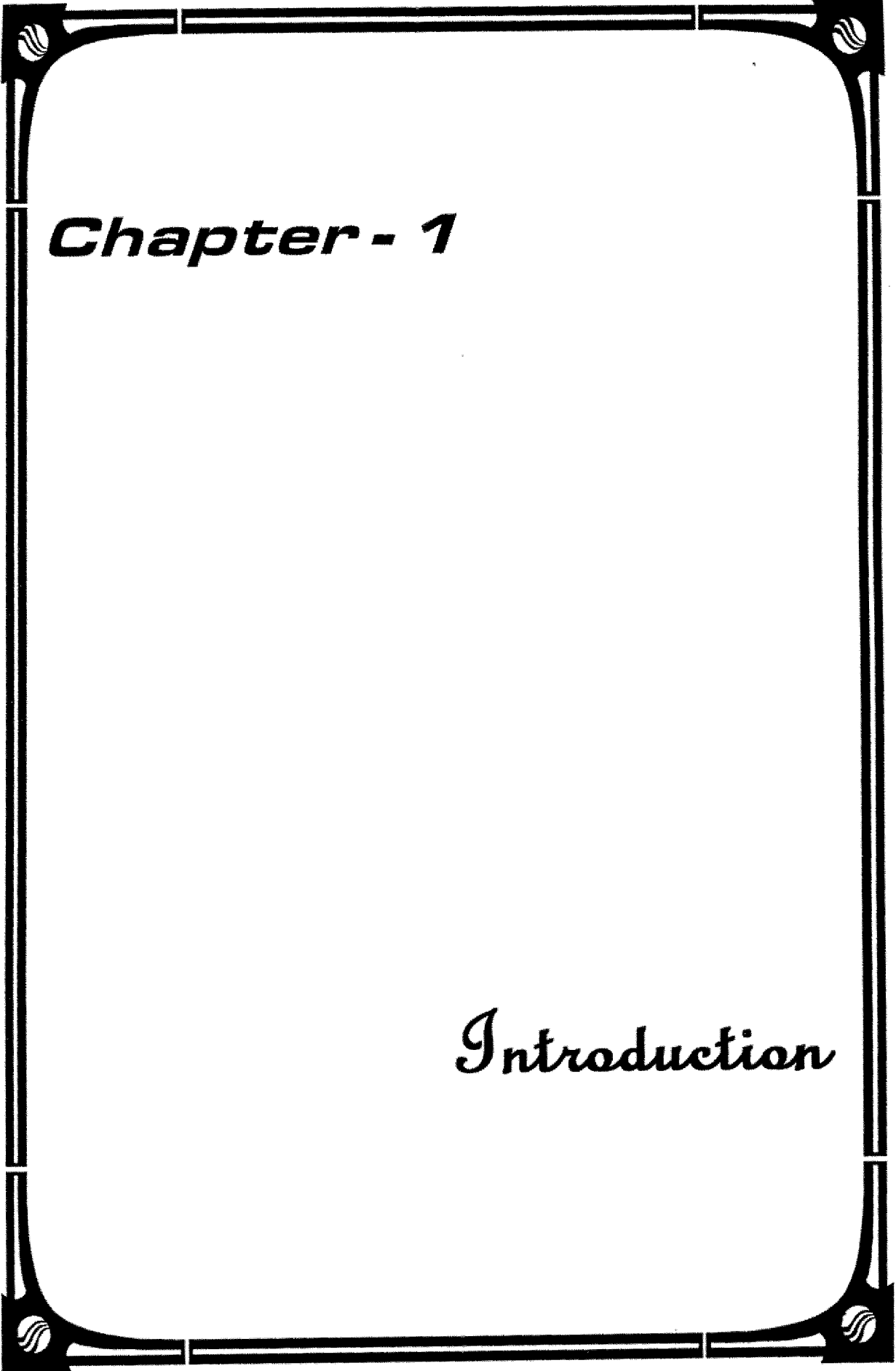
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Chapter - 1

Introduction

Introduction

The cucurbitaceous crops are important vegetables in India and also throughout the world. This constitutes the largest group of vegetables having 117 genera and 825 species distributed in warmer regions of both the hemispheres (Jeffrey, 1983) and 108 species belonging to 34 genera occur in India of which 38 species are apparently endemic in India (Chakravarty, 1959). The common cucurbits cultivated in India are bottle gourd (*Lagenaria siceraria*), sponge gourd (*Luffa cylindrica*), ridge gourd (*L. acutangula*), pumpkin and quash (*Cucurbita moschata*, *C. maxima* and *C. pepo*), bitter gourd (*Momordica charantia*), pointed gourd (*Trichosanthes dioica*), watermelon (*Citrullus lanatus*), cucumber (*Cucumis sativus*) and ash gourd (*Benincasa hispida*) (Nath, 1965).

Among them, bottle gourd or calabash gourd [*Lagenaria siceraria* (Mol.) Standl.] might be the only gourd that was known to man in both the new and the old world from very early prehistoric times (Esquinas - Alecazer and Garlick, 1983).

Bottle gourd is a popular vegetable in China, India, ^{South East} S. E. Asia and Sri Lanka where fruits have been selected which are less bitter in test. In India, it is grown throughout the country but commercially grown in a few states and its fruits are almost available in the market throughout the year.

Fruits are used for cooking, rayata, kapoorkand, pickles (especially on hills), kofta, petha, halwa and paratha etc. It has a cooling effect and also it is a cardiatonic and diuretic. The pulp is used for overcoming constipation, cough, nightblindness and as an antidote against certain poisons. Leaf extract with sugar is used against jaundice. The plant extract is used as a cathartic and the seeds are used in dropsy. Its seed-oil is used in headache. Its edible portion contains 96.3 percent water, 2.9 percent

carbohydrates, 0.2 percent protein, 0.5 percent fat, 0.5 percent mineral matter, vitamin A in trace and vitamin B 10 I. U. (Singh *et al.*, 2004).

A wide range of variability is available for maturity, yield and fruit characters in this crop. In spite of its old history and wide range of variability available, very little work has been done for improvement of this vegetable crop.

Bottle gourd, being monoecious is a cross pollinated crop and provides ample scope for exploiting its hybrid vigour. Hence, a speedy improvement in this crop can be brought about by assessing the genetic variability and exploitation of hybrid vigour. Hybrids offer opportunities for improvement in production, earliness, uniformity, quality and resistance to pest and diseases. In heterosis breeding, plant breeders often face problems to identify the suitable parents.

The analysis of combining ability might help to determine the feasibility of its utilization and identification of best combiners. A knowledge of gene action ^{for} of yield and its contributing characters are helpful to formulate an appropriate breeding procedure for achieving the desired objectives for the improvement of the crop. Having screened genetic variability for the nature of gene action, further approach is to identify highly heterotic combinations involving parents showing predominantly non-additive gene action for their commercial exploitation as hybrid variety. The knowledge of the genetic basis, which influences the expression of a character, is very meagre in bottle gourd.

With the uncontrolled population growth, the demand of food and vegetable is increasing very fast. As the land resources are limited, the need of increasing productivity is the priority of research. The superiority of hybrids has been well demonstrated in a variety of important vegetables. Single fruit of this vegetable gives large number of seeds and the cost of production of F₁ seeds is not high in comparison to other cucurbitaceous vegetables. Therefore, the demand for hybrid seed will definitely increase.

Two basic factors, which are highly responsible for increased hybrid seed yield, are the optimum row ratio of male and female line and pollination methods.

Among various problems of bottle gourd, flowering and fruiting have generally been of considerable interest to plant scientists. Bottle gourd exhibits a wide range of sex forms and sex expression. Sex expression is a complex characteristics in bottle gourd and influenced by genetic and environmental factors. By proper manipulation of these factors one can influence the sex expression in bottle gourd leading to either suppression of male flower or promotion of the number of female flower. Exogenous application of plant growth regulators and micro nutrients at ¹⁻²2-true leaf stage (most critical stage for promotion or suppression of either sex) affect sex expression in bottle gourd.

In the changing global scenario, malnutrition is one of the major problems and nutritional security of the growing population is of vital importance. Vegetable crops play an important role in the balanced diet of human beings as they provide not only the energy rich foods but also promise to supply vital protective nutrients like, proteins, vitamins and minerals. Generally, all cucurbit vegetables are considered low in nutritive value. But there are very few research reports available on the availability of minerals and vitamin in different cultivars and genotypes of bottle gourd and also about the gene action of nutritional traits of this vegetable.

Seed production in bottle gourd is more complicated than in dry-seeded grain crops because seed mature within a moist fruit and are often held at high moisture content for several week before seed harvest. Precocious germination is inhibited osmotically by the low water potential of the surrounding fruit tissue.

The seed quality comprising high viability and high vigour is essential for higher crop production. The basic reasons attributed to low productivity are non-availability of quality seed, lack of production

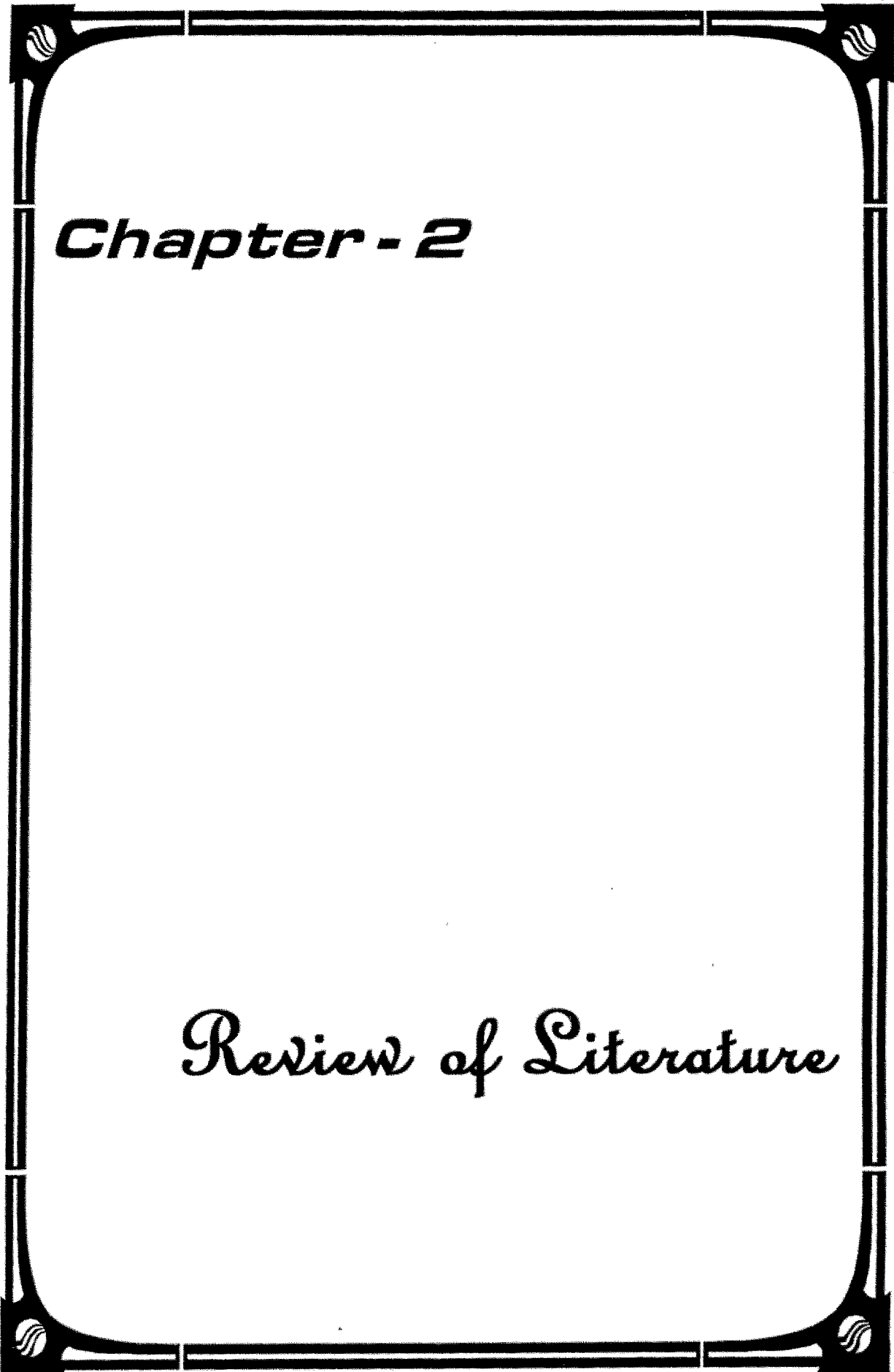
technology and environmental factors like high temperature and relative humidity (Tomar, 2000). In ancient times, only earthen pots or gunny bags were easiest possible storage containers, but they were not successful in proper storing of seeds. Several pre and post harvest factors contribute to the seed quality and among storage conditions, temperature and packaging are important factors.

In cucurbits, seed quality is affected by improper storage conditions. Seeds, when pass through hot humid monsoon month, deteriorate at a faster rate. Further, crop yield reduces on raising plants from older seeds. Seed viability is largely depending on age and nature of seeds and method of storage. Different kind of packaging material is used for protecting seeds from various extraneous factors like high humidity, insect and micro-organism. The choice of packaging depends on type of seed material and duration of storage (Doijode, 1997). Such information is lacking for conservation of bottle gourd germplasm.

On the above mentioned background, the present work on hybrid seed production, fruit qualities and seed storage of bottle gourd was undertaken with a view to understand the genetic background, heterotic effect in bottle gourd and safe storability of seeds.

The main objectives of the study were -

1. To study the genetic background of yield attributes of bottle gourd.
2. To identify suitable combiner for hybrid seed production.
3. To study the extent of manifestation of heterosis of some quantitative and qualitative traits including yield.
4. To evolve technology for maximisation of hybrid seed production.
5. To evaluate the chemical composition of bottle gourd.
6. To study the storage capability of bottle gourd seeds.
7. To identify the suitable method of seed storage for maintaining seed viability and vigour.



Chapter - 2

Review of Literature

Review of Literature

Bottle gourd is monoecious (male and female flower on same plant but different in position) plant. A wide range of variability is available for maturity, yield and fruit characters in this crop. In spite of its old history and wide range of variability available, very little work has been done for improvement of this vegetable crop. A short resume of the work done on this aspect is summarised below.

2.1 Variability, heritability and genetic advance

Sharma *et al.* (1990) estimated high heritability along with high genetic advance for node to first female flower, vine length, total number of primary branch per plant and fruits per plant in bottle gourd.

Kumar *et al.* (1999) reported high heritability coupled with high genetic advance (as percentage of mean) for fruit yield per plant, node number of first male flower, node number of first female flower, number of fruits per plant, fruit weight, fruit length, fruit diameter, vine length and number of primary branch per plant in bottle gourd.

Hawladar *et al.* (1999) exhibited high heritability coupled with genetic advance for fruit yield per plant in bottle gourd.

Samaik *et al.* (1999) reported that yield per plant and number of fruits per plant exhibited high values of GCV and PCV and estimated heritability associated with high genetic advance. The fruit diameter, fruit length showed high heritability and moderate genetic advance in ivy gourd.

Singh *et al.* (2002) recorded high PCV and GCV for node number of first male flower, sex ratio, fruits per plant, fruit weight, seeds per fruit and yield per plant. They also observed high heritability with high genetic advance for number of node of first male and female flower, length of main axis, number of primary branch per plant, sex ratio, fruits per plant, fruit

length, fruit weight, seeds per fruit, 100-seed weight and yield per plant in ridge gourd.

Singh *et al.* (2002) estimated high PCV than GCV and recorded high broad sense heritability for fruit yield per plant, vine length, number of days to first fruit harvest, node number of first male and female flower, number of primary branch per plant, fruit length, fruit weight and diameter. High heritability and high genetic advance were recorded for fruit yield per plant, vine length, fruit diameter, fruit length, fruit weight, node number of first male and female flower and number of primary branch per plant in bottle gourd.

Singh *et al.* (2002) observed high PCV and GCV for total fruit yield, average fruit weight and estimated high heritability coupled with high genetic advance for fruit diameter and total fruit yield in ash gourd.

In an experiment of bitter gourd, Bhavé *et al.* (2003) noticed that PCV was higher than GCV for vine length, branch number per vine, fruit length, average fruit weight, seeds number per fruit, total fruit yield per vine. The GCV and PCV were higher for branch per vine, total fruit yield per vine, and vine length.

2.2 Correlation and path analysis

Deunff *et al.* (1993) found a strong positive correlation between total seed number (including full and empty seeds), fruit length and weight at maturity in cucumber.

A significant positive correlation existed between seed number and fruits weight. Seed size showed a strong positive association with fruit weight in squash and *Cucurbita pepo* L. (Warid *et al.*, 1993).

Singh *et al.* (1993) indicated that yield per plant in pointed gourd was positively correlated with number of fruits per plant at both, genotypic and phenotypic levels. Path analysis indicated that number of fruits per

plant, average fruit weight and number of branches per plant should be considered for yield improvement.

Janakiram and Sirohi (1994) observed that total yield per plant was positive and significantly correlated with vine length, days to first fruit harvest, number of fruits per plant and fruit weight in bottle gourd.

Rajput *et al.* (1995) indicated that fruit yield per vine was positively correlated with number of fruits per vine, average fruit weight, fruit length, percentage fruit set and vine length. Fruit yield per vine was negatively correlated with number of days to first harvest in bitter gourd. Gogu and Scurtu (1996) found strong and direct correlation between fruit production and fruit per plant, as well as between seed number and seed yield per plant in cucumber.

Cui *et al.* (1996) showed that seeds per fruit was correlated with mean fruit weight (+), fruit width (+), fruit length (-), seed length (+), seed width (+) and 1000-seed weight (-) in cucumber.

Kumar and Singh (1998) reported that yield was positively correlated with average weight of edible fruit and number of fruits per plant at both genotypic and phenotypic levels in bottle gourd.

Hawlader *et al.* (1999) showed significant and positive association of fruits yield per plant with number of female flowers and fruits per plant. Path analysis also indicated that the highest contribution of number of female flowers per plant to fruit yield in bottle gourd.

Fruit yield per vine was significant and positive correlation with number of fruits per vine, fruit weight but was negatively correlated with days to first female flower. Path coefficient analysis confirmed that number of fruits per vine, fruit weight and days to first female flower were the major yield components having high direct effect on yield per vine in ridge gourd (Rao *et al.*, 1999).

Sarkar *et al.* (1999) observed that fruit weight, fruit diameter and number of primary branch per plant were positively and significantly correlated with yield per plant at phenotypic and genotypic levels. The path analysis revealed that fruit volume followed by fruit weight and diameter have maximum positive direct effects on yield in pointed gourd.

Rao *et al.* (2000) exhibited significant and positive correlation with fruits per vine and length of vine at both phenotypic and genotypic levels while fruit weight at genotypic level only. Days to first male and female flowered exhibited significant and negative correlation with yield per vine. Path analysis revealed that yield improvement could be achieved by direct selection for fruits per vine and length of vine in ridge gourd.

Badade *et al.* (2001) noted significant and positive correlation of yield with number of branches per vine, percentage of female flower and number of fruits per vine and significant and negative correlation with days to first male and female flower appearance and weight of deformed fruit per vine at both phenotypic and genotypic level. At genotypic level, vine length, diameter of fruit, number of seeds per fruit and 100-seed weight showed significant and negative correlation. Fruit length showed positive but non-significant correlation with fruit yield in bottle gourd.

Sharma and Bhutani (2001) revealed significant positive correlation for first female flowering node and fruit length with fruits per plant; fruit length and fruit diameter with average fruit weight; fruits per plant and average fruit weight with total yield per plant in bitter gourd. Pandey *et al.* (2002) reported significant and positive correlation of yield with number of fruits per plant, equatorial and polar circumference of fruit in pumpkin.

Bhave *et al.* (2003) showed significant and positive correlation between fruits number per vine with total yield per vine and vine length in bitter gourd.

2.3 Combining ability

Srivastava and Nath (1983) observed that several parental lines showed significant *gca* and *sca* effects for days to flowering, fruits per plant, fruit weight and total yield per plant in a 10 x 10 diallel cross of bitter gourd.

Combining ability in long-fruited bottle gourd in a 10 x 10 diallel cross was studied by Sivakami *et al.* (1987). The mean square of *gca* as well as *sca* was highly significant for all nine characters studied including yield per vine. This indicated the importance of both additive and non-additive variance for the expression of the characters. They suggested that improvement of bottle gourd can be brought about by both selection and hybridization method of breeding.

Janakiram and Sirohi (1988) reported in a 10 x 10 diallel cross of bottle gourd excluding reciprocals that the estimated components of variance of *gca* were larger than those for *sca* for all the nine characters studied, except days to first male flower and female flower opening and fruit polar diameter.

Munshi and Sirohi (1993) noticed that when either one or two of parental line having high *gca* effects for yield and its component characters were involved in the crosses, the F₁ hybrid showed promising result in bitter gourd.

Varghese and Rajan (1994) studied combining ability in snake gourd by line x tester mating design and recorded that the parents showing high *gca* for yield per plant and other characters also gave good *per se* performance.

In a Line x tester analysis of bottle gourd, Kumar *et al.* (1998) observed highly significant variance for all the traits due to specific combining ability. Verma *et al.* (2000) estimated combining ability effects in cucumber for 7 traits in a line x tester mating design. They observed significant differences among the parents and hybrids for *gca* and *sca*, respectively.

In a line x tester analysis, Sharma *et al.* (2002) studied combining ability in long-fruited bottle gourd for 12 characters. Some crosses exhibited significant *sca* effects for yield and some other related attributes.

Maurya *et al.* (2004) conducted combining ability analysis in bottle gourd by using line x tester mating design. Analysis of variance showed significant differences for all the characters, except for node number to first female flower.

2.4 Gene action

Srivastava and Nath (1976) reported dominant gene action for earlier and partial dominance for days to first female flower opening and fruit weight whereas, partial to complete dominance was observed for number of fruits and total yield in bitter gourd but total yield was controlled by complementary epistasis, dominance and dominance x dominance according to Sirohi and Choudhury (1979). They also reported predominance of additive and additive x additive components for days to first fruits harvest and number of fruits per plant and duplicate epistasis, dominance and dominance x dominance effect for vine length.

Sharma *et al.* (1983) observed partial dominance for days to first male flower opening and female flower opening in two crosses of bottle gourd. They found overdominance for number of fruits, weight of fruit and total marketable yield.

Gopalkrishnan (1986) reported additive gene action for number of primary branches and mean fruit weight. He also reported additive and non-additive gene action for vine length, number of fruits per vine, fruit diameter, number of seeds per plant and dominance for ascorbic acid in bitter gourd.

Janakiram and Sirohi (1987) conducted 10 x 10 diallel experiment of bottle gourd and observed overdominance for vine length, days to male flower opening, days to harvest, equatorial diameter, fruits per plant, fruit

weight and yield. In majority of the characters, non-additive gene action was predominant.

Sahni *et al.* (1987) observed high genetic advance associated with high heritability for fruit weight in ridge gourd indicating additive gene effects. But, for fruits per vine, female flower per vine, node number for the appearance of female flower and branches per plant, high heritability was not associated with high genetic advance indicating the presence of non-additive gene action.

Sirohi *et al.* (1988) reported non-additive genetic variance for vine length, days to open first male flower, days to open first female flower, days to first harvest, fruit diameter, number of fruits per plant, fruit weight and fruit yield per plant. Additive gene action was involved in the inheritance of fruit length only in bottle gourd.

Pitchaimuthu (1991) confirmed the preponderance of duplicate epistasis in the characters studied. He reported over dominance gene action for vine length, days to male and female flower opening, days to harvest, number of fruits per plant and total yield in bottle gourd.

Singh (1991) reported gene action in pointed gourd for days to first flower opening, first picking, vine length, branches per plant, fruits per plant, fruit size, fruit weight, seeds per fruit and yield. He also reported predominant role of non-additive gene action for all characters except fruit length which was controlled by additive gene action.

Maurya *et al.* (1993) found prepondence of non-additive gene action for all the characters except for node number at which first female flower appeared in bottle gourd. In a diallel analysis of 36 F₁ hybrids of pumpkin, Sirohi (1993) showed overdominance for vine length, fruits per plant, fruit size index, fruit flesh thickness and dominance gene action for fruit weight and yield per plant.

High magnitude of *sca* variance for majority of the characters except number of primary branches, fruit length, fruit yield per vine and crop duration in bitter gourd was reported by Richard Kennedy (1994).

Mishra *et al.* (1994) reported that both additive and non-additive gene action were involved in the expression of fruits per plant, fruit length, width, weight and yield in bitter gourd.

Varghese and Rajan (1994) recorded significant *gca* and *sca* variance for all characters except for sex ratio, fruits per plant, indicating role of both additive and non-additive gene action in snake gourd.

Kushawa and Ram (1996) reported highly significant additive and dominance components for fruit diameter and fruit length in bottle gourd over two season. The additive component was more pronounced and important indicating the need of pure line breeding.

Singh *et al.* (2000) reported additive gene effects for fruit length, days to first harvest, fruit weight and number of fruits per vine in bottle gourd.

Singh and Ram (2003) estimated more additive effects than that of the dominant effects for days to first male flower anthesis and days to first female flower anthesis whereas dominance effect was higher than that of additive effect for length of vine, number of vines per plant, fruit length, fruits per plant, fruit weight and yield per plant in bitter gourd.

Dubey and Maurya (2003) reported that the ratio $\sigma^2_{gca}/\sigma^2_{sca}$ suggested that non-additive gene action had greater role in the inheritance of total fruit yield per plant, number of fruits per plant, fruit length, days to anthesis first female flower and days to first fruit harvest while additive gene action had greater role in inheritance of average fruit weight at marketable stage, node number of first male flower, number of primary branch per plant and vine length in bottle gourd.

In a line x tester analysis of bottle gourd, Maurya *et al.* (2004) recorded high *gca* and *sca* variance for all the character except number of primary branches per main stem and days to first male flower anthesis.

2.5 Nutritional traits

Wang *et al.* (1993) observed that hybrid cucumber variety contain slightly more reducing sugar and ascorbic acid than those of the control. Generally bottle gourd is considered low in nutritive value (Bhatnagar and Sharma, 1994). Choudhury (1996) observed 6 mg vitamin C per 100 gm of edible portion of bottle gourd. Bhatnagar and Sharma (1997) reported 6.0 – 7.5 mg vitamin C per 100 gm of edible portion of bottle gourd.

In a diallel analysis, Sit and Sirohi (2000) studied 41 F₁ hybrids of bottle gourd. They showed overdominance for vitamin C contents in fruits of these vegetable crops. Non-additive gene action was predominant for the inheritance of characters. Dominant alleles for the inheritance of these characters were more frequent in parental lines. Low heritability (narrow-sense) for these characters also indicated the presence of non-additive gene action.

2.6 Heterosis

In bitter gourd, Pal and Singh (1946) were probably the first to report hybrid vigour as much as 191.3 percent increase in the yield of best hybrid combination. They observed that small size of fruit (from small fruited parent) of F₁ hybrid was compensated by more number of fruits, whereby the total yield was either equivalent or exceeded the performance of higher fruit varieties. They also observed heterobeltiosis for number of male and female flowers, main vine length, fruit size and total yield.

Rajendran (1961) was probably the first to report hybrid vigour as much as 266.51 percent increase over better parent in the yield of the best hybrid combination of bottle gourd at a high fertility level of the garden soil.

Roy (1964) observed 81.42 and 78.60 percent heterosis for yield in the best two F_1 hybrids in bottle gourd. He also observed that 45 percent of the hybrids showed heterosis in fruit weight, fruit size and yield.

Heterosis for earliness and high yield in ridge gourd was reported by Thakur and Singh (1968) when a gynocious female was crossed with four monoecious varieties. Choudhury and Singh (1971) recorded 75 and 106 percent higher yield in two F_1 hybrids than their respective better parents in bottle gourd. Tyagi (1973) reported significant heterosis in number of fruits per vine, length and girth of fruit and weight of fruit in bottle gourd.

Choudhury (1978) reported heterosis for all the ten characters studied except the number of days to first fruit harvest in bitter gourd. He reported 84 percent heterosis over the top parent. The minimum and maximum heterosis was 0.30 and 128.47 percent for days to first harvest and total yield per plant respectively.

Tozu (1981) reported that self-pollination resulted in inbreeding depression, while F_1 hybrids exhibited some heterosis in sponge gourd [*Luffa cylindrica* (Roem) L.]. Heterosis for number of fruits, fruit weight and total yield in the two F_1 crosses of bottle gourd was reported by Sharma *et al.* (1983). Pal *et al.* (1984) observed heterosis in four F_1 hybrids over their respective better parents in bottle gourd. F_1 hybrids which produced the female flowers at lower nodes and had 17-28 percent thicken flesh, 20 percent higher early yield and a longer harvesting period of 65-71 versus 55-65 days.

Natrajan *et al.* (1984) reported that crossing of high yielding strain and the local low yielding variety of snake gourd resulted in F_1 hybrids, which had significantly higher yield per hill and mean weight of fruit than the parents.

Appreciable heterosis for yield and its contributing characters like maturity, number of fruits per vine and fruit weight in long-fruited bottle gourd was reported by Sirohi *et al.* (1985). They also reported heterosis for

vine length (0.46 to 43.37%), fruit length (0.46 to 21.90%), fruit girth (0.91 to 7.67%), number of fruits per plant (1.38-22.91%) and yield per vine (0.90 to 76.46%).

Ranpise (1985) observed significant relative heterosis and heterobeltiosis for vine length, fruits per plant and yield per plant in bitter gourd. Relative heterosis and heterobeltiosis for yield and yield components besides calcium, magnesium, acidity, vitamin C content and TSS of fruit was reported by Gopalkerishna (1986) in bitter gourd.

In the year (1989) Janakiram and Sirohi[↓] observed 84.5 percent higher yield in a cross over the best parent in bottle gourd. Heterosis of bottle gourd for the characters namely, vine length, days to first male flower opening, fruit weight, fruit size index, number of fruits per plant and total yield per plant over better parent was reported by Pitchaimuthu (1991).

Janakiram and Sirohi (1992) observed significant heterosis in bottle gourd for different characters like vine length (13.58%), days to first female flower opening (-7.53%), fruit weight (58.06%) and total yield (82.96%). Man^ushi and Sirohi (1993) studied 45 F₁ hybrids of bitter gourd in a 10 x 10 diallel cross (without reciprocals). They reported heterosis over better parent for all the characters studied except days to first fruit harvest.

Wang *et al.* (1993) observed vigorous growth and high early yield in a hybrid variety of cucumber. They also noted that this variety contain slightly more reducing sugar, ascorbic acid, phosphorus, potassium and magnesium than those of the control. In a line x Tester analysis of bottle gourd, Sharma *et al.* (1993) observed heterosis over parents for number of fruits (106.63%) and total yield per plant (110.38%). In the year (1994) Richard Kennedy[✓] studied 60 crosses of bitter gourd in a line x tester mating design and reported significant relative heterosis in 37 crosses, heterobeltiosis in 19 crosses. He also reported positive and significant heterosis for total yield and fruit number but negative heterosis for fruit weight, length and diameter.

Kadam (1995) reported significant heterosis in favourable direction for female node number, fruits per plant (19.91%), yield (17.02%) and fruiting nodes per vine (14.10%) in ridge gourd. Singh *et al.* (1998) studied 28 F₁ hybrid of bottle gourd. One F₁ hybrid showed significant heterosis over the better parent for yield per vine and number of fruits per vine.

Robinson (1999) reported significant heterosis for earliness and yield in bottle gourd. In a line x tester mating design in bottle gourd, Kumar *et al.* (1999) found heterosis for yield and its component traits in the 20 F₁ hybrids, revealed significant heterosis for almost all the traits.

Samadia and Khandelwal (2001) studied 36 F₁ hybrid of bottle gourd. They found three superior F₁ hybrids and exhibited significant economic heterosis for fruit yield per plant and yield components such as number of fruits and female flower per plant. Most of the heterotic crosses were also heterobeltiotic.

Kushwaha and Ram (2002) evaluated heterosis in 15 bottle gourd hybrids and their parents. They exhibited higher heterosis in several crosses compared to the better parent in terms of fruit diameter and length.

Singh *et al.* (2002) studied heterosis for yield and yield components in 20 F₁ bottle gourd hybrids from line x tester mating design. Significant and positive heterotic effect over the better parent was observed for fruit yield per plant in one hybrid. Heterosis for fruit yield per plant was due to the node number, first female flower, number of fruits per plant and fruit weight.

Sit and Sirohi (2002) showed heterosis in bottle gourd for yield and yield component over top parent in F₁ hybrid, whereas some crosses showed heterosis for vitamin C, phosphorus, calcium and iron contents. Heterosis in 6 parent diallel set in bottle gourd was studied by Pandey *et al.* (2003). They found significant heterosis in a hybrid, over better parent for

the number of primary branches per plant and length of lateral shoot. In a line x tester analysis in bottle gourd, Maurya *et al.* (2003) studied 30 F₁ hybrid. They observed standard heterosis for early fruit yield per plant in some F₁ hybrids.

2.7 Container effects

Storing dry bottle gourd seed in a cooler environment extends their longevity. Seed packed in laminated aluminium foil pouches and stored at 20 to 33°C and 67 to 86% RH can be stored for ten months (Villereal *et al.*, 1972).

Selvaraj (1988) stored brinjal seeds for upto 24 months in three different types of container at ambient temperature. Seed germination and vigour index were generally acceptable upto 18 months but declined rapidly thereafter; up to 18 months they were highest in paper-aluminium foil-polyethylene line pouches.

Seeds of different vegetables were dried to 7% moisture content, packed into cloth bags and aluminium foil pouches and stored in ambient conditions for up to 18 months at 3 locations representing tropical, sub-tropical and temperate condition. Generally, seed stored in the aluminium foil pouches showed the highest germination percentage at the end of storage (Jayaraj *et al.*, 1988).

Doijode (1989) reported that bottle gourd seed lose viability under ambient condition. Viability decrease to 50% after 12 months and none germinated after 24 months of storage under ambient conditions. On deterioration seed germination and seedling vigour decrease.

Karivaratharaju *et al.* (1989) stored lablab seeds in cloth bags, polyethylene bags or covered mud pots for 3-18 months. Germination was higher from seed stored in polyethylene bags.

Meng *et al.* (1995) reported that germination percentage and germination index decrease with the increase of storage period in cucumber.

Doijode (1997) studied the effect of packaging on seed quality in long melon. Seeds were preserved in kraft paper, glass bottle, polyethylene bags and laminated aluminium foil pouches. Polyethylene bags were effective in preserving high viability and vigour at ambient condition.

Gurusamy *et al.* (1998) noticed that cauliflower seeds stored in 700 gauge polyethylene bags for 10 months maintained ^{high} greater germinability and vigour than seeds stored in paper bags.

Chung *et al.* (1999) reported that bottle gourd seed lost viability in paper bags at room temperature, but the degree of viability loss was related to cultivar.

2.8 Pollination methods

The fruit set of bottle gourd, pollinated by honey bees was 15% compare with 8.33% for hand pollinated flowers and 3.33-5% for isolated plants. Honey bee pollinated flowers also produced the greatest percentage of filled seed (60.35%) (Alam and Quadir, 1986).

Avila *et al.* (1989) reported that manual pollination was as effective as natural pollination with regard to the number of fruits per plant, but it was less effective in relation to seed production per plant in squash.

Hossain *et al.* (1990) observed that natural pollination supplemented with hand pollination was most successful (59.26%) for fruit set in bottle gourd.

Chand *et al.* (1990) showed that open pollination gave higher fruit set (>70%) than sibbing, self or cross pollination in cucumber.

Haslbachova *et al.* (1990) reported that total seed yield and seed per flower were greater on bee-pollinated plants than on hand pollinated ones in cabbage.

In pointed gourd, artificial pollination resulted in a two-fold increase in fruit set (Sachan *et al.*, 1990).

Shikhalia *et al.* (1990) observed that artificial pollination resulted in 87.67% fruit set compared with 25.67% under natural pollination in spine gourd.

Pinzauti and Magnani (1991) concluded that seed production was significantly improved by insect pollination, although the best seed set was obtained with manual pollination. A negative correlation emerged between the number of visits to the flowers and the weight of the pumpkins harvested.

Kuti and Rovelo (1992) compared hand and honeybee pollination in a field trial. Seeds per fruit did not differ significantly between methods, but honeybee pollination produced more fruits per plant, higher seed weight and greater seed viability than hand pollination in equi melon.

Devadas *et al.* (1992) reported that self-pollination resulted in a higher seed number per fruit and higher individual seed weight; however, the percentage of field emergence and seedling vigour were significantly higher in seeds obtained by cross pollination in bitter gourd.

In uncaged plots, honey bees were the most frequent visitors and seed set, 1000-seed weight and seed number were significantly higher, whereas germination capacity and number of seeds per floret did not differ from that observed in caged plots. Seed production was practically nil in caged plots without insects in onion (Lorenzon *et al.*, 1993).

2.9 Row ratio

Lal *et al.* (1990) showed that 2 female : 1 male ratio was highest hybrid seed producer in muskmelon.

Gill *et al.* (1993) studied the effect of male : female row ratio on fruit set and hybrid seed yield in chilli. They suggested that the 1 : 3 ratio for

commercial hybrid seed production would give maximum seed production per unit area.

Leibovich *et al.* (1993) observed that 3 female : 1 male ratio was more economical for hybrid seed production of sugarbeet.

Lorenzon *et al.* (1993) recommended 1 : 4 ratio of male and female plant for its higher productivity in onion.

Jabeen *et al.* (1993) obtained highest seed yield with male : female row ratio of 2 : 12 in pearl millet.

Soto *et al.* (1995) compared open pollination and hand pollination for reproduction of the parental lines with male : female ratio of 3 : 1, 6 : 1 and 9 : 1 in cucumber. The best economic results for hybrid seed production were obtained with the 6 : 1 ratio.

Dash *et al.* (1999) observed that 15 female plant around one male was effective for higher fruit yield per hectare in pointed gourd.

Khurana *et al.* (2002) reported that 2 : 1 ratio of female : male was optimum for hybrid seed yield in chilli.

2.10 Effect of Boron and Ethrel

Ethylene, the source of biological activity of ethrel is known to have many effects opposite to those of gibberellic acid (Scott and Leopold, 1967). On the basis of this antigibberellin hypothesis, Robinson *et al.* (1969) – assumed that ethrel may cause a reduction in gibberellin levels. This may perhaps bring a shift, favourable towards femaleness in cucumber plants (Alsmon *et al.*, 1968). The same hypothesis may hold good in case of bottle gourd also.

Various workers have observed that Ethrel causes a striking increase in female flowers of cucumber (McMurray and Millar, 1968 and Robinson *et al.*, 1969), muskmelon and squash (Rudich *et al.*, 1969).

The early and total yields in *Cucurbita pepo* were significantly increased by the application of Ethrel at 200 ppm and total yield increased from plants treated with Ethrel at 100-400 ppm, were 32 to 52 percent respectively above control (Kim *et al.*, 1970).

Ravindran (1971) observed that application of Ethrel at a concentration of 200-600 ppm on bitter gourd seedlings, the growth of the plants become stunted and the production of male flowers was significantly reduced.

Shanmugavelu *et al.* (1973) reported that Ethephon at 100, 250, 500 or 1000 ppm, when applied to pumpkin seedlings at weekly intervals, growth was inhibited in proportion to concentration used. Application of Ethephon at 100 ppm increased the fruit number, by 29.8% and fruit weight by 38.9% as compared with untreated plants.

Churata-masca *et al.* (1974) observed that Ethephon at the rate of 200 ppm at 2-3 leaf stage increase the early yield of marketable cucumber (47 days after planting) without affecting the final marketable yield or the average fruit weight.

