GENETIC STUDIES ON YIELD AND QUALITY TRAITS IN CUCUMBER (*Cucumis sativus* L.)

Thesis

by

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CERTIFICATE - I

This is to certify that the thesis entitled, **“Genetic studies on yield and quality traits in cucumber (*Cucumis sativus* L.)”**, submitted in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY VEGETABLE SCIENCE** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan HP is a record of bonafide research work carried out by **Mr Sandeep Kumar (H-2010-18-D)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations has been fully acknowledged.

Place: Nauni, Solan
Dated: 4th July, 2013

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CERTIFICATE - II

This is to certify that the thesis entitled, **"Genetic studies on yield and quality traits in cucumber (*Cucumis sativus* L.)"**, submitted by **Mr Sandeep Kumar (H-2010-18-D)** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan HP in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY VEGETABLE SCIENCE** has been approved by the student's advisory committee after an oral examination of the same in collaboration with the external examiner.

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I own entire responsibility for all the errors and omissions.

Place : Nauni, Solan *(Sandeep Kumar)*
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INTRODUCTION

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Introduction

Cucumber (*Cucumis sativus* L.) is one of the most important cucurbitaceous vegetable crops grown extensively in tropical and sub-tropical parts of the country. It is thought to have been originated in India (Harlan, 1975) because of the fact that *Cucumis sativus* var. *hardwickii*, progenitor of cultivated cucumber is found in the Himalayan foot hills of India. From India, it spreaded Eastwards to China and Westward to Asia Minor, North Africa and Southern Europe long before written history (Seshadri and Parthasarathy, 2002). Archeological evidences support that cultivation of cucumber in India dated back to 3000 years and 2000 years in China. China is considered as secondary center of genetic diversification of cucumber (De Candolle, 1882). It belongs to the family Cucurbitaceae consisting of 118 genera and 825 species (Jeffrey, 1990).

Cucumber is grown throughout the world and is the fourth most important vegetable crop after tomato, cabbage, and onion and the second most widely cultivated cucurbit after watermelon (Tatlioglu, 1993). Nowadays, cucumber is grown throughout the world in large commercial farms, glasshouses and small gardens. It is a low energy and high water content vegetable, which is a rich source of vitamin B and C, carbohydrates, calcium and phosphorus (Yawalkar, 1985). Its fruits are eaten at immature stage as refreshing salad vegetable and are said to have cooling effect, prevent constipation and are useful to jaundice patients. The fruits are also used as an astringent and antipyretic. Seeds contain oil, which is helpful for brain development and body smoothness. Hence, it is being used in Ayurvedic preparations (Robinson and Decker-Walter, 1999). In addition, cucumber extract has soothing, cleansing and softening properties which are important for the cosmetics industry and soap industries (Wang *et al.*, 2007).

At present, cucumber is grown in an area of 2,090 thousand ha with a production of 65.33 million tonnes and productivity of 31.25 t/ha in the world (Anonymous, 2011), whereas in India it is grown in an area of 41,000 hectares with a production of 6,10,000 tonnes and productivity of 14.88 t/ha (Anonymous, 2012a). In Himachal Pradesh, separate figures for area and production of cucumber are not available. However, cucurbits as a whole are cultivated in 2,436 hectares with an annual production and productivity of 62,169 tonnes and 25.52 t/ha, respectively and cucumber contributes to 70-80 per cent of total area and production of cucurbits in Himachal Pradesh (Anonymous, 2012b).

Cucumber is a thermophilic and frost susceptible species preferring warm weather and bright light for its better growth and development. However, it can be grown in both summer and rainy season in India, but it can't tolerate cold injury (Rastogi, 1998). It is a leading commercial crop and popular home garden vegetable in the mid and low hills of Himachal Pradesh. It is grown from April-October and brings profitable returns to the hill farmers during July-October, when it is not produced in the plains.

Inspite of being native to India and having sufficient genetic variability, very meager work has been done to understand its genetic architecture and endeavor for the improvement of this crop. Many important features of cultivated crops are not associated with discrete Mendelian traits, but are of a continuous or quantitative nature. Yielding ability is a prime example of such a trait and is of obvious importance. Breeding for higher yields in cucumber has been one of the important objectives of many cucumber breeding programmes since 1900's. Yield of cucumber has also been improved by breeding for disease resistance, as well as through the use of improved cultural practices (Cargill *et al.*, 1975). Moreover, development of hybrid cultivars have become easy after gynoecious sex expression was obtained from Korean cultivar. The first gynoecious hybrid cultivar, 'Spartan Dawn' was introduced in 1962.

The very basic problem in cucumbers is concerning with the low marketable yield. The lack of progress in increased fruit yield of cucumber might be partially due to the meager breeding effort relative to other crop or lack of variability for yield (Wehner *et al.*, 1989). Transfer of quantitatively inherited characters into commercially adapted cultivars from exotic germplasm can be an effective way to obtain greater genetic variation and response to selection (Bliss, 1981).

Heterosis breeding has come to play a pivot role in crop important for high production and productivity. It has direct relevance for developing hybrids and is the effective tool in the hands of breeders for improvement in yield, earliness and quality.

In cucumber too, success of F_1 hybrids has encouraged the breeders to develop hybrids which are early, vigorous, high yielding, tolerant to diseases and insect-pests and more efficient in the use of water and fertilizers. Moreover, use of gynoecious lines as a parent in producing cucumber hybrids ensure high yield level in the resultant hybrids.

Today, hybrid varieties of cucumber are very uncommon among the farmers, because farmers are purchasing the hybrid seeds from private companies which are charging exorbitantly. To tide over the situation, there is a need to develop location specific high yielding hybrids having desirable horticultural and quality traits and to make available their seeds to the farmers at a reasonable price. Heterosis has been utilized in many crops including cucurbits to exploit dominance variance through the production of hybrids (Cramer and Wehner, 1999).

Cucumber being monoecious and cross-pollinated crop and having appreciable number of seeds per fruit, it provides ample scope for the exploitation of hybrid vigour. The use of gynoecious lines in hybrids development will not only enhance the chances of getting high yielding hybrids, but also reduce the cost of hybrid seed production drastically. At national level, F_1 hybrid 'Pusa Sanyog' has been released by IARI Regional Research Station, Katrain by crossing gynoecious line, isolated from a Japanese variety 'Kaga Aomoga Fushinavi' with 'Green Long of Naples', an Italian variety, which out yielded the recommended variety by 128.78 per cent (Gill *et al*., 1973). However, its performance is confined only to cooler and sub-tropical conditions.

For exploitation of heterosis, choice of suitable parents is of utmost importance. The combining ability studies aiming to identify inbred lines with good GCA and SCA effects rely on the availability of genetic diversity among the genotypes involved in a breeding programme. General combining ability (GCA) enables the breeders to exploit the existing variability in the breeding materials, to identify individual genotypes having desirable attributes and to distinguish relatedness among genotypes. While, specific combining ability (SCA) is serving to determine heterotic patterns among populations or inbred lines, to identify promising single crosses and to assign inbred lines into heterotic groups. The combining ability of parents depends upon the nature of the genetic system operating in the parent, which predicts the efficiency of selection. Moreover, combining ability also indicates the nature and magnitude of gene action involved in the expression of quantitative traits. In order to exploit different types of gene actions present in the population, information regarding relative magnitude of genetic variances and combining ability of the parents is essential. Traits that contribute to fruit texture are important targets for genetic improvement in cucumber, and the knowledge of the combining abilities of parental genotypes is crucial for conducting systematic breeding of new F_1 hybrids cultivar that possess a desired fruit texture.

Amongst the different biometrical approaches available to determine the genetic information from the performance of hybrids and to identify appropriate cross-combinations, the “Line x Tester” mating design as proposed by Kempthorne (1957) has been used extensively to estimate inbred line performance in F_1 hybrid combinations, using GCA and SCA variances and their effects. It is also used in understanding the nature of gene action involved in the expression of economically important quantitative traits. “Line x Tester” mating design is a modified form of top cross scheme for inbred evaluation. The total number of crosses to be made is equal to the product of the number of lines and the number of testers included in the study.

Keeping in view the above facts in mind, the present investigation entitled, “Genetic studies on yield and quality traits in cucumber (*Cucumis sativus* L.)”, has been undertaken with the following broad objectives:

1) To compare the mean performance of parents and hybrids with respect to different horticultural, quality and seed traits along with tolerance to various biotic stresses in cucumber.

2) To evaluate the parents and hybrids with respect to their combining ability for yield and yield contributing traits.

3) To assess the nature and magnitude of gene action.

4) To ascertain the best heterotic combination(s) for marketable yield and quality traits.

Chapter-2

REVIEW OF LITERATURE

Chapter-2

Review of Literature

The success of any breeding program depends to a large extent on the amount of genetic variability present in the population. Genetic diversity is desirable for long-term crop improvement and reduction of vulnerability to important crop stresses. A wide range of genetic variability is available in cucumber, providing good scope for improvement in yield and other character of cucumber through selection. Assessment of genetic diversity could be suitable in crop breeding programmes for identification of diverse parental genotypes. Judicious choice of parents for hybridization and the selection procedure adopted in the early generation are important among the factors on which the success of any breeding programme primarily depends.

Genetic information, especially on nature and magnitude of genetic variability, combining ability, the type of gene action governing the inheritance of economic characters and the heterosis, is a pre-requisite in fixing the suitable parents and designing the appropriate breeding programme. Different methods have been developed to estimate the general and specific combining abilities. "Line x Tester" mating design as proposed by Kempthorne (1957) is useful to select suitable parents from a large number of germplasm collections. The information available in the literature pertaining to the present investigations has been reviewed here under the following heads:

2.1 Mean Performance

2.2 Combining ability studies

2.3 Gene action

2.4 Heterosis studies

2.1 MEAN PERFORMANCE

Cucumber improvement programmes have been in practice for more than half a century, but much of the improvement can be attributed to improved cultural practices and incorporation of better levels of disease resistance. The lack of progress in cucumber improvement might be partially due to the meager breeding efforts in cucumber relative to other crop species. Information on the mode of inheritance of quantitative characters should be available before proceeding to the formulation of appropriate breeding strategies. Selection within a population is futile, where there are no genetic variances for the desired characters. In the development of pure lines, progress from selection depends primarily on the additive action of genes. Dominance, on the other hand, could be efficiently utilized in the production of hybrids.

Cucumber genotypes had showed significant differences with regard to vegetative characters, reproductive characters, yield and yield components (Patil and Patil, 1985a and Patil and Patil, 1985b). A considerable amount of variability among the cucumber genotypes was observed for marketable and early fruit number per plot, fruit colour and overall performance (Strefeler and Wehner, 1986).

Stankovic *et al.* (1997) evaluated parents and F_1 hybrids of crosses involving 2 gynoecious female lines of indeterminate growth (21/3 and PMS) and 3 monoecious paternal lines of determinate growth (M-24/4, M-24/5 and M-24/6) planted in the field at Smederevska Palanka, Yugoslavia. Average yield of parents ranged from 1.28 (M-24/4) to 11.90 t/ha (PMS), while that of hybrids ranged from 6.03 (21/3 x M-24/5) to 10.52 t/ha (PMS x M-24/6).

Singh *et al.* (1999) assessed 45 hybrids of cucumber along with 10 parents for yield and its contributing traits. AC-38, AC-34 and AC-18 were found as three best performing parents for yield of edible fruits per plant. Two crosses, AC-20 x AC-28, and AC-34 x AC-38 recorded highest yield among all the hybrids under study. The highest yield recoded by these hybrids might be attributed to increase in average weight of edible fruits and number of fruits per plant.

Kanwar *et al.* (2003) screened 26 indigenous/exotic cucumber germplasm to select genotype(s) with better quality and better parental material for hybridization programme. A wide range of variation was observed with respect to different traits, except for harvest duration. In all other traits, a large portion of phenotypic variability was genetic in nature. Fazlika Coll-94 and Market Long were found high yielders, among all the genotypes under study. The poor performance for yield and its contributing characters was noticed in LC-7, but it performed best for rind thickness, flesh and TSS contents.

Morishita *et al.* (2003) using an improved method for evaluating powdery mildew resistance in cucumber, conducted experiments for the breeding of varieties resistant to powdery mildew that would be adapted to greenhouse cultivation during the period from winter to spring in Japan. The relationship between the resistance to the pathogen and the ambient temperature was analyzed by spray inoculation of a conidial suspension under controlled conditions. Although the varieties, ‘Asomidori-5-gou’ and ‘Natsufushinari’ were resistant at temperatures between 25 to 30ºC and they became susceptible at 15 to 20ºC. The resistance was affected by the duration of the exposure to 30 and 15ºC during the day. To screen resistant varieties and lines independently of the temperature, 295 cucumber accessions were inoculated at 20 and 26ºC. All the accessions tested could be divided into 3 types based on the difference in the resistance response to temperature. Many of the resistant accessions were Chinese varieties and lines. ‘PI197088-5’, a progeny of ‘PI197088’, which originated in India, displayed the highest level of resistance among all the accessions. Thus ‘PI197088-5’, whose resistance is temperature independent appears to be the most suitable parent for the breeding of powdery mildew-resistant cucumber varieties.

Verma (2003) studied variability in 25 diverse cucumber genotypes and observed significant differences for days to first female flower appearance, node at which first female flower appears, number of days to first picking, fruit colour, fruit length, fruit diameter, fruit weight, flesh to seed cavity ratio, number of marketable fruits per plant, harvest duration, fruit yield per plant and vine length.

Das *et al.* (2005) reported considerable variability in 18 diverse cucumber genotypes for stability in the summer and rainy seasons. Observations were recorded on vine length, fruit number, fruit length, fruit diameter, fruit weight and yield per vine. The variance for genotypes and environments was highly significant for all the characters, revealing the presence of genetic variability in the material for all the characters.

Kumar (2006) studied genetic variability in 35 diverse genotypes of cucumber. Analysis of variance indicated significant differences among all the genotypes for node number at which first female flower appears, days to first female flower appearance, days to marketable maturity, fruit weight, fruit length, flesh to seed cavity ratio, number of fruits per plant, yield per plant, rind firmness, total soluble solids and cucurbitacin content.

Uddin *et al.* (2006) observed considerable genetic variability in 25 diverse genotypes of cucumber. Significant differences were observed among all the genotypes together with significant variation for all the characters studied.

Bhat *et al.* (2007) conducted an extensive survey to reveal the presence of angular leaf spot in all cucumber growing areas of Kashmir valley with incidence and intensity ranging between 23.3 to 74.4 per cent and 10.5 to 26.0 per cent, respectively. The pooled data for 2004 and 2005 revealed that angular leaf spot of cucumber was prevalent in all the locations surveyed with varying degrees of incidence and intensity, which was minimum in first but maximum in last (third) stage of survey. Highest disease incidence and intensity at all the three stages was recorded at Narain Bagh, Srinagar, followed by Waskura, Shadipora, Dal area, and Mangnipora, respectively. Minimum disease incidence and intensity were recorded at Krimsher (Badgam).

Munshi *et al.* (2007) collected 31 accessions of wild and feral form of cucumber (*Cucumis sativus* var. *hardwickii*) from different regions of India and evaluated for days to first fruit set and first picking, fruit weight, fruits per plant, fruit length : diameter (L:D ratio) and yield per plant. Highly significant variation was observed among the genotypes for all the characters studied; hence individual plant selection could be effective for isolation of superior genotypes for these traits.

Hanchinamani *et al.* (2008) carried out a study on 45 diverse genotypes of cucumber to assess the mean variability for 20 characters. All the genotypes exhibited significant differences for all the characters under study. The genotype, BGDL recorded the maximum mean value for number of primary branches per vine, fruit length, average fruit weight, number of fruits per vine and fruit yield per vine, whereas DWD-2 gave maximum mean value for fruit diameter, flesh thickness and days to first male flower appearance, while BNGL-1 recorded maximum mean value for vine length. The genotype LL-02 registered maximum mean value for days to first female flower appearance and inter-nodal length, while the two genotypes CL-1 and CHC-2 showed the maximum mean value for node number at which first male and female flower appears, respectively.

Kumar *et al.* (2008) carried out the study on variability in 25 diverse cucumber genotypes for fruit yield and yield contributing traits. A wide range of variability along with estimates of phenotypic coefficients of variation and genotypic coefficients of variation was observed for days to first female flower anthesis, number of primary branches per plant, number of fruits per plant, number of node bearing female flowers per plant, fruit length, fruit weight, cavity of fruit at edible stage and fruit yield per plant. Therefore, these traits are more reliable for effective selection.

Sakata *et al.* (2008) identified ‘Kyuri Chukanbohon Nou 5 Go’, a cucumber cultivar with resistance to powdery mildew (*Podosphaera xanthii* (Castaggne) U. Braun & N. Shishkoff) not only at higher temperatures (above 26°C), but also at relatively cool temperatures (20°C) and was bred as potential breeding material. This cultivar is the progeney from crosses among CS-PMR1, ‘Sharp 1’ and ‘Rira’. The resistance to powdery mildew is thought to be controlled by 2 gene pairs, a major recessive gene and an incompletely dominant gene that enhances the resistance at cooler temperature. Fruits are borne on the main stem and lateral branches. The fruit is relatively small (approximately 60 g) and similar to ‘Beit Alfa’ type cucumber and has smooth surface without warts or spines. The color of the fruit skin is dark green. The skin is tougher and flesh is slightly softer without bitterness in fruit. Mature fruits are yellowish green with dense netting. This cultivar is a useful breeding material for powdery mildew-resistant cucumber.

Woltman *et al.* (2008) screened the 84 cucumber accessions for resistance to angular leaf spot under growth chamber conditions using a highly aggressive strain of *Pseudomonas syringae* pv. *lachrymans*. Most of the screened accessions were either susceptible or displayed intermediate resistance. The screening resulted in the identification of five F_1 hybrid cultivars moderately resistant to angular leaf spot. The identified F_1 hybrids were self-pollinated up to the F_4 generation. Individuals resistant to angular leaf spot were identified. These individuals can be used as a source of resistance to angular leaf spot in future breeding efforts.

Yadav *et al.* (2009) studied genetic variability for different characters in 20 diverse cucumber genotypes. The study indicated existence of considerable amount of genetic variability for all the traits *viz.*, number of days to 50 % germination, number of days to first male and female flower anthesis, node number bearing first male and female flower, main vine length, number of primary branches per plant at maturity, number of nodes bearing female flower/plant, number of fruits per plant, fruit diameter, length and weight at edible stage, 1000-seed weight and days to first fruit harvest except cavity of fruit at edible stage.

Hossain *et al.* (2010) conducted an experiment to study the field performance and variability among 58 long type cucumber accessions. Wide variability was found for the plant characteristics of days to seed germination, vine length, petiole length and yield contributing characters namely, days to first male and female flowering, number of fruits per plant, average fruit weight, fruit length and fruit diameter. Among the long type cucumber accessions, CSL51 gave the highest yield per plant.

Kumar *et al.* (2011a) conducted an experiment to study the genetic variability in F_2 of 'BGDL x Hot Season' cucumber hybrid. High variability was observed for number of female flowers per vine, number of male flowers per vine, number of branches per vine, average fruit weight, number of marketable fruits per vine, total number of fruits per vine and total fruit yield per vine.

Dogra and Kanwar (2011) attempted the crosses among 8 parents (including two gynoecious lines) in half diallel fashion. 28 F_1 hybrids and 8 parents along with one check were grown in a randomized complete block design with three replications at two different locations *viz.* Nauni (L1) and Chambaghat (L2). Sufficient genetic diversity among parents and F_1 hybrids for all the traits infers the scope of improvement through selection in the parental material. Among the parents, G2 took minimum value for number of days to first female flower appearance, node number of first female flower and days to marketable maturity. Very few crosses exhibited earliness for days to first female flower appearance, node number of first female flower appeared and days to marketable maturity and cross combination EC173934 x LC-40 being earliest at both locations. Among parents, K-90 and G2 recorded the highest yield/plant and number of fruits/plant, respectively. Cross combination K-90 x G2 produced the maximum yield/plant and number of fruits/plant, at both locations.

Call *et al.* (2012) screened the 86 cucumber cultigens (cultivars and breeding lines) for higher yield and resistance to the new strain of downy mildew. None of the cultigens tested in this study showed a high level of resistance, although differences in resistance were detected. Lines WI 2757 and M 21 and cultivar 'Picklet' were consistently among the top resistant lines in North Carolina and Michigan. The cultivars Coolgreen, Wis. SMR 18, and Straight 8 were identified as moderately to highly susceptible. An unreleased hybrid, 'Nun 5053 F_1', and the cultivar Cates were the top yielding lines overall. The best cultivars in this study were only moderately resistant and would likely require fungicide applications to achieve high yield and quality in the presence of downy mildew. Until high resistance becomes available, growers would benefit by using fungicides in combination with tolerant and moderately resistant cultigens.

Golabadi *et al.* (2012) evaluated twenty genotypes of cucumber (*Cucumis sativus* L.) for total fruit yield per pickling, fruit number per pickling, branch number per plant, plant height, distance between internode, length of branches, shoot diameter, leaf length, leaf width, fruit diameter, fruit length, plant vigor and fruit number per node. Analysis of variance showed that there was a high significant variation for all of the studied traits between genotypes. Mean comparison among the the genotypes showed wide phenotypic variations for all the traits studied.

2.1 COMBINING ABILITY STUDIES

The combining ability analysis gives useful information regarding the selection of parents in terms of the performance of their hybrids. The concept of combining ability originally developed in maize by Richey and Mayer (1925) is now extensively applied in almost all the crops. In any crop, a hybrid can be successful only if its performance is far superior to the performance of its parents and/or the best local standard. The lines, which produce superior hybrids in combination with others, are the most valuable one for the breeders. A study of combining ability is, therefore, important for the selection of superior parents for heterosis and recombination breeding programmes. The combining ability analysis provides a guideline for an assessment of the relative breeding potential of parents and also elucidates the nature and quantum of different types of gene actions involved.

The use of combining ability in its present form is based on the idea given by Sprague and Tatum (1942). According to them, the general combining ability (GCA) designates the average performance of a line in a series of crosses, while specific combining ability (SCA) involves those cases in which certain crosses do relatively better or worse than expected on the average performance of the lines involved and is regarded as an estimate of non-additive gene action.

Allard (1960) defined general combining ability as the average performance of a strain in a series of crosses and specific combining ability as the deviation from the performance predicted on the basis of general combining ability. Information on the relative importance of general (GCA) and specific combining ability (SCA) is of value in breeding programmes for species which are amenable to the development of F_1 hybrid cultivars such basic information on combining ability in cucumber would aid the breeder in developing improved hybrid cultivars (Tasdighi and Baker, 1981).

Mikhov and Petkova (1971) concluded that cucumbers Wiscosin, SMR-18, Pixie and Model had the best general combining ability among the 10 varieties studied. The crosses of all the three varieties with the tester Posrednik-97 as the female parent inherited the testers character of producing mainly female flowers. Strelnikova and Mashtakova (1975) studied general and specific combining ability in cucumber in two cycles of selection and obtained 5-20 per cent increased yield in a number of crosses. Paponov and Beridze (1977) estimated general and specific combining ability of cucumber variety with several varieties of female flowering type.

Tasdighi and Baker (1981) reported that parental lines 551F, 368G and 580Z exhibited the highest general combining ability effects in both single and three way crosses for total yield and marketable yield. They further concluded that best hybrid combination for yield could be predicted from GCA of parental lines.

El-Shawaf and Baker (1981a) reported that the GCA for time to harvest, gynoecious sex expression and yield of the female parent was greater than that of the male. However, the converse was true for days to flowering. Wang and Wang (1980) reported GCA and SCA effects were significant for a number of yield and maturity characters. Lines 3-6-11, 13-3-9, 24-3-22-2 and 3-11-2-1 had good GCA for yield.

Prudek and Wolf (1985) identified crosses with high general and specific combining ability involving crosses from 5 monoecious lines. Lines PS66 male sterile and PS13 had high GCA effects for all the characters and were recommended for breeding.

Prudek (1986) showed that both general and specific combining abilities (GCA and SCA) were of significance in determining both the number and weight of fruits per plant but GCA was more important, whereas specific combining has no importance with regard to earliness and mean single fruit weight. The lines PS66 which displayed male sterility determined by a single recessive gene had high GCA.

Musmade and Kale (1986), while evaluating 7 parents 21 F_1 hybrids in cucumber found that only 2 parents *viz.,* Turkish Long Green and Panvel exhibited high GCA for fruit length and diameter. Twelve hybrids had significant negative SCA effects for earliness. Positive SCA effects were recorded in ten crosses each for fruit length and yield per vine, nine for fruit diameter, six for average fruit weight and eight for number of fruits per vine. High SCA effects for yield per vine were observed in Poona Kheera x Japanese Long Green, followed by Kalyanpur Ageti x Panvel and White Long Cucumber x Poinsette.

Abhang (1987) reported that parents like Sel 75-7, Gy-4 and Improved Long Green were good combiner for most of characters *viz.*, for average fruit weight, yield per ha and per vine and vine length, however, the GY 664, white wonder and GY598 x 587 were found to be the best combiners for earliness.

Hormuzdi and More (1989b) studied GCA for 4 females and 8 male parents and SCA of 32 F1 hybrids (using line x tester mating design). They reported that magnitude variance due to GCA was greater than that of variance due to SCA for nodal position, days to anthesis, average fruit weight, fruit length, fruit diameter, vine length and early yield.

Kumari *et al.* (1993) reported that EC-129110 combined well for node of first female flower, days to anthesis of first female flower and number of fruits per plant, RKS-296 for node for first female flower, days to anthesis of first female flower, average fruit yield and total yield per vine. Gynoecious JPL (female) for node of first female flower, number of fruits and total yield per plant and H-302 is good specific combiner for one or the other components of earliness, H-318 for all the 3 components of yield and H-106 for average fruit weight and total yield per plant. They further reported that SR-551-F (female) combined well for node of first female flower, number of fruits per plant and total yield per plant and EC-129110 (male) for days to anthesis of first female flower and H-521 recorded significant Sij (specific combining ability effect of cross involving i^{th} line and j^{th} tester) effects for days to anthesis, number of fruits per plant and H-502 for average fruit weight.

Kupper and Staub (1988) studied 21 F_1 progenies (three females and seven males) in line x tester mating design and observed that GCA and SCA effects were significant for fruit number, fruit length, number of nodes and days to anthesis.

Hormuzdi and More (1989a) studied general combining ability of 4 female and 8 male parents using line x tester analysis in cucumber. Magnitude of variance due to GCA was greater than that of variance due to SCA for nodal length, days to anthesis, average fruit weight, fruit length, vine length and early yield.

Frederick and Staub (1989) evaluated 9 processing cucumber lines, including 5 derived from *Cucumis sativus* var. *hardwickii* for fruits per plant, number of primary lateral branches, percentage of pistillate flowers, days to anthesis, fruit length and ratio of fruit length to diameter at 2 planting densities (29,000 and 58,000 plants/ha) and 2 planting dates (2 weeks apart) for 3 harvests. GCA mean squares were significant at both planting densities for all the traits when combined over planting times except ratio of fruit length to diameter at the higher planting density. SCA mean squares were significant for days to anthesis. WI-2963 and 4-H-261 (a *hardwickii* line) had the highest GCA's as male and female parents, respectively, for total yield and primary lateral branch number, but the lowest GCA's for fruit size.

Prasad and Singh (1992) studied combining ability in 24 F_1 hybrids (4 females and 6 males using line x tester) for yield and its components and reported that variances due to GCA were higher than SCA for yield per plant, fruit number, fruit length, days to female flower, number of nodes, number of shoots and vine length.

Li *et al.* (1995) evaluated 4 inbred cucumber lines and their 6 F_1 hybrids and reported that line 112 had the highest GCA for average fruit weight and fruit length: diameter ratio. Hybrid 111 x 112 had the highest SCA for fruit number, average fruit weight, vine length, fruit length: diameter ratio and leaf area.

Jianwu (1995) derived the information on combining ability from the data on 9 yield components in 4 inbred cucumber lines and their 6 F_1 hybrids grown in Zhengzhou, China. Among the parents, line 112 had the greatest GCA for average fruit weight and fruit ratio. Hybrid 111 x 112 had the greatest SCA for fruit number, average fruit weight, vine length, fruit length: diameter ratio and leaf area.

Ananthan and Pappiah (1997) reported that general combining ability and specific combining ability were significant for days for first male flower, days for first female flower, sex ratio, fruit number per vine, fruit length, fruit girth, tender fruit weight per vine and ripe fruit weight per vine.

Dogra *et al.* (1997a) evaluated the crosses of 2 commercial cultivars (Khira-90 and Khira-75), one landrace, one exotic accession (EC-173934) and one gynoecious line (Gyn-1) of cucumber and the 10 resulting hybrids for combining ability of several quantitative traits at Solan. GCA and SCA variances were significant for all characters and non-additive gene action was predominated. Gyn-1 and Khira-90 were good general combiners for yield and its components. Khira-75 x Gyn-1 had the highest SCA estimates and best overall performance.

Dogra *et al.* (1997b) crossed 5 cucumber lines (4 monoecious and 1 gynoecious), both indigenous and exotic, in a diallel fashion, excluding reciprocals. The 5 lines, their 10 F_1 hybrids and a standard check cultivar Pusa Sanyog were evaluated at Nauni, Solan, during *kharif* 1994. Analysis of variance due to genotypes, GCA of parents and SCA of crosses were significant for flesh to seed cavity ratio, total soluble solids and yield per plant. K-75 x Gyn-1 recorded the highest SCA and *per se* performance for yield per plant, while LC-11 x K-75 showed the highest SCA for total soluble solids and flesh to seed cavity ratio. Hence, K-75 was the best general combiner and should be exploited for hybridization programmes.

Stankovic *et al.* (1997) attempted the crosses in 2 gynoecious female lines of indeterminate growth (21/3 and PMS) and 3 monoecious paternal lines of determinate growth (M-24/4, M-24/5 and M-24/6) and revealed that highly significant differences existed in general combining ability (GCA), but not in specific combining ability (SCA), the mean square for GCA being 6-23 times higher than that for SCA.

Singh *et al.* (1998) from 10 divergent genotypes/varieties and their 45 F_1 hybrids, observed that the parents AC-18 (Faizabadi Local), AC-2 and AC-30 (Long Green) proved the best general combiners for yield and yield contributing traits and were also suitable for summer season, while the parents AC-38, AC-34 and AC-18 were most promising for rainy season in respect of yield of edible fruits per plant. The hybrid AC-22 x AC-38 and AC-34 x AC-18 were most promising for rainy season in respect of yield of edible fruits per plant. The hybrid AC-22 x AC-38 and AC-22 x AC-32 were good specific combiners for days to anthesis of first female flower (earliness) during summer and rainy seasons, respectively. The hybrid AC-20 x AC-28 followed by AC-38 x AC-41 were found good specific combiners for number and yield of edible fruits per plant and average weight of edible fruit during both the seasons.

Sharma *et al.* (2000) studied the combining ability in cucumber using lines (10) x testers (3) mating design under different environments. The lines GYNL and Poona Khira for earliness (days to first female flower, nodal position and days to first picking) and Sel. 72-5, Swarapurna followed by GYNL and Sheetal for marketable fruit yield and its attributes (fruit number and size) were good general combiners. The hybrids Sel. 72-5 x Poinsette and Swarapurna x Poinsette displayed significant SCA effects for 4 and 6 characters, respectively out of seven characters under study.

Verma *et al.* (2000) estimated combining ability effects in cucumber for 7 traits *viz.* days to 50 % male flowers and female flowers, fruit length, weight and girth, number of fruits per hill and fruit yield per hill in a line x tester method comprising 21 hybrids obtained by crossing 7 lines and 3 testers. Significant differences were observed among the parents and hybrids for general and specific combining ability, respectively. Parents *viz.*, K-27080, LC-3, C-12 and GY-2 were found good general combiners for yield and its component traits. High SCA effects for yield and other traits were exhibited by the cross combinations Japanese Long Green x C-12, K-27080 x C-12 and K-27080 x LC-3.

Uddin and Ahmed (2002) generated 48 F_1 combinations by crossing 12 genetically diverse lines and 4 testers to study the combining ability effects for 12 traits in cucumber through the line x tester method. Parental lines SKAUST-K-2 and Sweet Delight revealed significant GCA effect for 11 and 8 traits, respectively. Similarly, the crosses Sel-75-2-10 x Poinsette, Green Express x Japanese Long Green, Poineer Pickling x Japanese Long Green and SKUAST-K-2 x EC-381606 revealed significant SCA effects for most of the traits.

Wadid *et al.* (2003) crossed the 5 inbred lines *viz.*, PI-267742, PI-436672, PI-344348, PI-135345 and Biet Alpha) in a full diallel to produce 10 F_1 single crosses and 10 reciprocal crosses, in order to evaluate their suitability as parents in hybrid combinations. All the parents and their F_1 progenies were evaluated for several characteristics related to vegetative, flowering and yield and its components under low temperature conditions, where maximum and minimum temperatures were 18 °C and 6 °C, respectively during the growing season. Data were subjected to analysis of variance of randomized complete block design to estimate general (GCA) and specific (SCA) combining ability effects following Griffing (1956), method 1 and model II. The results showed that there were significant difference among parents and crosses for all the characters studied. For most characters, the best mean performance of parental lines and GCA were observed in PI-267742.

Kumbhar *et al.* (2005) studied combining ability of 28 F_1 hybrids of cucumber obtained by 8 x 8 diallel among 8 parents for yield and its component traits (days to first female and male flowers, number of female and male flowers, days to first fruit picking, fruit length and diameter, number of fruits per vine and average fruit weight) in Pune, Maharashtra. The characters studied were governed by additive and non-additive gene action. There was close agreement between per cent performance of parents and general combining ability effects for all the characters. The best specific combinations were those involving parents with low and/or high combining ability. Shubhangi and Sheetal were identified as the best combiners for yield. The specific combinations Improved Long Green x Himangi and Poona Khira x Junnar Local were identified as the best hybrids.

Li *et al.* (2005) analyzed general (GCA) and specific combining ability (SCA) for 5 main quality characters (protein content, total sugar content, fruit length, flesh thickness and fruit dry weight) of pickling cucumber. GCA was higher for protein content, total sugar content, flesh thickness and fruit dry weight of line ZR-22, indicated its potential for use as parent in hybridization. SCA was high for all quality characters in LN-11 x ZR-22, indicated that this hybrid can be used in breeding for high-quality pickling cucumber.

Singh and Sharma (2006) studied the combining ability in cucumber for yield and its components following line x tester approach. 15 cross combinations (5 x 3) with 8 parents were studied for 12 characters. Significant differences in the parents indicated that the majority of the parents had diversity for almost all the characters studied. The parents AAUC-2 and Sel. 75-1-10 were good general combiners for marketable yield and component traits. The crosses involved in high SCA effects for yield and other component traits should be utilized in crossing programme aimed at improving the desired traits. The hybrids Sel. 75-1-10 x K. Paprola and CHC-2 x Sel. 75-2-10 displayed significant SCA effects for marketable yield per plant and marketable fruits per plant.

Hanchinamani and Patil (2009) studied 35 F_1 hybrids of cucumber involving 12 parents to work out the combining ability for yield and its contributing traits. Significant differences in the parents indicated that majority of the parents had diversity for total yield per vine, total number of fruits per vine, fruit length, vine length, fruit diameter, average fruit weight, number of branches per vine, days to first female flower appears, node number at which first female flower appears. Considering combining ability values, parents BGDL, DWD-2, GBGL and Poinsette were found superior for total fruit number per vine, parents BGDL, DWD-2 and Vejundra Dosa for total fruits yield per vine, parent BGDL, White Long, Vejundra Dosa and BGBL for average fruit weight and parents BGDL, PAU-1 and ARABL for high vigorous plants. The cross BGDL x Hot Season showed significant positive SCA for total fruit yield per vine and total number of fruits per vine.

Yoshioka *et al.* (2010) estimated the general combining ability (GCA) and specific combining ability (SCA) of fruit texture traits related to fruit firmness and crispness, using diallel set of 28 F_1 hybrids by crossing 8 cucumber genotypes in a half-diallel mating design. Quantitative scores of fruit texture were estimated by the means of mechanical measurement and were analyzed as per Griffing's combining ability approach to estimate the GCA and SCA effects of the parental genotypes. The GCA effect was of more significance than the SCA effect in determining hybrid performance. Estimates of the GCA effects were highly significant for most parental genotypes and were highly correlated with actual performance of parental genotypes.

Brar *et al.* (2011) crossed 8 genetically divergent parental lines in a diallel pattern to investigate general and specific combining ability effects for quality traits and reaction to downy mildew. The combining ability analysis revealed that both GCA and SCA variance was significant for all the characters. On the basis of GCA effects, parent Poinsette for TSS and vitamin C, Summer Khira for shelf life of fruit, SAKU-6 for reaction to downy mildew and bitterness, EC-27075 for total carotenoids and Sel-97-7 for total mineral matter were the best general combiners. Specific combining ability analysis revealed that hybrids Long Green x EC-27075 for TSS; Long Green x Bhari Mansa for total carotenoids and bitterness; Bhari Mansa x EC-27075 for vitamin C; Sel-97-7 x Summer Khira for total mineral matter; Poinsette x Summer Khira for reaction to downy mildew and Summer Khira x KH-1 for shelf life of fruits, showed highest SCA effects.

Dogra and Kanwar (2011) revealed that for the development of superior hybrids, estimates of general combining ability of parents and specific combining ability of the crosses help in proper selection of parents for hybridization. The high estimates of GCA were exhibited by G-2 and Gyn-1 for most of the characters. In general, there was a close agreement between GCA effects and *per se* performance but in certain cases, it did not hold good which may be due to higher degree of gene action involved. The superior cross combinations which recorded high SCA estimates and *per se* performance for yield and number of fruits were K-90 x G-2 and K-90 x Gyn-1.

Khushwaha *et al.* (2011) evaluated 7 parental lines of cucumber in a diallel cross along with their twenty one F_1's (excluding reciprocals) in a randomized block design to obtain information about combining ability. It was observed that both GCA and SCA variances were significant for all the characters studied. In general, the mean squares for GCA were greater than SCA for all the characters except yield per vine. In most of the cases heterobeltiosis observed was due to high SCA effects. The most promising hybrids were BC-11 x BC-16, BC-15 x Poinsette and BC-13 x BC-14 and these hybrids showed highest SCA effects for yield per vine.

Kumar *et al.* (2011b) conducted a study on the combining ability of cucumber genotypes using 6 × 6 half-diallel excluding reciprocals. The 15 F_1 hybrids along with six parental lines were grown in randomized block design with three replications. The parents P1, P2, P5 and P6 were observed good combiners for a number of characters, including yield per plant. The crosses, P1 × P5, P2 × P5 and P2 × P6 were most promising combinations for earliness and other desirable characters including yield per plant.

Kumar *et al.* (2013) attempted the crosses in 6 diverse cucumber lines (*Cucumis sativus* L.) in diallel fashion excluding reciprocals. The 15 F_1 hybrids along with six parental lines were grown in randomized block design with three replications. The mean square due to GCA and SCA were highly significant for almost all the characters under study. The parents P1, P2, P5 and P6 were observed to be good combiners for a number of characters, including yield per plant. The crosses, P1 x P5, P2 x P5 and P2 x P6 were most promising combinations for earliness and other desirable characters including yield per plant.

2.3 Gene action

Meaningful genetic analysis of the quantitative traits can be said to have begun with the work of Fisher (1918). He partitioned the hereditary variances into three components *viz.* additive portion resulting from the average effects of genes, dominance portion arising from intra-allelic interactions; and epistatic portion associated with inter allelic interactions.

The majority of the characters which showed heterosis are governed by polygenes and study of inheritance pattern of these characters is of immense importance in ascertaining the genetic basis of heterosis. Information on the dominance value in breeding programmes for species which are amenable to the development of F_1 hybrid on the contrary, significant additive variance suggested the effectiveness of selection for development of superior inbred lines (Ghaderi and Lower, 1979a).

Jakubkova (1973) observed that heterosis for number of fruits per plant resulted in most cases, from dominance effects but sometimes also from epistasis among non-allelic genes. The tendency to stop flowering after the picking of fruit was controlled by several genes acting additively.

Miller (1975) and Miller and Quisenberry (1976) studied the inheritance of 2 early and 2 late flowering parents and their F_1, F_2 and backcross progenies. They found that maximum proportion of genetic variance was primarily due to additive genetic variance. Partial dominance for early flowering and low nodal position of the first female flower was observed. Dominance effects were important in the inheritance of time to flowering. Broad sense heritability estimates for days to first flowering were high, suggesting that the total genetic components were large compared with the environmental components. Flowering time was found significantly correlated with mean maturity date.

Imam *et al.* (1977) observed that fruit characters were controlled by one to five pairs of genes. Short fruit were dominant over long and small diameter was dominant over large. Smith *et al.* (1978) reported that additive genetic variance was responsible for the expression of number of fruits, fruit weight and length to diameter ratio. Om *et al.* (1978) reported that both additive and non-additive effects were important and the former was the more significant for early yield per plant.

However, Ghaderi and Lower (1979b), in a study involving six crosses, reported dominance as the major contributing factor in the inheritance of fruit yield, fruit number and average fruit weight. Additive effects were significant for these characters in some cases and suggested the effectiveness of selection for development of superior genotypes.

Nienhuis and Lower (1980) found that most of the variation between generations for lateral number, main stem vine length, fruit weight per plant, fruit length, fruit diameter and L/D ratio was due to dominance and additive effects. Heterosis above best parent for fruits per plant and main stem vine length and variation for these traits was mostly due to dominance effects.

Wang and Wang (1980) reported that GCA and SCA effects were significant for a number of yield and maturity characters. Lines 3-6-11, 13-3-9, 24-3-22-2 and 3-11-2-1 had good GCA for yield. Additive genetic variance was of importance to phenotypic variation.

El-Shawaf and Baker (1981a and 1981b) obtained relatively high GCA and SCA effects for parthenocarpic yield indicating that both additive and non-additive gene effects were important. Many recessive genes were thought to be controlling yield, as measured by fruit number. Complete dominance was found for flowering time and dominance was partial for nodal position of the first female flower. Therefore, they suggested that selection for early flowering and lower nodal position of the first female flower could be used as criteria for selection for higher yields.

Tasdighi and Baker (1981) studied single and three way cross hybrids derived from 13 parental lines of cucumber and concluded that additive effects for yields were relatively more important than non-additive.

Lower *et al.* (1982), while evaluating F_1, F_2 and back cross generation of a cross between gynoecious pickling cucumber inbred (GY 14) and a *Cucumis sativus* var. *hardwickii* line, reported that additive effects were significant for length and diameter of the fruits as well as laterals (primary branches), whereas dominance effects were significant for fruit weight and main stem length.

Owens *et al.* (1983) concluded that an additive dominance model was adequate to explain the variation in generation means of cucumber for fruit length in the W-1925 population and fruit weight in the W-1928 population. A digenic epistasis model was needed to explain the variation in fruit weight and length in the W-1925 and W-1928 population.

Dolgikh and Sidorova (1983) reported that induced mutants had higher GCA for early and total yield and for fruit number per plant than their parents of cucumber. In the F_1 hybrids total yield, fruit number per plant and fruit weight were controlled mainly by additive gene effects, while early yield in the first month of harvest was controlled by non-additive genes.

In a 5 line diallel cross of cucumber studied by Prudek (1984) found that both GCA and SCA were significant for number and weight of fruit per plant, but the GCA was more important than SCA. Heterosis for number and weight of fruits per plant was high in some F_1 hybrids which was manifested by overdominance.

El-Shawaf *et al.* (1984) reported that additive genetic variance was greater and more important than dominant variance for fruit shape of cucumber.

Musmade and Kale (1986) reported that GCA and SCA variances were highly significant for all the characters. The mean squares of GCA were higher than SCA for all the traits except yield per vine, reported predominant role of additive gene action.

Strepler and Wehner (1986), while studying variance components for 3 fruit yield and 5 quality traits in 3 cucumber populations (elite, medium base and wide base) using North Carolina Design-I, found that in elite population, additive variance was higher than the dominance for cull fruits, whereas early marketable and total yield per plot were controlled by dominant gene action. Additive variance was higher than dominance for total yield and lower for marketable and early yield in medium base population. Additive gene action was accounted for all the traits in wide base population.

While studying 21 F_1 progenies (3 females and 7 males) in line x tester mating design, Kupper and Staub (1988) suggested that additive effects were more important as the magnitude of contribution of SCA was generally less than that of GCA.

Hormuzdi and More (1989a), in line (4) x tester (8) analysis, reported that magnitude of variance due to GCA was greater than that of variance due to SCA for nodal position, days to anthesis, average fruit weight, fruit length and early yield and suggested the predominance of additive genetic component in the expression of these characters.

Likewise, Prasad and Singh (1992) evaluated 24 F_1 hybrids developed by line (4) x tester (6) mating design and reported that variance due to GCA were higher than variance due to SCA for all the traits studied, which indicated that all the yield components were governed pre-dominantly by additive gene action.

Prasad and Singh (1994), in another study (diallel mating) involving 6 diverse parents, concluded that additive component seemed to be responsible for yield components of cucumber.

Dogra *et al.* (1997a), while studying 10 F_1 hybrids of cucumber (derived through diallel crossing, excluding reciprocals), found that all the characters *viz.*, days to first female flower appearance, nodal position of first female flower, number of fruits per vine, yield per plant and plant height exhibited higher mean square for SCA than GCA and suggested the predominant role of non-additive genes for controlling these traits.

Stankovic *et al.* (1997) in the crosses between 2 gynoecious female lines of indeterminate growth (21/3 and PMS) and 3 monoecious paternal lines of determinate growth (M-24/4, M-24/5 and M-24/6) revealed that additive gene effects play a more significant role in the inheritance of yield than non-additive gene effects.

Sharma *et al.* (2000) studied thirty F_1s of cucumber using line (10) x tester (3) mating design under different environments. They observed that additive gene action (σ^2A) had a predominant role in influencing the traits associated with earliness and fruit length and improvement in such traits could be achieved through simple selection. However, the involvement of non-additive component (number of fruits) or both additive and non-additive (fruit yield and fruit breadth) in the exploitation of hybrid vigour or reciprocal recurrent selection, which capitalizes on both additive and non-additive gene action for these traits.

Uddin and Ahmed (2002) used 12 genetically diverse lines and 4 testers to generate 48 F_1's to study the combining ability effects for 12 traits in cucumber. Variance due to GCA and SCA effects were significant for all the traits except GCA variance for nodal position of the first female flower and fruit length and the variance ratio (σ^2 GCA/σ^2 SCA) suggested that non-additive gene action played a greater role in the inheritance of most of the traits. High SCA effect was expressed by the average x average, high x average or high x low performing parents (general combiners) suggesting the involvement of additive x additive or additive x dominance type of gene action.

Fang *et al.* (2004) studied combining ability for early and total yield of 6 inbred lines of cucumber in China. The general combining ability variance for early yield comprised 91.92 per cent of the genotypic variance. Both early and total yield was controlled by additive genes, with their inheritance fitting in the dominant-additive model.

A study on gene action of three important fruit characters, namely fruit length, fruit diameter and fruit weight of cucumber, was conducted by Moushumi and Sirohi (2006). The results revealed that over-dominance for fruit length, fruit diameter and fruit weight. In all these characters, the dominance component of genetic variance was higher than the additive component. The proportion of genes with positive and negative effects in the parents showed asymmetry at the loci showing dominance. The mean degree of dominance was found more than one that confirmed the presence of over-dominance in the inheritance of these characters. The pre-dominance of non-additive gene action suggested that heterosis breeding might be advantageous to get higher gain in cucumber.

Munshi *et al.* (2006) analyzed the combining ability of a 6 x 6 diallel cross of cucumber excluding reciprocals. The mean square due to general (GCA) and specific combing abilities (SCA) were highly significant for almost all the characters indicated the importance of both additive and non-additive genetic components of variation. The SCA component of variance was higher than the GCA component of variance in all characters which indicated the importance of non-additive gene action for the control. Predictability ratio and average degree of dominance observed to be less than 0.5 and more than 1, respectively, for all the characters studied further confirmed the role of non-additive component of variance.

Singh and Sharma (2006) studied combining ability in 15 cross combinations (5 x 3) with 8 parents for 12 characters. Significant differences in the parents indicated that the majority of the parents had diversity for almost all the characters studied. Variance due to SCA was higher than that of GCA for all the characters except fruit length, fruit diameter and TSS, indicated the importance of non-additive gene action. The presence of non-additive gene action was predominant for most of the characters studied suggested the importance of hybrid vigour for these characters.

Brar *et al.* (2011) in the crosses between 8 genetically divergent parental lines in a diallel pattern revealed that non-additive gene action played a major role in controlling the characters like TSS, total carotenoids, vitamin C, total mineral matter, reaction to downy mildew, bitterness and shelf life of fruit.

Kumar *et al.* (2011) carried out a study on the combining ability of cucumber genotypes using 6 x 6 half-diallel excluding reciprocals. The 15 F_1's along with 6 parental lines were grown in randomized block design with three replications. The mean square due to GCA and SCA were highly significant for almost all the characters indicated the importance of both additive and non-additive genetic components for the characters under study. The predictability ratio and average degree of dominance was observed less than 0.5 and more than 1 for important yield contributing characters *viz.,* earliness, number of fruits per plant and total yield per plant suggested the importance of non-additive components of variance for the improvement of these characters. The results indicated the importance of heterosis breeding for effective utilization of non-additive genetic variance in cucumber.

2.4 Heterosis studies

Heterosis is the superiority of the F_1 over the parents in a given characteristic, assessed not by absolute value and appearance but by its usefulness for practical advantages in the given environments. East (1909) gave genetic nature of heterosis. Bruce (1910) reported that hybrid vigour is due to the presence of dominant genes in the hybrids.

Heterosis in desirable direction (hybrid vigour) is the ultimate aim of breeder. From the point of view of commercial exploitation of heterosis, the increased or decreased vigour of the hybrids over the standard check *i.e.,* standard heterosis is of utmost importance than heterobeltiosis (over the better parents) or the relative heterosis (over the average performance of parents).

Hayes and Jones (1916) were the first to observe heterosis in cucumber and they reported that first generation crosses might frequently be expected to exceed the higher yielding parent. It may be manifested by increase in fruit size or in number of fruits per plant.

Hutchins (1939) crossed the early pickling variety Mincu of cucumber with several slicing types and recorded heterosis for large number of fruits and earliness. Kartaloff (1963) observed that F_1 combinations of different cultivars of cucumber *viz.,* Orion x Satara, Zagora Langi x Stara and Zagora Langi x Spiers gave higher total yield than their respective better parent. Invariably higher yields were reported in hybrids than the standard cultivars by Salokangas (1965) but no significant differences were found between the hybrids.

Koros and Bajtay (1968) developed promising gynoecious F_1 hybrids *viz.,* Kecskemet 113 and 114 using gynoecious lines. The hybrids out yielded the standard cultivar by 32-46 per cent. While studying five hybrids with Kulenkampa as control, Bite (1969) found that female flower appeared first in the hybrid Spotresisting x Odnostebel'nyj, whereas first marketable fruits were found in Kulenkampa x

Odnostabel'nyj recorded highest yield of 22.98 kg/m^2 followed by Spotresisting x Mnogoplod'nyj with 22.05 kg yield per m^2. Increase in yield was 29.5 and 22.03%, respectively over seed parent and 96.75 and 46.79%, respectively over the pollen parent. Malycenko (1969) grouped twenty-five hybrids as early; nineteen as late and nineteen as intermediate among sixty three hybrids tested and most of them had a regular fruit production in the first fifteen days compared to standard cultivar. The increase in twenty nine hybrids was over 20 per cent. It was up to 20 per cent in twenty hybrids and the rest being inferior. Guseinov (1970) and Bite (1971) also reported heterosis for yield in cucumber.

Singh *et al.* (1970) reported positive heterosis for early and total yield and number of fruits per plant. The F_1, FL (female line) x Yamato 3 Shaku gave maximum increase in early yield (153.8%) over Japanese Long Green (standard check) and four out of seven F_1's out yielded the standard check in total yield. Two combinations *viz.,* FL x Glory of Basel (106.44%) and FL x Yamato 3 Shaku (103-68%) registered higher fruit number than the standard check. They further reported that in all the hybrids, the fruits were smaller than the mean of their parents as well as the standard check. For vine length, it was reported that five F_1s had no appreciable differences, whereas the other two F_1's were smaller than the standard cultivar. Similarly, non-significant differences for the mean number of branches were observed in all the combinations over the mid parent and the standard check.

Mikhov and Petkova (1971) observed marked heterosis for earliness and yield in the crosses of two cucumber lines *viz.,* Wisconsin SMR18 and Pixie with tester Posrednik 97. Petkova (1971) reported 40 per cent early and 22 per cent higher total yield in F_1's over their respective better parent. Pike and Mulkey (1971) crossed the gynoecious lines MSU 2059 and GY 3 with TAMU 950 (a hermaphrodite line). The resultant gynoecious hybrids exhibited heterosis for longer vine. Gill *et al.* (1973) recommended the hybrid Pusa Sanyog for cultivation in hilly areas of India. It was a cross between a gynoecious line derived from the Japanese variety Kaga Aomoga Fushinari and Green Long of Naples. It out yielded the standard cultivar Japanese Long Green by 23.05 to 128.78 per cent and was also earlier in maturity.

A hybrid between productive 713 (a female line) and Dindonyazalic Kekaru (local monoecious variety) had 86 per cent higher early yield. This was attributed to increase in leaf surface area (Varna and Maltseniestse, 1973). Kaeva (1975) developed hybrids using complex forms as female parents *viz.,* complex maternal forms and backcrossed complex maternal forms. The hybrids involving complex maternal forms and backcrossed complex maternal forms as female parents out yielded female line hybrids by 35-66 per cent. Mescerov and Malycenko (1975) reported that hybrids developed by complex forms as female parents outyielded the hybrids having involved either pure or partially gynoecious seed parents. Prend and John (1976) emphasized the importance of breeding determinate hybrids. Prend and John introduced the determinate character from Minnesota into gynoecious hybrids and recorded significantly increased yields. The average number of fruits per plant was found to be greater for the resultant dwarf hybrids than for the standard size gynoecious hybrid, Pioneer.

Yurina (1975) and Bite (1977) reported heterosis for higher yield and earliness. Horst and Lower (1978) observed in the crosses between *C. hardwickii* (indeterminate) and gynoecious indeterminate line GY-14 and monoecious determinate line (PG of *C. sativus*), an increase in the average and range of the number of fruits produced in the F_1, F_2 and BC_1 as compared with the *C. sativus* parent. Ghaderi and Lower (1978) reported superiority of hybrids to their respective better parent for yield and its components. In 1979, these researchers again reported heterosis for the total yield, number of fruits and average fruit weight.

Om *et al.* (1978) reported significant positive heterosis for total fruit yield and total number of fruits per plant. Pyzhenkov and Kosareva (1979) found that the mean fruit weight was less in hybrids than the parents. Timofeev (1979) observed 43.9-46.8 per cent, 61.4-61.8 per cent and 44.1 per cent heterosis over better parent in total yield, marketable yield and early yield, respectively. Nienhuis and Lower (1980), while studied crosses between GY 14 and LJ 90430, reported heterosis over FY 14 (female parent) for fruit weight per plant and main stem length.

Pyzhenkov and Kosareva (1981) observed that all the fourteen F_1's of cucumber studied, showed heterosis for earliness and total yield. El-Shawaf and Baker (1981a) reported hybrid vigour for early flowering and earlier pistillate node in hybrids, while involved four gynoecious lines with five hermaphrodite lines. Airapetyan (1981) reported that seven F_1s out of nine exhibited heterosis for number of fruits per plant and few F_1s indicated heterosis for earliness over their respective better parent.

Nuttall and Bonn (1982) reported a gynoecious hybrid (Harrow 75 x Harrow 7410) which produced high yield and fruits with good shape, colour, flesh and picking quality which out yielded Peto Triplemech and Multipick by 2.1 and 6.8 t/ha. Lower *et al.* (1982) observed heterosis over both mid and better parent for fruit weight and main stem length. Lateral number (primary branches) also showed heterosis over mid parent value. Solanki *et al.* (1982) reported positive heterosis for number of fruits (42.12%), average fruit weight (33.33%), fruit yield (83.81%) and negative heterosis for plant height (-55.93%), internodal length (-40.15%) and days to maturity (-31.49%). Prudek (1984) in a five-line diallel observed heterosis for both number and yield per plant.

Wehner and Miller (1985) studied three versions of the cucumber hybrid Meridian 76, differing on sex expression. The monoecious x monoecious hybrid had a higher percentage of Fancy and Number 1 grade fruits and a lower percentage of culls than the gynoecious x gynoecious hybrids. All the versions, however, had a similar yield. The gynoecious hybrids were earlier than the monoecious ones. Gynoecious x Gynoecious hybrids had a significantly higher yield than monoecious x monoecious in the first harvest but they were not better for total yield. Gynoecious x Monoecious tended to yield more than Gynoecious x Gynoecious but the differences but difference was non-significant.

Musmade and Kale (1986) studied 21 one F_1's of cucumber, reported significant heterosis for earliness in four hybrids over their respective better parent and five recorded significant heterosis for fruit length. The maximum heterosis for fruit length was exhibited in the hybrid Japanese Long Green x Panvel (24.9%). Fruit diameter was significantly higher in eight hybrids compared to their respective better parent. For number of fruits per vine, seven hybrids showed significant heterosis being maximum (112.5%) in Poona Kheera x Japanese Long Green. The heterosis for average fruit weight was significant in four hybrids. As many as thirteen hybrids showed significantly higher yield per vine over their respective better parent. The highest heterosis (135.47%) was recorded in Poona Kheera x Japanese Long Green.

Hormuzdi and More (1989b) evaluated twenty four F_1's along with their eleven parents during rainy season and thirty two F_1's along with twelve parents during summer season, found desirable heterosis for days to first female flower appearance (22.2 and 14.2%), average fruit weight (23.3 and 44.81%), fruits per plant

(104.2 and 44.5%) and total yield per plant (247.3 and 57.6%) in summer and rainy season, respectively. However, none of the hybrids exceeded their better parent for vine length in both the seasons.

Kumari *et al.* (1993) evaluated fifteen tropical and eight temperate hybrids in two separate trials during summer season. In trial-I (tropical hybrids), the combination Poinsette x JPL was the most heterotic for days to anthesis (15.1%), whereas GYN. JPL x EC 129110 expressed 37.3% heterosis over better parent for nodal position of first female flower. In trial-II (temperate hybrids), SR55IF x EC 129110 was the earliest, which recorded 11.9 and 18.7% heterosis over better parent for days to anthesis and nodal position, respectively. Six tropical hybrids and three temperate hybrids recorded significant heterosis over better parent for total yield. Li *et al.* (1995) reported positive heterosis for total yield, early yield, fruit number, average fruit weight, fruit shape index, whereas vine length had negative heterosis and shorter vines produced higher yield.

Jianwu (1995) derived the information on heterosis and combining ability on 9 yield components in 4 inbred cucumber lines and their 6 F_1 hybrids grown in China. Total yield, early yield, fruit number, average fruit weight, leaf area, fruit ratio and fruit shape index had positive heterosis. Vine length had negative heterosis; shorter vines produced greater yields. Yield was most affected by fruit number and average fruit weight.

Dogra *et al.* (1997b) crossed five cucumber lines (4 monoecious and 1 gynoecious), both indigenous and exotic, in a diallel fashion, excluding reciprocals. The lines, their 10 F_1's and a standard check cultivar Pusa Sanyog were grown in the field at Nauni, Solan. The cross K-75 x Gyn-1 recorded the highest heterobeltiosis (51.35%) for yield per plant and an increase of 29.56% over the standard check.

Forty five F_1 and F_2 crosses involving ten parents were assessed to determinate the magnitude of heterosis (heterobeltiosis) and inbreeding depression by Singh *et al.* (1999). AC-20 x AC-28, AC-22 x AC-41 and AC-2 x AC-32 crosses were observed the top performer for fruit yield per plant as they recorded significant heterosis of 187.80, 65.31 and 54.81 per cent, respectively, over the better parent. The maximum yield recorded by these hybrids has been attributed to the increase in number of fruits per plant and average fruit weight.

Cramer and Wehner (1999) hybridized two pickling cucumber inbreds (M 12, M 20) and inbreds from four open-pollinated monoecious cultivars of cucumber *viz.*, Addis, Clinton, Wisconsin SMR 18 and Tiny Dill' were hybridized to form four F_1 hybrids *viz.*, Addis x M 20, Addis x Wisconsin SMR 18, Clinton x M 12 and M 20 x Tiny Dill. The data were collected from once over harvest for vegetative, reproductive, yield, and fruit quality traits. Heterosis for fruit yield and yield components were not observed in three of the hybrids. Only Addis x Wisconsin SMR 18 exhibited high-parent heterosis for total, marketable and early fruit weight.

Bairagi *et al.* (2002) studied twenty eight hybrids and their parents (eight) and reported maximum heterobeltiosis for yield per plant in PCUC-98-25 x DC-1 (123.82%). They also reported heterobeltiosis for different traits *viz.*, days to anthesis of first female flower, nodal position of first female flower, vine length, number of primary branches per plant, average fruit length, average fruit diameter and number of fruits per plant.

The importance of parthenocarpy in fruit setting is well known. Therefore efforts were made by More (2002) to develop a new parthenocarpic tropical gynoecious line having fruits with yellow skin. He studied three tropical gynoecious cucumber lines *viz.*, GYC-1, GYC-2 and GYC-3 to develop tropical gynoecious hybrids. Some of these hybrids *viz.*, DCH 1 and DCH 2 are promising for high productivity and fruit quality both under open field and greenhouse cultivation. As a result, a new tropical gynoecious parthenocarpic line PKG-1 (GYC-4) was developed from a complex cross [(Tablegreen 68 x SC 3) x Poona Khira] F_3 x [(Gy-14 x Tablegreen 68) x Poona Khira] F_3. From this complex cross, two types of lines were developed. The first set included lines PKG-1-2, 1-11, 1-12 and 1-15 with yellow skinned fruits exhibiting gynoecy and parthenocarpy, whereas the second set comprised lines PKG-1-21, 1-23 and 1-24 with green skinned fruits exhibiting gynoecy and parthenocarpy. PKG-1 (GYC-4) along with GYC-1, GYC-2 and GYC-3 showed potential for heterosis breeding when subjected to heterosis and combining ability studies.

Bairagi *et al.* (2005) evaluated 28 non-reciprocal F_1's derived from 8 diverse cucumber genotypes during to study heterosis over better parents and the check cultivar, Pant Cucumber Hybrid-1 (PCUCH-1). The hybrids PCUC-83 x PCUC-15, PCUC-83 x PCUC-25 and PCUC-25 x PCUC-15 were found most promising ones.

Heterosis to the tune of 45.5, 43.7 and 38.5 per cent over their better parents and 20.2, 18.2 and 20.0 per cent, respectively over the check cultivar were evidenced by these three hybrids for fruit yield per plant.

Kumbhar *et al.* (2005) studied heterosis for yield and its components (days to first female and male flowers, number of female and male flowers, days to first fruit picking, fruit length and diameter, number of fruits per vine and average fruit weight) in Maharashtra with 28 F_1 hybrids of cucumber obtained by 8 x 8 diallel among 8 parents. The highest magnitude of heterosis (80.69%) was observed for yield per plant, followed by number of fruits per vine (67.12%) and days to first fruits picking (61.71%). High degree of heterosis was found between diverse parents. The specific combinations Improved Long Green x Himangi and Poona Khira x Junnar Local were identified as the best hybrids.

Munshi *et al.* (2005) evaluated 6 parental lines and 15 F_1 hybrids of cucumber obtained by half diallel cross to investigate the extent of heterosis for yield and yield contributing characters. Appreciable heterosis over better parent and top parent was recorded for all the characters studied for except fruit length. DC-1 x PCUC-8, CHC-1 x PCUC-8 and DC-1 x Poinsette were the superior F_1 hybrids for yield per plant. The highest yield recorded by these hybrids attributed to increased number of fruits, greater flesh thickness and higher fruit weight.

Sudhakar *et al.* (2005) used fifteen lines of cucumber to develop 77 F_1 hybrids in different combinations. There was wide variation in magnitude and direction of heterosis for all characters. Branches per plant, fruits per plant, fruit weight, fruit length, fruit diameter and total fruit yield were the most heterotic characters. Appreciable heterosis in desirable direction was observed over better and mid parents for all the characters. The hybrids DC-1 x B-159 and VRC-11-2 x Bihar-10 were the best hybrid combinations for total fruit yield as they recorded significant positive heterosis over better and mid parent. The high yield recorded in these attributed to high number of fruits per plant.

Heterosis for yield and yield components was studied in 15 F_1 hybrids and 6 parental cultivars of cucumber by Nehe *et al.* (2007). Significant heterosis was observed for all characters. Heterosis and heterobeltiosis were greatest for number of fruits per vine, followed by yield per vine, and diameter of fruit.

Yadav *et al.* (2007) conducted an experiment with 45 cucumber hybrids developed through line x tester technique by using 15 lines and 3 testers. The lines were 2015, 2016, 2017, 2028, 2020, 2225, 2227, 2229, 2230, 2231, 2332, 2333, 2334, 2336, 2337 and testers 2014, 2226, 2238 in Uttar Pradesh. The parent 2020 followed by 2017, 2231 and 2336 showed a significant general combining ability effect. Based on specific combining ability, 7 superior heterotic crosses, namely 2237 x 2226, 2237 x 2238, 2015 x 2014, 2228 x 2238, 2028 x 2238, 2336 x 2014 and 2229 x 2226 were selected for yield and yield traits.

Yadav *et al.* (2008) conducted a field trial in 18 cucumber lines at Uttar Pradesh. Among these lines, 15 were selected as female parents (lines) and 3 as male parents (testers). The line x tester analysis was used to assess the performance of 12 characters *viz.*, days to flowering of first male flower, days to flowering of first female flower, length of vine, number of primary branches per plant, number of nodes of first male flower, number of nodes of first female flower, number of nodes per vine, length of fruit, diameter of fruit, number of fruits per plant, fruit weight and fruit yield per plant. The average heterosis for yield per plant ranged from 19.03 to 60.00 per cent. The heterotic response of these crosses was also exhibited in most of the yield attributes and can be used in commercial hybrid seed production.

Singh *et al.* (2010) crossed 8 genetically diverse genotypes of cucumber *viz.*, PCUC-15, EC-43342, PCUC-15-1, CHC-2, BIHAR-1, C-99-12, C-98-6 and C-99-10, crossed in half diallel fashion. The parents along with 28 F_1's were evaluated for days to first female flower, node number of first female flower, fruit length, fruit diameter, fruit weight, number of fruits per vine, vine length and yield per vine. The data were subjected to analysis variance for heterosis over better parent. For days to first female flower most promising cross combinations were CHC-2 x BIHAR-1, PCUC-15-1 x CHC-2, BIHAR-1 x C-98-6, PCUC-15 x PCUC-15-1 and PCUC-15-1 x C-98-6; for node number of first female flower the most promising crosses were BIHAR-1 x C-99-10, PCUC-15-1 x BIHAR-1, PUCU-15-1 x CHC-2, CHC-2 x C-99-10 and BIHAR-1 x C-98-6. The magnitude of heterosis for fruit length was highest in hybrid PCUC-15 x PUCU-15-1, while maximum heterosis for fruit diameter was observed in the crosses EC-43342 x BIHAR-1, BIHAR-1 x C-98-6, EC-43342 x C-99-10 and PCUC-15 x PCUC-15-1. Heterosis for fruit weight was maximum in hybrid PCUC-15 x PCUC-15-1; for number of fruits per vine hybrids in order of merit were PCUC-15 x C-99-10, BIHAR-1 x C-99-10, BIHAR-1 x C-99-12 and C-99-12 x C-98-6; for vine length maximum heterosis was observed in cross PCUC-15 x PCUC-15-1 and for yield per vine, the magnitude of heterosis varied from 65.09 to 173.38 per cent. The most promising cross combinations in order of merit were EC-43342 x BIHAR-1, EC-43342 x C99-10, PCUC-15 x PCUC-15-1, PCUC-15 x C-98-6 and BIHAR-1 x C-99-10. For yield, the best three hybrids were EC-43342 x BIHAR-1, EC-43342 x C-99-10 and PCUC-15 x PCUC-15-1. These crosses had best heterotic effect for yield due to better performance of characters like fruit length, fruit diameter, fruit weight and number of fruits per vine. Among all the parents, CHC-2 for six characters, PCUC-15 and BIHAR-1 each for five characters and PCUC-15-1 for four characters were identified as better combiners. Significant and desirable heterosis in aforesaid crosses is due to dominance and dominance x dominance type of interaction. Thus, it is apparent that the commercial exploitation of hybrids may be achieved through heterosis breeding.

Dogra and Kanwar (2011) attempted the crosses among eight parents (including two gynoecious lines) in half diallel fashion. Twenty-eight F_1's, eight parents and one check were grown in a Randomized Block Design with three replications at two different locations *viz.* Nauni (L-1) and Chambaghat (L-2). Heterobeltiosis and standard heterosis for earliness was maximum in EC-173934 x LC-40 and G-2 x Gyn-1, respectively. The crosses G-2 x Gyn-1 and EC-173934 x LC-40 exhibited maximum negative heterobeltiosis and standard heterosis for earliness, while the cross K-90 x G-2 revealed maximum positive heterobeltiosis and standard heterosis for number of fruits per plant and yield.

Brar *et al.* (2011) crossed eight genetically divergent parental lines in a diallel pattern to investigate extent of heterosis for quality traits and reaction to downy mildew. Cross combination Long Green x Bhari Mansa manifested maximum heterosis over better parent for vitamin C and over standard check cultivar Punjab Naveen for shelf life of fruits. Hybrid Long Green x Bhari Mansa registered best overall performance for studied quality traits.

Khushwaha *et al.* (2011) evaluated seven parental lines of cucumber in a diallel cross along with their twenty one F_1's (excluding reciprocals) in a randomized block design to obtain information about heterosis. The hybrids BC-11 x BC-12 manifested highest significant heterobeltiosis for nodal position of first female flower while BC-16 x Poinsette for fruit length, BC-14 x BC-16 for fruit diameter, BC-15 x BC-16 for fruit weight and BC-11 x BC-16 for number of fruits per vine and fruit yield per vine. The most promising hybrids were BC-11 x BC-16, BC-15 x Poinsette and BC-13 x BC-14 and these hybrids also showed highest SCA effects for yield per vine.

Singh *et al.* (2012) evaluated fifteen parental lines (12 lines and 3 testers) and their 36 hybrids for heterosis of different fruit traits *viz.* fruit length, weight per fruit, number of fruits per plant and fruit yield per plant. The positive heterosis desirable for length of fruit, weight per fruit, number of fruits per plant and fruit yield per plant was common in most of the crosses. Most of the crosses showed positive and significant heterosis over standard variety and better parent. The cross combination BSC-1 x BSC-2, BSC-1 x CHC-1, VRC-11-2 x CC-5 and CC-7 x CHC-1 showed highly positive and significant heterosis over standard variety and better parent and can be utilized in heterosis breeding programme for the improvement of yield in cucumber.

Chapter-3

MATERIAL AND METHODS

Chapter-3

Material and Methods

The present studies entitled “Genetic studies on yield and quality traits in cucumber (*Cucumis sativus* L.)” were carried out at the Experimental Research Farm of the Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during 2011 and 2012. The details of experimental site, material used and methodologies employed have been described as under:

3.1 GENERAL FEATURES OF EXPERIMENTAL SITE

3.1.1 Location

The experimental site is located at Nauni, about 14 km away from Solan city at an altitude of 1,270 metres above mean sea level lying between 35.5° North latitude and 77.8° East longitude. The farm area falls in the mid hill zone of Himachal Pradesh.

3.1.2 Climate and weather conditions

The climate of the Experimental Research Farm is generally characterized as sub-humid, sub-temperate with cool winters. Weather conditions which prevailed during growing season were recorded and have been presented in Appendix-I. During the year 2011, mean temperature, relative humidity and rainfall varied from 23.29 (July) to 24.43^{o}C (May), 46.35 (May) to 80.24 % (July) and 31.70 (May) to 263.60 mm (July), respectively. Similarly, mean temperature, relative humidity and rainfall ranged from 22.92 (August) to 26.49 ^{o}C (June), 40.47 (May) to 84.06 % (August) and 2.60 (May) to 316.10 mm (August), respectively during the year 2012. Graphical representation of monthly data pertaining to the temperature, relative humidity and rainfall during the growing seasons have been given in Fig. 3.1 and 3.2.

3.1.3 Soil

The soil structure of the Experimental Research Farm is sandy loam to clay loam comprising of sand (46.09 %), silt (32.12 %) and clay (25.01 %). In general, amount of organic carbon, nitrogen, phosphorus and potassium content present in the soil were 12.60 (g/kg), 324.09 (kg/ha), 42.11 (kg/ha) and 147.16 (kg/ha), respectively. The pH of the soil ranged from 6.85-7.04.

3.2 EXPERIMENTAL MATERIAL AND LAYOUT PLAN

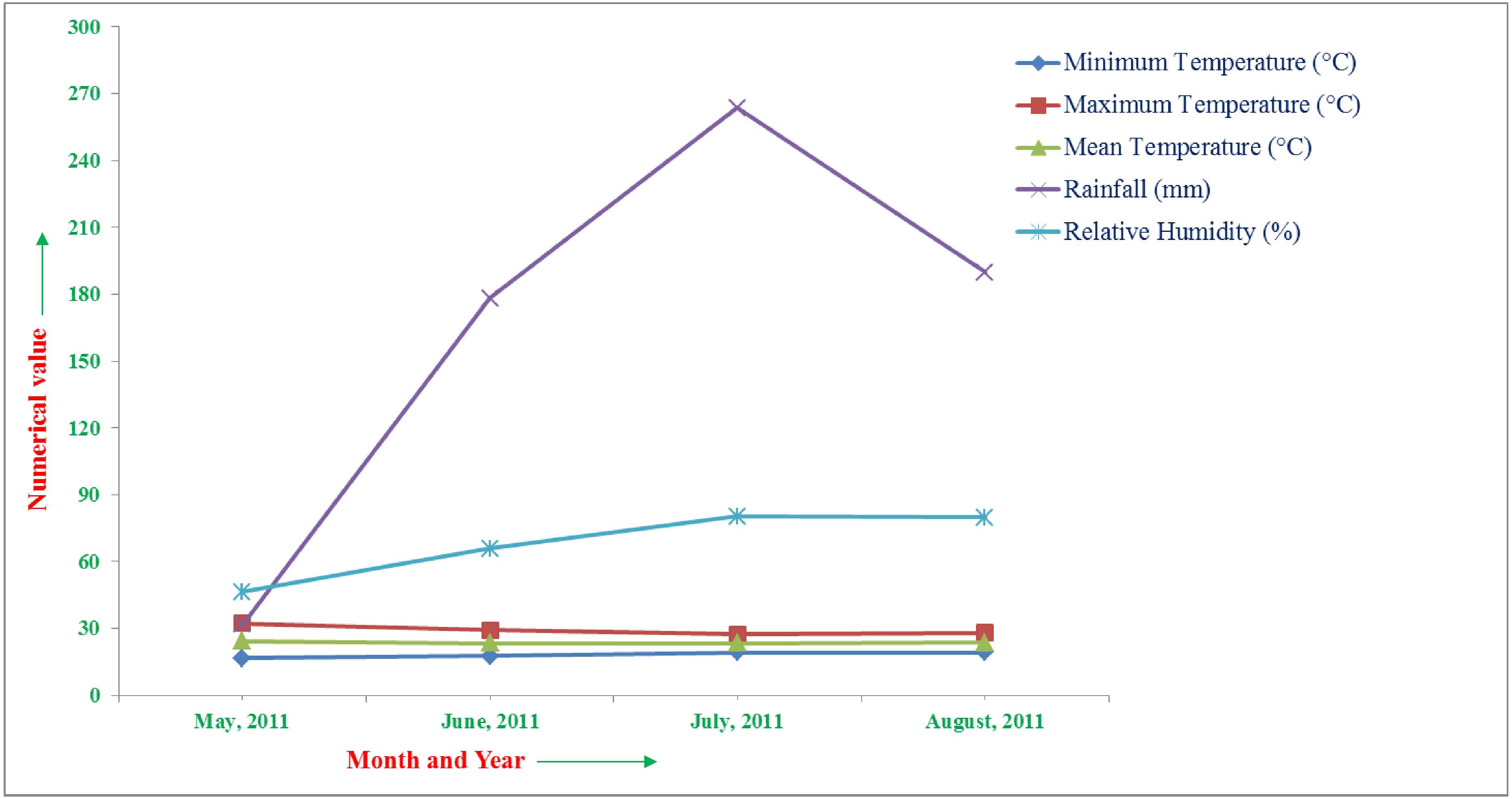
3.2.1 Experimental material

The experimental material for the present investigations was comprised of 16 lines and 3 testers (Table 3.1, Fig. 3.3a, 3.3b and 3.4). The crosses were attempted during the year 2011 as per Line x Tester design as suggested by Kempthrone (1957). The F_1 population of 48 crosses so obtained was evaluated along with parents and standard check cultivars (KH-1 and Pusa Sanyog) during the year 2012.

Table 3.1: Cucumber genotypes used in the hybridization along with standard check cultivars

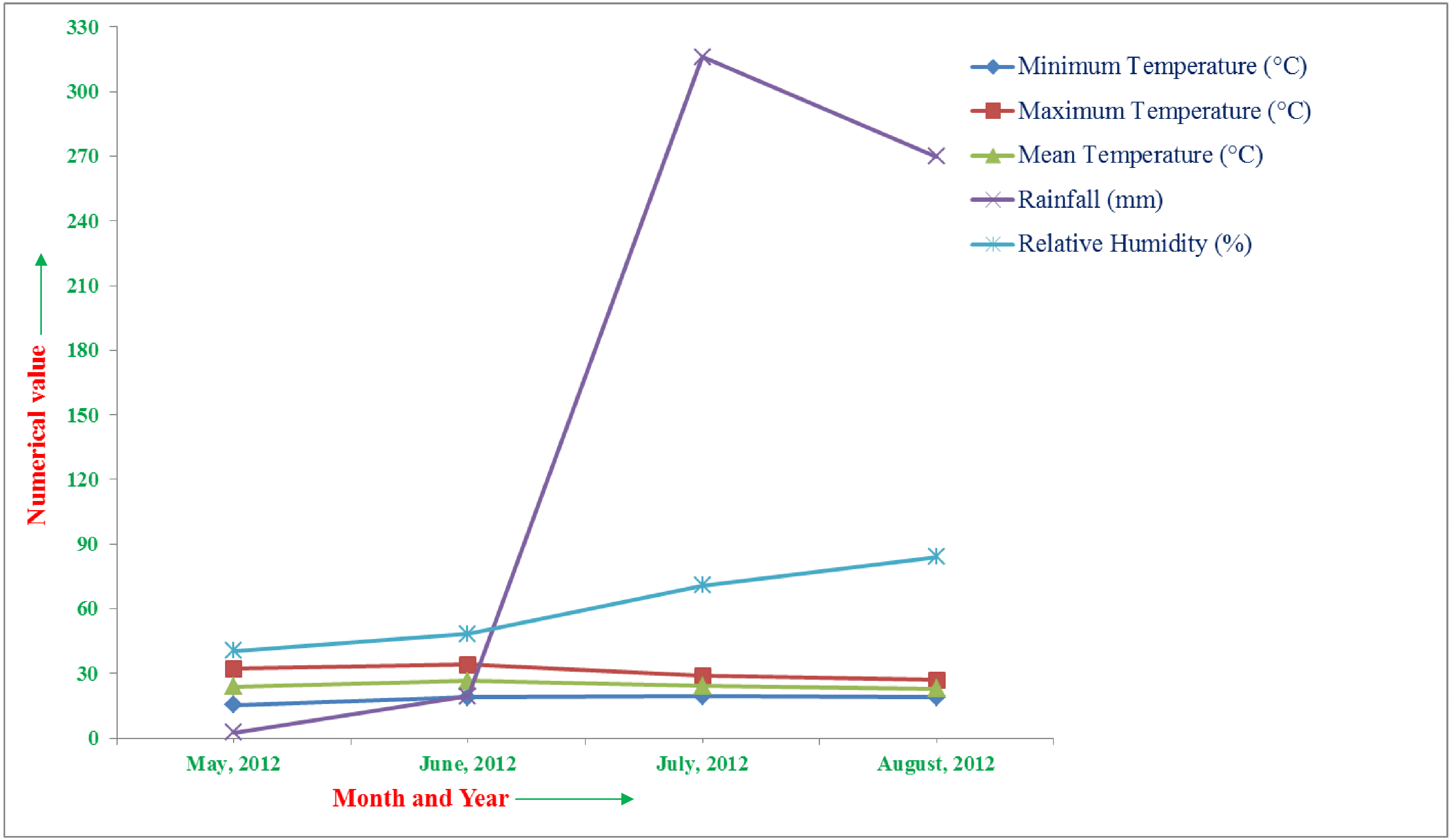
Sr. No.	Genotype	Source
(a)	**Lines**	
1.	CGN-19533	Centre for Crop Genetic Resources, the Netherlands
2.	CGN-20256	Centre for Crop Genetic Resources, the Netherlands
3.	CGN-20515	Centre for Crop Genetic Resources, the Netherlands
4.	CGN-20953	Centre for Crop Genetic Resources, the Netherlands
5.	CGN-20969	Centre for Crop Genetic Resources, the Netherlands
6.	CGN-21585	Centre for Crop Genetic Resources, the Netherlands
7.	CGN-22930	Centre for Crop Genetic Resources, the Netherlands
8.	LC-1-1	Dhangota, Hamirpur, Himachal Pradesh, India
9.	LC-2-2	Bhota, Hamirpur, Himachal Pradesh, India
10.	LC-3-3	Awahdevi, Hamirpur, Himachal Pradesh, India
11.	LC-12-4	Gagal, Kangra, Himachal Pradesh,India
12.	LC-15-5	Sarkaghat, Mandi, Himachal Pradesh, India
13.	LC-21-6	Dangar, Bilaspur, Himachal Pradesh, India
14.	LC-25-7	Saru, Chamba, Himachal Pradesh, India
15.	LC-28-8	Sambha, Jammu, Jammu and Kashmir, India
16.	Gyne-5	IARI Regional Research Station, Katrain,Kullu, India
(b)	**Testers**	
1.	K-75	UHF, Nauni, Solan, Himachal Pradesh,India
2.	Japanese Long Green	IARI Regional Research Station, Katrain, Kullu, India
3.	Poinsette	National Seeds Corporation, New Delhi, India
(c)	**Standard check cultivars**	
1.	KH-1	UHF, Nauni, Himachal Pradesh,Solan
2.	Pusa Sanyog	IARI Regional Research Station, Katrain, Kullu, India

Fig. 3.1 Mean monthly temperature (maximum and minimum), rainfall and relative humidity recorded during 2011

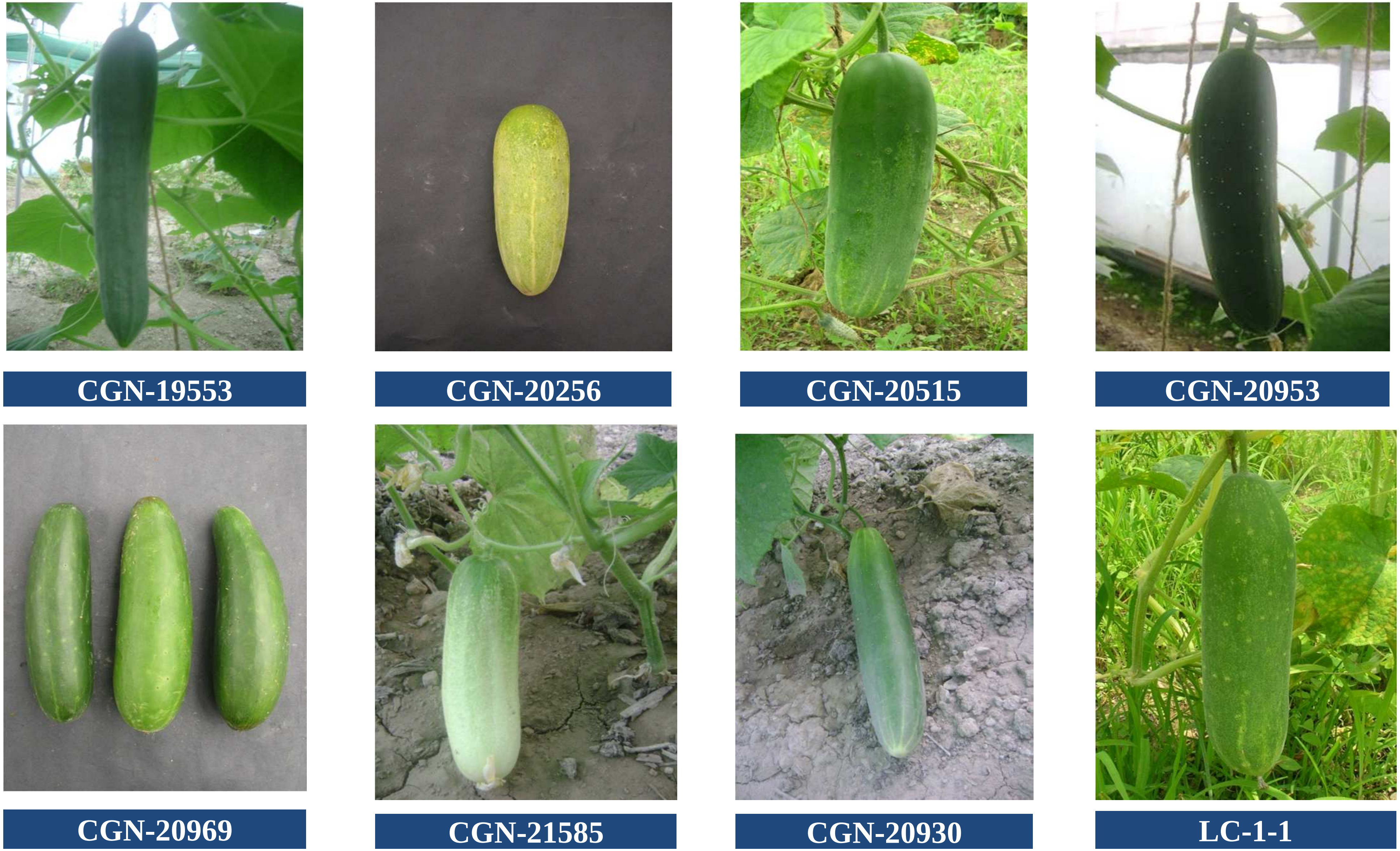


Source: Meteorological Observatory, Department of Environmental Science, College of Forestry, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, 173 230 HP

Fig. 3.2 Mean monthly temperature (maximum and minimum), rainfall and relative humidity recorded during 2012



Source: Meteorological Observatory, Department of Environmental Science, College of Forestry, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, 173 230 HP



CGN-19553

CGN-20256

CGN-20515

CGN-20953

CGN-20969

CGN-21585

CGN-20930

LC-1-1

Figure 3.3 (a) : Lines used in the present study

LC-2-2

LC-3-3

LC-12-4

LC-15-5

LC-21-6

LC-25-7

LC-28-8

Gyne-5

Figure 3.3 (b): Lines used in the present study

K-75 **Japanese Long Green** **Poinsette**

Figure 3.4: Testers used in the present study

(a) Healthy crop stand inside polyhouse

(b) Crossed flowers

(c) Field view of crossing block

(d) Well developed crossed fruit of a flower

Figure 3.5: Crossing block being maintained inside polyhouse and in open field conditions

(a) Mature fruits harvested for seed extraction

(b) Extraction of seeds

(c) Seed drying

Figure 3.6: Fruit harvesting, seed extraction and drying

3.2.2 Crossing plan/Development of hybrids

During *kharif* 2011, seeds of 16 lines and 3 testers were sown in polyhouse as well as in open field conditions during the month of May, 2011 at a spacing of 100 cm x 75 cm in a plot having size 3.0 m x 2.25 m, which accommodated 9 plants per plot (Fig. 3.5). All the parents were planted in unpaired fashion in the crossing blocks, according to the Line x Tester mating design as suggested by Kempthorne (1957). The population of male parents (testers) was kept higher (5-6 times) than female parents, because each tester was crossed with every line (female line). Simultaneously, each parent was also selfed for getting the sufficient seeds to raise the large population in the next season. Mature fruits of crossed as well as selfed progenies were harvested and seeds were extracted manually. Seeds were dried and then stored in cool place for sowing in the subsequent year (Fig. 3.6).

3.2.3 Experimental layout

During *kharif* 2012, seeds of all the parents (16 lines and 3 testers) and their 48 F_1's along with the standard checks (KH-1 and Pusa Sanyog) were sown during the month of May, 2012 in Randomized Complete Block Design (RCBD) with 3 replications for their comparative evaluation (Fig. 3.8). Row to row and plant to plant spacing of 100 cm x 75 cm was kept in a plot having size 4.0 m x 3.0 m, which accommodated 16 plants per plot. The standard cultural practices for raising a healthy crop of cucumber as recommended in the "Package of Practices" for Vegetable Crops, published by the Directorate of Extension Education, UHF, Nauni, Solan (Anonymous, 2009) have been followed during both the years of study.

3.3 OBSERVATIONS RECORDED

The observations were recorded on five randomly selected plants in each entry (genotype/hybrid) over the replications for all the characters except for fruit characters for which observations were recorded on ten randomly selected fruits per replication. The characters studied were described as follows:

3.3.1 Days to first female flower appearance

The number of days taken from the date of sowing to the date of first female flower appearance were recorded in each genotype/hybrid in each replication and mean number of days were worked out.

3.3.2 Node number bearing first female flower

Node number of each genotype/hybrid, at which the first female flower appeared, was counted from the ground surface in each replication and mean value was worked out to estimate the earliness of the variety.

3.3.3 Days to marketable maturity

Number of days from seed sowing to first fruit picking were noted in each replication for every genotype/hybrid and mean number of days for marketable maturity were worked out.

3.3.4 Fruit length (cm)

Polar length of selected fruits from each replication was recorded and mean value was worked out.

3.3.5 Fruit breadth (cm)

Diameter of the same fruits which were used for measuring length was recorded with the help of vernier caliper from the middle of the fruit.

3.3.6 Average fruit weight (g)

Selected fruits from each replication were weighed and average fruit weight was calculated.

3.3.7 Number of marketable fruits per plant

Total number of healthy fruits picked at each harvest were taken into consideration to work out mean number of marketable fruits per plant.

3.3.8 Harvest duration (days)

Total number of days from first fruit picking to final fruit picking were counted in each replication of every parent/hybrid and average value was expressed as harvest duration.

3.3.9 Marketable yield per plot (kg) and per hectare (q)

Total weight of marketable fruits harvested from each plot was recorded and expressed as yield per plot. From yield per plot, yield per hectare was calculated on conversion basis.

3.3.10 Total soluble solids (^{0}B)

Total soluble solids (TSS) of the randomly selected fruits were observed under room temperature with the help of 'ERMA Hand Refractometer' by putting 2-3 drops of juice on prism and the values expressed as TSS content of juice (AOAC, 1970).

3.3.11 Cucurbitacin content (µg/100g)

Fifty gram fruit sample of each genotype/hybrid was blended in pestle and mortar in 150 ml of 70 per cent methanol. About 2 ml saturated lead acetate solution was added to the blend and it was centrifuged at 2000 rpm for five minutes. The supernatant was transferred to fresh tubes and excess of lead acetate was neutralized with a few drops of saturated monobasic potassium phosphate solution. The extract was again centrifuged at 2000 rpm for five minutes to remove the precipitates. The contents were then transferred to separating funnel and were shaken twice with 100 ml petroleum ether (60-80 ^{o}C). The upper petroleum ether layer was then extracted and discarded. Ethanol fraction was shaken twice with 100 ml chloroform and chloroform layer extract was washed twice with equal amount of distilled de-ionized water and dried over sodium sulphate. Chloroform was driven out of the extract and the material was dissolved in minimum amount of methanol and final volume was made to 50 ml to get 100 per cent crude cucurbitacin extract. These extracts were analyzed using UV-visual spectrophotometer at 230 nm wavelength. The standard curve was obtained using pure cucurbitacin (40, 80, 120 and 160 µg/ml) and amount of cucurbitacin in different samples was determined by comparing with standard curve.

3.3.12 Fruit colour

The colour of fruits was observed visually after harvesting with the help of colour chart of Royal Horticultural Society, London.

3.3.13 Fruit fly incidence (%)

The total number of fruits per plant and fruits infested with fruit fly were counted from the randomly selected plants to work out the incidence of fruit fly as per the following formula:

$$\text{Fruit fly incidence (\%)} = \frac{\text{Number of fruit fly infested fruits}}{\text{Total number of fruits}} \text{ x } 100$$

3.3.14 Severity of powdery mildew (%)

The occurrence and severity of powdery mildew was recorded periodically under natural conditions. Fifteen leaves were randomly selected from different levels of height (from top to bottom) from 5 vines of each genotype/hybrid and disease severity for powdery mildew was recorded by adopting the 0-5 scale given by Ransom *et al.* (1991), as given below:

Disease class		**Description**
0	:	No disease
1	:	Trace levels- isolated colonies
2	:	Mildew colonies confluent on some leaves, no visible stem infection
3	:	Up to 50% infection on leaves, vine also infected, no fruit infection
4	:	More than 50% infection on leaves, slight on fruits
5	:	All the leaves and fruits severely affected

3.3.15 Severity of downy mildew (%)

Severity of downy mildew was recorded periodically in each replication of every genotype/hybrid. Fifteen leaves were randomly selected from 5 vines of each genotype/hybrid and disease severity for downy mildew was recorded by adopting the 0-4 scale given by Reuveni (1983) with slight modifications, as given below:

Disease class		**Description**
0	:	No disease
1	:	1-10 scattered small lesions per leaf and less than 25% of leaf area turned yellowish
2	:	11-20 scattered small lesions per leaf and yellowing covered >25-50% of leaf area
3	:	21-40 scattered or coalesced lesions per leaf and yellowing covered >50% of leaf area
4	:	More than 40 coalesced lesions per leaf and the infectedarea turned brown and died. Yellowing covered >75% of leaf area

3.3.16 Severity of angular leaf spot (%)

Occurrence and severity of the disease was recorded periodically in each replication of every genotype/hybrid. Fifteen leaves were randomly selected from different levels of height from 5 vines of each genotype/hybrid and disease severity for angular leaf spot was recorded by adopting the 0-5 scale given by Bhat *et al.* (2007) with slight modifications, as given below:

Disease class		Description
0	:	No disease
1	:	0.1-5.0 % infected leaf area
2	:	5.1-25.0 % infected leaf area
3	:	25.1-40.0 % infected leaf area with slight infection on vines
4	:	40.1-60.0 % infected leaf area with elongated infection on vines, along with spots on fruit
5	:	> 60% infected leaf area, vines and fruits were severely infected

Disease severity index (%) in all the diseases was calculated by using the formula as given below:

$$\text{Disease severity index (\%)} = \frac{\sum(n \times v)}{Z \times N} \times 100$$

Where,

n = number of leaves in each category

v = numerical value of each category

Z = numerical value of highest category

N = total number of leaves in sample

3.3.17 Seed germination (%)

Seed germination of each genotype/hybrid was tested as per ISTA (Anonymous, 1985) in the laboratory through blot paper method. Four hundred seeds of each genotype were grown in four replications (100 seeds each). Seeds were allowed to germinate on the top of germination paper and final count was taken on 8th day. Germination percentage of each replication was worked out by using following formula:

$$\text{Seed germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds placed for germination}} \times 100$$

Means of all the replications were taken to obtain germination percentage of each genotype/hybrid.

3.3.18 Seed vigor index-I and II

A sample of 20 seedlings from each replication was taken for vigour test. The dry weight (mg) and length (cm) of germinated seedlings was recorded. The average dry weight was calculated by dividing the total dry weight of seedlings with number of seedlings and outcome was multiplied by corresponding germination percentage for calculating seed vigour index-I. Whereas, in case of seed vigour index-II, average length of seedlings was calculated by dividing the total length of seedlings with number of seedlings and outcome was multiplied by corresponding germination percentage. Seed vigour index was calculated as per the formula given by Abdul-Baki and Anderson (1973):

Seed Vigor Index-I = Seed germination percentage x seedling length (cm)
Seed Vigor Index-II = Seed germination percentage x seedling dry weight (mg)

3.4 STATISTICAL ANALYSIS

The data recorded on forty eight crosses along with nineteen parents and two standard check cultivars were analyzed using MS-Excel, OPSTAT and SPAR 2.0 packagesas per the design of experiment for working out the following values:

3.4.1 Analysis of variance

For working out the analysis of variance, the data were analyzed by using the following model as suggested by Panse and Sukhatme (1967):

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

Where,

Y_{ij} = Phenotypic observation of i^{th} entry grown in j^{th} replication
μ = General population mean
g_i = Effect of i^{th}entry
r_j = Effect of j^{th} replication
e_{ij} = Error component

Analysis of variance

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	Expected mean sum of squares
Replication (r)	r-1	Sr	Sr/(r-1) = Mr	$\sigma^2e+g\sigma^2r$
Entries (g)	g-1	Sg	Sg/(g-1) = Mg	$\sigma^2e+r\sigma^2g$
Error (e)	(r-1) (g-1)	Se	Se/(r-1) (g-1) = Me	σ^2e

Where,

r = Number of replications

g = Number of entries

Sr = Sum of squares due to replications

Sg = Sum of squares due to genotypes

Se = Sum of squares due to error

Mr = Mean sum of squares due to replications

Mg = Mean sum of squares due to genotypes

Me = Mean sum of squares due to error

σ^2r = Variance due to replications

σ^2g = Variance due to entries

σ^2e = Error variance

The replication and entries mean sum of square were tested against error mean squares by ‘F’ test for (r-1), (r-1) (g-1) and (g-1), (r-1) (g-1) degree of freedom at P = 0.05. The calculated F-value was compared with tabulated F-value. When F-test was found significant, critical difference was calculated to find out the superiority of one entry over the others.

The standard error and critical differences were calculated as follows:

SE (m) ± = $\sqrt{Me/r}$

SE (d) ± = $\sqrt{2\,Me/r}$

$CD_{0.05}$ = S.E. (d) x $t_{(0.05)}$ (r-1) (g-1) df

Where,

SE (m) ± = Standard error of mean

SE (d) ± = Standard error of difference

$CD_{0.05}$ = Critical difference at 5 per cent level of significance

3.4.2 Line x tester analysis

For Line x tester analysis, replication wise mean values of F_1 generation of 48 crosses for each trait were subjected to statistical analysis as per the model suggested by Kempthorne (1957) and the solved example given by Dabholkar (1992) as follows:

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

Where,

Y_{ijk} = Value of the ijkth observation of the cross involving ith line and jth tester in kth replication

μ = General mean (an effect common to all hybrids in all replications

g_i = General combining ability (GCA) effect of ith line

g_j = General combining ability (GCA) effect of jth tester

s_{ij} = Specific combining ability (SCA) effect of the cross involving ith line and jth tester

e_{ijk} = Error associated with ijkth observation

i = ith line (1, 2, 3……………………16)

j = jth tester (17, 18, 19), and

k = kth replication (1, 2, 3)

Analysis of variance for crosses and combining ability

Source of variation	d.f.	Sum of squares	Mean squares	Expected mean squares
Replication	(r-1)	rss	Mr	-
Cross	(fm-1)	css	Mc	-
Lines	(f-1)	fss	M(f)	$\sigma^2e+r\sigma^2fm+rm\sigma^2f$
Testers	(m-1)	mss	M(m)	$\sigma^2e+r\sigma^2fm+rf\sigma^2m$
Line x tester	(f-1) (m-1)	fmss	M(fm)	$\sigma^2e+r\sigma^2fm$
Error	(fm-1) (r-1)	tss-rss-css	Me	σ^2e
Total	(fmr-1)	tss	-	-

Where,

rss = Replication sum of squares = $\sum_{k=1}^{r}\frac{(x..k)^2}{fm} - \frac{x^2...}{fmr}$

css = Cross sum of squares = $\sum_{ij=1}^{fm}\frac{x^2_{ij}.}{r} - \frac{x^2...}{fmr}$

fss = Line sum of squares = $\sum_{i=1}^{f}\frac{x_i^2..}{mr} - \frac{x^2...}{fmr}$

mss = Tester sum of squares = $\sum_{j=1}^{m}\frac{x_j^2.}{fr} - \frac{x^2...}{fmr}$

fmss = Line x tester sum of squares = $\sum_{ij=1}^{fm}\frac{x_{ij}^2.}{r} - \sum_{i=1}^{f}\frac{x_i^2..}{mr} - \sum_{j=1}^{m}\frac{x_j^2..}{fr} + \frac{x^2...}{fmr}$

tss = Total sum of squares = $\sum_{i=1}^{f}\ \sum_{j=1}^{m}\ \sum_{k=1}^{r} x^2_{ijk} - \frac{x^2...}{fmr}$

f = Number of lines

m = Number of testers

x..k = Sum of kth replication of crosses

x... = Sum of all crosses of all lines and testers over all replications

xij = Sum of ijth hybrid combination over all replications

xi.. = Sum of ith line over all testers and replications

xj.. = Sum of jth tester over all lines and replications

xijk = ijth observation in kth replication

M(f) = Mean squares due to lines

M(m) = Mean squares due to testers

M(f x m) = Mean squares due to line x tester interactions

Me = Error mean squares

σ^2f = Variance due to lines/progeny variance arising from differences among female parents/lines

σ^2m = Variance due to testers/progeny variance arising fromdifferences among male parents/testers

σ^2f x m = Variance due to lines x testers/progeny variance arising from interaction of the contribution of female and male parents

σ^2e = Environmental variance/error variance among individuals from same mating

3.4.3 Estimation of general and specific combining ability effects

GCA and SCA effects were obtained from the two way table of female parents vs. male parents in which each figure was total over replications. The individual effects were estimated as follow:

(i) GCA effects of ith line

$$\hat{gi} = \frac{Xi..}{mr} - \frac{X...}{fmr}$$

Where,

X… = sum total of all crosses

Xi.. = total of ith female parents over all males and replications

r = number of replications

f = number of lines/female parents

m = number of testers/male parents

(ii) GCA effects of jth tester

$$\hat{gi} = \frac{Xj..}{fr} - \frac{X...}{fmr}$$

Where,

X… = sum total of all crosses

Xj.. = total of jth male parents over all females and replications

r = number of replications

f = number of lines/female parents

m = number of testers/male parents

(iii) SCA effects of ijth cross

$$\hat{sij} = \frac{Xij}{r} - \frac{Xi..}{mr} - \frac{Xj..}{fr} + \frac{X...}{fmr}$$

Where,

Xij. = ijth combination total over all replications

r = number of replications

f = number of lines/female parents

m = number of testers/male parents

(iv) Standard errors for different combining ability effects

(a) SE $(\hat{g}_i)$ lines = $\pm\sqrt{Me/mr}$

(b) SE $(\hat{g}_j)$ testers = $\pm\sqrt{Me/fr}$

(c) SE $(\hat{s}_{ij})$ crosses = $\pm\sqrt{Me/r}$

(d) SE $(\hat{g}_i - \hat{g}_j)$ lines = $\pm\sqrt{2Me/mr}$

(e) SE $(\hat{g}_i - \hat{g}_j)$ testers = $\pm\sqrt{2Me/fr}$

(f) SE $(\hat{s}_{ij} - \hat{s}_{kj})$ crosses = $\pm\sqrt{2Me/r}$

Where,

Me = mean squares due to error

r = number of replications

f = number of lines/female parents

m = number of testers/male parents

(vi) Test of significance for GCA and SCA effects

There are two methods for testing the significance for GCA and SCA effects:

Method-I

GCA and SCA effects$\geq$ [($SE_{gi}/SE_{gj}/SE_{gij}$) x‘t’ tab at error degree of freedom and P = 0.05] were marked significant (*).