Application of Ethrel (100 ppm) at 2-3 leaf stage and again at 4-5 leaf in cucumber reduced the growth of the plant (Mishra *et al.*, 1976).

Singh and Jindal (1976) found that Ranchi variety of papaya at 25 ppm TIBA application, induced flowering at lower node (26th node as compared to 29 node in control). There was no significant difference among the treatment Ethrel (100 ppm, 250 ppm and 500 ppm), TIBA (50 ppm and 100 ppm) and Boron (2 ppm, 5 ppm and 10 ppm). They also observed that least number of days were required for first bud appearance by the treatment of 500 ppm Ethrel. The 100 ppm TIBA increased the percentage of female plants by 24.3% over control.

Hopping *et al.* (1979) reported that the total number of fruits per plant in pumpkin was not increased by the application of Ethrel at 100 mg/l lit.

Spraying of Ethephon on pickling cucumber did not markedly affect the total yield but increased the percentage of smaller fruits, thereby greatly increasing the commercial value (Nerson *et al.*, 1980).

Ethrel at 250 mg increased the number of secondary branches, number of female flower and yields over control in pumpkin (Arora and Partap, 1988).

In an experiment with the cucumber, watermelon and bottle gourd, Singh and Choudhury (1989) treated the plant with Boron at 2 or 4 ppm or with Ethrel at 50 or 100 ppm, MH at 50 or 100 ppm at the ^{two} 2-true leaf stage and again a week later. The highest number of fruits per vine in cucumber and bottle gourd was obtained with Ethrel at 50 and 100 ppm, respectively, and in watermelon with MH at 50 ppm or Boron at 2 ppm.

Arora *et al.* (1989) observed that Ethrel at 100 and 150 ppm significantly increased the number of fruits per vine and yield per ha over control in pumpkin.

Mandal *et al.* (1990) noticed a significant increased in number of fruits per plot for the early and total yields and fruits weight per plot for early and total yields with 10 ppm Ethrel treatment over control in bottle gourd.

Mandal *et al.* (1991) reported that Ethrel increased number of female flower per plant and lowered the sex ratio over control in bottle gourd.

Gad *et al.* (1993) studied that Ethrel at 225-300 ppm, markedly reduced the number of male flowers and increased the number of female flowers, early and total yield, number of fruits per plant and fruit weight, compared with unsprayed controls.

Ghanda *et al.* (1994) observed that boron increased hermaphroditism and decrease maleness in papaya.

In Ethrel treated plants the first flowers that appeared were pistillate flower. This treatment reduced sex ratio over control in pumpkin (Das and Das, 1995).

Pandya and Dixit (1997) sprayed 10 ppm GA₃, 250 ppm Ethephon, 50 ppm ccc (Chlormequat), 50 ppm TIBA, 150 ppm Maleic hydrazide, 3 ppm Boron or 20 ppm CaNO₃. Maleic hydrazide application significantly reduced the length of the main axis and increased the number of shoots per plant, lowered the node at which first female flower appeared, reduced the number of days to first female flower appearance, increased the number of female flowers, lowered the sex ratio and increased fruit girth and weight in bottle gourd. MH application resulted in the highest yields followed by Ethephon and Boron.

Gedam *et al.* (1998) reported earliest fruit in plant treated with 4 ppm boron in bitter gourd. These treatments were also highest in fruit and seed yields than other treatments.

Rahman and Shormeen (1999) investigated the effect of foliar application of IAA (100 ppm), GA₃ (50 ppm), TIBA (75 ppm), Boron (4 ppm) and Mo (2.5 ppm) alone or in combination in *Cucurbita moschata*. The highest yield were obtained from plants treated with IAA + TIBA, Boron and IAA + GA₃.

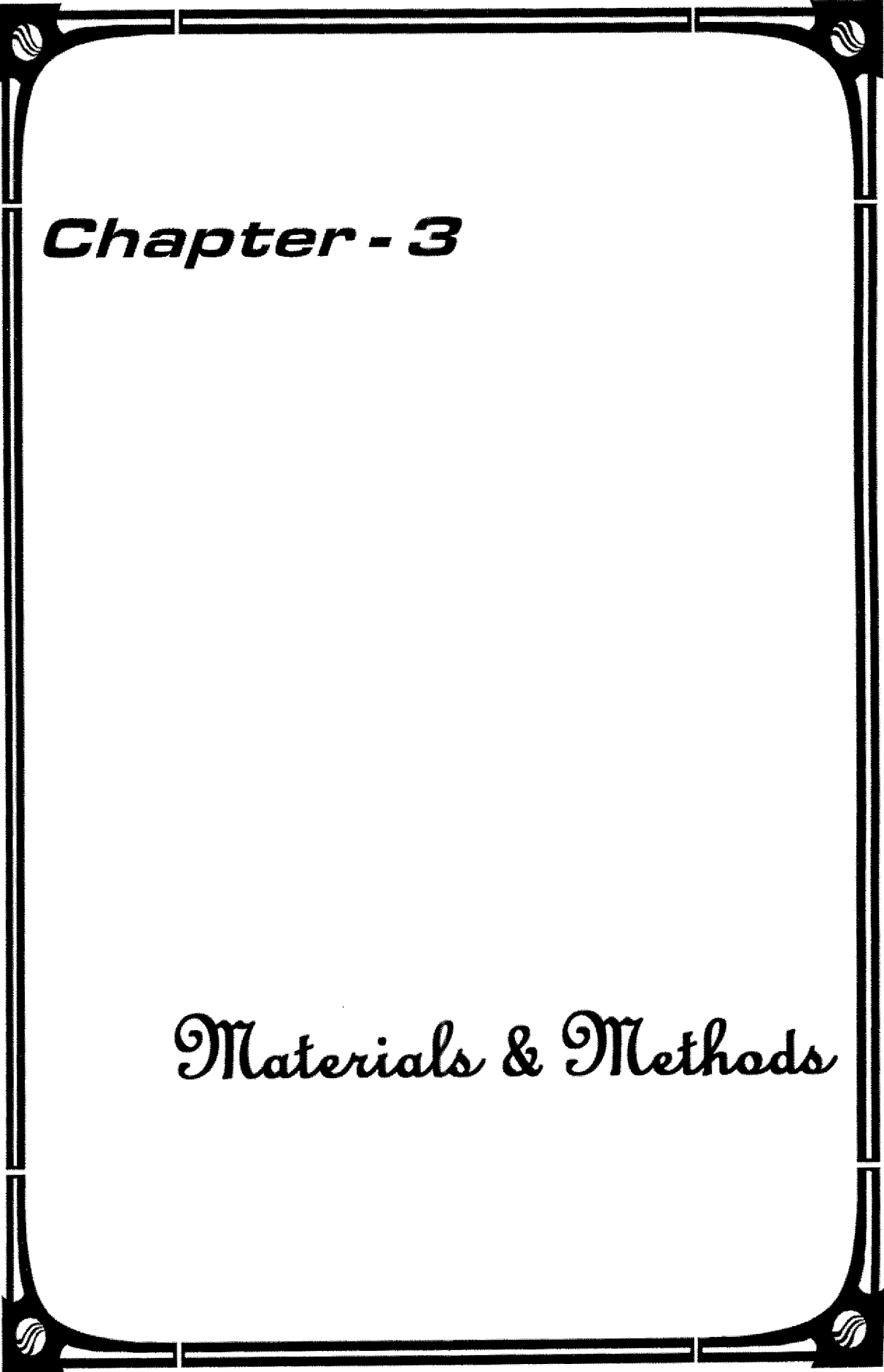
A significant efficiency of Ethephon (100-400 ppm) was observed on yield and earliness in *Cucurbita pepo* by Mancini *et al.*, 1999.

Ethephon reduced the number of male flowers as compared with the untreated control. Seed yield of 400 ppm Ethephon treated plants was approximately half that of the untreated control (Korzeniewska *et al.*, 2000).

Kooner *et al.* (2000) reported earlier female flower production, narrow sex ratio by treatment with Ethrel over control in bottle gourd.

Vadigeri *et al.* (2001) found increased in number of pistillate flower, number of fruits per plant and yield per hectare with 200-400 ppm Ethrel treatment in cucumber.

Adirai *et al.* (2001) observed that application of 250 ppm Ethrel at 2nd and 4th-true leaf stage increased fruit yield, seed yield over control in pumpkin.



Chapter - 3

Materials & Methods

Materials and Methods

The present investigation was undertaken with a view to study the hybrid seed production, fruit qualities and seed storage of bottle gourd. The materials used and methods followed during the course of investigation are described below.

3.1 Experimental materials

The experimental materials for the present study consisted of six promising lines (females) namely, BCBG-1 (L₁), BCBG-4 (L₂), BCBG-7 (L₃), BCBG-15 (L₄), BCBG-17 (L₅) and BCBG-34 (L₆) and three testers (males) namely, BCBG-3 (T₁), BCBG-20 (T₂) and BCBG-33 (T₃) selected from a group of germplasm received from Department of Vegetable Crops, B.C.K.V., ^{Ly} Details of these parental lines and tester are given in Table 3.1.

3.2 Experimental site

The field experiment was conducted during 2002-05. The experiment was laid out at "Central Research Farm", Gayeshpur, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The Farm is situated at 23.5°N latitude, 89°E longitude and at an altitude of 9.75 metres above mean sea level.

3.3 Soil Type

The experimental plot had sandy loamy, slightly acidic soil with good drainage facility.

3.4 Climatic condition

The experiments were conducted in a sub-tropical humid climate having a short and mild winter. The average annual rainfall is 1457 mm, mostly being precipitated during June to September and the temperature was in the range of 10°C to 37°C. The mean monthly meteorological data during the experiment is given in Table 3.2. Broadly, the seasons are classified as :-

- i) The cold season extends from November to February when the minimum monthly temperature falls below 20°C with a lower humidity, rainfall being occasional.
- ii) The dry season extending from March to May is characterized by high temperature, fairly high relative humidity and occasional rainfall in the form of Norwesters.
- iii) Wet season extends from June to September. In this season the normal temperature is relatively low compared to the dry season. The humidity is maximum and most of the annual precipitation occurs during this time.

3.4.1 Temperature

The mean annual temperature falls below 20°C in November and continues till the early part of February. The winter is thus mild and short in the Gangetic plains of West Bengal. The temperature begins to rise from the second fortnight of February and reaches its maximum generally in May. The mean monthly maximum temperature goes up to 37°C in May.

3.4.2 Rainfall

Generally the monsoon breaks in the area by the second week of June with some natural variations in different years while it is delayed upto last week of this month in some years. Norwester showers amounting to 150-250 mm during April to early June precede the monsoon, though the amount of rainfall, its advent and extend are irregular. During the month of November to March, rainfall is very scarce.

3.4.3 Relative humidity

Maximum relative humidity usually remains in the range of 80 to 90% throughout the year, usually having the higher extremes during the wet season. The minimum value of the relative humidity varies to a great extent across the seasons.

Table 3.1 : Characteristic features of different bottle gourd genotypes used as experimental materials.

Genotypes	Place of collection	Characteristic features of fruits	Geographical location
BCBG-1	Gadamara, Barasat, 24-Parganas(N)	Fruit-greenish white colour and globular shape.	La-22°48'N, Lo-88°30'E
BCBG-3	Suri, Birbhum	Fruit-whitish green colour and globular shape.	La-23°55'N, Lo-87°32'
BCBG-4	Suri, Birbhum	Fruit-whitish green and oval or elliptical shape.	La-23°55'N, Lo-87°32'
BCBG-7	Gadamara, Barasat, 24-Parganas(N)	Fruit-whitish green colour and club shape.	La-22°48'N, Lo-88°30'E
BCBG-15	Suri, Birbhum	Fruit-greenish white colour and pyriform shape.	La-23°55'N, Lo-87°32'
BCBG-17	Seoraphuli, Hoogly	Fruit-patchy green colour and oval or elliptical shape.	La-22°84'N, Lo-88°18'E
BCBG-20	Suri, Birbhum	Fruit-greenish white colour and oval or elliptical shape.	La-23°55'N, Lo-87°32'
BCBG-33	Seoraphuli, Hoogly	Fruit-whitish green colour and globular shape.	La-22°84'N, Lo-88°18'E
BCBG-34	Seoraphuli, Hoogly	Fruit-whitish green colour and oval or elliptical shape.	La-22°84'N, Lo-88°18'E

Table 3.2 : Mean monthly meteorological data of the site during the experiment

Month	Average Temperature (°C)		Average R. H. (%)		Bright sunshine hours	Total rainfall (mm)
	Maximum	Minimum	At 06:35 hr	At 13.35 hr		
Oct. '02	32.4	22.1	96	67	8.3	100.8
Nov. '02	28.8	17.6	95	61	7.8	25.8
Dec. '02	27.4	12.4	99	37	7.9	0.0
Jan. '03	23.7	9.5	99	58	7.2	0.0
Feb. '03	29.2	15.9	98	53	8.0	0.0
Mar. '03	32.0	19.1	95	51	8.5	64.2
Apr. '03	36.2	25.0	92	53	9.2	6.0
May '03	36.5	29.9	93	58	9.2	81.4
Jun. '03	34.8	25.9	94	74	5.2	361.7
Jul. '03	33.4	25.3	97	76	5.2	295.2
Aug. '03	33.4	25.5	98	78	6.4	155.7
Sept. '03	33.4	25.5	99	80	5.3	162.0
Oct. '03	31.9	23.9	99	79	5.1	172.8
Nov. '03	29.6	16.7	99	55	8.8	0.2
Dec. '03	26.2	13.2	99	57	7.0	20.2
Jan. '04	24.2	11.5	99	57	6.9	1.6
Feb. '04	29.6	14.3	97	40	9.1	0.0
Mar. '04	35.3	20.7	94	43	8.6	10.8
Apr. ' 04	36.2	24.0	94	59	9.1	112.0
May '04	37.4	25.9	89	55	9.2	104.6
Jun. '04	34.5	25.8	95	73	5.3	251.7
Jul. '04	33.5	25.7	96	79	4.7	229.9
Aug. '04	33.8	25.7	98	84	5.3	324.0
Sept. '04	32.7	24.8	98	79	4.9	425.9
Oct. '04	32.0	21.8	98	67	7.7	205.7
Nov. '04	30.5	16.7	98	51	8.8	0.0
Dec. '04	27.7	13.9	99	53	7.5	0.0
Jan. '05	24.9	12.0	99	55	6.5	20.2
Feb. '05	30.3	16.1	95	46	8.8	1.2
Mar. '05	33.7	21.2	95	51	8.1	122.5

Source : Department of Agrometeorology, B.C.K.V.

3.5 Experimental details

The present investigation was conducted taking into consideration the objectives of the study. For convenience, the investigation was divided into four experiments to deal with the different objectives.

3.5.1 Experiment I

The first part of the investigation was taken up to study the genetic background of yield attributes to identify suitable combiners for hybrid seed production to study the extent of heterotic manifestation and to evaluate the chemical composition of fruit.

Seeds of all lines were sown in Oct, 2002 in separate plots and selfing was made to raise selfed seeds. In next year, F₁ hybrid seeds were raised by crossing lines (L₁, L₂, L₃, L₄, L₅ and L₆) with testers (T₁, T₂ and T₃). The hybrid seeds of 18 combinations and the parents were sown in separate plots with 75 cm spacing between the seven plants in a plot. The sowing was made in RBD design with 3 replications.

3.5.1.1 Observation recorded

The materials were sown in Randomized Block Design with 3 replications. In each replication, seven plants of each parents and F₁ hybrid were raised and observation for important characters were recorded on five plants after discarding the border plants at both the extreme ends in each treatment. The average value of five plants for each character was used for statistical calculation. The characters observed in this experiment were as follows –

(N.B. Germination percentage was considered only for mean performances including correlation and path analysis)

3.5.1.1.1 Vine length

Length of main axis was measured in metre at the end of the last fruit harvest.

3.5.1.1.2 Number of primary branch per plant

The total number of primary branches that came out from each vine at final harvest was counted.

3.5.1.1.3 Node number of first male and female flower

This was recorded by counting the node number of first male and female flower appearance.

3.5.1.1.4 Days to first male and female flower anthesis

The date of opening of male and female flower were recorded and the number of days taken from the date of sowing to the date of opening of first male and female flower were calculated.

3.5.1.1.5 Sex ratio

The sex ratio was recorded at flowering stage, dividing number of male flowers by number of female flowers.

3.5.1.1.6 Days to first fruit harvest

The number of days taken from the sowing to the first fruit harvest at the edible maturity stage was recorded.

3.5.1.1.7 Fruit length

Fruit length was measured as a perpendicular distance between the point of attachment of the stalk and centre of the bottom end with the help of measuring tape in centimetre.

3.5.1.1.8 Fruit diameter

The measurement of fruit equatorial diameter at the thickest portion of the fruit was taken with the help of measuring tape in centimetre. The fruits taken for measuring length were used for recording diameter also.

3.5.1.1.9 Fruit weight

Five fruits were randomly chosen from each treatment and their average weight was recorded in Kilogram.

3.5.1.1.10 Number of fruits per plant

Total number of fruits harvested from each plot (five plant) were counted and the number of fruits per plant was calculated by dividing the number of plants.

3.5.1.1.11 Fruit yield per plant

This was recorded in kilogram by multiplying average fruit number with average fruit weight per plant.

3.5.1.1.12 Estimation of total soluble solids

TSS (Total Soluble Solids) per fruit was recorded by hand refractometer in terms of percentage.

3.5.1.1.13 Estimation of total sugar

The total sugar content of the fruit pulp of bottle gourd was determined by the standard procedure of A.O.A.C. (1984). The value was expressed in percentage.

3.5.1.1.14 Estimation of ascorbic acid (Vitamin C)

Ascorbic acid content of the fruit pulp of bottle gourd was estimated by using 2, 6-dichlorophenol indophenol dye which is reduced by ascorbic acid to a colourless form (Ranganna, 1990). The value was expressed in mg per 100 gram pulp.

3.5.1.1.15 Seed length and width

Ten seeds were selected randomly from each plot for measuring length and width in centimetre.

3.5.1.1.16 100-seed weight

The weight of 100 seeds collected from ripe fruit in each plot were recorded in gram.

3.5.1.1.17 Germination percentage

The germination test was carried out using germination papers by the between paper (BP) method (ISTA, 1985). Three hundred seeds of each treatment in 3 replications of 100 each, were taken for the test. The seeds were placed between two moist sheets of paper towel, which were then rolled carefully ensuring no excess pressure is placed on seeds, wrapped in a sheet of butter paper to reduce surface evaporation and placed in a germination chamber at $25\pm 2^{\circ}\text{C}$ in an upright position. On the 14th day, number of germinated seeds were counted.

$$\text{Germination percentage} = \frac{\text{No. of normal seedling}}{\text{Total no. of seed taken}} \times 100$$

3.5.1.1.18 Number of seeds per fruit

Five ripe fruits were selected randomly from each plot for counting the seeds. Seeds were extracted, washed and counted. The number of seeds per fruit was found by dividing the total number of seeds obtained from five fruits by five.

3.5.2 Experiment II

The second part of the investigation was taken up to study the effect of storage containers on the storability of bottle gourd seeds.

Sufficient quantity of seeds of one parental line, BCBG-7 (V_1) and one F_1 hybrid, BCBG-4 $\times$ BCBG-20 (V_2) were used to conduct the storage experiment. The seeds of both, parental line and F_1 hybrid were stored in various seed storage container like, cloth bag, desiccator, earthen pot, glass bottle and polyethylene packets of less than 700 gauge thickness for a period of 11 months. During this period, regular seed viability and vigour tests were conducted at one month intervals to study the rate of loss of viability and vigour. The characters observed in this investigation were as follows –

3.5.2.1 Germination percentage

Germination was calculated as in 3.5.1.1.17

3.5.2.2 Seedling root and shoot length

Ten normal seedlings from each rolled towel paper were selected on the 14th days of the germination test (i.e. final count day) and their root and shoot lengths were measured in centimetre. The mean seedling root and shoot length was calculated based on ten seedlings.

3.5.2.3 Seedling dry weight

Ten normal seedlings from each rolled towel paper were selected on the 14th day of germination test and were dried in an oven at 85°C for 24 hours. Weight of the oven dried seedlings was taken after cooling and dry weight of seedling was expressed as mean of ten seedlings in milligram.

3.5.2.4 Seed vigour index

Seed vigour index was calculated using the formula suggested by Abdul-Baki and Anderson (1973).

Seed vigour index (SVI) = Germination (%) × Mean seedling dry weight (mg)

3.5.3 Experiment III

This part of the investigation was undertaken to determine the effect of different pollination methods on fruit and seed yield in bottle gourd. Seeds of two inbred line (i.e. BCBG-4 as female and BCBG-20 as male) were used to conduct the experiment. Female and male parent plants were planted in ratio of 4 : 1 and 4 : 2. Pollination was performed by hand in one set and other set was by natural means. Both hand and natural pollinations were observed in the plots having 4 : 1 and 4 : 2 (female : male) plants. The characters observed in this experiment were as follows -

3.5.3.1 Number of immature seeds per fruit

Five ripe fruits were selected randomly, from each plot for counting the immature seeds. Seed were extracted, washed and counted. The number of immature seeds per fruit was found by dividing the total number of immature seeds obtained from five fruits by five.

The calculation and measurement of number of fruits per plant, fruit weight, fruit yield per plant, number of mature seeds per fruit and 100-

seed weight were made following the methods mentioned in the earlier pages in this chapter.

3.5.4 Experiment IV

The fourth part of the investigation was taken up to study the effect of boron and ethrel on vegetative growth, flowering, fruit yield and seed yield in bottle gourd. Seeds of one inbred line i.e. BCBG-4 was used for the experiment. The plants of bottle gourd were subjected to various treatments such as boron (5, 10 and 15 ppm), ethrel (200, 250 and 300 ppm) and control (water spray). The seedlings were sprayed first at 2-true leaf stage and again after 7 days at 4-true leaf stage. Other cultural operations were performed following scheduled of bottle gourd cultivation. The characters observed in this experiment were as follows.

3.5.4.1 Internode length

This was measured in main vine of 1st five internode in centimetre.

3.5.4.2 Leaf number at the time of first male and female flower appearance

The number of leaves per plant were counted separately during first male and female flower appearance.

3.5.4.3 Pollen viability

Pollens of fresh flower were dusted on the slide containing 1% acetocarmine, covered with a cover slip and observed under the compound microscope, the pollens which were fertile get stained and some remain unstained which were sterile. Percent of pollen viability was calculated using the following formula –

$$\% \text{ of pollen viability} = \frac{\text{No. of fertile pollen}}{\text{Total no. of pollen}} \times 100$$

The calculation and measurement of vine length, number of primary branch per plant, node number of first male and female flower, number of days to first male and female flower anthesis, sex ratio, fruit length and diameter, fruit weight, number of fruits per plant, fruit yield per plant, seed length and width, 100-seed weight and number of seeds per fruit, were made following the methods mentioned in earlier pages in this chapter.

3.5.5 METHODS OF STATISTICAL ANALYSIS OF DATA

3.5.5.1 Experiment I

3.5.5.1.1 Genetic variability

The following statistical analysis was utilized to determine the genetic variability and genetic components by employing the observations recorded on different characters of bottle gourd.

Analysis of variance

Differences between genotypes for different characters were tested for significance using analysis of variance. Analysis of variance was done by using the following model

$$Y_{ij} = M + g_i + r_j + e_{ij}$$

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

M = general mean, g_i = effect of j -th replication

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	$R^2e + r\sigma^2g$	Mt / Me
Replications	(r - 1)	Mr		
Error	(r-1) (t - 1)	Me	σ^2e	

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.

$$S.E. = \sqrt{MSe/r}$$

$S.Ed. = \sqrt{2 MSe/r}$ Where, MSe = Error mean sum of square, r = number of replications.

$$\text{And C.D.} = S. E_d \times t$$

(Distribution of t probability at error degrees of freedom)

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

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

Where MSe = 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 (MSe) will be partly a random environmental variance.

$$\text{i.e. Error variance} = \sigma_e = \text{MSe}$$

$$\text{So, Genotype variance} = \sigma^2_g = (\text{MSg} - \text{MSe})/r$$

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

$$\text{Phenotypic variance} = \sigma^2_p = (\sigma^2_g + \sigma^2_e)$$

Where, MSg and MSe stand for mean sum of squares due to genotype and error respectively.

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

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

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

Heritability in broad sense (H) was estimated by the following formula -

$$H (\%) = \frac{\text{Genotypic variance } (\sigma^2_g)}{\text{Phenotypic variance } (\sigma^2_p)} \times 100$$

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

$$GA = \frac{\text{Genotypic variance } (\sigma^2_g)}{\text{Phenotypic variance } (\sigma^2_p)} \times \kappa \times \sigma_p$$

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

Where, H = Heritability in broad sense,

σ_p = Phenotypic standard deviation,

κ = Selection differential, a constant value is 2.06 for 5% selection intensity.

3.5.5.1.2 Phenotypic and genotypic correlation studies

Correlation co-efficient is a statistical measure which is used to find out the degree and direction of relationship between two or more variables. Therefore, in plant breeding, correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield and other characters.

Using the variance and covariances, phenotypic and genotypic correlation were worked out as follows :-

$$\text{Phenotypic correlation } (r_p) = \frac{\text{PCov. XY}}{[\text{PVX.PVY}]^{.5}}$$

$$\text{Genotypic correlation (r}_g\text{)} = \frac{\text{GCov. XY}}{[\text{GVX.GVY}]^{.5}}$$

Where,

PCov.XY = Phenotypic covariance between X and Y

GCov.XY = Genotypic covariance between X and Y

PVX and PVY = Phenotypic variance of X and Y

GVX and GVY = Genotypic variance of X and Y

Test of significance

The test of significance is accomplished by t-test as under

$$t = \frac{r_p}{\text{S.E. (r}_p\text{)}} \text{ and } \frac{r_g}{\text{S.E. (r}_g\text{)}} \\ [\text{S.E. (r}_p \text{ or r}_g\text{)} = \sqrt{\frac{1 - r_p^2 \text{ or } r_g^2}{n - 2}}]$$

The calculated value of 't' was compared with table value at (n-2) d.f. at 5% and 1% level of significance.

3.5.5.1.3 Path coefficient analysis

Path coefficient analysis as suggested by Dewey and Lu (1959) was used to partition the phenotypic and genotypic correlation into components of direct and indirect effects. By keeping fruit 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 phenotypic and genotypic level were utilized for this purpose.

The direct and indirect effects were classified based on the scale given by Lenka and Mishra (1973).

Scale	Category
More than 1.0	- Very high

0.30 to 0.99	-	High
0.20 to 0.29	-	Moderate
0.10 to 0.19	-	Low
0.00 to 0.09	-	Negligible

3.5.5.1.4 Line x tester analysis

The experimental data obtained from Randomised Block Design (RBD) for different 21 characters were statistically analysis following the analysis of variance for single factor experiment in RBD (Gomez and Gomez, 1984). General combining ability (*gca*) and specific combining ability (*sca*) effects and genetic component of variance were estimated for 20 characters (except seed germination percentage) following line x tester analysis as outlined by Kempthorne (1957).

To study the extent of variability among parents and crosses the following statistics were computed.

i) Mean ($\bar{X}$)

Mean values for each character were calculated from the following formula

$$\bar{X} = \sum_{i=1}^n \frac{X_i}{N},$$

Where $\sum_{i=1}^n X_i$ = Sum of all the observations

N = No. of observations

ii) Standard error (S. E.)

The standard error (S. E.) of mean difference was estimated with the following formula

$$S. E. = \sqrt{\frac{MSe}{r}}$$

Where, MSe = Error mean sum of square, r = No. of replications.

iii) Critical difference (C. D.)

$$C. D. = S. E. \sqrt{2} \times t_{5\% \text{ at error d.f.}}$$

The significance of genotypic difference (Genotype MS/Error MS) in the analysis of variance was compared with table value of 'F' at the desired level of significance (at 5% and 1%) for genotype and error degrees of freedom respectively.

Line x Tester analysis was further carried out where these differences were found significant. Then, the analysis of variance for line x tester crosses comprises two aspects –

a) ANOVA for parents and hybrids

It involves analysis of variance for parents and hybrids, again the parents partitioned into lines (females), testers (males) and female vs. male components. Analysis of variance table is presented in Table 3.3.

Table 3.3 : ANOVA for parents and hybrids

Source	d.f.	Sum of squares	Mean sum squares
Replications	(r-1) = 2	Sr	Mr
Entries/Genotypes	(g-1) = 26	Sg	Mg
Parents	(f+m)-1 = 8	Sp	Mp
Hybrids	(fm-1) = 17	Sh	Mh
Parents Vs. hybrids	(g-1) - (fm-1) - (f+m)-1 = 1	Sph	Mph
Error	(r-1) - (g-1) = 52	Se	Me
Total	77		

Significant variances for these components necessitates ANOVA for combining ability i.e. Line x Tester hybrid analysis.

b) ANOVA for combining ability

This analysis involves further partitioning of variance due to hybrids into three components, namely females in hybrids, males in hybrids

and female x male in hybrids. Accordingly, contributions of females, males and their interaction to the hybrids are ascertained.

Analysis of variance is presented in Table 3.4.

A. Combining ability analysis

For estimation of general and specific combining ability effects and variance, the line x tester analysis as outlined by Kempthorne (1957) was followed.

The form of analysis of variance for line x tester along with mean square expectation is given in Table 3.4.

Table 3.4 : ANOVA for Line x Tester design with mean square expectations

Source of variation	d.f.	Sum of squares	Mean sum squares	Expectation of mean squares
Females	$(f-1) = 5$	S_f	M_1	$\sigma^2_e + r \sigma^2_{fm} + rm\sigma^2_f$
Males	$(m-1) = 2$	S_m	M_2	$\sigma^2_e + r \sigma^2_{fm} + rf\sigma^2_m$
Females x males	$(f-1)(m-1) = 10$	S_{fm}	M_3	$\sigma^2_e + r \sigma^2_{fm}$
Error	$(r-1)(fm-1) = 34$	S_e	M_4	σ^2_e
Total	53			

Where, f , m and r represent the number of females, males and replications respectively

σ^2_e = variance among individuals from same mating

σ^2_f = Progeny variance arising from differences among female parents

σ^2_m = Progeny variance arising from differences among male parents

σ^2_{fm} = Progeny variance arising from interaction of the contribution of male and female parents.

The estimates of the mean of square for line x tester were calculated to assess the ability of the different testers for evaluating the lines for general combining ability.

i) Estimation of general and specific combining ability effects

The linear model (Arunachalam, 1974) used to estimate the combining ability effects of the ijk^{th} observations are as follows :-

$$Y_{ijk} = \mu + g_i + g_j + S_{ij} + r_k + e_{ijk}$$

Where,

μ = general mean

g_i = gca effect of the i^{th} line

g_j = gca effect of the j^{th} tester

S_{ij} = sca effect of the ij^{th} combinations

e_{ijk} = error associated with ij observations at k^{th} plots.

$I = 1, 2, 3, \dots, f$

$j = 1, 2, 3, \dots, m$

The individual effect was estimated as below -

$\mu = \frac{Y_{...}}{rfm}$, where $Y_{...}$ = Grand total of all the hybrid combinations

gca effect (lines) :

$$g_i = \frac{Y_{i...}}{rm} - \frac{Y_{...}}{rmf}, i = 1, 2, 3, \dots, 6$$

$Y_{i...}$ = Total of i^{th} line over all testers and replications

gca effect (testers) :

$$g_j = \frac{Y_{.j.}}{rf} - \frac{Y_{...}}{rmf}, j = 1, 2, 3$$

$Y_{.j.}$ = Total of j^{th} tester over lines and replications.

Sca effects (hybrids) :

$$S_{ij} = \frac{Y_{ij.}}{r} - \frac{Y_{i...}}{rm} - \frac{Y_{.j.}}{rf} + \frac{Y_{...}}{rmf}$$

$Y_{ij.}$ = Total of ij^{th} combinations over all the replications.

Test of significance for combining ability

Standard error for combining ability effects were calculated as given below :

$$\text{S.E. (gi) lines} = \sqrt{\frac{eMs}{rm}}$$

$$\text{S.E. (gj) testers} = \sqrt{\frac{eMs}{rf}}$$

$$\text{S.E. (gi - gj) lines} = \sqrt{\frac{2eMs}{rm}}$$

$$\text{S.E. (gi - gj) testers} = \sqrt{\frac{2eMs}{rf}}$$

$$\text{S.E. (Sij)} = \sqrt{\frac{eMs}{r}}$$

$$\text{S.E. (Sij - Skl)} = \sqrt{\frac{2eMs}{r}}$$

The significance of the *gca* lines, *gca* testers and *sca* effects of hybrids were tested using “student-t-test” and is given as

$$t = \frac{g_i}{\text{S.E. (gi)}}, \frac{g_j}{\text{S.E. (gj)}}, \frac{S_{ij}}{\text{S.E. (Sij)}} \text{ lines, testers and hybrids at 5\% and 1\% “t” value}$$

$$G_i = 1, 2, 3, \dots, 6$$

$$G_j = 1, 2, 3$$

$$S_{ij} = 1, 2, 3, \dots, 18$$

ii) Proportional contribution of lines, testers and their interactions

$$\text{Contribution of lines(\%)} = \frac{S_f}{S_h} \times 100$$

$$\text{Contribution of testers (\%)} = \frac{S_m}{S_h} \times 100$$

$$\text{Contribution of lines x testers (\%)} = \frac{S_{fm}}{S_h} \times 100$$

Where, S_m , S_f , S_{fm} and S_h are sum of squares due to male, female, female x male and hybrids respectively.

iii) Estimation of genetic components of variance

$$\text{Cov H. S. (line)} = \frac{M_1 - M_3}{rm} = \sigma^2_f$$

$$\text{Cov H. S. (tester)} = \frac{M_2 - M_3}{rf} = \sigma^2_m$$

$$\text{Cov. H. S. (average)} = \frac{(M_1 - M_3) + (M_2 - M_3)}{r(f+m)}$$

$$\begin{aligned} \text{Cov F. S.} = & \frac{(M_1 - M_4) + (M_2 - M_4) + (M_3 - M_4)}{3r} \\ & - \frac{6r (\text{Cov H.S.}) - r(f+m) \text{Cov H.S.}}{3r} \end{aligned}$$

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

Variance due to general combining ability (σ^2_{GCA}) = Cov H.S.

Variance due to specific combining ability (σ^2_{SCA}) = Cov F.S. - 2 Cov H.S.

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

$$\text{Additive genetic variance } \sigma^2_A = \sigma^2_{GCA} / \frac{(1+F)}{4} \quad (F = 0)$$

$$\text{Non-additive genetic variance } \sigma^2_D = \sigma^2_{SCA} / \frac{(1+F)^2}{4} \quad (F = 0)$$

Where,

F = Inbreeding coefficient.

B. Estimation of Heterosis

The heterosis expressed as per cent increase or decrease of F_1 's, in the present investigation was measured in two ways.

(i) Heterosis over the better parents ($\overline{BP}$) :

$$\text{i.e. Heterobeltiosis } (H_{\overline{BP}}) = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where, $\overline{BP}$ = Mean of the better parent

The better parent was considered as that parents which was better in the desired direction with respect to specific character.

(ii) Heterosis over the mid parents ($\overline{MP}$) :

$$\text{i.e. Relative heterosis } (H_{\overline{MP}}) = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Where, } MP = \frac{\overline{P_1} + \overline{P_2}}{2}$$

Test of significance of heterosis

i) The standard errors for testing the significance of heterosis were calculated following the method of Bitzer *et al.* (1967).

Standard error for better parent heterosis

$$S.E. (\overline{BP}) = \sqrt{\frac{2MSe}{r}}$$

Standard error for mid parent heterosis

$$S. E. (\overline{MP}) = \sqrt{\frac{3MSe}{2r}}$$

Where, MSe is the mean sum of square due to error

r is the number of replications.

(ii) The critical difference (C.D.) for testing the significance of difference between the F_1 hybrid and parental mean values were calculated as follows :

C. D. = S. E. x t at error d.f. for 5% and 1% levels of probability

Where, S. E. are the standard error due to and heterobeltiosis S. E. ($\overline{BP}$) and relative heterosis S. E. ($\overline{MP}$)

This test of significance of heterosis over the better parent/mid parent was made by comparison between the deviation of the respective mean value of the hybrid from that of their better parent/mid parent and the calculated C.D. at 5% and 1% level. If the deviation was greater as compared to C. D. values at 5%, the heterosis was found to be significant and an

asterisk is placed over the estimate. If the deviation was greater at C.D. 1%, the heterosis was found to be highly significant and double asterisk was placed over the estimates. Otherwise, the estimate is considered as non-significant.

3.5.5.2 Experiment II

The data obtained from germination were subjected to angular transformation and analysis by ANOVA method for 3-Factor Complete Randomized Design (FCRD) was done and significance was tested for variety, month, container, variety x month, variety x container, month x container and variety x month x container interaction as per the procedure prescribed by Gomez and Gomez (1984). The data obtained from seedling root and shoot length, dry weight and vigour index measurement/calculation, without angular transformation, were also subjected to same type of analysis described above.

3.5.5.3 Experiment III

The data obtained as described earlier were subjected to statistical analysis by the analysis of variance method for simple Randomized Block Design (RBD) (Gomez and Gomez, 1984) and the significance of different sources of variations were tested by Error Mean Square by Fisher and Snedecor's 'F' test at probability level of 5%. For determination of Critical Difference (C.D.) at 5% level of significance, Fisher and Yate's table (1963) was consulted. The value of Critical Difference (C.D.) between treatment means have been provided in the table of results.

3.5.5.4 Experiment IV

The data obtained from field experiment were subjected to statistical analysis by ANOVA method for 2-factor Randomized Block Design (RBD) (Gomez and Gomez, 1984). The significance of sources of variations were tested by Fisher and Snedecor's 'F' test at 5% level of significance. For comparison of 'F' values and for computation of Critical Difference (C.D.) at 5% level of significance Fishers and Yate's table (1963) were consulted.

Chapter - 4

Results & Discussion

Results and Discussion

4.1 Experiment I

The six lines (L₁, L₂, L₃, L₄, L₅ and L₆) were crossed with three testers (T₁, T₂ and T₃) in a line x tester mating design. The resultant 18 hybrids were evaluated for heterosis and combining ability for effective selection of parents and hybrids and to understand their breeding values. The data recorded from nine parents (6 lines + 3 testers) and eighteen hybrids (all possible crosses between lines and testers) on different quantitative traits and quality traits were statistically analysed.

The basic idea of hybridization programme is to combine favourable genes present in different parents into a single genotype. The hybrids thus obtained can be utilized directly (as F₁ hybrids) to exploit vigour or forwarding to further generations. The utilization of hybrid will depend upon its genetic constitutions, which are usually measured by *per se* performance.

In the present study, *per se* performance of hybrids was taken up as first step for evaluation of hybrids.

The experimental results and discussion on the following parameters are furnished here under.

- a) Mean performance of parents and hybrids
- b) Variability studies of parents
- c) Correlation and path coefficient analysis
- d) Combining ability effect and gene action
- e) Heterosis
 - 1. Heterobeltiosis
 - 2. Relative heterosis

4.1.1 Mean performance of parents and hybrids

The results on the observed mean values of each parents and hybrids for each trait are furnished below. The mean values of parents and hybrids are given in Table 4.1, 4.2.

4.1.1.1 Length of main vine (m)

The vine length ranged from 4.80 m to 6.90 m in the lines and from 4.85 m to 6.47 m in the testers. Among the lines, L₁ (6.82 m), L₅ (6.90 m) and L₆ (6.41 m) and only T₂ tester (6.47 m) had significantly higher length compared to their respective means.