Method-II

(a) t_i (cal) for GCA of lines (females) = (g_i – 0)/SE (g_i)

(b) t_j (cal for GCA of testers (males) = (g_j – 0)/SE (g_j)

(c) t_{ij} (cal) for SCA of crosses = (S_{ij} – 0)/SE (S_{ij})

Where,

t_i (cal), t_j (cal) and t_{ij} (cal) are the calculaed ‘t’ values

g_i = GCA effect of i^{th} lines

g_j = GCA effect of j^{th} tester

s_{ij} = SCA effect of ij^{th} cross

The GCA effects of lines and testers and SCA effects of crosses were marked significant **(*)** when the values of t_1 (cal), t_j (cal) and t_{ij} (cal) $\geq$‘t’ tabulated value at error degree of freedom and P = 0.05.

(vii) Critical differences (CD) for comparing GCA effects of lines/testers and SCA effect of crosses

(a) CD for GCA (lines) = SE (D1) x 't' tab (error df, P=0.05)

(b) CD for GCA (testers) = SE (D2) x 't' tab (error df, P=0.05)

(c) CD for SCA (crosses)= SE (D3) x 't' tab (error df, P=0.05)

The difference between GCA of any two lines/testers and SCA of any two crosses were $\geq$ respective CD values.

3.4.4 Estimation of variance components

The variance components were estimated by covariance of full sib and half sibs as suggested by Singh and Chaudhary (1997) and Dabholkar (1992) as follows:

Cov (HS) = σ^2f (females) = (Mf-Mfm)/mr

Cov (HS) = σ^2m (males) = (Mm-Mfm)/fr

σ^2fm (females x males) = (Mfm-Me)/r = σ^2SCA

(i) Estimation of Cov HS (average) and Cov (FS)

These were calculated as:

Cov HS (average) = (mσ^2f+fσ^2m)/(f+m)

Cov (FS) = σ^2fm+2 Cov (HS)

These can also be calculated from the expectation of mean squares as:

Cov HS (average) = (Mf + Mm-2 Mfm) r (f + m)

Cov HS (FS) = [Mf+Mm+Mfm-3 Me+6r Cov (HS)-r (f+m) Cov (HS)]/3r

(ii) Estimation of GCA and SCA variances

From the estimates of Cov (HS) and Cov (FS), variances due to general combining and specific combining ability were calculated as:

σ^2GCA = Cov (HS) = (Mf + Mm – 2 Mfm)/rE(f + m)

σ^2SCA = Cov (FS)-2 Cov (HS) = (mfm – Me) / r

(iii) Estimation of additive (σ^2A) and dominance (σ^2D) component of variances

For computing the additive and dominance components of variances following formulae have been used (Singh and Chaudhary, 1997 and Dabholkar, 1992):

σ^2GCA = $[(1 + F)/4]\ \sigma^2A = ¼\ \sigma^2A$

So σ^2A = $4\sigma^2$GCA

σ^2SCA = $[(1+F)/2]^2\sigma^2D = ¼\ \sigma^2D$

So σ^2D = $4\ \sigma^2$ SCA

Where,

F = Inbreeding coefficient (F=0, since cucumber is cross pollinated in nature)

σ^2A = Additive variance

σ^2D = Dominance variance

3.4.5 Per cent contrition of lines, testers and their interactions

These were computed as per the formulae suggested by Singh and Chaudhary (1997):

(i) Per cent contribution of lines = [SS (lines)/SS (crosses)] x 100

(ii) Per cent contribution to testers = [SS (testers)/SS (crosses)] x 100

(iii) Per cent contribution of lines x testers = [SS (lines x testers)/SS (crosses)] x 100

Where,

SS (lines) = Sum of squares due to lines

SS (testers) = Sum of squares due to testers

SS (lines x testers) = Sum of squares due to lines x testers

3.4.6 Estimation of heterosis

The estimates of heterosis were calculated as the deviation of F_1 mean from the mid parent (MP), better parent (BP) and standard check-1 (KH-1) and standard check-2 (Pusa Sanyog). The following formulae were followed for the calculation of different estimates of heterosis:

(i) Heterosis over mid parent (%) = $[(\overline{F}_1 - \overline{MP})/\overline{MP}]$ x 100

(ii) Heterosis over better parent (%) = $[(\overline{F}_1 - \overline{BP})/\overline{BP}]$ x 100

(iii)Heterosis over standard check-I (%) = $[(\overline{F}_1 - \overline{SC}_1)/\overline{SC}_1]$ x 100

(iv)Heterosis over standard check-II (%) = $[(\overline{F}_1 - \overline{SC}_2)/\overline{SC}_2]$ x 100

1) Calculation of standard errors

(i) SE for testing heterosis over mid parent:

SE (H1) = $\pm$ $(2Me/r)^{1/2}$

(ii) SE for testing heterosis over better parent:

SE (H2) = $\pm$ $(2Me/r)^{1/2}$

(iii) SE for testing heterosis over standard check-1:

SE (H3) = $\pm$ $(2Me/r)^{1/2}$

(iv) SE for testing heterosis over standard check-2:

SE (H4) = $\pm$ $(2Me/r)^{1/2}$

Where,

Me = Error due to mean sum of squares

r = Number of replications

2) Test of significance for heterosis

There are two methods of testing the significance for heterosis:

Method-I

The difference of $(\bar{F}_1 - \overline{MP})$; $(\bar{F}_1 - \overline{BP})$; $(\bar{F}_1 - \overline{SC}\text{-}1)$ or $(\bar{F}_1 - \overline{SC}\text{-}2) \geq [SE(H_1);$ $SE(H_2); SE(H_2)$ or $SE(H_2)]$ x 't' tab, at error degree of freedom and P=0.05 were considered significant and the asterisk **(*)** was put on the per cent values only. This method is relatively less time consuming.

Method-II

In order to test the significance for different estimates of heterosis, t-test was conducted as follows:

(i) 't' calculated values for heterosis over MP = $(\bar{F}_1 - \overline{MP})/SE(H_1)$

(ii) 't' calculated values for heterosis over BP = $(\bar{F}_1 - \overline{BP})/SE(H_2)$

(iii)'t' calculated values for heterosis over SC-1 = $(\bar{F}_1 - \overline{SC\text{-}1})/SE(H_3)$

(iv)'t' calculated values for heterosis over SC2 = $(\bar{F}_1 - \overline{SC\text{-}2})/SE(H_4)$

The 't' calculated values for heterosis over mid parent (MP), better parent (BP), standard check-1 (SC-I) and standard check-2 (SC-II) were compared with 't' tabulated values at error degree of freedom and P = 0.05. 't' calculated values $\geq$ 't' tabulated values were marked as significant and asterisk **(*)** was put on per cent values only.

Chapter-4

EXPERIMENTAL RESULTS

Chapter-4

Experimental Results

The present investigations were carried out by crossing sixteen lines and three testers in Line x Tester mating design. Forty eight hybrid combinations so obtained were evaluated along with nineteen parents and two standard check cultivars *viz.*, KH-1 and Pusa Sanyog for their mean performance, combining ability, nature and magnitude of gene action and to ascertain best heterotic combination(s) for marketable yield and quality traits. The experimental results so obtained have been presented under the following heads:

4.1 Mean performance
4.2 Combining ability studies
4.3 Gene action
4.4 Heterosis studies

4.1 MEAN PERFORMANCE

The mean performance of parents and hybrids along with standard check cultivars *viz.*, KH-1 (Check-I) and Pusa Sanyog (Check-II) for various traits under study has been described as below:

4.1.1 Days to first female flower appearance

Significant differences were obtained among the parents and hybrids for days to first female flower appearance (Appendix-II). Among the parents, days to first female flower appearance ranged from 50.17-62.33 (Table 4.1). The genotype CGN-20953 recorded minimum days to first female flower appearance (50.17) and it was found statistically at par with CGN-19533 (50.23), CGN-20515 (51.70), CGN-20969 (50.97) and Gyne-5 (51.73), whereas significant maximum days to first female flower appearance (62.33) were observed in the genotype LC-21-6. Among the hybrids, days to first female flower appearance ranged from 47.20-63.77 (Table 4.1). Minimum days to first female flower appearance (47.20) were recorded in the cross combination CGN-20953 x Poinsette and it was found statistically at par with three other cross combinations *viz.*, LC-1-1 x K-75 (48.30), LC-2-2 x Poinsette (48.40) and

Table 4.1 Mean performance of parents and hybrids for days to first female flower appearance (DTFFFA)

Parents/Hybrids	DTFFFA	Hybrids	DTFFFA
CGN-19533	50.23	CGN-21585 x JLG	59.10
CGN-20256	53.00	CGN-21585 x Poinsette	50.10
CGN-20515	51.70	CGN-22930 x K-75	54.77
CGN-20953	50.17	CGN-22930 x JLG	56.10
CGN-20969	50.97	CGN-22930 x Poinsette	53.80
CGN-21585	52.17	LC-1-1 x K-75	48.30
CGN-22930	51.90	LC-1-1 x JLG	56.10
LC-1-1	53.07	LC-1-1 x Poinsette	53.70
LC-2-2	54.13	LC-2-2 x K-75	52.03
LC-3-3	55.93	LC-2-2 x JLG	61.17
LC-12-4	59.80	LC-2-2 x Poinsette	48.40
LC-15-5	54.53	LC-3-3 x K-75	56.33
LC-21-6	62.33	LC-3-3 x JLG	61.57
LC-25-7	57.67	LC-3-3 x Poinsette	51.30
LC-28-8	57.60	LC-12-4 x K-75	58.67
Gyne-5	51.73	LC-12-4 x JLG	62.17
K-75	57.60	LC-12-4 x Poinsette	52.73
Japanese Long Green (JLG)	59.27	LC-15-5 x K-75	58.90
Poinsette	52.20	LC-15-5 x JLG	60.40
CGN-19533 x K-75	48.40	LC-15-5 x Poinsette	51.73
CGN-19533 x JLG	57.20	LC-21-6 x K-75	55.33
CGN-19533 x Poinsette	53.13	LC-21-6 x JLG	63.77
CGN-20256 x K-75	59.47	LC-21-6 x Poinsette	58.90
CGN-20256 x JLG	58.67	LC-25-7 x K-75	55.80
CGN-20256 x Poinsette	54.80	LC-25-7 x JLG	56.30
CGN-20515 x K-75	54.70	LC-25-7 x Poinsette	54.23
CGN-20515 x JLG	56.03	LC-28-8 x K-75	53.80
CGN-20515 x Poinsette	52.87	LC-28-8 x JLG	61.73
CGN-20953 x K-75	49.97	LC-28-8 x Poinsette	57.83
CGN-20953 x JLG	62.57	Gyne-5 x K-75	49.73
CGN-20953 x Poinsette	47.20	Gyne-5 x JLG	57.40
CGN-20969 x K-75	54.97	Gyne-5 x Poinsette	55.20
CGN-20969 x JLG	55.83	**KH-1 (Check-I)**	50.63
CGN-20969 x Poinsette	53.20	**Pusa Sanyog (Check-II)**	51.77
CGN-21585 x K-75	56.23	**Mean**	55.09
S.E. (d) ±	**0.85**	**C.D.$_{(0.05)}$**	**1.70**

CGN-19533 x K-75 (48.40). While, the cross combination LC-21-6 x Japanese Long Green took maximum days to first female flower appearance (63.77) and was found at par with CGN-20953 x Japanese Long Green (62.57) and LC-12-4 x Japanese Long Green (62.17). Amongst all the hybrids, seven hybrid combinations *viz.*, CGN-20953 x Poinsette (47.20), LC-1-1 x K-75 (48.30), LC-2-2 x Poinsette (48.40), CGN-19533 x K-75 (48.40), Gyne-5 x K-75 (49.73), CGN-20953 x K-75 (49.97) and CGN-21585 x Poinsette (50.10) resulted in early first female flower appearance than both the check cultivars KH-1 (50.63) and Pusa Sanyog (51.77), whereas only two hybrid combinations *viz.*, LC-3-3 x Poinsette (51.30) and LC-15-5 x Poinsette (51.73) were found superior over check Pusa Sanyog for days to first female flower appearance.

4.1.2 Node number bearing first female flower

All the parents and hybrids revealed significant variations for node number bearing first female flower (Appendix-II). Among the parents, the node number at which first female flower appeared ranged from 3.23-9.87 (Table 4.2). The genotype CGN-20953 produced the first female flower at lower most node (3.23) and it was found statistically at par with genotypes CGN-19533 (3.47) and CGN-20969 (3.87), whereas first female flower appeared at later node (9.87) in the genotype LC-21-6. Among the hybrids, node number bearing first female flower ranged from 2.73-10.95 (Table 4.2). Cross combination CGN-20953 x Poinsette produced the first female flower at lower most node (2.73) and it was found statistically at par with three other cross combinations *viz.*, CGN-19533 x K-75 (3.10), LC-1-1 x K-75 (3.15) and LC-2-2 x Poinsette (3.17). While, the cross combination LC-21-6 x Japanese Long Green produced the first female flower at later node (10.95), which was followed by LC-12-4 x Japanese Long Green (10.28). Amongst the hybrids, eight hybrid combinations *viz.*, CGN-20953 x Poinsette (2.73), CGN-19533 x K-75 (3.10), LC-1-1 x K-75 (3.15), LC-2-2 x Poinsette (3.17), Gyne-5 x K-75 (3.50), CGN-21585 x Poinsette (3.72), LC-15-5 x Poinsette (4.20) and LC-3-3 x Poinsette (4.38) resulted in early female flower appearance at lower node than both the checks KH-1 (4.82) and Pusa Sanyog (5.38), whereas only three hybrid combinations *viz.*, CGN-20953 x K-75 (4.82), LC-12-4 x Poinsette (4.83) and LC-3-3 x K-75 (5.02) were found superior over check cultivar Pusa Sanyog for the trait under study.

Table 4.2 Mean performance of parents and hybrids for node number bearing first female flower (NNBFFF)

Parents/Hybrids	**NNBFFF**	**Hybrids**	**NNBFFF**
CGN-19533	3.47	CGN-21585 x JLG	8.68
CGN-20256	5.00	CGN-21585 x Poinsette	3.72
CGN-20515	4.27	CGN-22930 x K-75	6.48
CGN-20953	3.23	CGN-22930 x JLG	6.78
CGN-20969	3.87	CGN-22930 x Poinsette	5.77
CGN-21585	4.53	LC-1-1 x K-75	3.15
CGN-22930	4.40	LC-1-1 x JLG	7.98
LC-1-1	5.07	LC-1-1 x Poinsette	5.38
LC-2-2	5.60	LC-2-2 x K-75	5.02
LC-3-3	6.60	LC-2-2 x JLG	10.08
LC-12-4	8.80	LC-2-2 x Poinsette	3.17
LC-15-5	5.87	LC-3-3 x K-75	7.37
LC-21-6	9.87	LC-3-3 x JLG	9.88
LC-25-7	7.60	LC-3-3 x Poinsette	4.38
LC-28-8	7.53	LC-12-4 x K-75	8.10
Gyne-5	4.27	LC-12-4 x JLG	10.28
K-75	7.53	LC-12-4 x Poinsette	4.83
Japanese Long Green (JLG)	8.47	LC-15-5 x K-75	7.45
Poinsette	4.53	LC-15-5 x JLG	9.37
CGN-19533 x K-75	3.10	LC-15-5 x Poinsette	4.20
CGN-19533 x JLG	8.40	LC-21-6 x K-75	6.33
CGN-19533 x Poinsette	5.90	LC-21-6 x JLG	10.95
CGN-20256 x K-75	8.73	LC-21-6 x Poinsette	8.27
CGN-20256 x JLG	8.23	LC-25-7 x K-75	7.57
CGN-20256 x Poinsette	6.40	LC-25-7 x JLG	7.55
CGN-20515 x K-75	6.38	LC-25-7 x Poinsette	6.35
CGN-20515 x JLG	6.68	LC-28-8 x K-75	5.70
CGN-20515 x Poinsette	5.70	LC-28-8 x JLG	9.98
CGN-20953 x K-75	4.82	LC-28-8 x Poinsette	7.95
CGN-20953 x JLG	9.82	Gyne-5 x K-75	3.50
CGN-20953 x Poinsette	2.73	Gyne-5 x JLG	7.70
CGN-20969 x K-75	6.48	Gyne-5 x Poinsette	6.30
CGN-20969 x JLG	6.82	**KH-1 (Check-I)**	4.82
CGN-20969 x Poinsette	5.87	**Pusa Sanyog (Check-II)**	5.38
CGN-21585 x K-75	7.22	**Mean**	6.44
S.E. (d) ±	**0.38**	**C.D.$_{(0.05)}$**	**0.76**

4.1.3 Days to marketable maturity

Significant variations among the parents and hybrids were observed for days to marketable maturity (Appendix-II). Among the parents, days to marketable maturity ranged from 58.13-70.33 (Table 4.3). Minimum days to marketable maturity (58.13) were recorded in the genotype CGN-20953 and it was found statistically at par with CGN-19533 (58.23) and CGN-20969 (58.97). Whereas, the genotype LC-21-6 resulted in maximum days to marketable maturity (70.33). Among the hybrids, days to marketable maturity ranged from 55.00-72.40 (Table 4.3). Hybrid combination CGN-20953 x Poinsette recorded minimum days to marketable maturity (55.00) and found statistically at par with LC-1-1 x K-75 (56.03) and LC-2-2 x Poinsette (56.27). The cross combination LC-21-6 x Japanese Long Green took maximum days (72.40) to marketable maturity followed by CGN-20953 x Japanese Long Green (71.17). Amongst all the hybrids, seven hybrid combinations *viz.*, CGN-20953 x Poinsette (55.00), LC-1-1 x K-75 (56.03), LC-2-2 x Poinsette (56.27), CGN-19533 x K-75 (56.87), Gyne-5 x K-75 (57.53), CGN-20953 x K-75 (57.93) and CGN-21585 x Poinsette (58.03) were found superior over both the checks *viz.*, KH-1 (58.63) and Pusa Sanyog (60.03), whereas hybrid combinations LC-3-3 x K-75 (59.50) and LC-15-5 x Poinsette (59.63) were found better over check cultivar Pusa Sanyog for days to marketable maturity**.**

4.1.4 Fruit length (cm)

The parents and hybrids studied indicated significant variations for fruit length (Appendix-II). Among the parents, fruit length ranged from 12.20-24.17 cm (Table 4.4). Significantly maximum fruit length of 24.17 cm was recorded in the genotype Japanese Long Green and minimum (12.20 cm) was observed in CGN-20256. Among the hybrids, fruit length ranged from 14.80-24.60 cm in the present study (Table 4.4). Cross combination LC-25-7 x Japanese Long Green recorded the longest fruit of 24.60 cm among all cross combinations. Whereas, minimum fruit length (14.80 cm) was observed in the hybrid combination CGN-20969 x Poinsette, which was followed by CGN-20256 x Poinsette (15.07 cm), CGN-20969 x K-75 (15.23 cm), KH-1 (15.53 cm), LC-21-6 x K-75 (15.93 cm) and LC-21-6 x Poinsette (16.10 cm). Amongst all the hybrids, twenty three hybrid combinations resulted in higher fruit length than both the check cultivars KH-1 (15.53 cm) and Pusa Sanyog (18.93 cm), whereas twenty two hybrid combinations were found superior over KH-1 for this trait.

Table 4.3 Mean performance of parents and hybrids for days to marketable maturity (DTMM)

Parents/Hybrids	**DTMM**	**Hybrids**	**DTMM**
CGN-19533	58.23	CGN-21585 x JLG	67.10
CGN-20256	61.00	CGN-21585 x Poinsette	58.03
CGN-20515	59.70	CGN-22930 x K-75	63.20
CGN-20953	58.13	CGN-22930 x JLG	64.40
CGN-20969	58.97	CGN-22930 x Poinsette	62.33
CGN-21585	60.17	LC-1-1 x K-75	56.03
CGN-22930	59.90	LC-1-1 x JLG	64.53
LC-1-1	61.13	LC-1-1 x Poinsette	61.50
LC-2-2	62.13	LC-2-2 x K-75	60.53
LC-3-3	63.93	LC-2-2 x JLG	69.60
LC-12-4	67.80	LC-2-2 x Poinsette	56.27
LC-15-5	62.60	LC-3-3 x K-75	64.63
LC-21-6	70.33	LC-3-3 x JLG	70.03
LC-25-7	65.67	LC-3-3 x Poinsette	59.50
LC-28-8	65.60	LC-12-4 x K-75	67.03
Gyne-5	59.67	LC-12-4 x JLG	70.77
K-75	65.60	LC-12-4 x Poinsette	61.23
Japanese Long Green (JLG)	67.20	LC-15-5 x K-75	66.80
Poinsette	60.13	LC-15-5 x JLG	68.37
CGN-19533 x K-75	56.87	LC-15-5 x Poinsette	59.63
CGN-19533 x JLG	66.37	LC-21-6 x K-75	63.50
CGN-19533 x Poinsette	61.60	LC-21-6 x JLG	72.40
CGN-20256 x K-75	68.10	LC-21-6 x Poinsette	66.97
CGN-20256 x JLG	66.97	LC-25-7 x K-75	64.10
CGN-20256 x Poinsette	63.33	LC-25-7 x JLG	64.57
CGN-20515 x K-75	63.10	LC-25-7 x Poinsette	62.53
CGN-20515 x JLG	64.67	LC-28-8 x K-75	62.07
CGN-20515 x Poinsette	60.97	LC-28-8 x JLG	70.33
CGN-20953 x K-75	57.93	LC-28-8 x Poinsette	66.33
CGN-20953 x JLG	71.17	Gyne-5 x K-75	57.53
CGN-20953 x Poinsette	55.00	Gyne-5 x JLG	65.63
CGN-20969 x K-75	63.43	Gyne-5 x Poinsette	63.17
CGN-20969 x JLG	64.20	**KH-1 (Check-I)**	58.63
CGN-20969 x Poinsette	61.77	**Pusa Sanyog (Check-II)**	60.03
CGN-21585 x K-75	64.57	**Mean**	63.29
S.E. (d) ±	**0.75**	**C.D.$_{(0.05)}$**	**1.51**

Table 4.4 Mean performance of parents and hybrids for fruit length (FL)

Parents/Hybrids	FL (cm)	Hybrids	FL (cm)
CGN-19533	18.40	CGN-21585 x JLG	18.37
CGN-20256	12.20	CGN-21585 x Poinsette	16.67
CGN-20515	14.73	CGN-22930 x K-75	19.93
CGN-20953	19.83	CGN-22930 x JLG	20.23
CGN-20969	15.30	CGN-22930 x Poinsette	19.70
CGN-21585	15.37	LC-1-1 x K-75	22.10
CGN-22930	19.60	LC-1-1 x JLG	19.73
LC-1-1	17.77	LC-1-1 x Poinsette	20.17
LC-2-2	15.70	LC-2-2 x K-75	18.53
LC-3-3	17.23	LC-2-2 x JLG	19.73
LC-12-4	16.10	LC-2-2 x Poinsette	18.47
LC-15-5	17.87	LC-3-3 x K-75	20.07
LC-21-6	16.77	LC-3-3 x JLG	18.33
LC-25-7	21.93	LC-3-3 x Poinsette	19.97
LC-28-8	17.50	LC-12-4 x K-75	17.73
Gyne-5	16.03	LC-12-4 x JLG	19.27
K-75	15.47	LC-12-4 x Poinsette	18.20
Japanese Long Green (JLG)	24.17	LC-15-5 x K-75	19.47
Poinsette	15.73	LC-15-5 x JLG	21.00
CGN-19533 x K-75	21.90	LC-15-5 x Poinsette	18.17
CGN-19533 x JLG	19.57	LC-21-6 x K-75	15.93
CGN-19533 x Poinsette	19.50	LC-21-6 x JLG	18.40
CGN-20256 x K-75	16.37	LC-21-6 x Poinsette	16.10
CGN-20256 x JLG	16.50	LC-25-7 x K-75	20.53
CGN-20256 x Poinsette	15.07	LC-25-7 x JLG	24.60
CGN-20515 x K-75	17.60	LC-25-7 x Poinsette	18.20
CGN-20515 x JLG	17.23	LC-28-8 x K-75	18.87
CGN-20515 x Poinsette	16.70	LC-28-8 x JLG	21.00
CGN-20953 x K-75	20.83	LC-28-8 x Poinsette	18.70
CGN-20953 x JLG	19.47	Gyne-5 x K-75	21.60
CGN-20953 x Poinsette	21.63	Gyne-5 x JLG	20.17
CGN-20969 x K-75	15.23	Gyne-5 x Poinsette	18.87
CGN-20969 x JLG	17.50	**KH-1 (Check-I)**	15.53
CGN-20969 x Poinsette	14.80	**Pusa Sanyog (Check-II)**	18.93
CGN-21585 x K-75	18.20	**Mean**	18.39
S.E. (d) ±	**0.67**	**C.D.$_{(0.05)}$**	**1.33**

4.1.5 Fruit breadth (cm)

The analysis of variance revealed significant differences among parents and hybrids for fruit breadth (Appendix-II). Among the parents, fruit breadth ranged from 3.40-5.60 cm (Table 4.5). The genotype CGN-20515 recorded maximum fruit breadth (5.60 cm) and it was found at par with LC-15-5 (5.47 cm). Minimum fruit breadth of 3.40 cm was observed in Japanese Long Green. Fruit breadth ranged from 3.53-6.23 cm among the hybrids (Table 4.5). Highest fruit breadth of 6.23 cm was recorded in the hybrid combination CGN-20515 x Japanese Long Green and lowest (3.53 cm) was observed in the cross combinations CGN-20256 x Japanese Long Green and CGN-20969 x Japanese Long Green, which were followed by CGN-22930 x Japanese Long Green (3.57 cm) and CGN-20953 x Japanese Long Green (3.67 cm). Eleven hybrid combinations were found superior over both the check cultivars.

4.1.6 Average fruit weight (g)

Significant differences were obtained among the parents and hybrids for average fruit weight (Appendix-II). It ranged from 167.30-348.63 g in parents (Table 4.6). Significantly highest average fruit weight of 348.63 g was recorded in the genotype Japanese Long Green and lowest (167.30 g) in CGN-20256. Among the hybrids, average fruit weight ranged from 214.33-369.60 g (Table 4.6). Hybrid combination LC-25-7 x Japanese Long Green recoded highest average fruit weight (369.60 g) among all cross combinations, which was found statistically at par with LC-1-1 x K-75 (352.60 g). The cross combination CGN-20969 x Poinsette resulted in lowest average fruit weight (214.33 g) followed by CGN-20256 x Poinsette (216.60 g), CGN-20256 x Japanese Long Green (220.57 g), LC-21-6 x Poinsette (224.53 g) and CGN-20969 x K-75 (227.85 g). Fourteen cross combinations among all the hybrids resulted in higher average fruit weight than both the check cultivars KH-1 (254.17 g) and Pusa Sanyog (297.53 g). Twenty five hybrid combinations were found superior over KH-1 for this trait.

4.1.7 Number of marketable fruits per plant

All the parents and hybrids revealed significant variations for this character (Appendix-II). Among the parents, number of marketable fruits per plant ranged from 3.77-8.67 (Table 4.7). The genotype Gyne-5 recorded maximum number of marketable fruits per plant (8.67), followed by LC-1-1 (8.63), CGN-20515 (8.60) and

Table 4.5 Mean performance of parents and hybrids for fruit breadth (FB)

Parents/Hybrids	FB (cm)	Hybrids	FB (cm)
CGN-19533	4.47	CGN-21585 x JLG	4.47
CGN-20256	4.70	CGN-21585 x Poinsette	5.00
CGN-20515	5.60	CGN-22930 x K-75	5.40
CGN-20953	4.03	CGN-22930 x JLG	3.57
CGN-20969	4.83	CGN-22930 x Poinsette	4.60
CGN-21585	4.43	LC-1-1 x K-75	5.70
CGN-22930	4.27	LC-1-1 x JLG	4.00
LC-1-1	4.90	LC-1-1 x Poinsette	5.23
LC-2-2	5.10	LC-2-2 x K-75	5.60
LC-3-3	4.93	LC-2-2 x JLG	4.33
LC-12-4	4.70	LC-2-2 x Poinsette	4.73
LC-15-5	5.47	LC-3-3 x K-75	5.29
LC-21-6	5.03	LC-3-3 x JLG	3.93
LC-25-7	4.10	LC-3-3 x Poinsette	5.38
LC-28-8	4.50	LC-12-4 x K-75	5.27
Gyne-5	4.87	LC-12-4 x JLG	3.93
K-75	4.97	LC-12-4 x Poinsette	5.40
Japanese Long Green (JLG)	3.40	LC-15-5 x K-75	4.63
Poinsette	5.20	LC-15-5 x JLG	4.83
CGN-19533 x K-75	5.50	LC-15-5 x Poinsette	5.87
CGN-19533 x JLG	4.53	LC-21-6 x K-75	5.23
CGN-19533 x Poinsette	4.60	LC-21-6 x JLG	4.20
CGN-20256 x K-75	5.27	LC-21-6 x Poinsette	4.17
CGN-20256 x JLG	3.53	LC-25-7 x K-75	4.60
CGN-20256 x Poinsette	4.73	LC-25-7 x JLG	4.20
CGN-20515 x K-75	4.77	LC-25-7 x Poinsette	4.40
CGN-20515 x JLG	6.23	LC-28-8 x K-75	5.17
CGN-20515 x Poinsette	5.73	LC-28-8 x JLG	4.20
CGN-20953 x K-75	5.60	LC-28-8 x Poinsette	4.10
CGN-20953 x JLG	3.67	Gyne-5 x K-75	5.37
CGN-20953 x Poinsette	5.27	Gyne-5 x JLG	5.03
CGN-20969 x K-75	5.15	Gyne-5 x Poinsette	4.50
CGN-20969 x JLG	3.53	**KH-1 (Check-I)**	5.30
CGN-20969 x Poinsette	4.87	**Pusa Sanyog (Check-II)**	5.33
CGN-21585 x K-75	4.50	**Mean**	4.78
S.E. (d) ±	**0.15**	**C.D.$_{(0.05)}$**	**0.29**

Table 4.6 Mean performance of parents and hybrids for average fruit weight (AFW)

Parents/Hybrids	AFW (g)	Hybrids	AFW (g)
CGN-19533	268.73	CGN-21585 x JLG	268.17
CGN-20256	167.30	CGN-21585 x Poinsette	248.33
CGN-20515	225.67	CGN-22930 x K-75	310.67
CGN-20953	285.73	CGN-22930 x JLG	285.93
CGN-20969	222.27	CGN-22930 x Poinsette	293.10
CGN-21585	216.60	LC-1-1 x K-75	352.60
CGN-22930	285.73	LC-1-1 x JLG	283.47
LC-1-1	265.33	LC-1-1 x Poinsette	311.80
LC-2-2	233.60	LC-2-2 x K-75	290.27
LC-3-3	256.83	LC-2-2 x JLG	289.13
LC-12-4	233.60	LC-2-2 x Poinsette	274.40
LC-15-5	276.67	LC-3-3 x K-75	311.12
LC-21-6	250.60	LC-3-3 x JLG	258.53
LC-25-7	322.57	LC-3-3 x Poinsette	310.95
LC-28-8	254.00	LC-12-4 x K-75	271.00
Gyne-5	235.30	LC-12-4 x JLG	274.40
K-75	227.37	LC-12-4 x Poinsette	281.20
Japanese Long Green (JLG)	348.63	LC-15-5 x K-75	289.70
Poinsette	235.87	LC-15-5 x JLG	319.17
CGN-19533 x K-75	345.80	LC-15-5 x Poinsette	288.57
CGN-19533 x JLG	290.37	LC-21-6 x K-75	239.83
CGN-19533 x Poinsette	289.70	LC-21-6 x JLG	264.20
CGN-20256 x K-75	247.77	LC-21-6 x Poinsette	224.53
CGN-20256 x JLG	220.57	LC-25-7 x K-75	307.27
CGN-20256 x Poinsette	216.60	LC-25-7 x JLG	369.60
CGN-20515 x K-75	260.23	LC-25-7 x Poinsette	264.20
CGN-20515 x JLG	278.93	LC-28-8 x K-75	288.57
CGN-20515 x Poinsette	261.37	LC-28-8 x JLG	308.40
CGN-20953 x K-75	329.37	LC-28-8 x Poinsette	267.60
CGN-20953 x JLG	273.27	Gyne-5 x K-75	338.43
CGN-20953 x Poinsette	337.30	Gyne-5 x JLG	308.40
CGN-20969 x K-75	227.85	Gyne-5 x Poinsette	277.23
CGN-20969 x JLG	237.57	**KH-1 (Check-I)**	254.17
CGN-20969 x Poinsette	214.33	**Pusa Sanyog (Check-II)**	297.53
CGN-21585 x K-75	265.90	**Mean**	274.37
S.E. (d) ±	**11.28**	**C.D.$_{(0.05)}$**	**22.57**

Table 4.7 Mean performance of parents and hybrids for number of marketable fruits per plant (NMFPP)

Parents/Hybrids	**NMFPP**	**Hybrids**	**NMFPP**
CGN-19533	6.37	CGN-21585 x JLG	6.27
CGN-20256	7.93	CGN-21585 x Poinsette	11.28
CGN-20515	8.60	CGN-22930 x K-75	8.57
CGN-20953	7.83	CGN-22930 x JLG	8.25
CGN-20969	6.97	CGN-22930 x Poinsette	9.18
CGN-21585	7.67	LC-1-1 x K-75	11.95
CGN-22930	6.00	LC-1-1 x JLG	6.98
LC-1-1	8.63	LC-1-1 x Poinsette	9.58
LC-2-2	8.03	LC-2-2 x K-75	9.93
LC-3-3	7.07	LC-2-2 x JLG	5.08
LC-12-4	4.20	LC-2-2 x Poinsette	11.88
LC-15-5	7.23	LC-3-3 x K-75	7.70
LC-21-6	3.77	LC-3-3 x JLG	5.18
LC-25-7	6.20	LC-3-3 x Poinsette	10.73
LC-28-8	6.53	LC-12-4 x K-75	6.90
Gyne-5	8.67	LC-12-4 x JLG	4.62
K-75	7.10	LC-12-4 x Poinsette	10.10
Japanese Long Green (JLG)	6.03	LC-15-5 x K-75	7.60
Poinsette	8.43	LC-15-5 x JLG	5.57
CGN-19533 x K-75	11.93	LC-15-5 x Poinsette	10.85
CGN-19533 x JLG	6.60	LC-21-6 x K-75	8.67
CGN-19533 x Poinsette	9.17	LC-21-6 x JLG	4.02
CGN-20256 x K-75	6.33	LC-21-6 x Poinsette	6.77
CGN-20256 x JLG	6.88	LC-25-7 x K-75	7.40
CGN-20256 x Poinsette	8.77	LC-25-7 x JLG	7.45
CGN-20515 x K-75	8.68	LC-25-7 x Poinsette	8.72
CGN-20515 x JLG	8.43	LC-28-8 x K-75	9.38
CGN-20515 x Poinsette	9.42	LC-28-8 x JLG	5.05
CGN-20953 x K-75	9.97	LC-28-8 x Poinsette	7.03
CGN-20953 x JLG	5.17	Gyne-5 x K-75	11.67
CGN-20953 x Poinsette	12.03	Gyne-5 x JLG	7.20
CGN-20969 x K-75	8.55	Gyne-5 x Poinsette	8.63
CGN-20969 x JLG	8.28	**KH-1 (Check-I)**	10.45
CGN-20969 x Poinsette	9.20	**Pusa Sanyog (Check-II)**	9.62
CGN-21585 x K-75	7.72	**Mean**	7.98
S.E. (d) ±	**0.27**	**C.D.$_{(0.05)}$**	**0.54**

Poinsette (8.43). Minimum number of marketable fruits per plant (3.77) were observed in the genotype LC-21-6 and it was found statistically at par with LC-12-4 (4.20). Number of marketable fruits per plant ranged from 4.02-12.03 in hybrids (Table 4.7). Maximum number of marketable fruits per plant (12.03) were obtained in the cross combination CGN-20953 x Poinsette and it was found at par with four other hybrid combinations *viz.*, LC-1-1 x K-75 (11.95), CGN-19533 x K-75 (11.93), LC-2-2 x Poinsette (11.88) and Gyne-5 x K-75 (11.67). Significantly minimum number of marketable fruits per plant were (4.02) observed in LC-21-6 x Japanese Long Green. Eight cross combinations, CGN-20953 x Poinsette (12.03), LC-1-1 x K-75 (11.95), CGN-19533 x K-75 (11.93), LC-2-2 x Poinsette (11.88), Gyne-5 x K-75 (11.67), CGN-21585 x Poinsette (11.28), LC-15-5 x Poinsette (10.85) and LC-3-3 x Poinsette (10.73) were found superior over KH-1 (10.45) and Pusa Sanyog (9.62) for number of marketable fruits per plant. Only three cross combinations, LC-12-4 x Poinsette (10.10), CGN-20953 x K-75 (9.97) and LC-2-2 x K-75 (9.93) performed better than Pusa Sanyog.

4.1.8 Harvest duration (days)

Significant variations were observed among the parents and hybrids for harvest duration (Appendix-II). Among the parents, harvest duration ranged from 14.55-28.17 days (Table 4.8). Longest harvest duration of 28.17 days was recorded in the genotype LC-1-1 and it was found statistically at par with Poinsette (26.61 days), LC-2-2 (26.49 days) and Gyne-5 (26.27 days). Shortest harvest duration of 14.55 days was reported LC-21-6 followed by LC-12-4 (15.76 days). Among the hybrids, harvest duration ranged from 14.25-36.69 days (Table 4.8). Longest harvest duration (36.69 days) was observed in the cross combination CGN-20953 x Poinsette and it was found statistically at par with the hybrid combinations, LC-1-1 x K-75 (36.46 days), CGN-19533 x K-75 (36.41 days), LC-2-2 x Poinsette (36.27 days) and Gyne-5 x K-75 (35.67 days). Shortest harvest duration of 14.25 days was observed in the cross combination LC-21-6 x Japanese Long Green and found statistically similar with LC-12-4 x Japanese Long Green (15.93 days). Among all hybrid combinations, eight cross combinations *viz.*, CGN-20953 x Poinsette (36.69 days), LC-1-1 x K-75 (36.46 days), CGN-19533 x K-75 (36.41 days), LC-2-2 x Poinsette (36.27 days), Gyne-5 x K-75 (35.67 days), CGN-21585 x Poinsette (34.59 days), LC-15-5 x Poinsette (33.38 days) and LC-3-3 x Poinsette (33.05 days) performed better than KH-1 (32.26 days)

Table 4.8 Mean performance of parents and hybrids for harvest duration (HD)

Parents/Hybrids	HD (days)	Hybrids	HD (days)
CGN-19533	20.83	CGN-21585 x JLG	20.55
CGN-20256	25.21	CGN-21585 x Poinsette	34.59
CGN-20515	26.08	CGN-22930 x K-75	26.99
CGN-20953	24.93	CGN-22930 x JLG	26.10
CGN-20969	22.51	CGN-22930 x Poinsette	28.71
CGN-21585	24.47	LC-1-1 x K-75	36.46
CGN-22930	19.80	LC-1-1 x JLG	22.55
LC-1-1	28.17	LC-1-1 x Poinsette	29.63
LC-2-2	26.49	LC-2-2 x K-75	30.81
LC-3-3	23.79	LC-2-2 x JLG	17.23
LC-12-4	15.76	LC-2-2 x Poinsette	36.27
LC-15-5	24.25	LC-3-3 x K-75	24.56
LC-21-6	14.55	LC-3-3 x JLG	17.51
LC-25-7	21.36	LC-3-3 x Poinsette	33.05
LC-28-8	22.29	LC-12-4 x K-75	22.32
Gyne-5	26.27	LC-12-4 x JLG	15.93
K-75	23.88	LC-12-4 x Poinsette	31.28
Japanese Long Green (JLG)	20.89	LC-15-5 x K-75	24.28
Poinsette	26.61	LC-15-5 x JLG	18.59
CGN-19533 x K-75	36.41	LC-15-5 x Poinsette	33.38
CGN-19533 x JLG	20.81	LC-21-6 x K-75	27.27
CGN-19533 x Poinsette	28.47	LC-21-6 x JLG	14.25
CGN-20256 x K-75	20.73	LC-21-6 x Poinsette	21.95
CGN-20256 x JLG	22.27	LC-25-7 x K-75	24.05
CGN-20256 x Poinsette	27.55	LC-25-7 x JLG	23.86
CGN-20515 x K-75	27.31	LC-25-7 x Poinsette	27.41
CGN-20515 x JLG	26.28	LC-28-8 x K-75	29.27
CGN-20515 x Poinsette	29.03	LC-28-8 x JLG	17.14
CGN-20953 x K-75	30.91	LC-28-8 x Poinsette	22.69
CGN-20953 x JLG	17.47	Gyne-5 x K-75	35.67
CGN-20953 x Poinsette	36.69	Gyne-5 x JLG	23.16
CGN-20969 x K-75	26.94	Gyne-5 x Poinsette	27.17
CGN-20969 x JLG	26.19	**KH-1 (Check-I)**	32.26
CGN-20969 x Poinsette	28.76	**Pusa Sanyog (Check-II)**	29.93
CGN-21585 x K-75	24.94	**Mean**	25.45
S.E. (d) ±	**0.97**	**C.D.$_{(0.05)}$**	**1.95**

and Pusa Sanyog (29.93 days). Three cross combinations, LC-12-4 x Poinsette (31.28 days), CGN-20953 x K-75 (30.91 days) and LC-2-2 x K-75 (30.81 days) were found superior over Pusa Sanyog for harvest duration.

4.1.9 Marketable yield per plot (kg)

The analysis of variance revealed significant differences among the parents and hybrids for yield per plot (Appendix-II). It ranged from 15.19-36.64 kg among the parents (Table 4.9). Highest yield of 36.64 kg was recorded in the genotype LC-1-1, which was followed by CGN-20953 (35.76 kg) and Japanese Long Green (33.63 kg). While, the genotype LC-21-6 reported lowest (15.19 kg) yield per plot and was found statistically similar with LC-12-4 (15.59 kg). Among the hybrids, a wide range of 16.98-67.39 kg was observed for this trait (Table 4.9). Highest yield was recorded in the hybrid LC-1-1 x K-75 (67.39 kg) and it was found statistically at par with CGN-19533 x K-75 (66.06 kg) and CGN-20953 x Poinsette (64.92 kg). Lowest yield per plot (16.98 kg) was reported in the hybrid combination, LC-21-6 x Japanese Long Green, which was followed by LC-12-4 x Japanese Long Green (20.26 kg). Ten cross combinations *viz.*, LC-1-1 x K-75 (67.39 kg), CGN-19533 x K-75 (66.06 kg), CGN-20953 x Poinsette (64.92 kg), Gyne-5 x K-75 (63.19 kg), LC-3-3 x Poinsette (53.41 kg), CGN-20953 x K-75 (52.54 kg), LC-2-2 x Poinsette (52.17 kg), LC-15-5 x Poinsette (50.10 kg), LC-1-1 x Poinsette (47.83 kg) and LC-2-2 x K-75 (46.10 kg) were found superior over KH-1 (42.50 kg) and Pusa Sanyog (45.79 kg). Only six hybrid combinations *viz.*, LC-12-4 x Poinsette (45.46 kg), CGN-21585 x Poinsette (44.84 kg), LC-25-7 x Japanese Long Green (44.05 kg), LC-28-8 x K-75 (43.32 kg), CGN-22930 x Poinsette (43.06 kg) and CGN-22930 x K-75 (42.58 kg) reported higher yield per plot than check cultivar KH-1.

4.1.10 Marketable yield per hectare (q)

The parents and hybrids studied indicated significant variations for yield per hectare (Appendix-II). Among the parents, yield per hectare ranged from 101.30-244.36 q (Table 4.10). The genotype LC-1-1 recorded highest yield per hectare (244.36 q), which was found statistically at par with CGN-20953 (238.55 q) and Japanese Long Green (224.33 q). Lowest yield per hectare (101.30 q) was observed in the genotype LC-21-6 followed by LC-12-4 (103.98 q). A wide range of 113.27-449.52 q for yield per hectare was observed among the hybrids (Table 4.10). The

Table 4.9 Mean performance of parents and hybrids for marketable yield per plot (MYPP)

Parents/Hybrids	MYPP (kg)	Hybrids	MYPP (kg)
CGN-19533	27.32	CGN-21585 x JLG	26.91
CGN-20256	21.15	CGN-21585 x Poinsette	44.84
CGN-20515	31.00	CGN-22930 x K-75	42.58
CGN-20953	35.76	CGN-22930 x JLG	37.73
CGN-20969	24.74	CGN-22930 x Poinsette	43.06
CGN-21585	26.46	LC-1-1 x K-75	67.39
CGN-22930	27.27	LC-1-1 x JLG	31.66
LC-1-1	36.64	LC-1-1 x Poinsette	47.83
LC-2-2	30.02	LC-2-2 x K-75	46.10
LC-3-3	29.05	LC-2-2 x JLG	23.54
LC-12-4	15.59	LC-2-2 x Poinsette	52.17
LC-15-5	32.02	LC-3-3 x K-75	38.28
LC-21-6	15.19	LC-3-3 x JLG	21.48
LC-25-7	31.82	LC-3-3 x Poinsette	53.41
LC-28-8	26.54	LC-12-4 x K-75	29.90
Gyne-5	32.61	LC-12-4 x JLG	20.26
K-75	25.90	LC-12-4 x Poinsette	45.46
Japanese Long Green (JLG)	33.63	LC-15-5 x K-75	35.25
Poinsette	31.84	LC-15-5 x JLG	28.41
CGN-19533 x K-75	66.06	LC-15-5 x Poinsette	50.10
CGN-19533 x JLG	30.66	LC-21-6 x K-75	33.25
CGN-19533 x Poinsette	42.49	LC-21-6 x JLG	16.98
CGN-20256 x K-75	25.13	LC-21-6 x Poinsette	24.28
CGN-20256 x JLG	24.31	LC-25-7 x K-75	36.36
CGN-20256 x Poinsette	30.39	LC-25-7 x JLG	44.05
CGN-20515 x K-75	36.15	LC-25-7 x Poinsette	36.86
CGN-20515 x JLG	37.64	LC-28-8 x K-75	43.32
CGN-20515 x Poinsette	39.38	LC-28-8 x JLG	24.93
CGN-20953 x K-75	52.54	LC-28-8 x Poinsette	30.10
CGN-20953 x JLG	22.59	Gyne-5 x K-75	63.19
CGN-20953 x Poinsette	64.92	Gyne-5 x JLG	35.51
CGN-20969 x K-75	31.18	Gyne-5 x Poinsette	38.29
CGN-20969 x JLG	31.48	**KH-1 (Check-I)**	42.50
CGN-20969 x Poinsette	31.54	**Pusa Sanyog (Check-II)**	45.79
CGN-21585 x K-75	32.84	**Mean**	35.30
S.E. (d) ±	**1.72**	**C.D.$_{(0.05)}$**	**3.44**

Table 4.10 Mean performance of parents and hybrids for marketable yield per hectare (MYPH)

Parents/Hybrids	MYPH (q)	Hybrids	MYPH (q)
CGN-19533	182.25	CGN-21585 x JLG	179.51
CGN-20256	141.06	CGN-21585 x Poinsette	299.10
CGN-20515	206.75	CGN-22930 x K-75	284.03
CGN-20953	238.55	CGN-22930 x JLG	251.69
CGN-20969	164.99	CGN-22930 x Poinsette	287.24
CGN-21585	176.51	LC-1-1 x K-75	449.52
CGN-22930	181.87	LC-1-1 x JLG	211.20
LC-1-1	244.36	LC-1-1 x Poinsette	319.03
LC-2-2	200.20	LC-2-2 x K-75	307.48
LC-3-3	193.78	LC-2-2 x JLG	156.98
LC-12-4	103.98	LC-2-2 x Poinsette	348.00
LC-15-5	213.54	LC-3-3 x K-75	255.30
LC-21-6	101.30	LC-3-3 x JLG	143.30
LC-25-7	212.27	LC-3-3 x Poinsette	356.23
LC-28-8	177.00	LC-12-4 x K-75	199.46
Gyne-5	217.51	LC-12-4 x JLG	135.13
K-75	172.78	LC-12-4 x Poinsette	303.22
Japanese Long Green (JLG)	224.33	LC-15-5 x K-75	235.11
Poinsette	212.35	LC-15-5 x JLG	189.52
CGN-19533 x K-75	440.61	LC-15-5 x Poinsette	334.19
CGN-19533 x JLG	204.48	LC-21-6 x K-75	221.75
CGN-19533 x Poinsette	283.44	LC-21-6 x JLG	113.27
CGN-20256 x K-75	167.62	LC-21-6 x Poinsette	161.94
CGN-20256 x JLG	162.14	LC-25-7 x K-75	242.52
CGN-20256 x Poinsette	202.68	LC-25-7 x JLG	293.85
CGN-20515 x K-75	241.11	LC-25-7 x Poinsette	245.84
CGN-20515 x JLG	251.08	LC-28-8 x K-75	288.97
CGN-20515 x Poinsette	262.68	LC-28-8 x JLG	166.27
CGN-20953 x K-75	350.42	LC-28-8 x Poinsette	200.74
CGN-20953 x JLG	150.70	Gyne-5 x K-75	421.47
CGN-20953 x Poinsette	433.04	Gyne-5 x JLG	236.88
CGN-20969 x K-75	207.96	Gyne-5 x Poinsette	255.39
CGN-20969 x JLG	209.98	**KH-1 (Check-I)**	283.44
CGN-20969 x Poinsette	210.38	**Pusa Sanyog (Check-II)**	305.44
CGN-21585 x K-75	219.04	**Mean**	235.45
S.E. (d) ±	**11.45**	**C.D.$_{(0.05)}$**	**22.93**

cross combination LC-1-1 x K-75 (449.52 q) recorded highest yield per hectare and it was found statistically at par with CGN-19533 x K-75 (440.61 q) and CGN-20953 x Poinsette (433.04 q). Lowest yield per hectare (113.27 q) was noticed in the hybrid combination, LC-21-6 x Japanese Long Green, followed by LC-12-4 x Japanese Long Green (135.13 q). Among all cross combinations, ten combinations *viz.*, LC-1-1 x K-75 (449.52 q), CGN-19533 x K-75 (440.61 q), CGN-20953 x Poinsette (433.04 q), Gyne-5 x K-75 (421.47 q), LC-3-3 x Poinsette (356.23 q), CGN-20953 x K-75 (350.42 q), LC-2-2 x Poinsette (348.00 q), LC-15-5 x Poinsette (334.19 q), LC-1-1 x Poinsette (319.03 q) and LC-2-2 x K-75 (307.48 q) performed better than KH-1 (283.44 q) and Pusa Sanyog (305.44 q). Six hybrid combinations *viz.*, LC-12-4 x Poinsette (303.22 q), CGN-21585 x Poinsette (299.10 q), LC-25-7 x Japanese Long Green (293.85 q), LC-28-8 x K-75 (288.97 q), CGN-22930 x Poinsette (287.24 q) and CGN-22930 x K-75 (284.03 q) were found superior over KH-1 (Check-I) for yield per hectare.

4.1.11 Total soluble solids (^{o}B)

The observations recorded on this trait showed significant differences among the parents and hybrids (Appendix-II). Total soluble solids (TSS) content in parents varied from 2.67-4.03 ^{o}B (Table 4.11). Maximum TSS of 4.03 ^{o}B was recorded in the genotype CGN-21585 and minimum in LC-21-6 (2.67 ^{o}B). TSS content among the hybrids ranged from 2.63-4.07 ^{o}B (Table 4.11). Cross combination CGN-21585 x Japanese Long Green recorded maximum TSS (4.07 ^{o}B), whereas minimum was reported in the combination LC-21-6 x K-75 (2.63 ^{o}B) followed by LC-21-6 x Poinsette (2.70 ^{o}B). TSS content in nine hybrid combination *viz.*, CGN-21585 x Japanese Long Green (4.07 ^{o}B), LC-28-8 x K-75 (3.90 ^{o}B), LC-28-8 x Japanese Long Green (3.75 ^{o}B), CGN-21585 x Poinsette (3.60 ^{o}B), LC-1-1 x K-75 (3.60 ^{o}B), CGN-20953 x Japanese Long Green (3.57 ^{o}B), CGN-21585 x K-75 (3.48 ^{o}B), LC-1-1 x Poinsette (3.47 ^{o}B) and LC-28-8 x Poinsette (3.47 ^{o}B) was found higher than KH-1 (3.30 ^{o}B) and Pusa Sanyog (3.43 ^{o}B). Only six cross combinations *viz.*, CGN-20256 x Japanese Long Green (3.43 ^{o}B), Gyne-5 x Poinsette (3.42 ^{o}B), Gyne-5 x K-75 (3.37 ^{o}B), CGN-19533 x K-75 (3.37 ^{o}B), CGN-19533 x Japanese Long Green (3.33 ^{o}B) and CGN-20953 x K-75 (3.33 ^{o}B) performed better than KH-1.

Table 4.11 Mean performance of parents and hybrids for total soluble solids (TSS)

Parents/Hybrids	TSS (^{o}B)	Hybrids	TSS (^{o}B)
CGN-19533	2.93	CGN-21585 x JLG	4.07
CGN-20256	3.37	CGN-21585 x Poinsette	3.60
CGN-20515	2.90	CGN-22930 x K-75	3.03
CGN-20953	3.17	CGN-22930 x JLG	3.17
CGN-20969	3.20	CGN-22930 x Poinsette	3.05
CGN-21585	4.03	LC-1-1 x K-75	3.60
CGN-22930	3.07	LC-1-1 x JLG	3.12
LC-1-1	3.20	LC-1-1 x Poinsette	3.47
LC-2-2	3.10	LC-2-2 x K-75	2.98
LC-3-3	2.97	LC-2-2 x JLG	3.30
LC-12-4	2.93	LC-2-2 x Poinsette	3.02
LC-15-5	3.07	LC-3-3 x K-75	3.12
LC-21-6	2.67	LC-3-3 x JLG	3.17
LC-25-7	3.07	LC-3-3 x Poinsette	3.07
LC-28-8	3.73	LC-12-4 x K-75	2.97
Gyne-5	3.20	LC-12-4 x JLG	3.22
K-75	3.10	LC-12-4 x Poinsette	3.03
Japanese Long Green (JLG)	3.23	LC-15-5 x K-75	3.00
Poinsette	3.17	LC-15-5 x JLG	3.30
CGN-19533 x K-75	3.37	LC-15-5 x Poinsette	3.10
CGN-19533 x JLG	3.33	LC-21-6 x K-75	2.63
CGN-19533 x Poinsette	3.10	LC-21-6 x JLG	3.00
CGN-20256 x K-75	3.13	LC-21-6 x Poinsette	2.70
CGN-20256 x JLG	3.43	LC-25-7 x K-75	3.17
CGN-20256 x Poinsette	3.08	LC-25-7 x JLG	3.20
CGN-20515 x K-75	3.10	LC-25-7 x Poinsette	3.10
CGN-20515 x JLG	3.03	LC-28-8 x K-75	3.90
CGN-20515 x Poinsette	2.88	LC-28-8 x JLG	3.75
CGN-20953 x K-75	3.33	LC-28-8 x Poinsette	3.47
CGN-20953 x JLG	3.57	Gyne-5 x K-75	3.37
CGN-20953 x Poinsette	3.12	Gyne-5 x JLG	3.10
CGN-20969 x K-75	3.15	Gyne-5 x Poinsette	3.42
CGN-20969 x JLG	3.27	**KH-1 (Check-I)**	3.30
CGN-20969 x Poinsette	3.10	**Pusa Sanyog (Check-II)**	3.43
CGN-21585 x K-75	3.48	**Mean**	3.21
S.E. (d) ±	**0.08**	**C.D.$_{(0.05)}$**	**0.16**

4.1.12 Cucurbitacin content (µg/100g)

The estimates of cucurbitacin content varied significantly among the parents and hybrids (Appendix-II). It was ranged from 100.62-120.17 µg/100g among the parents (Table 4.12). The genotype CGN-21585 recorded minimum cucurbitacin content of 100.62 µg/100g and was found statistically at par with CGN-20256 (101.06 µg/100g) and CGN-20969 (102.41 µg/100g). Significantly maximum cucurbitacin content (120.17 µg/100g) was observed in LC-12-4 followed by LC-21-6 (118.98 µg/100g). Cucurbitacin content among the hybrids ranged from 95.57-123.58 µg/100g (Table 4.12). Significantly minimum cucurbitacin content (95.57 µg/100g) was reported in the cross combination CGN-21585 x Japanese Long Green, whereas maximum (123.58 µg/100g) was observed in LC-21-6 x Poinsette, followed by LC-12-4 x Poinsette (122.84 µg/100g). Cucurbitacin content in seven cross combination *viz.*, CGN-21585 x Japanese Long Green (95.57 µg/100g), LC-28-8 x K-75 (98.61 µg/100g), CGN-20256 x Japanese Long Green (99.27 µg/100g), CGN-20953 x Japanese Long Green (99.88 µg/100g), LC-1-1 x K-75 (100.36 µg/100g) and LC-28-8 x Poinsette (103.22 µg/100g) was found lower than KH-1 (104.79 µg/100g) and Pusa Sanyog (103.62 µg/100g). Three hybrid combinations CGN-21585 x K-75 (104.10 µg/100g), CGN-19533 x Japanese Long Green (104.25 µg/100g) and CGN-22930 x Japanese Long Green (104.44 µg/100g) were also found lower in cucurbitacin content than KH-1.

4.1.13 Fruit colour

Among the parents, five (CGN-19533, CGN-20953, Poinsette, CGN-22930 and CGN-20969), six (CGN-20515, LC-3-3, LC-12-4, LC-15-5, LC-28-8, and Japanese Long Green), five (LC-1-1, LC-21-6, LC-25-7, Gyne-5 and K-75) and three (LC-2-2, CGN-21585 and CGN-20256) parents had dark green, green, light green and yellow green coloured fruits, respectively (Table 4.13). Among the hybrids, three (CGN-22930 x Poinsette, CGN-20969 x Poinsette and CGN-20953 x Poinsette), twenty six (CGN-19533 x Japanese Long Green, CGN-19533 x Poinsette, CGN-20256 x Poinsette, CGN-20515 x Poinsette, CGN-20953 x K-75, CGN-20953 x Japanese Long Green, CGN-20969 x K-75, CGN-20969 x Japanese Long Green, CGN-21585 x Japanese Long Green, CGN-21585 x Poinsette, CGN-22930 x K-75, CGN-22930 x Japanese Long Green, LC-1-1 x Poinsette, LC-3-3 x Japanese Long Green, LC-3-3 x Poinsette, LC-12-4 x Poinsette, LC-15-5 x K-75, LC-15-5 x

Table 4.12 Mean performance of parents and hybrids for cucurbitacin content (CC)

Parents/Hybrids	**CC (μg/100g)**	**Hybrids**	**CC (μg/100g)**
CGN-19533	106.14	CGN-21585 x JLG	95.57
CGN-20256	101.06	CGN-21585 x Poinsette	106.31
CGN-20515	106.54	CGN-22930 x K-75	107.19
CGN-20953	103.99	CGN-22930 x JLG	104.44
CGN-20969	102.41	CGN-22930 x Poinsette	108.24
CGN-21585	100.62	LC-1-1 x K-75	100.36
CGN-22930	104.58	LC-1-1 x JLG	108.63
LC-1-1	113.18	LC-1-1 x Poinsette	106.81
LC-2-2	114.75	LC-2-2 x K-75	108.87
LC-3-3	115.72	LC-2-2 x JLG	114.70
LC-12-4	120.17	LC-2-2 x Poinsette	111.49
LC-15-5	114.63	LC-3-3 x K-75	111.25
LC-21-6	118.98	LC-3-3 x JLG	109.03
LC-25-7	114.63	LC-3-3 x Poinsette	119.39
LC-28-8	109.63	LC-12-4 x K-75	112.23
Gyne-5	107.17	LC-12-4 x JLG	111.00
K-75	115.69	LC-12-4 x Poinsette	122.84
Japanese Long Green (JLG)	111.75	LC-15-5 x K-75	118.40
Poinsette	116.10	LC-15-5 x JLG	111.00
CGN-19533 x K-75	108.53	LC-15-5 x Poinsette	113.96
CGN-19533 x JLG	104.25	LC-21-6 x K-75	116.18
CGN-19533 x Poinsette	110.11	LC-21-6 x JLG	114.70
CGN-20256 x K-75	107.44	LC-21-6 x Poinsette	123.58
CGN-20256 x JLG	99.27	LC-25-7 x K-75	108.24
CGN-20256 x Poinsette	108.43	LC-25-7 x JLG	115.19
CGN-20515 x K-75	109.12	LC-25-7 x Poinsette	112.97
CGN-20515 x JLG	107.19	LC-28-8 x K-75	98.61
CGN-20515 x Poinsette	110.40	LC-28-8 x JLG	112.97
CGN-20953 x K-75	107.30	LC-28-8 x Poinsette	103.22
CGN-20953 x JLG	99.88	Gyne-5 x K-75	106.31
CGN-20953 x Poinsette	108.29	Gyne-5 x JLG	110.26
CGN-20969 x K-75	109.77	Gyne-5 x Poinsette	108.29
CGN-20969 x JLG	105.23	**KH-1 (Check-I)**	104.79
CGN-20969 x Poinsette	112.48	**Pusa Sanyog (Check-II)**	103.62
CGN-21585 x K-75	104.10	**Mean**	109.42
S.E. (d) ±	**1.31**	**C.D.$_{(0.05)}$**	**2.61**

Table 4.13 Mean performance of parents and hybrids for fruit colour (FC)

Parents/Hybrids	*FC	Hybrids	FC
CGN-19533	DG (G 133 A)	CGN-21585 x JLG	G (G 135 C)
CGN-20256	YG (YG 145 B)	CGN-21585 x Poinsette	G (G 141 B)
CGN-20515	G (G 143 A)	CGN-22930 x K-75	G (G 141 B)
CGN-20953	DG (G 141 A)	CGN-22930 x JLG	G (G 141 A)
CGN-20969	DG (G 139 A)	CGN-22930 x Poinsette	DG (G 139 A)
CGN-21585	YG (G 144 B)	LC-1-1 x K-75	LG (G 136 C)
CGN-22930	DG (G 141 A)	LC-1-1 x JLG	LG (G 141 C)
LC-1-1	LG (G 141 C)	LC-1-1 x Poinsette	G (G 141 B)
LC-2-2	YG (YG 144 C)	LC-2-2 x K-75	LG (G 141 D)
LC-3-3	G (G 141 B)	LC-2-2 x JLG	LG (G 144 B)
LC-12-4	G (G 141 B)	LC-2-2 x Poinsette	LG (G 144 D)
LC-15-5	G (G 143 B)	LC-3-3 x K-75	LG (G 140 B)
LC-21-6	LG (G 142 A)	LC-3-3 x JLG	G (G 139 B)
LC-25-7	LG (G 141 C)	LC-3-3 x Poinsette	G (G 139 B)
LC-28-8	G (G 141 B)	LC-12-4 x K-75	LG (G 141 C)
Gyne-5	LG (G 143 C)	LC-12-4 x JLG	LG (G 143 C)
K-75	LG (G 141 C)	LC-12-4 x Poinsette	G (G 141 B)
Japanese Long Green (JLG)	G (G 141 B)	LC-15-5 x K-75	G (G 141 B)
Poinsette	DG (G 139 B)	LC-15-5 x JLG	G (G 141 B)
CGN-19533 x K-75	LG (G 143 A)	LC-15-5 x Poinsette	G (G 139 B)
CGN-19533 x JLG	G (G 135 B)	LC-21-6 x K-75	LG (G 141 D)
CGN-19533 x Poinsette	G (G 139 B)	LC-21-6 x JLG	LG (G 141 C)
CGN-20256 x K-75	YG (YG 145 A)	LC-21-6 x Poinsette	G (G 137 C)
CGN-20256 x JLG	YG (YG 144 B)	LC-25-7 x K-75	LG (G 139 C)
CGN-20256 x Poinsette	G (G 143 B)	LC-25-7 x JLG	G (G 139 B)
CGN-20515 x K-75	LG (G 143 C)	LC-25-7 x Poinsette	G (G 141 B)
CGN-20515 x JLG	LG (G 141 C)	LC-28-8 x K-75	LG (G 141 C)
CGN-20515 x Poinsette	G (G 141 B)	LC-28-8 x JLG	G (G 137 B)
CGN-20953 x K-75	G (G 139 B)	LC-28-8 x Poinsette	G (G 139 B)
CGN-20953 x JLG	G (G 141 B)	Gyne-5 x K-75	LG (G 141 C)
CGN-20953 x Poinsette	DG (G 141 A)	Gyne-5 x JLG	G (G 143 B)
CGN-20969 x K-75	G (G 141 B)	Gyne-5 x Poinsette	G (G 141 B)
CGN-20969 x JLG	G (G 141 B)	**KH-1 (Check-I)**	G (141 B)
CGN-20969 x Poinsette	DG (139 A)	**Pusa Sanyog (Check-II)**	G (G 143 A)
CGN-21585 x K-75	LG (G 141 C)	**Mean**	-

*G: green; LG: light green; DG: dark green and YG; yellow green

Japanese Long Green, LC-15-5 x Poinsette, LC-21-6 x Poinsette, LC-25-7 x Japanese Long Green, LC-25-7 x Poinsette, LC-28-8 x Japanese Long Green, LC-28-8 x Poinsette, Gyne-5 x Japanese Long Green and Gyne-5 x Poinsette), seventeen (CGN-19533 x K-75, CGN-20515 x K-75, CGN-20515 x Japanese Long Green, CGN-21585 x K-75, LC-1-1 x K-75, LC-1-1 x Japanese Long Green, LC-2-2 x K-75, LC-2-2 x Japanese Long Green, LC-2-2 x Poinsette, LC-3-3 x K-75, LC-12-4 x K-75, LC-12-4 x Japanese Long Green, Gyne-5 x K-75, LC-25-7 x K-75, LC-28-8 x K-75, LC-21-6 x K-75 and LC-21-6 x Japanese Long Green) and two (CGN-20256 x Japanese Long Green and CGN-20256 x K-75) had dark green, green, light green and yellow green coloured fruits, respectively. Check cultivars *viz.*, KH-1 and Pusa Sanyog were having fruits of green colour.

4.1.14 Fruit fly incidence (^{o}B)

Data recorded for incidence of fruit fly showed significant differences among the parents and hybrids (Appendix-II). Fruit fly incidence in the parents varied from 16.86-29.65 per cent (Table 4.14). Lowest incidence (16.86 %) of fruit fly was recorded in LC-2-2, followed by LC-1-1 (17.37 %). Significantly highest (29.65 %) fruit fly incidence was reported in Japanese Long Green. Among the hybrids, fruit fly incidence ranged from 10.87-33.71 per cent (Table 4.14). Lowest fruit fly incidence of 10.87 per cent was recorded in the cross combination LC-1-1 x K-75 and it was found statistically at par with LC-3-3 x Poinsette (11.20 %) and LC-15-5 x Poinsette (11.40 %). Highest incidence of fruit fly infestation (33.71 %) was observed in the cross combination CGN-21585 x Japanese Long Green followed by CGN-20953 x Japanese Long Green (32.79 %), Gyne-5 x Japanese Long Green (32.58 %) and CGN-20969 x Japanese Long Green (31.75 %). Among all the hybrids, fruit fly incidence in sixteen cross combinations was found lower than KH-1 (18.52 %) and Pusa Sanyog (19.66 %). Besides this, seven hybrid combinations were found superior over Pusa Sanyog (Check-II).

4.1.15 Severity of powdery mildew (%)

Significant variations were observed among the parents and hybrids for severity of powdery mildew after analysis of data (Appendix-II). Among the parents, severity of powdery mildew ranged from 10.20-23.60 per cent (Table 4.15). Minimum severity of powdery mildew (10.20 %) was recorded in the genotype LC-

Table 4.14 Mean performance of parents and hybrids for fruit fly incidence (FFI)

Parents/Hybrids	*FFI (%)	Hybrids	FFI (%)
CGN-19533	22.96 (28.62)	CGN-21585 x JLG	33.71 (35.47)
CGN-20256	26.32 (30.85)	CGN-21585 x Poinsette	17.63 (24.80)
CGN-20515	21.06 (27.30)	CGN-22930 x K-75	18.27 (25.29)
CGN-20953	20.86 (27.16)	CGN-22930 x JLG	27.07 (31.34)
CGN-20969	25.48 (30.30)	CGN-22930 x Poinsette	18.93 (25.77)
CGN-21585	24.45 (29.62)	LC-1-1 x K-75	10.87 (19.24)
CGN-22930	23.25 (28.81)	LC-1-1 x JLG	29.91 (33.14)
LC-1-1	17.37 (24.62)	LC-1-1 x Poinsette	15.44 (23.13)
LC-2-2	16.86 (24.23)	LC-2-2 x K-75	12.80 (20.94)
LC-3-3	19.48 (26.18)	LC-2-2 x JLG	30.70 (33.62)
LC-12-4	25.47 (30.30)	LC-2-2 x Poinsette	15.29 (23.00)
LC-15-5	19.18 (25.96)	LC-3-3 x K-75	18.72 (25.61)
LC-21-6	24.42 (29.60)	LC-3-3 x JLG	25.95 (30.59)
LC-25-7	23.41 (28.89)	LC-3-3 x Poinsette	11.20 (19.53)
LC-28-8	24.22 (29.47)	LC-12-4 x K-75	18.68 (25.58)
Gyne-5	25.46 (30.29)	LC-12-4 x JLG	31.29 (33.99)
K-75	21.28 (27.46)	LC-12-4 x Poinsette	22.65 (28.41)
Japanese Long Green (JLG)	29.65 (32.98)	LC-15-5 x K-75	15.73 (23.35)
Poinsette	22.43 (28.25)	LC-15-5 x JLG	29.72 (33.01)
CGN-19533 x K-75	17.22 (24.50)	LC-15-5 x Poinsette	11.40 (19.72)
CGN-19533 x JLG	30.67 (33.61)	LC-21-6 x K-75	18.57 (25.51)
CGN-19533 x Poinsette	19.10 (25.90)	LC-21-6 x JLG	30.29 (33.37)
CGN-20256 x K-75	25.12 (30.07)	LC-21-6 x Poinsette	19.19 (25.96)
CGN-20256 x JLG	30.79 (33.69)	LC-25-7 x K-75	21.46 (27.58)
CGN-20256 x Poinsette	18.72 (25.62)	LC-25-7 x JLG	28.57 (32.29)
CGN-20515 x K-75	18.07 (25.14)	LC-25-7 x Poinsette	15.71 (23.33)
CGN-20515 x JLG	29.20 (32.70)	LC-28-8 x K-75	17.56 (24.74)
CGN-20515 x Poinsette	19.84 (26.43)	LC-28-8 x JLG	31.22 (33.95)
CGN-20953 x K-75	13.24 (21.33)	LC-28-8 x Poinsette	20.29 (26.76)
CGN-20953 x JLG	32.79 (34.92)	Gyne-5 x K-75	16.42 (23.89)
CGN-20953 x Poinsette	15.51 (23.18)	Gyne-5 x JLG	32.58 (34.79)
CGN-20969 x K-75	23.05 (28.68)	Gyne-5 x Poinsette	19.91 (26.49)
CGN-20969 x JLG	31.75 (34.28)	**KH-1 (Check-I)**	18.52 (25.47)
CGN-20969 x Poinsette	20.52 (26.92)	**Pusa Sanyog (Check-II)**	19.66 (26.31)
CGN-21585 x K-75	23.05 (28.68)	**Mean**	22.15 (27.86)
S.E. (d) ±	**0.96 (0.66)**	**C.D.$_{(0.05)}$**	**1.92 (1.33)**

*Figures in the parentheses are arc sine transformed

Table 4.15 Mean performance of parents and hybrids for severity of powdery mildew (SPM)

Parents/Hybrids	***SPM (%)**	**Hybrids**	**SPM (%)**
CGN-19533	18.40 (4.28)	CGN-21585 x JLG	20.70 (4.54)
CGN-20256	20.17 (4.48)	CGN-21585 x Poinsette	16.57 (4.07)
CGN-20515	12.43 (3.52)	CGN-22930 x K-75	28.20 (5.31)
CGN-20953	11.68 (3.41)	CGN-22930 x JLG	18.17 (4.26)
CGN-20969	16.53 (4.05)	CGN-22930 x Poinsette	15.53 (3.94)
CGN-21585	18.82 (4.33)	LC-1-1 x K-75	12.93 (3.59)
CGN-22930	23.60 (4.85)	LC-1-1 x JLG	16.33 (4.04)
LC-1-1	17.27 (4.16)	LC-1-1 x Poinsette	12.00 (3.46)
LC-2-2	14.47 (3.80)	LC-2-2 x K-75	15.52 (3.93)
LC-3-3	13.53 (3.68)	LC-2-2 x JLG	16.63 (4.08)
LC-12-4	15.40 (3.92)	LC-2-2 x Poinsette	12.27 (3.50)
LC-15-5	10.20 (3.19)	LC-3-3 x K-75	11.73 (3.42)
LC-21-6	11.33 (3.36)	LC-3-3 x JLG	15.80 (3.97)
LC-25-7	14.17 (3.76)	LC-3-3 x Poinsette	9.57 (3.09)
LC-28-8	15.90 (3.99)	LC-12-4 x K-75	19.73 (4.44)
Gyne-5	20.43 (4.52)	LC-12-4 x JLG	13.10 (3.62)
K-75	15.60 (3.95)	LC-12-4 x Poinsette	14.25 (3.77)
Japanese Long Green (JLG)	12.23 (3.50)	LC-15-5 x K-75	8.90 (2.98)
Poinsette	10.30 (3.21)	LC-15-5 x JLG	12.07 (3.47)
CGN-19533 x K-75	26.01 (5.09)	LC-15-5 x Poinsette	11.58 (3.39)
CGN-19533 x JLG	16.55 (4.06)	LC-21-6 x K-75	20.67 (4.54)
CGN-19533 x Poinsette	13.37 (3.65)	LC-21-6 x JLG	13.50 (3.67)
CGN-20256 x K-75	25.07 (5.01)	LC-21-6 x Poinsette	14.77 (3.84)
CGN-20256 x JLG	16.70 (4.07)	LC-25-7 x K-75	15.23 (3.90)
CGN-20256 x Poinsette	14.30 (3.78)	LC-25-7 x JLG	17.37 (4.17)
CGN-20515 x K-75	13.73 (3.71)	LC-25-7 x Poinsette	12.00 (3.46)
CGN-20515 x JLG	16.13 (4.02)	LC-28-8 x K-75	15.30 (3.91)
CGN-20515 x Poinsette	9.47 (3.07)	LC-28-8 x JLG	15.10 (3.88)
CGN-20953 x K-75	10.20 (3.19)	LC-28-8 x Poinsette	12.57 (3.54)
CGN-20953 x JLG	14.17 (3.76)	Gyne-5 x K-75	21.20 (4.60)
CGN-20953 x Poinsette	11.40 (3.37)	Gyne-5 x JLG	18.33 (4.28)
CGN-20969 x K-75	24.62 (4.96)	Gyne-5 x Poinsette	9.90 (3.15)
CGN-20969 x JLG	17.07 (4.13)	**KH-1 (Check-I)**	12.83 (3.58)
CGN-20969 x Poinsette	15.40 (3.92)	**Pusa Sanyog (Check-II)**	15.70 (3.96)
CGN-21585 x K-75	25.13 (5.01)	**Mean**	15.62 (3.92)
S.E. (d) ±	**1.26 (0.15)**	**C.D.$_{(0.05)}$**	**2.53 (0.31)**

***** Figures in the parentheses are square root transformed

15-5 and it was found statistically at par with Poinsette (10.30 %), LC-21-6 (11.33 %), CGN-20953 (11.68 %) and Japanese Long Green (12.23 %). Significantly, maximum severity of powdery mildew (23.60 %) was noticed in CGN-22930. Response to severity of powdery mildew among the hybrids ranged from 8.90-28.20 per cent (Table 4.15). Cross combination LC-15-5 x K-75 recorded minimum severity of powdery mildew followed by CGN-20515 x Poinsette (9.47 %), LC-3-3 x Poinsette (9.57 %), Gyne-5 x Poinsette (9.90 %) and CGN-20953 x K-75 (10.20 %). Whereas, maximum response to severity of powdery mildew (28.20 %) was observed CGN-22930 x K-75 and found statistically at par with the three cross combinations *viz.*, CGN-19533 x K-75 (26.01 %), CGN-21585 x K-75 (25.13 %) and CGN-20256 x K-75 (25.07 %). Thirteen hybrid combinations showed less severity of powdery mildew as compared to KH-1 (12.83 %) and Pusa Sanyog (15.70 %) and fifteen other hybrid combinations recoded comparatively less severity of powdery mildew than Pusa Sanyog.

4.1.16 Severity of downy mildew (%)

All the parents and hybrids screened for severity of downy mildew revealed significant differences among themselves (Appendix-II). Severity of downy mildew among the parents ranged from 12.77-38.30 per cent (Table 4.16). Genotype CGN-20969 recorded minimum severity of downy mildew (12.77 %) and similar response was observed in Poinsette (12.90 %), K-75 (13.20 %) and LC-3-3 (14.70 %). Maximum severity of downy mildew (38.30 %) was reported in the genotype CGN-22930 followed by CGN-20256 (35.53 %). Among the hybrids, severity of downy mildew ranged from 10.17-41.73 per cent (Table 4.16). Minimum response to severity of downy mildew was reported in the cross combination LC-3-3 x K-75 (10.17 %) and it was found statistically at par with CGN-20969 x Japanese Long Green (10.43 %), LC-2-2 x Poinsette (11.30 %) and LC-15-5 x K-75 (11.50 %). Hybrid combination CGN-22930 x Japanese Long Green recorded maximum severity of downy mildew (41.73 %) followed by CGN-19533 x Japanese Long Green (38.70 %). Response to severity of downy mildew in seven cross combinations was found less than KH-1 (16.30 %) and Pusa Sanyog (14.17 %). Eleven other cross combinations were found superior over KH-1 for this trait.

Table 4.16 Mean performance of parents and hybrids for severity of downy mildew (SDM)

Parents/Hybrids	*SDM (%)	Hybrids	SDM (%)
CGN-19533	33.47 (35.33)	CGN-21585 x JLG	24.77 (29.83)
CGN-20256	35.53 (36.57)	CGN-21585 x Poinsette	17.23 (24.50)
CGN-20515	18.60 (25.53)	CGN-22930 x K-75	23.87 (29.21)
CGN-20953	20.50 (26.89)	CGN-22930 x JLG	41.73 (40.22)
CGN-20969	12.77 (20.90)	CGN-22930 x Poinsette	21.23 (27.43)
CGN-21585	28.90 (32.49)	LC-1-1 x K-75	15.07 (22.82)
CGN-22930	38.30 (38.21)	LC-1-1 x JLG	26.60 (31.03)
LC-1-1	24.60 (29.70)	LC-1-1 x Poinsette	18.83 (25.70)
LC-2-2	16.83 (24.17)	LC-2-2 x K-75	17.20 (24.48)
LC-3-3	14.70 (22.49)	LC-2-2 x JLG	23.37 (28.89)
LC-12-4	21.53 (27.62)	LC-2-2 x Poinsette	11.30 (19.63)
LC-15-5	16.47 (23.92)	LC-3-3 x K-75	10.17 (18.58)
LC-21-6	23.30 (28.81)	LC-3-3 x JLG	22.63 (28.39)
LC-25-7	16.17 (23.65)	LC-3-3 x Poinsette	15.53 (23.20)
LC-28-8	19.83 (26.38)	LC-12-4 x K-75	16.30 (23.79)
Gyne-5	17.27 (24.48)	LC-12-4 x JLG	26.37 (30.87)
K-75	13.20 (21.24)	LC-12-4 x Poinsette	14.30 (22.20)
Japanese Long Green (JLG)	19.33 (26.01)	LC-15-5 x K-75	11.50 (19.80)
Poinsette	12.90 (20.91)	LC-15-5 x JLG	16.03 (23.58)
CGN-19533 x K-75	16.37 (23.83)	LC-15-5 x Poinsette	17.10 (24.41)
CGN-19533 x JLG	38.70 (38.45)	LC-21-6 x K-75	13.83 (21.80)
CGN-19533 x Poinsette	18.50 (25.46)	LC-21-6 x JLG	28.67 (32.35)
CGN-20256 x K-75	24.60 (29.72)	LC-21-6 x Poinsette	17.93 (25.03)
CGN-20256 x JLG	22.80 (28.51)	LC-25-7 x K-75	14.67 (22.50)
CGN-20256 x Poinsette	17.27 (24.52)	LC-25-7 x JLG	15.23 (22.96)
CGN-20515 x K-75	17.53 (24.73)	LC-25-7 x Poinsette	13.40 (21.46)
CGN-20515 x JLG	30.93 (33.77)	LC-28-8 x K-75	17.40 (24.62)
CGN-20515 x Poinsette	16.30 (23.80)	LC-28-8 x JLG	23.30 (28.85)
CGN-20953 x K-75	17.23 (24.49)	LC-28-8 x Poinsette	14.53 (22.40)
CGN-20953 x JLG	24.17 (29.41)	Gyne-5 x K-75	12.87 (21.01)
CGN-20953 x Poinsette	15.40 (23.09)	Gyne-5 x JLG	21.23 (27.42)
CGN-20969 x K-75	15.97 (23.53)	Gyne-5 x Poinsette	19.17 (25.94)
CGN-20969 x JLG	10.43 (18.83)	**KH-1 (Check-I)**	16.30 (23.80)
CGN-20969 x Poinsette	16.67 (24.08)	**Pusa Sanyog (Check-II)**	14.17 (22.09)
CGN-21585 x K-75	22.50 (28.29)	**Mean**	19.76 (26.10)
S.E. (d) ±	**1.52 (1.11)**	**C.D.$_{(0.05)}$**	**3.03 (2.22)**

***** Figures in the parentheses are arc sine transformed

4.1.17 Severity of angular leaf spot (%)

Observations recorded for this trait showed significant differences among the parents and hybrids (Appendix-II). Severity of angular leaf spot among the parents ranged from 9.07-31.23 per cent (Table 4.17). Minimum severity of angular leaf spot (9.07 %) was observed in the genotype LC-1-1 and similar response was noticed in CGN-20969 (9.37 %), LC-12-4 (11.27 %) and CGN-20953 (11.33 %). Whereas, the genotype CGN-21585 recorded significantly maximum severity of angular leaf spot (31.23 %) among all the parents. Response to severity of angular leaf spot among the crosses ranged from 8.23-36.03 per cent (Table 4.17). Minimum severity of angular leaf spot was recorded in the cross combination LC-1-1 x K-75 (8.23 %) followed by CGN-20969 x Japanese Long Green (8.80 %), LC-2-2 x Poinsette (10.30 %) and CGN-20953 x K-75 (10.37 %). Significantly maximum (36.03 %) severity of angular leaf spot was recorded in the cross combination CGN-21585 x K-75. Nine cross combinations showed less severity of angular leaf spot than KH-1 (15.50 %) and Pusa Sanyog (12.80 %). Seven other hybrid combinations recorded comparatively less severity of angular leaf spot than check cultivar KH-1.

4.1.18 Seed germination (%)

The data recorded for seed germination showed significant differences among the parents and hybrids (Appendix-II). Among the parents, it ranged from 66.67-85.33 per cent (Table 4.18). Highest seed germination of 85.33 per cent was recorded in the genotype CGN-20953 and lowest was observed in LC-12-4 (66.67 %). Seed germination among the hybrids ranged from 68.00-86.00 per cent (Table 4.18). Cross combination CGN-20953 x Poinsette recorded highest seed germination (86.00 %) followed by LC-1-1 x K-75 (84.00 %). Significantly, lowest seed germination (68.00 %) was observed in the hybrid combination LC-12-4 x K-75. Seed germination of eight hybrid combination *viz.,* CGN-20953 x Poinsette (86.00 %), LC-1-1 x K-75 (84.00 %), CGN-20515 x Poinsette (83.33 %), CGN-19533 x Poinsette (83.00 %), Gyne-5 x Poinsette (83.00 %), LC-3-3 x Japanese Long Green (83.00 %), CGN-20953 x Japanese Long Green (81.67 %) and LC-15-5 x Poinsette (81.67 %) was found higher than KH-1 (80.67 %) and Pusa Sanyog (81.33 %). Only cross combination CGN-20515 x K-75 (81.33 %) performed better than KH-1 for per cent seed germination.

Table 4.17 Mean performance of parents and hybrids for severity of angular leaf spot (SALS)

Parents/Hybrids	*SALS (%)	Hybrids	SALS (%)
CGN-19533	23.33 (28.84)	CGN-21585 x JLG	24.53 (29.67)
CGN-20256	25.57 (30.35)	CGN-21585 x Poinsette	27.37 (31.53)
CGN-20515	24.27 (29.48)	CGN-22930 x K-75	16.47 (23.92)
CGN-20953	11.33 (19.60)	CGN-22930 x JLG	14.50 (22.33)
CGN-20969	9.37 (17.73)	CGN-22930 x Poinsette	18.63 (25.55)
CGN-21585	31.23 (33.95)	LC-1-1 x K-75	8.23 (16.61)
CGN-22930	23.43 (28.92)	LC-1-1 x JLG	11.93 (20.18)
LC-1-1	9.07 (17.43)	LC-1-1 x Poinsette	11.40 (19.72)
LC-2-2	13.37 (21.39)	LC-2-2 x K-75	15.87 (23.45)
LC-3-3	17.13 (24.41)	LC-2-2 x JLG	13.70 (21.71)
LC-12-4	11.27 (19.54)	LC-2-2 x Poinsette	10.30 (18.70)
LC-15-5	23.67 (29.08)	LC-3-3 x K-75	16.00 (23.56)
LC-21-6	16.13 (23.66)	LC-3-3 x JLG	13.73 (21.73)
LC-25-7	13.77 (21.73)	LC-3-3 x Poinsette	19.90 (26.47)
LC-28-8	15.67 (23.27)	LC-12-4 x K-75	18.53 (25.49)
Gyne-5	23.53 (28.97)	LC-12-4 x JLG	11.80 (20.08)
K-75	19.07 (25.85)	LC-12-4 x Poinsette	16.97 (24.31)
Japanese Long Green (JLG)	12.27 (20.44)	LC-15-5 x K-75	21.83 (27.84)
Poinsette	18.53 (25.43)	LC-15-5 x JLG	16.43 (23.90)
CGN-19533 x K-75	25.87 (30.53)	LC-15-5 x Poinsette	16.60 (24.01)
CGN-19533 x JLG	16.27 (23.77)	LC-21-6 x K-75	22.57 (28.35)
CGN-19533 x Poinsette	17.80 (24.92)	LC-21-6 x JLG	11.70 (19.98)
CGN-20256 x K-75	28.30 (32.11)	LC-21-6 x Poinsette	16.53 (23.96)
CGN-20256 x JLG	16.80 (24.18)	LC-25-7 x K-75	11.50 (19.81)
CGN-20256 x Poinsette	18.70 (25.60)	LC-25-7 x JLG	13.30 (21.36)
CGN-20515 x K-75	22.67 (28.42)	LC-25-7 x Poinsette	16.40 (23.85)
CGN-20515 x JLG	17.20 (24.48)	LC-28-8 x K-75	21.73 (27.76)
CGN-20515 x Poinsette	17.63 (24.80)	LC-28-8 x JLG	13.10 (21.20)
CGN-20953 x K-75	10.37 (18.76)	LC-28-8 x Poinsette	14.77 (22.58)
CGN-20953 x JLG	13.43 (21.48)	Gyne-5 x K-75	17.80 (24.92)
CGN-20953 x Poinsette	16.40 (23.87)	Gyne-5 x JLG	16.23 (23.75)
CGN-20969 x K-75	18.40 (25.39)	Gyne-5 x Poinsette	20.77 (27.08)
CGN-20969 x JLG	8.80 (17.24)	**KH-1 (Check-I)**	15.50 (23.13)
CGN-20969 x Poinsette	17.10 (24.40)	**Pusa Sanyog (Check-II)**	12.80 (20.93)
CGN-21585 x K-75	36.03 (36.87)	**Mean**	17.29 (24.29)
S.E. (d) ±	**1.45 (1.11)**	**C.D.$_{(0.05)}$**	**2.90 (2.22)**

***** Figures in the parentheses are arc sine transformed

Table 4.18 Mean performance of parents and hybrids for seed germination (SG)

Parents/Hybrids	*SG (%)	Hybrids	SG (%)
CGN-19533	81.33 (64.39)	CGN-21585 x JLG	78.00 (62.03)
CGN-20256	75.67 (60.43)	CGN-21585 x Poinsette	77.00 (61.33)
CGN-20515	82.00 (64.89)	CGN-22930 x K-75	76.33 (60.87)
CGN-20953	85.33 (67.50)	CGN-22930 x JLG	79.00 (62.70)
CGN-20969	76.00 (60.65)	CGN-22930 x Poinsette	80.00 (63.41)
CGN-21585	77.67 (61.78)	LC-1-1 x K-75	84.00 (66.40)
CGN-22930	81.00 (64.15)	LC-1-1 x JLG	76.33 (60.90)
LC-1-1	75.33 (60.21)	LC-1-1 x Poinsette	80.67 (63.94)
LC-2-2	77.67 (61.78)	LC-2-2 x K-75	78.00 (62.01)
LC-3-3	80.00 (63.43)	LC-2-2 x JLG	76.67 (61.10)
LC-12-4	66.67 (54.72)	LC-2-2 x Poinsette	80.33 (63.68)
LC-15-5	78.00 (62.02)	LC-3-3 x K-75	76.33 (60.87)
LC-21-6	72.33 (58.25)	LC-3-3 x JLG	83.00 (65.63)
LC-25-7	73.67 (59.11)	LC-3-3 x Poinsette	79.00 (62.70)
LC-28-8	71.00 (57.40)	LC-12-4 x K-75	68.00 (55.53)
Gyne-5	78.67 (62.48)	LC-12-4 x JLG	73.33 (58.90)
K-75	73.33 (58.90)	LC-12-4 x Poinsette	76.00 (60.65)
Japanese Long Green (JLG)	79.00 (62.72)	LC-15-5 x K-75	74.67 (59.78)
Poinsette	80.33 (63.66)	LC-15-5 x JLG	80.00 (63.43)
CGN-19533 x K-75	74.00 (59.33)	LC-15-5 x Poinsette	81.67 (64.65)
CGN-19533 x JLG	75.67 (60.42)	LC-21-6 x K-75	74.33 (59.54)
CGN-19533 x Poinsette	83.00 (65.63)	LC-21-6 x JLG	76.00 (60.64)
CGN-20256 x K-75	72.00 (58.04)	LC-21-6 x Poinsette	77.67 (61.80)
CGN-20256 x JLG	77.67 (61.78)	LC-25-7 x K-75	70.33 (56.99)
CGN-20256 x Poinsette	76.33 (60.88)	LC-25-7 x JLG	74.00 (59.32)
CGN-20515 x K-75	81.33 (64.38)	LC-25-7 x Poinsette	76.00 (60.65)
CGN-20515 x JLG	75.00 (59.98)	LC-28-8 x K-75	72.67 (58.46)
CGN-20515 x Poinsette	83.33 (65.88)	LC-28-8 x JLG	78.00 (62.01)
CGN-20953 x K-75	75.33 (60.20)	LC-28-8 x Poinsette	77.00 (61.33)
CGN-20953 x JLG	81.67 (64.63)	Gyne-5 x K-75	79.00 (62.70)
CGN-20953 x Poinsette	86.00 (68.06)	Gyne-5 x JLG	77.00 (61.34)
CGN-20969 x K-75	79.00 (62.70)	Gyne-5 x Poinsette	83.00 (65.63)
CGN-20969 x JLG	76.67 (61.10)	**KH-1 (Check-I)**	80.67 (63.91)
CGN-20969 x Poinsette	79.00 (62.73)	**Pusa Sanyog (Check-II)**	81.33 (64.38)
CGN-21585 x K-75	73.67 (59.11)	**Mean**	77.54 (61.78)
S.E. (d) ±	**1.49 (1.03)**	**C.D.$_{(0.05)}$**	**2.99 (2.06)**

***** Figures in the parentheses are arc sine transformed

4.1.19 Seed vigour index-I

Significant variations among the parents and hybrids were recorded for the trait under study (Appendix-II). Seed vigour index-I among the parents ranged from 2011.07-2960.67 (Table 4.19). The genotype LC-3-3 recorded highest seed vigour index-I (2960.67) followed by LC-2-2 (2786.93). Lowest seed vigour index-I (2011.07) was observed in CGN-20969 and it was found statistically at par with CGN-20256 (2084.27), LC-25-7 (2106.33), LC-21-6 (2150.20), CGN-21585 (2169.73) and LC-12-4 (2170.33). Among the hybrids, seed vigour index-I was ranged from 1947.93-3216.90 (Table 4.19). Highest seed vigour index-I (3216.90) was recorded in the hybrid combination LC-1-1 x K-75 followed by CGN-20953 x Poinsette (3063.20). Lowest seed vigour index-I (1947.93) was observed lowest in CGN-20256 x Poinsette and it was found statistically at par with five cross combinations *viz.*, CGN-20969 x Japanese Long Green (2047.33), LC-12-4 x K-75 (2078.07), CGN-21585 x Japanese Long Green (2089.60), LC-28-8 x Poinsette (2096.07) and LC-25-7 x Poinsette (2133.73). Four hybrid combinations *viz.*, LC-1-1 x K-75 (3216.90), CGN-20953 x Poinsette (3063.20), LC-3-3 x K-75 (3002.90) and LC-2-2 x Poinsette (2995.00) recorded higher seed vigour index-I than KH-1 (2767.80) and Pusa Sanyog (2873.60). Beside this, two cross combinations *viz.*, LC-15-5 x Poinsette (6862.27) and LC-3-3 x Japanese Long Green (2799.33) were also found superior over check cultivar KH-1 for this trait.

4.1.20 Seed vigour index-II

All the parents and hybrids revealed significant differences among the parents and hybrids for seed vigour index-II (Appendix-II). Among the parents, it ranged from 833.37-1576.73 (Table 4.20). Highest seed vigour index-II (1576.73) was observed in the genotype LC-3-3 and it was found statistically at par with LC-2-2 (1512.29) and LC-1-1 (1408.43). The genotype CGN-21585 recorded lowest seed vigour index-II (833.37) followed by LC-25-7 (843.63), CGN-20256 (855.03), CGN-19533 (870.29), LC-21-6 (918.55), CGN-20969 (920.17) and CGN-22930 (964.78). Seed vigour index-II among the hybrids ranged from 687.93-1996.00 (Table 4.20). Hybrid combination LC-1-1 x K-75 recorded highest seed vigour index-II (1996.00) followed by LC-3-3 x K-75 (1893.07). Lowest seed vigour index-II (687.93) was observed in the hybrid CGN-21585 x Japanese Long Green and it was found statistically at par with four cross combinations *viz.*, CGN-20969 x Japanese Long

Table 4.19 Mean performance of parents and hybrids for seed vigour index-I (SVI-I)

Parents/Hybrids	SVI-I	Hybrids	SVI-I
CGN-19533	2380.87	CGN-21585 x JLG	2089.60
CGN-20256	2084.27	CGN-21585 x Poinsette	2195.10
CGN-20515	2419.93	CGN-22930 x K-75	2446.77
CGN-20953	2688.27	CGN-22930 x JLG	2525.53
CGN-20969	2011.07	CGN-22930 x Poinsette	2273.23
CGN-21585	2169.73	LC-1-1 x K-75	3216.90
CGN-22930	2349.80	LC-1-1 x JLG	2373.00
LC-1-1	2581.60	LC-1-1 x Poinsette	2460.73
LC-2-2	2786.93	LC-2-2 x K-75	2604.73
LC-3-3	2960.67	LC-2-2 x JLG	2450.40
LC-12-4	2170.33	LC-2-2 x Poinsette	2995.00
LC-15-5	2513.07	LC-3-3 x K-75	3002.90
LC-21-6	2150.20	LC-3-3 x JLG	2799.33
LC-25-7	2106.33	LC-3-3 x Poinsette	2286.83
LC-28-8	2338.53	LC-12-4 x K-75	2078.07
Gyne-5	2580.27	LC-12-4 x JLG	2248.97
K-75	2434.40	LC-12-4 x Poinsette	2340.07
Japanese Long Green (JLG)	2397.13	LC-15-5 x K-75	2499.53
Poinsette	2404.00	LC-15-5 x JLG	2526.33
CGN-19533 x K-75	2602.40	LC-15-5 x Poinsette	2862.27
CGN-19533 x JLG	2225.27	LC-21-6 x K-75	2298.30
CGN-19533 x Poinsette	2323.10	LC-21-6 x JLG	2306.43
CGN-20256 x K-75	2260.40	LC-21-6 x Poinsette	2413.80
CGN-20256 x JLG	2291.20	LC-25-7 x K-75	2169.10
CGN-20256 x Poinsette	1947.93	LC-25-7 x JLG	2336.17
CGN-20515 x K-75	2691.80	LC-25-7 x Poinsette	2133.73
CGN-20515 x JLG	2432.30	LC-28-8 x K-75	2483.80
CGN-20515 x Poinsette	2381.17	LC-28-8 x JLG	2418.87
CGN-20953 x K-75	2759.93	LC-28-8 x Poinsette	2096.07
CGN-20953 x JLG	2262.07	Gyne-5 x K-75	2677.13
CGN-20953 x Poinsette	3063.20	Gyne-5 x JLG	2484.23
CGN-20969 x K-75	2507.37	Gyne-5 x Poinsette	2346.63
CGN-20969 x JLG	2047.33	**KH-1 (Check-I)**	2767.80
CGN-20969 x Poinsette	2356.40	**Pusa Sanyog (Check-II)**	2873.60
CGN-21585 x K-75	2203.90	**Mean**	2434.26
S.E. (d) ±	**104.21**	**C.D.$_{(0.05)}$**	**208.62**

Table 4.20 Mean performance of parents and hybrids for seed vigour index-II (SVI-II)

Parents/Hybrids	SVI-II	Hybrids	SVI-II
CGN-19533	870.29	CGN-21585 x JLG	687.93
CGN-20256	855.03	CGN-21585 x Poinsette	850.37
CGN-20515	1021.93	CGN-22930 x K-75	1195.37
CGN-20953	1250.43	CGN-22930 x JLG	1201.00
CGN-20969	920.17	CGN-22930 x Poinsette	984.20
CGN-21585	833.37	LC-1-1 x K-75	1996.00
CGN-22930	964.78	LC-1-1 x JLG	1101.33
LC-1-1	1408.43	LC-1-1 x Poinsette	1263.00
LC-2-2	1512.29	LC-2-2 x K-75	1359.20
LC-3-3	1576.73	LC-2-2 x JLG	1195.50
LC-12-4	1054.03	LC-2-2 x Poinsette	1802.93
LC-15-5	1282.37	LC-3-3 x K-75	1893.07
LC-21-6	918.55	LC-3-3 x JLG	1479.47
LC-25-7	843.63	LC-3-3 x Poinsette	1095.67
LC-28-8	1081.39	LC-12-4 x K-75	931.67
Gyne-5	1186.29	LC-12-4 x JLG	1019.47
K-75	1211.17	LC-12-4 x Poinsette	1216.07
Japanese Long Green (JLG)	1056.85	LC-15-5 x K-75	1309.27
Poinsette	1198.40	LC-15-5 x JLG	1141.93
CGN-19533 x K-75	1164.40	LC-15-5 x Poinsette	1649.13
CGN-19533 x JLG	796.33	LC-21-6 x K-75	1072.70
CGN-19533 x Poinsette	1163.17	LC-21-6 x JLG	996.70
CGN-20256 x K-75	1129.53	LC-21-6 x Poinsette	1182.03
CGN-20256 x JLG	960.50	LC-25-7 x K-75	981.00
CGN-20256 x Poinsette	1203.40	LC-25-7 x JLG	858.17
CGN-20515 x K-75	1358.27	LC-25-7 x Poinsette	899.47
CGN-20515 x JLG	959.70	LC-28-8 x K-75	1340.07
CGN-20515 x Poinsette	1249.50	LC-28-8 x JLG	1116.53
CGN-20953 x K-75	1021.80	LC-28-8 x Poinsette	899.90
CGN-20953 x JLG	1249.83	Gyne-5 x K-75	1589.13
CGN-20953 x Poinsette	1151.90	Gyne-5 x JLG	1325.47
CGN-20969 x K-75	1204.00	Gyne-5 x Poinsette	1120.57
CGN-20969 x JLG	743.47	**KH-1 (Check-I)**	1181.63
CGN-20969 x Poinsette	1008.77	**Pusa Sanyog (Check-II)**	1301.20
CGN-21585 x K-75	949.50	**Mean**	1153.58
S.E. (d) ±	**91.84**	**C.D.$_{(0.05)}$**	**183.86**

Green (743.47), CGN-19533 x Japanese Long Green (796.33), CGN-21585 x Poinsette (850.37) and LC-25-7 x Japanese Long Green (858.17). Seed vigour index-II of eleven cross combination was found higher than both the check cultivars, KH-1 (1181.63) and Pusa Sanyog (1301.20). Moreover, ten hybrid combinations were also found superior than KH-1 for seed vigour index-II.