Among the hybrids, seven hybrids exhibited significantly higher length of main vine and the highest length (7.73 m) was recorded in L₁ × T₂. However, the performances of the two parents of this cross were high among the parents.

4.1.1.2 Number of primary branch per plant

Among the lines, the highest number of primary branch per plant was recorded in L₆ (16.47) and the lowest in L₃ (11.80). The lines L₅ (14.40) and L₆ (16.47) and the tester, T₂ (14.67) showed significantly higher number of primary branch per plant compared to their mean values, 13.24 and 13.06 respectively. Among the hybrids, five had significantly higher primary branches and the hybrid, L₆ × T₂ had the maximum number.

4.1.1.3 Node number of first male and female flower

The node number of first male flower ranged from 6.67 to 8.27 in lines and 7.00 to 7.33 in testers. The respective lines (L₃, L₅, L₆) and tester (T₃) had lower node number in comparison to their respective means.

For the node number of the first female flower, the lines, L₃ (8.33), L₅ (7.93) and L₆ (8.40) had significantly lower values than the mean (8.61). But there was no significant difference among the testers.

Table 4.1 : Mean performance of parents for different characters

Parents	Length of main vine (m)	Number of primary branch per plant	Node number of first male flower	Node number of first female flower	Number of days to first male flower anthesis	Number of days to first female flower anthesis	Sex ratio (male flowers/female flowers)	Number of days to first fruit harvest	Fruit length (cm)	Fruit diameter (cm)
Lines										
L ₁	6.82	12.67	8.27	9.27	55.33	61.30	8.49	74.67	15.25	16.50
L ₂	5.00	11.73	7.80	8.93	55.67	61.00	8.95	82.33	19.25	16.25
L ₃	5.36	11.80	7.13	8.33	52.00	58.33	7.31	79.00	28.62	12.33
L ₄	4.80	12.40	7.60	8.80	51.67	58.00	7.68	77.33	25.80	14.43
L ₅	6.90	14.40	6.67	7.93	44.33	50.33	8.77	78.00	20.82	17.10
L ₆	6.41	16.47	7.13	8.40	51.67	57.67	9.25	80.67	27.85	15.45
Mean	5.88	13.24	7.43	8.61	51.78	57.78	8.41	78.67	22.93	15.34
C.D. at 5%	0.16	0.60	0.09	0.13	0.69	0.49	0.18	0.71	0.74	0.65
Testers										
T ₁	5.24	12.58	7.27	8.47	53.67	59.67	7.45	77.67	17.15	18.27
T ₂	6.47	14.67	7.33	8.47	52.67	57.33	10.84	81.67	17.67	15.11
T ₃	4.85	12.00	7.00	8.53	51.33	57.33	9.43	82.33	20.13	18.75
Mean	5.52	13.06	7.20	8.49	52.26	58.11	9.24	80.56	18.32	17.38
C.D. at 5%	0.14	0.47	0.08	NS	0.56	0.39	0.13	0.56	0.58	0.50

Table 4.1 (Contd....)

Parents	Fruit weight (kg)	Number of fruits per plant	Fruit yield per plant (kg)	TSS (°Brix)	Ascorbic acid (mg/100 gm)	Total sugar (%)	Seed length (cm)	Seed width (cm)	100-seed weight (gm)	Germination (%)	Number of seeds per fruit
Lines											
L ₁	1.87	3.63	6.77	2.00	6.76	1.62	1.75	0.73	19.58	95.67 (78.10)	394.27
L ₂	1.79	3.93	7.30	2.43	6.62	1.75	1.68	0.72	17.73	89.67 (71.32)	384.73
L ₃	2.46	4.07	9.67	2.83	7.70	2.33	1.98	0.82	14.25	83.33 (65.92)	480.33
L ₄	2.15	4.20	9.03	2.67	7.01	1.84	1.93	0.93	19.72	94.00 (75.95)	437.20
L ₅	2.01	4.43	8.90	3.43	7.38	2.14	1.86	0.84	18.33	92.33 (73.98)	406.67
L ₆	2.47	3.80	9.39	2.40	8.10	2.00	1.84	0.84	17.18	82.67 (65.42)	540.73
Mean	2.12	4.01	8.51	2.63	7.26	1.95	1.84	0.81	17.80	89.61 (71.78)	440.65
C.D. at 5%	0.07	0.11	0.22	0.09	0.11	0.07	0.07	0.02	0.67	1.49	11.36
Testers											
T ₁	2.05	4.13	8.37	3.26	6.52	2.10	1.78	0.75	14.77	85.67 (66.77)	418.80
T ₂	1.88	4.33	8.15	2.60	7.71	1.50	1.74	0.86	17.45	88.33 (70.13)	360.33
T ₃	2.64	3.73	9.85	2.43	6.42	2.24	2.26	1.00	28.12	98.00 (82.33)	592.67
Mean	2.19	4.06	8.79	2.76	6.88	1.95	1.93	0.87	20.11	90.67 (73.41)	457.27
C.D. at 5%	0.06	0.08	0.19	0.06	0.08	0.06	0.06	0.03	0.53	1.17	8.97

Figures in the parenthesis are arc-sine transformation value

Table 4.2 : Mean performances of hybrids for different characters

Hybrids	Length of main vine (m)	Number of primary branch per plant	Node number of first male flower	Node number of first female flower	Number of days to first male flower anthesis	Number of days to first female flower anthesis	Sex ratio (male flowers/ female flowers)	Number of days to first fruit harvest	Fruit length (cm)	Fruit diameter (cm)
L ₁ x T ₁	6.68	16.20	6.13	8.07	51.33	58.00	7.56	76.67	16.72	17.80
L ₁ x T ₂	7.73	13.80	6.73	8.47	53.00	59.67	8.76	75.33	17.52	15.92
L ₁ x T ₃	6.53	15.60	8.07	9.40	54.33	59.67	7.31	74.33	24.25	17.53
L ₂ x T ₁	5.76	16.40	6.87	8.67	52.33	59.00	6.74	75.67	24.40	19.21
L ₂ x T ₂	6.34	16.87	7.13	9.53	51.67	57.67	9.41	77.33	19.18	17.33
L ₂ x T ₃	5.35	14.33	7.93	8.27	52.00	57.67	6.87	79.33	25.14	21.30
L ₃ x T ₁	5.76	14.80	7.40	9.53	52.67	58.00	5.80	77.67	28.00	14.10
L ₃ x T ₂	6.28	14.20	6.60	8.80	53.00	59.67	7.20	78.67	30.53	14.00
L ₃ x T ₃	5.50	14.67	8.27	10.07	51.00	56.00	8.00	78.33	29.55	15.54
L ₄ x T ₁	6.24	16.00	7.47	9.80	52.00	57.00	5.13	72.00	28.50	17.24
L ₄ x T ₂	5.35	18.47	8.20	10.20	52.33	57.00	5.72	78.33	29.42	18.10
L ₄ x T ₃	5.24	13.67	7.40	9.40	51.33	55.67	6.71	72.00	25.61	15.62
L ₅ x T ₁	6.70	17.53	6.20	9.40	47.00	56.67	6.83	79.33	21.57	19.63
L ₅ x T ₂	7.71	18.40	6.67	9.60	48.00	54.00	7.50	75.67	17.10	15.61
L ₅ x T ₃	6.57	16.53	7.27	9.07	48.00	53.53	7.35	78.33	25.33	18.15
L ₆ x T ₁	7.17	14.80	6.80	8.73	52.33	57.00	8.52	80.00	26.74	16.53
L ₆ x T ₂	6.72	20.33	7.67	9.73	53.33	58.33	9.43	79.67	25.71	17.60
L ₆ x T ₃	6.30	15.37	6.60	8.53	49.00	56.67	7.37	81.33	29.70	18.72
Mean	6.33	16.00	7.19	9.18	51.37	57.28	7.37	77.22	24.72	17.33
C.D. at 5%	0.22	0.77	0.12	0.18	0.89	0.63	0.31	0.91	0.93	0.83

Table 4.2 (Contd...)

Hybrids	Fruit weight (kg)	Number of fruits per plant	Fruit yield per plant (kg)	TSS ($^{\circ}$ Brix)	Ascorbic acid (mg/100 gm)	Total sugar ($^{\circ}$ %)	Seed length (cm)	Seed width (cm)	100 seed weight (gm)	Germination (%)	Number of seeds per fruit
$L_1 \times T_1$	1.94	3.80	7.36	3.40	6.96	2.05	1.72	0.84	18.88	92.00 (73.73)	450.67
$L_1 \times T_2$	1.88	4.20	7.90	2.90	7.24	1.86	1.94	0.94	20.30	93.67 (75.56)	417.60
$L_1 \times T_3$	2.24	4.27	9.56	2.13	6.53	1.95	2.00	0.96	23.96	97.00 (80.46)	475.55
$L_2 \times T_1$	1.90	4.27	8.12	2.77	6.25	1.60	1.98	0.96	19.38	90.67 (72.31)	426.33
$L_2 \times T_2$	1.75	5.13	8.98	2.50	7.62	1.67	2.02	1.00	23.42	94.00 (75.95)	390.67
$L_2 \times T_3$	2.66	5.00	13.30	2.00	6.37	1.64	2.35	0.90	21.38	93.67 (75.70)	512.20
$L_3 \times T_1$	2.79	4.73	13.20	1.90	7.37	1.80	1.88	1.00	17.14	81.33 (66.44)	535.40
$L_3 \times T_2$	2.07	5.33	11.03	3.03	8.13	2.14	2.07	0.94	21.73	91.33 (73.34)	437.60
$L_3 \times T_3$	2.30	5.13	11.80	2.57	7.13	2.14	1.88	0.96	20.72	95.67 (78.10)	485.00
$L_4 \times T_1$	2.32	5.20	12.06	2.73	6.77	1.74	1.94	0.98	21.51	87.33 (69.23)	497.00
$L_4 \times T_2$	2.45	4.53	11.10	3.47	7.97	1.70	1.98	1.02	22.25	85.67 (67.83)	506.33
$L_4 \times T_3$	2.57	4.13	10.61	2.87	6.85	2.10	1.96	1.08	27.23	96.33 (79.24)	518.33
$L_5 \times T_1$	2.48	5.47	13.67	2.53	7.27	2.00	1.82	0.92	19.33	86.67 (68.63)	522.13
$L_5 \times T_2$	1.98	5.40	10.69	3.60	7.82	1.95	2.04	1.00	23.13	92.67 (74.40)	444.33
$L_5 \times T_3$	2.31	4.20	9.70	3.37	6.68	2.67	2.10	0.96	25.35	94.33 (67.49)	478.53
$L_6 \times T_1$	2.25	4.53	10.19	2.77	7.73	1.87	1.94	1.00	21.03	89.00 (70.72)	470.67
$L_6 \times T_2$	2.13	4.27	9.08	2.30	9.41	1.60	1.87	0.90	18.74	84.67 (66.99)	465.73
$L_6 \times T_3$	2.80	4.87	13.64	3.53	8.27	2.10	2.16	1.14	27.82	96.33 (79.24)	635.20
Mean	2.27	4.69	10.67	2.80	7.35	1.92	1.98	0.97	21.85	91.24 (73.47)	481.63
C.D. at 5%	0.08	0.16	0.85	0.10	0.16	0.08	0.10	0.02	0.87	1.93	14.64

Figures in the parenthesis are the arc-sine transformation values

Among the hybrids, the node number of first male flowers was lowest in the hybrid $L_1 \times T_1$ (6.13) but it was highest in cross combination of $L_3 \times T_3$. For node number of first female flower, the cross combination $L_4 \times T_2$ (10.20) recorded the highest node number of first female flower, while the hybrid, $L_1 \times T_1$ (8.07) had the lowest node number of first female flower. Among the parents, L_5 had the lowest node number of first female flower.

4.1.1.4 Number of days to first male and female flower anthesis

The line L_5 (44.33) and tester T_3 (51.33) showed significant less days to first male flower anthesis compared to their mean and the rest lines and testers had high value over their means. But the hybrid, $L_5 \times T_1$ and other three hybrids exhibited less days and minimum days were taken by the $L_5 \times T_1$ combination. The common parents, L_5 had also less days to first male flower anthesis. However, hybrids performed better than the parents.

For number of days to first female flower anthesis, the line L_5 (50.33) and T_2 and T_3 testers exhibited significantly less days than their respective means. Among the hybrids, the combination of $L_5 \times T_3$ had least days to first female flower anthesis while $L_1 \times T_2$, $L_1 \times T_3$ and $L_3 \times T_2$ combinations had longest days for this trait.

4.1.1.5 Sex ratio

With respect to sex ratio, it was observed that the lines, L_3 (7.31) and L_4 (7.68) and tester T_1 (7.45) showed significantly less sex ratio compared to their means (the less ratio indicates less number of male flowers for each female flower) (Fig. 4.1). In the hybrids, $L_4 \times T_1$ recorded the lowest sex ratio while $L_6 \times T_2$ had the highest ratio (Fig. 4.2). One of the parent (L_4) of hybrid had lower sex ratio value.

4.1.1.6 Days to first fruit harvest

Days to first fruit harvest ranged from 74.67 to 82.33 in lines and 77.67 to 82.33 in testers while tester T_1 (77.67) showed significant less days

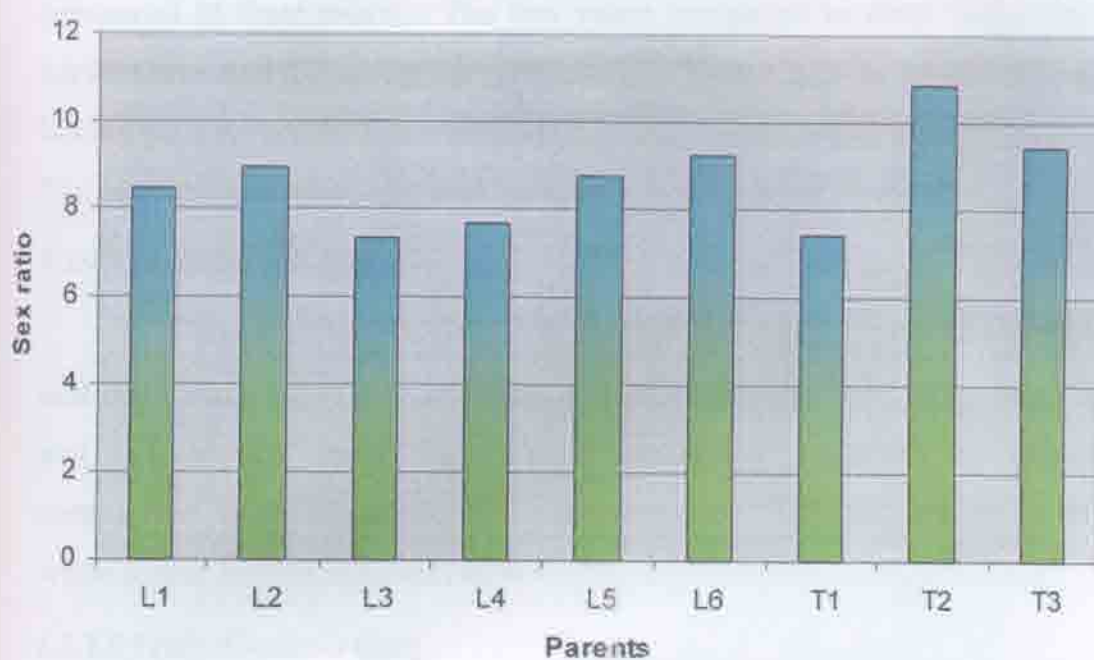


Fig.4.1 : Performance of parents for sex ratio

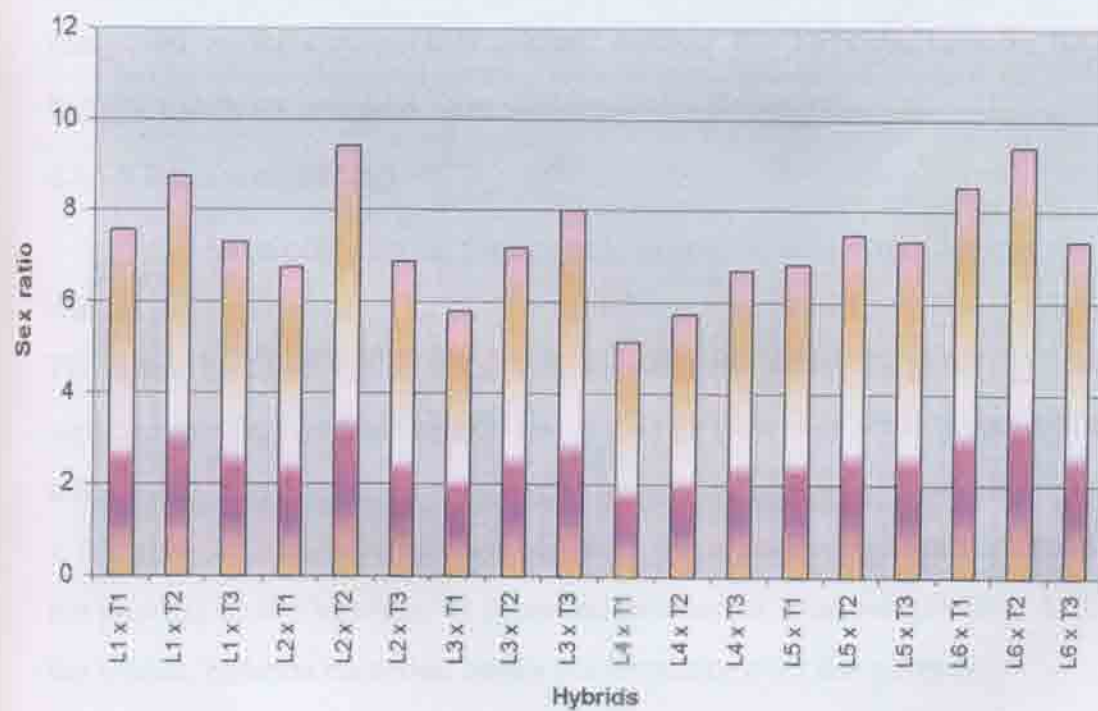


Fig.4.2 : Performance of hybrids for sex ratio

compared to their means. The less value compared to mean indicates that harvest was early. Among the hybrids, $L_4 \times T_1$ and $L_5 \times T_3$ combinations had lowest days to first fruit harvest while $L_6 \times T_3$ combination took longest days. The parents, L_4 and T_1 also had lowest days to first fruit harvest.

4.1.1.7 Fruit length (cm)

The fruit length ranged from 15.25 cm (L_1) to 28.62 cm (L_3) in lines and from 17.15 cm (T_1) to 20.13 cm (T_3) in testers (Fig. 4.3). The lines, L_3 , L_4 and L_6 and the tester, T_3 showed significantly higher fruit length in comparison to their means. The same trend was noticed in $L_3 \times T_2$ hybrid while it was lowest in $L_1 \times T_1$ hybrid (Fig. 4.4).

4.1.1.8 Fruit diameter (cm)

The fruit diameter among the lines showed variation and ranged from 12.33 cm to 17.10 cm in lines and 15.11 cm to 18.75 cm in the testers (Fig. 4.5). The lines L_1 (16.50 cm), L_2 (16.25 cm) and L_5 (17.10 cm) and the testers T_1 (18.27 cm) and T_3 (18.75 cm) showed significantly higher diameter compared to their respective means. Among the hybrids, $L_2 \times T_3$ had the highest diameter and $L_3 \times T_2$ hybrid had lowest diameter (Fig. 4.6).

4.1.1.9 Fruit weight (kg)

As in other traits, the lines exhibited variation and the highest fruit weight was recorded in L_6 (2.47 kg) and the lowest in L_2 (1.79 kg) (Fig. 4.7). The lines, L_3 (2.46 kg) and L_6 (2.47 kg) and the tester T_3 (2.64 kg) showed significantly higher fruit weight compared to their respective means. On the other hand, the hybrid ($L_6 \times T_3$) recorded the highest weight and lowest in $L_2 \times T_2$ hybrid. Other five hybrids also had the higher weight of fruit. Among the parents of the hybrids, T_3 recorded maximum fruit weight (Fig. 4.8). On the whole, hybrids recorded better performance over the parents.

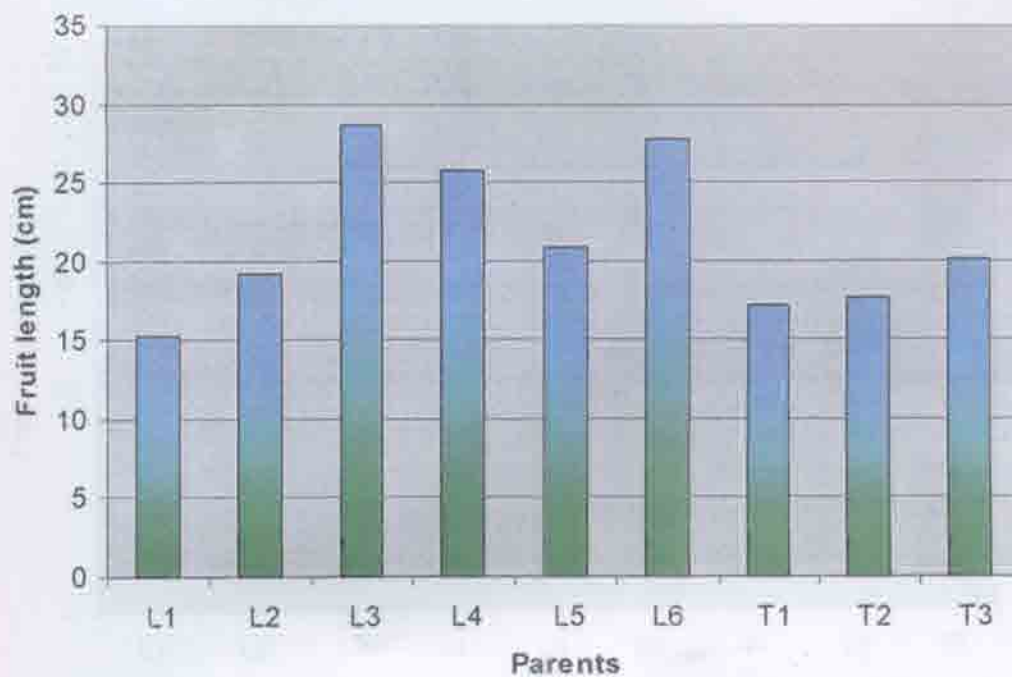


Fig.4.3 : Performance of parents for fruit length

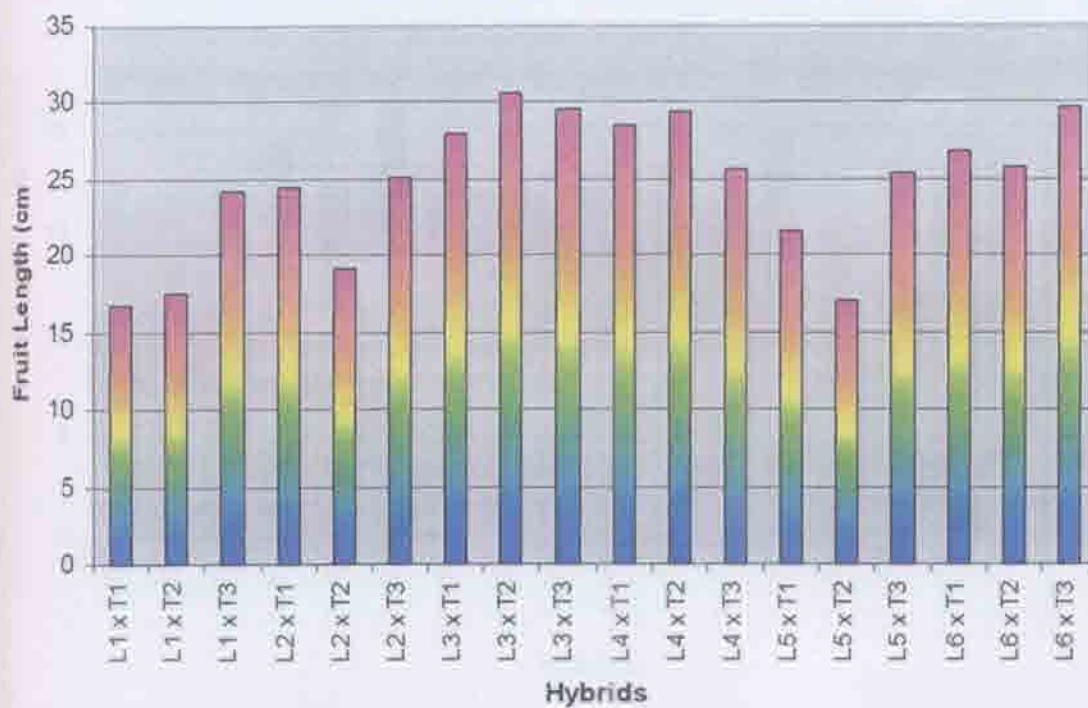


Fig.4.4 : Performance of hybrids for fruit length

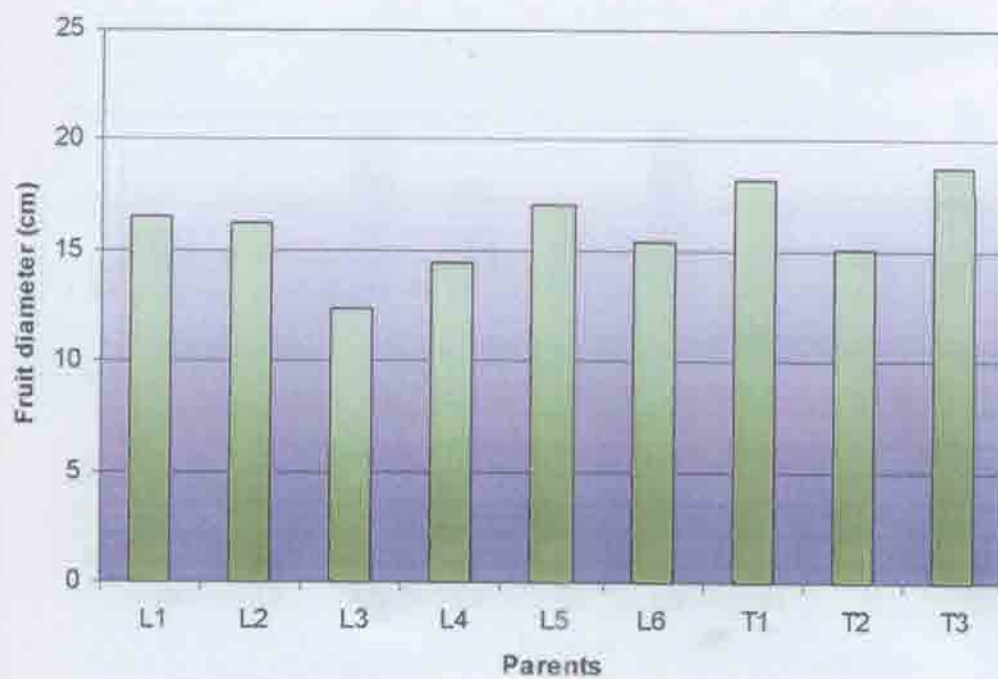


Fig.4.5 : Performance of parents for fruit diameter

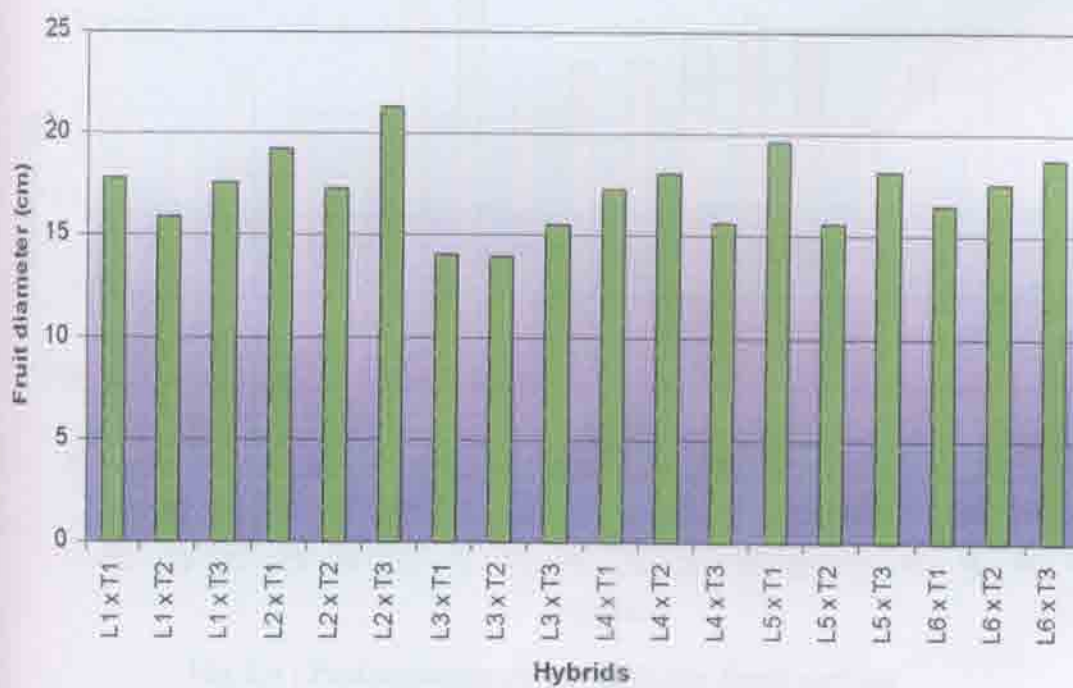


Fig.4.6 : Performance of hybrids for fruit diameter

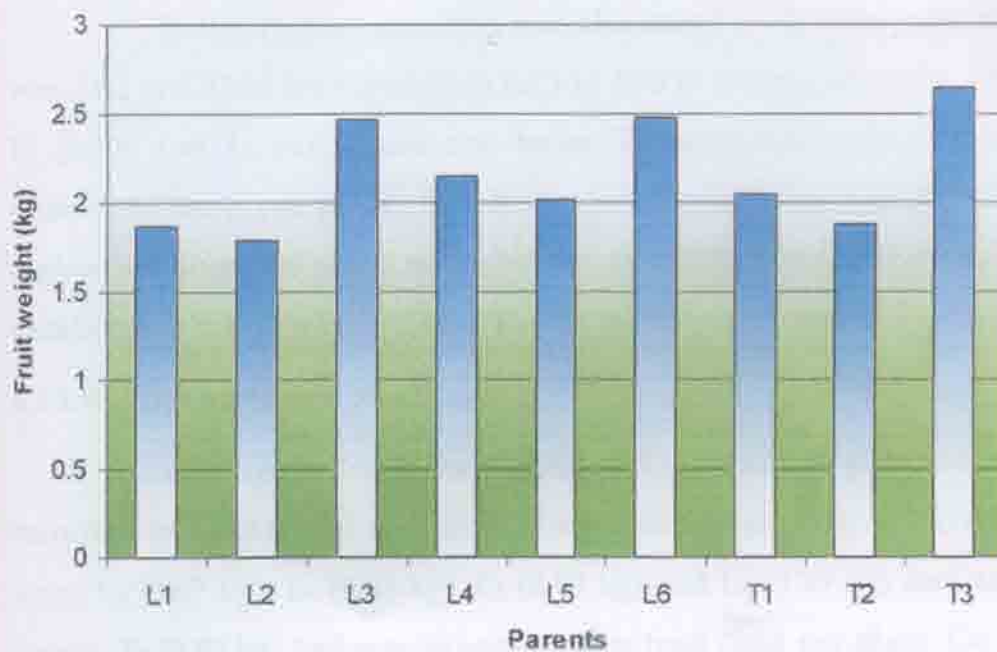


Fig.4.7 : Performance of parents for fruit weight

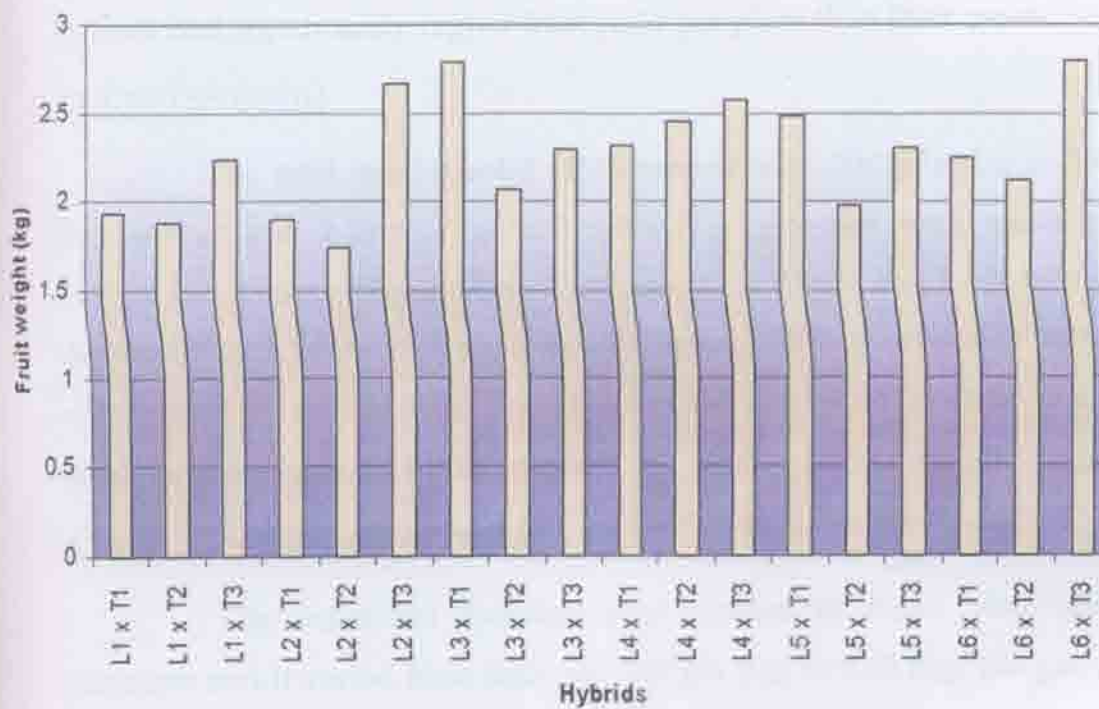


Fig.4.8 : Performance of hybrids for fruit weight

4.1.1.10 Number of fruits per plant

In this respect variation was also noted as in other traits and range was 3.63 to 4.43 in lines and from 3.73 to 4.33 in testers (Fig. 4.9). Two lines, L₄ (4.20) and L₅ (4.43) and one tester T₂ (4.33) had significantly higher number of fruits per plant. But the range in hybrid was 3.80 to 5.47 and the highest number was noted in the hybrid, L₅ × T₁ (Fig. 4.10). Over all, the fruit number was more in hybrid than that in the lines and testers.

4.1.1.11 Fruit yield per plant (kg)

Among the lines, the highest and lowest fruit yield per plant was recorded in L₃ (9.67 kg) and L₁ (6.77 kg) respectively (Fig. 4.11). Among the lines, L₃ (9.67 kg), L₄ (9.03 kg), L₅ (8.90 kg) and L₆ (9.39 kg) and among the testers, T₃ (9.85 kg) had significantly higher fruit yield per plant. On the other hand, fruit yield per plant was maximum in L₅ × T₁ combination (13.67 kg) and minimum in L₁ × T₁ combination (7.36 kg) (Fig. 4.12). Moreover, eight hybrids had significantly higher fruit yield per plant than their mean.

4.1.1.12 TSS (°Brix)

The total soluble solid (TSS) ranged from 2.00° Bx (L₁) to 3.43° Bx (L₅) in lines and 2.43° Bx (T₃) to 3.26° Bx (T₁) in testers with mean values 2.63° Bx and 2.76° Bx respectively. The lines, L₃ (2.83° Bx) and L₅ (3.43° Bx) and the tester, T₁ (3.26° Bx) had significantly higher TSS. However, the hybrid, L₅ × T₂ scored the highest TSS (3.60 Bx) against the lowest content in L₃ × T₁ combination with 2.80° Bx TSS mean.

4.1.1.13 Ascorbic acid (mg/100 gm)

The estimated ascorbic acid content in fruits also exhibited variation and it varied from 6.62 mg/100 gm (L₂) to 8.10 mg/100 gm (L₆) in lines and from 6.42 mg/100 gm (T₃) to 7.71 mg/100 gm (T₂) in testers. Among the lines, L₃ (7.70 mg/100 gm), L₅ (7.38 mg/100 gm) and L₆ (8.10 mg/100 gm) and among the testers, T₂ (7.71 mg/100 gm) had significantly

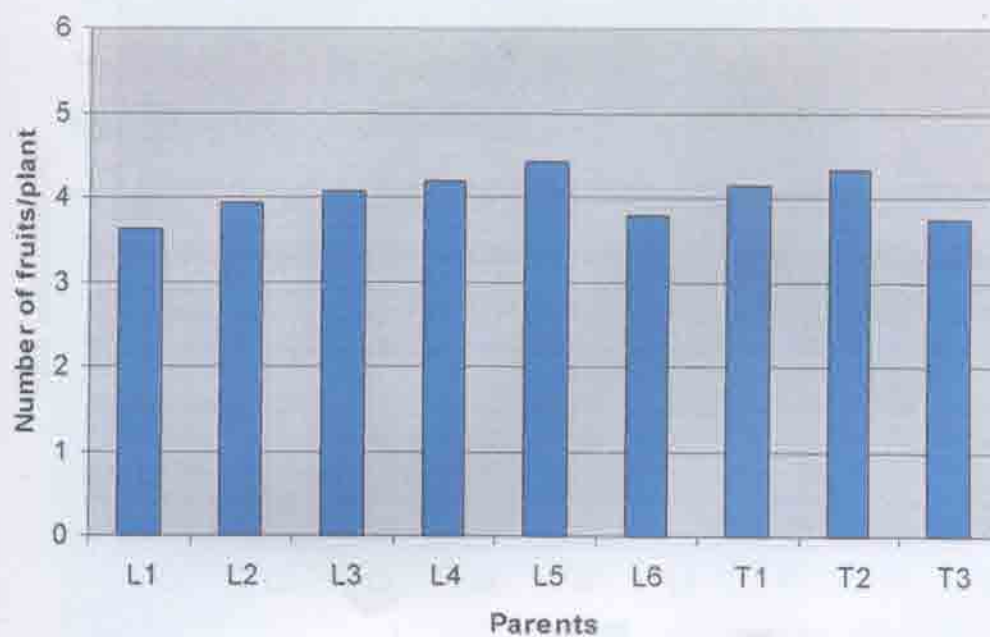


Fig.4.9 : Performance of parents for number of fruits per plant.

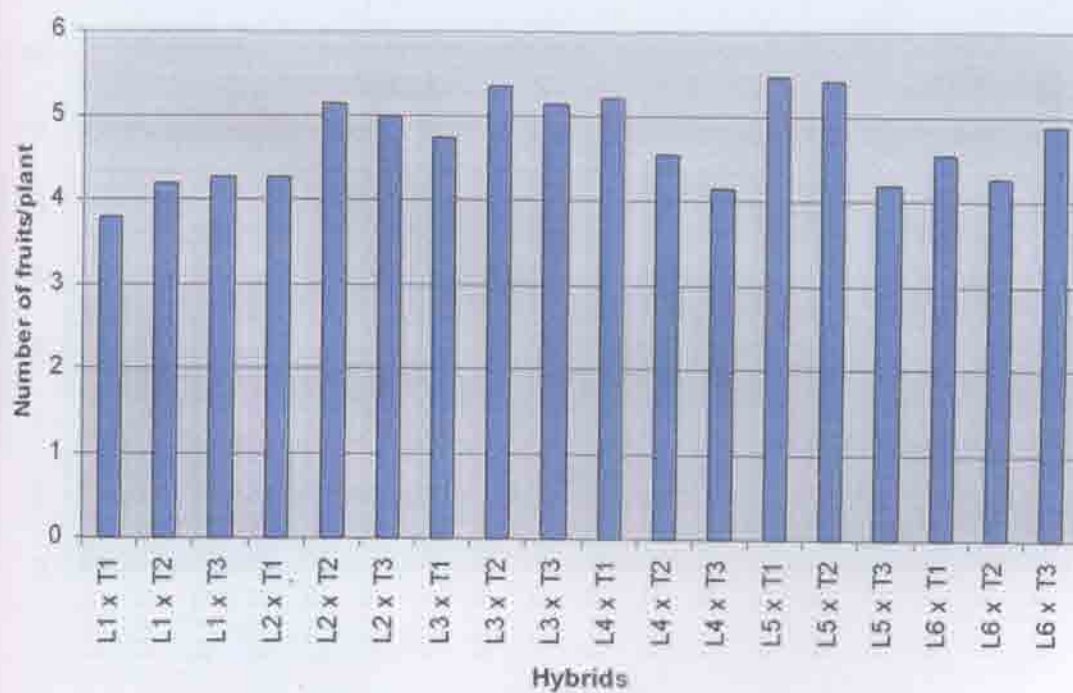


Fig.4.10 : Performance of hybrids for number of fruits per plant.

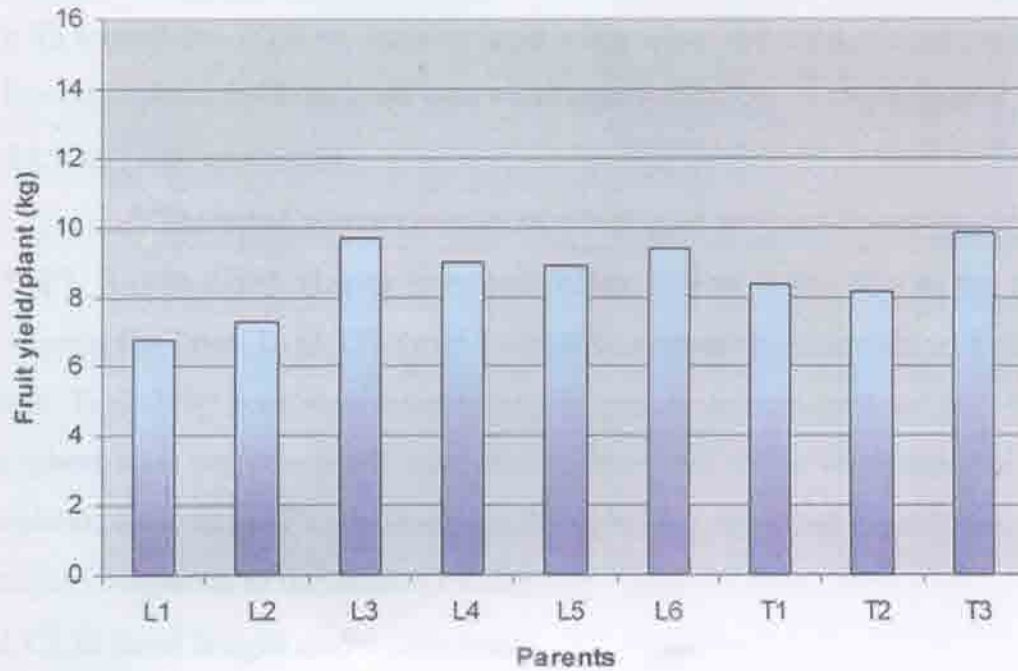


Fig.4.11 : Performance of parents for fruit yield per plant

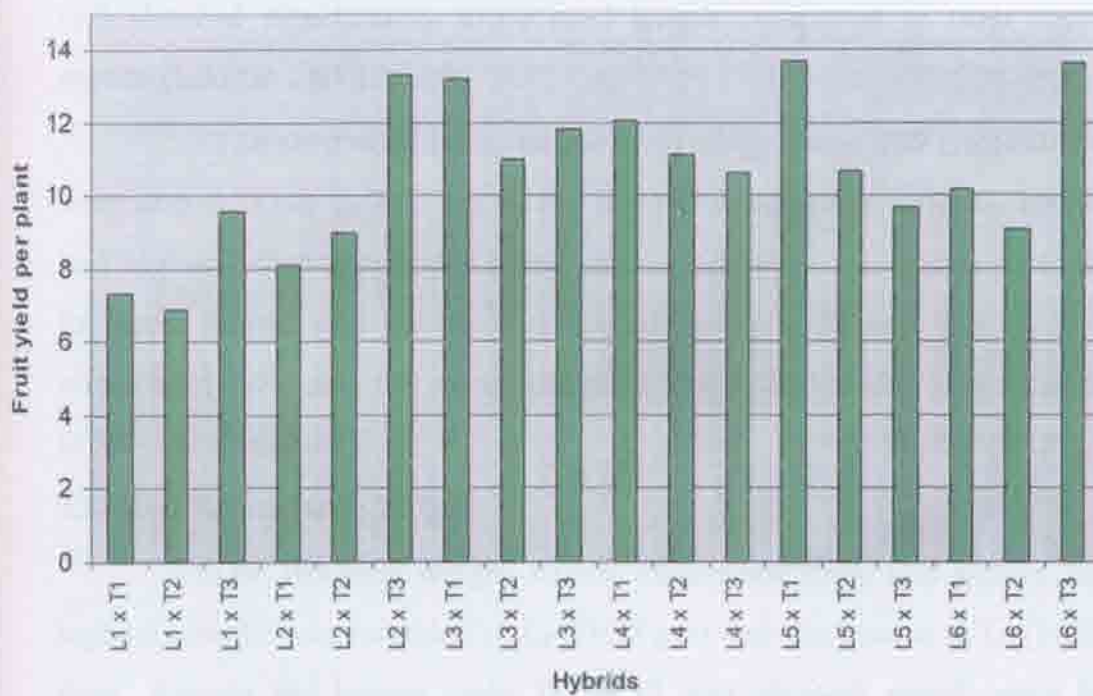


Fig.4.12 : Performance of hybrids for fruit yield per plant

higher content than their respective means. On the other hand, the hybrid, $L_6 \times T_2$ scored the highest ascorbic acid even more than the parents while the lowest content (6.25 mg/100 gm) was recorded in $L_2 \times T_1$ combination.

4.1.1.14 Total sugar (%)

The total sugar content (%) had also variation and ranged from 1.62% (L_1) to 2.33% (L_3) in lines and 1.50% (T_2) to 2.24% (T_3) in the testers. Among the lines, L_3 (2.33%) and L_5 (2.14%) and among the testers, T_1 (2.10%) and T_3 (2.24%) had significantly higher percentage of total sugar. But the highest total sugar content than that in lines and tester was recorded in the hybrid, $L_5 \times T_3$ (2.67%). Other six hybrids also recorded significant higher sugar compared to the mean (1.92%).

4.1.1.15 Seed length and width (cm)

With respect to seed length the variation ranged from 1.68 cm (L_2) to 1.98 cm (L_3) in lines and from 1.74 cm (T_2) to 2.26 cm (T_3) in testers. Among the lines, L_3 (1.98 cm) and L_4 (1.93 cm) and among the testers, only T_3 (2.26 cm) showed significantly more seed length compared to their respective means (1.84 cm and 1.93 cm).

The seed width also varied with range, from 0.72 cm to 0.93 cm in lines and 0.75 cm to 1.00 cm in the testers. Among the parents, testers (T_3) had higher length and width of the seeds. However, maximum performance for seed length and width was scored in $L_2 \times T_3$ and $L_6 \times T_3$ hybrids, respectively whereas the minimum seed length and width was recorded by $L_1 \times T_1$ combination.

4.1.1.16 100-seed weight (gm)

The 100-seed weight varied among the lines and testers and the highest weight was recorded in L_4 (19.72 gm) and the lowest in L_3 (14.25 gm) lines. Among the testers, only T_3 (28.12 gm) showed significantly higher 100-seed weight compared to mean. But the weight in $L_6 \times T_3$ hybrid (27.82 gm) was less compared to the T_3 parent.

4.1.1.17 Germination percentage

The germination percentage of seed ranged from 82.67% (L₆) to 95.67% (L₁) in the lines and from 85.67% (T₁) to 98.00% (T₃) in the testers. However, the testers T₃ had significantly higher germination percentage (98.00%) compared to the mean. On the other hand, minimum and maximum germination were 81.33% in L₃ × T₁ and 97.00% in L₁ × T₃ combinations.

4.1.1.18 Number of seeds per fruit

As before, number of seeds per fruit also had variation and ranged from 384.73 (L₂) to 540.73 (L₆) in lines and from 360.33 (T₂) to 592.67 (T₃) in testers. Among the lines, L₃ (480.33) and L₆ (540.73) and among the testers, T₃ (592.67) had significantly higher number of seeds per fruit compared to their respective means 440.65 and 457.27. Among the hybrids, L₆ × T₃ combination scored highest number of seeds per fruit (635.20) and lowest number (390.67) in L₂ × T₂ hybrid.

Among the lines, L₁ was superior for length of main vine, number of days to first fruit harvest, fruit diameter, 100-seed weight and germination percentage, as it exhibited significantly higher values than the grand mean for these traits. The line L₂ registered significantly higher value for only fruit diameter and L₃ recorded superiority for node number of first male flower, node number of first female flower, sex ratio, fruit length, fruit weight, fruit yield per plant, TSS, ascorbic acid, total sugar, seed length and number of seeds per fruit. The line L₄ was superior for sex ratio, number of days to first fruit harvest, fruit length, number of fruits per plant, fruit yield per plant, seed length, seed width, 100-seed weight and germination percentage. The other line L₅ exhibited superiority over mean value for length of main vine, number of primary branch per plant, node number of first male flower, node number of first female flower, number of days to first male flower anthesis, number of days to first female flower anthesis, fruit diameter, number of

fruits per plant, fruit yield per plant, TSS, ascorbic acid, total sugar, seed width and germination percentage. The line L₆ showed superiority for length of main vine, number of primary branch per plant, node number of first male flower, node number of first female flower, fruit length, fruit weight, fruit yield per plant, ascorbic acid, seed width and number of seeds per fruit.

It can be inferred on the basis of *per se* performance that the line, L₅ was the best as it exhibited good performance for fruit yield per plant and other thirteen important characters. The line L₅ was followed by L₃ as it recorded better performance for fruit yield per plant and other ten important characters. The line L₆ exhibited superiority for ten important characters including fruit yield per plant and it was followed by L₄ for nine important characters. On the contrary, the line L₁ possessed good performance for five important characters other than fruit yield per plant. The line L₂ had superior performance only for one yield attributing characters.

It is obvious that the lines vary with respect to different traits including the quality characters. It shows that genetic variability exist among the lines.

Among the testers, T₁ registered significant desirable value for sex ratio, number of days to first fruit harvest, fruit diameter, TSS and total sugar. The tester T₂ was found to be superior for length of main vine, number of primary branch per plant, number of days to first female flower anthesis, number of fruits per plant and ascorbic acid. On the other hand, the tester, T₃ was superior for node number of first male flower, number of days to first male flower anthesis, number of days to first female flower anthesis, fruit length, fruit diameter, fruit weight, fruit yield per plant, total sugar, seed length, seed width, 100-seed weight, germination percentage and number of seeds per fruit.

It may be concluded that among the testers, T_3 ranked first as it registered superior performance for thirteen important characters including fruit yield per plant. T_1 and T_2 testers also had good performance for five important characters excluding fruit yield per plant.

As in lines, the testers also exhibited variations with respect to different traits and it indicates the presence of genetic variability in three testers.

Among the hybrids, $L_5 \times T_1$ had better length of main vine, number of primary branch per plant, node number of first male flower, number of days to first male flower anthesis, sex ratio, fruit diameter, fruit weight, number of fruits per plant, fruit yield per plant and number of seeds per fruit.

Another hybrid, $L_6 \times T_3$ exhibited significant desirable performance for node number of first male flower, node number of first female flower, number of days to first male flower anthesis, fruit length, fruit diameter, fruit weight, number of fruits per plant, fruit yield per plant, TSS, ascorbic acid, total sugar, seed length, seed width, 100-seed weight, germination percentage and number of seeds per fruit compared to mean (hybrid) for these traits. The other hybrid, $L_2 \times T_3$ recorded superiority for node number of first female flower, sex ratio, fruit diameter, fruit weight, number of fruits per plant, fruit yield per plant, seed length, germination percentage and number of seeds per fruit. The hybrid, $L_3 \times T_1$ recorded superiority for sex ratio, fruit length, fruit weight, fruit yield per plant, seed width and number of seeds per fruit. Other two hybrids, $L_4 \times T_1$ and $L_3 \times T_3$ recorded superiority for only six traits including fruit yield per plant. The hybrid $L_4 \times T_2$ showed significant performance for number of primary branch per plant, sex ratio, fruit length, fruit weight, fruit yield per plant, TSS, ascorbic acid, seed width and number of seeds per fruit. On the other hand, the hybrid $L_3 \times T_2$ was superior for eight traits *viz.*, node number of first male

flower, node number of first female flower, fruit length, number of fruits per plant, fruit yield per plant, TSS, ascorbic acid and total sugar.

Based on *per se* performance, it can be concluded that the hybrid, $L_5 \times T_1$ was the best as it produced highest fruit yield per plant along with nine important characters, closely followed by $L_6 \times T_3$. But the hybrid, $L_6 \times T_3$ was the best for sixteen important traits. Other two hybrids, $L_2 \times T_3$ and $L_3 \times T_1$ produced good fruit yield per plant with eight and five important characters respectively.

4.1.2 Coefficient of variation, heritability and genetic advance for different characters

The phenotypic and genotypic coefficient of variation (PCV, GCV), heritability and genetic advance as percentage of mean are presented in Table 4.3.

The magnitude of PCV was higher than GCV for all characters suggesting the influence of environmental factors on the expression of these traits. The GCV and PCV were high for fruit length and 100-seed weight followed by number of seeds per fruit, TSS, length of main vine, total sugar, fruit weight, sex ratio, fruit yield per plant, fruit diameter, number of primary branch per plant, seed length, number of fruits per plant, number of days to first male flower anthesis, node number of first male flower, number of days to first female flower anthesis, ascorbic acid content, node number of first female flower and number of days to first fruit harvest. So selection of these characters are likely to be highly effective.

Panwar *et al.* (1977) observed high GCV and PCV in sponge gourd for fruit yield per plant, fruit length, average fruit weight and length of main vine. Suresh Babu *et al.* (1996) reported high GCV and PCV for 100-seed weight and seeds per fruit in pumpkin. The high magnitude of GCV further revealed great extent of variability present in these characters thereby suggesting a scope of selection.

Table 4.3 : Coefficient of variation, heritability and genetic advance for different characters

Characters	Coefficient of variations		Heritability (%)	Genetic advance (%)
	GCV	PCV		
Length of main vine (m)	14.91	15.81	88.9	28.99
No. of primary branch/plant	11.36	12.98	82.6	22.25
Node number of first male flower	6.21	6.88	81.4	11.55
Node number of first female flower	4.23	4.97	72.5	7.47
No. of days to first male flower anthesis	6.24	6.54	91.1	12.30
No. of days to first female flower anthesis	5.49	5.68	88.7	10.92
Sex ratio (male flowers/female flowers)	12.79	13.12	92.4	25.37
No. of days to first fruit harvest	3.09	3.75	68.1	5.26
Fruit length (cm)	22.29	23.64	88.9	43.29
Fruit diameter (cm)	12.01	12.97	85.8	22.91
Fruit weight (kg)	13.96	14.75	89.5	26.78
No. of fruits/plant	6.59	7.26	82.3	12.41
Fruit yield/plant (kg)	12.18	12.42	96.1	24.65
TSS (°Brix)	16.59	16.92	96.2	33.71
Ascorbic acid (mg/100 gm)	4.41	4.65	90.0	8.63
Total sugar (%)	14.35	15.23	88.7	27.69
Seed length (cm)	9.27	9.50	95.2	18.72
Seed width (cm)	10.77	11.27	90.9	17.57
100-seed weight (gm)	21.50	22.23	93.5	42.86
No. of seeds/fruit	17.09	17.78	92.4	33.84

The genotypic coefficient of variation does not lead to estimate the variation that is heritable and therefore, estimation of heritability becomes necessary. The estimation of heritability ranged from 68.10% (number of days to first fruit harvest) to 96.2% (TSS). Here very high heritability in

broad sense (80% and above) was recorded for all the characters except number of days to first fruit harvest and node number of first female flower. This finding has the support of Janakiram and Sirohi (1994), Kumar *et al.* (1999), Sharma and Dhankhar (1990). Above average to high heritability estimates (60-79%) were recorded for number of days to first fruit harvest and node number of first female flower. This was in conformity with the findings of Narayan *et al.* (1996) in bottle gourd. High heritability estimates suggested the major role of genetic constitution in the expression of the characters and such traits are considered to be dependable from breeding point of view.

High genetic advance (as percentage of mean) was recorded for fruit length (43.29%), TSS (33.71%), 100-seed weight (42.86%) and average GA (as percentage of mean) was recorded for length of main vine, number of primary branch per plant, sex ratio, fruit diameter, fruit weight, fruit yield per plant and total sugar, ranging from 20-30 percent (Table 4.3). The six characters (*viz.*, node number of first male flower, number of days to first male flower anthesis, number of days to first female flower anthesis, number of fruits per plant, seed length and seed width) recorded below average GA percentage (10-20%) and low estimates for node number of first female flower, number of days to first fruit harvest and ascorbic acid content (below 10%) with the lowest GA percentage (5.26%) for the number of days to first fruit harvest.

Johnson *et al.* (1955) had suggested that heritability estimates along with genetic gain is usually more helpful than the heritability alone in predicting the resultant effect for selecting the best individual. So these two genetic parameters must be considered together to predict the expected genetic progress possible through selection. Four characters namely, fruit length, TSS, 100-seed weight and number of seeds per fruit showed high heritability above (80%) coupled with high genetic advance.

High heritability and high GA for the above mentioned characters suggest that most probably such characters are controlled by additive action of the polygenes (Panse, 1957). So these characters are more dependable for effective selection. High heritability coupled with average to below average GA was recorded for length of main vine, number of primary branch per plant, node number of first male flower, number of days to first male flower anthesis, number of days to first female flower anthesis, sex ratio, fruit diameter, fruit weight, number of fruits per plant, fruit yield per plant, total sugar, seed length and seed width. High heritability coupled with low GA was recorded for ascorbic acid while node number of first female flower and number of days to first fruit harvest had above average to high heritability and low GA. Such conditions indicate the influence of non-additive gene action. So these are comparatively less dependable for direct selection in crop improvement.

From the results of genetic variability fruit length, TSS, 100-seed weight and number of seeds per fruit emerged as most dependable characters for selection as they are governed by the additive action of polygenes. The other important characters, namely length of main vine, number of primary branch per plant, sex ratio, fruit diameter, fruit weight, fruit yield per plant and total sugar may also be considered for indirect selection because of the revelation of high heritability with average GA for them. In the present investigation, magnitude of estimated genetic parameters for some characters have deviated from earlier reports, which might have happened due to different set of genotypes and variable environmental influence.

4.1.3 Studies on characters association and path analysis

Yield is a complex entity associated with a number of contributing characters based on which a plant breeder proceeds and selection programme are envisaged. According to Graffius (1964) all changes in yield

must be accomplished by changes in one or more characters. However, all the changes in the components need not be expressed by changes in one or more characters. However, all changes in the yield might be due to the varying degree of positive and negative correlation between important characters. The study of association help in selection of genotypes and also to suggest the advantage of a scheme of selection for more than one characters at a time (Kalloo, 1998).

The knowledge of direct and indirect influence of different characters on the ultimate end product i.e., yield in any crop is of prime importance in fixing the criteria for selection of high yielding genotypes. The present investigation is designed to furnish information on the direct and indirect effects of different characters on yield in bottle gourd. The aim is to make a detailed examination of specific factors to produce a given correlation and relative importance of each factor. This will help in designing appropriate breeding procedures for evolving high yielding genotypes.

4.1.3.1 Phenotypic (rp) and genotypic (rg) correlation between fruit yield per plant and other characters

Fruit yield per plant showed significant and positive association with fruit length ($r_p = 0.684$, $r_g = 0.742$) and fruit weight ($r_p = 0.860$, $r_g = 0.898$) at phenotypic and genotypic levels. Fruit length had positive and significant correlation with fruit weight ($r_g = 0.674$) but negative and significant correlation with fruit diameter ($r_g = -0.702$) at genotypic level only. Correlation at genotypic and phenotypic level also existed between vine length and number of primary branch per plant (Table 4.4). Thus improving these characters or any one trait, can definitely serve in the process of improving yield per plant. This was in accordance with the report of Lawande and Patil (1989) in bitter melon; Janakiram and Sirohi (1994) in bottle gourd; Saikia *et al.* (1995) in cucumber.

Table 4.4 : Phenotypic (rp) and genotypic (rg) correlation coefficient among different pair of yield characters

Characters		Vine length (m)	Number of primary branch per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (kg)	Number of fruits per plant	Fruit yield per plant (kg)
Vine length (m)	rp	1.000	0.667*	-0.217	-0.015	-0.293	0.130	-0.285
	rg	1.000	0.704*	-0.233	-0.001	-0.343	0.106	-0.317
Number of primary branch per plant	rp		1.000	0.176	-0.046	0.039	0.179	0.146
	rg		1.000	0.201	-0.029	0.056	0.172	0.143
Fruit length (cm)	rp			1.000	-0.594	0.602	0.077	0.684*
	rg			1.000	-0.702*	0.674*	0.078	0.742*
Fruit diameter (cm)	rp				1.000	-0.049	-0.230	-0.144
	rg				1.000	-0.086	-0.207	-0.165
Fruit weight (kg)	rp					1.000	-0.295	0.860**
	rg					1.000	-0.309	0.898**
Number of fruits per plant	rp						1.000	0.172
	rg						1.000	0.164
Fruit yield per plant (kg)	rp							1.000
	rg							1.000

** = Significant at 1% level; * = Significant at 5% level

On the contrary, the fruit diameter had negative correlation with fruit length, fruit number, fruit weight and fruits yield per plant as well. It shows that fruit diameter needs to be minimised so that yield should not be affected. However, logical reason is not known to justify the increase of fruit diameter would affected the yield.

4.1.3.2 Path coefficient analysis

The phenotypic and genotypic correlation coefficient was partitioned into direct and indirect effects by path analysis and presented in Table 4.5.

4.1.3.2.1 Direct effects on fruit yield per plant

Fruit weight ($P = 0.881$, $G = 0.951$) and number of fruits per plant ($P = 0.439$, $G = 0.478$) had positive and high direct effect and fruit length ($P = 0.122$, $G = 0.179$) had low positive direct effect on fruit yield per plant at phenotypic and genotypic level. But fruit diameter ($G = 0.141$) had low positive direct effect at genotypic level only. Number of primary branch per plant ($P = 0.094$) had negligible direct effect at phenotypic level. On the other hand, vine length ($P = -0.119$) had negative and low direct effect on fruit yield per plant.

From the path analysis, it is confirmed that for improvement of yield per plant, the improvement of fruit weight, number of fruits per plant, fruit length is necessary as these have direct and positive effect on fruit yield per plant. On the other hand, improvement of these traits would lead to improve yield.

These result corroborate the findings of Rao *et al.* (2000) in ridge gourd; Rajput *et al.*, (1991) in cucumber; Sharma *et al.* (1993) in bottle gourd and Saikia *et al.* (1995) in cucumber.

Table 4.5: Direct (diagonal) and indirect (off diagonal) effect at phenotypic (P) and genotypic (G) level for various characters on fruit yield per plant

Characters	Vine length (m)	Number of primary branch per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (kg)	Number of fruits per plant	Phenotypic and genotypic correlation with fruit yield per plant
Vine length (m)	P	0.063	-0.027	-0.001	-0.258	0.057	-0.285
	G	-0.034	-0.042	0.000	-0.326	0.051	-0.317
Number of primary branch per plant	P	-0.079	0.022	-0.003	0.034	0.079	0.146
	G	0.024	0.036	-0.004	0.053	0.082	0.143
Fruit length (cm)	P	0.026	0.122	-0.045	0.530	0.034	0.684*
	G	-0.008	0.179	-0.099	0.641	0.038	0.742*
Fruit diameter (cm)	P	0.002	-0.073	0.075	-0.043	-0.101	-0.144
	G	0.000	-0.126	0.141	-0.082	-0.099	-0.165
Fruit weight (kg)	P	0.035	0.074	-0.004	0.881	-0.129	0.860**
	G	-0.012	0.121	-0.012	0.951	-0.148	0.898**
Number of fruits per plant	P	-0.015	0.009	-0.017	-0.260	0.439	0.172
	G	0.004	0.014	-0.029	-0.294	0.478	0.164

** = Significant at 1% level; * = Significant at 5% level

Residual effect : P = 0.0466, G = 0.0253

4.1.3.2.2 Indirect effect of fruit yield per plant

Apart from positive and direct effect of different traits on fruit yield per plant, indirect effect of other traits on the fruits yield was also noticed. Vine length had indirect effect on yield through number of fruits per plant at phenotypic and genotypic level. Fruit length had indirect effect, through fruit weight ($P=0.530$, $G = 0.641$) at phenotypic and genotypic level apart from low direct positive effect on yield.

The residual effect was low ($P=0.0466$, $G = 0.0253$) which indicates that maximum traits directly or indirectly influencing fruit yield per plant were considered in the path analysis.

The results from the path analysis indicated that the three characters, fruit weight, number of fruits per plant and fruit length had direct effect on fruit yield per plant at both phenotypic and genotypic level. These three characters also showed positive correlation with fruit yield per plant. Based on these results, simultaneous selection pressure on these traits may lead to selection of high fruit yielding plants.

4.1.3.3 Phenotypic (rp) and genotypic (rg) correlation between fruit yield per plant, fruit weight and seed characters.

The correlation study revealed that the fruit yield per plant had significant and positive correlation with seed length ($rp = 0.748$, $rg = 0.797$), seed width ($rp = 0.742$, $rg = 0.756$), 100-seed weight ($rp = 0.643$, $rg = 0.669$), number of seeds per fruit ($rp = 0.749$, $rg=0.771$) and fruit weight ($rp = 0.860$, $rg = 0.898$) at phenotypic and genotypic level. By improving these characters or any one trait, one can definitely improve the fruit yield per plant (Table 4.6).

Seed length showed significant and positive correlation with seed width ($rp = 0.796$, $rg = 0.843$), 100-seed weight ($rp = 0.893$, $rg = 0.967$) and fruit weight ($rp = 0.804$, $rg = 0.872$) at phenotypic and genotypic level. Seed

Table 4.6 : Phenotypic (rp) and genotypic (rg) correlation coefficient among different pair of seed characters

Characters		Seed length (cm)	Seed width (cm)	100-seed weight (gm)	Germination (%)	Number of seeds per fruit	Fruit weight (kg)	Fruit yield per plant (kg)
Seed length (cm)	rp	1.000	0.796*	0.893**	0.450	0.794*	0.804**	0.748*
	rg	1.000	0.843**	0.967**	0.485	0.845**	0.872**	0.797*
Seed width (cm)	rp		1.000	0.704*	0.412	0.612	0.630	0.742*
	rg		1.000	0.711*	0.467	0.638	0.678*	0.756*
100-seed weight (gm)	rp			1.000	0.430	0.870**	0.801**	0.643*
	rg			1.000	0.521	0.926**	0.885**	0.669*
Germination (%)	rp				1.000	0.109	0.005	-0.116
	rg				1.000	0.109	0.021	-0.095
Number of seeds per fruit	rp					1.000	0.902**	0.749*
	rg					1.000	0.983**	0.771*
Fruit weight (kg)	rp						1.000	0.860**
	rg						1.000	0.898**
Fruit yield per plant (kg)	rp							1.000
	rg							1.000

** = Significant at 1% level; * = Significant at 5% level

width had significant and positive correlation with 100-seed weight ($r_p = 0.704$, $r_g = 0.711$) at phenotypic and genotypic level but with fruit weight ($r_g = 0.678$) at genotypic level only. 100-seed weight had positive and significant correlation with number of seeds per fruit ($r_p = 0.870$, $r_g = 0.926$) and fruit weight ($r_p = 0.801$, $r_g = 0.885$) at both, phenotypic and genotypic level. Number of seeds per fruit had positive and significant correlation with fruit weight ($r_p = 0.902$, $r_g = 0.983$) at phenotypic and genotypic level. These results corroborate the findings of Cui *et al.* (1996) in cucumber and Mukunda Lakshmi *et al.* (2002) who reported significant and positive association between fruit weight and fruit yield per plant in pumpkin. Seed size showed strong positive correlation with fruit weight in squash (Warid *et al.*, 1993).

4.1.3.4 Effect of seed characters on fruit yield per plant

Seed width ($P = 0.470$), seed length ($P = 0.462$) and fruit weight ($P = 0.344$) had positive and high direct effect on fruit yield per plant at phenotypic level. At genotypic level, fruit weight ($G = 0.564$), seed width ($G = 0.526$) and 100-seed weight ($G = 0.478$) had positive and high direct effect on fruit yield per plant but seed length had moderate and positive direct effect.

Among the characters, seed width, seed length and fruit weight had positive direct effect on fruit yield per plant. These three characters were also significant and positively correlated with fruit yield per plant. This indicates the importance of these three characters on fruit yield per plant. On the other hand, improvement of fruit yield would lead to improve the seed characters.

Though 100-seed weight had negative direct effect at phenotypic level on the fruit yield per plant but 100-seed weight had indirect effect through fruit weight. Another trait, number of seeds per fruit had also negative direct effect on fruit yield per plant at both phenotypic and

Table 4.7: Direct (diagonal) and indirect (off diagonal) effect at phenotypic (P) and genotypic (G) level for various seed characters on fruit yield per plant

Characters		Seed length (cm)	Seed width (cm)	100-seed weight (gm)	Germination (%)	Number of seeds per fruit	Fruit weight (kg)	Phenotypic and genotypic correlation with fruit yield per plant
Seed length (cm)	P	0.462	0.374	-0.162	-0.199	-0.003	0.276	0.748*
	G	0.235	0.443	0.462	-0.287	-0.548	0.491	0.797*
Seed width (cm)	P	0.367	0.470	-0.128	-0.182	-0.003	0.217	0.742*
	G	0.198	0.526	0.340	-0.276	-0.413	0.382	0.756*
100-seed weight (gm)	P	0.412	0.331	-0.182	-0.190	-0.004	0.275	0.643*
	G	0.227	0.374	0.478	-0.308	-0.600	0.499	0.669*
Germination (%)	P	0.208	0.194	-0.078	-0.441	0.000	0.002	-0.116
	G	0.114	0.246	0.249	-0.592	-0.123	0.012	-0.095
Number of seeds per fruit	P	0.367	0.283	-0.158	-0.048	-0.004	0.310	0.749*
	G	0.199	0.335	0.443	-0.112	-0.648	0.554	0.771*
Fruit weight (kg)	P	0.371	0.296	-0.145	-0.002	-0.004	0.344	0.860**
	G	0.205	0.356	0.423	-0.012	-0.637	0.564	0.898**

** = Significant at 1% level; * = Significant at 5% level
Residual effect : P = 0.0792, G = 0.0328

genotypic levels but this trait had indirect effect on fruit yield per plant through fruit weight, seed length and seed width (Table 4.7).

The residual effect was low ($P=0.0792$, $G = 0.0328$) and it indicates that maximum traits directly or indirectly influencing fruit yield per plant were considered in the path analysis.

4.1.4 Analysis of variance

4.1.4.1 Analysis of variance with parents and hybrids

An effective selection programme is attributed by exploiting the available genetic variation in the population. For obtaining sound knowledge on this variation, its amount is measured as the variance. Analysis of variance estimated by using line x tester design with 6 parental lines, 3 testers and 18 hybrids in the present investigation (Table 4.8) revealed highly significant differences among the genotypes for the 20 characters.

The variation due to parents was found to be significant for all characters except ascorbic acid content. Significant variations due to lines were observed for almost all the characters studied, but among the testers significant variances were recorded for all characters except node number of first female flower. This revealed the significant genetic variability in the genotypes for almost all characters.

The lines vs. testers variance was significant for the characters-length of main vine, node number of first male flower, sex ratio, number of days to first fruit harvest, fruit length, fruit diameter, number of fruits per plant, TSS, ascorbic acid, seed width and 100-seed weight, thus indicating testers were divergent from lines which might satisfy the choice of testers for these characters.

The significant differences among hybrids for almost all the characters, however, revealed varying performance of cross combination (Sharma, 1998). The comparison between parents and hybrids indicated

Table 4.8 : Analysis of variance of parents and hybrids for different characters

Sources of variation	d.f.	Mean sum of squares							
		Length of main vine (m)	Number of primary branch per plant	Node number of first male flower	Node number of first female flower	Number of days to first male flower anthesis	Number of days to first female flower anthesis	Sex ratio (male flowers/ female flowers)	Number of days to first fruit harvest
Replications	2	0.05	0.83	0.002	0.03	0.12	0.70	0.064	2.61
Genotypes	26	2.03**	14.37**	1.084**	1.17**	18.55**	16.03**	5.120**	22.91**
Parents	8	2.29**	7.97**	0.673**	0.44**	32.70**	30.99**	3.772**	20.87**
Lines	5	2.65**	10.30**	0.975**	0.69**	49.96**	47.29**	1.726**	21.47**
Testers	2	2.14**	6.04**	0.093*	0.01	4.11*	5.44**	8.700**	19.11**
Lines vs. Testers	1	0.78**	0.21	0.327*	0.09	3.63	0.67	4.150**	21.40**
Hybrids	17	1.68**	9.83**	1.312**	1.18**	12.51**	9.54**	4.216**	20.67**
Parents vs. Hybrids	1	5.81**	142.75**	0.500**	6.72**	8.01*	6.73**	31.266**	77.44**
Error	52	0.07	0.79	0.026	0.04	1.29	0.81	0.080	2.03**

Table 4.8 (Contd...)

Sources of variation	d.f.	Mean sum of squares					
		Fruit length (cm)	Fruit diameter (cm)	Fruit weight (kg)	Number of fruits per plant	Fruit yield per plant (kg)	TSS (°Brix)
Replications	2	1.89	0.10	0.007	0.08	0.10	0.02
Genotypes	26	69.94**	12.43**	0.291**	0.89**	11.77**	0.74**
Parents	8	71.05**	11.72**	0.280**	0.23**	3.34**	0.60**
Lines	5	85.08**	9.10**	0.254**	0.25**	4.22**	0.70**
Testers	2	7.60*	11.73**	0.472**	0.28**	2.56**	0.58**
Lines vs. Testers	1	127.79**	24.81**	0.026	1.17**	0.48	0.11*
Hybrids	17	61.81**	11.68**	0.298**	0.78**	11.93**	0.84**
Parents vs. Hybrids	1	199.27**	30.81**	0.269**	7.99**	76.56**	0.29**
Error	52	2.01	1.15	0.013	0.04	0.15	0.02

Table 4.8 (Contd...)

Sources of variation	d.f.	Mean sum of squares					
		Ascorbic acid (mg/100 gm)	Total sugar (%)	Seed length (cm)	Seed width (cm)	100-seed weight (gm)	Number of seeds per fruit
Replications	2	0.004	0.0084	0.010	0.00004	0.95	499.56
Genotypes	26	1.596**	0.2141**	0.075**	0.03053**	30.88**	12314.39**
Parents	8	0.011	0.2438**	0.091**	0.02571**	48.94**	17924.62**
Lines	5	0.981**	0.2046**	0.037*	0.01844**	12.08**	10822.07**
Testers	2	1.530**	0.4636**	0.251**	0.04710*	149.63**	43815.52**
Lines vs. Testers	1	0.862**	0.0001	0.045	0.01927**	32.15**	1655.63
Hybrids	17	1.872**	0.2120**	0.058**	0.01385**	25.31**	9069.37**
Parents vs. Hybrids	1	0.862**	0.0111	0.225**	0.35280**	193.68**	22600.00**
Error	52	0.031	0.0099	0.013	0.00080	1.35	426.70

** = Significant at 1% level; * = Significant at 5% level

average heterosis (Sharma, 1998) which was significant for 20 characters. However, non-significant variance due to parents vs. hybrids was observed for total sugar indicating non-additive gene effects among the parents for these characters. The effects of such genes might have been influenced by environmental effects.

4.1.4.2 Analysis of variance for combining ability

Further partitioning of variation among the hybrids in the analysis of variance for combining ability (Table 4.9) revealed the presence of significant mean squares due to lines and testers for all the characters (except the number of days to first female flower anthesis and number of days to first fruit harvest of testers) indicated the importance of *gca* variances for these traits. On the other hand, mean squares due to lines x testers were significant for all the characters except seed length indicating the importance of *sca* variance for these traits. The significant mean squares due to either lines or testers and lines x testers interaction for all the characters (except seed length) indicated the importance of both *gca* and *sca* variance for these characters.

4.1.5 Proportional contribution of line, tester and line x tester interaction to total variance

The proportional contribution of line, tester and their interaction to the total variance for all characters under study are presented in Table 4.10.

The highest contribution to the total variation was made by line followed by line x tester interaction and tester for the characters, number of days to first male flower anthesis, number of days to first female flower anthesis, sex ratio, number of days to first fruit harvest, fruit length, fruit diameter and total sugar. The highest contribution of line followed by tester and line x tester were observed for length of main vine and ascorbic acid. On the other hand, the highest contribution by line x tester interaction followed by line and testers was observed for the characters, number of primary

Table 4.9 : Analysis of variance of combining ability for different characters

Sources of variation	d.f.	Mean sum of squares							
		Length of main vine (m)	Number of primary branch per plant	Node number of first male flower	Node number of first female flower	Number of days to first male flower anthesis	Number of days to first female flower anthesis	Sex ratio (male flowers/female flowers)	Number of days to first fruit harvest
Replications	2	0.08	1.04	0.02	0.02	0.51	1.17	0.039	1.72
Lines	5	3.67**	10.17**	1.12**	1.70**	31.41**	21.19**	7.671**	42.49**
Testers	2	2.73**	17.73**	2.73**	0.62**	4.13	8.22**	6.932**	1.73
Lines x Testers	10	0.48**	8.08**	1.12**	1.04**	4.73*	3.98**	1.946**	13.30**
Error	34	0.09	1.16	0.03	0.06	1.56	0.77	0.060	1.66

Table 4.9 (Contd...)

Sources of variation	d.f.	Mean sum of squares					TSS (°Brix)
		Fruit length (cm)	Fruit diameter (cm)	Fruit weight (kg)	Number of fruits per plant	Fruit yield per plant (kg)	
Replications	2	1.37	0.44	0.016	0.09	0.32	0.012
Lines	5	114.75**	21.86**	0.272**	1.17**	15.71**	0.758**
Testers	2	52.75**	13.37**	0.863**	0.20*	12.22**	0.400**
Lines x Testers	10	22.15**	6.25**	0.198**	0.71**	9.98**	0.963**
Error	34	1.74	1.36	0.015	0.05	0.17	0.020

Table 4.9 (Contd...)