4.2 COMBINING ABILITY STUDIES

The analysis of variance for combining ability revealed significant differences among the parents and hybrids for all the traits under study (Appendix-III). Further, partitioning of the sum of squares of crosses into lines (females), testers (males) and line x tester (female x male) interactions indicated that mean sum of squares due to lines and testers were significant for all the traits when tested either against mean sum of squares due to error or against variances due to line x tester interactions. Mean sum of squares due to lines and testers were also significant for all the traits, when tested against mean sum of squares due to error (Appendix-III).

4.2.1 Estimates of general combining ability (GCA) effects of parents

Since, mean sum of squares due to lines and testers were significant for all the characters, hence general combining ability (GCA) effects have been estimated for all the traits under study and have been described as below:

4.2.1.1 Days to first female flower appearance

The lines or testers exhibited significant negative or positive GCA effects were designated as good or poor general combiners, respectively. The remaining lines/testers exhibited non-significant GCA effects were assigned as average general combiners for early female flower appearance (Table 4.21). Among the lines, LC-1-1 (-2.77) followed by CGN-19533 (-2.56), CGN-20953 (-2.22), LC-2-2 (-1.60), Gyne-5 (-1.36), CGN-20515 (-0.93) and CGN-20969 (-0.80) exhibited significant negative GCA effects indicated their good general combining ability. On the other hand, the lines *viz.*, LC-21-6 (3.86), LC-12-4 (2.38), LC-28-8 (2.31), CGN-20256 (2.17), LC-15-5 (1.54) and LC-3-3 (0.92) indicated poor general combining ability due to their significant positive GCA effects. The remaining lines had non-significant GCA effects and were designated as average general combiners. Among the testers, Poinsette (-2.40) and K-75 (-1.25) exhibited significant negative GCA effects indicated their good general combining ability and Japanese Long Green (3.66) revealed significant positive GCA effect, indicated its poor general combining ability.

Table 4.21 Estimates of general combining ability (GCA) effects of parents for different phenological traits in cucumber

Parents/Traits → ↓	Days to first female flower appearance	Node number bearing first female flower	Days to marketable maturity
Lines			
CGN-19533	-2.56^{*}	-0.94^{*}	-2.15^{*}
CGN-20256	2.17^{*}	1.04^{*}	2.36^{*}
CGN-20515	-0.93^{*}	-0.48^{*}	-0.85^{*}
CGN-20953	-2.22^{*}	-0.95^{*}	-2.39^{*}
CGN-20969	-0.80^{*}	-0.35^{*}	-0.63^{*}
CGN-21585	-0.32	-0.20	-0.53
CGN-22930	-0.58	-0.39^{*}	-0.45
LC-1-1	-2.77^{*}	-1.23^{*}	-3.07^{*}
LC-2-2	-1.60^{*}	-0.65^{*}	-1.63^{*}
LC-3-3	0.92^{*}	0.47^{*}	0.95^{*}
LC-12-4	2.38^{*}	0.99^{*}	2.58^{*}
LC-15-5	1.54^{*}	0.26	1.16^{*}
LC-21-6	3.86^{*}	1.77^{*}	3.85^{*}
LC-25-7	-0.02	0.41^{*}	-0.03
LC-28-8	2.31^{*}	1.13^{*}	2.48^{*}
Gyne-5	-1.36^{*}	-0.90^{*}	-1.65^{*}
Testers			
K-75	-1.25^{*}	-0.65^{*}	-1.30^{*}
Japanese Long Green	3.66^{*}	1.96^{*}	3.80^{*}
Poinsette	-2.40^{*}	-1.30^{*}	-2.50^{*}
S.E. (g_i) Lines	0.35	0.15	0.31
S.E. (g_j) Testers	0.15	0.06	0.13
S.E. (g_i- g_j) Lines	0.49	0.22	0.43
S.E. (g_i- g_j) Testers	0.21	0.09	0.19
C.D.$_{(0.05)}$ (g_i) Lines	0.68	0.30	0.60
C.D.$_{(0.05)}$ (g_i) Testers	0.29	0.13	0.26
C.D.$_{(0.05)}$ (g_i- g_j) Lines	0.97	0.43	0.86
C.D.$_{(0.05)}$ (g_i- g_j) Testers	0.42	0.18	0.37

*Significant at 5% level of significance

4.2.1.2 Node number bearing first female flower

For node number bearing first female flower, the line LC-1-1 (-1.23) followed by CGN-20953 (-0.95), CGN-19533 (-0.94), Gyne-5 (-0.90), LC-2-2 (-0.65), CGN-20515 (-0.48), CGN-22930 (-0.39) and CGN-20969 (-0.35) were good general combiners as indicated by their negative GCA effects (Table 4.21). While, the lines LC-21-6 (1.77), LC-28-8 (1.13), CGN-20256 (1.04), LC-12-4 (0.99), LC-3-3 (0.47), LC-25-7 (0.41) and LC-15-5 (0.26) indicated poor general combining ability due to significant positive GCA effects for this trait. The remaining lines had shown non-significant GCA effects and were average general combiners. The testers, Poinsette (-1.30) and K-75 (-0.65) exhibited significant negative GCA effects indicated their good general combining ability, whereas Japanese Long Green (1.96) was poor general combiner.

4.2.1.3 Days to marketable maturity

Significant negative GCA effects among the lines were exhibited by LC-1-1 (-3.07) followed by CGN-20953 (-2.39), CGN-19533 (-2.15), Gyne-5 (-1.65), LC-2-2 (-1.63), CGN-20515 (-0.85) and CGN-20969 (-0.63), indicated their good general combining ability (Table 4.21). Whereas, LC-21-6 (3.85), LC-12-4 (2.58), LC-28-8 (2.48), CGN-20256 (2.36), LC-15-5 (1.16) and LC-3-3 (0.95) indicated poor general combining ability due to their significant positive GCA effects. The remaining lines had non-significant GCA effects and were designated as average general combiners. Among the testers, Poinsette (-2.50) and K-75 (-1.30) revealed significant negative GCA effects indicated their good general combining ability and Japanese Long Green (3.80) exhibited significant positive GCA effect, indicated its poor general combining ability.

4.2.1.4 Fruit length

For fruit length, lines or testers exhibited significant positive or negative GCA effects were designated as good or poor general combiners, respectively. The lines/testers exhibited non-significant GCA effects were assigned as average general combiners (Table 4.22). The line, LC-25-7 (2.21) followed by LC-1-1 (1.77), CGN-20953 (1.75), CGN-19533 (1.42), Gyne-5 (1.31), CGN-22930 (1.06), LC-15-5 (0.65), LC-28-8 (0.62) and LC-3-3 (0.56) exhibited significant positive GCA effects indicated their good general combining ability for fruit length. Significant negative GCA effects were revealed by CGN-20969 (-3.04), CGN-20256 (-2.91), LC-21-6 (-2.08), CGN-20515 (-1.71) and CGN-21585 (-1.14) and were designated as poor general combiners. The remaining two lines *viz.*, LC-2-2 and LC-12-4 had non-significant GCA effects and were designated as average general combiners. The testers, Japanese Long Green (0.55) and Poinsette (-0.71) revealed significant positive and negative GCA effects, indicated their good and poor general combining abilities, respectively. K-75 was found average general combiner for fruit length.

Table 4.22 Estimates of general combining ability (GCA) effects of parents for different fruit traits in cucumber

Parents/Traits → ↓	Fruit length (cm)	Fruit breadth (cm)	Average fruit weight (g)
Lines			
CGN-19533	1.42*	0.08	25.96*
CGN-20256	-2.91*	-0.27*	-54.35*
CGN-20515	-1.71*	0.78*	-15.81*
CGN-20953	1.75*	0.05	30.65*
CGN-20969	-3.04*	-0.26*	-56.07*
CGN-21585	-1.14*	-0.13*	-21.86*
CGN-22930	1.06*	-0.26*	13.90*
LC-1-1	1.77*	0.18*	33.29*
LC-2-2	0.01	0.10	1.93
LC-3-3	0.56*	0.08	10.88
LC-12-4	-0.49	0.07	-7.12
LC-15-5	0.65*	0.32*	16.48*
LC-21-6	-2.08*	-0.25*	-39.80*
LC-25-7	2.21*	-0.38*	31.02*
LC-28-8	0.62*	-0.30*	5.52
Gyne-5	1.31*	0.17*	25.36*
Testers			
K-75	0.16	0.40*	9.61*
Japanese Long Green	0.55*	-0.52*	0.47
Poinsette	-0.71*	0.12*	-10.08*
S.E. (g_i) Lines	0.27	0.06	6.56
S.E. (g_j) Testers	0.11	0.02	2.01
S.E. (g_i- g_j) Lines	0.38	0.08	2.84
S.E. (g_i- g_j) Testers	0.16	0.03	4.64
C.D.$_{(0.05)}$ (g_i) Lines	0.53	0.11	12.87
C.D.$_{(0.05)}$ (g_i) Testers	0.23	0.05	3.94
C.D.$_{(0.05)}$ (g_i- g_j) Lines	0.76	0.16	5.57
C.D.$_{(0.05)}$ (g_i- g_j) Testers	0.32	0.07	9.10

*Significant at 5% level of significance

4.2.1.5 Fruit breadth

General combining ability effects for fruit breadth revealed that four lines *viz.*, CGN-20515 (0.78), LC-15-5 (0.32), LC-1-1 (0.18) and Gyne-5 (0.17) had significant positive GCA effects indicated their good general combining ability, whereas significant negative GCA effects were observed for LC-25-7 (-0.38), LC-28-8 (-0.30),

CGN-20256 (-0.27), CGN-22930 (-0.26), CGN-20969 (-0.26), LC-21-6 (-0.25) and CGN-21585 (-0.13), which revealed their poor general combining ability (Table 4.22). Remaining five lines had non-significant GCA effects and were designated as average general combiners. Among the testers, K-75 (0.40) and Poinsette (0.12) revealed significant positive GCA effects, indicated their good general combining ability, whereas Japanese Long Green (-0.52) was found poor general combiner for fruit breadth, as indicated by its significant negative GCA effect.

4.2.1.6 Average fruit weight

Significant positive GCA effects among the lines were exhibited by LC-1-1 (33.29), LC-25-7 (31.02), CGN-20953 (30.65), CGN-19533 (25.96), Gyne-5 (25.36), LC-15-5 (16.48) and CGN-22930 (13.90), indicated their good general combining ability (Table 4.22). The line, CGN-20969 (-56.07) followed by CGN-20256 (-54.35), LC-21-6 (-39.80), CGN-21585 (-21.86) and CGN-20515 (-15.81) were designated as poor general combiners due to their significant negative GCA effects. Remaining four lines had non-significant GCA effects and were designated as average general combiners. The testers, K-75 (9.61) and Poinsette (-10.08) revealed significant positive and negative GCA effects, indicated their good and poor general combining abilities, respectively. Japanese Long Green (0.47) was found average general combiner for average fruit weight.

4.2.1.7 Number of marketable fruits per plant

Among the lines, LC-1-1 (1.23) followed by CGN-19533 (0.94), Gyne-5 (0.89), CGN-20953 (0.76), LC-2-2 (0.69), CGN-20515 (0.56), CGN-20969 (0.41) and CGN-22930 (0.39) were found good general combiners for number of fruits per plant due to their significant positive GCA effects (Table 4.23). On the other hand, line LC-21-6 (-1.79) followed by LC-28-8 (-1.12), LC-12-4 (-1.07), CGN-20256 (-0.95), LC-25-7 (-0.42), LC-3-3 (-0.39) and LC-15-5 (-0.26) were designated as poor general combiners due to their significant negative GCA effects. Only one line, CGN-21585 (0.14) had non-significant GCA effect and was average general combiner for this trait. Significant positive GCA effects were observed for the testers Poinsette (1.30) and K-75 (0.65), indicated their good general combining ability, whereas Japanese Long Green (-1.96) was found poor general combiner due to its significant negative general combining ability.

Table 4.23 Estimates of general combining ability (GCA) effects of parents for number of marketable fruits per plant, harvest duration and marketable yield in cucumber

Parents/Traits → ↓	Number of marketable fruits per plant	Harvest duration (days)	Marketable yield per plot (kg)	Marketable yield per hectare (q)
Lines				
CGN-19533	0.94*	2.40*	8.62*	57.60*
CGN-20256	-0.95*	-2.63*	-11.14*	-74.41*
CGN-20515	0.56*	1.38*	-0.04	-0.29
CGN-20953	0.76*	2.19*	8.92*	59.48*
CGN-20969	0.41*	1.13*	-6.36*	-42.46*
CGN-21585	0.14	0.54	-2.89*	-19.34*
CGN-22930	0.39*	1.11*	3.36*	22.40*
LC-1-1	1.23*	3.38*	11.17*	74.67*
LC-2-2	0.69*	1.94*	2.81*	18.90*
LC-3-3	-0.39*	-1.12*	-0.04	-0.29
LC-12-4	-1.07*	-2.96*	-5.88*	-39.29*
LC-15-5	-0.26*	-0.73	0.16	1.03
LC-21-6	-1.79*	-4.98*	-12.92*	-86.26*
LC-25-7	-0.42*	-1.05*	1.32	8.83
LC-28-8	-1.12*	-3.12*	-5.00*	-33.25*
Gyne-5	0.890*	2.51*	7.907*	52.67*
Testers				
K-75	0.65*	1.90*	4.70*	31.36*
Japanese Long Green	-1.96*	-5.50*	-9.12*	-60.90*
Poinsette	1.30*	3.60*	4.42*	29.53*
S.E. (g_i) Lines	0.11	0.40	0.70	4.69
S.E. (g_j) Testers	0.04	0.17	0.30	2.03
S.E. (g_i- g_j) Lines	0.15	0.56	0.99	6.64
S.E. (g_i- g_j) Testers	0.06	0.24	0.43	2.87
C.D.$_{(0.05)}$ (g_i) Lines	0.21	0.78	1.38	9.20
C.D.$_{(0.05)}$ (g_i) Testers	0.09	0.33	0.59	3.98
C.D.$_{(0.05)}$ (g_i- g_j) Lines	0.30	1.11	1.95	13.02
C.D.$_{(0.05)}$ (g_i- g_j) Testers	0.13	0.48	0.84	5.63

*Significant at 5% level of significance

4.2.1.8 Harvest duration

General combining ability effects of lines and testers have been presented in the table 4.23. Significant positive GCA effects of line LC-1-1 (3.38) followed by

Gyne-5 (2.51), CGN-19533 (2.40), CGN-20953 (2.19), LC-2-2 (1.94), CGN-20515 (1.38), CGN-20969 (1.13) and CGN-22930 (1.11), revealed their good general combining ability. While, six lines *viz.*, LC-21-6 (-4.98), LC-28-8 (-3.12), LC-12-4 (-2.96), CGN-20256 (-2.63), LC-3-3 (-1.12) and LC-25-7 (-1.05) had significant negative GCA effects, hence they were assigned as poor general combiners. Remaining two lines *viz.*, CGN-21585 (0.54) and LC-15-5 (-0.73) had average general combining ability effects due to non-significant GCA effects. Among the testers, Poinsette (3.64) and K-75 (1.90) were good general combiners due to significant positive GCA effects, whereas Japanese Long Green (-5.54) was found poor general combiner due to its significant negative general combining ability for harvest duration.

4.2.1.9 Marketable yield per plot

For higher yields per plot, line LC-1-1 (11.17) followed by CGN-20953 (8.92), CGN-19533 (8.62), Gyne-5 (7.90), CGN-22930 (3.36) and LC-2-2 (2.81) revealed significant positive GCA effects, indicated their good general combining ability (Table 4.23). Significant negative GCA effects were observed for LC-21-6 (-12.92), CGN-20256 (-11.14), CGN-20969 (-6.36), LC-12-4 (-5.88), LC-28-8 (-5.00) and CGN-21585 (-2.89) and were found poor general combiners for yield per plot. The lines with non-significant combining ability effects *viz.*, CGN-20515, LC-3-3, LC-15-5 and LC-25-7 were designated as average general combiners. The testers, K-75 (4.70) and Poinsette (4.42) due to their significant positive GCA effects, were found good general combiners, while Japanese Long Green (-9.12) due to its significant negative general combining ability was found poor general combiner for the trait under study.

4.2.1.10 Marketable yield per hectare

Significant positive GCA effects were observed for the line LC-1-1 (74.67) followed by CGN-20953 (59.48), CGN-19533 (57.60), Gyne-5 (52.67), CGN-22930 (22.40) and LC-2-2 (18.90), indicated their good general combining ability (Table 4.23). The lines *viz.*, LC-21-6 (-86.26), CGN-20256 (-74.41), CGN-20969 (-42.46), LC-12-4 (-39.29), LC-28-8 (-33.25) and CGN-21585 (-19.34) were found poor general combiners for yield per hectare due to their significant negative GCA effects.

Remaining four lines were found average general combiners due to non-significant combining ability effects. Among the testers, K-75 (31.36) and Poinsette (29.53) were found good general combiners due to their significant positive GCA effects, whereas Japanese Long Green (-60.90) due to its significant negative general combining ability was found poor general combiner for marketable yield per hectare.

4.2.1.11 Total soluble solids

Data pertaining to GCA effects of lines and testers as presented in the table 4.24 revealed that five lines *viz.*, CGN-21585 (0.49), LC-28-8 (0.48), LC-1-1 (0.17), CGN-20953 (0.11) and Gyne-5 (0.07) had significant positive GCA effects, which showed that they are good general combiners. Significant negative GCA effects were exhibited by the line LC-21-6 (-0.44), followed by CGN-20515 (-0.21), LC-12-4 (-0.15), CGN-22930 (-0.13), LC-2-2 (-0.12), LC-3-3 (-0.10), LC-15-5 (-0.08) and LC-25-7 (-0.06). Hence, they were found poor general combiners for total soluble solids content. The lines with non-significant combining ability effects *viz.*, CGN-19533, CGN-20256 and CGN-20969 were found average general combiners. The tester, Japanese Long Green (0.09) and Poinsette (-0.07) exhibited significant positive and negative GCA effects, indicated their good and poor general combining ability, respectively. K-75 (-0.01) was found average general combiner for total soluble solids content due to its non-significant combining ability effect.

4.2.1.12 Cucurbitacin content

For low cucurbitacin content, line CGN-21585 (-7.25) followed by LC-28-8 (-4.31), CGN-20256 (-4.20), CGN-20953 (-4.09), LC-1-1 (-3.98), CGN-22930 (-2.62) and CGN-19533 (-1.62) exhibited significant negative GCA effects and were designated as good general combiners (Table 4.24). While, six lines *viz.*, LC-21-6 (8.90), LC-12-4 (6.10), LC-15-5 (5.20), LC-3-3 (3.97), LC-25-7 (2.88) and LC-2-2 (2.43) were found poor general combiners, as revealed by their significant positive GCA effects. Remaining three lines *viz.*, CGN-20515, CGN-20969 and Gyne-5 were found average general combiner for cucurbitacin content. Significant negative GCA effects were exhibited by the tester Japanese Long Green (-1.54) and K-75 (-0.88), indicated their good general combining ability, while Poinsette (2.42) was found poor general combiner for the trait under study.

Table 4.24 Estimates of general combining ability (GCA) effects of parents for quality traits in cucumber

Parents/Traits → ↓	Total soluble solids (^{o}B)	Cucurbitacin content (µg/100g)
Lines		
CGN-19533	0.04	-1.62*
CGN-20256	-0.01	-4.20*
CGN-20515	-0.21*	-0.34
CGN-20953	0.11*	-4.09*
CGN-20969	-0.05	-0.09
CGN-21585	0.49*	-7.25*
CGN-22930	-0.13*	-2.62*
LC-1-1	0.17*	-3.98*
LC-2-2	-0.12*	2.43*
LC-3-3	-0.10*	3.97*
LC-12-4	-0.15*	6.10*
LC-15-5	-0.08*	5.20*
LC-21-6	-0.44*	8.90*
LC-25-7	-0.06*	2.88*
LC-28-8	0.48*	-4.31*
Gyne-5	0.07*	-0.96
Testers		
K-75	-0.01	-0.88*
Japanese Long Green	0.09*	-1.54*
Poinsette	-0.07*	2.42*
S.E. (g_i) Lines	0.03	0.53
S.E. (g_j) Testers	0.01	0.23
S.E. (g_i- g_j) Lines	0.04	0.75
S.E. (g_i- g_j) Testers	0.02	0.32
C.D.$_{(0.05)}$ (g_i) Lines	0.06	1.05
C.D.$_{(0.05)}$ (g_i) Testers	0.02	0.45
C.D.$_{(0.05)}$ (g_i- g_j) Lines	0.09	1.48
C.D.$_{(0.05)}$ (g_i- g_j) Testers	0.04	0.64

*Significant at 5% level of significance

4.2.1.13 Fruit fly incidence

Among the lines, LC-3-3 (-3.38), LC-1-1 (-3.26), LC-15-5 (-3.05), LC-2-2 (-2.41) and CGN-20953 (-1.49) were found good general combiners for low incidence of fruit fly due to their significant negative GCA effects (Table 4.25). On the other hand, significant positive GCA effects exhibited by CGN-20969 (3.09), CGN-20256 (-2.87), CGN-21585 (2.78), LC-12-4 (2.20) and LC-28-8 (1.01), Gyne-5 (0.96) and designated as poor general combiners. Rest of four lines *viz.,* CGN-19533, CGN-20515, CGN-22930, LC-21-6 and LC-25-7 with non-significant GCA effects, were found as average general combiners for fruit fly incidence. Among the testers, Poinsette (-4.42) and K-75 (-3.95) were found good general combiners due to their significant negative GCA effects, whereas Japanese Long Green (8.38) was found poor general combiner for fruit fly incidence, as indicated by its significant positive general combining ability.

4.2.1.14 Severity of powdery mildew

General combining ability effects of lines and testers for severity of powdery mildew have been presented in the table 4.25. The line, LC-15-5 (-4.91), followed by CGN-20953 (-3.84), LC-3-3 (-3.40), CGN-20515 (-2.65), LC-1-1 (-2.01) and LC-28-8 (-1.44) were found good combiners for low severity of powdery mildew, as indicated by their significant negative GCA effects. While, CGN-21585 (5.03), CGN-22930 (4.86), CGN-20969 (3.26), CGN-20256 (2.92) and CGN-19533 (2.87) due to their significant positive GCA effects were designated as poor general combiners. Non-significant GCA effects were exhibited by the lines, LC-2-2, LC-12-4, LC-21-6, LC-25-7 and Gyne-5, indicated their average general combining ability. The tester, Poinsette (-2.95) and K-75 (2.61) revealed significant negative and positive GCA effects, indicated their good and poor general combining ability, respectively. Japanese Long Green (0.31) due to its non-significant GCA effect was found average general combiner for this trait.

4.2.1.15 Severity of downy mildew

For low severity of downy mildew, the line CGN-20969 (-4.99) followed by LC-25-7 (-4.91), LC-15-5 (-4.47), LC-3-3 (-3.23), LC-2-2 (-2.06) and Gyne-5 (-1.59) were found good general combiners, as revealed by their significant negative GCA effects (Table 4.25). On the other hand, five lines *viz.,* CGN-22930 (9.59), CGN-19533 (5.17), CGN-20515 (2.24), CGN-20256 (2.20) and CGN-21585 (2.15) exhibited significant positive GCA effects, indicated their poor general combining ability. Remaining five lines, CGN-20953, CGN-20930, LC-12-4, LC-21-6 and LC-28-8 were found average general combiners for severity of downy mildew.

Significant negative GCA effects were exhibited by the testers, Poinsette (-2.80) and K-75 (-2.65) indicated their good general combining ability, whereas Japanese Long Green (5.46) due to significant positive GCA effect was found poor general combiner for the trait under study.

Table 4.25 Estimates of general combining ability (GCA) effects of parents for economically important insect-pest and diseases in cucumber

Parents/Traits → ↓	Fruit fly incidence (%)	Severity of powdery mildew (%)	Severity of downy mildew (%)	Severity of angular leaf spot (%)
Lines				
CGN-19533	0.32	2.87*	5.17*	2.83*
CGN-20256	2.87*	2.92*	2.20*	4.12*
CGN-20515	0.36	-2.65*	2.24*	2.02*
CGN-20953	-1.49*	-3.84*	-0.41	-3.74*
CGN-20969	3.09*	3.26*	-4.99*	-2.37*
CGN-21585	2.78*	5.03*	2.15*	12.16*
CGN-22930	-0.58	4.86*	9.59*	-0.61
LC-1-1	-3.26*	-2.01*	0.81	-6.62*
LC-2-2	-2.41*	-0.96	-2.06*	-3.85*
LC-3-3	-3.38*	-3.40*	-3.23*	-0.59
LC-12-4	2.20*	-0.07	-0.36	-1.37*
LC-15-5	-3.05*	-4.91*	-4.47*	1.14
LC-21-6	0.67	0.54	0.79	-0.21
LC-25-7	-0.09	-0.90	-4.91*	-3.41*
LC-28-8	1.01*	-1.44*	-0.93	-0.61
Gyne-5	0.96*	0.71	-1.59*	1.12
Testers				
K-75	-3.95*	2.61*	-2.65*	2.36*
Japanese Long Green	8.38*	0.34	5.46*	-2.55*
Poinsette	-4.42*	-2.95*	-2.80*	0.18
S.E. (g_i) Lines	0.39	0.51	0.62	0.59
S.E. (g_j) Testers	0.17	0.22	0.27	0.25
S.E. (g_i- g_j) Lines	0.55	0.73	0.88	0.83
S.E. (g_i- g_j) Testers	0.24	0.31	0.38	0.36
C.D.$_{(0.05)}$ (g_i) Lines	0.77	1.01	1.22	1.15
C.D.$_{(0.05)}$ (g_i) Testers	0.33	0.43	0.52	0.50
C.D.$_{(0.05)}$ (g_i- g_j) Lines	1.09	1.43	1.73	1.63
C.D.$_{(0.05)}$ (g_i- g_j) Testers	0.47	0.62	0.74	0.71

*Significant at 5% level of significance

4.2.1.16 Severity of angular leaf spot

Significant negative GCA effects were observed for severity of angular leaf spot by the line, LC-1-1 (-6.62) followed by LC-2-2 (-3.85), CGN-20953 (-3.74), LC-

25-7 (-3.41), CGN-20969 (-2.37) and LC-12-4 (-1.37), indicated their good general combining ability (Table 4.25). On the other hand, significant positive GCA effects were exhibited by CGN-21585 (12.16), CGN-20256 (4.12) and CGN-20515 (2.02), and were designated as poor general combiners. Non-significant GCA effects were exhibited by the lines, CGN-22930, LC-3-3, LC-15-5, LC-21-6, LC-28-8 and Gyne-5, which revealed their average general combining ability for severity of angular leaf spot. The tester, Japanese Long Green (-2.55) and K-75 (2.36) exhibited significant negative and positive GCA effects, indicated their good and poor general combining ability, respectively. Non-significant GCA effect was found for Poinsette (0.18) and was designated as average general combiner.

4.2.1.17 Seed germination

Data pertaining to GCA effects of lines and testers as presented in the table 4.26 revealed that six lines *viz.,* CGN-20953 (3.43), LC-1-1 (2.77), CGN-20515 (2.32), Gyne-5 (2.10), LC-3-3 (1.88) and LC-15-5 (1.21) had significant positive GCA effects, which showed that they were good general combiners for seed germination. Significant negative GCA effects were exhibited by the line LC-12-4 (-5.11), LC-25-7 (-4.11), CGN-20256 (-2.22), LC-28-8 (-1.67), LC-21-6 (-1.56) and CGN-21585 (-1.34), indicated their poor general combining ability. Remaining lines with non-significant combining ability effects *viz.,* CGN-19533, CGN-20969, CGN-22930 and LC-2-2 were found average general combiners. Among the testers, Poinsette (2.18) and K-75 (-2.00) revealed significant positive and negative GCA effects, indicated their good and poor general combining ability, respectively. Japanese Long Green (-0.18) was found average general combiner for seed germination.

4.2.1.18 Seed vigour index-I

Among the lines, LC-3-3 (263.11), CGN-20953 (261.83), LC-1-1 (250.30), LC-2-2 (250.14) and LC-15-5 (196.14), were found good general combiners due to their significant positive GCA effects (Table 4.26). On the other hand, seven lines *viz.,* CGN-21585 (-270.36), CGN-20256 (-266.72), LC-25-7 (-220.23), LC-12-4 (-210.86), CGN-20969 (-129.53), LC-28-8 (-100.32) and LC-21-6 (-93.72) had poor general combining ability for seed germination. Three lines, CGN-19533, CGN-22930 and Gyne-5 were found average general combiners. Two testers *viz.,* K-75 (98.20) and Japanese Long Green (-69.67) were found good and poor general combiners due to their significant positive and negative GCA effects, respectively. Poinsette was found average general combiner due to its non-significant GCA effect.

Table 4.26 Estimates of general combining ability (GCA) effects of parents for seed traits in cucumber

Parents/Traits → ↓	Seed germination (%)	Seed vigour index-I	Seed vigour index-II
Lines			
CGN-19533	-0.01	-49.64	-126.79*
CGN-20256	-2.22*	-266.72*	-70.28
CGN-20515	2.32*	68.52	21.06
CGN-20953	3.43*	261.83*	-26.91
CGN-20969	0.66	-129.53*	-182.68*
CGN-21585	-1.34*	-270.36*	-338.82*
CGN-22930	0.88	-18.05	-41.23
LC-1-1	2.77*	250.30*	285.35*
LC-2-2	0.77	250.14*	284.45*
LC-3-3	1.88*	263.11*	321.30*
LC-12-4	-5.11*	-210.86*	-112.35*
LC-15-5	1.21*	196.14*	198.68*
LC-21-6	-1.56*	-93.72*	-84.28*
LC-25-7	-4.11*	-220.23*	-255.21*
LC-28-8	-1.67*	-100.32*	-49.25
Gyne-5	2.10*	69.43	176.96*
Testers			
K-75	-2.00*	98.20*	112.84*
Japanese Long Green	-0.18	-69.67*	-116.00*
Poinsette	2.18*	-28.53	3.16
S.E. (g_i) Lines	0.61	42.86	37.68
S.E. (g_j) Testers	0.26	18.56	16.31
S.E. (g_i- g_j) Lines	0.86	60.61	53.29
S.E. (g_i- g_j) Testers	0.37	26.24	23.07
C.D.$_{(0.05)}$ (g_i) Lines	1.20	84.01	73.86
C.D.$_{(0.05)}$ (g_i) Testers	0.51	36.37	31.98
C.D.$_{(0.05)}$ (g_i- g_j) Lines	1.69	118.80	104.45
C.D.$_{(0.05)}$ (g_i- g_j) Testers	0.73	51.44	45.22

*Significant at 5% level of significance

4.2.1.19 Seed vigour index-II

Data pertaining to GCA effects of seed vigour index-II have been presented in the Table 4.26. The line LC-1-1 (285.35) followed by LC-2-2 (284.45), LC-3-3 (321.30), LC-15-5 (198.68) and Gyne-5 (176.96) were found good general combiners due to their significant positive GCA effects. Poor general combining ability was exhibited by six lines *viz.*, CGN-21585 (-338.82), LC-25-7 (-255.21), CGN-20969 (-182.68), CGN-19533 (-126.79), LC-12-4 (-112.35) and LC-21-6 (-84.28) due to their significant negative GCA effects. Remaining five lines *viz.*, CGN-20256, CGN-20515, CGN-20953, CGN-22930 and LC-28-8 were designated as average general combiners due to their non-significant GCA effects. Among the testers, K-75 (112.84) and Japanese Long Green (-116.00) were found good and poor general combiners due to their positive and negative GCA effects, respectively. Poinsette was found average general combiner due to its non-significant GCA effect for seed vigour index-II.

4.2.2 Estimates of specific combining ability (SCA) effects of crosses

Since, mean sum of squares due to lines x testers interactions were significant for all the characters, hence specific combining ability (SCA) effects have been estimated for all the traits under study and have been described as below:

4.2.2.1 Days to first female flower appearance

The cross combinations exhibited significant negative or positive SCA effects were designated as good or poor specific combiners, respectively. The remaining crosses exhibited non-significant SCA effects were assigned as average specific combiners for early female flower appearance (Table 4.27). Out of forty eight cross combinations, seventeen crosses exhibited significant negative SCA effects, indicated that these were good cross combinations. Out of these seventeen combinations, top five best cross combiners were CGN-20953 x Poinsette (-3.64), CGN-19533 x K-75 (-3.25), LC-1-1 x K-75 (-3.14), Gyne-5 x K-75 (-3.11) and LC-2-2 x Poinsette (-3.06), which involved the parents with good x good GCA effects. Seventeen cross combinations revealed significant positive SCA effects, indicated that these were poor cross combinations. Remaining fourteen crosses exhibited non-significant SCA effects and thus were average cross combinations.

4.2.2.2 Node number bearing first female flower

For node number bearing first female flower, significant negative SCA effects were exhibited by sixteen crosses out of forty eight cross combinations, indicated that these were good specific cross combinations (Table 4.27). The top five crosses were CGN-19533 x K-75 (-2.04), CGN-20953 x Poinsette (-1.74), LC-1-1 x K-75 (-1.70), Gyne-5 x K-75 (-1.68) and LC-2-2 x Poinsette (-1.61) for this trait. All of these top

Table 4.27 Estimates of specific combining ability (SCA) effects of crosses for different phenological traits in cucumber

Crosses/Traits → ↓	Days to first female flower appearance	Node number bearing first female flower	Days to marketable maturity
CGN-19533 X K-75	-3.25*	-2.04*	-3.44*
CGN-19533 X Japanese Long Green	0.62	0.64*	0.95
CGN-19533 X Poinsette	2.62*	1.40*	2.49*
CGN-20256 X K-75	3.08*	1.59*	3.26*
CGN-20256 X Japanese Long Green	-2.63*	-1.51*	-2.97*
CGN-20256 X Poinsette	-0.44	-0.08	-0.29
CGN-20515 X K-75	1.42*	0.78*	1.48*
CGN-20515 X Japanese Long Green	-2.16*	-1.53*	-2.04*
CGN-20515 X Poinsette	0.73	0.75*	0.56
CGN-20953 X K-75	-2.01*	-0.32	-2.13*
CGN-20953 X Japanese Long Green	5.66*	2.06*	5.99*
CGN-20953 X Poinsette	-3.64*	-1.74*	-3.86*
CGN-20969 X K-75	1.55*	0.74*	1.60*
CGN-20969 X Japanese Long Green	-2.49*	-1.53*	-2.73*
CGN-20969 X Poinsette	0.93	0.78*	1.13*
CGN-21585 X K-75	2.34*	1.33*	2.63*
CGN-21585 X Japanese Long Green	0.29	0.18	0.06
CGN-21585 X Poinsette	-2.64*	-1.51*	-2.69*
CGN-22930 X K-75	1.13	0.79*	1.18*
CGN-22930 X Japanese Long Green	-2.44*	-1.52*	-2.71*
CGN-22930 X Poinsette	1.31*	0.73*	1.52*
LC-1-1 X K-75	-3.14*	-1.70*	-3.35*
LC-1-1 X Japanese Long Green	-0.26	0.51	0.04
LC-1-1 X Poinsette	3.40*	1.18*	3.31*
LC-2-2 X K-75	-0.57	-0.42	-0.30
LC-2-2 X Japanese Long Green	3.64*	2.03*	3.66*
LC-2-2 X Poinsette	-3.06*	-1.61*	-3.36*
LC-3-3 X K-75	1.19*	0.80*	1.21*
LC-3-3 X Japanese Long Green	1.50*	0.71*	1.50*
LC-3-3 X Poinsette	-2.69*	-1.52*	-2.71*
LC-12-4 X K-75	2.07*	1.01*	1.98*
LC-12-4 X Japanese Long Green	0.65	0.58*	0.61
LC-12-4 X Poinsette	-2.72*	-1.59*	-2.60*
LC-15-5 X K-75	3.14*	1.09*	3.16*
LC-15-5 X Japanese Long Green	-0.27	0.40	-0.37
LC-15-5 X Poinsette	-2.87*	-1.49*	-2.79*
LC-21-6 X K-75	-2.74*	-1.53*	-2.82*
LC-21-6 X Japanese Long Green	0.77	0.47	0.97
LC-21-6 X Poinsette	1.96*	1.058*	1.84*
LC-25-7 X K-75	1.61*	1.06*	1.66*
LC-25-7 X Japanese Long Green	-2.80*	-1.56*	-2.97*
LC-25-7 X Poinsette	1.19	0.50	1.30*
LC-28-8 X K-75	-2.73*	-1.52*	-2.87*
LC-28-8 X Japanese Long Green	0.28	0.14	0.28
LC-28-8 X Poinsette	2.44*	1.38*	2.59*
Gyne-5 X K-75	-3.11*	-1.68*	-3.27*
Gyne-5 X Japanese Long Green	-0.37	-0.09	-0.28
Gyne-5 X Poinsette	3.49*	1.77*	3.56*
S.E. (S_{ij})	0.60	0.27	0.53
S.E. (S_{ij}-S_{kj})	0.86	0.38	0.76
C.D.$_{(0.05)}$(S_{ij})	1.19	0.53	1.05
C.D.$_{(0.05)}$(S_{ij}-S_{kj})	1.68	0.75	1.49

*Significant at 5% level of significance

five crosses involved the parents with good x good general combining ability effects. Significant positive SCA effects were recorded in twenty two cross combinations, which revealed that these were poor cross combinations. On the other hand, ten crosses with non-significant SCA effects were found as average specific cross combinations for node number bearing first female flower.

4.2.2.3 Days to marketable maturity

For this trait also, negative SCA effects are desirable. Out of forty eight crosses, significant negative SCA effects were exhibited by eighteen hybrid combinations, due to which they were designated as good specific cross combinations for days to marketable maturity (Table 4.27). The crosses, CGN-20953 x Poinsette (-3.86), CGN-19533 x K-75 (-3.44), LC-2-2 x Poinsette (-3.36), LC-1-1 x K-75 (-3.35) and Gyne-5 x K-75 (-3.27) were the top five cross combinations, which involved parents with good x good GCA effects. Twenty cross combinations revealed significant positive SCA effects, indicated that these were poor cross combinations. Remaining, eight crosses were designated as average specific cross combinations due to their non-significant SCA effects.

4.2.2.4 Fruit length

Significant positive SCA effects were exhibited by eight cross combinations, which revealed that these were good specific cross combinations for the trait under study (Table 4.28). Among these eight crosses, LC-25-7 x Japanese Long Green (2.93), CGN-20953 x Poinsette (1.70), CGN-19533 x K-75 (1.41), LC-1-1 x K-75 (1.27) and Gyne-5 x K-75 (1.22) were the top five cross combinations, which involved parents with good x good, good x poor, good x average, good x average and good x average GCA effects, respectively. On the other hand, six hybrids were found poor specific cross combiners due to their significant negative SCA effects. Other thirty four cross combinations revealed non-significant SCA effects, which indicated that these hybrid combinations were average specific combiners for fruit length.

4.2.2.5 Fruit breadth

Data pertaining to estimates of SCA effects revealed that twenty one cross combinations exhibited significant positive SCA effects and these were found good specific cross combinations for fruit breadth (Table 4.28). The crosses, CGN-20515 x Japanese Long Green (1.18), LC-15-5 x Poinsette (0.63), Gyne-5 x Japanese Long

Table 4.28 Estimates of specific combining ability (SCA) effects of crosses for different fruit traits in cucumber

Crosses/Traits	Fruit length (cm)	Fruit breadth (cm)	Average fruit weight (g)
CGN-19533 X K-75	1.41*	0.21*	27.56*
CGN-19533 X Japanese Long Green	-1.30*	0.18	-18.72*
CGN-19533 X Poinsette	-0.11	-0.40*	-8.83
CGN-20256 X K-75	0.22	0.35*	9.84
CGN-20256 X Japanese Long Green	-0.02	-0.45*	-8.21
CGN-20256 X Poinsette	-0.19	0.09	-1.62
CGN-20515 X K-75	0.26	-1.21*	-16.22*
CGN-20515 X Japanese Long Green	-0.49	1.18*	11.61
CGN-20515 X Poinsette	0.23	0.03	4.60
CGN-20953 X K-75	0.02	0.35*	6.44
CGN-20953 X Japanese Long Green	-1.72*	-0.65*	-40.51*
CGN-20953 X Poinsette	1.70*	0.29*	34.07*
CGN-20969 X K-75	-0.77	0.24*	-8.33
CGN-20969 X Japanese Long Green	1.10*	-0.46*	10.50
CGN-20969 X Poinsette	-0.33	0.22*	-2.17
CGN-21585 X K-75	0.29	-0.55*	-4.51
CGN-21585 X Japanese Long Green	0.07	0.33*	6.89
CGN-21585 X Poinsette	-0.36	0.22*	-2.38
CGN-22930 X K-75	-0.18	0.47*	4.48
CGN-22930 X Japanese Long Green	-0.27	-0.42*	-11.10
CGN-22930 X Poinsette	0.45	-0.04	6.61
LC-1-1 X K-75	1.27*	0.31*	27.03*
LC-1-1 X Japanese Long Green	-1.48*	-0.45*	-32.95*
LC-1-1 X Poinsette	0.21	0.13	5.92
LC-2-2 X K-75	-0.54	0.30*	-3.94
LC-2-2 X Japanese Long Green	0.27	-0.02	4.063
LC-2-2 X Poinsette	0.26	-0.27*	-0.11
LC-3-3 X K-75	0.44	0.01	7.97
LC-3-3 X Japanese Long Green	-1.67*	-0.41*	-35.48*
LC-3-3 X Poinsette	1.22*	0.39*	27.50*
LC-12-4 X K-75	-0.82	-0.01	-14.14
LC-12-4 X Japanese Long Green	0.31	-0.40*	-1.60
LC-12-4 X Poinsette	0.51	0.41*	15.75
LC-15-5 X K-75	-0.24	-0.88*	-19.05*
LC-15-5 X Japanese Long Green	0.90	0.24*	19.55*
LC-15-5 X Poinsette	-0.66	0.63*	-0.49
LC-21-6 X K-75	-1.04*	0.29*	-12.63
LC-21-6 X Japanese Long Green	1.03*	0.19	20.87*
LC-21-6 X Poinsette	0.01	-0.49*	-8.23
LC-25-7 X K-75	-0.74	-0.20	-16.03*
LC-25-7 X Japanese Long Green	2.93*	0.32*	55.44*
LC-25-7 X Poinsette	-2.19*	-0.12	-39.40*
LC-28-8 X K-75	-0.81	0.27*	-9.23
LC-28-8 X Japanese Long Green	0.92	0.23*	19.74*
LC-28-8 X Poinsette	-0.11	-0.512*	-10.50
Gyne-5 X K-75	1.22*	-0.01	20.79*
Gyne-5 X Japanese Long Green	-0.59	0.59*	-0.09
Gyne-5 X Poinsette	-0.63	-0.59*	-20.70*
S.E. (S_{ij})	0.47	0.10	8.04
S.E. (S_{ij}-S_{kj})	0.67	0.14	11.37
C.D.$_{(0.05)}$(S_{ij})	0.93	0.20	15.77
C.D.$_{(0.05)}$(S_{ij}-S_{kj})	1.32	0.28	22.30

*Significant at 5% level of significance

Green (0.59), CGN-22930 x K-75 (0.47) and LC-12-4 x Poinsette (0.41) were the top five cross combinations, which involved parents with good x poor, good x good, good x poor, poor x good and average x good GCA effects, respectively. Twelve cross combinations revealed significant negative SCA effects, indicated that these were poor cross combinations. Out of forty eight crosses, twelve were found average specific combinations, due to their non-significant SCA effects.

4.2.2.6 Average fruit weight

For average fruit weight, nine hybrid combinations exhibited significant positive SCA effects, indicated that these crosses were good specific cross combiners (Table 4.28). Among these crosses, LC-25-7 x Japanese Long Green (55.44), CGN-20953 x Poinsette (34.07), CGN-19533 x K-75 (27.56), LC-3-3 x Poinsette (27.50) and LC-1-1 x K-75 (27.03) were the top five cross combinations, which involved parents with good x average, good x poor, good x good, average x poor and good x good GCA effects, respectively. On the other hand, nine hybrids were found poor specific cross combiners due to their significant negative SCA effects. Non-significant SCA effects were exhibited by thirty crosses, indicated that these were average specific combinations for average fruit weight.

4.2.2.7 Number of marketable fruits per plant

Out of forty eight hybrid combinations, eighteen were found good specific cross combinations due to their significant positive SCA effects (Table 4.29). The crosses, CGN-19533 x K-75 (2.04), Gyne-5 x K-75 (1.83), LC-1-1 x K-75 (1.78), CGN-20953 x Poinsette (1.67) and LC-2-2 x Poinsette (1.61) were the top five best combinations and involved the parents with good x good GCA effects. Significant negative SCA effects were observed for twenty five cross combinations, indicated that these were poor specific hybrid combinations. Remaining five crosses were found average specific combinations, due to their non-significant SCA effects.

4.2.2.8 Harvest duration

For this trait, significant positive SCA effects were exhibited by seventeen crosses out of forty eight cross combinations as presented in the table 4.29. Hence, these crosses were found as good specific cross combiners. Top five cross combinations *viz.* CGN-19533 x K-75 (5.94), Gyne-5 x K-75 (5.09), LC-1-1 x K-75 (4.99), CGN-20953 x Poinsette (4.68) and LC-2-2 x Poinsette (4.52) were involved

Table 4.29 Estimates of specific combining ability (SCA) effects of crosses for number of marketable fruits per plant, harvest duration and marketable yield in cucumber

Crosses/Traits → ↓	Number of marketable fruits per plant	Harvest duration (days)	Marketable yield per plot (kg)	Marketable yield per hectare (q)
CGN-19533 X K-75	2.04*	5.94*	14.96*	99.72*
CGN-19533 X Japanese Long Green	-0.67*	-2.21*	-6.60*	-44.10*
CGN-19533 X Poinsette	-1.37*	-3.72*	-8.35*	-55.61*
CGN-20256 X K-75	-1.65*	-4.69*	-6.19*	-41.22*
CGN-20256 X Japanese Long Green	1.52*	4.28*	6.83*	45.54*
CGN-20256 X Poinsette	0.12	0.40	-0.64	-4.32
CGN-20515 X K-75	-0.81*	-2.1*	-6.26*	-41.88*
CGN-20515 X Japanese Long Green	1.53*	4.2*	9.03*	60.36*
CGN-20515 X Poinsette	-0.72*	-2.14*	-2.77*	-18.48*
CGN-20953 X K-75	0.25	0.65	1.16	7.67
CGN-20953 X Japanese Long Green	-1.92*	-5.33*	-14.97*	-99.78*
CGN-20953 X Poinsette	1.67*	4.68*	13.81*	92.10*
CGN-20969 X K-75	-0.78*	-2.25*	-4.91*	-32.84*
CGN-20969 X Japanese Long Green	1.56*	4.41*	9.21*	61.46*
CGN-20969 X Poinsette	-0.77*	-2.16*	-4.30*	-28.61*
CGN-21585 X K-75	-1.35*	-3.66*	-6.74*	-44.86*
CGN-21585 X Japanese Long Green	-0.20	-0.59	1.18	7.87
CGN-21585 X Poinsette	1.56*	4.26*	5.56*	36.99*
CGN-22930 X K-75	-0.76*	-2.16*	-3.23*	-21.64*
CGN-22930 X Japanese Long Green	1.55*	4.34*	5.72*	38.29*
CGN-22930 X Poinsette	-0.78*	-2.17*	-2.49*	-16.64*
LC-1-1 X K-75	1.78*	4.99*	13.75*	91.58*
LC-1-1 X Japanese Long Green	-0.56*	-1.45*	-8.18*	-54.47*
LC-1-1 X Poinsette	-1.22*	-3.54*	-5.56*	-37.11*
LC-2-2 X K-75	0.30	0.79	0.80	5.28
LC-2-2 X Japanese Long Green	-1.91*	-5.32*	-7.92*	-52.94*
LC-2-2 X Poinsette	1.61*	4.52*	7.12*	47.65*
LC-3-3 X K-75	-0.81*	-2.36*	-4.16*	-27.71*
LC-3-3 X Japanese Long Green	-0.72*	-1.99*	-7.09*	-47.37*
LC-3-3 X Poinsette	1.53*	4.36*	11.25*	75.08*
LC-12-4 X K-75	-0.96*	-2.75*	-6.69*	-44.51*
LC-12-4 X Japanese Long Green	-0.61*	-1.71*	-2.46*	-16.57*
LC-12-4 X Poinsette	1.58*	4.47*	9.15*	61.08*
LC-15-5 X K-75	-1.04*	-3.05*	-7.40*	-49.18*
LC-15-5 X Japanese Long Green	-0.49*	-1.28	-0.37	-2.54
LC-15-5 X Poinsette	1.53*	4.33*	7.77*	51.72*
LC-21-6 X K-75	1.52*	4.19*	3.68*	24.72*
LC-21-6 X Japanese Long Green	-0.49*	-1.35	1.28	8.52
LC-21-6 X Poinsette	-1.02*	-2.84*	-4.96*	-33.24*
LC-25-7 X K-75	-1.12*	-2.93*	-7.43*	-49.58*
LC-25-7 X Japanese Long Green	1.56*	4.27*	14.09*	94.02*
LC-25-7 X Poinsette	-0.43*	-1.34	-6.65*	-44.44*
LC-28-8 X K-75	1.57*	4.33*	5.86*	38.94*
LC-28-8 X Japanese Long Green	-0.13	-0.35	1.26	8.51
LC-28-8 X Poinsette	-1.43*	-3.97*	-7.12*	-47.45*
Gyne-5 X K-75	1.83*	5.09*	12.81*	85.52*
Gyne-5 X Japanese Long Green	0.01	0.04	-1.01	-6.80
Gyne-5 X Poinsette	-1.85*	-5.14*	-11.80*	-78.71*
S.E. (S_{ij})	0.19	0.69	1.22	8.13
S.E. (S_{ij}-S_{kj})	0.27	0.98	1.72	11.50
C.D.$_{(0.05)}$(S_{ij})	0.37	1.36	2.39	15.94
C.D.$_{(0.05)}$(S_{ij}-S_{kj})	0.53	1.92	3.38	22.55

*Significant at 5% level of significance

the parents with good x good GCA effects. While, twenty two hybrids were found poor specific cross combinations due to their significant negative SCA effects. Non-significant SCA effects were revealed by nine crosses, indicated that these were average specific combiners for harvest duration.