Sources of variation	d.f.	Mean sum of squares					
		Ascorbic acid (mg/100 gm)	Total sugar (%)	Seed length (cm)	Seed width (cm)	100-seed weight (gm)	Number of seeds per fruit
Replications	2	0.008	0.006	0.016	0.0006	0.16	386.37
Lines	5	3.373**	0.334**	0.053*	0.0156**	16.41**	9144.13**
Testers	2	6.247**	0.435**	0.172**	0.0117**	107.41**	24535.00**
Lines x Testers	10	0.245**	0.106**	0.038	0.0134**	13.33**	5938.87**
Error	34	0.046	0.010	0.019	0.0010	1.50	421.65

** = Significant at 1 % level; * = Significant at 5 % level

Table 4.10 : Contribution (%) of lines, testers and their interaction (lines x testers) for different characters

Characters	Contribution (percentage)		
	Lines	Testers	Lines x Testers
Length of main vine (m)	64.07	19.08	16.81
No. of primary branch/plant	30.42	21.22	48.35
Node number of first male flower	25.02	24.48	50.49
Node number of first female flower	42.23	6.11	51.61
No. of days to first male flower anthesis	73.87	3.89	22.25
No. of days to first female flower anthesis	63.33	10.14	24.53
Sex ratio (male flowers/female flowers)	53.52	19.34	27.15
No. of days to first fruit harvest	61.16	0.98	37.85
Fruit length (cm)	68.88	10.04	21.08
Fruit diameter (cm)	55.06	13.47	31.46
Fruit weight (kg)	26.82	34.12	39.05
No. of fruits/plant	43.77	3.08	53.15
Fruit yield/plant (kg)	38.75	12.05	49.20
TSS (°Brix)	26.65	5.63	67.72
Ascorbic acid (mg/100 gm)	53.03	39.26	7.70
Total sugar (%)	46.39	24.17	29.44
Seed length (cm)	26.84	34.81	38.35
Seed width (cm)	33.08	9.89	57.03
100-seed weight (gm)	19.08	49.93	30.99
No. of seeds/fruit	29.65	31.83	38.52

branch per plant, node number of first male flower, node number of first female flower, number of fruits per plant, fruit yield per plant, TSS and seed width. The highest contribution by line x tester followed by tester and line

were recorded for fruit weight, number of seeds per fruit and seed length. However, in case of 100-seed weight, tester contributed the highest proportion to the total variation followed by line x tester interaction and line.

From the above results, it can be concluded that for the characters-length of main vine, number of days to first male flower anthesis, number of days to first female flower anthesis, sex ratio, number of days to first fruit harvest, fruit length, fruit diameter, ascorbic acid, total sugar, the maximum contribution to the total variation was made by line, but difference among lines with respect of such contribution were significant. It indicated that simple selection procedure for isolating better female parents for suitable breeding procedure would be rewarding in such area. But the character-100-seed weight recorded the maximum contribution by tester. On the other hand, for the characters number of primary branch per plant, node number of first male flower, node number of first female flower, fruit weight, number of fruits per plant, fruit yield per plant, TSS, seed length, seed width and number of seeds per fruit the maximum contribution to the total variation was made by line x tester interaction. Moreover, owing to highly significant line x tester variance (except seed length), specific cross combinations were significantly superior over others, thus indicating the scope for heterosis breeding programme for improvement in such area.

4.1.6 Combining ability

In breeding programme, the common approach of selecting the parents on the basis of *per se* performance does not necessarily lead to fruitful results (Allard, 1960). Hence, the potential parents have to be selected based on their genetic architecture and combining ability, besides their special attributes. Thus, the concept of combining ability is important in crop improvement to identify the best combiners and utilize them in hybridization, either to exploit for heterosis or to combine the favourable genes.

4.1.6.1 General combining ability (*gca*) effects

The general combining ability is defined as average performance of a strain in a series of cross combinations. Dhillon (1975) suggested that combining ability provides useful information on the choice of parents in terms of expected performance of the hybrids and progenies. Singh and Hari Singh (1985) had also suggested that parents having high *gca* effects could produce transgressive segregants in F_2 or later generations.

Among the lines, L_5 registered favourable *gca* effects for ten traits *viz.*, length of main vine (Kumareson, 2000), number of primary branch per plant (Dubey and Maurya, 2003), node number of first male flower, number of days to first male flower anthesis, number of days to first female flower anthesis (Nisha, 1999), number of fruits per plant (Dhaliwal and Tarsemlal, 1996), fruit yield per plant (Nisha, 1999 and Kharita *et al.*, 1994), TSS, total sugar and 100-seed weight (Richard Kannedy, 1994). It was followed by the line, L_6 which had significant *gca* effects for ten characters *viz.*, length of main vine, number of primary branch per plant, node number of first male flower, node number of first female flower (Sharma *et al.*, 2002), fruit length (Munshi and Sirohi, 1994), fruit weight, fruit yield per plant, ascorbic acid, seed width, 100-seed weight and number of seeds per fruit (Devdas *et al.*, 1995). The L_4 line recorded desirable *gca* effects for ten important traits *viz.*, number of days to first female flower anthesis, sex ratio, number of days to first fruit harvest (Sharma *et al.*, 2002), fruit length, fruit weight, fruit yield per plant, TSS, seed width, 100-seed weight and number of seeds per fruit. The other line, L_3 was the best combiners for seven traits *viz.*, sex ratio, fruit length, fruit weight, number of fruits per plant, fruit yield per plant, ascorbic acid and total sugar. On the other hand, L_2 line had significant *gca* effects for five characters *viz.*, node number of first female flower, fruit diameter (Varghese, 1991), number of fruits per plant and seed length excluding fruit yield per plant followed by L_1 line having significantly superior *gca* effects for four

Table 4.11 : General combining ability (*gca*) effects of parents for different characters

Parents	Length of main vine (m)	Number of primary branch per plant	Node number of first male flower	Node number of first female flower	Number of days to first male flower anthesis	Number of days to first female flower anthesis	Sex ratio (male flowers/female flowers)	Number of days to first fruit harvest	Fruit length (cm)	Fruit diameter (cm)
Lines										
L ₁	0.65**	-0.80**	-0.21**	-0.54**	1.52**	1.83**	0.51**	-1.78**	-5.22**	0.42
L ₂	-0.51**	-0.13	0.12**	-0.36**	0.63	0.83**	0.30**	0.22	-1.81**	1.95**
L ₃	-0.48**	-1.44**	0.23**	0.29**	0.85**	0.61**	-0.37**	1.00**	4.64**	-2.78**
L ₄	-0.72**	0.05	0.50**	0.62**	0.52	-0.72**	-1.51**	-3.11**	3.12**	-0.34
L ₅	0.66**	1.49**	-0.48**	0.17**	-3.70**	-2.61**	-0.14	0.56	-3.39**	0.47
L ₆	0.40**	0.84**	-0.17**	-0.18**	0.19	0.06	1.21**	3.11**	2.66**	0.29
Testers										
T ₁	0.06	-0.04	-0.38**	-0.15**	-0.09	0.33*	-0.60**	-0.33	-0.40	0.09
T ₂	0.36**	1.01**	-0.02	0.21**	0.52*	0.44**	0.64**	0.28	-1.48**	-0.90**
T ₃	-0.41**	0.97**	0.40**	-0.06	-0.43*	-0.78**	-0.03	0.06	1.88**	0.81**

Table 4.11 (Contd...)

Parents	Fruit weight (kg)	Number of fruits per plant	Fruit yield per plant (kg)	TSS (°Brix)	Ascorbic acid (mg/100 gm)	Total sugar (%)	Seed length (cm)	Seed width (cm)	100-seed weight (gm)	Number of seeds per fruit
Lines										
L ₁	-0.25**	-0.60**	-2.39**	0.01	-0.44**	0.03	-0.09**	-0.06**	-0.80*	-33.69**
L ₂	-0.17**	0.12*	-0.53**	-0.38**	-0.60**	-0.29**	0.14**	-0.02	-0.46	-38.56**
L ₃	0.12**	0.37**	1.34**	-0.30**	0.19**	0.11**	-0.04	-0.01	-1.99**	4.37
L ₄	0.18**	-0.07	0.59**	0.22**	-0.16**	-0.07*	-0.02	0.05**	1.81**	25.59**
L ₅	-0.01	0.33**	0.69**	0.37**	0.10	0.29**	0.01	-0.01	0.75*	0.04
L ₆	0.12**	-0.14**	0.30**	0.07	1.11**	-0.06	0.01	0.04**	0.68*	42.24**
Testers										
T ₁	0.01	-0.02	0.10	-0.11**	-0.30**	-0.08**	-0.10**	-0.02	-2.31**	2.07
T ₂	-0.22**	0.12**	-0.87**	0.17**	0.68**	-0.10**	0.01	-0.01	-0.26	-37.92**
T ₃	0.21**	-0.09**	0.77**	-0.05*	-0.38**	0.18**	0.09**	0.03**	2.56**	35.84**

** = Significant at 1% level; * = Significant at 5% level

Table 4.12: General combining ability (*gca*) effects on different characters of parents

Parents	Characters	
	Significant and positive <i>gca</i> effects	Significant and negative <i>gca</i> effects
Lines		
L ₁	Length of main vine (m), number of days to first male flower anthesis, number of days to first female flower anthesis, sex ratio.	Number of primary branch per plant, node number of first male flower, node number of first female flower, number of days to first fruit harvest, fruit length (cm), fruit weight (kg), number of fruits per plant, fruit yield per plant (kg) ascorbic acid (mg/100 gm), seed length (cm), seed width (cm), 100-seed weight (gm), number of seeds per fruit.
L ₂	Node number of first male flower, number of days to first male flower anthesis, sex ratio, fruit diameter (cm), number of fruits per plant, seed length (cm).	Length of main vine (m), node number of first female flower, fruit length (cm), fruit weight (kg), fruit yield per plant (kg), TSS (^o Bx), ascorbic acid (mg/100 gm), Total sugar (%), number of seeds per fruit.
L ₃	Node number of first male flower, node number of first female flower, number of days to first male flower anthesis, number of days to first female flower anthesis, number of days to first fruit harvest, fruit length (cm), fruit weight (kg), number of fruits per plant, fruit yield per plant (kg), ascorbic acid (mg/100 gm), total sugar (%).	Length of main vine (m), number of primary branch per plant, sex ratio, fruit diameter (cm), TSS (^o Bx), 100-seed weight (gm).
L ₄	Node number of first male flower, node number of first female flower, fruit length (cm), fruit weight (kg), fruit yield per plant (kg), TSS (^o Bx), seed width (cm), 100-seed weight (gm), number of seeds per fruit.	Length of main vine (m), number of days to first female flower anthesis, sex ratio, number of days to first fruit harvest, ascorbic acid (mg/100 gm), total sugar (%).
L ₅	Length of main vine (m), number of primary branch per plant, node number of first female flower, number of fruits per plant, fruit yield per plant (kg), TSS (^o Bx),	Node number of first male flower, number of days to first male flower anthesis, number of days to first female flower anthesis, fruit length (cm).

Table 4.12 (Contd...)

Parents	Characters	
	Significant and positive <i>gca</i> effects	Significant and negative <i>gca</i> effects
	Total sugar (%), 100-seed weight (gm).	
L ₆	Length of main vine (m), number of primary branch per plant, sex ratio, number of days to first fruit harvest, fruit length (cm), fruit weight (kg), fruit yield per plant (kg), ascorbic acid (mg/100), seed width (cm), 100-seed weight (gm), number of seeds per fruit.	Node number of first male flower, node number of first female flower, number of fruits per plant.
Tester		
T ₁	Number of days to first female flower anthesis.	Node number of first male flower, node number of first female flower, sex ratio, TSS (°Bx), ascorbic acid (mg/100 gm), total sugar (%), seed length (cm), 100-seed weight (gm).
T ₂	Length of main vine (m), number of primary branch per plant, node number of first female flower, number of days to first male flower anthesis, number of days to first female flower anthesis, sex ratio, number of fruits per plant, TSS (°Bx), ascorbic acid (mg/100 gm).	Fruit length (cm), fruit diameter (cm), fruit weight (kg), fruit yield per plant (kg), total sugar (%) number of seeds per fruit.
T ₃	Number of primary branch per plant, node number of first male flower, fruit length (cm), fruit diameter (cm), fruit weight (kg), fruit yield per plant (kg), total sugar (%), seed length (cm), seed width (cm), 100-seed weight (gm), number of seeds per fruit.	Length of main vine (m), number of days to first male flower anthesis, number of days to first female flower anthesis, number of fruits per plant, TSS (°Bx), ascorbic acid (mg/100 gm).

characters *viz.*, length of main vine, node number of first male flower, node number of first female flower and number of days to first fruit harvest excluding fruit yield per plant (Table 4.11, 4.12).

(The references given in parenthesis are the records of their own best combiner for the same trait)

Among the testers, T₃ had significantly favourable *gca* effects for twelve characters *viz.*, number of primary branch per plant, number of days to first male flower anthesis, number of days to first female flower anthesis, fruit length, fruit diameter, fruit weight, fruit yield per plant, total sugar, seed length, seed width, 100-seed weight and number of seeds per fruit. The second tester, T₂ recorded significantly high *gca* effects for five traits *viz.*, length of main vine, number of primary branch per plant, number of fruits per plant, TSS and ascorbic acid. The third tester, T₁ recorded superior *gca* effects for only three characters *viz.*, node number of first male flower, node number of first female flower and sex ratio. From the above results, it may be concluded that the parents L₃, L₄, L₅, L₆ and T₃ were the best general combiners (Table 4.11, 4.12).

The positive and significant effects indicate that any trait having such effects has additive gene effects and combination of positive effects of tester and line would show transgressive segregation in F₂ due to additive effects of both parents. Selection in such F₂ segregants would lead to establish a new strain which would be stable and may prove to be a good recombinant.

4.1.6.2 Specific combining ability (*sca*) effect

The specific combining ability is defined as average performance of specific cross combination expressed as deviation from population mean. According to Sprague and Tatum (1942), the specific combining ability is controlled by non-additive gene action. The *sca* effects of hybrids have also been attributed to the combination of positive favourable genes from different parents or might be due to the presence of linkage in replication phase.

The hybrid, L₆ × T₃ recorded significant desirable *sca* effect for twelve characters *viz.*, node number of first male flower, node number of first female flower (Dubey and Maurya, 2003), number of days to first male

flower anthesis, sex ratio, fruit weight (Mishra *et al.*, 1993), number of fruits per plant (Solanklan and Aghal Shah, 1990), fruit yield per plant (Sharma *et al.*, 2002), TSS (Richard Kennedy, 1994), ascorbic acid (Kumaresan, 2000), seed width, 100-seed weight (Richard Kennedy, 1994) and number of seeds per fruit (Devadas *et al.*, 1995). Among other hybrids showing high *sca* effects, $L_4 \times T_2$ had superior positive *sca* effects for eight traits *viz.*, number of primary branch per plant, sex ratio, fruit length (Munshi and Sirohi, 1994), fruit diameter (Sharma *et al.*, 2002), fruit weight, fruit yield per plant, TSS and number of seeds per fruit.

(The references given in parenthesis are the records of their own best combiner for the same trait)

The hybrid, $L_2 \times T_3$ had recorded significant favourable *sca* for eight traits *viz.*, node number of first female flower, sex ratio, fruit diameter, fruit weight, number of fruits per plant, fruit yield per plant, seed length and number of seeds per fruit. It was observed that the hybrid, $L_5 \times T_1$ had significant superior *sca* effects for node number of first male flower, fruit diameter, fruit weight, number fruits per plant, fruit yield per plant, ascorbic acid content and number of seeds per fruit.

The other hybrid, $L_4 \times T_1$ registered desirable *sca* effects for only five important characters *viz.*, length of main vine, number of days to first fruit harvest, fruit length, number of fruits per plant and fruit yield per plant.

The significant and positive *sca* effects for fruit yield per plant were recorded by the combinations, $L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_3$, $L_3 \times T_1$, $L_4 \times T_1$, $L_4 \times T_2$, $L_5 \times T_1$ and $L_6 \times T_3$. Among the parents of these combinations L_3 , L_4 , L_5 , L_6 and T_3 exhibited positive and significant *gca* effects, but all these combinations showed positive and significant *sca* effects whereas their parents do not show positive and significant *gca* effects, except $L_6 \times T_3$ combination (Table 4.13, 4.14). Hence, the combinations have to be raised every time as there is no possibility of selection in advance generation. So estimates of *sca* effects for fruit yield per plant are due to interaction of genes.

Table 4.13 : Specific combining ability (*sca*) effects of the hybrids for different characters

Hybrids	Length of main vine (m)	Number of primary branch per plant	Node number of first male flower	Node number of first female flower	Number of days male flower anthesis	Number of days female flower anthesis	Sex ratio (male flowers/female flowers)	Number of days to first fruit harvest	Fruit length (cm)	Fruit diameter (cm)
L ₁ × T ₁	-0.36**	1.04**	-0.47**	-0.43**	-1.46**	-1.44**	0.29*	1.56**	-2.38**	-0.04
L ₁ × T ₂	0.39**	-2.41**	-0.22**	-0.39**	-0.41	0.11	0.25	-0.39	-0.50	-0.93*
L ₁ × T ₃	-0.04	1.37**	0.69**	0.81**	1.87**	1.33**	-0.54**	-1.17*	2.88**	0.97*
L ₂ × T ₁	-0.11	0.58	-0.07	-0.01	0.43	0.56	-0.33*	-1.44**	1.89**	-0.16
L ₂ × T ₂	0.16	-0.01	-0.16*	0.50**	-0.85	-0.89**	1.10**	-0.39	-2.25**	-1.05*
L ₂ × T ₃	-0.05	-0.57	0.22**	-0.50**	0.43	0.33	-0.77**	1.83**	0.36	1.21**
L ₃ × T ₁	-0.14	0.29	0.36**	0.21*	0.54	-0.22	-0.60**	-0.22	-0.96*	-0.54
L ₃ × T ₂	0.07	-1.37**	-0.80**	-0.87**	0.26	1.33**	-0.44**	0.17	2.65**	0.36
L ₃ × T ₃	0.07	1.08**	0.44**	0.66**	-0.80	-1.11**	1.03**	0.06	-1.69**	0.18
L ₄ × T ₁	0.57**	0.00	0.16*	0.15	0.20	0.11	-0.12	-1.78**	1.06*	0.16
L ₄ × T ₂	-0.62**	1.41**	0.53**	0.19*	-0.07	0.00	-0.77**	3.94**	3.05**	2.02**
L ₄ × T ₃	-0.04	-1.41**	-0.69**	-0.34**	-0.13	-0.11	0.89**	-2.17**	-4.11**	-2.18**
L ₅ × T ₁	-0.35**	0.09	-0.13*	0.19*	-0.57	1.67**	0.21	1.89**	0.64	1.74**
L ₅ × T ₂	0.36**	-0.10	-0.02	0.04	-0.19	-1.11**	-0.36*	-2.39**	-2.76**	-1.28**
L ₅ × T ₃	-0.01	0.01	0.16*	-0.23*	0.76	-0.56	0.15	0.50	2.12**	-0.46
L ₆ × T ₁	0.39**	-1.99**	0.16*	-0.12	0.87	-0.67*	0.55**	0.00	-0.24	-1.18**
L ₆ × T ₂	-0.37**	2.48**	0.67**	0.53**	1.26**	0.56	0.22	-0.94*	-0.20	0.89*
L ₆ × T ₃	-0.01	-0.49	-0.82**	-0.41**	-2.13**	0.11	-0.77**	0.94*	0.44	0.29

Table 4.13 (Contd...).

Hybrids	Fruit weight (kg)	Number of fruits per plant	Fruit yield per plant (kg)	TSS (°Brix)	Ascorbic acid (mg/100 gm)	Total sugar (%)	Seed length (cm)	Seed width (cm)	100-seed weight (gm)	Number of seeds per fruit
L ₁ × T ₁	-0.10*	-0.27**	-1.01**	0.70**	0.35**	0.17**	-0.07	-0.05**	0.14	0.66
L ₁ × T ₂	0.09*	-0.01	0.50**	-0.80**	-0.35**	0.01	0.05	0.03**	-0.49	7.58
L ₁ × T ₃	0.01	0.27**	0.52**	-0.62**	0.00	-0.18**	0.02	0.02	0.35	-8.24
L ₂ × T ₁	-0.21**	-0.49**	-2.11**	0.46**	-0.20*	0.04	-0.04	0.03**	0.29	-18.81*
L ₂ × T ₂	-0.13**	0.20*	-0.28	-0.09	0.20*	0.13**	-0.10	0.05**	2.28**	-14.48
L ₂ × T ₃	0.34**	0.28**	2.40**	-0.37**	0.00	-0.17**	0.14**	-0.08**	-2.57**	33.29**
L ₃ × T ₁	0.39**	-0.31**	1.09**	-0.49**	0.12	-0.15**	0.04	0.06**	-0.42	47.33**
L ₃ × T ₂	-0.09*	0.15	-0.11	0.36**	-0.09	0.22**	0.12*	-0.02	2.12**	-10.48
L ₃ × T ₃	-0.30**	0.16	-0.98**	0.12*	-0.03	-0.07	-0.16**	-0.03**	-1.70**	-36.84**
L ₄ × T ₁	-0.14**	0.60**	0.70**	-0.17**	-0.13	-0.03	0.08	-0.02	0.15	-12.29
L ₄ × T ₂	0.23**	-0.21*	0.71**	0.28**	0.10	-0.04	0.01	0.00	-1.16*	37.03**
L ₄ × T ₃	-0.09*	-0.40**	-1.42**	-0.10	0.04	0.07	-0.09	0.03**	1.01*	-24.73**
L ₅ × T ₁	0.21**	0.47**	2.22**	-0.52**	0.31**	-0.13**	-0.07	-0.02	-0.97*	38.39**
L ₅ × T ₂	-0.05	0.26**	0.21	0.26**	-0.11	-0.16**	0.05	0.05	0.78	0.58
L ₅ × T ₃	-0.16**	-0.73**	-2.42**	0.25**	-0.19*	0.29**	0.02	-0.03**	0.19	-38.97**
L ₆ × T ₁	-0.16**	0.00	-0.88**	0.01	-0.44*	0.09*	0.05	0.01	0.81	-55.27**
L ₆ × T ₂	-0.04	-0.40**	-1.02**	-0.74**	0.26**	-0.15**	-0.13*	-0.11**	-3.53**	-20.22**
L ₆ × T ₃	0.20**	0.41**	1.90**	0.72**	0.18*	0.06	0.08	0.10**	2.73**	75.49**

** = Significant at 1% level; * = Significant at 5% level

Table 4.14 : Specific combining ability (*sca*) effects on different characters of hybrids

Characters	Specific combining ability (<i>sca</i>) effects	
	Significant and positive	Significant and negative
Length of main vine (m)	$L_1 \times T_2$, <u>$L_4 \times T_1$</u> , $L_5 \times T_2$, $L_6 \times T_1$	$L_1 \times T_1$, $L_4 \times T_2$, $L_5 \times T_1$, $L_6 \times T_2$
No. of primary branch/plant	$L_1 \times T_1$, $L_1 \times T_3$, $L_3 \times T_3$, $L_4 \times T_2$, <u>$L_6 \times T_2$</u>	$L_1 \times T_2$, $L_3 \times T_2$, $L_4 \times T_3$, $L_6 \times T_1$
Node number of first male flower	$L_1 \times T_3$, $L_2 \times T_3$, $L_3 \times T_1$, $L_3 \times T_3$, $L_4 \times T_1$, $L_4 \times T_2$, $L_5 \times T_3$, $L_6 \times T_1$, <u>$L_6 \times T_2$</u>	$L_1 \times T_1$, $L_1 \times T_2$, $L_2 \times T_2$, $L_3 \times T_2$, $L_4 \times T_3$, $L_5 \times T_1$, <u>$L_6 \times T_3$</u>
Node number of first female flower	$L_1 \times T_3$, $L_2 \times T_2$, $L_3 \times T_1$, $L_3 \times T_3$, <u>$L_4 \times T_2$</u> , $L_5 \times T_1$, $L_6 \times T_2$	$L_1 \times T_1$, $L_1 \times T_2$, $L_2 \times T_3$, <u>$L_3 \times T_2$</u> , $L_4 \times T_3$, $L_5 \times T_3$, $L_6 \times T_3$
No. of days to first male flower anthesis	$L_1 \times T_3$, $L_6 \times T_2$	$L_1 \times T_1$, <u>$L_6 \times T_3$</u>
No. of days to first female flower anthesis	$L_1 \times T_3$, $L_3 \times T_2$, $L_5 \times T_1$	<u>$L_1 \times T_1$</u> , $L_2 \times T_2$, $L_3 \times T_3$, $L_5 \times T_2$, $L_6 \times T_1$
Sex ratio (male flowers/female flowers)	$L_1 \times T_1$, $L_2 \times T_2$, $L_3 \times T_3$, $L_4 \times T_3$, <u>$L_6 \times T_1$</u>	$L_1 \times T_3$, $L_2 \times T_1$, <u>$L_2 \times T_3$</u> , $L_3 \times T_1$, $L_3 \times T_2$, <u>$L_4 \times T_2$</u> , $L_5 \times T_2$, <u>$L_6 \times T_3$</u>
No. of days to first fruit harvest	$L_1 \times T_1$, $L_2 \times T_3$, $L_4 \times T_2$, $L_5 \times T_1$, <u>$L_6 \times T_3$</u>	$L_1 \times T_3$, $L_2 \times T_1$, $L_4 \times T_1$, $L_4 \times T_3$, <u>$L_5 \times T_2$</u> , $L_6 \times T_2$
Fruit length (cm)	$L_1 \times T_3$, $L_2 \times T_1$, $L_3 \times T_2$, $L_4 \times T_1$, <u>$L_4 \times T_2$</u> , $L_5 \times T_3$	$L_1 \times T_1$, $L_2 \times T_2$, $L_3 \times T_1$, $L_3 \times T_3$, $L_4 \times T_3$, $L_6 \times T_2$
Fruit diameter (cm)	$L_1 \times T_3$, $L_2 \times T_3$, <u>$L_4 \times T_2$</u> , $L_5 \times T_1$, <u>$L_6 \times T_2$</u>	$L_1 \times T_2$, $L_2 \times T_2$, $L_4 \times T_3$, $L_5 \times T_2$, $L_6 \times T_1$
Fruit weight (kg)	$L_1 \times T_2$, $L_2 \times T_3$, <u>$L_3 \times T_1$</u> , $L_4 \times T_2$, $L_5 \times T_1$, $L_6 \times T_3$	$L_1 \times T_1$, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_2$, $L_3 \times T_3$, $L_4 \times T_1$, $L_4 \times T_3$, $L_5 \times T_3$, <u>$L_6 \times T_1$</u>
No. of fruits/plant	$L_1 \times T_3$, $L_2 \times T_2$, $L_2 \times T_3$, <u>$L_4 \times T_1$</u> , $L_5 \times T_1$, $L_5 \times T_2$, $L_6 \times T_3$	$L_1 \times T_1$, $L_2 \times T_1$, $L_3 \times T_1$, $L_4 \times T_2$, $L_4 \times T_3$, $L_5 \times T_3$, $L_6 \times T_2$
Fruit yield per plant (kg)	$L_1 \times T_2$, $L_1 \times T_3$, <u>$L_2 \times T_3$</u> , $L_3 \times T_1$, $L_4 \times T_1$, $L_4 \times T_2$, $L_5 \times T_1$, $L_6 \times T_3$	$L_1 \times T_1$, $L_2 \times T_1$, $L_3 \times T_3$, $L_4 \times T_3$, $L_5 \times T_3$, $L_6 \times T_1$, $L_6 \times T_2$
TSS ⁰ (Brix)	$L_1 \times T_1$, $L_2 \times T_1$, $L_3 \times T_2$, $L_3 \times T_3$, $L_4 \times T_2$, $L_5 \times T_2$, $L_5 \times T_3$, <u>$L_6 \times T_3$</u>	$L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_3$, $L_3 \times T_1$, $L_4 \times T_1$, $L_6 \times T_1$, $L_6 \times T_2$
Ascorbic acid (mg/100 gm)	<u>$L_1 \times T_1$</u> , $L_2 \times T_2$, $L_5 \times T_1$, $L_6 \times T_2$, <u>$L_6 \times T_3$</u>	$L_1 \times T_2$, $L_2 \times T_1$, $L_5 \times T_3$, $L_6 \times T_1$
Total sugar (%)	$L_1 \times T_1$, $L_2 \times T_2$, $L_3 \times T_2$, <u>$L_5 \times T_3$</u> , <u>$L_6 \times T_1$</u>	$L_1 \times T_3$, $L_2 \times T_3$, $L_3 \times T_1$, $L_5 \times T_1$, $L_5 \times T_2$, $L_6 \times T_2$
Seed length (cm)	<u>$L_2 \times T_3$</u> , $L_3 \times T_2$	$L_3 \times T_3$, $L_6 \times T_2$
Seed width (cm)	$L_1 \times T_2$, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_1$, $L_4 \times T_3$, <u>$L_6 \times T_3$</u>	$L_1 \times T_1$, $L_2 \times T_3$, $L_3 \times T_3$, $L_5 \times T_3$, $L_6 \times T_2$
100-seed weight (gm)	$L_2 \times T_2$, $L_3 \times T_2$, $L_4 \times T_3$, <u>$L_6 \times T_3$</u>	$L_2 \times T_3$, $L_3 \times T_3$, $L_4 \times T_2$, $L_5 \times T_1$, $L_6 \times T_2$
No. of seeds/fruit	$L_2 \times T_3$, $L_3 \times T_1$, $L_4 \times T_2$, $L_5 \times T_1$, <u>$L_6 \times T_3$</u>	$L_2 \times T_1$, $L_3 \times T_3$, $L_4 \times T_3$, $L_5 \times T_3$, $L_6 \times T_1$, $L_6 \times T_2$

The underline hybrids are superior in *sca* effects

But with regard to fruit yield per plant and number of fruits per plant the combination of $L_6 \times T_3$ showed significant *sca* effects, when both parents of this combination show significant *gca* effects in desirable direction. So for fruit yield per plant and number of fruits per plant there is a possibility of selection in advance generation.

With respect to quality of the fruit (TSS, ascorbic acid and total sugar content), number of combinations recorded positive and significant *sca* effects but the combinations - $L_4 \times T_2$ and $L_5 \times T_2$ for TSS, $L_6 \times T_2$ for ascorbic acid and $L_5 \times T_3$ for total sugar had parents with positive and significant *gca* effects (Table 4.13, 4.14). So for quality of the fruits, there is a possibility of selection in advance generation of the following combinations $L_6 \times T_2$, $L_5 \times T_2$, $L_6 \times T_2$ and $L_5 \times T_3$.

For fruit yield per plant and quality, there is possibility of selection in advance generation. However, combinations - $L_4 \times T_2$, $L_5 \times T_1$ and $L_6 \times T_3$ recorded significant and positive effect for fruit yield per plant along with TSS and ascorbic acid (Table 4.13, 4.14). Hence, among the combinations, the three hybrids, $L_4 \times T_2$, $L_5 \times T_1$ and $L_6 \times T_3$ had both quality and quantity of fruit.

4.1.7 Gene action .

Success in any breeding programme largely depends on the knowledge of genetic architecture of the population handled by the breeders. The estimates of components of variance provides an idea about additive and non-additive type of gene action. Panse (1942) opined that, if additive variance is greater than non-additive variance, the chance of fixing superior genotypes in the early segregation generation would be greater, whereas, if non-additive gene action is predominant, selection has to be postponed to later generation. Recent developments in the biometrical methods have led to the formulation of number of statistical procedures for the genetical analysis of quantitative characters. Line x tester analysis is one of the tools,

which provides information on additive and non-additive gene actions. The results inferred from line x tester analysis are discussed here under.

The significance of σ^2GCA and σ^2SCA obtained from analysis of line x tester design cannot be tested, hence these statistics appear to be of exploratory nature only. However, the magnitude of genetic variance and their relative proportions for all the 20 characters are presented in Table 4.15. The ratio of σ^2GCA/σ^2SCA ranged - 0.009 (TSS) to 5.19 (ascorbic acid) and showed additive and non-additive gene action for all traits.

Table 4.15 : Magnitude of genetic variance for different characters

Characters	σ^2GCA	σ^2SCA	σ^2GCA/σ^2SCA	σ^2A	σ^2D
Length of main vine (m)	0.20	0.43	0.15	0.08	0.52
No. of primary branch/plant	0.43	2.30	0.19	1.74	9.22
Node number of first male flower	0.06	0.37	0.16	0.24	1.46
Node number of first female flower	0.01	0.33	0.03	0.04	1.31
No. of days to first male flower anthesis	0.97	1.06	0.91	3.86	4.23
No. of days to first female flower anthesis	0.79	1.07	0.74	3.18	4.27
Sex ratio (male flowers/female flowers)	0.40	0.65	0.61	1.59	2.59
No. of days to first fruit harvest	0.67	3.88	0.17	2.68	15.51
Fruit length (cm)	5.67	6.80	0.83	22.70	27.22
Fruit diameter (cm)	0.84	1.63	0.52	3.37	6.52
Fruit weight (kg)	0.03	0.06	0.46	0.11	0.24
No. of fruits/plant	-0.002	0.22	-0.01	-0.01	0.88
Fruit yield/plant (kg)	0.30	3.27	0.30	3.23	10.74
TSS ($^{\circ}$ Brix)	-0.03	0.31	-0.09	-0.11	1.26
Ascorbic acid (mg/100 gm)	0.34	0.07	5.19	1.35	0.26
Total sugar (%)	0.02	0.03	0.62	0.08	0.13
Seed length (cm)	0.006	0.005	1.20	0.02	0.02
Seed width (cm)	0.00002	0.00413	0.00	0.00	0.02
100-seed weight (gm)	3.60	3.94	0.91	14.39	15.77
No. of seeds/fruit	807.46	1829.07	0.44	3229.84	7356.29

In the present study, the ratio of GCA/SCA variance exhibited additive and non-additive gene action. Additive gene action was exhibited by ascorbic acid and seed length. This was parallel with the findings of Kabilar (1999). This indicates that the breeding will be effective for improvement of these traits.

All other traits such as length of main vine, number of primary branch per plant, node number of first male flower, node number of first female flower, number of days to first male flower anthesis, number of days to first female flower anthesis, sex ratio, number of days to first fruit harvest, fruit length, fruit diameter, fruit weight, number of fruits per plant, fruit yield per plant, TSS, total sugar, seed width, 100-seed weight and number of seeds per fruit were governed by dominant gene action. Since dominant genetic variance is not fixable, the above traits can be improved through heterosis breeding. This result corroborates the findings of Richard Kennedy (1994) for vine length and 100-seed weight and Khattra *et al.* (2000) for single fruit weight.

Dubey and Maurya (2003) reported that non-additive gene action had greater role in the inheritance of total fruit yield per plant, number of fruits per plant, fruit length, days to anthesis first female flower and days to first fruit harvest.

4.1.8 Heterosis

Heterosis is a genetic phenomenon and conventionally refers to the expression of increased or decreased vigour of hybrids over better parent (heterobeltiosis) and mid parent (relative heterosis) in plant breeding programmes. Hybrid vigour is a direct property of heterozygosity. Heterosis for yield, reflects through the heterosis in individual components, a quick and convenient way of combining desirable characters has assumed greater significance in the production of F₁ hybrids in bottle gourd. The possibility of getting much better hybrids was explored to strengthen the

heterosis breeding with available combination of parents in the present study.

Expression of heterosis even to a small magnitude for individual component character is a desirable factor (Hathcock and David, 1973).

Hybrid vigour was estimated for different traits in eighteen cross combinations and expressed over better and mid parent in percentage (Table 4.16).

4.1.8.1 Length of main vine

The F_1 hybrid, $L_4 \times T_2$ showed negative and minimum values for heterosis over better parent (-17.31%) and mid parent (-5.06%). But $L_4 \times T_1$ hybrid recorded maximum heterosis, 19.08% more over better parent (heterobeltiosis) and 24.30% more over mid parent (relative heterosis). Out of 18 F_1 hybrids, five showed significant and positive heterosis over better parent whereas fifteen F_1 hybrids recorded significant and positive relative heterosis.

4.1.8.2 Number of primary branch per plant

For this trait, thirteen F_1 hybrids registered significant and positive heterobeltiosis. The maximum relative heterosis was recorded by $L_4 \times T_2$ hybrid (36.46%) in addition to fourteen hybrids showing significant and positive relative heterosis.

4.1.8.3 Node number of first male and female flower

The range of heterosis over better parent for node number of 1st male flower varied from - 15.60% ($L_1 \times T_1$) to 18.10% ($L_3 \times T_3$) when only seven hybrids exhibited negative significant heterosis (heterobeltiosis). On the other hand, relative heterosis for this trait ranged from - 21.10% ($L_1 \times T_1$) to 16.98% ($L_3 \times T_3$) and other nine hybrids had negative relative heterosis.

The heterosis over better parent for node number of first female flower varied from -4.72% ($L_1 \times T_1$) to 21.01% ($L_5 \times T_2$) and the relative heterosis from - 9.02% ($L_1 \times T_1$) to 19.37% ($L_3 \times T_3$). However, 3 hybrids had negative significant heterosis over mid parent.

Table 4.16 : Heterosis (%) over better parent (H_{BP}) and mid parent (H_{MP}) for different characters

Hybrids	Length of main vine (m)		Number of primary branch per plant		Node number of first male flower		Node number of first female flower		Number of days to first male flower anthesis	
	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}
$L_1 \times T_1$	-2.05	10.78**	27.86**	28.57**	-15.60**	-21.10**	-4.72*	-9.02**	-4.35*	-5.81**
$L_1 \times T_2$	13.34**	16.33**	-5.93	0.95	-8.18**	-13.68**	0.00	-4.51**	0.63	-1.85
$L_1 \times T_3$	-4.25	11.91**	23.13**	26.47**	15.24**	5.68**	10.16**	5.62**	5.84**	1.88
$L_2 \times T_1$	9.92*	12.50**	30.86**	35.20**	-5.50**	-8.85**	2.36	-0.38	-2.48	-4.27**
$L_2 \times T_2$	-2.01	10.55**	15.00**	27.80**	-2.73	-5.73**	12.60**	9.54*	-1.90	-4.62**
$L_2 \times T_3$	7.00	8.63*	19.42**	20.78**	13.33**	7.21**	-3.13	-5.27**	1.30	-2.80
$L_3 \times T_1$	7.46	8.68*	18.12**	21.66**	3.74*	2.78	14.40**	13.49**	1.28	-0.32
$L_3 \times T_2$	-2.94	6.17	-3.20	7.29	-7.48**	-8.76**	5.60**	4.76**	1.92	1.27
$L_3 \times T_3$	2.61	7.74*	22.25**	23.28**	18.10**	16.98**	20.80**	19.37**	-0.65	-1.29
$L_4 \times T_1$	19.08*	24.30**	27.69**	28.36**	2.75	0.45	15.75**	13.51**	0.65	-1.27
$L_4 \times T_2$	-17.31**	-5.06	25.90**	36.46**	11.82**	9.82**	20.47**	18.15**	1.29	0.32
$L_4 \times T_3$	8.04	8.60*	10.24	12.05*	5.71**	1.37	10.16**	8.46**	0.00	-0.32
$L_5 \times T_1$	-2.90	10.38**	21.74**	30.19**	-7.00**	-11.00**	18.49**	14.63**	6.02**	-4.08*
$L_5 \times T_2$	11.74**	15.33**	25.43**	26.59**	0.00	-4.76**	21.01**	17.07**	8.27**	-1.03
$L_5 \times T_3$	-4.78	11.83**	14.79**	25.23**	9.00**	6.34**	14.29**	10.21**	8.27**	0.35
$L_6 \times T_1$	11.86**	23.09**	-10.14*	2.07	-4.67*	-5.56**	3.97	3.56*	1.29	-0.63
$L_6 \times T_2$	3.81	4.30	23.44**	30.57**	7.48**	5.99*	15.87**	15.42**	3.23	2.24
$L_6 \times T_3$	-1.72	11.90**	-6.68	7.97	-5.71**	-6.60**	1.59	0.78	-4.55*	-4.85**

Table 4.16 (Contd...)

Hybrids	Number of days to first female flower anthesis		Sex ratio (male flowers/female flowers)		Days to first fruit harvest		Fruit length (cm)		Fruit diameter (cm)	
	H _{BP}	H _{MP}	H _{BP}	H _{MP}	H _{BP}	H _{MP}	H _{BP}	H _{MP}	H _{BP}	H _{MP}
L ₁ x T ₁	-2.79*	-4.13**	1.48	-5.14*	2.68	0.66	-2.51	3.21	-2.57	2.39
L ₁ x T ₂	4.07**	0.56	3.18	-9.36**	0.67	-3.62**	-0.85	6.44	-3.52	0.73
L ₁ x T ₃	4.07**	0.56	-13.90**	-18.42**	-0.33	-5.31**	20.47**	37.08**	4.16	10.81*
L ₂ x T ₁	-1.12	-2.21*	-9.53**	-17.80**	-2.58	-5.42**	26.75**	34.07**	5.15	11.30*
L ₂ x T ₂	0.58	-2.54*	5.14	-4.90*	-5.31**	-5.69**	-0.36	3.90	6.65	10.52*
L ₂ x T ₃	0.58	-2.54*	-23.28**	-25.28**	-3.64*	-3.64**	24.89**	27.68**	13.60**	21.71**
L ₃ x T ₁	-0.57	-1.69	-20.66**	-21.41**	0.00	-0.85	-2.17	22.35**	-22.82**	-7.84
L ₃ x T ₂	4.07**	3.17**	-1.50	-20.66**	-0.42	-2.07	6.67	31.91**	-7.35	2.04
L ₃ x T ₃	-2.33	-3.17**	9.44**	-4.42	-0.84	-2.89*	3.25	21.23**	-17.12**	0.00
L ₄ x T ₁	-1.72	-3.12**	-31.14**	-32.19**	-6.90**	-7.10**	10.47*	32.71**	-5.64	5.44
L ₄ x T ₂	-0.58	-1.16	-25.52**	-38.23**	1.29	-1.47	14.03**	35.36**	19.79**	22.55**
L ₄ x T ₃	-2.91*	-3.47**	-12.63**	-21.57**	-6.90**	-9.81**	-0.74	11.52*	-16.69**	-5.85
L ₅ x T ₁	12.58**	3.03*	-8.32**	-15.78**	2.15	1.93	3.60	13.62*	7.44	11.00**
L ₅ x T ₂	7.28**	0.31	-14.48**	-23.51**	-2.99	-5.22**	-17.87**	-11.15*	-8.71	-3.07
L ₅ x T ₃	5.96**	-0.93	-16.19**	-19.23**	-0.43	-2.29	21.66**	23.71**	-3.20	1.26
L ₆ x T ₁	-1.16	-2.84*	14.36**	2.04	3.00	1.05	-3.99	18.84**	-9.52	-1.96
L ₆ x T ₂	1.74	1.45	1.95	-6.12**	-1.24	-1.85	-7.68	12.96**	13.92*	15.18**
L ₆ x T ₃	-1.16	-1.45	-15.89**	-16.70**	0.83	-0.20	6.64	23.80**	-0.16	9.47*

Table 4.16 (Contd...)

Hybrids	Fruit weight (kg)		Number of fruits per plant		Fruit yield per plant (kg)		Total soluble solid (°Brix)		Ascorbic acid (mg/100 gm pulp)	
	H _{BP}	H _{MP}	H _{BP}	H _{MP}	H _{BP}	H _{MP}	H _{BP}	H _{MP}	H _{BP}	H _{MP}
L ₁ x T ₁	-5.51	-1.05	-7.99*	-2.06	-12.09**	-2.79	4.29	29.28**	2.91	4.79*
L ₁ x T ₂	-0.05	0.43	-3.00	5.53	-3.10	5.88	11.54**	26.09**	-6.05**	0.06
L ₁ x T ₃	-14.90**	-0.29	14.48**	16.03**	-2.94	15.04**	-12.21**	-3.69	-3.43	-0.92
L ₂ x T ₁	-7.22	-1.01	3.39	5.95*	-3.01	3.64	-15.13**	-2.75	-5.53*	-4.82*
L ₂ x T ₂	-7.06	-4.79	18.48**	24.21**	10.14*	16.24**	-3.85	-0.60	-1.05	6.45**
L ₂ x T ₃	0.72	19.93**	27.23**	30.55**	35.03**	55.12**	-17.70**	-17.70**	-3.75	-2.28
L ₃ x T ₁	13.46**	23.77**	14.53**	15.37**	36.50**	46.32**	-41.72**	-37.60**	-4.31*	3.65*
L ₃ x T ₂	-15.65**	-4.44	23.09**	26.90**	14.06**	23.77**	7.18	11.72**	5.50**	5.51**
L ₃ x T ₃	-12.81**	-9.77**	26.04**	31.54**	19.80**	20.09**	-9.31*	-2.41	-7.46**	0.94
L ₄ x T ₁	8.14	10.71**	23.81**	24.85**	33.55**	38.60**	-16.16**	-7.81*	-3.43	0.03
L ₄ x T ₂	13.95**	21.50**	4.62	6.21	22.92*	29.20**	29.84**	31.56**	3.43	8.34**
L ₄ x T ₃	-2.46	7.48*	-1.67	4.16	7.72*	12.39**	7.37	12.42**	-2.28	1.97
L ₅ x T ₁	23.76**	24.07**	23.48**	27.80**	53.40**	58.31**	-26.14**	-24.27**	-1.45	4.61*
L ₅ x T ₂	-1.39	1.82	21.90**	23.29**	20.06*	25.34**	4.96	19.40**	1.52	3.73*
L ₅ x T ₃	-12.32**	-0.47	-5.19	2.94	-1.52	3.44	-1.85	14.90**	-9.39**	-3.12
L ₆ x T ₁	-9.11*	-0.66	9.69*	14.25**	8.57*	14.76**	-15.13**	-2.24	-4.57*	5.73**
L ₆ x T ₂	-13.89**	-2.27	-1.39	5.04	-3.26	3.54	-11.54**	-8.00*	16.19**	19.08**
L ₆ x T ₃	6.25	9.75**	28.16**	29.35**	38.48**	41.82**	45.40**	46.31**	2.05	13.84**

Table 4.16 (Contd...)

Hybrids	Total sugar (%)		Seed length (cm)		Seed width (cm)		100-seed weight (gm)		Number of seeds per fruit	
	H _{BP}	H _{KP}	H _{BP}	H _{KP}	H _{BP}	H _{KP}	H _{BP}	H _{KP}	H _{BP}	H _{KP}
L ₁ x T ₁	-2.38	10.22**	-3.37	-2.55	12.00**	13.51**	-3.58	9.93*	7.61	10.86**
L ₁ x T ₂	14.81*	19.23**	10.86*	11.17*	9.30**	18.24**	3.68	9.64	5.92	10.68**
L ₁ x T ₃	-12.95**	1.04	-11.50**	-0.25	-4.00	10.98**	-14.79**	0.46	-19.76**	-3.64
L ₂ x T ₁	-23.81**	-16.88**	11.24*	14.45**	28.00**	30.61**	9.31	19.26**	1.80	6.11
L ₂ x T ₂	-4.76	2.56	16.09**	18.13**	16.28**	26.58**	32.09**	33.14**	1.54	4.87
L ₂ x T ₃	-26.79**	-17.79**	4.13	19.46**	-10.00**	4.65	-23.97**	-6.74	-13.58**	4.81
L ₃ x T ₁	-22.64**	-18.67**	-5.05	0.00	21.95**	27.39**	16.05*	18.13**	11.47**	19.09**
L ₃ x T ₂	-8.02	11.85**	4.55	11.29*	9.30**	11.90**	24.53**	57.10**	-8.90*	4.11
L ₃ x T ₃	-8.02	6.28*	-16.81**	-11.32**	-4.00	5.49*	-26.32**	-2.19	-18.17**	-9.60**
L ₄ x T ₁	-17.14**	-11.68*	0.52	4.58	5.38*	16.67**	9.08	24.73**	13.68**	16.12**
L ₄ x T ₂	-7.61	1.80	2.59	7.90	9.68**	13.97**	12.83*	19.72**	40.52**	26.97**
L ₄ x T ₃	-6.25	2.94	-13.27**	-6.44	8.00**	11.92**	-3.17	13.84**	-12.54**	0.66
L ₅ x T ₁	-6.54	-5.66	-2.15	0.00	9.52**	15.72**	5.46	16.80**	24.67**	26.51**
L ₅ x T ₂	-8.88	7.14	9.68	13.33**	16.28**	17.65**	26.19**	29.29**	9.26*	15.86**
L ₅ x T ₃	19.20**	21.92**	-7.08	1.94	-4.00	4.35	-9.84**	9.16*	-19.26**	-4.23
L ₆ x T ₁	-11.43*	-9.27*	5.43	7.18	19.05**	25.79**	22.41**	31.64**	-12.96**	-1.90
L ₆ x T ₂	-20.00**	-8.57*	1.63	4.47	4.65	5.88*	7.39	8.23	-13.87**	3.37
L ₆ x T ₃	-6.25	-0.94	-4.42	5.37	14.00**	23.91**	-1.07	22.83**	7.18*	12.09**

** = Significant at 1% level; * = Significant at 5% level

4.1.8.4 Number of days to first male and female flower anthesis

The heterosis over better parent (heterobeltiosis) for number of days to first male flower anthesis varied from -4.55% ($L_6 \times T_3$) to 8.27% ($L_5 \times T_2$ and $L_5 \times T_3$) whereas only two hybrids recorded significant and negative heterobeltiosis. The relative heterosis ranged from -5.81% ($L_1 \times T_1$) to 2.24% ($L_6 \times T_2$) and five hybrids recorded significant and negative relative heterosis.

On the other hand, heterosis over better parent for number of days to first female flower anthesis was significant and negative in two hybrids. Only eight hybrids recorded significant and negative heterosis over mid parent.

4.1.8.5 Sex ratio

The eleven hybrids recorded significant and negative heterosis over better parent (heterobeltiosis). However, sixteen hybrids exhibited negatively significant relative heterosis.

4.1.8.6 Number of days to first fruit harvest

The negative and significant heterosis over better parent for this trait was noted in four hybrids while nine F_1 hybrids had relative heterosis over mid parent.

4.1.8.7 Fruit length

The range of heterosis over the better parent for this trait varied from -17.87% ($L_5 \times T_2$) to 26.75% ($L_2 \times T_1$) and six F_1 hybrids exhibited significant and positive heterobeltiosis. Fourteen hybrids showed significant and positive relative heterosis. The maximum heterosis was noted in $L_1 \times T_3$ hybrid (37.08%) and minimum in $L_5 \times T_2$ (-11.15%).

4.1.8.8 Fruit diameter

In case of fruit diameter, the range of heterosis percentage over better parent varied from -22.82% ($L_3 \times T_1$) to 19.79% ($L_4 \times T_2$) while, three F_1 hybrids recorded significant and positive heterobeltiosis. The positive and significant heterosis over mid parent was observed in eight F_1 hybrids.

4.1.8.9 Fruit weight

The heterosis over better parent was found to be significant and positive in three hybrids. On the other hand, the relative heterosis was significant and positive in seven F_1 hybrids when maximum heterosis (24.07%) was recorded in $L_5 \times T_1$ hybrid.

4.1.8.10 Number of fruits per plant

The heterosis over better parent for number of fruits per plant was significant and positive in 11 hybrids and the range was from -7.99% ($L_1 \times T_1$) to 28.16% ($L_6 \times T_3$). On the other hand, the heterosis over mid parent for this trait varied from -2.06% ($L_1 \times T_1$) to 31.54% ($L_3 \times T_3$) with twelve hybrids recording significant and positive relative heterosis.

4.1.8.11 Fruit yield per plant

The range of heterosis over better parent for fruit yield per plant was from -12.09% ($L_1 \times T$) to 53.40% ($L_5 \times T_1$) and twelve F_1 hybrids recorded positive and significant heterobeltiosis, whereas only one hybrid exhibited significant and negative heterosis. The relative heterosis varied from -2.79% ($L_1 \times T_1$) to 58.31% ($L_5 \times T_1$) and significant and positive heterosis was recorded in thirteen F_1 hybrids.

4.1.8.12 Total soluble solid (TSS)

The heterobeltiosis for this trait was maximum (45.40%) in $L_6 \times T_3$ hybrid while only three hybrids recorded significant and positive heterobeltiosis. The eight hybrids exhibited significantly positive relative heterosis when the maximum value (46.31%) was found in $L_6 \times T_3$ hybrid.

4.1.8.13 Ascorbic acid

The heterosis over better parent (heterobeltiosis) was maximum in $L_6 \times T_2$ hybrid (16.19%) and only two hybrids recorded significant and positive heterosis over better parent. The relative heterosis for this trait was positive and significant in ten hybrids.

4.1.8.14 Total sugar

The estimates of heterosis over better parent for total sugar showed a range of -26.79% ($L_2 \times T_3$) to 19.20% ($L_5 \times T_3$) when only two hybrids exhibited positively significant heterobeltiosis. On the other hand, heterosis over mid parent was positive and significant in five hybrids.

4.1.8.15 Seed length

The range of heterosis over better parent for seed length varied from -16.81% ($L_3 \times T_3$) to 16.09% ($L_2 \times T_2$) when three hybrids recorded positive and significant heterobeltiosis. On the other hand, six hybrids showed significantly positive heterosis over mid parent with maximum heterosis being in $L_2 \times T_3$ hybrid.

4.1.8.16 Seed width

The heterosis over better parent for seed width was significant and positive in 13 F_1 hybrids, when 16 F_1 hybrids, recorded significant and positive heterosis over mid parent with the maximum and minimum heterosis over mid parent in $L_2 \times T_1$ and $L_5 \times T_3$ hybrids, respectively.

4.1.8.17 100-seed weight

Among eighteen hybrids, six recorded significant and positive heterobeltiosis and the maximum heterosis (32.09%) was in $L_2 \times T_2$ hybrid. The relative heterosis was significant and positive in thirteen hybrids.

4.1.8.18 Number of seeds per fruit

The heterobeltiosis for number of seeds per fruit was maximum (40.52%) in $L_4 \times T_2$ hybrid. The positive and significant heterosis over better parent was noted in six F_1 hybrids. On the other hand, the positive and significant relative heterosis was recorded in eight hybrids.

It is apparent from the table that the hybrids, $L_4 \times T_1$, $L_4 \times T_3$, $L_4 \times T_2$, $L_5 \times T_1$, $L_6 \times T_3$, $L_6 \times T_2$, $L_5 \times T_3$ and $L_2 \times T_1$ showed the best heterotic manifestation constantly over better and mid parent for length of main vine,

number of days to first fruit harvest, fruit diameter, fruit weight and fruit yield per plant, TSS, ascorbic acid, total sugar and seed width respectively. The hybrid, $L_1 \times T_1$ was the best over better parent and mid parent for node number of first male flower, node number of first female flower and number of days to first female flower anthesis, while $L_4 \times T_2$ hybrid for number of seeds per fruit. The cross combinations - $L_2 \times T_1$ and $L_4 \times T_2$ for number of primary branch per plant; $L_6 \times T_3$ and $L_1 \times T_1$ hybrids for number of days to first male flower anthesis; $L_2 \times T_1$ and $L_1 \times T_3$ for fruit length; $L_6 \times T_3$ and $L_3 \times T_3$ for number of fruits per plant; $L_2 \times T_2$ and $L_2 \times T_3$ for seed length; $L_2 \times T_2$ and $L_3 \times T_2$ for 100-seed weight exhibited best heterotic manifestation over better and mid parent respectively.

These results corroborate the findings of Celine and Sirohi (1996) for length of main vine, fruit weight and number of fruits per plant; Pandey *et al.* (2003) for number of primary branch per plant; Kadam (1995) for node number of first female flower; Pitchaimuthu (1991) for days to first female flower anthesis; Kushwaha and Ram (2002) for days to first fruit harvest; Singh *et al.* (2002), Ram *et al.* (1997), Kumaresan (2000) for fruit length and fruit diameter; Singh and Rajesh Kumar (2002), Kabilar (1999), Kolhe (1972) for fruit yield per plant; Richard Kennedy (1994) for TSS; Sit and Sirohi (2002), Wang *et al.* (1993) for ascorbic acid; Kabilar (1999) for 100-seed weight.

Among the hybrids, $L_4 \times T_2$ cross combination recorded heterotic effects over better parent for ten traits, followed by $L_4 \times T_1$ for nine traits. The $L_5 \times T_1$, $L_5 \times T_2$ and $L_6 \times T_3$ hybrids recorded heterotic effects over better parents for eight traits each followed by $L_2 \times T_2$ and $L_2 \times T_3$ hybrids for seven traits each. The other hybrids, $L_3 \times T_2$ and $L_6 \times T_1$ registered heterotic effect for six traits, $L_4 \times T_3$ for five characters and $L_3 \times T_3$ hybrid over better parent for only three traits. All the above hybrids exhibited heterosis over better parents for fruit yield per plant.

On the other hand, the hybrids - $L_2 \times T_2$, $L_5 \times T_1$ and $L_6 \times T_3$ recorded heterosis over mid parent for fourteen characters each followed by $L_5 \times T_2$, $L_2 \times T_3$ and $L_4 \times T_1$, $L_3 \times T_1$ and $L_3 \times T_2$ and $L_4 \times T_3$, $L_3 \times T_3$ and $L_6 \times T_1$ hybrids for thirteen, twelve, eleven and nine characters respectively. All the above hybrids registered heterosis over mid parent for fruit yield per plant.

On the basis of number of characters, the hybrid, $L_4 \times T_2$ recorded heterosis over better parent for ten traits and the hybrid, $L_2 \times T_2$, $L_5 \times T_1$ and $L_6 \times T_3$ manifested heterosis over mid parent for fourteen traits.

Based on the *per se* performance, *sca* effect and heterobeltiosis, the hybrid $L_5 \times T_1$ was highly suitable for heterosis breeding since it expressed high fruit yield per plant along with desirable performance in four traits *viz.*, node number of first male flower, fruit weight, number of fruits per plant and number of seeds per fruit. The $L_6 \times T_3$ hybrid recorded second highest mean performance for fruit yield per plant along with other six important characters *viz.*, node number of first male flower, number of days to first male flower anthesis, number of fruits per plant, TSS, seed width and number of seeds per fruit. The $L_2 \times T_3$ hybrid recorded superior fruit yield per plant along with three yield attributing characters *viz.*, sex ratio, fruit diameter and number of fruits per plant followed by $L_3 \times T_1$ hybrid for fruit yield per plant. However, $L_6 \times T_3$ hybrid was the best for fruit yield per plant as well as quality (Table 4.5, 4.8, 4.16).

From the above observation, it could be concluded that the hybrids - $L_5 \times T_1$, $L_2 \times T_3$ and $L_3 \times T_1$ were superior for fruit yield per plant and $L_6 \times T_3$ hybrid for fruit yield per plant as well as quality. These four hybrids may be recommended for commercial use.

4.2 Experiment II

The experiment of seed storage was conducted with two varieties *viz.*, BCBG-7 (V_1) and BCBG-4 $\times$ BCBG-20 (V_2). The data regarding the effect of variety, month (period) of storage and container on germination

percentage, seedling root and shoot length, seedling dry weight and seed vigour index (by calculation) were recorded.

4.2.1 Effect on germination percentage

The number of normal seedling obtained in each set of rolled towel paper was counted and expressed as the percentage of germination. The germination percentage gradually decreased with the increase of month (period) of storage irrespective of containers and variety (Table 4.17 and Fig. 4.13). The seeds in general kept in desiccator recorded significantly higher germination percentage (73.3%) even at the end of storage period followed by that in glass bottle (64.2%). On the other hand, seeds kept in cloth bag recorded the lowest germination (29.5%) after eleven month of storage.

The germination percentage at initial stage (i.e., 'O' month storage) was significantly more in the hybrid, V₂ (95.3%) against that in V₁ (93.7%). It was observed that the V₂ (hybrid) recorded higher viability over that in V₁ for storage upto two month in earthen pot and polyethylene packet, for three month in cloth bag and five month in desiccator and glass bottle. But the trend declined and V₁ registered higher viability than that in V₂. The rate of reduction in germination percentage during entire storage period was more in V₂ (hybrid) than that in V₁. However, there was significant difference among different containers and months (period) of storage.

The interaction effect of variety x container, variety x month and month x container showed significant difference. But that of variety x month x containers was statistically non-significant. It shows that varietal effect on germination was related to the containers and month (period) of storage.

Table 4.17 : Effect of variety, month (period) of storage and container on germination percentage

Month	Cloth bag		Mean (Mx C)		Desiccator		Mean (Mx C)		Earthen pot		Mean (Mx C)		Glass bottle		Mean (Mx C)		Polyethylene packet		Mean (Mx C)		Mean (V x M)		Mean (M)
	V ₁	V ₂			V ₁	V ₂			V ₁	V ₂			V ₁	V ₂			V ₁	V ₂			V ₁	V ₂	
0	93.7 (75.5)	95.3 (77.6)	94.5 (76.6)		93.7 (75.5)	95.3 (77.6)	94.5 (76.6)		93.7 (75.5)	95.3 (77.6)	94.5 (76.6)		93.7 (75.5)	95.3 (77.6)	94.5 (76.6)		93.7 (75.5)	95.3 (77.6)	94.5 (76.6)		93.7 (75.5)	95.3 (77.6)	94.5 (76.6)
1	90.3 (71.9)	93.0 (74.7)	91.7 (73.3)		93.7 (75.5)	95.3 (77.6)	94.5 (76.6)		91.7 (73.3)	93.3 (75.1)	92.5 (74.2)		93.7 (75.5)	95.3 (77.6)	94.5 (76.6)		91.7 (73.3)	93.3 (75.1)	92.5 (74.2)		92.2 (73.9)	94.1 (76.0)	93.1 (75.0)
2	86.7 (68.6)	88.3 (70.1)	87.5 (69.3)		91.3 (72.9)	92.7 (74.3)	92.0 (73.6)		88.0 (69.8)	89.3 (71.0)	88.7 (70.4)		91.0 (72.6)	92.7 (74.3)	91.8 (73.5)		88.3 (70.1)	88.7 (70.4)	88.5 (70.2)		89.1 (70.8)	90.3 (72.0)	89.7 (71.4)
3	82.3 (65.2)	83.0 (65.7)	82.7 (65.5)		88.7 (70.4)	89.7 (71.3)	89.2 (70.8)		84.3 (67.0)	83.7 (66.2)	84.0 (66.4)		88.0 (69.7)	89.0 (70.7)	88.5 (70.2)		84.0 (66.4)	83.7 (66.2)	83.8 (66.3)		85.5 (67.7)	85.8 (68.0)	85.6 (67.8)
4	77.0 (61.4)	74.7 (59.8)	75.8 (60.6)		86.0 (68.1)	87.3 (69.2)	86.7 (68.6)		79.3 (63.0)	77.3 (61.6)	78.3 (62.3)		84.7 (67.0)	85.7 (67.8)	85.2 (67.4)		79.7 (63.2)	78.3 (62.3)	79.0 (62.7)		81.3 (64.5)	80.7 (64.1)	81.0 (64.3)
5	72.0 (58.1)	68.0 (55.6)	70.0 (56.8)		84.7 (67.0)	85.0 (67.2)	84.8 (67.1)		74.7 (60.0)	71.0 (57.4)	72.8 (58.6)		82.0 (64.9)	82.7 (65.4)	82.3 (65.2)		76.0 (60.7)	73.7 (59.1)	74.8 (59.9)		77.9 (62.1)	76.1 (61.0)	77.0 (61.5)
6	65.7 (54.1)	60.0 (50.8)	62.8 (52.5)		83.0 (65.7)	82.7 (65.4)	82.8 (65.5)		68.7 (56.0)	63.7 (52.9)	66.2 (54.4)		80.0 (63.4)	79.3 (63.0)	79.7 (63.2)		71.0 (57.4)	67.7 (55.4)	69.3 (56.4)		73.7 (59.3)	70.7 (57.5)	72.2 (58.4)
7	59.3 (50.4)	52.0 (46.1)	55.7 (48.3)		81.0 (64.2)	80.3 (63.7)	80.7 (63.9)		63.3 (52.7)	57.7 (49.4)	60.5 (51.1)		77.7 (61.8)	75.7 (60.4)	76.7 (61.1)		67.3 (55.1)	63.3 (52.7)	65.3 (53.9)		69.7 (56.9)	65.8 (54.5)	67.8 (55.7)
8	53.3 (46.9)	43.3 (41.2)	48.3 (44.0)		79.7 (63.2)	78.0 (62.0)	78.8 (62.6)		59.3 (50.4)	51.7 (46.0)	55.5 (48.2)		74.7 (59.8)	72.3 (58.3)	73.5 (59.0)		64.0 (53.1)	59.0 (50.2)	61.5 (51.7)		66.2 (54.7)	60.9 (51.5)	63.5 (53.1)
9	48.0 (43.9)	37.0 (37.5)	42.5 (40.7)		78.5 (62.5)	76.3 (60.9)	77.5 (61.7)		56.0 (48.4)	46.3 (42.9)	51.2 (45.7)		72.3 (58.3)	69.0 (56.2)	70.7 (57.2)		60.3 (51.0)	55.0 (47.9)	57.7 (49.4)		63.1 (52.8)	56.7 (49.1)	59.9 (50.9)
10	43.0 (41.0)	31.0 (33.8)	37.0 (37.4)		77.3 (61.6)	74.0 (59.3)	75.7 (60.5)		53.0 (46.7)	41.3 (40.0)	47.2 (43.4)		70.0 (56.8)	66.0 (54.3)	68.0 (55.6)		57.3 (49.2)	51.0 (45.6)	54.2 (47.4)		60.1 (51.1)	52.7 (46.6)	56.4 (48.8)
11	35.7 (36.7)	23.3 (28.9)	29.5 (32.8)		75.7 (60.4)	71.0 (57.4)	73.3 (58.9)		47.3 (43.5)	35.0 (36.3)	41.2 (39.9)		67.0 (54.9)	61.3 (51.6)	64.2 (53.3)		53.0 (46.7)	45.3 (42.3)	49.2 (44.5)		55.7 (48.4)	47.2 (43.3)	51.5 (45.9)
Mean (V x C)	67.3 (56.1)	62.4 (53.5)			84.4 (67.2)	84.0 (67.1)			71.6 (58.8)	67.1 (56.4)			81.2 (65.0)	80.4 (64.8)			73.9 (60.1)	71.2 (58.7)					
Mean (C)	64.8 (54.8)				84.2 (67.2)				69.4 (57.6)				80.8 (64.9)				72.5 (59.4)			variety →	75.7 (61.5)	73.0 (60.1)	

Figures in the parenthesis are arc-sine transformation value

C.D. at 5%

Variety (V) 0.31

Month (M) 0.76

Container (C) 0.49

V x M 1.07

V x C 0.69

M x C 1.69

V x C x M NS

4.2.2 Effect on seedling root and shoot length

The root and shoot length of seedlings from the stored seeds, gradually decreased with the increase of seed storage period irrespective of container and variety (Table 4.18, 4.19 and Fig. 4.14, 4.15). Seeds in general kept in desiccator recorded significantly higher seedling root length (15.86 cm) and shoot length (15.86 cm) even at the end of eleven months of storage followed by that in glass bottle 14.13 cm and 14.12 cm respectively in root and shoot length. Seeds kept in cloth bag recorded the lowest seedling root length (10.66 cm) and shoot length (11.61 cm).

The seedling root and shoot length at initial stage (in '0' month storage) was significantly more in the V_2 (20.54 cm and 21.62 cm respectively in root and shoot length) against that in the V_1 (19.59 cm and 18.24 cm respectively). It was observed that V_2 (hybrid) had higher seedling root length over that in V_1 for storage upto three month in polyethelene packet, four month in cloth bag, earthen pot and glass bottle and five month in desiccator. The trend changed after those periods and V_1 showed higher seedling root length compared to that in the V_2 hybrid, whereas V_2 (hybrid) recorded higher seedling shoot length over that in V_1 during entire storage period irrespective of container. The seedling shoot length of both varieties was significantly different. But the seedling root length of both varieties was almost same. The months (period) of storage showed significant difference among themselves for seedling root and shoot length.

The interaction effect of variety x month and month x container on seedling root and shoot length were statistically significant. But the interaction effect of variety x container and variety x month x container on seedling root and shoot length did not show significant difference.

Table 4.18 : Effect of variety, month (period) of storage and container on seedling root length

Month	Cloth bag		Desiccator		Mean (MxC)		Earthen pot		Mean (MxC)		Glass bottle		Mean (MxC)		Polyethylene packet		Mean (V x M)		Mean (M)
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	
0	19.59	20.54	19.59	20.54	20.07	20.07	19.59	20.54	20.07	20.07	19.59	20.54	20.07	20.07	19.59	20.54	19.59	20.54	20.07
1	19.14	20.00	19.44	20.27	19.86	19.86	19.17	20.07	19.62	19.62	19.35	20.21	19.78	19.78	19.23	20.07	19.27	20.14	19.71
2	18.44	19.16	19.17	19.83	19.50	19.50	18.56	19.35	18.96	18.96	19.00	19.66	19.33	19.33	18.73	19.35	18.78	19.52	19.15
3	17.57	18.11	18.77	19.28	19.03	19.03	17.81	18.40	18.11	18.11	18.53	18.96	18.76	18.76	18.05	18.40	18.15	18.71	18.43
4	16.45	16.83	18.43	18.68	18.56	18.56	16.91	17.23	17.07	17.07	17.93	18.18	18.36	18.36	17.30	17.23	17.52	17.75	17.64
5	15.74	15.61	18.15	18.16	18.15	18.15	16.26	16.18	16.22	16.22	17.53	17.43	17.48	17.48	16.70	16.18	16.87	16.86	16.87
6	14.33	14.31	17.84	17.57	17.71	17.71	15.27	14.89	15.08	15.08	16.88	16.67	16.78	16.78	15.90	14.89	16.04	15.86	15.95
7	13.63	13.31	17.48	17.12	17.30	17.30	14.49	13.91	14.20	14.20	16.30	15.83	16.07	16.07	15.15	13.91	15.41	15.02	15.21
8	13.03	12.49	17.18	16.72	16.95	16.95	13.89	13.12	13.51	13.51	15.85	15.27	15.56	15.56	14.55	13.12	14.90	14.37	14.64
9	12.48	11.88	16.92	16.40	16.66	16.66	13.39	12.62	13.01	13.01	15.52	14.88	15.20	15.20	14.15	12.62	14.49	13.91	14.20
10	11.98	11.33	16.66	16.00	16.33	16.33	12.92	12.14	12.53	12.53	15.14	14.46	14.80	14.80	13.70	12.14	14.08	13.45	13.77
11	10.96	10.35	16.26	15.45	15.86	15.86	12.19	11.22	11.71	11.71	14.52	13.74	14.13	14.13	13.03	11.22	13.39	12.65	13.02
Mean (V x C)	15.27	15.33	17.99	18.00			15.87	15.81			17.23	17.15			16.34	16.54			
Mean (C)	15.30		17.99				15.84				17.19				16.44		16.54		

C.D. at 5%

Variety (V) NS

Month (M) 0.28

Container (C) 0.18

V x M 0.40

V x C NS

M x C 0.63

V x C x M NS

variety →

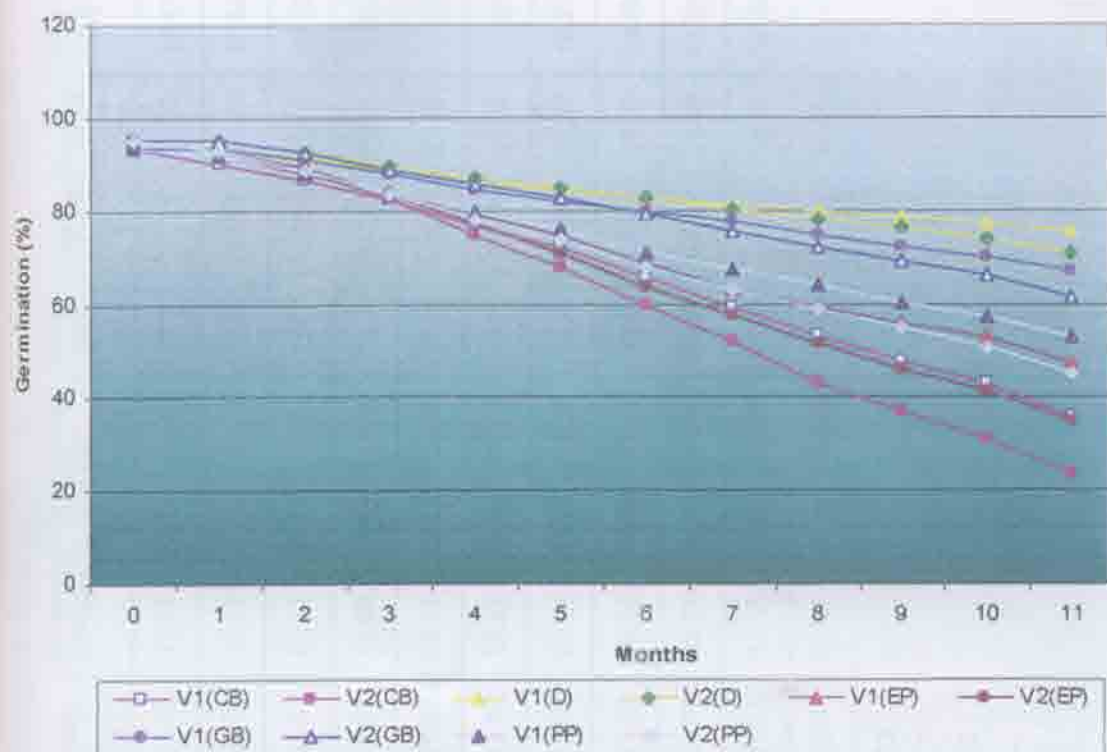


Fig.4.13 : Effect of variety, month (period) of storage and container on germination percentage

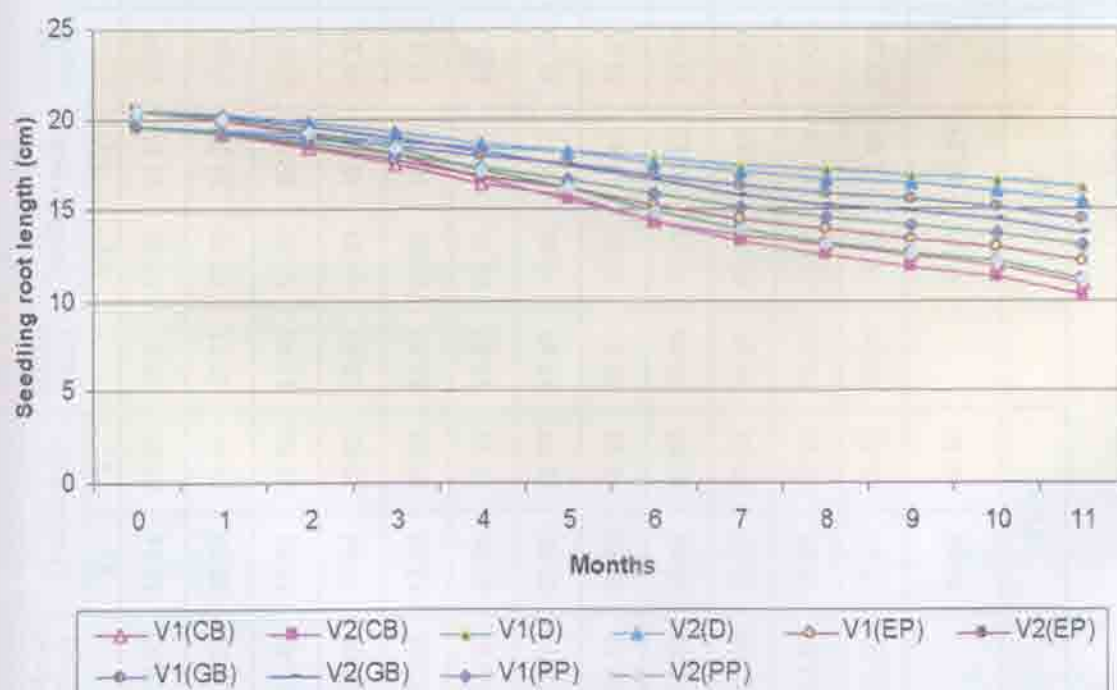


Fig.4.14 : Effect of variety, month (period) of storage and container on seedling root length

CB = Clothbag
D = Desiccator
EP = Earthen pot
GB = Glass bottle
PP = Polyethelene packet

Table 4.19 : Effect of variety, month (period) of storage and container on seedling shoot length

Month	Cloth bag		Mean (MxC)		Desiccator		Mean (MxC)		Earthen pot		Mean (MxC)		Glass bottle		Mean (MxC)		Polyethylene packet		Mean (MxC)		Mean (V x M)		Mean (M)
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	
0	18.24	21.62	18.24	21.62	18.24	21.62	18.24	21.62	18.24	21.62	18.24	21.62	18.24	21.62	18.24	21.62	18.24	21.62	18.24	21.62	18.24	21.62	19.93
1	17.92	21.13	18.09	21.41	17.96	21.22	19.75	21.41	17.96	21.22	19.75	21.41	18.05	21.36	19.71	21.36	17.92	21.28	19.60	21.28	17.99	21.28	19.64
2	17.33	20.44	17.84	20.96	17.50	20.59	19.40	20.96	17.50	20.59	19.40	20.96	17.68	20.82	19.25	20.82	17.49	20.66	19.08	20.66	17.57	20.69	19.13
3	16.63	19.49	17.44	20.46	17.44	20.46	18.95	20.46	16.81	19.72	18.95	20.46	17.23	20.13	18.68	20.13	16.89	19.89	18.39	19.89	17.00	19.94	18.47
4	15.78	18.25	17.02	19.88	17.09	19.88	18.49	19.88	16.01	18.60	18.49	19.88	16.69	19.37	18.03	19.37	16.17	18.99	17.57	18.99	16.34	19.02	17.68
5	15.04	17.27	16.16	19.33	16.80	19.33	18.07	19.33	15.31	17.69	18.07	19.33	16.34	18.72	17.53	18.72	15.65	18.18	16.92	18.18	15.83	18.24	17.03
6	14.11	15.92	15.02	18.75	16.50	18.75	17.63	18.75	14.44	16.44	17.63	18.75	15.84	18.02	16.93	18.02	15.03	17.21	16.12	17.21	15.18	17.27	16.23
7	13.42	14.99	14.21	18.30	16.19	18.30	17.25	18.30	13.72	15.49	17.25	18.30	15.23	17.23	16.23	17.23	14.50	16.36	15.43	16.36	14.61	16.47	15.54
8	12.90	14.25	13.58	17.87	15.92	17.87	16.90	17.87	13.17	14.81	16.90	17.87	14.78	16.72	15.75	16.72	14.07	15.77	14.92	15.77	14.17	15.88	15.03
9	12.33	13.63	12.98	17.54	15.67	17.54	16.61	17.54	12.77	14.29	16.61	17.54	14.44	16.31	15.38	16.31	13.66	15.28	14.47	15.28	13.77	15.41	14.59
10	11.83	13.19	12.51	17.16	15.44	17.16	16.30	17.16	12.37	13.74	16.30	17.16	14.14	15.91	15.03	15.91	13.29	14.88	14.09	14.88	13.41	14.98	14.20
11	10.97	12.24	11.61	16.46	15.07	16.46	15.86	16.46	11.56	12.84	15.86	16.46	13.62	15.21	14.42	15.21	12.72	14.13	13.43	14.13	12.79	14.21	13.50
Mean (V x C)	14.71	16.87		16.69	19.16				14.99	17.25			16.02	18.45			15.47	17.85					
Mean (C)	15.79			17.93					16.12				17.34				16.66				15.58		17.92

C.D. at 5%

Variety (V) 0.12

Month (M) 0.29

Container (C) 0.18

V x M 0.41

V x C NS

M x C 0.65

V x C x M NS

4.2.3 Effect on seedling dry weight

It is evident from the Table 4.20 and Fig. 4.16 that seedling dry weight gradually decreased with the increase of storage period irrespective of container and genotype. Seeds kept in desiccator recorded significantly highest dry weight (73.06 mg/seedling) at the end of storage period followed by that in glass bottle (70.74 mg/seedling). On the contrary, seeds kept in cloth bag had the lowest seedling dry weight (48.97 mg/seedling). It was also noted that significant difference between V_1 and V_2 (hybrid) existed in seedling dry weight.