4.2.2.9 Marketable yield per plot

Significant positive SCA effects were exhibited by sixteen cross combinations, which revealed that these were good specific cross combinations for the trait under study (Table 4.29). Among these, crosses *viz.,* CGN-19533 x K-75 (14.96), LC-25-7 x Japanese Long Green (14.09), CGN-20953 x Poinsette (13.81), LC-1-1 x K-75 (13.75) and Gyne-5 x K-75 (12.81) were the top five cross combinations, which involved the parents with good x good, average x poor, good x good, good x good and good x good GCA effects, respectively. Significant negative SCA effects were observed for twenty four crosses, which indicated that these were poor specific cross combinations. Remaining eight crosses due to their non-significant SCA effects were found as average specific cross combinations.

4.2.2.10 Marketable yield per hectare

Data pertaining to SCA effects for marketable yield per hectare have been presented in the table 4.29. Sixteen cross combinations exhibited significant positive SCA effects for yield per hectare, hence designated as good specific cross combinations. The crosses, CGN-19533 x K-75 (99.72), LC-25-7 x Japanese Long Green (94.02), CGN-20953 x Poinsette (92.10), LC-1-1 x K-75 (91.58) and Gyne-5 x K-75 (85.52) were the top five cross combinations, which involved the parents with good x good, average x poor, good x good, good x good and good x good GCA effects, respectively. On the other hand, twenty four hybrids were found poor specific cross combiners due to their significant negative SCA effects. Non-significant SCA effects were exhibited by remaining eight crosses, indicated that these were average specific combinations for the trait under study.

4.2.2.11 Total soluble solids

The estimation of specific combining ability effects for total soluble solids revealed that nine hybrid combinations exhibited significant positive values, which indicated that these crosses were good specific cross combiners (Table 4.30). Top five cross combinations *viz.,* CGN-21585 x Japanese Long Green (0.25), LC-1-1 x K-75

Table 4.30 Estimates of specific combining ability (SCA) effects of crosses for quality traits in cucumber

Crosses/Traits → ↓	Total soluble solids (°B)	Cucurbitacin content (µg/100g)
CGN-19533 X K-75	0.11*	1.78
CGN-19533 X Japanese Long Green	-0.02	-1.83*
CGN-19533 X Poinsette	-0.08	0.05
CGN-20256 X K-75	-0.07	3.27*
CGN-20256 X Japanese Long Green	0.12*	-4.23*
CGN-20256 X Poinsette	-0.05	0.95
CGN-20515 X K-75	0.10	1.09
CGN-20515 X Japanese Long Green	-0.06	-0.16
CGN-20515 X Poinsette	-0.04	-0.93
CGN-20953 X K-75	0.00	3.02*
CGN-20953 X Japanese Long Green	0.13*	-3.73*
CGN-20953 X Poinsette	-0.14*	0.70
CGN-20969 X K-75	-0.01	1.48
CGN-20969 X Japanese Long Green	0.01	-2.38*
CGN-20969 X Poinsette	0.01	0.89
CGN-21585 X K-75	-0.22*	2.98*
CGN-21585 X Japanese Long Green	0.25*	-4.88*
CGN-21585 X Poinsette	-0.03	1.89*
CGN-22930 X K-75	-0.03	1.44
CGN-22930 X Japanese Long Green	-0.00	-0.63*
CGN-22930 X Poinsette	0.04	-0.81
LC-1-1 X K-75	0.21*	-4.02*
LC-1-1 X Japanese Long Green	-0.36*	4.90*
LC-1-1 X Poinsette	0.15*	-0.88
LC-2-2 X K-75	-0.10	-1.93*
LC-2-2 X Japanese Long Green	0.10	4.55*
LC-2-2 X Poinsette	-0.01	-2.61*
LC-3-3 X K-75	0.01	-1.09
LC-3-3 X Japanese Long Green	-0.04	-2.65*
LC-3-3 X Poinsette	0.02	3.74*
LC-12-4 X K-75	-0.09	-2.24*
LC-12-4 X Japanese Long Green	0.05	-2.81*
LC-12-4 X Poinsette	0.03	5.05*
LC-15-5 X K-75	-0.12*	4.82*
LC-15-5 X Japanese Long Green	0.07	-1.91*
LC-15-5 X Poinsette	0.04	-2.91*
LC-21-6 X K-75	-0.13*	-1.09
LC-21-6 X Japanese Long Green	0.13*	-1.91*
LC-21-6 X Poinsette	0.00	3.01*
LC-25-7 X K-75	0.02	-3.01*
LC-25-7 X Japanese Long Green	-0.04	4.60*
LC-25-7 X Poinsette	0.02	-1.58
LC-28-8 X K-75	0.20*	-5.44*
LC-28-8 X Japanese Long Green	-0.04	9.58*
LC-28-8 X Poinsette	-0.16*	-4.13*
Gyne-5 X K-75	0.08	-1.09
Gyne-5 X Japanese Long Green	-0.28*	3.51*
Gyne-5 X Poinsette	0.20*	-2.42*
S.E. (S_{ij})	0.05	0.93
S.E. (S_{ij}-S_{kj})	0.08	1.31
C.D.$_{(0.05)}$(S_{ij})	0.11	1.82
C.D.$_{(0.05)}$(S_{ij}-S_{kj})	0.16	2.57

*Significant at 5% level of significance

(0.21), LC-28-8 x K-75 (0.20), Gyne-5 x Poinsette (0.20) and LC-1-1 x Poinsette (0.15) involved the parents with good x good, good x average, good x average, good x poor and good x poor GCA effects, respectively. Out of forty eight hybrid combinations, seven crosses exhibited significant negative SCA effects indicated that these were poor specific cross combinations. Remaining thirty two crosses due to their non-significant SCA effects were found as average specific cross combinations for total soluble solids.

4.2.2.12 Cucurbitacin content

For this trait, significant negative SCA effects are desirable. Out of forty eight hybrid combinations, nineteen revealed significant negative SCA effects as presented in the table 4.30. Hence, these crosses were found as good specific cross combinations. The cross combinations, LC-28-8 x K-75 (-5.44), CGN-21585 x Japanese Long Green (-4.88), CGN-20256 x Japanese Long Green (-4.23), LC-28-8 x Poinsette (-4.13) and LC-1-1 x K-75 (-4.02) were the top five cross combinations, which involved the parents with good x good, good x good, good x good, good x poor and good x good GCA effects, respectively. Significant positive SCA effects were observed for thirteen crosses, which indicated that these were poor specific hybrid combinations. Non-significant SCA effects were exhibited by sixteen crosses and were designated as average specific cross combinations.

4.2.2.13 Fruit fly incidence

Out of forty eight hybrid combinations, sixteen were found good specific cross combinations due to their significant negative SCA effects (Table 4.31). The top five cross combinations *viz.* LC-1-1 x K-75 (-3.91), CGN-20953 x K-75 (-3.31), LC-15-5 x Poinsette (-3.12), LC-3-3 x Poinsette (-2.99) and LC-2-2 x K-75 (-2.84) involved the parents with good x good GCA effects, respectively. On the other hand, fourteen hybrids were found poor specific cross combiners due to their significant positive SCA effects. Non-significant SCA effects were exhibited by remaining eighteen crosses, which indicated that these were average specific cross combinations for this trait.

4.2.2.14 Severity of powdery mildew

Data regarding SCA effects for severity of powdery mildew have been presented in the table 4.31. Significant negative SCA effects were exhibited by

Table 4.31 Estimates of specific combining ability (SCA) effects of crosses for economically important insect-pest and diseases in cucumber

Crosses/Traits → ↓	Fruit fly incidence (%)	Severity of powdery mildew (%)	Severity of downy mildew (%)	Severity of angular leaf spot (%)
CGN-19533 X K-75	-1.15	4.75*	-5.49*	3.52*
CGN-19533 X Japanese Long Green	-0.04	-2.43*	8.71*	-1.15
CGN-19533 X Poinsette	1.19	-2.31*	-3.21*	-2.36*
CGN-20256 X K-75	4.20*	3.75*	5.70*	4.66*
CGN-20256 X Japanese Long Green	-2.46*	-2.32*	-4.21*	-1.91
CGN-20256 X Poinsette	-1.73*	-1.43	-1.48	-2.75*
CGN-20515 X K-75	-0.34	-1.99*	-1.39	1.13
CGN-20515 X Japanese Long Green	-1.54*	2.68*	3.88*	0.58
CGN-20515 X Poinsette	1.89*	-0.68	-2.48*	-1.71
CGN-20953 X K-75	-3.31*	-4.34*	0.95	-5.40*
CGN-20953 X Japanese Long Green	3.89*	1.90*	-0.22	2.58*
CGN-20953 X Poinsette	-0.58	2.43*	-0.72	2.81*
CGN-20969 X K-75	1.90*	2.97*	4.26*	1.26
CGN-20969 X Japanese Long Green	-1.74*	-2.30*	-9.38*	-3.41*
CGN-20969 X Poinsette	-0.16	-0.66	5.11*	2.14*
CGN-21585 X K-75	2.20*	1.71	3.65*	4.35*
CGN-21585 X Japanese Long Green	0.53	-0.44	-2.19*	-2.22*
CGN-21585 X Poinsette	-2.74*	-1.27	-1.46	-2.13*
CGN-22930 X K-75	0.80	4.94*	-2.42*	-2.43*
CGN-22930 X Japanese Long Green	-2.73*	-2.80*	7.32*	0.51
CGN-22930 X Poinsette	1.93*	-2.14*	-4.90*	1.91
LC-1-1 X K-75	-3.91*	-3.44*	-2.44*	-4.65*
LC-1-1 X Japanese Long Green	2.79*	2.23*	0.97	3.96*
LC-1-1 X Poinsette	1.12	1.20	1.47	0.69
LC-2-2 X K-75	-2.84*	-1.90*	2.56*	0.21
LC-2-2 X Japanese Long Green	2.72*	1.48	0.61	2.96*
LC-2-2 X Poinsette	0.12	0.42*	-3.18*	-3.17*
LC-3-3 X K-75	4.05*	-3.25*	-3.28*	-2.91*
LC-3-3 X Japanese Long Green	-1.05	3.09*	1.06	-0.25
LC-3-3 X Poinsette	-2.99*	0.15	2.22*	3.17*
LC-12-4 X K-75	-1.57*	1.42	-0.03	0.40
LC-12-4 X Japanese Long Green	-1.29	-2.93*	1.91	-1.41
LC-12-4 X Poinsette	2.86*	1.51	-1.88	1.01
LC-15-5 X K-75	0.73	-4.56*	-0.72	1.17
LC-15-5 X Japanese Long Green	2.39*	0.87	-4.30*	0.69
LC-15-5 X Poinsette	-3.12*	3.69*	5.02*	-1.87
LC-21-6 X K-75	-0.15	1.73	-3.65*	3.26*
LC-21-6 X Japanese Long Green	-0.77	-3.15*	3.06*	-2.68*
LC-21-6 X Poinsette	0.92	1.41	0.59	-0.58
LC-25-7 X K-75	3.50*	-2.25*	2.89*	-4.60*
LC-25-7 X Japanese Long Green	-1.72*	2.16*	-4.66*	2.11*
LC-25-7 X Poinsette	-1.77*	0.09	1.77	2.48*
LC-28-8 X K-75	-1.51*	-1.64	1.64	2.83*
LC-28-8 X Japanese Long Green	-0.18	0.43	-0.57	-0.88
LC-28-8 X Poinsette	1.69*	1.20	-1.07	-1.95
Gyne-5 X K-75	-2.59*	2.10*	-2.23*	-2.83*
Gyne-5 X Japanese Long Green	1.23	1.51	-1.98	0.51
Gyne-5 X Poinsette	1.36*	-3.61*	4.21*	2.31*
S.E. (S_{ij})	0.68	0.89	1.08	1.02
S.E. (S_{ij}-S_{kj})	0.96	1.27	1.53	1.44
C.D.$_{(0.05)}$(S_{ij})	1.34	1.76	2.12	2.01
C.D.$_{(0.05)}$(S_{ij}-S_{kj})	1.89	2.48	2.99	2.84

*Significant at 5% level of significance

sixteen cross combinations, indicated that these were good specific cross combinations among the forty eight hybrids. The cross combinations, LC-15-5 x K-75(-4.56), CGN-20953 x K-75 (-4.34), Gyne-5 x Poinsette (-3.61), LC-1-1 x K-75 (-3.44) and LC-3-3 x K-75 (-3.25) were the top five hybrids, which involved the parents with good x poor, good x poor, average x good, good x poor and good x poor GCA effects, respectively. Thirteen crosses were designated as poor specific cross combiners, due to their significant positive SCA effects. While, remaining nineteen hybrids due to their non-significant SCA effects were found as average specific cross combinations for severity of powdery mildew.

4.2.2.15 Severity of downy mildew

The estimates of specific combining ability effects revealed that fifteen crosses exhibited significant negative values for severity of downy mildew, indicated that these crosses were good specific cross combinations (Table 4.31). The top five crosses *viz.,* CGN-20969 x Japanese Long Green (-9.38), CGN-19533 x K-75 (-5.49), CGN-22930 x Poinsette (-4.90), LC-25-7 x Japanese Long Green (-4.66) and LC-15-5 x Japanese Long Green (-4.30), involved the parents with good x poor, poor x good, poor x good, good x poor and good x poor GCA effects, respectively. Significant positive SCA effects were exhibited by thirteen crosses, indicated that these were poor specific cross combinations. Non-significant SCA effects were revealed by twenty crosses and were found average specific cross combinations.

4.2.2.16 Severity of angular leaf spot

For severity of angular leaf spot, SCA effects have been presented in the table 4.31. Out of forty eight hybrid combinations, thirteen revealed significant negative SCA effects and these crosses were designated as good specific cross combinations. The crosses, *viz.,* CGN-20953 x K-75 (-5.40), LC-1-1 x K-75 (-4.65), LC-25-7 x K-75 (-4.60), CGN-20969 x Japanese Long Green (-3.41) and LC-2-2 x Poinsette (-3.17) were the top five hybrids, which involved the parents with good x poor, good x poor, good x poor, good x good and good x average GCA effects, respectively. On the other hand, fourteen crosses were found poor specific cross combinations, due to their significant positive SCA effects. Remaining twenty one hybrids due to their non-significant SCA effects were found as average specific cross combinations for this trait.

4.2.2.17 Seed germination

Out of forty eight hybrid combinations, eight were found good specific cross combinations due to their significant positive SCA effects (Table 4.32). Among these crosses, top five cross combinations were LC-1-1 x K-75 (5.66), LC-3-3 x Japanese Long Green (3.74), CGN-20515 x K-75 (3.44), CGN-19533 x Poinsette (3.25) and CGN-20953 x Poinsette (2.81), which involved the parents with good x poor, good x average, good x poor, average x good and good x good GCA effects, respectively. Significant negative SCA effects were revealed by seven crosses, indicated that these were poor specific cross combinations. Non-significant SCA effects were exhibited by thirty three crosses and were found average specific cross combinations for seed germination.

4.2.2.18 Seed vigour index-I

Significant positive SCA effects were exhibited by eleven cross combinations, which revealed that these were good specific cross combinations for the trait under study (Table 4.32). The crosses, LC-1-1 x K-75 (435.15), CGN-20953 x Poinsette (396.66), LC-2-2 x Poinsette (340.15), LC-15-5 x Poinsette (261.42) and LC-3-3 x K-75 (208.34), which involved the parents with good x good, good x average, good x average, good x average and good x good GCA effects, respectively were the top best combinations for this trait. Eleven cross combinations were designated as poor specific cross combiners, due to their significant negative SCA effects. While, remaining twenty six hybrids due to their non-significant SCA effects were found average specific cross combinations.

4.2.2.19 Seed vigour index-II

Data pertaining to SCA effects for seed vigour index-II have been presented in the table 4.32. Out of forty eight hybrids, significant positive SCA effects were exhibited by eight crosses, indicated that these were good specific cross combinations. The top five crosses were LC-1-1 x K-75 (429.71), LC-2-2 x Poinsette (347.22), LC-3-3 x K-75 (290.82), LC-15-5 x Poinsette (279.19) and CGN-20953 x Japanese Long Green (224.66), involved the parents with good x good, good x average, good x good, good x average and average x poor GCA effects, respectively for this character. On the other hand, twelve crosses were found poor specific cross combinations, due to their significant negative SCA effects. Remaining twenty eight hybrids due to their non-significant SCA effects were found as average specific cross combinations for the trait under study.

Table 4.32 Estimates of specific combining ability (SCA) effects of crosses for seed traits in cucumber

Crosses/Traits → ↓	Seed germination (%)	Seed vigour index-I	Seed vigour index-II
CGN-19533 X K-75	-1.55	120.60	10.25
CGN-19533 X Japanese Long Green	-1.70	-88.65	-128.95*
CGN-19533 X Poinsette	3.25*	-31.95	118.70
CGN-20256 X K-75	-1.33	-4.31	-81.12
CGN-20256 X Japanese Long Green	2.52*	194.36*	-21.30
CGN-20256 X Poinsette	-1.18	-190.04*	102.42
CGN-20515 X K-75	3.44*	91.84	56.26
CGN-20515 X Japanese Long Green	-4.70*	0.21	-113.44
CGN-20515 X Poinsette	1.25	-92.05	57.18
CGN-20953 X K-75	-3.66*	-33.33	-232.22*
CGN-20953 X Japanese Long Green	0.85	-363.32*	224.66*
CGN-20953 X Poinsette	2.81*	396.66*	7.55
CGN-20969 X K-75	2.77*	105.46	105.74
CGN-20969 X Japanese Long Green	-1.36	-186.69*	-125.93
CGN-20969 X Poinsette	-1.41	81.23	20.19
CGN-21585 X K-75	-0.55	-57.17	7.38
CGN-21585 X Japanese Long Green	1.96	-3.59	-25.32
CGN-21585 X Poinsette	-1.41	60.76	17.93
CGN-22930 X K-75	-0.11	-66.61	-44.33
CGN-22930 X Japanese Long Green	0.74	180.02*	190.15*
CGN-22930 X Poinsette	-0.63	-113.41	-145.81*
LC-1-1 X K-75	5.66*	435.15*	429.71*
LC-1-1 X Japanese Long Green	-3.81*	-240.87*	-236.10*
LC-1-1 X Poinsette	-1.85	-194.27*	-193.60*
LC-2-2 X K-75	1.66	-176.84*	-206.18*
LC-2-2 X Japanese Long Green	-1.47	-163.30*	-141.03*
LC-2-2 X Poinsette	-0.18	340.15*	347.22*
LC-3-3 X K-75	-1.11	208.34*	290.82*
LC-3-3 X Japanese Long Green	3.74*	172.64*	106.07
LC-3-3 X Poinsette	-2.63*	-380.99*	-396.89*
LC-12-4 X K-75	-2.44*	-242.50*	-236.91*
LC-12-4 X Japanese Long Green	1.07	96.27	79.74
LC-12-4 X Poinsette	1.36	146.23*	157.17*
LC-15-5 X K-75	-2.11*	-228.04*	-170.35*
LC-15-5 X Japanese Long Green	1.41	-33.37	-108.83
LC-15-5 X Poinsette	0.70	261.42*	279.19*
LC-21-6 X K-75	0.33	-139.41	-123.95
LC-21-6 X Japanese Long Green	0.18	36.59	28.89
LC-21-6 X Poinsette	-0.52	102.82	95.05
LC-25-7 X K-75	-1.11	-142.10	-44.72
LC-25-7 X Japanese Long Green	0.74	192.83*	61.29
LC-25-7 X Poinsette	0.36	-50.73	-16.57
LC-28-8 X K-75	-1.22	52.68	108.38
LC-28-8 X Japanese Long Green	2.29*	155.62*	113.70
LC-28-8 X Poinsette	-1.07	-208.31*	-222.09*
Gyne-5 X K-75	1.33	76.26	131.23*
Gyne-5 X Japanese Long Green	-2.47*	51.23	96.41
Gyne-5 X Poinsette	1.14	-127.50	-227.65*
S.E. (S_{ij})	1.06	74.24	65.27
S.E. (S_{ij}-S_{kj})	1.50	104.99	92.30
C.D.$_{(0.05)}$(S_{ij})	2.08	145.51	127.93
C.D.$_{(0.05)}$(S_{ij}-S_{kj})	2.94	205.78	180.92

*Significant at 5% level of significance

4.3 GENE ACTION

4.3.1 Estimates of genetic components of variance

The mean sum of squares due to GCA and SCA were highly significant for all the traits under study, indicated the importance of both additive and non-additive genetic components of variance (Appendix-III). Further, the mean sum of squares due to GCA and SCA were used to estimate the variances for GCA and SCA, respectively, based on which nature of gene action (additive and dominance components) has been worked out and presented in the table 4.33.

A perusal of the data indicated that the estimates of σ^2 SCA were higher in magnitude as compared to σ^2 GCA (average) for all the traits under study *viz.,* days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length and breadth, average fruit weight, number of marketable fruits per plant, harvest duration, yield per plot and per hectare, total soluble solids, cucurbitacin content, severity of powdery mildew, downy mildew and angular leaf spot, seed germination, seed vigour index-I and II, except for fruit fly incidence, thereby indicated the predominant role of non-additive gene action governed in these traits under study.

The results pertaining to analysis of variance for combining ability were also confirmed from the study of additive (σ^2g) and dominant (σ^2s) components of variance. In all the traits studied, where SCA variances were higher than GCA values, dominant components of variance (σ^2s) were also higher than the additive components (σ^2g), indicated the role of non-additive gene action.

Further, variance ratio was found less than one for all the traits *viz.,* days to first female flower appearance (0.96), node number bearing first female flower (0.98), days to marketable maturity (0.95), fruit length (0.50) and breadth (0.57), average fruit weight (0.30), number of marketable fruits per plant (0.96), harvest duration (0.99), yield per plot (0.55) and per hectare (0.55), total soluble solids (0.59), cucurbitacin content (0.35), severity of powdery mildew (0.79), downy mildew (0.97) and angular leaf spot (0.70), seed germination (0.65), seed vigour index-I (0.15) and II (0.31), except fruit fly incidence (6.39), for which it was recorded higher than one. Again it confirmed the role of non-additive gene action controlling almost all the traits in cucumber under study.

Table 4.33 Estimates of genetic components of variance for different horticultural and seed traits in cucumber

Sr. No.	Character	σ^2 GCA (Lines)	σ^2 GCA (Testers)	σ^2 GCA (Average)	σ^2 SCA	σ^2g	σ^2s	σ^2g/σ^2s (Variance Ratio)
1.	Days to first female flower appearance	0.99	9.81	8.42	8.80	33.68	35.20	0.96
2.	Node number bearing first female flower	-0.01	3.83	2.39	2.44	9.56	9.76	0.98
3.	Days to marketable maturity	0.95	10.61	9.09	9.52	36.36	38.08	0.95
4.	Fruit length (cm)	2.43	0.33	0.66	1.32	2.64	5.28	0.50
5.	Fruit breadth (cm)	-0.01	0.21	0.17	0.30	0.68	1.20	0.57
6.	Average fruit weight (g)	702.53	61.29	162.53	532.96	650.12	2131.84	0.30
7.	Number of marketable fruits per plant	-0.03	2.84	2.38	2.47	9.52	9.88	0.96
8.	Harvest duration (days)	-0.47	22.53	18.93	19.08	75.72	76.32	0.99
9.	Marketable yield per plot (kg)	19.82	56.73	50.88	92.07	203.52	368.28	0.55
10.	Marketable yield per hectare (q)	881.62	2524.06	2264.43	4092.58	9057.72	16370.32	0.55
11.	Total soluble solids (^{o}B)	0.049	0.005	0.013	0.022	0.05	0.09	0.59
12.	Cucurbitacin content (µg/100g)	15.01	3.51	5.33	15.04	21.32	60.16	0.35
13.	Fruit fly incidence (%)	2.38	52.26	44.38	6.95	177.52	27.80	6.39
14.	Severity of powdery mildew (%)	6.25	7.25	7.09	8.99	28.36	35.96	0.79
15.	Severity of downy mildew (%)	8.01	21.10	19.04	19.71	76.16	78.84	0.97
16.	Severity of angular leaf spot	14.66	5.41	6.87	9.81	27.48	39.24	0.70
17.	Seed germination (%)	3.70	3.96	3.92	6.06	15.68	24.24	0.65
18.	Seed vigour index-I	21459.66	4346.86	7047.21	47023.50	28188.84	188094.00	0.15
19.	Seed vigour index-II	24561.21	10259.58	12517.43	41010.21	50069.72	164040.84	0.31

4.3.2 Proportional contribution of lines, testers and their interactions (%)

Proportional contribution of lines, testers and their interactions has been presented in the table 4.34. Contribution of lines for different traits ranged from 10.28 (fruit fly incidence) to 72.74 (total soluble solids) per cent. The contribution of lines was found higher than the individual contribution of testers and lines x testers interactions for total soluble solids (72.74 %), fruit length (69.73 %), average fruit weight (66.43 %), severity of angular leaf spot (61.54 %), cucurbitacin content (59.36 %), seed vigour index-II (50.06 %), seed vigour index-I (48.98 %), severity of powdery mildew (43.99 %) and seed germination (43.51 %). The range of the proportional contribution of testers varied from 5.14 (average fruit weight) to 79.23 (fruit fly incidence) per cent.

Table 4.34 Proportional contribution of lines, testers and their interactions to sum of squares of the hybrids

Sr. No.	Character	% contribution of		
		Lines	Testers	Lines x Testers
1.	Days to first female flower appearance	22.95	42.66	34.39
2.	Node number bearing first female flower	17.68	46.48	35.84
3.	Days to marketable maturity	22.43	42.98	34.59
4.	Fruit length (cm)	69.73	7.10	23.17
5.	Fruit breadth (cm)	19.94	35.07	44.99
6.	Average fruit weight (g)	66.43	5.14	28.43
7.	Number of marketable fruits per plant	17.30	46.48	36.22
8.	Harvest duration (days)	16.79	47.00	36.21
9.	Marketable yield per plot (kg)	32.30	28.25	39.45
10.	Marketable yield per hectare (q)	32.30	28.25	39.45
11.	Total soluble solids (^{o}B)	72.74	6.66	20.60
12.	Cucurbitacin content (µg/100g)	59.36	9.36	31.28
13.	Fruit fly incidence (%)	10.28	79.23	10.49
14.	Severity of powdery mildew (%)	43.99	25.86	30.15
15.	Severity of downy mildew (%)	33.42	35.90	30.68
16.	Severity of angular leaf spot	61.54	14.62	23.84
17.	Seed germination (%)	43.51	22.42	34.07
18.	Seed vigour index-I	48.98	6.82	44.20
19.	Seed vigour index-II	50.06	11.74	38.20

The contribution of testers was found higher in fruit fly incidence (79.23 %), harvest duration (47.00 %), node number bearing first female flower (46.48 %), number of marketable fruits per plant (46.48 %), days to marketable maturity (42.98 %), days to first female flower appearance (42.66 %) and severity of downy mildew (35.90 %) as compared to individual contribution of lines and lines x testers interactions.

The proportional contribution of lines x tester interactions ranged from 10.49 (fruit fly incidence) to 44.99 (fruit breadth) per cent. The contribution of lines x testers was found higher than the individual contribution of lines and testers interactions for fruit breadth (44.99 %), yield per plot (39.45 %) and per hectare (39.45 %).

4.4 HETEROSIS STUDIES

The present study was carried out to find out the superior heterotic cross combinations in comparison to mid parent, better parent and standard checks, KH-1 (Standard check-I) and Pusa Sanyog (Standard check-II). The heterotic response of all the F_1 hybrids for various traits under study has been described as below:

4.4.1 Days to first female flower appearance

Estimates of heterosis revealed significant differences among the different cross combinations for days to first female flower appearance (Table 4.35). Heterosis over mid parent, better parent, standard check-I and standard check-II ranged from -12.71 (LC-1-1 x K-75) to 14.35 (CGN-20953 x Japanese Long Green), -8.99 (LC-1-1 x K-75) to 24.72 (CGN-20953 x Japanese Long Green), -6.77 (CGN-20953 x Poinsette) to 25.95 (LC-21-6 x Japanese Long Green) and -8.83 (CGN-20953 x Poinsette) to 23.18 (LC-21-6 x Japanese Long Green) per cent, respectively. Significant negative average heterosis (mid parent), heterobeltiosis (better parent) and standard heterosis over check-I and check-II was recorded in fourteen, ten, four and seven hybrid combinations, respectively. In overall, the crosses CGN-19533 x K-75 (-10.23, -3.64, -4.40 and -6.51), CGN-20953 x Poinsette (-7.79, -5.92, -6.77 and -8.83), LC-1-1 x K-75 (-12.71, -8.99, -4.60 and -6.70) and LC-2-2 x Poinsette (-8.96, -7.28, -4.40 and -6.51) revealed significant negative values for all estimates of heterosis *viz.*, average heterosis, heterobeltiosis and standard heterosis over both the check cultivars.

Table 4.35 Estimates of heterosis for days to first female flower appearance in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	-10.23*	-3.64*	-4.40*	-6.51*
CGN-19533 X Japanese Long Green	4.47*	13.88*	12.98*	10.49*
CGN-19533 X Poinsette	3.74*	5.77*	4.94*	2.63
CGN-20256 X K-75	7.54*	12.21*	17.46*	14.87*
CGN-20256 X Japanese Long Green	4.52*	10.70*	15.88*	13.33*
CGN-20256 X Poinsette	4.18*	4.98*	8.24*	5.85*
CGN-20515 X K-75	0.09	5.80*	8.04*	5.66*
CGN-20515 X Japanese Long Green	0.98	8.38*	10.67*	8.23*
CGN-20515 X Poinsette	1.77	2.26	4.42*	2.12
CGN-20953 X K-75	-7.27*	-0.40	-1.30	-3.48*
CGN-20953 X Japanese Long Green	14.35*	24.72*	23.58*	20.86*
CGN-20953 X Poinsette	-7.79*	-5.92*	-6.77*	-8.83*
CGN-20969 X K-75	1.26	7.85*	8.57*	6.18*
CGN-20969 X Japanese Long Green	1.29	9.54*	10.27*	7.84*
CGN-20969 X Poinsette	3.13	4.38*	5.08*	2.76
CGN-21585 X K-75	2.45	7.78*	11.06*	8.62*
CGN-21585 X Japanese Long Green	6.07*	13.28*	16.73*	14.16*
CGN-21585 X Poinsette	-4.00*	-3.97*	-1.05	-3.23*
CGN-22930 X K-75	0.04	5.53*	8.18*	5.79*
CGN-22930 X Japanese Long Green	0.93	8.09*	10.80*	8.36*
CGN-22930 X Poinsette	3.36*	3.66*	6.26*	3.92*
LC-1-1 X K-75	-12.71*	-8.99*	-4.60*	-6.70*
LC-1-1 X Japanese Long Green	-0.12	5.71*	10.80*	8.36*
LC-1-1 X Poinsette	2.02	2.87	6.06*	3.73*
LC-2-2 X K-75	-6.86*	-3.88*	2.77	0.50
LC-2-2 X Japanese Long Green	7.88*	13.01*	20.82*	18.16*
LC-2-2 X Poinsette	-8.96*	-7.28*	-4.40*	-6.51*
LC-3-3 X K-75	-0.77	0.72	11.26*	8.81*
LC-3-3 X Japanese Long Green	6.89*	10.08*	21.61*	18.93*
LC-3-3 X Poinsette	-5.11*	-1.72	1.32	-0.91
LC-12-4 X K-75	-0.05	1.86	15.88*	13.33*
LC-12-4 X Japanese Long Green	4.43*	4.89*	22.79*	20.09*
LC-12-4 X Poinsette	-5.84*	1.02	4.15*	1.85
LC-15-5 X K-75	5.06*	8.01*	16.33*	13.77*
LC-15-5 X Japanese Long Green	6.15*	10.76*	19.30*	16.67*
LC-15-5 X Poinsette	-3.06	-0.90	2.17	-0.08
LC-21-6 X K-75	-7.73*	-3.94*	9.28*	6.88*
LC-21-6 X Japanese Long Green	4.88*	7.59*	25.95*	23.18*
LC-21-6 X Poinsette	2.86	12.84*	16.33*	13.77*
LC-25-7 X K-75	-3.18*	-3.13*	10.21*	7.78*
LC-25-7 X Japanese Long Green	-3.71*	-2.38	11.20*	8.75*
LC-25-7 X Poinsette	-1.28	3.89*	7.11*	4.75*
LC-28-8 X K-75	-6.60*	-6.60*	6.26*	3.92*
LC-28-8 X Japanese Long Green	5.64*	7.17*	21.92*	19.24*
LC-28-8 X Poinsette	5.34*	10.79*	14.22*	11.71*
Gyne-5 X K-75	-9.03*	-3.87*	-1.78	-3.94*
Gyne-5 X Japanese Long Green	3.42*	10.96*	13.37*	10.88*
Gyne-5 X Poinsette	6.23*	6.71*	9.03*	6.63*

*Significant at 5% level of significance

4.4.2 Node number bearing first female flower

Significant differences were observed among the hybrid combinations for different estimates of heterosis for this trait (Table 4.36). It was ranged from -50.00 (LC-1-1 x K-75) to 67.86 (CGN-20953 x Japanese Long Green), -37.87 (LC-1-1 x K-75) to 204.02 (CGN-20953 x Japanese Long Green), -43.36 (CGN-20953 x Poinsette) to 127.18 (LC-21-6 x Japanese Long Green) and -49.26 (CGN-20953 x Poinsette) to 103.53 (LC-21-6 x Japanese Long Green) per cent heterosis over mid parent, better parent, standard check-I and standard check-II, respectively. In overall, twelve, six, six and eight hybrid combinations resulted in significant negative heterosis for this trait over the mid parent, better parent, standard check-I and standard check-II, respectively. Among all crosses, CGN-21585 x Poinsette (-17.88, -17.88, -22.82 and -30.86), LC-1-1 x K-75 (-50.00, -37.87, -34.65 and -41.45), LC-2-2 x Poinsette (-37.41, -30.02, -34.23 and -41.08) and Gyne-5 x K-75 (-40.68, -18.03, -27.39 and -34.94) exhibited significant negative estimates of heterosis for average heterosis, heterobeltiosis and standard heterosis over KH-1 and Pusa Sanyog.

4.4.3 Days to marketable maturity

Heterotic response for days to marketable maturity varied significantly among the different cross combinations (Table 4.37). Heterosis over mid parent, better parent, standard check-I and standard check-II ranged from -11.58 (LC-1-1 x K-75) to 13.57 (CGN-20953 x Japanese Long Green), -8.34 (LC-1-1 x K-75) to 22.43 (CGN-20953 x Japanese Long Green), -6.19 (CGN-20953 x Poinsette) to 23.49 (LC-21-6 x Japanese Long Green) and -8.38 (CGN-20953 x Poinsette) to 20.61 (LC-21-6 x Japanese Long Green) per cent, respectively. Significant negative heterosis over the mid parent, better parent, standard check-I and standard check-II was recorded in fifteen, ten, four and seven hybrid combinations, respectively for days to marketable maturity. Out of forty eight hybrid combinations, significant negative values for all the estimates of heterosis *viz.*, average heterosis, heterobeltiosis and standard heterosis over both the checks were recorded by the cross combinations CGN-19533 x K-75 (-8.15, -2.34, -3.00 and -5.26), CGN-20953 x Poinsette (-6.98, -5.38, -6.19 and -8.38), LC-1-1 x K-75 (-11.58, -8.34, -4.43 and -6.66) and LC-2-2 x Poinsette (-7.95, -6.42, -4.03 and -6.26).

Table 4.36 Estimates of heterosis for node number bearing first female flower in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	-43.64*	-10.66	-35.68*	-42.38*
CGN-19533 X Japanese Long Green	40.70*	142.07*	74.27*	56.13*
CGN-19533 X Poinsette	47.50*	70.03*	22.41*	9.67
CGN-20256 X K-75	39.35*	74.60*	81.12*	62.27*
CGN-20256 X Japanese Long Green	22.20*	64.60*	70.75*	52.97*
CGN-20256 X Poinsette	34.31*	41.28*	32.78*	18.96*
CGN-20515 X K-75	8.14	49.41*	32.37*	18.59*
CGN-20515 X Japanese Long Green	4.87	56.44*	38.59*	24.16*
CGN-20515 X Poinsette	29.55*	33.49*	18.26*	5.95
CGN-20953 X K-75	-10.41	49.23*	0.00	-10.41
CGN-20953 X Japanese Long Green	67.86*	204.02*	103.73*	82.53*
CGN-20953 X Poinsette	-29.64*	-15.48	-43.36*	-49.26*
CGN-20969 X K-75	13.68*	67.44*	34.44*	20.45*
CGN-20969 X Japanese Long Green	10.53	76.23*	41.49*	26.77*
CGN-20969 X Poinsette	39.76*	51.68*	21.78*	9.11
CGN-21585 X K-75	19.73*	59.38*	49.79*	34.20*
CGN-21585 X Japanese Long Green	33.54*	91.61*	80.08*	61.34*
CGN-21585 X Poinsette	-17.88*	-17.88*	-22.82*	-30.86*
CGN-22930 X K-75	8.63	47.27*	34.44*	20.45*
CGN-22930 X Japanese Long Green	5.36	54.09*	40.66*	26.02*
CGN-22930 X Poinsette	29.23*	31.14*	19.71*	7.25
LC-1-1 X K-75	-50.00*	-37.87*	-34.65*	-41.45*
LC-1-1 X Japanese Long Green	17.87*	57.40*	65.56*	48.33*
LC-1-1 X Poinsette	12.08	18.76*	11.62	0.00
LC-2-2 X K-75	-23.53*	-10.36	4.15	-6.69
LC-2-2 X Japanese Long Green	43.28*	80.00*	109.13*	87.36*
LC-2-2 X Poinsette	-37.41*	-30.02*	-34.23*	-41.08*
LC-3-3 X K-75	4.32	11.67*	52.90*	36.99*
LC-3-3 X Japanese Long Green	31.12*	49.70*	104.98*	83.64*
LC-3-3 X Poinsette	-21.29*	-3.31	-9.13	-18.59*
LC-12-4 X K-75	-0.80	7.57	68.05*	50.56*
LC-12-4 X Japanese Long Green	19.05*	21.37*	113.28*	91.08*
LC-12-4 X Poinsette	-27.53*	6.62	0.21	-10.22
LC-15-5 X K-75	11.19*	26.92*	54.56*	38.48*
LC-15-5 X Japanese Long Green	30.68*	59.63*	94.40*	74.16*
LC-15-5 X Poinsette	-19.23*	-7.28	-12.86	-21.93*
LC-21-6 X K-75	-27.24*	-15.94*	31.33*	17.66*
LC-21-6 X Japanese Long Green	19.41*	29.28*	127.18*	103.53*
LC-21-6 X Poinsette	14.86*	82.56*	71.58*	53.72*
LC-25-7 X K-75	0.07	0.53	57.05*	40.71*
LC-25-7 X Japanese Long Green	-6.04	-0.66	56.64*	40.33*
LC-25-7 X Poinsette	4.70	40.18*	31.74*	18.03*
LC-28-8 X K-75	-24.30*	-24.30*	18.26*	5.95
LC-28-8 X Japanese Long Green	24.75*	32.54*	107.05*	85.50*
LC-28-8 X Poinsette	31.84*	75.50*	64.94*	47.77*
Gyne-5 X K-75	-40.68*	-18.03*	-27.39*	-34.94*
Gyne-5 X Japanese Long Green	20.88*	80.33*	59.75*	43.12*
Gyne-5 X Poinsette	43.18*	47.54*	30.71*	17.10*

*Significant at 5% level of significance

Table 4.37 Estimates of heterosis for days to marketable maturity in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	-8.15*	-2.34*	-3.00*	-5.26*
CGN-19533 X Japanese Long Green	5.83*	13.98*	13.20*	10.56*
CGN-19533 X Poinsette	4.09*	5.79*	5.07*	2.62*
CGN-20256 X K-75	7.58*	11.64*	16.15*	13.44*
CGN-20256 X Japanese Long Green	4.48*	9.79*	14.22*	11.56*
CGN-20256 X Poinsette	4.57*	5.32*	8.02*	5.50*
CGN-20515 X K-75	0.72	5.70*	7.62*	5.11*
CGN-20515 X Japanese Long Green	1.92	8.32*	10.30*	7.73*
CGN-20515 X Poinsette	1.76	2.13	3.99*	1.57
CGN-20953 X K-75	-6.36*	-0.34	-1.19	-3.50*
CGN-20953 X Japanese Long Green	13.57*	22.43*	21.39*	18.56*
CGN-20953 X Poinsette	-6.98*	-5.38*	-6.19*	-8.38*
CGN-20969 X K-75	1.84	7.56*	8.19*	5.66*
CGN-20969 X Japanese Long Green	1.77	8.87*	9.50*	6.95*
CGN-20969 X Poinsette	3.73*	4.75*	5.36*	2.90*
CGN-21585 X K-75	2.68*	7.31*	10.13*	7.56*
CGN-21585 X Japanese Long Green	5.36*	11.52*	14.45*	11.78*
CGN-21585 X Poinsette	-3.52*	-3.49*	-1.02	-3.33*
CGN-22930 X K-75	0.72	5.51*	7.79*	5.28*
CGN-22930 X Japanese Long Green	1.34	7.51*	9.84*	7.28*
CGN-22930 X Poinsette	3.86*	4.06*	6.31*	3.83*
LC-1-1 X K-75	-11.58*	-8.34*	-4.43*	-6.66*
LC-1-1 X Japanese Long Green	0.57	5.56*	10.06*	7.50*
LC-1-1 X Poinsette	1.43	2.28	4.90*	2.45*
LC-2-2 X K-75	-5.22*	-2.58*	3.24*	0.83
LC-2-2 X Japanese Long Green	7.63*	12.02*	18.71*	15.94*
LC-2-2 X Poinsette	-7.95*	-6.42*	-4.03*	-6.26*
LC-3-3 X K-75	-0.21	1.09	10.23*	7.66*
LC-3-3 X Japanese Long Green	6.81*	9.54*	19.44*	16.66*
LC-3-3 X Poinsette	-4.08*	-1.05	1.48	-0.88
LC-12-4 X K-75	0.49	2.18	14.33*	11.66*
LC-12-4 X Japanese Long Green	4.84*	5.31*	20.71*	17.89*
LC-12-4 X Poinsette	-4.28*	1.83	4.43*	2.00
LC-15-5 X K-75	4.21*	6.71*	13.93*	11.28*
LC-15-5 X Japanese Long Green	5.35*	9.22*	16.61*	13.89*
LC-15-5 X Poinsette	-2.83*	-0.83	1.71	-0.67
LC-21-6 X K-75	-6.57*	-3.20*	8.31*	5.78*
LC-21-6 X Japanese Long Green	5.29*	7.74*	23.49*	20.61*
LC-21-6 X Poinsette	2.67*	11.38*	14.22*	11.56*
LC-25-7 X K-75	-2.34*	-2.29*	9.33*	6.78*
LC-25-7 X Japanese Long Green	-2.81*	-1.68	10.13*	7.56*
LC-25-7 X Poinsette	-0.59	3.99*	6.65*	4.16*
LC-28-8 X K-75	-5.38*	-5.38*	5.87*	3.40*
LC-28-8 X Japanese Long Green	5.92*	7.21*	19.96*	17.16*
LC-28-8 X Poinsette	5.51*	10.31*	13.13*	10.49*
Gyne-5 X K-75	-8.15*	-3.59*	-1.88	-4.16*
Gyne-5 X Japanese Long Green	3.46*	9.99*	11.94*	9.33*
Gyne-5 X Poinsette	5.46*	5.87*	7.74*	5.23*

*Significant at 5% level of significance

4.4.4 Fruit length

Estimation of heterosis for fruit length revealed significant differences among the different hybrid combinations (Table 4.38). It was ranged from -11.50 (CGN-20953 x Japanese Long Green) to 37.14 (Gyne-5 x K-75), -31.73 (CGN-20256 x Japanese Long Green) to 34.75 (Gyne-5 x K-75), -4.70 (CGN-20969 x Poinsette) to 58.40 (LC-25-7 x Japanese Long Green) and -21.82 (CGN-20969 x Poinsette) to 29.95 (LC-25-7 x Japanese Long Green) per cent heterosis over mid parent, better parent, standard check-I and standard check-II, respectively. In overall, twenty eight, sixteen, thirty nine and nine cross combinations revealed significant positive heterosis for fruit length over the mid parent, better parent, standard check-I and standard check-II, respectively. In overall, three crosses *viz.* CGN-19533 x K-75 (29.32, 19.02, 41.02 and 15.69), LC-1-1 x K-75 (32.97, 24.37, 42.31 and 16.75) and Gyne-5 x K-75 (37.14, 34.75, 39.09 and 14.10) revealed significant positive values for all the estimates of heterosis *viz.,* average heterosis, heterobeltiosis and standard heterosis over both the checks KH-1 and Pusa Sanyog.

4.4.5 Fruit breadth

Significant variations were observed among the cross combinations for different estimates of heterosis for the trait under study (Table 4.39). Heterosis over mid parent, better parent, standard check-I and standard check-II ranged from -18.48 (LC-21-6 x Poinsette) to 38.34 (CGN-20515 x Japanese Long Green), -26.92 (CGN-20969 x Japanese Long Green) to 14.69 (LC-1-1 x K-75), -33.40 (CGN-20969 x Japanese Long Green and CGN-20256 x Japanese Long Green) to 17.55 (CGN-20515 x Japanese Long Green) and -33.77 (CGN-20969 x Japanese Long Green and CGN-20256 x Japanese Long Green) to 16.89 (CGN-20515 x Japanese Long Green) per cent, respectively. Significant positive heterosis over the mid parent, better parent, standard check-I and standard check-II was recorded in twenty three, eleven, six and four hybrid combinations, respectively for fruit breadth. Among all crosses, CGN-20515 x Japanese Long Green (38.44, 11.25, 17.55 and 16.89), LC-1-1 x K-75 (15.50, 14.69, 7.55 and 6.94) and LC-15-5 x Poinsette (10.03, 7.31, 10.75 and 10.13) exhibited significant positive estimates of heterosis for average heterosis, heterobeltiosis and standard heterosis over both the checks.

Table 4.38 Estimates of heterosis for fruit length in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	29.32*	19.02*	41.02*	15.69*
CGN-19533 X Japanese Long Green	-8.06*	-19.03*	26.01*	3.38
CGN-19533 X Poinsette	14.27*	5.98	25.56*	3.01
CGN-20256 X K-75	18.32*	5.82	5.41	-13.52*
CGN-20256 X Japanese Long Green	-9.27*	-31.73*	6.25	-12.84*
CGN-20256 X Poinsette	7.91*	-4.20	-2.96	-20.39*
CGN-20515 X K-75	16.56*	13.77*	13.33*	-7.03*
CGN-20515 X Japanese Long Green	-11.41*	-28.71*	10.95*	-8.98*
CGN-20515 X Poinsette	9.65*	6.17	7.53	-11.78*
CGN-20953 X K-75	18.02*	5.04	34.13*	10.04*
CGN-20953 X Japanese Long Green	-11.50*	-19.45*	25.37*	2.85
CGN-20953 X Poinsette	21.65*	9.08*	39.28*	14.26*
CGN-20969 X K-75	-1.01	-1.55	-1.93	-19.55*
CGN-20969 X Japanese Long Green	-11.33*	-27.60*	12.69*	-7.55*
CGN-20969 X Poinsette	-4.61	-5.91	-4.70	-21.82*
CGN-21585 X K-75	18.03*	17.65*	17.19*	-3.86
CGN-21585 X Japanese Long Green	-7.08*	-24.00*	18.29*	-2.96
CGN-21585 X Poinsette	7.20*	5.98	7.34	-11.94*
CGN-22930 X K-75	13.66*	1.68	28.33*	5.28
CGN-22930 X Japanese Long Green	-7.56*	-16.30*	30.26*	6.87
CGN-22930 X Poinsette	11.52*	0.51	26.85*	4.07
LC-1-1 X K-75	32.97*	24.37*	42.31*	16.75*
LC-1-1 X Japanese Long Green	-5.91	-18.37*	27.04*	4.23
LC-1-1 X Poinsette	20.42*	13.51*	29.88*	6.55
LC-2-2 X K-75	18.90*	18.03*	19.32*	-2.11
LC-2-2 X Japanese Long Green	-1.03	-18.37*	27.04*	4.23
LC-2-2 X Poinsette	17.53*	17.42*	18.93*	-2.43
LC-3-3 X K-75	22.75*	16.48*	29.23*	6.02
LC-3-3 X Japanese Long Green	-11.45*	-24.16*	18.03*	-3.17
LC-3-3 X Poinsette	21.18*	15.90*	28.59*	5.49
LC-12-4 X K-75	12.32*	10.12*	14.17*	-6.34
LC-12-4 X Japanese Long Green	-4.30	-20.27*	24.08*	1.80
LC-12-4 X Poinsette	14.36*	13.04*	17.19*	-3.86
LC-15-5 X K-75	16.80*	8.95*	25.37*	2.85
LC-15-5 X Japanese Long Green	-0.10	-13.12*	35.22*	10.94*
LC-15-5 X Poinsette	8.15*	1.68	17.00*	-4.01
LC-21-6 X K-75	-1.18	-5.01	2.58	-15.85*
LC-21-6 X Japanese Long Green	-10.11*	-23.87*	18.48*	-2.80
LC-21-6 X Poinsette	-0.92	-4.00	3.67	-14.95*
LC-25-7 X K-75	9.79*	-6.38*	32.20*	8.45*
LC-25-7 X Japanese Long Green	6.72*	1.78	58.40*	29.95*
LC-25-7 X Poinsette	-3.35	-17.01*	17.19*	-3.86
LC-28-8 X K-75	14.47*	7.83*	21.51*	-0.32
LC-28-8 X Japanese Long Green	0.79	-13.12*	35.22*	10.94*
LC-28-8 X Poinsette	12.55*	6.86	20.41*	-1.22
Gyne-5 X K-75	37.14*	34.75*	39.09*	14.10*
Gyne-5 X Japanese Long Green	0.35	-16.55*	29.88*	6.55
Gyne-5 X Poinsette	18.83*	17.72*	21.51*	-0.32

*Significant at 5% level of significance

Table 4.39 Estimates of heterosis for fruit breadth in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	16.53*	10.66*	3.77	3.19
CGN-19533 X Japanese Long Green	15.12*	1.34	-14.53*	-15.01*
CGN-19533 X Poinsette	-4.86	-11.54*	-13.21*	-13.70*
CGN-20256 X K-75	9.00*	6.04*	-0.57	-1.13
CGN-20256 X Japanese Long Green	-12.84*	-24.89*	-33.40*	-33.77*
CGN-20256 X Poinsette	-4.44	-9.04*	-10.75*	-11.26*
CGN-20515 X K-75	-9.74*	-14.82*	-10.00*	-10.51*
CGN-20515 X Japanese Long Green	38.44*	11.25*	17.55*	16.89*
CGN-20515 X Poinsette	6.11*	2.32	8.11*	7.50*
CGN-20953 X K-75	24.44*	12.68*	5.66*	5.07
CGN-20953 X Japanese Long Green	-1.21	-8.93*	-30.75*	-31.14*
CGN-20953 X Poinsette	14.19*	1.35	-0.57	-1.13
CGN-20969 X K-75	5.10	3.62	-2.83	-3.38
CGN-20969 X Japanese Long Green	-14.22*	-26.92*	-33.40*	-33.77*
CGN-20969 X Poinsette	-2.89	-6.35*	-8.11*	-8.63*
CGN-21585 X K-75	-4.26	-9.46*	-15.09*	-15.57*
CGN-21585 X Japanese Long Green	14.18*	0.90	-15.66*	-16.14*
CGN-21585 X Poinsette	3.84*	-3.85	-5.66*	-6.19*
CGN-22930 X K-75	16.88*	8.65*	1.89	1.31
CGN-22930 X Japanese Long Green	-6.91*	-16.39*	-32.64*	-33.02*
CGN-22930 X Poinsette	-2.85	-11.54*	-13.21*	-13.70*
LC-1-1 X K-75	15.50*	14.69*	7.55*	6.94*
LC-1-1 X Japanese Long Green	-3.61	-18.37*	-24.53*	-24.95*
LC-1-1 X Poinsette	3.56	0.58	-1.32	-1.88
LC-2-2 X K-75	11.22*	9.80*	5.66*	5.07
LC-2-2 X Japanese Long Green	1.88	-15.10*	-18.30*	-18.76*
LC-2-2 X Poinsette	-8.16*	-9.04*	-10.75*	-11.26*
LC-3-3 X K-75	6.87*	6.44*	-0.19	-0.75
LC-3-3 X Japanese Long Green	-5.64	-20.28*	-25.85*	-26.27*
LC-3-3 X Poinsette	6.22*	3.46	1.51	0.94
LC-12-4 X K-75	9.00*	6.04*	-0.57	-1.13
LC-12-4 X Japanese Long Green	-2.96	-16.38*	-25.85*	-26.27*
LC-12-4 X Poinsette	9.09*	3.85	1.89	1.31
LC-15-5 X K-75	-11.30*	-15.36*	-12.64*	-13.13*
LC-15-5 X Japanese Long Green	8.91*	-11.70*	-8.87*	-9.38*
LC-15-5 X Poinsette	10.03*	7.31*	10.75*	10.13*
LC-21-6 X K-75	4.60	3.98	-1.32	-1.88
LC-21-6 X Japanese Long Green	-0.36	-16.50*	-20.75*	-21.20*
LC-21-6 X Poinsette	-18.48*	-19.81*	-21.32*	-21.76*
LC-25-7 X K-75	1.43	-7.44*	-13.21*	-13.70*
LC-25-7 X Japanese Long Green	12.00*	2.44	-20.75*	-21.20*
LC-25-7 X Poinsette	-5.38	-15.38*	-16.98*	-17.45*
LC-28-8 X K-75	9.19*	4.02	-2.45	-3.00
LC-28-8 X Japanese Long Green	6.33*	-6.67*	-20.75*	-21.20*
LC-28-8 X Poinsette	-15.46*	-21.15*	-22.64*	-23.08*
Gyne-5 X K-75	9.15*	8.05*	1.32	0.75
Gyne-5 X Japanese Long Green	21.64*	3.29	-5.09	-5.63*
Gyne-5 X Poinsette	-10.63*	-13.46*	-15.09*	-15.57*

*Significant at 5% level of significance

4.4.6 Average fruit weight

Average fruit weight revealed significant differences among all cross combinations for different estimates of heterosis (Table 4.40). It was ranged from -16.77 (CGN-20969 x Japanese Long Green) to 46.29 (Gyne-5 x K-75), -36.73 (CGN-20256 x Japanese Long Green) to 43.83 (Gyne-5 x K-75), -15.67 (CGN-20969 x Poinsette) to 45.41 (LC-25-7 x Japanese Long Green) and -27.96 (CGN-20969 x Poinsette) to 24.22 (LC-25-7 x Japanese Long Green) per cent heterosis over mid parent, better parent, standard check-I and standard check-II, respectively. In overall, twenty seven, nineteen, twenty seven and six hybrid combinations revealed significant positive heterosis for average fruit weight over the mid parent, better parent, standard check-I and standard check-II, respectively. Significant positive values for all the estimates heterosis *viz.,* average heterosis, heterobeltiosis and standard heterosis over both the checks were recorded by the five cross combinations *viz.*, CGN-19533 x K-75 (39.41, 28.68, 36.05 and 16.22), CGN-20953 x K-75 (28.38, 15.27, 29.59 and 10.70), CGN-20953 x Poinsette (29.33, 18.05, 32.71 and 13.37), LC-1-1 x K-75 (43.13, 32.89, 38.73 and 18.51) and Gyne-5 x K-75 (46.29, 43.83, 33.15 and 13.75).

4.4.7 Number of fruits per plant

Estimates of heterosis revealed significant variations among the different hybrid combinations for number of fruits per plant (Table 4.41). Heterosis over mid parent, better parent, standard check-I and standard check-II ranged from -27.74 (LC-2-2 x Japanese Long Green) to 77.13 (CGN-19533 x K-75), -36.74 (LC-2-2 x Japanese Long Green) to 68.03 (CGN-19533 x K-75), -61.53 (LC-21-6 x Japanese Long Green) to 15.12 (CGN-20953 x Poinsette) and -58.21 (LC-21-6 x Japanese Long Green) to 25.05 (CGN-20953 x Poinsette) per cent, respectively. Significant positive heterosis over the mid parent, better parent, standard check-I and standard check-II was recorded in thirty one, twenty four, six and eight hybrid combinations, respectively for number of fruits per plant. In overall, CGN-19533 x K-75 (77.13, 68.03, 14.16 and 24.01), CGN-20953 x Poinsette (47.97, 42.70, 15.12 and 25.05) CGN-21585 x Poinsette (40.12, 33.81, 7.94 and 17.26), LC-1-1 x K-75 (51.94, 38.47, 14.35 and 24.22), LC-2-2 x Poinsette (44.35, 40.93, 13.68 and 23.49) and Gyne-5 x K-75 (48.00, 34.60, 11.67 and 21.31) revealed significant positive values for all the respective estimates of heterosis *viz.*, average heterosis (mid parent), heterobeltiosis (better parent) and standard heterosis (check cultivars; KH-1 and Pusa Sanyog).

Table 4.40 Estimates of heterosis for average fruit weight in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	39.41*	28.68*	36.05*	16.22*
CGN-19533 X Japanese Long Green	-5.93	-16.71*	14.24*	-2.41
CGN-19533 X Poinsette	14.82*	7.80	13.98*	-2.63
CGN-20256 X K-75	25.56*	8.97*	-2.52	-16.72*
CGN-20256 X Japanese Long Green	-14.50*	-36.73*	-13.22*	-25.87*
CGN-20256 X Poinsette	7.45	-8.17	-14.78*	-27.20*
CGN-20515 X K-75	14.88*	14.45*	2.38	-12.54*
CGN-20515 X Japanese Long Green	-2.86	-19.99*	9.74*	-6.25
CGN-20515 X Poinsette	13.26*	10.81*	2.83	-12.15*
CGN-20953 X K-75	28.38*	15.27*	29.59*	10.70*
CGN-20953 X Japanese Long Green	-13.84*	-21.62*	7.51	-8.15*
CGN-20953 X Poinsette	29.33*	18.05*	32.71*	13.37*
CGN-20969 X K-75	1.35	0.21	-10.36*	-23.42*
CGN-20969 X Japanese Long Green	-16.77*	-31.86*	-6.53	-20.15*
CGN-20969 X Poinsette	-6.43	-9.13*	-15.67*	-27.96*
CGN-21585 X K-75	19.78*	16.95*	4.62	-10.63*
CGN-21585 X Japanese Long Green	-5.11	-23.08*	5.51	-9.87*
CGN-21585 X Poinsette	9.77*	5.28	-2.30	-16.54*
CGN-22930 X K-75	21.10*	8.73*	22.23*	4.42
CGN-22930 X Japanese Long Green	-9.85*	-17.98*	12.50*	-3.90
CGN-22930 X Poinsette	12.38*	2.58	15.32*	-1.49
LC-1-1 X K-75	43.13*	32.89*	38.73*	18.51*
LC-1-1 X Japanese Long Green	-7.66*	-18.69*	11.53*	-4.73
LC-1-1 X Poinsette	24.42*	17.51*	22.67*	4.80
LC-2-2 X K-75	25.94*	24.26*	14.20*	-2.44
LC-2-2 X Japanese Long Green	-0.68	-17.07*	13.75*	-2.82
LC-2-2 X Poinsette	16.90*	16.34*	7.96	-7.77*
LC-3-3 X K-75	28.51*	21.14*	22.41*	4.57
LC-3-3 X Japanese Long Green	-14.60*	-25.84*	1.72	-13.11*
LC-3-3 X Poinsette	26.22*	21.07*	22.34*	4.51
LC-12-4 X K-75	17.58*	16.01*	6.62	-8.92*
LC-12-4 X Japanese Long Green	-5.74	-21.29*	7.96	-7.77*
LC-12-4 X Poinsette	19.79*	19.22*	10.63*	-5.49
LC-15-5 X K-75	14.95*	4.71	13.98*	-2.63
LC-15-5 X Japanese Long Green	2.09	-8.45*	25.57*	7.27
LC-15-5 X Poinsette	12.60*	4.30	13.53*	-3.01
LC-21-6 X K-75	0.35	-4.30	-5.64	-19.39*
LC-21-6 X Japanese Long Green	-11.82*	-24.22*	3.95	-11.20*
LC-21-6 X Poinsette	-7.69	-10.40*	-11.66*	-24.54*
LC-25-7 X K-75	11.75*	-4.74	20.89*	3.27
LC-25-7 X Japanese Long Green	10.13*	6.01	45.41*	24.22*
LC-25-7 X Poinsette	-5.38	-18.10*	3.95	-11.20*
LC-28-8 X K-75	19.90*	13.61*	13.53*	-3.01
LC-28-8 X Japanese Long Green	2.35	-11.54*	21.34*	3.65
LC-28-8 X Poinsette	9.25*	5.35	5.28	-10.06*
Gyne-5 X K-75	46.29*	43.83*	33.15*	13.75*
Gyne-5 X Japanese Long Green	5.63	-11.54*	21.34*	3.65
Gyne-5 X Poinsette	17.68*	17.54*	9.07*	-6.82

*Significant at 5% level of significance

Table 4.41 Estimates of heterosis for number of marketable fruits per plant in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	77.13*	68.03*	14.16*	24.01*
CGN-19533 X Japanese Long Green	6.45	3.61	-36.84*	-31.39*
CGN-19533 X Poinsette	23.92*	8.78*	-12.25*	-4.68
CGN-20256 X K-75	-15.77*	-20.18*	-39.43*	-34.20*
CGN-20256 X Japanese Long Green	-1.43	-13.24*	-34.16*	-28.48*
CGN-20256 X Poinsette	7.21*	4.03	-16.08*	-8.84*
CGN-20515 X K-75	10.57*	0.93	-16.94*	-9.77*
CGN-20515 X Japanese Long Green	15.24*	-1.98	-19.33*	-12.37*
CGN-20515 X Poinsette	10.63*	9.53*	-9.86*	-2.08
CGN-20953 X K-75	33.56*	27.33*	-4.59	3.64
CGN-20953 X Japanese Long Green	-25.40*	-33.97*	-50.53*	-46.26*
CGN-20953 X Poinsette	47.97*	42.70*	15.12*	25.05*
CGN-20969 X K-75	21.54*	20.42*	-18.18*	-11.12*
CGN-20969 X Japanese Long Green	27.38*	18.79*	-20.77*	-13.93*
CGN-20969 X Poinsette	19.48*	9.13*	-11.96*	-4.37
CGN-21585 X K-75	4.54	0.65	-26.12*	-19.75*
CGN-21585 X Japanese Long Green	-8.47*	-18.25*	-40.00*	-34.82*
CGN-21585 X Poinsette	40.12*	33.81*	7.94*	17.26*
CGN-22930 X K-75	30.84*	20.70*	-17.99*	-10.91*
CGN-22930 X Japanese Long Green	37.16*	36.82*	-21.05*	-14.24*
CGN-22930 X Poinsette	27.23*	8.90*	-12.15*	-4.57
LC-1-1 X K-75	51.94*	38.47*	14.35*	24.22*
LC-1-1 X Japanese Long Green	-4.77	-19.12*	-33.21*	-27.44*
LC-1-1 X Poinsette	12.31*	11.01*	-8.33*	-0.42
LC-2-2 X K-75	31.26*	23.66*	-4.98	3.22
LC-2-2 X Japanese Long Green	-27.74*	-36.74*	-51.39*	-47.19*
LC-2-2 X Poinsette	44.35*	40.93*	13.68*	23.49*
LC-3-3 X K-75	8.68*	8.45*	-26.32*	-19.96*
LC-3-3 X Japanese Long Green	-20.92*	-26.73*	-50.43*	-46.15*
LC-3-3 X Poinsette	38.45*	27.28*	2.68	11.54*
LC-12-4 X K-75	22.12*	-2.82	-33.97*	-28.27*
LC-12-4 X Japanese Long Green	-9.68*	-23.38*	-55.79*	-51.98*
LC-12-4 X Poinsette	59.94*	19.81*	-3.35	4.99
LC-15-5 X K-75	6.07	5.12	-27.27*	-21.00*
LC-15-5 X Japanese Long Green	-15.99*	-22.96*	-46.70*	-42.10*
LC-15-5 X Poinsette	38.57*	28.71*	3.83	12.79*
LC-21-6 X K-75	59.52*	22.11*	-17.03*	-9.88*
LC-21-6 X Japanese Long Green	-17.96*	-33.33*	-61.53*	-58.21*
LC-21-6 X Poinsette	10.98*	-19.69*	-35.22*	-29.63*
LC-25-7 X K-75	11.28*	4.23	-29.19*	-23.08*
LC-25-7 X Japanese Long Green	21.83*	20.16*	-28.71*	-22.56*
LC-25-7 X Poinsette	19.21*	3.44	-16.56*	-9.36*
LC-28-8 X K-75	37.64*	32.11*	-10.24*	-2.49
LC-28-8 X Japanese Long Green	-19.59*	-22.66*	-51.67*	-47.51*
LC-28-8 X Poinsette	-6.02	-16.61*	-32.73*	-26.92*
Gyne-5 X K-75	48.00*	34.60*	11.67*	21.31*
Gyne-5 X Japanese Long Green	-2.04	-16.96*	-31.10*	-25.16*
Gyne-5 X Poinsette	0.94	-0.46	-17.42*	-10.29*

*Significant at 5% level of significance

4.4.8 Harvest duration

Significant differences were recorded among the hybrid combinations for different estimates of heterosis for this trait (Table 4.42). It was ranged from -27.27 (LC-2-2 x Japanese Long Green) to 62.87 (CGN-19533 x K-75), -34.96 (LC-2-2 x Japanese Long Green) to 52.47 (CGN-19533 x K-75), -55.83 (LC-21-6 x Japanese Long Green) to 13.73 (CGN-20953 x Poinsette) and -52.39 (LC-21-6 x Japanese Long Green) to 22.59 (CGN-20953 x Poinsette) per cent heterosis over mid parent, better parent, standard check-I and standard check-II, respectively. Among all the hybrid combinations, twenty seven, twenty one, six and eight cross combinations revealed significant positive heterosis for this character over mid parent, better parent, standard check-I and standard check-II, respectively. Six cross combinations *viz.*, CGN-19533 x K-75 (62.87, 52.47, 12.86 and 21.65), CGN-20953 x Poinsette (42.37, 37.88, 13.73 and 22.59), CGN-21585 x Poinsette (35.43, 29.99, 7.22 and 15.57), LC-1-1 x K-75 (40.10, 29.43, 13.02 and 21.82), LC-2-2 x Poinsette (36.61, 36.30, 12.43, and 21.18) and Gyne-5 x K-75 (42.25, 35.78, 10.57 and 19.18) exhibited significant positive estimates of heterosis for average heterosis, heterobeltiosis and standard heterosis over both the check cultivars.

4.4.9 Yield per plot

Heterotic response for yield per plot varied significantly among the different hybrid combinations (Table 4.43). Heterosis over mid parent, better parent, standard check-I and standard check-II ranged from -34.89 (CGN-20953 x Japanese Long Green) to 148.25 (CGN-19533 x K-75), -49.51 (LC-21-6 x Japanese Long Green) to 141.80 (CGN-19533 x K-75), -60.05 (LC-21-6 x Japanese Long Green) to 58.56 (LC-1-1 x K-75) and -62.92 (LC-21-6 x Japanese Long Green) to 47.17 (LC-1-1 x K-75) per cent, respectively. Significant positive heterosis over the mid parent, better parent, standard check-I and standard check-II was recorded in thirty two, twenty nine, ten and eight hybrid combinations, respectively for yield per plot. Out of forty eight hybrid combinations, significant positive values for all the respective estimates of heterosis *viz.*, average heterosis, heterobeltiosis and standard heterosis over both the checks were recorded by the cross combinations CGN-19533 x K-75 (148.25, 141.80, 55.44 and 44.27), CGN-20953 x K-75 (70.42, 46.92, 23.62 and 14.74), CGN-20953 x Poinsette (92.07, 81.54, 52.75 and 41.78), LC-1-1 x K-75 (115.51, 83.92, 58.56 and 47.17), LC-2-2 x Poinsette (68.67, 63.85, 22.75 and 13.93), LC-3-3 x Poinsette (75.43, 67.74, 25.67 and 16.64), LC-15-5 x Poinsette (56.91, 56.46, 17.88 and 9.41) and Gyne-5 x K-75 (116.00, 93.77, 48.68 and 38.00).

Table 4.42 Estimates of heterosis for harvest duration (days) in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	62.87*	52.47*	12.86*	21.65*
CGN-19533 X Japanese Long Green	-0.24	-0.38	-35.49*	-30.47*
CGN-19533 X Poinsette	20.03*	6.99	-11.75*	-4.88
CGN-20256 X K-75	-15.54*	-17.77*	-35.74*	-30.74*
CGN-20256 X Japanese Long Green	-3.38	-11.66*	-30.97*	-25.59*
CGN-20256 X Poinsette	6.33	3.53	-14.60*	-7.95*
CGN-20515 X K-75	9.33*	4.72	-15.34*	-8.75*
CGN-20515 X Japanese Long Green	11.90*	0.77	-18.54*	-12.20*
CGN-20515 X Poinsette	10.19*	9.09*	-10.01*	-3.01
CGN-20953 X K-75	26.65*	23.99*	-4.18	3.27
CGN-20953 X Japanese Long Green	-23.75*	-29.92*	-45.85*	-41.63*
CGN-20953 X Poinsette	42.37*	37.88*	13.73*	22.59*
CGN-20969 X K-75	16.15*	12.81*	-16.49*	-9.99*
CGN-20969 X Japanese Long Green	20.69*	16.35*	-18.82*	-12.50*
CGN-20969 X Poinsette	17.10*	8.08*	-10.85*	-3.91
CGN-21585 X K-75	3.16	1.92	-22.69*	-16.67*
CGN-21585 X Japanese Long Green	-9.39*	-16.02*	-36.30*	-31.34*
CGN-21585 X Poinsette	35.43*	29.99*	7.22*	15.57*
CGN-22930 X K-75	23.58*	13.02*	-16.34*	-9.82*
CGN-22930 X Japanese Long Green	28.29*	24.94*	-19.09*	-12.80*
CGN-22930 X Poinsette	23.72*	7.89*	-11.00*	-4.08
LC-1-1 X K-75	40.10*	29.43*	13.02*	21.82*
LC-1-1 X Japanese Long Green	-8.07*	-19.95*	-30.10*	-24.66*
LC-1-1 X Poinsette	8.18*	5.18	-8.15*	-1.00
LC-2-2 X K-75	22.33*	16.31*	-4.49	2.94
LC-2-2 X Japanese Long Green	-27.27*	-34.96*	-46.59*	-42.43*
LC-2-2 X Poinsette	36.61*	36.30*	12.43*	21.18*
LC-3-3 X K-75	3.04	2.85	-23.87*	-17.94*
LC-3-3 X Japanese Long Green	-21.62*	-26.40*	-45.72*	-41.50*
LC-3-3 X Poinsette	31.15*	24.20*	2.45	10.42*
LC-12-4 X K-75	12.61*	-6.53	-30.81*	-25.43*
LC-12-4 X Japanese Long Green	-13.07*	-23.74*	-50.62*	-46.78*
LC-12-4 X Poinsette	47.65*	17.55*	-3.04	4.51
LC-15-5 X K-75	0.89	0.12	-24.74*	-18.88*
LC-15-5 X Japanese Long Green	-17.63*	-23.34*	-42.37*	-37.89*
LC-15-5 X Poinsette	31.26*	25.44*	3.47	11.53*
LC-21-6 X K-75	41.92*	14.20*	-15.47*	-8.89*
LC-21-6 X Japanese Long Green	-19.58*	-31.79*	-55.83*	-52.39*
LC-21-6 X Poinsette	6.66	-17.51*	-31.96*	-26.66*
LC-25-7 X K-75	6.32	0.71	-25.45*	-19.65*
LC-25-7 X Japanese Long Green	12.95*	11.70*	-26.04*	-20.28*
LC-25-7 X Poinsette	14.28*	3.01	-15.03*	-8.42*
LC-28-8 X K-75	26.79*	22.57*	-9.27*	-2.21
LC-28-8 X Japanese Long Green	-20.61*	-23.10*	-46.87*	-42.73*
LC-28-8 X Poinsette	-7.20	-14.73*	-29.67*	-24.19*
Gyne-5 X K-75	42.25*	35.78*	10.57*	19.18*
Gyne-5 X Japanese Long Green	-1.78	-11.84*	-28.21*	-22.62*
Gyne-5 X Poinsette	2.76	2.10	-15.78*	-9.22*

*Significant at 5% level of significance

Table 4.43 Estimates of heterosis for yield per plot (kg) in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	148.25*	141.80*	55.44*	44.27*
CGN-19533 X Japanese Long Green	0.61	-8.83	-27.86*	-33.04*
CGN-19533 X Poinsette	43.64*	33.45*	-0.02	-7.21
CGN-20256 X K-75	6.82	-2.97	-40.87*	-45.12*
CGN-20256 X Japanese Long Green	-11.24	-27.71*	-42.80*	-46.91*
CGN-20256 X Poinsette	14.70*	-4.55	-28.49*	-33.63*
CGN-20515 X K-75	27.07*	16.61*	-14.94*	-21.05*
CGN-20515 X Japanese Long Green	16.48*	11.92*	-11.44*	-17.80*
CGN-20515 X Poinsette	25.33*	23.68*	-7.34	-14.00*
CGN-20953 X K-75	70.42*	46.92*	23.62*	14.74*
CGN-20953 X Japanese Long Green	-34.89*	-36.83*	-46.85*	-50.67*
CGN-20953 X Poinsette	92.07*	81.54*	52.75*	41.78*
CGN-20969 X K-75	23.14*	20.39*	-26.64*	-31.91*
CGN-20969 X Japanese Long Green	7.86	-6.39	-25.93*	-31.25*
CGN-20969 X Poinsette	11.49*	-0.94	-25.79*	-31.12*
CGN-21585 X K-75	25.44*	24.11*	-22.73*	-28.28*
CGN-21585 X Japanese Long Green	-10.43*	-19.98*	-36.68*	-41.23*
CGN-21585 X Poinsette	53.83*	40.83*	5.51	-2.07
CGN-22930 X K-75	60.17*	56.14*	0.19	-7.01
CGN-22930 X Japanese Long Green	23.91*	12.19*	-11.22*	-17.60*
CGN-22930 X Poinsette	45.69*	35.24*	1.32	-5.96
LC-1-1 X K-75	115.51*	83.92*	58.56*	47.17*
LC-1-1 X Japanese Long Green	-9.89*	-13.59*	-25.51*	-30.86*
LC-1-1 X Poinsette	39.69*	30.54*	12.54*	4.46
LC-2-2 X K-75	64.88*	53.56*	8.47*	0.68
LC-2-2 X Japanese Long Green	-26.03*	-30.00*	-44.61*	-48.59*
LC-2-2 X Poinsette	68.67*	63.85*	22.75*	13.93*
LC-3-3 X K-75	39.33*	31.77*	-9.93*	-16.40*
LC-3-3 X Japanese Long Green	-31.46*	-36.13*	-49.46*	-53.09*
LC-3-3 X Poinsette	75.43*	67.74*	25.67*	16.64*
LC-12-4 X K-75	44.13*	15.44*	-29.65*	-34.70*
LC-12-4 X Japanese Long Green	-17.68*	-39.76*	-52.33*	-55.75*
LC-12-4 X Poinsette	91.69*	42.78*	6.96	-0.72
LC-15-5 X K-75	21.72*	10.09	-17.06*	-23.02*
LC-15-5 X Japanese Long Green	-13.45*	-15.52*	-33.15*	-37.96*
LC-15-5 X Poinsette	56.91*	56.46*	17.88*	9.41*
LC-21-6 X K-75	61.84*	28.38*	-21.76*	-27.39*
LC-21-6 X Japanese Long Green	-30.44*	-49.51*	-60.05*	-62.92*
LC-21-6 X Poinsette	3.25	-23.74*	-42.87*	-46.98*
LC-25-7 X K-75	25.99*	14.27*	-14.45*	-20.59*
LC-25-7 X Japanese Long Green	34.61*	30.98*	3.65	-3.80
LC-25-7 X Poinsette	15.80*	15.77*	-13.27*	-19.50*
LC-28-8 X K-75	65.22*	63.23*	1.93	-5.39
LC-28-8 X Japanese Long Green	-17.13*	-25.87*	-41.34*	-45.56*
LC-28-8 X Poinsette	3.12	-5.46	-29.18*	-34.27*
Gyne-5 X K-75	116.00*	93.77*	48.68*	38.00*
Gyne-5 X Japanese Long Green	7.22	5.59	-16.45*	-22.45*
Gyne-5 X Poinsette	18.82*	17.42*	-9.91*	-16.38*

*Significant at 5% level of significance

4.4.10 Yield per hectare

Estimation of heterosis for yield per hectare revealed significant differences among different cross combinations (Table 4.44). It was ranged from -34.89 (CGN-20953 x Japanese Long Green) to 148.21 (CGN-19533 x K-75), -49.51 (LC-21-6 x Japanese Long Green) to 141.76 (CGN-19533 x K-75), -60.04 (LC-21-6 x Japanese Long Green) to 58.59 (LC-1-1 x K-75) and -62.92 (LC-21-6 x Japanese Long Green) to 47.17 (LC-1-1 x K-75) per cent over mid parent, better parent, standard check-I and standard check-II, respectively. Among all the hybrid combinations, thirty two, twenty nine, ten and eight cross combinations revealed significant positive heterosis for yield per hectare over mid parent, better parent, standard check-I and standard check-II, respectively. Eight hybrid combinations *viz.*, CGN-19533 x K-75 (148.21, 141.76, 55.45 and 44.25), CGN-20953 x K-75 (70.38, 46.90, 23.63 and 14.73), CGN-20953 x Poinsette (92.08, 81.53, 52.78 and 41.78), LC-1-1 x K-75 (115.52, 83.96, 58.59 and 47.17), LC-2-2 x Poinsette (68.71, 63.88, 22.78 and 13.93), LC-3-3 x Poinsette (75.43, 67.76, 25.68 and 16.63), LC-15-5 x Poinsette (56.94, 56.50, 17.91 and 9.41) and Gyne-5 x K-75 (115.98, 93.77, 48.70 and 37.99) exhibited significant positive values for average heterosis, heterobeltiosis and standard heterosis over both the check cultivars (KH-1 and Pusa Sanyog).

4.4.11 Total soluble solids (TSS)

Total soluble solids revealed significant differences among all cross combinations for different estimates of heterosis (Table 4.45). Heterosis over mid parent, better parent, standard check-I and standard check-II ranged from -8.84 (LC-21-6 x K-75) to 14.29 (LC-1-1 x K-75), -15.16 (LC-21-6 x K-75) to 12.50 (LC-1-1 x K-75), -20.30 (LC-21-6 x K-75) to 23.33 (CGN-21585 x Japanese Long Green) and -23.32 (LC-21-6 x K-75) to 18.66 (CGN-21585 x Japanese Long Green) per cent, respectively. Significant positive heterosis over mid parent, better parent, standard check-I and standard check-II was recorded in eleven, eight, nine and five hybrid combinations, respectively for total soluble solids. In overall, significant positive values for all the estimates of heterosis *viz.*, average heterosis, heterobeltiosis and standard heterosis over both the check cultivars were recorded by the crosses LC-1-1 x K-75 (14.29, 12.50, 9.09 and 4.96) and LC-28-8 x K-75 (14.20, 4.56, 18.18 and 13.70) among all the hybrid combinations.

Table 4.44 Estimates of heterosis for yield per hectare (q) in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	148.21*	141.76*	55.45*	44.25*
CGN-19533 X Japanese Long Green	0.59	-8.85	-27.86*	-33.05*
CGN-19533 X Poinsette	43.66*	33.48*	0.00	-7.20
CGN-20256 X K-75	6.82	-2.99	-40.86*	-45.12*
CGN-20256 X Japanese Long Green	-11.25	-27.72*	-42.80*	-46.92*
CGN-20256 X Poinsette	14.70*	-4.55	-28.49*	-33.64*
CGN-20515 X K-75	27.06*	16.62*	-14.93*	-21.06*
CGN-20515 X Japanese Long Green	16.49*	11.92*	-11.42*	-17.80*
CGN-20515 X Poinsette	25.35*	23.70*	-7.32	-14.00*
CGN-20953 X K-75	70.38*	46.90*	23.63*	14.73*
CGN-20953 X Japanese Long Green	-34.89*	-36.83*	-46.83*	-50.66*
CGN-20953 X Poinsette	92.08*	81.53*	52.78*	41.78*
CGN-20969 X K-75	23.14*	20.36*	-26.63*	-31.91*
CGN-20969 X Japanese Long Green	7.87	-6.40	-25.92*	-31.25*
CGN-20969 X Poinsette	11.51*	-0.93	-25.78*	-31.12*
CGN-21585 X K-75	25.42*	24.09*	-22.72*	-28.29*
CGN-21585 X Japanese Long Green	-10.43*	-19.98*	-36.67*	-41.23*
CGN-21585 X Poinsette	53.83*	40.85*	5.52	-2.08
CGN-22930 X K-75	60.17*	56.17*	0.21	-7.01
CGN-22930 X Japanese Long Green	23.92*	12.20*	-11.20*	-17.60*
CGN-22930 X Poinsette	45.73*	35.27*	1.34	-5.96
LC-1-1 X K-75	115.52*	83.96*	58.59*	47.17*
LC-1-1 X Japanese Long Green	-9.88*	-13.57*	-25.49*	-30.85*
LC-1-1 X Poinsette	39.71*	30.56*	12.56*	4.45
LC-2-2 X K-75	64.88*	53.59*	8.48*	0.67
LC-2-2 X Japanese Long Green	-26.05*	-30.02*	-44.62*	-48.61*
LC-2-2 X Poinsette	68.71*	63.88*	22.78*	13.93*
LC-3-3 X K-75	39.30*	31.75*	-9.93*	-16.42*
LC-3-3 X Japanese Long Green	-31.45*	-36.12*	-49.44*	-53.08*
LC-3-3 X Poinsette	75.43*	67.76*	25.68*	16.63*
LC-12-4 X K-75	44.14*	15.44*	-29.63*	-34.70*
LC-12-4 X Japanese Long Green	-17.68*	-39.76*	-52.33*	-55.76*
LC-12-4 X Poinsette	91.71*	42.79*	6.98	-0.73
LC-15-5 X K-75	21.72*	10.10	-17.05*	-23.03*
LC-15-5 X Japanese Long Green	-13.44*	-15.52*	-33.14*	-37.95*
LC-15-5 X Poinsette	56.94*	56.50*	17.91*	9.41*
LC-21-6 X K-75	61.81*	28.34*	-21.76*	-27.40*
LC-21-6 X Japanese Long Green	-30.43*	-49.51*	-60.04*	-62.92*
LC-21-6 X Poinsette	3.26	-23.74*	-42.87*	-46.98*
LC-25-7 X K-75	25.97*	14.25*	-14.44*	-20.60*
LC-25-7 X Japanese Long Green	34.61*	30.99*	3.67	-3.79
LC-25-7 X Poinsette	15.79*	15.77*	-13.27*	-19.51*
LC-28-8 X K-75	65.23*	63.26*	1.95	-5.39
LC-28-8 X Japanese Long Green	-17.14*	-25.88*	-41.34*	-45.56*
LC-28-8 X Poinsette	3.12	-5.47	-29.18*	-34.28*
Gyne-5 X K-75	115.98*	93.77*	48.70*	37.99*
Gyne-5 X Japanese Long Green	7.22	5.59	-16.43*	-22.45*
Gyne-5 X Poinsette	18.82*	17.42*	-9.90*	-16.39*

*Significant at 5% level of significance

Table 4.45 Estimates of heterosis for total soluble solids (°B) in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	11.77*	8.71*	2.12	-1.75
CGN-19533 X Japanese Long Green	8.12*	3.10	0.91	-2.92
CGN-19533 X Poinsette	1.64	-2.21	-6.06*	-9.62*
CGN-20256 X K-75	-3.25	-7.12*	-5.15*	-8.75*
CGN-20256 X Japanese Long Green	3.94	1.78	3.94	0.00
CGN-20256 X Poinsette	-5.81*	-8.61*	-6.67*	-10.20*
CGN-20515 X K-75	3.33	0.00	-6.06*	-9.62*
CGN-20515 X Japanese Long Green	-1.14	-6.19*	-8.18*	-11.66*
CGN-20515 X Poinsette	-5.11	-9.15*	-12.73*	-16.03*
CGN-20953 X K-75	6.22*	5.05*	0.91	-2.92
CGN-20953 X Japanese Long Green	11.56*	10.53*	8.18*	4.08
CGN-20953 X Poinsette	-1.58	-1.58	-5.45*	-9.04*
CGN-20969 X K-75	0.00	-1.56	-4.55	-8.16*
CGN-20969 X Japanese Long Green	1.71	1.24	-0.91	-4.66*
CGN-20969 X Poinsette	-2.67	-3.13	-6.06*	-9.62*
CGN-21585 X K-75	-2.38	-13.65*	5.45*	1.46
CGN-21585 X Japanese Long Green	12.12*	0.99	23.33*	18.66*
CGN-21585 X Poinsette	0.00	-10.67*	9.09*	4.96*
CGN-22930 X K-75	-1.78	-2.26	-8.18*	-11.66*
CGN-22930 X Japanese Long Green	0.63	-1.86	-3.94	-7.58*
CGN-22930 X Poinsette	-2.24	-3.79	-7.58*	-11.08*
LC-1-1 X K-75	14.29*	12.50*	9.09*	4.96*
LC-1-1 X Japanese Long Green	-2.95	-3.41	-5.45*	-9.04*
LC-1-1 X Poinsette	8.95*	8.44*	5.15*	1.17
LC-2-2 X K-75	-3.87	-3.87	-9.70*	-13.12*
LC-2-2 X Japanese Long Green	4.27	2.17	0.00	-3.79
LC-2-2 X Poinsette	-3.67	-4.73	-8.48*	-11.95*
LC-3-3 X K-75	2.80	0.65	-5.45*	-9.04*
LC-3-3 X Japanese Long Green	2.26	-1.86	-3.94	-7.58*
LC-3-3 X Poinsette	0.00	-3.15	-6.97*	-10.50*
LC-12-4 X K-75	-1.49	-4.19	-10.00*	-13.41*
LC-12-4 X Japanese Long Green	4.55	-0.31	-2.42	-6.12*
LC-12-4 X Poinsette	-0.66	-4.42	-8.18*	-11.66*
LC-15-5 X K-75	-2.76	-3.23	-9.09*	-12.54*
LC-15-5 X Japanese Long Green	4.76	2.17	0.00	-3.79
LC-15-5 X Poinsette	-0.64	-2.21	-6.06*	-9.62*
LC-21-6 X K-75	-8.84*	-15.16*	-20.30*	-23.32*
LC-21-6 X Japanese Long Green	1.69	-7.12*	-9.09*	-12.54*
LC-21-6 X Poinsette	-7.53*	-14.83*	-18.18*	-21.28*
LC-25-7 X K-75	2.76	2.26	-3.94	-7.58*
LC-25-7 X Japanese Long Green	1.59	-0.93	-3.03	-6.71*
LC-25-7 X Poinsette	-0.64	-2.21	-6.06*	-9.62*
LC-28-8 X K-75	14.20*	4.56*	18.18*	13.70*
LC-28-8 X Japanese Long Green	7.76*	0.54	13.64*	9.33*
LC-28-8 X Poinsette	0.58	-6.97*	5.15*	1.17
Gyne-5 X K-75	6.98*	5.31*	2.12	-1.75
Gyne-5 X Japanese Long Green	-3.58	-4.02	-6.06*	-9.62*
Gyne-5 X Poinsette	7.38*	6.87*	3.64	-0.29

*Significant at 5% level of significance

4.4.12 Cucurbitacin content

Estimates of heterosis revealed significant variations among the different hybrid combinations for cucurbitacin content (Table 4.46). It was ranged from -12.47 (LC-28-8 x K-75) to 5.14 (LC-21-6 x Poinsette), -11.33 (LC-1-1 x K-75) to 9.83 (CGN-20969 x Poinsette), -8.80 (CGN-21585 x Japanese Long Green) to 17.93 (LC-21-6 x Poinsette) and -7.77 (CGN-21585 x Japanese Long Green) to 19.26 (LC-21-6 x Poinsette) per cent over mid parent, better parent, standard check-I and standard check-II, respectively. Among all the hybrid combinations, twenty one, thirteen, five and five cross combinations revealed significant negative heterosis for cucurbitacin content over mid parent, better parent, standard Check-II and standard Check-II, respectively. In overall, four crosses *viz.*, CGN-20953 x Japanese Long Green (-7.41, -3.95, -4.69 and -3.61), CGN-21585 x Japanese Long Green (-10.00, -5.02, -8.80 and -7.77), LC-1-1 x K-75 (-12.30, -11.33, -4.23 and -3.15) and LC-28-8 x K-75 (-12.47, -10.05, -5.90 and -4.83) revealed significant negative values for all the estimates of heterosis *viz.*, average heterosis, heterobeltiosis and standard heterosis over both the check cultivars, KH-1 and Pusa Sanyog.

4.4.13 Fruit fly incidence

Significant differences were observed among the hybrid combinations for different estimates of heterosis for this trait (Table 4.47). Heterosis over mid parent, better parent, standard check-I and standard check-II ranged from -46.55 (LC-3-3 x Poinsette) to 32.01 (LC-2-2 x Japanese Long Green), -42.51 (LC-3-3 x Poinsette) to 82.09 (LC-2-2 x Japanese Long Green), -41.31 (LC-1-1 x K-75) to 82.02 (CGN-21585 x Japanese Long Green) and -44.71 (LC-1-1 x K-75) to 71.46 (CGN-21585 x Japanese Long Green) per cent, respectively. Significant negative heterosis over the mid parent, better parent, standard check-I and standard check-II was recorded in twenty six, twenty three, eleven and fourteen hybrid combinations, respectively for fruit fly incidence. Significant negative estimates of heterosis *viz.*, average heterosis, heterobeltiosis and standard heterosis over both the check cultivars (KH-1 and Pusa Sanyog) were recorded by the nine cross combinations *viz.*, CGN-20953 x K-75 (-37.16, -36.53, -28.51 and -32.66), CGN-20953 x Poinsette (-28.34, -25.65, -16.25 and -21.11), LC-1-1 x K-75 (-43.75, -37.42, -41.31 and -44.71), LC-1-1 x Poinsette (-22.41, -11.11, -16.63 and -21.46), LC-3-3 x Poinsette (-46.55, -42.51, -39.52, and -43.03), LC-15-5 x K-75 (-22.24, -17.99, -15.06 and -19.99), LC-15-5 x Poinsette (-45.21, -40.56, -38.44 and -42.01), LC-25-7 x Poinsette (-31.46, -29.96, -15.17 and -20.09) and Gyne-5 x K-75 (-29.74, -22.84, -11.34 and -16.48).

Table 4.46 Estimates of heterosis for cucurbitacin content (μg/100g) in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	-2.15	2.25	3.57*	4.74*
CGN-19533 X Japanese Long Green	-4.31*	-1.78	-0.52	0.61
CGN-19533 X Poinsette	-0.91	3.74*	5.08*	6.26*
CGN-20256 X K-75	-0.86	6.31*	2.53*	3.69*
CGN-20256 X Japanese Long Green	-6.71*	-1.77	-5.27*	-4.20*
CGN-20256 X Poinsette	-0.14	7.29*	3.47*	4.64*
CGN-20515 X K-75	-1.80	2.42*	4.13*	5.31*
CGN-20515 X Japanese Long Green	-1.79	0.61	2.29	3.45*
CGN-20515 X Poinsette	-0.83	3.62*	5.35*	6.54*
CGN-20953 X K-75	-2.31	3.18*	2.40	3.55*
CGN-20953 X Japanese Long Green	-7.41*	-3.95*	-4.69*	-3.61*
CGN-20953 X Poinsette	-1.59	4.14*	3.34*	4.51*
CGN-20969 X K-75	0.66	7.19*	4.75*	5.94*
CGN-20969 X Japanese Long Green	-1.73	2.75*	0.42	1.55
CGN-20969 X Poinsette	2.95*	9.83*	7.34*	8.55*
CGN-21585 X K-75	-3.75*	3.46*	-0.66	0.46
CGN-21585 X Japanese Long Green	-10.00*	-5.02*	-8.80*	-7.77*
CGN-21585 X Poinsette	-1.89	5.65*	1.45	2.60*
CGN-22930 X K-75	-2.67*	2.50*	2.29	3.45*
CGN-22930 X Japanese Long Green	-3.44*	-0.13	-0.33	0.79
CGN-22930 X Poinsette	-1.90	3.50*	3.29*	4.46*
LC-1-1 X K-75	-12.30*	-11.33*	-4.23*	-3.15*
LC-1-1 X Japanese Long Green	-3.41*	-2.79*	3.66*	4.83*
LC-1-1 X Poinsette	-6.83*	-5.63*	1.93	3.08*
LC-2-2 X K-75	-5.51*	-5.12*	3.89*	5.07*
LC-2-2 X Japanese Long Green	1.28	2.64*	9.46*	10.69*
LC-2-2 X Poinsette	-3.41*	-2.84*	6.39*	7.60*
LC-3-3 X K-75	-3.85*	-3.84*	6.16*	7.36*
LC-3-3 X Japanese Long Green	-4.14*	-2.43*	4.05*	5.22*
LC-3-3 X Poinsette	3.00*	3.17*	13.93*	15.22*
LC-12-4 X K-75	-4.83*	-2.99*	7.10*	8.31*
LC-12-4 X Japanese Long Green	-4.28*	-0.67	5.93*	7.12*
LC-12-4 X Poinsette	3.98*	5.81*	17.22*	18.55*
LC-15-5 X K-75	2.81*	3.29*	12.99*	14.26*
LC-15-5 X Japanese Long Green	-1.93	-0.67	5.93*	7.12*
LC-15-5 X Poinsette	-1.22	-0.58	8.75*	9.98*
LC-21-6 X K-75	-0.98	0.42	10.87*	12.12*
LC-21-6 X Japanese Long Green	-0.58	2.64*	9.46*	10.69*
LC-21-6 X Poinsette	5.14*	6.44*	17.93*	19.26*
LC-25-7 X K-75	-6.01*	-5.57*	3.29*	4.46*
LC-25-7 X Japanese Long Green	1.77	3.08*	9.92*	11.17*
LC-25-7 X Poinsette	-2.08	-1.45	7.81*	9.02*
LC-28-8 X K-75	-12.47*	-10.05*	-5.90*	-4.83*
LC-28-8 X Japanese Long Green	2.06	3.05*	7.81*	9.02*
LC-28-8 X Poinsette	-8.55*	-5.85*	-1.50	-0.39
Gyne-5 X K-75	-4.59*	-0.80	1.45	2.60*
Gyne-5 X Japanese Long Green	0.73	2.88*	5.22*	6.41*
Gyne-5 X Poinsette	-3.00*	1.05	3.34*	4.51*

*Significant at 5% level of significance

Table 4.47 Estimates of heterosis for fruit fly incidence (%) in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	-22.15*	-19.08*	-7.02	-12.41*
CGN-19533 X Japanese Long Green	16.59*	33.58*	65.60*	56.00*
CGN-19533 X Poinsette	-15.84*	-14.85*	3.13	-2.85
CGN-20256 X K-75	5.55	18.05*	35.64*	27.77*
CGN-20256 X Japanese Long Green	10.02*	16.98*	66.25*	56.61*
CGN-20256 X Poinsette	-23.20*	-16.54*	1.08	-4.78
CGN-20515 X K-75	-14.64*	-14.20*	-2.43	-8.09
CGN-20515 X Japanese Long Green	15.16*	38.65*	57.67*	48.52*
CGN-20515 X Poinsette	-8.76*	-5.79	7.13	0.92
CGN-20953 X K-75	-37.16*	-36.53*	-28.51*	-32.66*
CGN-20953 X Japanese Long Green	29.84*	57.19*	77.05*	66.79*
CGN-20953 X Poinsette	-28.34*	-25.65*	-16.25*	-21.11*
CGN-20969 X K-75	-1.41	8.32	24.46*	17.24*
CGN-20969 X Japanese Long Green	15.18*	24.61*	71.44*	61.50*
CGN-20969 X Poinsette	-14.34*	-8.52*	10.80*	4.37
CGN-21585 X K-75	0.81	8.32	24.46*	17.24*
CGN-21585 X Japanese Long Green	24.62*	37.87*	82.02*	71.46*
CGN-21585 X Poinsette	-24.79*	-21.40*	-4.81	-10.33*
CGN-22930 X K-75	-17.94*	-14.14*	-1.35	-7.07
CGN-22930 X Japanese Long Green	2.34	16.43*	46.17*	37.69*
CGN-22930 X Poinsette	-17.12*	-15.60*	2.21	-3.71
LC-1-1 X K-75	-43.75*	-37.42*	-41.31*	-44.71*
LC-1-1 X Japanese Long Green	27.22*	72.19*	61.50*	52.14*
LC-1-1 X Poinsette	-22.41*	-11.11*	-16.63*	-21.46*
LC-2-2 X K-75	-32.88*	-24.08*	-30.89*	-34.89*
LC-2-2 X Japanese Long Green	32.01*	82.09*	65.77*	56.15*
LC-2-2 X Poinsette	-22.17*	-9.31	-17.44*	-22.23*
LC-3-3 X K-75	-8.15	-3.90	1.08	-4.78
LC-3-3 X Japanese Long Green	5.64	33.21*	40.12*	31.99*
LC-3-3 X Poinsette	-46.55*	-42.51*	-39.52*	-43.03*
LC-12-4 X K-75	-20.09*	-12.22*	0.86	-4.98
LC-12-4 X Japanese Long Green	13.53*	22.85*	68.95*	59.16*
LC-12-4 X Poinsette	-5.43	0.98	22.30*	15.21*
LC-15-5 X K-75	-22.24*	-17.99*	-15.06*	-19.99*
LC-15-5 X Japanese Long Green	21.73*	54.95*	60.48*	51.17*
LC-15-5 X Poinsette	-45.21*	-40.56*	-38.44*	-42.01*
LC-21-6 X K-75	-18.73*	-12.73*	0.27	-5.54
LC-21-6 X Japanese Long Green	12.04*	24.04*	63.55*	54.07*
LC-21-6 X Poinsette	-18.08*	-14.44*	3.62	-2.39
LC-25-7 X K-75	-3.96	0.85	15.87*	9.16
LC-25-7 X Japanese Long Green	7.69*	22.04*	54.27*	45.32*
LC-25-7 X Poinsette	-31.46*	-29.96*	-15.17*	-20.09*
LC-28-8 X K-75	-22.81*	-17.48*	-5.18	-10.68*
LC-28-8 X Japanese Long Green	15.91*	28.90*	68.57*	58.80*
LC-28-8 X Poinsette	-13.01*	-9.54*	9.56	3.20
Gyne-5 X K-75	-29.74*	-22.84*	-11.34*	-16.48*
Gyne-5 X Japanese Long Green	18.24*	27.97*	75.92*	65.72*
Gyne-5 X Poinsette	-16.85*	-11.23*	7.51	1.27

*Significant at 5% level of significance

4.4.14 Severity of powdery mildew

Heterotic response for severity of powdery mildew varied significantly among different hybrid combinations (Table 4.48). It was ranged from -35.57 (Gyne-5 x Poinsette) to 53.51 (LC-21-6 x K-75), -17.12 (LC-1-1 x K-75) to 82.44 (LC-21-6 x K-75), -30.63 (LC-15-5 x K-75) to 119.80 (CGN-20930 x K-75) and -43.31 (LC-15-5 x K-75) to 79.62 (CGN-20930 x K-75) per cent over mid parent, better parent, standard check-I and standard check-II, respectively. Among all the hybrid combinations, five, one, five and fifteen cross combinations revealed significant negative heterosis for severity of powdery mildew over mid parent, better parent, standard check-I and standard check-II, respectively. The cross combination CGN-20515 x Poinsette (-26.19 and -39.68), CGN-20953 x K-75 (-20.50 and -35.03), LC-3-3 x Poinsette (-25.41 and -39.04), LC-15-5 x K-75 (-30.63 and -43.31) and Gyne-5 x Poinsette (-22.84 and -36.94) revealed significant negative values for standard heterosis.