It is also observed that hybrid, V_2 recorded higher seedling dry weight over that in V_1 for storage upto four month in glass bottle, five month in cloth bag, earthen pot and six month in desiccator and polyethylene packet. But, the trend reversed and V_1 registered higher seedling dry weight compared to that in V_2 (hybrid). The rate of reduction was more in V_2 with the advancement of storage period. The containers and month (period) of storage also exhibited significant difference.

The interaction effect of variety x container, variety x month and month x container was significant. But that of variety x month x container was statistically non-significant.

4.2.4 Effect on seedling vigour index

The vigour index was estimated by multiplying germination percentage and seedling dry weight. Here the vigour index gradually decreased with the advancement of storage, irrespective of containers and variety. The seeds kept in desiccator, generally recorded significantly highest vigour index (5361) even at the end of storage period followed by that in glass bottle (4547). As expected, the seeds kept in cloth bag, the vigour index was the lowest (1461) (Table 4.21 and Fig. 4.17).

Table 4.20 : Effect of variety, month (period) of storage and container on seedling dry weight

Month	Cloth bag		Mean (MxC)	Desiccator		Mean (MxC)	Earthen pot		Mean (MxC)	Glass bottle		Mean (MxC)	Polyethylene packet		Mean (MxC)	Mean (V x M)		Mean (M)
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂		V ₁	V ₂		V ₁	V ₂		V ₁	V ₂	
0	94.50	98.42	96.46	94.50	98.42	96.46	94.50	98.42	96.46	94.50	98.42	96.46	94.50	98.42	96.46	94.50	98.42	96.46
1	92.00	95.51	93.76	93.85	97.25	95.55	92.12	95.90	94.01	93.43	96.90	95.17	92.54	96.63	94.59	92.79	96.44	94.61
2	88.52	90.84	89.68	92.31	94.83	93.57	89.14	92.53	90.84	91.42	94.43	92.93	90.02	93.71	91.87	90.28	93.27	91.78
3	84.15	85.70	84.93	89.93	91.50	90.72	85.55	87.45	86.50	88.95	90.57	89.76	86.53	89.45	87.99	87.02	88.93	87.98
4	79.13	79.52	79.33	88.18	88.67	88.43	81.03	81.78	81.41	86.56	86.98	86.77	82.46	83.97	83.22	83.47	84.19	83.83
5	74.60	73.54	74.07	86.14	86.33	86.24	76.76	76.26	76.51	84.50	83.80	84.15	78.65	78.94	78.60	80.13	79.77	79.95
6	69.11	66.85	67.89	84.06	83.54	83.80	71.74	70.03	70.89	82.64	81.13	81.89	74.17	72.98	73.58	76.34	74.91	75.63
7	64.62	60.52	62.57	81.23	81.07	81.15	67.13	64.03	65.58	80.52	78.21	79.37	70.13	67.14	68.64	72.73	70.19	71.46
8	61.40	56.62	59.01	79.65	78.84	79.25	64.15	59.71	61.93	78.86	75.74	73.30	67.20	62.97	65.09	70.25	66.78	68.51
9	58.34	53.71	56.03	78.17	76.86	77.52	61.47	57.04	59.26	77.13	73.56	75.35	65.03	60.20	62.62	68.03	64.27	66.15
10	55.31	51.24	53.28	76.50	74.73	75.62	58.90	54.67	56.79	75.64	71.53	73.59	63.05	57.93	60.49	65.88	62.02	63.95
11	51.23	46.70	48.97	74.04	72.07	73.06	55.24	50.43	52.84	73.12	68.35	70.74	59.92	54.15	57.04	62.71	58.34	60.53
Mean (V x C)	72.74	71.60		84.88	85.34		74.81	74.02		83.94	83.30		77.02	76.37				
Mean (C)	72.17			85.11			74.42			83.62			76.70		variety →	78.68	78.13	

C.D. at 5%

Variety (V) 0.32

Month (M) 0.79

Container (C) 0.51

V x M 1.11

V x C 0.69

M x C 1.76

V x C x M NS

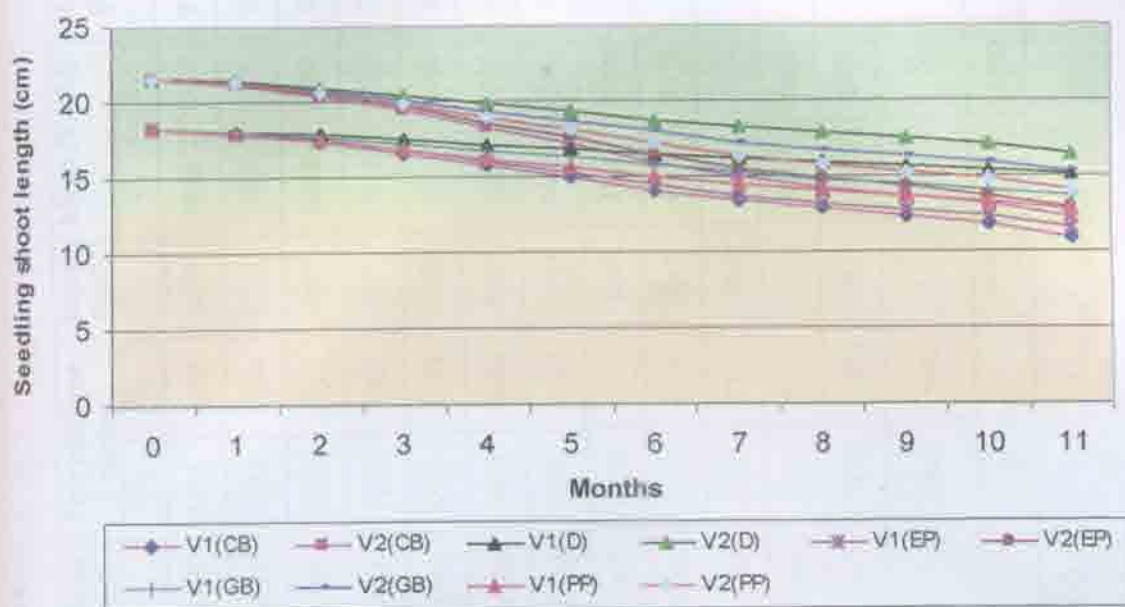


Fig.4.15 : Effect of variety, month (period) of storage and container on seedling shoot length.

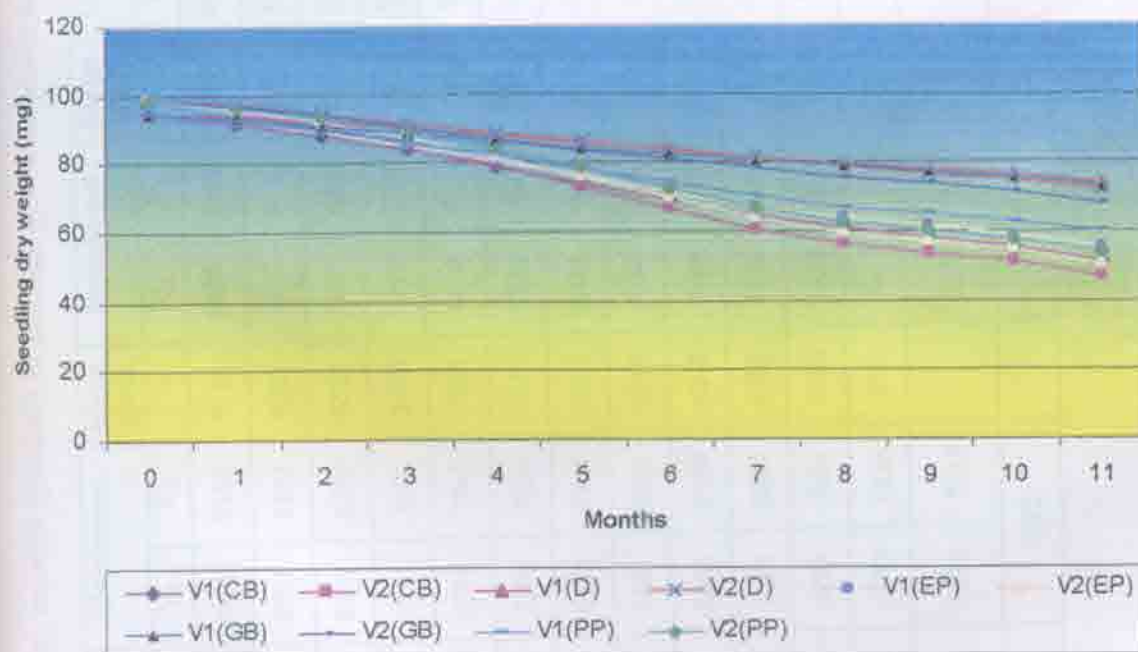


Fig.4.16 : Effect of variety, month (period) of storage and container on seedling dry weight

CB = Clothbag
D = Desiccator
EP = Earthen pot
GB = Glass bottle
PP = Polyethelene packet

Table 4.21 : Effect of variety, month (period) of storage and container on vigour index

Month	Cloth bag		Mean (Mx C)	Desiccator		Mean (Mx C)	Earthen pot		Mean (Mx C)	Glass bottle		Mean (Mx C)	Polyethylene packet		Mean (Mx C)	Mean (V x M)		Mean (M)
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂		V ₁	V ₂		V ₁	V ₂		V ₁	V ₂	
0	8852	9384	9118	8852	9384	9118	8852	9384	9118	8852	9384	9118	8852	9384	9118	8852	9385	9118
1	8312	8883	8598	8791	9272	9031	8445	8952	8699	8752	9239	8995	8484	9020	8752	8557	9073	8815
2	7673	8026	7849	8432	8789	8611	7845	8268	8057	8320	8751	8536	7953	8311	8132	8045	8429	8237
3	6930	7115	7022	7975	8206	8090	7215	7318	7266	7828	8062	7945	7269	7485	7377	7443	7637	7540
4	6094	5939	6016	7585	7745	7665	6430	6326	6378	7330	7452	7391	6571	6579	6575	6802	6808	6805
5	5372	5003	5187	7294	7339	7317	5733	5416	5574	6930	6930	6930	5978	5816	5897	6262	6101	6181
6	4540	4012	4276	6978	6907	6943	4927	4461	4694	6612	6438	6525	5267	4940	5103	5665	5351	5508
7	3837	3149	3493	6581	6514	6547	4254	3695	3974	6255	5919	6087	4724	4254	4489	5130	4706	4918
8	3276	2456	2866	6346	6150	6248	3808	3087	3447	5890	5480	5685	4302	3716	4009	4724	4178	4451
9	2801	1988	2395	6150	5868	6009	3444	2644	3044	5581	5076	5328	3925	3313	3619	4380	3778	4079
10	2379	1591	1985	5917	5531	5724	3122	2261	2692	5295	4721	5008	3617	2955	3286	4066	3412	3739
11	1830	1091	1461	5603	5118	5361	2617	1766	2191	4901	4194	4547	3173	2456	2815	3625	2925	3275
Mean (V x C)	5158	4887		7209	7235		5558	5298		6879	6804		5843	5686				
Mean (C)	5022			7222			5428			6841			5764		variety	6129	5982	

C.D. at 5%

Variety (V) 53.18

Month (M) 130.26

Container (C) 84.08

V x M 184.22

V x C 118.91

M x C 291.28

V x C x M NS

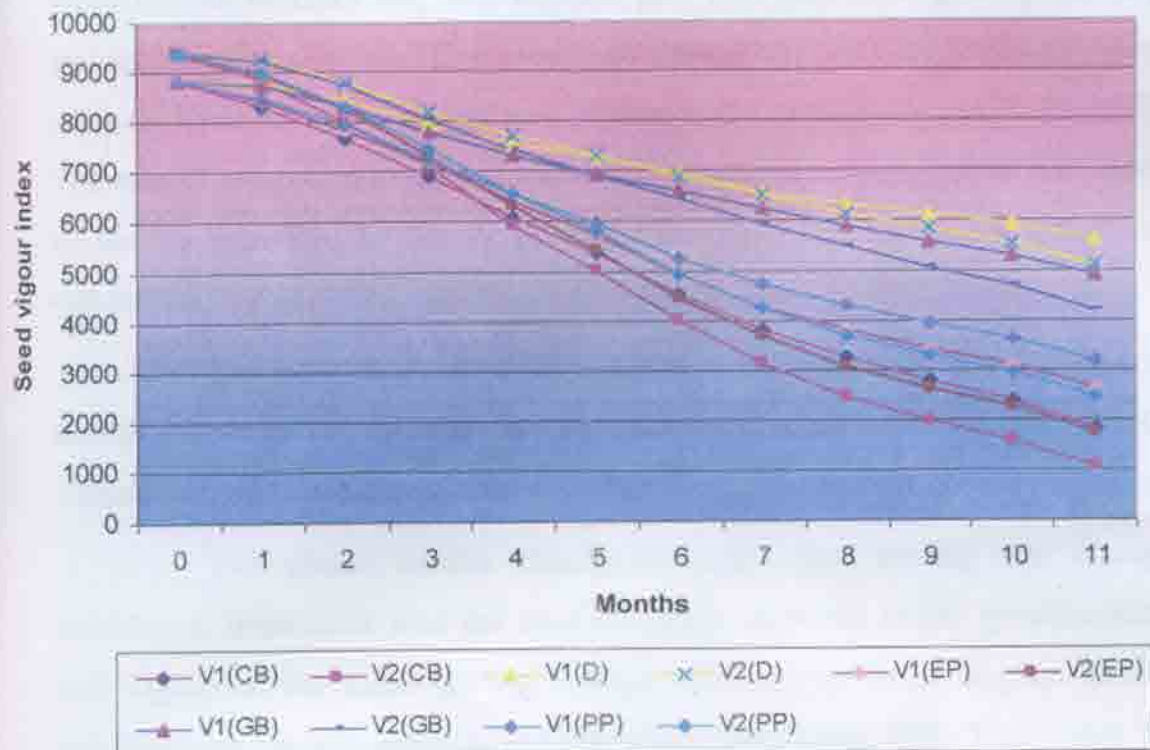


Fig.4.17 : Effect of variety, month (period) of storage and container on seed vigour index

CB = Clothbag
D = Desiccator
EP = Earthen pot
GB = Glass bottle
PP = Polyethelene packet

The vigour index at initial stage (i.e., '0' month storage) was significantly more in the hybrid, V₂ (9384) against that in the V₁ (8852). It is recorded that hybrid, V₂ had higher vigour index over that in V₁ for upto three month in cloth bag and earthen pot, four month in glass bottle and polyethylene packet and five month in desiccator. But the trend reversed after that period and V₁ registered higher viability than that in V₂ (hybrid). The rate of reduction in vigour index during entire storage period was more in the V₂ than that in the V₁. It was noted that the significant difference existed among varieties, containers and month (period) of storage.

The interaction effect of variety x container, variety x month and month x container showed significant difference. But that of variety x month x container was statistically non-significant.

The above results clearly indicated that among the storage containers, desiccator was the best container showing better germinability and vigour of the seeds during storage followed by those in glass bottle, polyethylene packet, earthen pot and cloth bag (Table 4.21) This might be due to removal of moisture by silica gel present in desiccator during storage. Glass bottle (moisture proof container) had better result over polyethylene packet due to no entry of moisture.

Seed moisture during storage is considered as the main factor, which is responsible for maintenance of seed viability and vigour. Low moisture content of the seeds brings down the rate of deterioration and help in maintenance of viability and vigour for a longer period. On the other hand, with slight increase in moisture content, remarkable decline in viability and vigour was noticed.

Seeds are hygroscopic in nature. They absorb or give out moisture from/to the surrounding air depending on the relative humidity of the atmosphere. During the storage period of seeds, there is wide fluctuation in the relative humidity in the atmosphere. Thus, the seeds also absorb or

release moisture frequently. High moisture content speeds up the respiration rate and other metabolic process, leading to the quick seed deterioration. It is well known that seeds with higher moisture content favour the growth and development of various species of storage fungi belonging to the *Aspergillus* and *Penicillium* genera thereby causing loss of viability (Singh, 1999). Hence, storage of seeds in ambient conditions and in moisture pervious container like earthen pot and cloth bag leads to a quick decline in the viability and vigour of the seeds. The rate of reduction in germination percentage, seedling root and shoot length, seedling dry weight and vigour index with the advancement of storage period were more in V₂ (hybrid) than that in the V₁ irrespective of container.

The silica gel present in desiccator absorbed moisture during storage. Thus, it helped to maintain seed viability and vigour for longer period. Similar observation was reported by Doijode (1995). Glass bottle (moisture impervious container) prevented the absorption of outside moisture by the seeds and the seed viability and vigour were maintained for longer period than that in polyethylene packet. Seeds stored in polyethylene packet maintained greater germinability and vigour than seeds stored in earthen pot and cloth bag (Karivaratharaju *et al.*, 1989 and Bajpai *et al.*, 2002). Germination percentage and germination index in cucumber decreased with increasing storage period (Meng *et al.*, 1995) but the degree of viability loss in bottle gourd was related to cultivar (Chung *et al.*, 1999) as the difference between the two variety has been noted in the presence investigation.

4.3 Experiment III

4.3.1 Effect of pollination method on fruit and seed yield

The effects of pollination by hand and natural means on fruit characters were significantly different (Table 4.22 and Fig. 4.18). The different type of pollination in 4 : 1 and 4 : 2 row ratio of planting produced more or less similar number of fruit. However, numerical difference (ranging 7.1% -

12.77% variation) in fruit number, was noted. Similar result was noted in fruit weight also.

Table 4.22 : Effect of pollination method on fruit characters including yield

Treatments	Number of fruits per plant	Percentage increase in number of fruits per plant	Fruit weight (kg)	Fruit yield per plant (kg)	Percentage increase in fruit yield per plant
Natural pollination	4.50	14.50 % over hand pollination	1.57	7.097	13.17% over hand pollination
Hand pollination	3.93	-	1.59	6.271	-
C.D. at 5%	0.22	-	NS	0.48	-
4 : 1 row ratio	4.02	-	1.493	5.986	-
4 : 2 row ratio	4.42	9.95% over 4 : 1 row ratio	1.669	7.382	23.32% over 4 : 1 row ratio
C.D. at 5%	0.22	-	NS	0.48	-
Natural pollination with 4 : 1 row ratio	4.23	11.32% more over 4 : 1 hand pollination	1.456	6.158	5.92% more over 4 : 1 hand pollination
Natural pollination with 4 : 2 row ratio	4.77	12.77% and 17.19% more over 4 : 1 natural pollination and 4 : 2 hand pollination	1.685	8.037	30.51% and 19.46% more over 4 : 1 natural pollination and hand pollination
Hand pollination with 4 : 1 row ratio	3.80	-	1.530	5.814	-
Hand pollination with 4 : 2 row ratio	4.07	7.1% more over 4:1 hand pollination	1.653	6.728	15.15% more over 4 : 1 hand pollination
C.D. at 5%	NS	-	NS	0.67	-

When average data of 4 : 1 and 4 : 2 planting ratio of female and male plants were computed, it was revealed that fruit number per plant due to natural pollination was significantly more (14.50%) over that in hand pollination. But, average fruit weight was more or less equal. However, fruit yield per plant was significantly higher (13.17%) due to natural pollination over that in hand pollination. On the contrary, fruit yield per

plant in both type of row ratio and pollination method exhibited significant difference. Natural pollination in both row ratio showed better and significant different result over those in hand pollination. In 4 : 2 row ratio of planting, fruit yield per plant was more in both type of pollination, compared to that in 4 : 1 row ratio of planting (Table 4.22 and Fig.4.18).

On the contrary, the statistical analysis of combined data of both hand and natural pollination in separate, 4 : 1 and 4 : 2 row ratio revealed that 4 : 2 row ratio produced significantly higher number of fruits per plant, fruit yield, healthy seeds and 100-seed weight.

There was also significant difference in the effect of hand and natural pollinations on seed setting (in the fruit) and other characters (Table 4.23 and Fig. 4.18). The setting of healthy seeds was more (12.05%) and immature seeds less in natural pollination over that in hand pollination. On the other hand, 100-seed weight was numerically less (not statistically different) compared to that in hand pollination. However, natural pollination in 4 : 1 and 4 : 2 ratio of planting enhanced healthy seed number (11.33% and 12.62% respectively) over that in hand pollination.

It is also noted that the natural pollination in 4 : 2 ratio of planting showed enhanced seed number per fruit (27.79%) over the same type of pollination in 4 : 1 ratio of planting. Similar trend was also noted in hand pollination (Table 4.23 and Fig. 4.19).

The effect of natural pollination was better compared to that in hand pollination with respect to fruit and seed characters. The observation corroborates the report of Alam and Quadir (1986) in bottle gourd and Chand *et al.* (1990) in cucumber. The reason for higher fruit set in natural pollination method can be attributed to more efficient pollination due to better bee activity with least injury to flower parts but it is likely that the activation of stigma by insect visit or due to some mild injury to stigma might have induced stigmatic secretion enhancing pollen germination and

pollen tube growth leading to enhanced fertilization and fruit set. Higher fruit set regulated into higher yield. Awasthi (1969) also expressed the same view.

Table 4.23 : Effect of pollination method on seed characters

Treatments	Number of healthy seeds per fruit	Percentage increase in number of healthy seed per fruit	Number of immature seeds per fruit	100-seed weight (gm)
Natural pollination	437.79	12.05% over hand pollination	48.37	15.18
Hand pollination	390.70	-	67.75	16.02
C.D. at 5%	15.88	-	7.92	NS
4 : 1 row ratio	364.80	-	76.80	14.99
4 : 2 row ratio	460.69	26.29% over 4 : 1 row ratio	39.32	16.20
C.D. at 5%	15.18	-	7.92	1.13
Natural pollination with 4 : 1 row ratio	384.37	11.33% more over 4 : 1 hand pollination	64.33	13.21
Natural pollination with 4 : 2 row ratio	491.20	27.79% and 12.62% more over (4 : 1) natural and 4 : 2 hand pollination	32.50	17.14
Hand pollination with 4 : 1 row ratio	345.23	-	89.37	16.78
Hand pollination with 4 : 2 ratio	436.17	26.34% more over 4 : 1 hand pollination	46.13	15.26
C.D. at 5%	NS	-	NS	1.60

In sunflower, opposite result was reported i.e., hand pollination enhanced more seed than that in natural pollination. It was assumed that more pollen were available by hand pollination enhancing more seed set (Shinde and Dhoble, 1979).

On the other hand, the better result in fruit and seed character due to 4 : 2 row ratio of planting in both types of pollination may be due to abundant pollen (produced by two male plants) available for pollination.

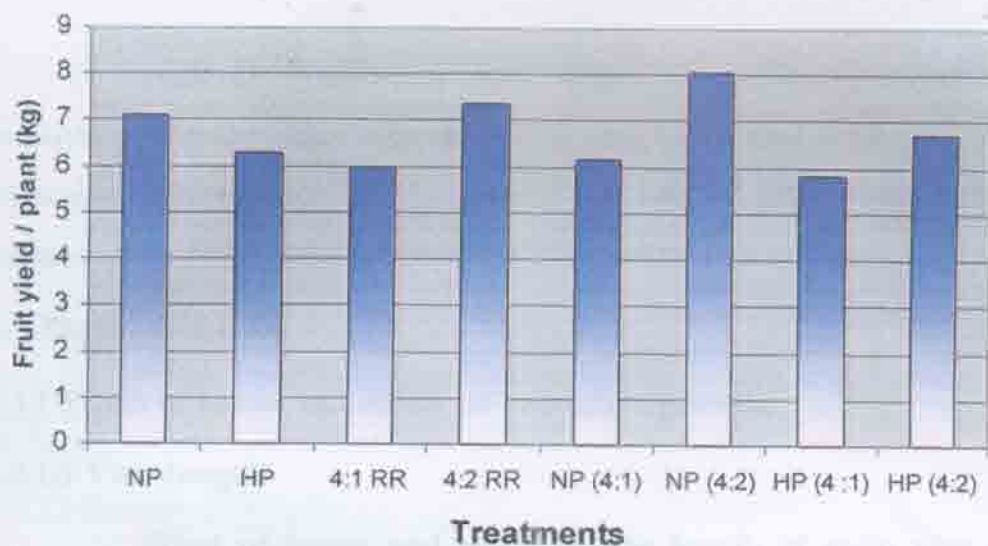


Fig.4.18 : Effect of pollination method and row ratio on fruit yield per plant

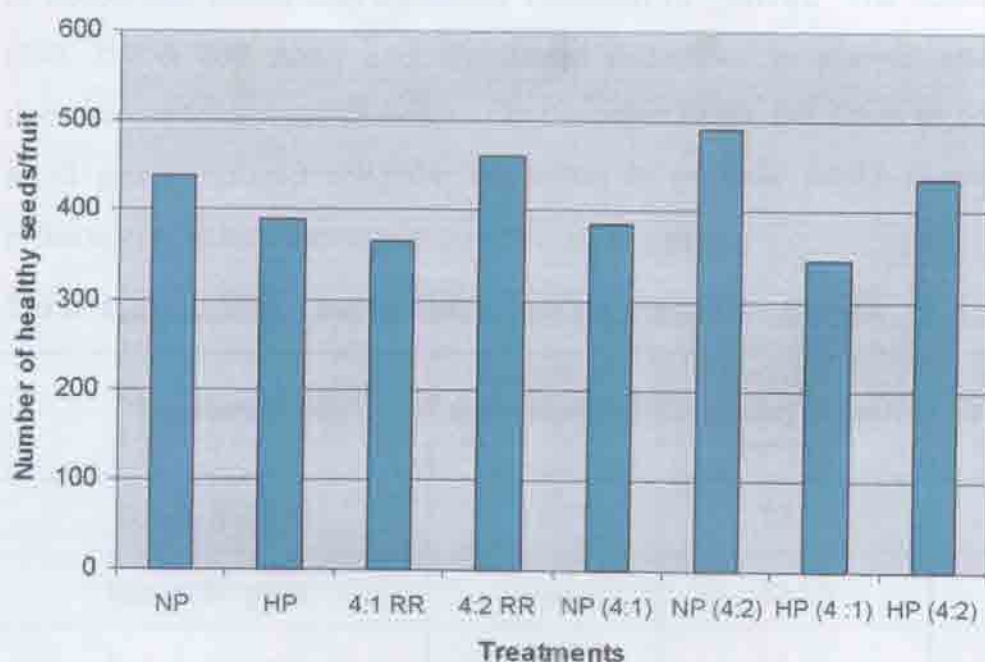


Fig.4.19 : Effect of pollination method and row ratio on number of healthy seeds per fruit

NP = Natural pollination
 HP = Hand Pollination
 4 : 1 RR = 4 : 1 row ratio
 4 : 2 RR = 4 : 2 row ratio
 NP (4 : 1) = Natural Pollination with 4 : 1 row ratio
 NP (4 : 2) = Natural Pollination with 4 : 2 row ratio
 HP (4 : 1) = Hand Pollination with 4 : 1 row ratio
 HP (4 : 2) = Hand Pollination with 4 : 2 row ratio

Natural pollination was better in performance over hand pollination. At the same time, it is also concluded that 4 : 2 row ratio had enhanced performance. It is apparent that natural pollination in 4 : 2 row ratio sowing, might be recommended for general cultivation.

4.4 Experiment IV

4.4.1 Effect of boron and ethrel on vegetative growth.

4.4.1.1 Vine length

Effect of boron and ethrel on the length of main vine showed significant reduction in growth compared to control (Table 4.24). Three doses of boron and ethrel also exhibited variation in growth. The doses of ethrel (200, 250 & 300 ppm) had significant difference in growth and gradual decrease with increase of doses. On the other hand, the doses of boron (5, 10 & 15 ppm) induced irregular reduction in growth. At 15 ppm dose less reduction was noted compared to that in 10 ppm.

Table 4.24 : Effect of boron and ethrel on vegetative growth

Treatments	Length of main vine (m)	Number of primary branch per plant	Internode length (cm)
Boron 5 ppm	4.33	12.53	5.42
Boron 10 ppm	4.16	13.53	4.21
Boron 15 ppm	4.65	13.00	4.65
Ethrel 200 ppm	4.57	12.40	4.93
Ethrel 250 ppm	4.28	13.20	4.15
Ethrel 300 ppm	4.07	13.93	3.73
Control (water spray)	5.07	11.53	6.00
C. D. at 5%	0.39	0.49	0.29

4.4.1.2 Number of primary branch per plant

The number of primary branch per plant increased significantly due to boron and ethrel treatments compared to control. There was also variation in the effect of doses of both, boron and ethrel. The 10 ppm dose of boron induced the maximum branches, significantly different from that due to 5 and 15 ppm doses. On the other hand, the number of branches increased with the increase of ethrel doses (200, 250 & 300 ppm) (Table 4.24).

4.4.1.3 Internode length

The internode length significantly reduced due to the treatments. Three doses of boron and ethrel also showed variation in internode length. But the length decreased significantly with increase of ethrel doses. However, the doses of boron induced irregular reduction in internode length. The highest reduction was at 10 ppm dose. The boron treatments showed significantly different effect (Table 4.24).

Though the length of the main vine reduced due to treatments, the internode length decreased significantly compared to that in control. Hence, the total number of node remains equal, if not more in the treated plant. As leaf and flower bud originate from node, the flower number remain static, if not more. On the other hand, the treatments of different doses of boron and ethrel induced more number of primary branches per plant and each branch was likely to bear more flower leading to high fruit setting. On the whole, the treatment had positive effect with respect to yield as primary branches and number of node increased showing possibility of increased bearing.

Boron and ethrel reduced the length of main vine, internode length but produced more number of primary branch. This may possibly be due to early induction of reproductive phase which inhibited normal growth thereby resulting in reduced length of main vine which is in line with the finding of Shanmugavelu *et al.* (1973) with ethrel in pumpkin and Mishra *et al.* (1976) in cucumber.

4.4.2 Effect of boron and ethrel on flowering and sex ratio

4.4.2.1 Number of days to first female and male flower anthesis

On the other hand, number of days to first female flower anthesis decreased significantly due to treatments of boron and ethrel doses. The 10 ppm boron dose remarkably decreased the number of days to first female flower anthesis against other two doses. But, the dose of 300 ppm ethrel had the highest decrease in number of days.

The days to first male flower anthesis were also variable due to boron and ethrel application. The doses of boron did not show any trend but those of ethrel had a trend and the days to first male flower anthesis increased with increase of doses.

But, the days to first male flower anthesis due to treatments of ethrel were more than that in the control with significant difference. On the contrary, days to first female flower anthesis were significantly less than the control (Table 4.25).

4.4.2.2 Node number of first female and male flower

The effects of boron and ethrel on the node number of first female flower showed significant reduction with variation in effect of different doses (Table 4.25). The 10 ppm boron dose decreased node number of first female flower compared to the effect of other two doses. The ethrel doses also showed the same trend i.e., less node number at 250 ppm against 200 and 300 ppm doses. Contrary to that, the node number of first male flower increased significantly due to treatments compared to control. The boron treatments had the same effect in male flower like female flower. But increased in node number was noted with increase of ethrel doses compared to that in female flower.

Table 4.25 : Effect of boron and ethrel on flowering and sex ratio

Treatments	Node number of first male flower	Node number of first female flower	Number of days to first male flower	Number of days to first female flower	Number of leaves during first male flower	Number of leaves during first female flower	Sex ratio (male flowers/ female flowers)	Pollen viability percentage
Boron 5 ppm	8.40	9.40	56.67	59.67	39.96	49.17	7.38	95.47 (77.75)
Boron 10 ppm	8.13	9.00	55.33	57.33	47.27	54.23	6.44	85.74 (67.78)
Boron 15 ppm	8.60	9.20	57.33	59.33	43.13	53.47	8.16	91.85 (73.46)
Ethrel 200 ppm	8.07	9.80	54.33	60.33	40.63	48.27	7.27	92.25 (73.89)
Ethrel 250 ppm	8.60	9.27	56.00	60.00	43.37	51.73	6.74	88.13 (69.82)
Ethrel 300 ppm	8.73	9.53	57.33	58.67	47.57	55.67	6.23	81.54 (64.53)
Control (water spray)	7.80	10.73	53.33	62.67	33.33	44.73	8.34	96.53 (79.22)
C. D. at 5%	0.30	0.38	0.85	1.40	2.69	2.99	0.27	2.27

Figures in the parenthesis are arc-sine transformation value

4.4.2.3 Number of leaves during first female and male flower anthesis

The number of leaves at the time of first female flower anthesis increased significantly due to treatments of boron and ethrel than that in the control (Table 4.25). On the other hand, number of leaves increased with increase of ethrel doses and 10 ppm boron dose.

The same trend was also noted in leaves number at first male flower anthesis. The effects were significantly different in male and female flower anthesis.

4.4.2.4 Sex ratio

The ratio of male : female flowers greatly determine the yield of fruit and seed in bottle gourd. Application of boron and ethrel significantly lowered the sex ratio against that in the control (Table 4.25 and Fig. 4.20). There was also variation in the effect of three doses of boron and ethrel, while 10 ppm boron decreased the ratio remarkably. On the other hand, the ratio of male : female flower narrowed with increase in ethrel doses (200, 250 & 300 ppm).

4.4.2.5 Pollen viability

The pollen viability (expressed as percentage) decreased significantly due to treatments of boron and ethrel with variation in effect of three doses of boron and ethrel. The pollen viability (percentage) decreased significantly with increase of ethrel doses (200, 250 & 300 ppm). But the effect of boron doses reduced the fertility but not in the pattern as in ethrel and maximum reduction was at 10 ppm boron dose (Table 4.25).

The experiment was conducted to study the effect of boron and ethrel and the overall improvement in all characters under study have been noted. The first effect was on the female flower at earlier node number whereas the male flower at later node. So earliness for female flowering due to treatments is indicated. This may be due to ethylene released from ethrel,

obstructed the biosynthesis responsible for formation of staminate flowers. Exogenous ethrel application might have probably increased the abscissic acid and decreased the endogenous level of gibberelline and auxins, thus producing earlier pistillate flowers. This evidence is supported by Saimbhi and Gill (1988) and Karik *et al.* (1990) in their earlier findings. The earliness is further confirmed by taking less days to anthesis of first female flower and late anthesis of first male flower compared to those in the control.

The number of leaves was more due to treatments during first male and female flower anthesis. It is assumed that more leaves produce more photosynthate available for the nutrition and growth of the plant.

The sex ratio (male flowers / female flowers) greatly determine the yield of fruit and seed in bottle gourd. The narrow ratio of male and female flower is desirable i.e. more female flowers lead to higher fruit set. Due to treatments of boron and ethrel, the narrow ratio of male and female flower was recorded with variation in dose effect such as 10 ppm dose of boron and 250 and 300 ppm doses of ethrel had the narrow ratio compared to other respective doses. The possible reason for narrow sex ratio with boron and ethrel might be due to production of more female flowers.

A similar type of result in case of bitter gourd was obtained by Verma *et al.* (1984) where foliar application of boron (4 ppm) and ethrel (200 and 400 ppm) increased the number of female flowers.

Weaver (1974) explained the phenomenon that ethylene producing chemicals like ethrel played a role in transcription and translocation of the genetic code from DNA to RNA and protein might incorporate into RNA. Thus, it would contribute to the regulation of development phenomena like flowering, which cause transformation of male to female one.

According to Gedam *et al.* (1998) the increase number of pistillate flowers in boron (4 ppm) treated plant can be attributed to physiological and

biochemical changes caused by the boron in the plant tissues by the exogenous application.

Though the pollen fertility reduced due to boron and ethrel treatments, the male flowers had lower potentiality to pollinate and fertilize the ovary of female flowers. However, the pollen was collected from the untreated plants (control) and pollination was performed. Hence, normal setting of fruit was not affected. But that the treatments of boron and ethrel could reduced fertility was confirmed.

4.4.3 Effect of boron and ethrel on fruit characters and yield

4.4.3.1 Fruit length

As before, the treatments induced increase in fruit length significantly, while the doses of boron increased the fruit length irregularly. On the other hand, the length reduced significantly with the increase of ethrel doses but the control had even less length than those in the treatments (Table 4.26).

4.4.3.2 Fruit diameter

The significant increased in fruit diameter was recorded in the treatments of boron and ethrel (Table 4.26). The 10 ppm boron dose increased maximum fruit diameter compared to other two doses. Contrary to that, the diameter reduced with the increase of ethrel doses (200, 250 & 300 ppm) but more than that in control.

4.4.3.3 Fruit Weight

Fruit weight increased significantly due to treatments of boron and ethrel (Table 4.26). The dose of 15 ppm boron increased maximum fruit weight. On the other hand, fruit weight reduced significantly with the increase of ethrel doses but more than that in the control.

Table 4.26 : Effect of boron and ethrel on fruit characters and yield

Treatments	Fruit length (cm)	Fruit diameter (cm)	Number of fruits per plant	Fruit weight (kg)	Fruit yield per plant (Kg)	Percent increase in fruit yield over control (Av.)
Boron 5 ppm	22.61	17.82	4.47	1.870	8.353	15.34
Boron 10 ppm	21.49	18.51	5.07	1.796	9.105	25.72
Boron 15 ppm	23.42	18.00	4.20	1.975	8.295	14.54
Ethrel 200 ppm	24.07	20.03	4.27	2.052	8.762	20.99
Ethrel 250 ppm	23.64	19.49	4.73	1.920	9.081	25.39
Ethrel 300 ppm	21.50	18.76	5.13	1.831	9.393	29.70
Control (water spray)	20.25	17.25	4.13	1.752	7.242	-
C. D. at 5%	1.29	0.72	0.21	0.10	0.43	-

4.4.3.4 Number of fruits per plant

Like previous cases, significant difference in number of fruits per plant was noted among the treatments (Table 4.26 and Fig. 4.21). Three doses of boron and ethrel also exhibited variation in fruit number, while 10 ppm boron increased maximum fruit number in comparison to other two doses. On the contrary, the number of fruits increased with the increase of ethrel doses.

4.4.3.5 Fruit yield per plant

The effect of boron and ethrel also had significant difference in fruit yield per plant. The dose of 10 ppm boron increased maximum fruit yield per plant. On the other hand, the yield increased with the increase of ethrel doses (Table 4.26 and Fig. 4.22).

4.4.3.6 Percent increase in fruit yield over control

The three doses of boron and ethrel exhibited variation in percentage increase in fruit yield over that in the control (Table 4.26). The 10 ppm boron dose increased the percentage when the increase of ethrel doses (200, 250 & 300 ppm) had gradual increased in percentage of fruit yield.

The fruit length, fruit diameter and fruit weight were more due to the treatments of some doses of boron and ethrel. On the other hand, the more leaf number at first female flower anthesis provided more photosynthate used for nutrition and growth of plant and yield. The possible reason for more number of fruits and fruit yield per plant might be due to production of more female flowers which lead to higher fruit set. This result corroborates with the findings of Singh and Choudhury (1989) with boron and ethrel in cucumber and water melon and Arora *et al.* (1989) in pumpkin.

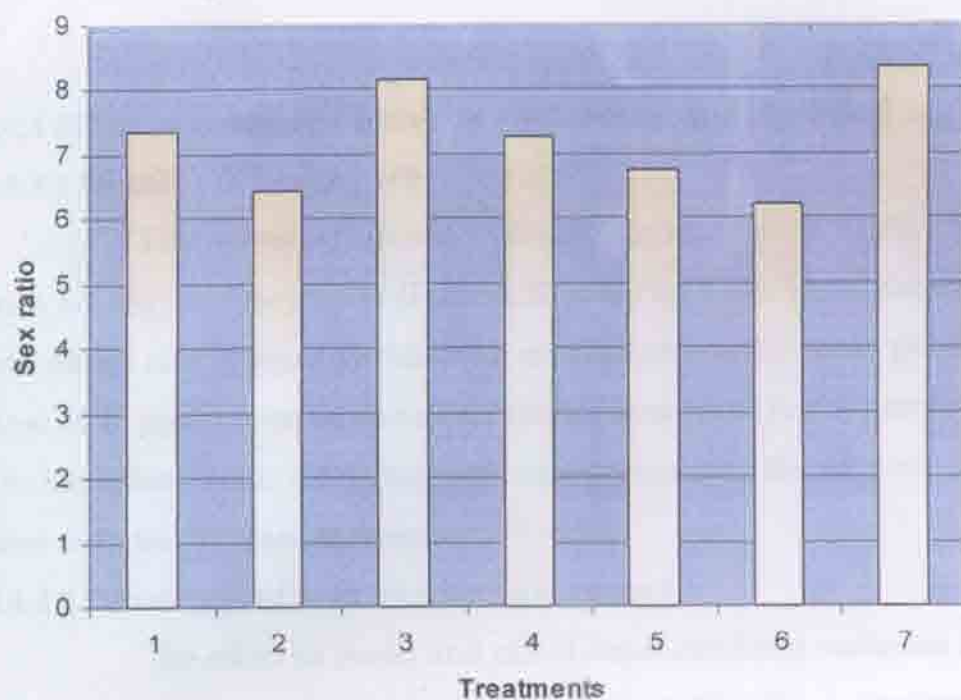


Fig.4.20: Effect of boron and ethrel on sex ratio

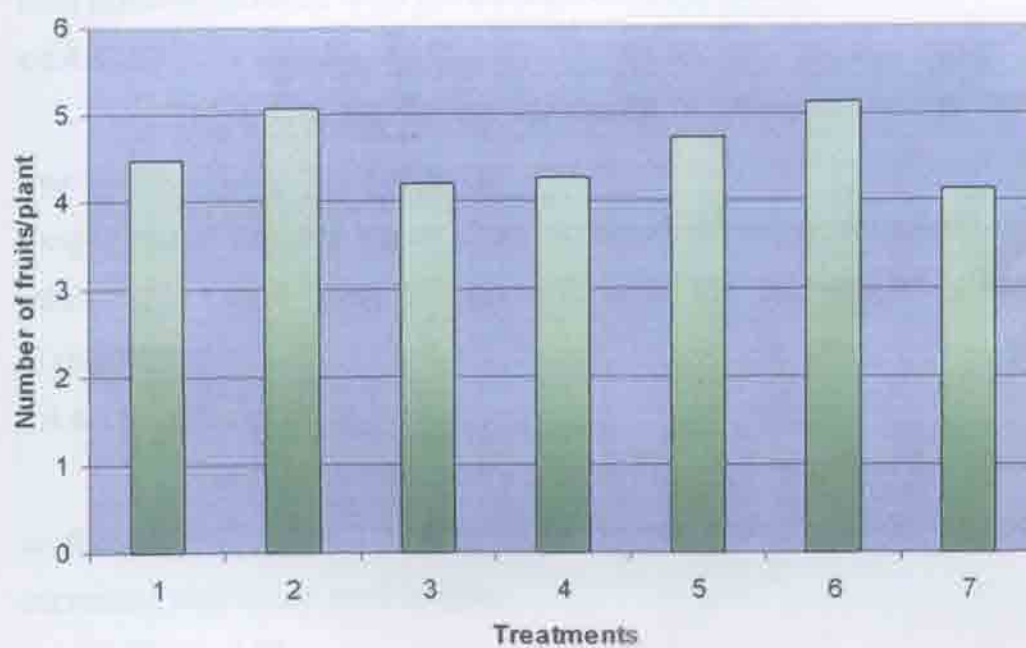


Fig.4.21: Effect of boron and ethrel on number of fruits per plant

- 1 = Boron 5 ppm
- 2 = Boron 10 ppm
- 3 = Boron 15 ppm
- 4 = Ethrel 5 ppm
- 5 = Ethrel 10 ppm
- 6 = Ethrel 15 ppm
- 7 = Control (Water spray)

4.4.4 Effect of boron and ethrel on seed content and characters

4.4.4.1 Number of healthy seeds per fruit

There was significant difference in number of healthy seeds per fruit among the treatments (Table 4.27 and Fig. 4.23). Three doses of boron and ethrel also showed variation in number of healthy seeds per fruit. The dose of 10 ppm boron increased maximum number of healthy seeds per fruit. On the other hand, three doses of ethrel decreased the number of healthy seed with the increase of doses.

4.4.4.2 Percentage of seed number over control

The effect of boron and ethrel doses exhibited variation in percent increased in seed number over control (Table 4.27). The percentage increase was maximum in 10 ppm dose of boron. On the other hand, percentage of seed number reduced with the increase of ethrel doses.

4.4.4.3 100-seed weight

There was significant difference in 100-seed weight among the treatments. Three doses of boron and ethrel exhibited variation in 100 seed weight when 10 ppm boron dose increased the same remarkably. On the other hand, seed weight decreased with the increase of ethrel doses (Table 4.27).

4.4.4.4 Seed length

There was significant difference in seed length in the treated lines as shown in (Table 4.27). The 10 ppm dose of boron and 200 ppm ethrel increased maximum seed length.

4.4.4.5 Seed width

As in length, there was significant difference in seed width due to treatments and variation was noted in the effect of three dose of boron and ethrel. Application of 15 ppm boron increased seed width significantly over that in control. The effect of three doses of ethrel on seed width was irregular while 250 ppm dose had the maximum effect in increasing seed width (Table 4.27).

Table 4.27: Effect of boron and ethrel on seed content and characters

Treatments	Number of healthy seeds per fruit	Percent increase in seed number over control (Av.)	100-seed weight (gm)	Seed length (cm)	Seed width (cm)
Boron 5 ppm	498.27	10.14	19.72	1.84	0.84
Boron 10 ppm	549.73	21.51	26.23	2.04	0.84
Boron 15 ppm	510.60	12.86	21.83	1.86	0.87
Ethrel 200 ppm	423.73	-6.34	17.43	1.88	0.78
Ethrel 250 ppm	365.87	-19.13	16.16	1.76	0.86
Ethrel 300 ppm	313.28	-30.76	14.17	1.84	0.76
Control (water spray)	452.40	-	18.35	1.78	0.82
C. D. at 5%	41.69	-	2.56	0.04	0.02

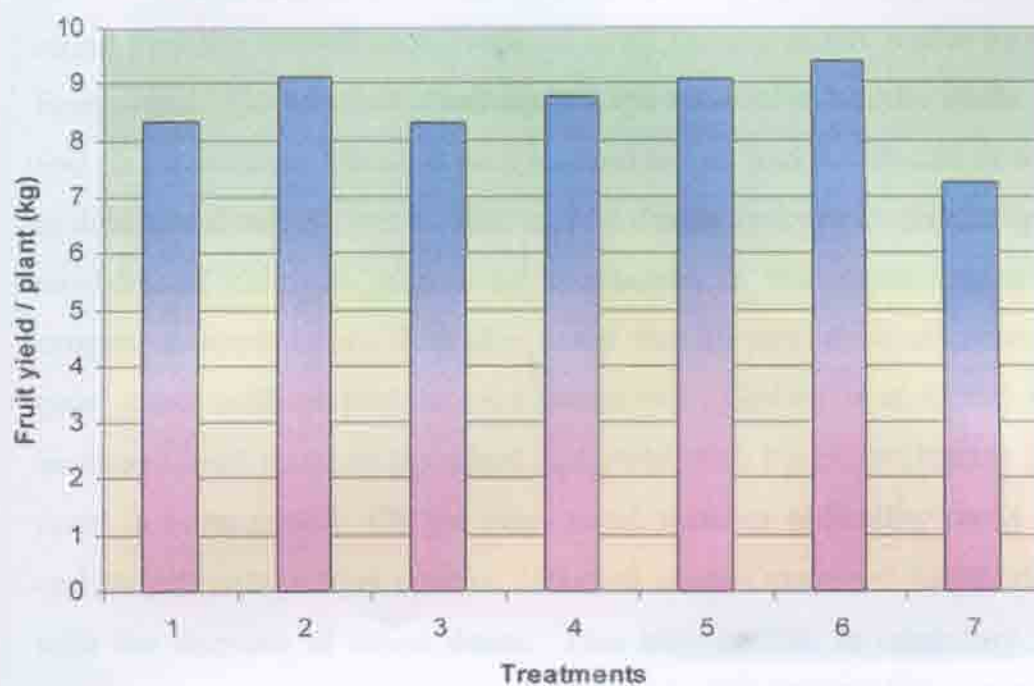


Fig.4.22 : Effect of boron and ethrel on fruit yield per plant

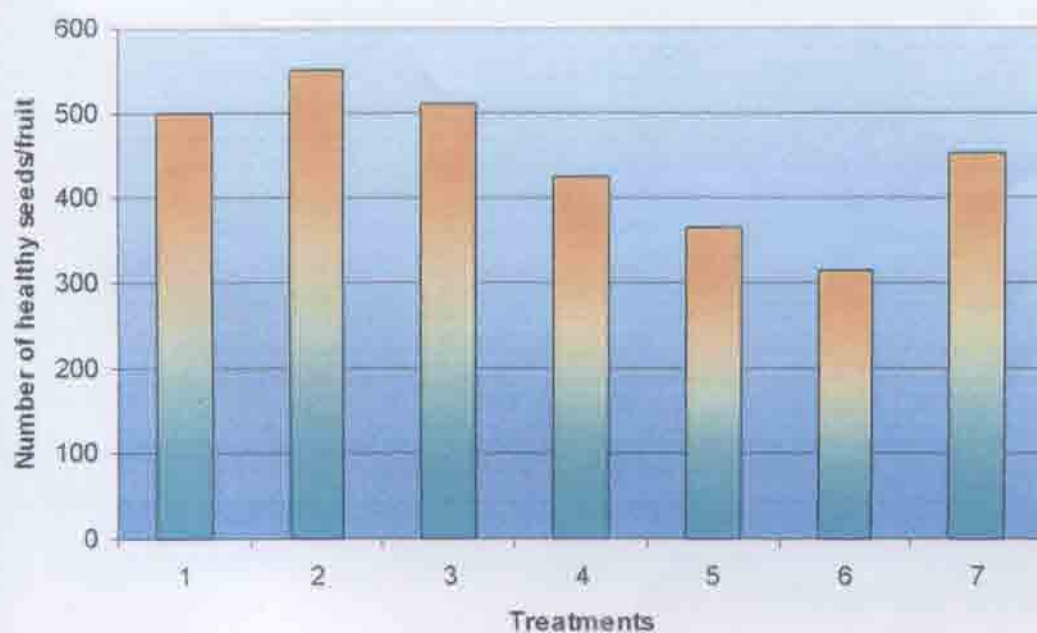
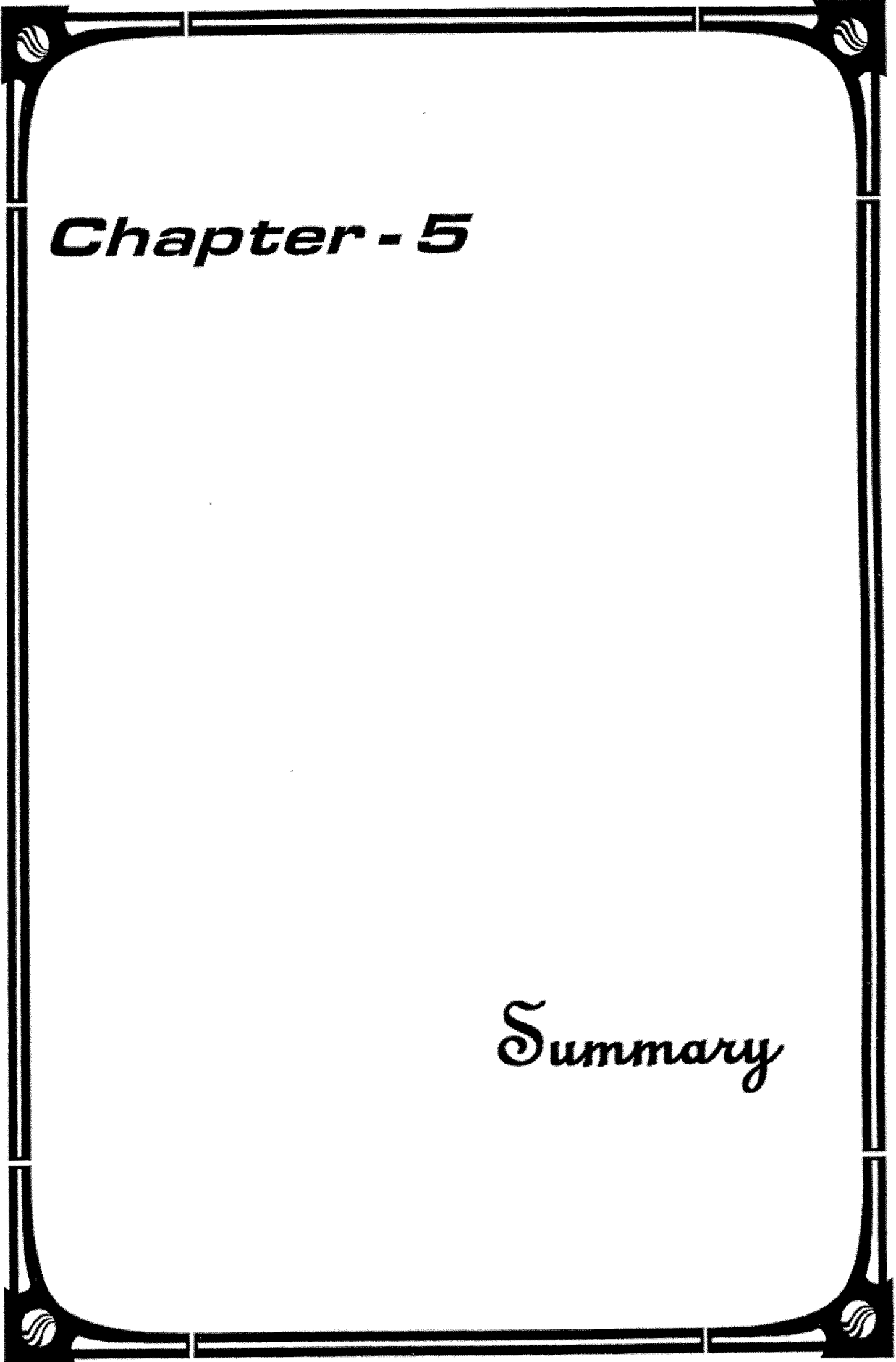


Fig.4.23 : Effect of boron and ethrel on number of healthy seeds per fruit

- 1 = Boron 5 ppm
- 2 = Boron 10 ppm
- 3 = Boron 15 ppm
- 4 = Ethrel 5 ppm
- 5 = Ethrel 10 ppm
- 6 = Ethrel 15 ppm
- 7 = Control (Water spray)

The experiment was conducted to study the effect of boron and ethrel and the overall improvement in all the characters under study have been noted. The positive effect was on the number of healthy seeds per fruit and its percentage, 100-seed weight, seed length and width due to treatment of different doses of boron. This may be due to favourable physiological and biochemical changes caused by the boron in the plant tissues by the exogenous application. It is also noted that 10 ppm dose of boron had the good effect with respect to seed characters. Gedam *et al.* (1998) reported increased seed number per plant and yield with boron treatments (2, 4 & 6 ppm) in bitter gourd. On the other hand, number of healthy seeds per fruit and its percentage over control, 100-seed weight and seed length decreased with the increase of ethrel doses. This may be due to inhibitory effect of ethrel on seed formation. This result corroborates the findings of Arora and Partap (1988) with ethrel (100 & 250 mg/l) in pumpkin.



Chapter - 5

Summary

Summary

The present investigation was undertaken with a view to study ~~combination, relative contribution, methods of pollination, etc.~~ hybrid-seed production, fruit qualities and seed storage of bottle-gourd. The experimental material consisted six promising lines (female) namely, BCBG-1 (L₁), BCBG-4 (L₂), BCBG-7 (L₃), BCBG-15 (L₄), BCBG-17 (L₅) and BCBG-34 (L₆) and three testers (males) namely, BCBG-3 (T₁), BCBG-20 (T₂) and BCBG-33 (T₃) selected from a group of germplasm. Eighteen hybrids were raised by crossing selfed lines with testers to study genetical background by analysing line x tester mating design.

Seeds of one parental line and one F₁ hybrid were stored in various seed storage containers. The effect of row ratio of male and female plants and natural vis-à-vis hand pollination were also explored. The effects of boron and ethrel doses on different traits were evaluated. Summary of the results and conclusion of the 4 experiment are given below -

On the basis of *per se* performance, the line, L₅ was the best as it exhibited good performance for fourteen characters including fruit yield per plant. The next better line was L₃ recording better performance for fruit yield per plant and other ten important characters. The lines - L₆ and L₄ exhibited superiority for ten and nine characters, including fruit yield per plant, respectively. On the contrary, the line L₁ and L₂ had superior performance for five and one important characters excluding fruit yield per plant, respectively. It may be inferred that the line, L₅ was the best followed by L₃ and L₆.

Among the testers, T₃ was superior in *per se* performance for thirteen characters including fruit yield per plant while T₁ and T₂ testers had significant favourable performance for five traits each excluding fruit yield per plant.

The hybrid, $L_5 \times T_1$ was the best as it produced the highest fruit yield per plant along with nine important characters closely followed by $L_6 \times T_3$ hybrid. Other two hybrids $L_2 \times T_3$ and $L_3 \times T_1$ produced good fruit yield per plant with eight and five important characters, respectively.

The magnitude of PCV was higher than GCV for all characters suggesting the influence of environmental factors on the expression of traits of bottle gourd. Higher GCV and PCV were recorded for fruit length and 100-seed weight followed by another seventeen traits

High heritability coupled with high genetic advance was recorded for fruit length, TSS, 100-seed weight and number seeds per fruit indicating that such characters are under the control of additive genes. So there is a scope of selection to improve these characters.

High heritability coupled with average to below average GA recorded for sex ratio, fruit weight, number of fruits per plant, fruit yield per plant, total sugar and seven other traits. High heritability coupled with low GA recorded for ascorbic acid and above average heritability with low GA for node number of first female flower and number of days to first fruit harvest suggesting that these characters are under the influence of non-additive gene action.

The phenotypic correlation study revealed that the fruit weight and fruit length had significant and positive correlation with fruit yield per plant. The genotypic correlation revealed the same trend with variation in magnitude of correlation value. Hence, selecting genotypes with more fruit weight and fruit length is likely to improve the fruit yield per plant.

The path analysis at phenotypic and genotypic levels revealed that the fruit weight and fruit length had direct effect on yield.

The analysis of correlation also revealed that the seed length, seed width, 100-seed weight, number of seeds per fruit and fruit weight had

significant and positive correlation with fruit yield per plant. Hence, selection of genotype with more seed length, seed width, 100-seed weight and number of seeds per fruit is likely to improve the fruit yield per plant.

The path analysis at phenotypic and genotypic levels revealed that the seed width, seed length, fruit weight had direct effect on fruit yield per plant.

The analysis of variance for parents and crosses in the present study revealed significant difference among them for all characters. Further, among the highly significant parental variations, variances among line were high for almost all the characters and testers were significant for all the characters except node number of first male flower. However, it revealed the significant genetic variability in the parents for almost all characters.

The significant variance due to parent vs. crosses for almost all the characters excluding, fruit length, fruit diameter, fruit weight and total sugar indicated the considerable amount of heterosis reflected in the hybrids. Also significant difference among the crosses for almost all characters revealed varying performance of cross combinations.

The maximum contribution to the total variation was made by line for the characters ^{Y₁₃} sex ratio, fruit length, fruit diameter, ascorbic acid, total sugar and four other characters. But 100-seed weight recorded the maximum contribution by tester. On the other hand, fruit weight, number of fruits per plant, fruit yield per plant, TSS and other six characters, the maximum contribution to the total variation was made by line x tester interaction.

On the whole, it is apparent that contribution of line x tester interaction was maximum for ten characters followed by lines for nine characters mentioned above.

Among the lines, L₄, L₅ and L₆ registered favourable *gca* effects for eleven traits including fruit yield per plant. The L₃ line was the best combiner

for seven traits including fruit yield per plant. On the other hand, the L_2 and L_1 lines had significant superior *gca* effects for five and four characters (excluding fruit yield per plant) respectively. It is apparent that the lines, L_5 , L_6 , L_4 and L_3 were the best general combiner.

Among the testers, T_3 had significantly favourable *gca* effects for twelve characters including fruit yield per plant and T_2 and T_1 testers recorded significantly desirable *gca* effect for five and three traits excluding fruit yield per plant. Considering the *per se* performance and *gca* effects of the parents, the lines L_6 , L_5 , L_3 and L_4 and T_3 among the testers emerged as the outstanding.

The estimates of specific combining ability (*sca*) effects, revealed that the $L_6 \times T_3$ combination had significant and favourable *sca* effects for twelve characters including fruit yield per plant. The parents L_6 and T_3 exhibited positive and significant *gca* effects. For fruit yield per plant, there is a possibility of selection from $L_6 \times T_3$ cross combination in advance generation.

With respect to quality of fruit (TSS, ascorbic acid and total sugar content), number of combinations had positive and significant *sca* effects but the combinations $L_4 \times T_2$ and $L_5 \times T_2$ had better TSS; $L_6 \times T_2$ better ascorbic acid and $L_5 \times T_3$ better total sugar when their parents had positive and significant *gca* effects. So for quality of the fruits, there is a possibility of selection in advance generation of those combinations.

The combinations $L_4 \times T_2$, $L_5 \times T_1$ and $L_6 \times T_3$ recorded significant and positive *sca* effects for fruit yield per plant along with TSS and ascorbic acid i.e., these three hybrids had both quality and quantity of fruit.

The analysis of additive and dominant variance and the ratio of σ^2_{GCA} and σ^2_{SCA} revealed that ascorbic acid and seed length were under the control of additive gene components while the rest 18 characters were under the control of dominant gene components.

Based on mean performance, *sca* effects and heterosis over better parent, the hybrid $L_5 \times T_1$ was suitable for heterosis breeding since it expressed high fruit yield per plant along with other four traits *viz.*, node number of first male flower, fruit weight, number of fruits per plant and number of seeds per fruit. The next better hybrid was $L_6 \times T_3$ which recorded second highest mean performance for fruit yield per plant along with other six important character. The cross combination, $L_2 \times T_3$ recorded superiority for fruit yield per plant along with three yield attributing characters followed by $L_3 \times T_1$ for fruit yield per plant. For, fruit yield per plant as well as quality, $L_6 \times T_3$ hybrid was the best.

Based on the above observation it can be concluded that the hybrids $L_5 \times T_1$, $L_2 \times T_3$ and $L_3 \times T_1$ were better for fruit yield per plant and $L_6 \times T_3$ for fruit yield per plant as well as quality. These four hybrids can be used commercially.

Among the storage containers, desiccator ~~was the best~~ showing better germinability, seedling root and shoot length, seedling dry weight and vigour index during storage followed by glass bottle, polyethylene packet, earthen pot and cloth bag. The rate of reduction in the above characters with the advance of storage period were more in V_2 (hybrid) than that in the V_1 (genotype) irrespective of container.

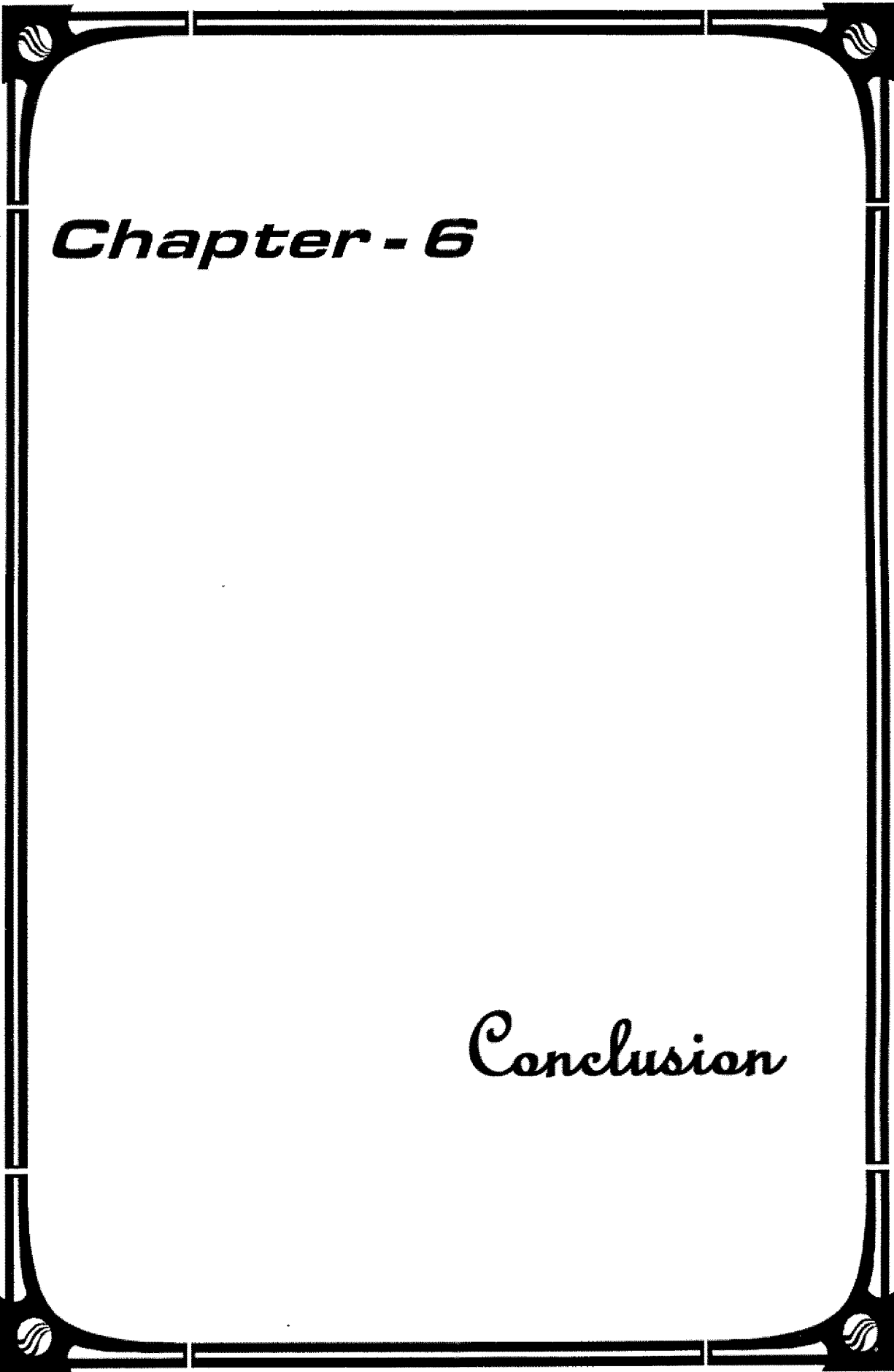
Natural pollination had better performance over hand pollination. At the same time, 4 : 2 row ratio produced better performance. It is apparent that natural pollination in 4 : 2 row ratio sowing, might be recommended for general cultivation.

The treatments of boron and ethrel generally enhanced leave number and narrowed down the sex ratio i.e., female flower increased in number leading to setting more fruits but reduced the pollen fertility. However, boron (10 ppm) and ethrel (300 ppm) produced more fruit number

reflected in increased fruit yield per plant. Fruit length, diameter and weight also increased due to application of boron and ethrel.

The number of healthy seed and 100-seed weight increased due to application of 10 ppm boron. But, gradual decrease was noted with the increase of ethrel doses.

The doses of 10 ppm boron and 300 ppm ethrel induced more yield as number of fruit set per plant was more. Thus, these two doses of boron and ethrel were more effective in increasing female flowers and modifying sex ratio thereby increasing number of fruits per plant.



Chapter - 6

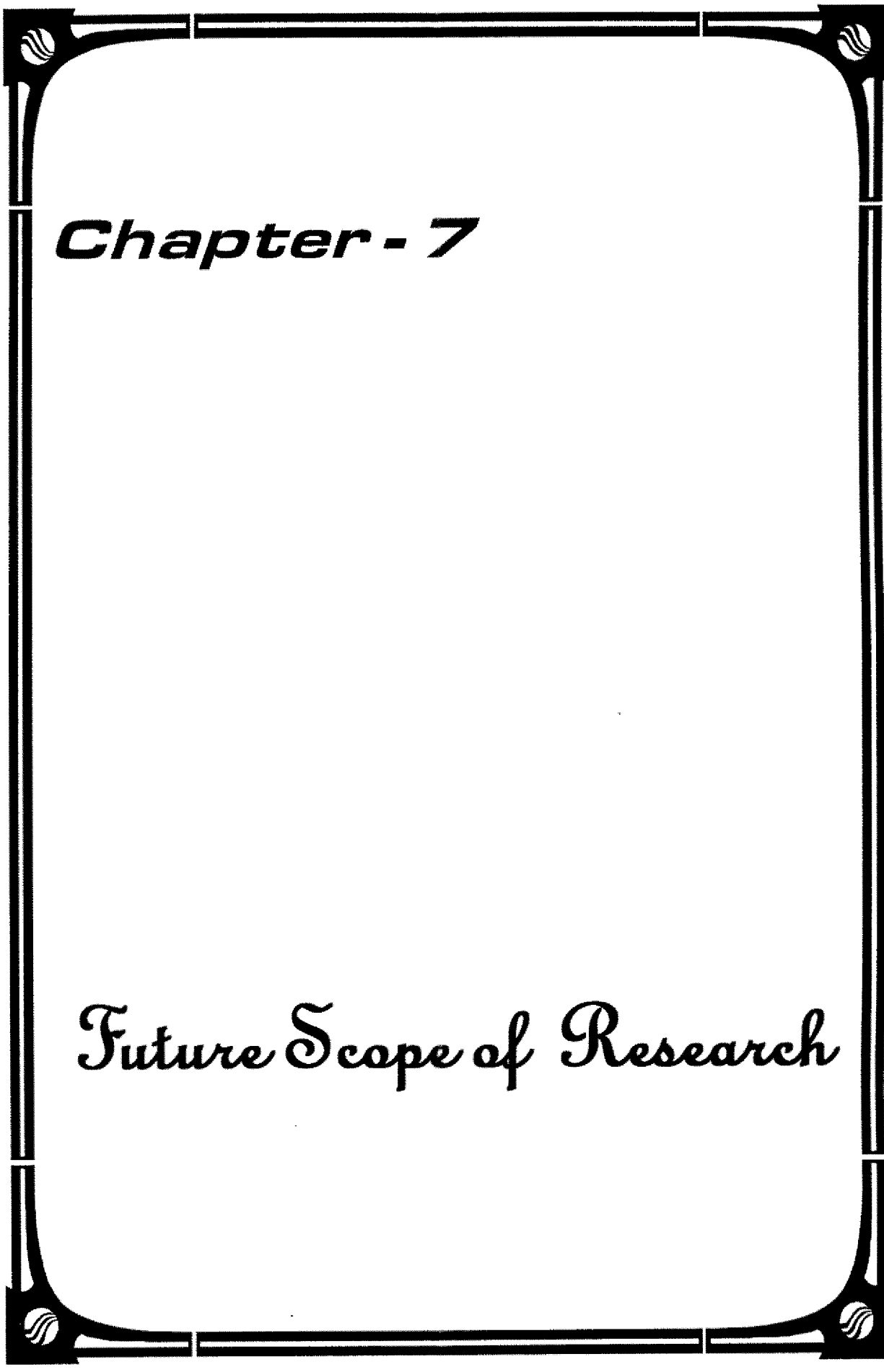
Conclusion

Conclusion

The results of the present study lead to conclude the followings :

- ❖ The line, L_5 was the best as it exhibited good *per se* performance for fruit yield per plant and other fourteen important characters.
- ❖ Among the testers, T_3 ranked first as it registered superior *per se* performance for fruit yield per plant along with thirteen traits.
- ❖ It has been noted that increase in fruit diameter leads to decrease in fruit length, number of fruits per plant and fruit yield. Keeping this trend in view, plants with less fruit diameter but more number of longer fruits should be selected for utilization in raising hybrids seed.
- ❖ The hybrid, $L_5 \times T_1$ was the best and had best heterotic manifestation over both, better and mid parent with respect to fruit yield per plant.
- ❖ The fruit length, TSS, 100-seed weight and number seeds per fruit are under the control of additive gene action. There is a scope of selecting plants with desirable improved traits.
- ❖ The traits like sex ratio, fruit yield per plant, node number of first female flower, number of days to first fruit harvest are under the influence of non-additive gene action leaving no scope of selection.
- ❖ Among the parents, L_3 , L_4 , L_5 , L_6 and T_3 were the best general combiners.
- ❖ The hybrid, $L_6 \times T_3$ was the best for *sca* effects. Its parents had positive and significant *gca* effect. There is a scope of selection for fruit yield per plant in advance generation.
- ❖ The analysis of additive and dominant variance and the ratio of σ^2GCA and σ^2SCA revealed that ascorbic acid and seed length are under the control of additive gene action while the rest of traits are under the control of non-additive gene action.

- ❖ Based on *per se* performance, *sca* effects and heterosis over better parent, the hybrids $L_5 \times T_1$, $L_2 \times T_3$ and $L_3 \times T_1$ were superior for fruit yield per plant while $L_6 \times T_3$ hybrid was superior for fruit yield per plant as well as quality. These four hybrids may be used commercially.
- ❖ Among the storage containers, desiccator was the best showing better germinability and vigour of the seeds during storage followed by glass bottle, polyethylene packet, earthen pot and cloth bag. The rate of reduction in germination percentage and vigour was more in V_2 (hybrid) than that in the V_1 irrespective of containers.
- ❖ Natural pollination registered better performance over hand pollination. At the same time, planting in 4 : 2 row ratio (4 female : 2 male) had enhanced performance. The natural pollination in 4 : 2 row ratio sowing, might be recommended for general cultivation.
- ❖ The doses of 10 ppm boron and 300 ppm ethrel induced more yield due to more number of fruits set per plant caused by increased female flowers and modified sex ratio. These two doses might be suggested for wide application.

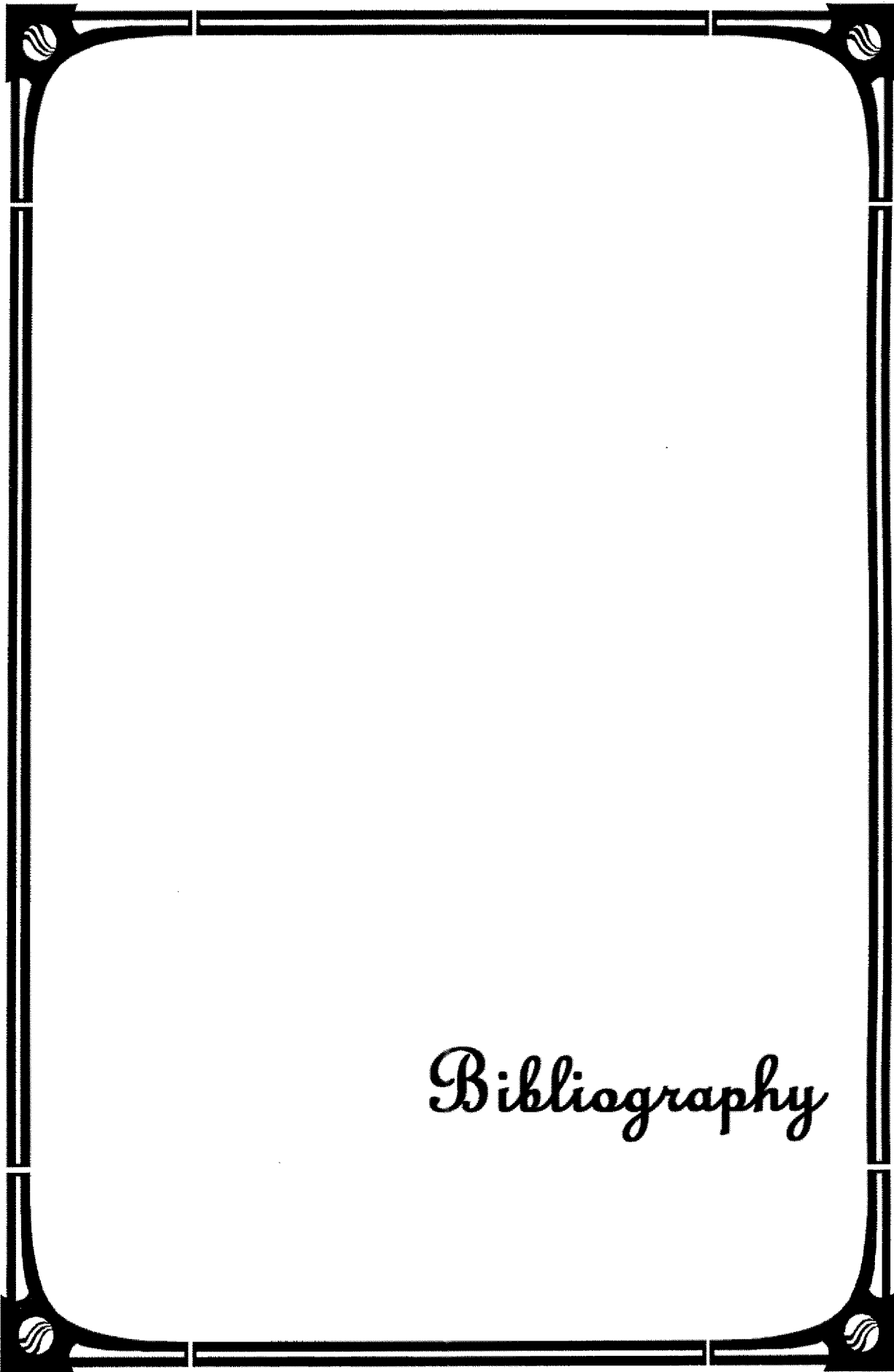


Chapter - 7

Future Scope of Research

Future Scope of Research

1. It has been noted that increase in fruit diameter leads to decrease in fruit length, number of fruits per plant and fruit yield. The reason for such phenomenon needs to be explained.
2. The hybrid, $L_6 \times T_3$ had both quality and quantity of fruits and the parents are best combiners with positive *gca* estimates. There is a scope of exploiting the hybrid vigour as well as selection of desirable recombinants in later generation.
3. Further work is needed to evolve improved and cheap storage method for storing large quantity of seed of hybrid and normal variety. Investigation is also needed to explain the phenomenon of sharp deterioration of hybrid seeds after storage for more than 3-5 months against that in the normal variety seeds.
4. The present investigation has revealed that natural pollination had better performance in yield and yield attributes than that in hand pollination. The exact reason of this phenomenon is not known. This provides opportunity for detailed work to explore the reason. There is also scope of further work to evolve modified hand pollination technology for better result.
5. Though 4 : 2 row ratio of planting is better over 4 : 1 row ratio, further work with other row ratio is desirable for more hybrid seed production in the limited space.
6. The treatment of 300 ppm ethrel dose produced positive result. Further work with higher doses of ethrel (more than 300 ppm) is needed for inducing best fruit yield of bottle gourd.



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