4.4.15 Severity of downy mildew

Estimation of heterosis revealed significant differences among the different hybrid combinations for severity of downy mildew (Table 4.49). Heterosis over mid parent, better parent, standard check-I and standard check-II ranged from -35.02 (CGN-20969 x Japanese Long Green) to 63.09 (CGN-20515 x Japanese Long Green), -22.95 (LC-3-3 x K-75) to 115.88 (CGN-22930 x Japanese Long Green), -37.61 (LC-3-3 x K-75) to 156.01 (CGN-22930 x Japanese Long Green) and -28.23 (LC-3-3 x K-75) to 194.50 (CGN-22930 x Japanese Long Green) per cent, respectively. Significant negative heterosis over mid parent, better parent, standard check-I and standard check-II was recorded in thirteen, one, five and two cross combinations, respectively for severity of downy mildew. Only one cross combination, LC-3-3 x K-75 (-27.10, -22.95, -37.61 and -28.23) exhibited significant negative estimates of heterosis for average heterosis, heterobeltiosis and standard heterosis over KH-1 and Pusa Sanyog.

4.4.16 Severity of angular leaf spot

Severity of angular leaf spot revealed significant variations among all the hybrid combinations for different estimates of heterosis (Table 4.50). It was ranged from -41.51 (LC-1-1 x K-75) to 43.26 (CGN-21585 x K-75), -22.96 (LC-2-2 x Poinsette) to 99.92 (CGN-21585 x Japanese Long Green), -46.90 (LC-1-1 x K-75) to

Table 4.48 Estimates of heterosis for severity of powdery mildew (%) in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	**Better parent**	**Standard Check-I**	**Standard Check-II**
CGN-19533 X K-75	53.00*	66.73*	102.73*	65.67*
CGN-19533 X Japanese Long Green	8.06	35.32*	28.99*	5.41
CGN-19533 X Poinsette	-6.83	29.81*	4.21	-14.84
CGN-20256 X K-75	40.17*	60.71*	95.40*	59.68*
CGN-20256 X Japanese Long Green	3.09	36.55*	30.16*	6.37
CGN-20256 X Poinsette	-6.14	38.83*	11.46	-8.92
CGN-20515 X K-75	-2.03	10.46	7.01	-12.55
CGN-20515 X Japanese Long Green	30.82*	31.89*	25.72*	2.74
CGN-20515 X Poinsette	-16.67	-8.06	-26.19*	-39.68*
CGN-20953 X K-75	-25.22*	-12.67	-20.50*	-35.03*
CGN-20953 X Japanese Long Green	18.53	21.32*	10.44	-9.75
CGN-20953 X Poinsette	3.73	10.68	-11.15	-27.39*
CGN-20969 X K-75	53.25*	57.82*	91.89*	56.82*
CGN-20969 X Japanese Long Green	18.71*	39.57*	33.05*	8.73
CGN-20969 X Poinsette	14.80	49.51*	20.03*	-1.91
CGN-21585 X K-75	46.02*	61.09*	95.87*	60.06*
CGN-21585 X Japanese Long Green	33.33*	69.26*	61.34*	31.85*
CGN-21585 X Poinsette	13.80	60.87*	29.15*	5.54
CGN-22930 X K-75	43.88*	80.77*	119.80*	79.62*
CGN-22930 X Japanese Long Green	1.42	48.57*	41.62*	15.73*
CGN-22930 X Poinsette	-8.38	50.78*	21.04*	-1.08
LC-1-1 X K-75	-21.33*	-17.12*	0.78	-17.64*
LC-1-1 X Japanese Long Green	10.71	33.52*	27.28*	4.01
LC-1-1 X Poinsette	-12.95	16.50	-6.47	-23.57*
LC-2-2 X K-75	3.23	7.26	20.97*	-1.15
LC-2-2 X Japanese Long Green	24.57*	35.98*	29.62*	5.92
LC-2-2 X Poinsette	-0.93	19.13	-4.36	-21.85*
LC-3-3 X K-75	-19.46*	-13.30	-8.57	-25.29*
LC-3-3 X Japanese Long Green	22.67*	29.19*	23.15*	0.64
LC-3-3 X Poinsette	-19.68	-7.09	-25.41*	-39.04*
LC-12-4 X K-75	27.29*	28.12*	53.78*	25.67*
LC-12-4 X Japanese Long Green	-5.18	7.11	2.10	-16.56*
LC-12-4 X Poinsette	10.89	38.35*	11.07	-9.24
LC-15-5 X K-75	-31.01*	-12.75	-30.63*	-43.31*
LC-15-5 X Japanese Long Green	7.62	18.33	-5.92	-23.12*
LC-15-5 X Poinsette	12.98	13.53	-9.74	-26.24*
LC-21-6 X K-75	53.51*	82.44*	61.11*	31.66*
LC-21-6 X Japanese Long Green	14.60	19.15	5.22	-14.01
LC-21-6 X Poinsette	36.57*	43.40*	15.12	-5.92
LC-25-7 X K-75	2.32	7.48	18.71	-2.99
LC-25-7 X Japanese Long Green	31.59*	42.03*	35.39*	10.64
LC-25-7 X Poinsette	-1.92	16.50	-6.47	-23.57*
LC-28-8 X K-75	-2.86	-1.92	19.25*	-2.55
LC-28-8 X Japanese Long Green	7.36	23.47*	17.69	-3.82
LC-28-8 X Poinsette	-4.05	22.04*	-2.03	-19.94*
Gyne-5 X K-75	17.68*	35.90*	65.24*	35.03*
Gyne-5 X Japanese Long Green	12.25	49.88*	42.87*	16.75*
Gyne-5 X Poinsette	-35.57*	-3.88	-22.84*	-36.94*

*Significant at 5% level of significance

Table 4.49 Estimates of heterosis for severity of downy mildew (%) in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	-29.85*	24.02*	0.43	15.53
CGN-19533 X Japanese Long Green	46.59*	100.21*	137.42*	173.11*
CGN-19533 X Poinsette	-20.21*	43.41*	13.50	30.56*
CGN-20256 X K-75	0.96	86.36*	50.92*	73.61*
CGN-20256 X Japanese Long Green	-16.88*	17.95*	39.88*	60.90*
CGN-20256 X Poinsette	-28.68*	33.88*	5.95	21.88*
CGN-20515 X K-75	10.25	32.80*	7.55	23.71*
CGN-20515 X Japanese Long Green	63.09*	66.29*	89.75*	118.28*
CGN-20515 X Poinsette	3.49	26.36*	0.00	15.03
CGN-20953 X K-75	2.26	30.53*	5.71	21.59*
CGN-20953 X Japanese Long Green	21.37*	25.04*	48.28*	70.57*
CGN-20953 X Poinsette	-7.78	19.38	-5.52	8.68
CGN-20969 X K-75	22.99*	25.06*	-2.02	12.70
CGN-20969 X Japanese Long Green	-35.02*	-18.32	-36.01*	-26.39*
CGN-20969 X Poinsette	29.88*	30.54*	2.27	17.64
CGN-21585 X K-75	6.89	70.45*	38.04*	58.79*
CGN-21585 X Japanese Long Green	2.72	28.14*	51.96*	74.81*
CGN-21585 X Poinsette	-17.56*	33.57*	5.71	21.59*
CGN-22930 X K-75	-7.30	80.83*	46.44*	68.45*
CGN-22930 X Japanese Long Green	44.82*	115.88*	156.01*	194.50*
CGN-22930 X Poinsette	-17.07*	64.57*	30.25*	49.82*
LC-1-1 X K-75	-20.26*	14.17	-7.55	6.35
LC-1-1 X Japanese Long Green	21.10*	37.61*	63.19*	87.72*
LC-1-1 X Poinsette	0.43	45.97*	15.52	32.89*
LC-2-2 X K-75	14.55	30.30*	5.52	21.38*
LC-2-2 X Japanese Long Green	29.26*	38.86*	43.37*	64.93*
LC-2-2 X Poinsette	-23.98*	-12.40	-30.67*	-20.25
LC-3-3 X K-75	-27.10*	-22.95*	-37.61*	-28.23*
LC-3-3 X Japanese Long Green	33.00*	53.95*	38.83*	59.70*
LC-3-3 X Poinsette	12.54	20.39	-4.72	9.60
LC-12-4 X K-75	-6.13	23.48*	0.00	15.03
LC-12-4 X Japanese Long Green	29.07*	36.42*	61.78*	86.10*
LC-12-4 X Poinsette	-16.93*	10.85	-12.27	0.92
LC-15-5 X K-75	-22.48*	-12.88	-29.45*	-18.84
LC-15-5 X Japanese Long Green	-10.45	-2.67	-1.66	13.13
LC-15-5 X Poinsette	16.45	32.56*	4.91	20.68
LC-21-6 X K-75	-24.22*	4.77	-15.15	-2.40
LC-21-6 X Japanese Long Green	34.51*	48.32*	75.89*	102.33*
LC-21-6 X Poinsette	-0.94	38.99*	10.00	26.53*
LC-25-7 X K-75	-0.10	11.14	-10.00	3.53
LC-25-7 X Japanese Long Green	-14.20	-5.81	-6.56	7.48
LC-25-7 X Poinsette	-7.81	3.88	-17.79	-5.43
LC-28-8 X K-75	5.36	31.82*	6.75	22.79*
LC-28-8 X Japanese Long Green	19.00*	20.54*	42.94*	64.43*
LC-28-8 X Poinsette	-11.21	12.64	-10.86	2.54
Gyne-5 X K-75	-15.52	-2.50	-21.04*	-9.17
Gyne-5 X Japanese Long Green	16.01	22.93*	30.25*	49.82*
Gyne-5 X Poinsette	27.08*	48.60*	17.61	35.29*

*Significant at 5% level of significance

Table 4.50 Estimates of heterosis for Severity of angular leaf spot (%) in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	22.03*	35.66*	66.90*	102.11*
CGN-19533 X Japanese Long Green	-8.60	32.60*	4.97	27.11*
CGN-19533 X Poinsette	-14.95*	-3.94	14.84	39.06*
CGN-20256 X K-75	26.79*	48.40*	82.58*	121.09*
CGN-20256 X Japanese Long Green	-11.21	36.92*	8.39	31.25*
CGN-20256 X Poinsette	-15.19*	0.92	20.65*	46.09*
CGN-20515 X K-75	4.61	18.88*	46.26*	77.11*
CGN-20515 X Japanese Long Green	-5.86	40.18*	10.97	34.38*
CGN-20515 X Poinsette	-17.62*	-4.86	13.74	37.73*
CGN-20953 X K-75	-31.78*	-8.47	-33.10*	-18.98
CGN-20953 X Japanese Long Green	13.81	18.53	-13.35	4.92
CGN-20953 X Poinsette	9.85	44.75*	5.81	28.13*
CGN-20969 X K-75	29.40*	96.37*	18.71*	43.75*
CGN-20969 X Japanese Long Green	-18.67*	-6.08	-43.23*	-31.25*
CGN-20969 X Poinsette	22.58*	82.50*	10.32	33.59*
CGN-21585 X K-75	43.26*	88.94*	132.45*	181.48*
CGN-21585 X Japanese Long Green	12.78	99.92*	58.26*	91.64*
CGN-21585 X Poinsette	10.01	47.71*	76.58*	113.83*
CGN-22930 X K-75	-22.49*	-13.63	6.26	28.67*
CGN-22930 X Japanese Long Green	-18.77*	18.17	-6.45	13.28
CGN-22930 X Poinsette	-11.20	0.54	20.19*	45.55*
LC-1-1 X K-75	-41.51*	-9.26	-46.90*	-35.70*
LC-1-1 X Japanese Long Green	11.81	31.53*	-23.03*	-6.80
LC-1-1 X Poinsette	-17.39*	25.69*	-26.45*	-10.94
LC-2-2 X K-75	-2.16	18.70	2.39	23.98*
LC-2-2 X Japanese Long Green	6.86	11.65	-11.61	7.03
LC-2-2 X Poinsette	-35.42*	-22.96*	-33.55*	-19.53
LC-3-3 X K-75	-11.60	-6.60	3.23	25.00*
LC-3-3 X Japanese Long Green	-6.60	11.90	-11.42	7.27
LC-3-3 X Poinsette	11.61	16.17	28.39*	55.47*
LC-12-4 X K-75	22.15*	64.42*	19.55*	44.77*
LC-12-4 X Japanese Long Green	0.25	4.70	-23.87*	-7.81
LC-12-4 X Poinsette	13.89	50.58*	9.48	32.58*
LC-15-5 X K-75	2.15	14.47	40.84*	70.55*
LC-15-5 X Japanese Long Green	-8.57	33.90*	6.00	28.36*
LC-15-5 X Poinsette	-21.33*	-10.42	7.10	29.69*
LC-21-6 X K-75	28.24*	39.93*	45.61*	76.33*
LC-21-6 X Japanese Long Green	-17.61*	-4.65	-24.52*	-8.59
LC-21-6 X Poinsette	-4.62	2.48	6.65	29.14*
LC-25-7 X K-75	-29.96*	-16.49	-25.81*	-10.16
LC-25-7 X Japanese Long Green	2.15	8.39	-14.19	3.91
LC-25-7 X Poinsette	1.55	19.10*	5.81	28.13*
LC-28-8 X K-75	25.10*	38.67*	40.19*	69.77*
LC-28-8 X Japanese Long Green	-6.23	6.76	-15.48	2.34
LC-28-8 X Poinsette	-13.63	-5.74	-4.71	15.39
Gyne-5 X K-75	-16.43*	-6.66	14.84	39.06*
Gyne-5 X Japanese Long Green	-9.33	32.27*	4.71	26.80*
Gyne-5 X Poinsette	-1.24	12.09	34.00*	62.27*

*Significant at 5% level of significance

132.45 (CGN-21585 x K-75) and -35.70 (LC-1-1 x K-75) to 181.48 (CGN-21585 x K-75) per cent over mid parent, better parent, standard check-I and standard check-II, respectively. Among all the cross combinations, fourteen, one, nine and two cross combinations revealed significant negative heterosis for severity of angular leaf spot over mid parent, better parent, standard check-I and standard check-II, respectively. Out of forty eight hybrid combinations, significant negative standard heterosis over both the check cultivars were recorded by the two cross combinations *viz.,* CGN-20969 x Japanese Long Green (-43.23 and -31.25) and LC-1-1 x K-75 (-46.90 and -35.70).

4.4.17 Seed germination

Estimates of heterosis revealed significant variations among the different hybrid combinations for seed germination (Table 4.51). Heterosis over mid parent, better parent, standard check-I and standard check-II ranged from -6.83 (CGN-20515 x Japanese Long Green) to 13.01 (LC-1-1 x K-75), -11.72 (CGN-20953 x K-75) to 11.51 (LC-1-1 x K-75), -15.71 (LC-12-4 x K-75) to 6.61 (CGN-20953 x Poinsette) and -16.39 (LC-12-4 x K-75) to 5.74 (CGN-20953 x Poinsette) per cent, respectively. Significant positive heterosis over mid parent, better parent, standard check-I and standard check-II was recorded in eight, three, two and one hybrid combinations, respectively for seed germination. Cross combination CGN-20953 x Poinsette (6.61 and 5.74) revealed significant positive standard heterosis over both the check cultivars, while LC-1-1 x K-75 (13.01 and 11.51) exhibited significant positive average heterosis and heterobeltiosis.

4.4.18 Seed vigour index-I

Significant differences were recorded among the hybrid combinations for different estimates of heterosis for this trait (Table 4.52). It was ranged from -14.74 (LC-3-3 x Poinsette) to 28.27 (LC-1-1 x K-75), -22.76 (LC-3-3 x Poinsette) to 24.61 (LC-1-1 x K-75), -29.62 (CGN-20256 x Poinsette) to 16.23 (LC-1-1 x K-75) and -32.21 (CGN-20256 x Poinsette) to 11.95 (LC-1-1 x K-75) per cent heterosis over mid parent, better parent, standard check-I and standard check-II, respectively. Among all the cross combinations, seven, five, four and one cross combinations revealed significant positive heterosis for seed vigour index-I over mid parent, better parent, standard Check-II and standard Check-II, respectively. Significant positive values for

Table 4.51 Estimates of heterosis for seed germination (%) in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	-4.31*	-9.01*	-8.27*	-9.01*
CGN-19533 X Japanese Long Green	-5.61*	-6.96*	-6.20*	-6.96*
CGN-19533 X Poinsette	2.68	2.05	2.89	2.05
CGN-20256 X K-75	-3.36	-4.85*	-10.75*	-11.47*
CGN-20256 X Japanese Long Green	0.43	-1.68	-3.72*	-4.50*
CGN-20256 X Poinsette	-2.14	-4.98*	-5.38*	-6.15*
CGN-20515 X K-75	4.72*	-0.82	0.82	0.00
CGN-20515 X Japanese Long Green	-6.83*	-8.54*	-7.03*	-7.78*
CGN-20515 X Poinsette	2.67	1.62	3.30	2.46
CGN-20953 X K-75	-5.04*	-11.72*	-6.62*	-7.38*
CGN-20953 X Japanese Long Green	-0.60	-4.29*	1.24	0.42
CGN-20953 X Poinsette	3.83*	0.79	6.61*	5.74*
CGN-20969 X K-75	5.81*	3.95*	-2.07	-2.86
CGN-20969 X Japanese Long Green	-1.07	-2.95	-4.96*	-5.73*
CGN-20969 X Poinsette	1.07	-1.66	-2.07	-2.86
CGN-21585 X K-75	-2.42	-5.15*	-8.68*	-9.42*
CGN-21585 X Japanese Long Green	-0.43	-1.27	-3.31	-4.09*
CGN-21585 X Poinsette	-2.53	-4.15*	-4.55*	-5.32*
CGN-22930 X K-75	-1.08	-5.77*	-5.38*	-6.15*
CGN-22930 X Japanese Long Green	-1.25	-2.47	-2.07	-2.86
CGN-22930 X Poinsette	-0.82	-1.23	-0.83	-1.64
LC-1-1 X K-75	13.01*	11.51*	4.13*	3.28
LC-1-1 X Japanese Long Green	-1.08	-3.38	-5.38*	-6.15*
LC-1-1 X Poinsette	3.65	0.42	0.00	-0.81
LC-2-2 X K-75	3.31	0.42	-3.31	-4.09*
LC-2-2 X Japanese Long Green	-2.13	-2.95	-4.96*	-5.73*
LC-2-2 X Poinsette	1.68	0.00	-0.42	-1.23
LC-3-3 X K-75	-0.44	-4.59*	-5.38*	-6.15*
LC-3-3 X Japanese Long Green	4.40*	3.75*	2.89	2.05
LC-3-3 X Poinsette	-1.45	-1.66	-2.07	-2.86
LC-12-4 X K-75	-2.86	-7.27*	-15.71*	-16.39*
LC-12-4 X Japanese Long Green	0.68	-7.18*	-9.10*	-9.84*
LC-12-4 X Poinsette	3.40	-5.39*	-5.79*	-6.55*
LC-15-5 X K-75	-1.32	-4.27*	-7.44*	-8.19*
LC-15-5 X Japanese Long Green	1.91	1.27	-0.83	-1.64
LC-15-5 X Poinsette	3.16	1.67	1.24	0.42
LC-21-6 X K-75	2.06	1.36	-7.86*	-8.61*
LC-21-6 X Japanese Long Green	0.44	-3.80*	-5.79*	-6.55*
LC-21-6 X Poinsette	1.76	-3.31	-3.72*	-4.50*
LC-25-7 X K-75	-4.31*	-4.53*	-12.82*	-13.53*
LC-25-7 X Japanese Long Green	-3.06	-6.33*	-8.27*	-9.01*
LC-25-7 X Poinsette	-1.30	-5.39*	-5.79*	-6.55*
LC-28-8 X K-75	0.70	-0.90	-9.92*	-10.65*
LC-28-8 X Japanese Long Green	4.00*	-1.27	-3.31	-4.09*
LC-28-8 X Poinsette	1.76	-4.15*	-4.55*	-5.32*
Gyne-5 X K-75	3.95*	0.42	-2.07	-2.86
Gyne-5 X Japanese Long Green	-2.33	-2.53	-4.55*	-5.32*
Gyne-5 X Poinsette	4.40*	3.32	2.89	2.05

*Significant at 5% level of significance

Table 4.52 Estimates of heterosis for seed vigour index-I in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	8.09	6.90	-5.98	-9.44*
CGN-19533 X Japanese Long Green	-6.85	-7.17	-19.60*	-22.56*
CGN-19533 X Poinsette	-2.90	-3.37	-16.07*	-19.16*
CGN-20256 X K-75	0.05	-7.15	-18.33*	-21.34*
CGN-20256 X Japanese Long Green	2.25	-4.42	-17.22*	-20.27*
CGN-20256 X Poinsette	-13.20*	-18.97*	-29.62*	-32.21*
CGN-20515 X K-75	10.90*	10.57*	-2.75	-6.33
CGN-20515 X Japanese Long Green	0.99	0.51	-12.12*	-15.36*
CGN-20515 X Poinsette	-1.28	-1.60	-13.97*	-17.14*
CGN-20953 X K-75	7.75	2.67	-0.28	-3.96
CGN-20953 X Japanese Long Green	-11.04*	-15.85*	-18.27*	-21.28*
CGN-20953 X Poinsette	20.31*	13.95*	10.67*	6.60
CGN-20969 X K-75	12.81*	3.00	-9.41*	-12.74*
CGN-20969 X Japanese Long Green	-7.11	-14.59*	-26.03*	-28.75*
CGN-20969 X Poinsette	6.74	-1.98	-14.86*	-18.00*
CGN-21585 X K-75	-4.26	-9.47*	-20.37*	-23.31*
CGN-21585 X Japanese Long Green	-8.49	-12.83*	-24.50*	-27.28*
CGN-21585 X Poinsette	-4.01	-8.69*	-20.69*	-23.61*
CGN-22930 X K-75	2.29	0.51	-11.60*	-14.85*
CGN-22930 X Japanese Long Green	6.41	5.36	-8.75*	-12.11*
CGN-22930 X Poinsette	-4.36	-5.44	-17.87*	-20.89*
LC-1-1 X K-75	28.27*	24.61*	16.23*	11.95*
LC-1-1 X Japanese Long Green	-4.67	-8.08*	-14.26*	-17.42*
LC-1-1 X Poinsette	-1.29	-4.68	-11.09*	-14.37*
LC-2-2 X K-75	-0.23	-6.54	-5.89	-9.36*
LC-2-2 X Japanese Long Green	-5.46	-12.08*	-11.47*	-14.73*
LC-2-2 X Poinsette	15.39*	7.47*	8.21*	4.22
LC-3-3 X K-75	11.32*	1.43	8.49*	4.50
LC-3-3 X Japanese Long Green	4.50	-5.45	1.14	-2.58
LC-3-3 X Poinsette	-14.74*	-22.76*	-17.38*	-20.42*
LC-12-4 X K-75	-9.74*	-14.64*	-24.92*	-27.68*
LC-12-4 X Japanese Long Green	-1.52	-6.18	-18.75*	-21.74*
LC-12-4 X Poinsette	2.31	-2.66	-15.45*	-18.57*
LC-15-5 X K-75	1.04	-0.54	-9.69*	-13.02*
LC-15-5 X Japanese Long Green	2.90	0.53	-8.72*	-12.08*
LC-15-5 X Poinsette	16.42*	13.90*	3.41	-0.39
LC-21-6 X K-75	0.26	-5.59	-16.96*	-20.02*
LC-21-6 X Japanese Long Green	1.44	-3.78	-16.67*	-19.74*
LC-21-6 X Poinsette	6.00	0.41	-12.79*	-16.00*
LC-25-7 X K-75	-4.46	-10.90*	-21.63*	-24.52*
LC-25-7 X Japanese Long Green	3.75	-2.54	-15.59*	-18.70*
LC-25-7 X Poinsette	-5.38	-11.24*	-22.91*	-25.75*
LC-28-8 X K-75	4.08	2.03	-10.26*	-13.56*
LC-28-8 X Japanese Long Green	2.16	0.91	-12.61*	-15.82*
LC-28-8 X Poinsette	-11.61*	-12.81*	-24.27*	-27.06*
Gyne-5 X K-75	6.77	3.75	-3.28	-6.84
Gyne-5 X Japanese Long Green	-0.18	-3.72	-10.25*	-13.55*
Gyne-5 X Poinsette	-5.84	-9.05*	-15.22*	-18.34*

*Significant at 5% level of significance

Table 4.53 Estimates of heterosis for seed vigour index-II in cucumber

Cross combination(s)	Per cent increase/decrease over			
	Mid parent	Better parent	Standard Check-I	Standard Check-II
CGN-19533 X K-75	11.88	-3.86	-1.46	-10.51
CGN-19533 X Japanese Long Green	-17.36*	-24.65*	-32.61*	-38.80*
CGN-19533 X Poinsette	12.45	-2.94	-1.56	-10.61
CGN-20256 X K-75	9.33	-6.74	-4.41	-13.19
CGN-20256 X Japanese Long Green	0.48	-9.12	-18.71*	-26.18*
CGN-20256 X Poinsette	17.21*	0.42	1.84	-7.52
CGN-20515 X K-75	21.65*	12.15	14.95	4.39
CGN-20515 X Japanese Long Green	-7.67	-9.19	-18.78*	-26.25*
CGN-20515 X Poinsette	12.55	4.26	5.74	-3.97
CGN-20953 X K-75	-16.98*	-18.28*	-13.53	-21.47*
CGN-20953 X Japanese Long Green	8.34	-0.05	5.77	-3.95
CGN-20953 X Poinsette	-5.92	-7.88	-2.52	-11.47
CGN-20969 X K-75	12.98	-0.59	1.89	-7.47
CGN-20969 X Japanese Long Green	-24.79*	-29.65*	-37.08*	-42.86*
CGN-20969 X Poinsette	-4.77	-15.82*	-14.63	-22.47*
CGN-21585 X K-75	-7.12	-21.60*	-19.64*	-27.03*
CGN-21585 X Japanese Long Green	-27.21*	-34.91*	-41.78*	-47.13*
CGN-21585 X Poinsette	-16.29	-29.04*	-28.03*	-34.65*
CGN-22930 X K-75	9.87	-1.30	1.16	-8.13
CGN-22930 X Japanese Long Green	18.82*	13.64	1.64	-7.70
CGN-22930 X Poinsette	-9.00	-17.87*	-16.71*	-24.36*
LC-1-1 X K-75	52.39*	41.72*	68.92*	53.40*
LC-1-1 X Japanese Long Green	-10.65	-21.80*	-6.80	-15.36*
LC-1-1 X Poinsette	-3.10	-10.33	6.89	-2.94
LC-2-2 X K-75	-0.19	-10.12	15.03	4.46
LC-2-2 X Japanese Long Green	-6.93	-20.95*	1.17	-8.12
LC-2-2 X Poinsette	33.02*	19.22*	52.58*	38.56*
LC-3-3 X K-75	35.81*	20.06*	60.21*	45.49*
LC-3-3 X Japanese Long Green	12.35	-6.17	25.21*	13.70
LC-3-3 X Poinsette	-21.04*	-30.51*	-7.27	-15.80*
LC-12-4 X K-75	-17.74*	-23.08*	-21.15*	-28.40*
LC-12-4 X Japanese Long Green	-3.41	-3.54	-13.72	-21.65*
LC-12-4 X Poinsette	7.98	1.47	2.91	-6.54
LC-15-5 X K-75	5.01	2.10	10.80	0.62
LC-15-5 X Japanese Long Green	-2.37	-10.95	-3.36	-12.24
LC-15-5 X Poinsette	32.95*	28.60*	39.56*	26.74*
LC-21-6 X K-75	0.74	-11.43	-9.22	-17.56*
LC-21-6 X Japanese Long Green	0.91	-5.69	-15.65*	-23.40*
LC-21-6 X Poinsette	11.67	-1.37	0.03	-9.16
LC-25-7 X K-75	-4.52	-19.00*	-16.98*	-24.61*
LC-25-7 X Japanese Long Green	-9.69	-18.80*	-27.37*	-34.05*
LC-25-7 X Poinsette	-11.90	-24.94*	-23.88*	-30.87*
LC-28-8 X K-75	16.91*	10.64	13.41	2.99
LC-28-8 X Japanese Long Green	4.43	3.25	-5.51	-14.19*
LC-28-8 X Poinsette	-21.05*	-24.91*	-23.84*	-30.84*
Gyne-5 X K-75	32.57*	31.21*	34.49*	22.13*
Gyne-5 X Japanese Long Green	18.18*	11.73	12.17	1.87
Gyne-5 X Poinsette	-6.02	-6.49	-5.17	-13.88*

*Significant at 5% level of significance

all the estimates of heterosis *viz.*, average heterosis, heterobeltiosis and standard heterosis over both the check cultivars were recorded by only LC-1-1 x K-75 combination (28.27, 24.61, 16.23 and 11.95), among all the hybrids.

4.4.19 Seed vigour index-II

Heterotic response for seed vigour index-II varied significantly among the different hybrid combinations (Table 4.53). Heterosis over mid parent, better parent, standard check-I and standard check-II ranged from -27.21 (CGN-21585 x Japanese Long Green) to 52.39 (LC-1-1 x K-75), -34.91 (CGN-21585 x Japanese Long Green) to 11.51 (LC-1-1 x K-75), -41.78 (CGN-21585 x Japanese Long Green) to 68.92 (LC-1-1 x K-75) and -47.13 (CGN-21585 x Japanese Long Green) to 53.40 (LC-1-1 x K-75) per cent, respectively. Significant positive heterosis over mid parent, better parent, standard check-I and standard check-II was recorded in nine, five, six and five hybrid combinations, respectively for seed vigour index-II. In overall, five crosses *viz.*, LC-1-1 x K-75 (52.39, 41.72, 68.92 and 53.40), LC-2-2 x Poinsette (33.02, 19.22, 52.58 and 38.56), LC-3-3 x K-75 (35.81, 20.06, 60.21 and 45.49), LC-15-5 x Poinsette (32.95, 28.60, 39.56 and 26.74) and Gyne-5 x K-75 (32.57, 31.21, 34.49 and 22.13) revealed significant positive values for all the estimates of heterosis *viz.*, average heterosis, heterobeltiosis and standard heterosis over KH-1 and Pusa Sanyog.

Chapter-5

DISCUSSION

Chapter-5

Discussion

Cucumber (*Cucumis sativus* L.) is one of the most important cucurbitaceous vegetable crops grown extensively in tropical and sub-tropical parts of the country. It is a leading commercial crop in the mid and low hills of Himachal Pradesh and can be grown round the year in open and protected structures, which becomes an off-season crop for the markets of plains during July-September, when it is not produced in the plains due to water logging conditions in rainy season and brings remunerative returns to the hilly farmers. Moreover, Himachal Pradesh is endowed with micro-climatic conditions, which are suitable for carrying out the breeding and seed production programmes of cucumber.

Inspite of being native to India and having sufficient genetic variability, very meager work has been done to understand its genetic architecture and endeavor for the improvement of this crop. The very basic problem in cucumbers is concerning with the low marketable yield and higher yields has been one of the important objectives of many cucumber breeding programmes since 1900's. The lack of progress in increased fruit yield of cucumber might be partially due to the meager breeding efforts relative to other crops or lack of variability for yield (Wehner *et al.*, 1989). Moreover, there is a consumer's preference for different colours at marketable stage. In most parts of the country, green coloured fruits are preferred whereas, in Himachal Pradesh crispy, flavoured and light green fruits with white stripes are the first choice of the consumers. Therefore, in order to increase the productivity of good quality fruits within short duration of the time, heterosis breeding can proved to be a better option for the breeders by selecting desirable parents.

Heterosis breeding has come to play a pivot role in crop improvement for high production and productivity. It has direct relevance for developing hybrids and is the effective tool in the hands of breeders for improvement in yield, earliness and quality. Today, hybrid varieties of cucumber are very uncommon among the farmers because farmers are purchasing the hybrids seeds from private companies which are charging exorbitantly. To tide over the situation, there is a need to develop location specific high yielding hybrids having desirable horticultural and quality traits and to make available their seeds to the farmers at reasonable prices.

Cucumber being a monoecious and cross-pollinated crop and having appreciable number of seeds per fruit provides ample scope for the exploitation of hybrid vigour. The use of gynoecious lines in hybrids development will not only enhance the chances of getting high yielding hybrids, but also reduce the cost of hybrid seed production drastically. At national level, first F_1 hybrid 'Pusa Sanyog' has been released by IARI Regional Research Station, Katrain. However, its performance is confined only to cooler and sub-tropical conditions. In Himachal Pradesh, two more hybrids *viz.*, KH-1 and KH-2 have been developed, but they perform poorly under high rainfall areas. Therefore, the need was felt to develop cucumber hybrids involving diverse (monoecious and gynoecious) parents, as the hybrids bear high proportion of female flowers, resulting in earliness and higher yield.

For exploitation of heterosis, choice of suitable parents is of utmost importance. The combining ability studies aiming to identify inbred lines with good general combining ability (GCA) and specific combining ability (SCA) effects rely on the availability of genetic diversity among the genotypes involved in a breeding programme. General combining ability enables the breeders to exploit the existing variability in the breeding materials, to identify individual genotypes having desirable attributes and to distinguish relatedness among genotypes. While, specific combining ability is serving to determine heterotic patterns among populations or inbred lines, to identify promising single crosses and to assign inbred lines into heterotic groups. Moreover, combining ability also indicates the nature and magnitude of gene action involved in the expression of quantitative traits. The knowledge of the combining abilities of parental genotypes is crucial for conducting systematic breeding of new F_1 hybrid cultivars that possess desired horticultural and quality traits.

Therefore, the present investigations were carried out on 16 lines, 3 testers and their hybrids along with two standard check cultivars (KH-1 and Pusa Sanyog) to study their mean performance, combining ability, nature and magnitude of gene action and to ascertain best heterotic combination(s) for marketable yield and quality traits and have been discussed in the light of available literature under the following heads:

5.1 MEAN PERFORMANCE

Significant differences were observed among the parents and hybrids for all the characters under study *viz.*, days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length and breadth, average fruit weight, fruit colour, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, total soluble solids, cucurbitacin content, fruit fly incidence, severity of powdery mildew, downy mildew and angular leaf spot, seed germination and seed vigour index-I and II. Trait wise list of parents and their hybrids exhibited significantly high mean performance were presented in the table 5.1 and 5.2, respectively and have been discussed under the following sub-heads:

5.1.1 Horticultural traits

Among the horticultural traits, days to first female flower appearance, node number bearing female flower and days to marketable maturity are the characters which determine the earliness of a variety. Wide variations were observed among the parents and hybrids with respect to these traits *viz.*, days to first female flower appearance (50.17-62.33 and 47.20-63.77, respectively), node number bearing female flower (3.23-9.87 and 2.73-10.95, respectively) and days to marketable maturity (58.13-70.33 and 55.00-72.40, respectively). The genotype CGN-20953 followed by CGN-19533 and CGN-20969 and the cross combination CGN-20953 x K-75 followed by LC-1-1 x K-75 and CGN-19533 x K-75 were found superior for earliness among all the parents and hybrid combinations, respectively on the basis of these characters. Wide variations with respect to earliness were also reported by Kanwar *et al.* (2003), Verma (2003), Bairagi *et al.* (2005), Munshi *et al.* (2007), Kumar *et al.* (2008), Hanchinamani *et al.* (2008), Yadav *et al.* (2009), Kumar *et al.* (2010), Singh *et al.* (2010) and Dogra and Kanwar (2011) in cucumber.

All the parents and hybrids also revealed tremendous variations with respect to yield and yield contributing traits *viz.*, fruit length (12.20-24.17 and 14.80-24.60 cm, respectively) and breadth (3.40-5.60 and 3.53-6.23 cm, respectively), average fruit weight (167.30-348.63 and 214.33-369.60 g, respectively), number of marketable fruits per plant (3.77-8.67 and 4.02-12.03, respectively), harvest duration (14.55-28.17 and 14.25-36.69 days, respectively), marketable yield per plot (15.19-36.64 and 16.98-67.39 kg, respectively) and per hectare (101.30-244.36 and 113.27-449.52 q,

Table 5.1: Trait wise list of parents (lines and testers) exhibiting significantly high mean performance

Trait	Line(s)	Tester(s)
Days to first female flower appearance	CGN-20953, CGN-19533, CGN-20515, CGN-20969, Gyne-5	Poinsette
Node number bearing first female flower	CGN-20953 , CGN-20969, CGN-19533	Poinsette
Days to marketable maturity	CGN-20953 , CGN-20969, CGN-19533	Poinsette
Fruit length	CGN-22930, CGN-20953, LC-25-7	Japanese Long Green
Fruit breadth	LC-2-2, LC-15-5, CGN-20515	Poinsette, K-75
Average fruit weight	CGN-20953, CGN-22930, LC-25-7	Japanese Long Green
Number of marketable fruits per plant	CGN-20515, LC-1-1, Gyne-5	Poinsette
Harvest duration	LC-1-1, LC-2-2, Gyne-5	Poinsette
Marketable yield per plot and per hectare	LC-1-1, CGN-20953, Gyne-5	Japanese Long Green, Poinsette
Total soluble solids	CGN-21585	Japanese Long Green
Cucurbitacin content	CGN-21585, CGN-20256, CGN-20969	Poinsette
Fruit fly incidence	LC-2-2, LC-1-1	K-75
Severity of powdery mildew	LC-15-5, LC-21-6, CGN-20953	Poinsette, Japanese Long Green
Severity of downy mildew	CGN-20969, LC-3-3	Poinsette, K-75
Severity of angular leaf spot	LC-1-1, CGN-20969, LC-12-4	Japanese Long Green
Seed germination	CGN-20953	Poinsette, Japanese Long Green
Seed vigour index-I	LC-3-3, LC-2-2	K-75, Poinsette
Seed vigour index-II	LC-3-3, LC-2-2, LC-1-1	K-75, Poinsette

respectively). The genotype, Japanese Long Green and cross combination LC-25-7 x Japanese Long Green recoded longest fruits, while maximum fruit breadth was observed in the genotype CGN-20515 followed by LC-15-5 and the hybrid combination LC-15-5 x Japanese Long Green. Highest average fruit weight was recorded in the genotype Japanese Long Green and the cross combination LC-25-7 x Japanese Long Green followed by LC-1-1 x K-75. The genotype, Gyne-5 recorded maximum number of marketable fruits per plant, followed by LC-1-1, CGN-20515 and Poinsette, while among the hybrids, maximum number of marketable fruits per plant were obtained in the cross combination CGN-20953 x Poinsette followed by LC-1-1 x K-75, CGN-19533 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75. Longest harvest duration was recorded in the genotype LC-1-1 followed by Poinsette, LC-2-2 and Gyne-5, while among the hybrid combinations harvest duration was observed maximum in the cross combination CGN-20953 x Poinsette followed by LC-1-1 x K-75, CGN-19533 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75. Among the parents, highest yield per plot and per hectare was observed in the genotype LC-1-1, which was followed by CGN-20953 and Japanese Long Green, while among the hybrids LC-1-1 x K-75 followed by CGN-19533 x K-75 and CGN-20953 x Poinsette recorded highest yield per plot and per hectare. Wide variations with respect to yield and yield contributing traits in cucumber have also been reported earlier by several workers *viz.*, Stankovic *et al.* (1997), Singh *et al.* (1999), Wadid *et al.* (2003), Kanwar *et al.* (2003), Bairagi *et al.* (2005), Das *et al.* (2005), Munshi *et al.* (2007), Kumar *et al.* (2008), Hanchinamani *et al.* (2008), Yadav *et al.* (2009), Kumar *et al.* (2010), Singh *et al.* (2010), Hossain *et al.* (2010), Dogra and Kanwar (2011), Kumar *et al.* (2011), Golabadi *et al.* (2012) and Singh *et al.* (2012).

5.1.2 Fruit quality characteristics

A wide variation was observed among the parents and hybrids for fruit quality characteristics *viz.,* total soluble solids (2.67-4.03 and 2.63-4.07 ^{o}B, respectively), cucurbitacin content (100.62-120.17 and 95.57-123.58 µg/100g, respectively) and fruit colour (Dark green, Green, Light green and Yellow green), which decide the consumer’s preference. Maximum total soluble solids (TSS) was recorded in the genotype CGN-21585 and cross combination CGN-21585 x Japanese Long Green. The genotype CGN-21585 recorded minimum cucurbitacin content followed by CGN-20256 and CGN-20969, while among hybrids significantly minimum

Table 5.2: Trait wise list of best hybrids exhibiting significantly high mean performance

Trait	Hybrid(s)
Days to first female flower appearance	CGN-20953 x Poinsette, LC-1-1 x K-75, CGN-19533 x K-75, LC-2-2 x Poinsette
Node number bearing first female flower	CGN-20953 x Poinsette, CGN-19533 x K-75, LC-1-1 x K-75, LC-2-2 x Poinsette
Days to marketable maturity	CGN-20953 x Poinsette, LC-1-1 x K-75, LC-2-2 x Poinsette
Fruit length	LC-25-7 x Japanese Long Green
Fruit breadth	CGN-20515 x Japanese Long Green, LC-15-5 x Poinsette, LC-15-5 x Poinsette
Average fruit weight	LC-25-7 x Japanese Long Green, LC-1-1 x K-75
Number of marketable fruits per plant	CGN-20953 x Poinsette, LC-1-1 x K-75, CGN-19533 x K-75, LC-2-2 x Poinsette, Gyne-5 x K-75
Harvest duration	CGN-20953 x Poinsette, LC-1-1 x K-75, CGN-19533 x K-75, LC-2-2 x Poinsette, Gyne-5 x K-75
Marketable yield per plot and per hectare	LC-1-1 x K-75, CGN-19533 x K-75, CGN-20953 x Poinsette, Gyne-5 x K-75, LC-3-3 x Poinsette, LC-2-2 x Poinsette
Total soluble solids	CGN-21585 x Japanese Long Green
Cucurbitacin content	CGN-21585 x Japanese Long Green
Fruit fly incidence	LC-1-1 x K-75, LC-3-3 x Poinsette, LC-15-5 x Poinsette
Severity of powdery mildew	LC-15-5 x K-75, CGN-20515 x Poinsette, LC-3-3 x Poinsette, Gyne-5 x Poinsette
Severity of downy mildew	LC-3-3 x K-75, CGN-20969 x Japanese Long Green, LC-2-2 x Poinsette, LC-15-5 x K-75
Severity of angular leaf spot	LC-1-1 x K-75, CGN-20969 x Japanese Long Green, LC-2-2 x Poinsette, CGN-20953 x K-75
Seed germination	CGN-20953 x Poinsette , LC-1-1 x K-75
Seed vigour index-I	LC-1-1 x K-75, CGN-20953 x Poinsette
Seed vigour index-II	LC-1-1 x K-75, LC-3-3 x K-75

cucurbitacin content was reported in the cross combination CGN-21585 x Japanese Long Green. Five parents and seventeen hybrids had light green coloured fruits, which are in general preferred by consumers. Check cultivars *viz.*, KH-1 and Pusa Sanyog were having green coloured fruits. For fruit quality traits, similar findings had also been reported by Kanwar *et al.* (2003), Kumar (2010), Brar *et al.* (2011) and Dogra and Kanwar (2011) for total soluble solids (TSS), Kumar (2006), Gu *et al.* (2007), Brar *et al.* (2011) and Zhang *et al.* (2012) for bitterness/cucurbitacin content and Strefeler and Wehner (1986), Verma (2003) and Kumar (2010) for fruit colour in cucumber.

Table 5.3: Best parents (lines and testers) identified on the basis of overall mean performance

Parents	**Trait**
Lines	
LC-1-1	Number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, fruit fly incidence, severity of angular leaf spot and seed vigour index-II
CGN-20953	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length, average fruit weight, marketable yield per plot and per hectare, severity of powdery mildew and seed germination
LC-15-5	Fruit breadth and severity of powdery mildew
Gyne-5	Number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare
LC-25-7	Fruit length and average fruit weight
Testers	
Japanese Long Green	Fruit length, average fruit weight, marketable yield per plot and per hectare, total soluble solids, fruit fly incidence, severity of angular leaf spot
Poinsette	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity fruit breadth, number of marketable fruits per plant, harvest duration, cucurbitacin content, severity of powdery mildew and downy mildew and seed germination

5.1.3 Incidence/severity of economically important insect-pest and diseases

All the parents and hybrids studied, respond differently to the attack of different insect-pest and diseases. Wide variations were recorded among the parents and hybrids for fruit fly incidence (16.86-29.65 and 10.87-33.71 %, respectively) severity of powdery mildew (10.20-23.60 and 8.90-28.20 %, respectively), downy mildew (12.77-38.30 and 10.17-41.73 %, respectively) and angular leaf spot (9.07-31.23 and 8.23-36.03 %, respectively). The lowest fruit fly incidence was recorded in the genotype LC-2-2, followed by LC-1-1 and the cross combination LC-1-1 x K-75 followed by LC-3-3 x Poinsette and LC-15-5 x Poinsette. Minimum severity of powdery mildew was recorded in the genotype LC-15-5 followed by Poinsette, LC-21-6, CGN-20953 and Japanese Long Green, while hybrid combination LC-15-5 x K-75 followed by CGN-20515 x Poinsette, LC-3-3 x Poinsette, Gyne-5 x Poinsette and CGN-20953 x K-75 recorded least severity of powdery mildew. The genotype CGN-20969 recorded minimum severity of downy mildew and similar response was observed in Poinsette, K-75 and LC-3-3. Among the crosses, minimum response to severity of downy mildew was reported in the cross combination LC-3-3 x K-75 followed by CGN-20969 x Japanese Long green, LC-2-2 x Poinsette and LC-15-5 x K-75. Minimum severity of angular leaf spot was observed in the genotype LC-1-1 and similar response was noticed in CGN-20969, LC-12-4 and CGN-20953, while among the different hybrid combinations, LC-1-1 x K-75 followed by CGN-20969 x Japanese Long Green, LC-2-2 x Poinsette and CGN-20953 x K-75 recorded minimum severity of angular leaf spot. Variation in response to fruit fly incidence was also reported earlier by Nath *et al.* (1976) in *Cucurbita* sp., Gupta and Verma (1978) and Pal *et al.* (1983) in muskmelon, Thakur *et al.* (1992) in bittergourd and Kumar (2006) and Sharma (2010) in cucumber. Wide variations with respect to severity of different diseases in cucumber were also recorded by Morishita *et al.* (2003), Block and Reitsma (2005) and Sakata *et al.* (2008) for severity of powdery mildew, Charoenwattana (2009), Brar *et al.* (2011) and Call *et al.* (2012) for severity of downy mildew and Bhat *et al.* (2007) and Woltman *et al.* (2008) for severity of angular leaf spot in cucumber.

5.1.4 Seed traits

Wide variations were observed among the parents and hybrids for seed traits *viz.*, seed germination (66.67-85.33 and 68.00-86.00 %, respectively), seed vigor index-I (2011.07-2960.67 and 1947.93-3216.90, respectively) and seed vigor index-II

(833.37-1576.73 and 687.93-1996.00, respectively). The highest seed germination was recorded in the genotype CGN-20953 and cross combination CGN-20953 x Poinsette, which was followed by LC-1-1 x K-75. The genotype LC-3-3 recorded highest seed vigour index-I (2960.67) followed by LC-2-2 (2786.93), while among the hybrids maximum seed vigour index-I was recorded in the hybrid combination LC-1-1 x K-75 followed by CGN-20953 x Poinsette. Highest seed vigour index-II was observed in the genotype LC-3-3 followed by LC-2-2 and LC-1-1, whereas among crosses, hybrid combination LC-1-1 x K-75 recorded highest seed vigour index-II followed by LC-3-3 x K-75. Similar results were reported by Hamid *et al.* (2002) for seed germination, Nerson (2007) for seedling vigour and Kumar (2010) for seed germination and seed vigour index-I and II in cucumber.

Table 5.4: Top five hybrid combinations (F_1's) identified on the basis of overall mean performance

Hybrids	**Trait**
LC-1-1 x K-75	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, average fruit weight, number of marketable fruits, harvest duration, marketable yield per plot and per hectare, fruit fly incidence, severity of angular leaf spot, seed germination, seed vigour index-I and II
CGN-20953 x Poinsette	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, seed germination and seed vigour index-I
CGN-19533 x K-75	Days to first female flower appearance, node number bearing first female flower, number of marketable fruits per plant, harvest duration and marketable yield per plot and per hectare
LC-2-2 x Poinsette	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare and severity of downy mildew and angular leaf spot
Gyne-5 x K-75	Number of marketable fruits per plant, harvest duration and marketable yield per plot and per hectare

On the basis of mean performance it is concluded that Parents LC-1-1, CGN-20953, LC-15-5, Gyne-5 and LC-25-7 among lines, while Japanese Long Green and Poinsette among the testers excelled for most of the horticultural and quality traits (Table 5.3). These lines/testers can be selected for hybrid seed production. Among the hybrids *viz.*, LC-1-1 x K-75, CGN-20953 x Poinsette, CGN-19533 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75 were found most promising (Table 5.4) and these hybrids after multilocation testing can be adopted for commercial cultivation.

5.2 COMBINING ABILITY STUDIES

Development of new varieties/hybrids superior to the existing ones, with respect to yield and other desirable traits is one of the primary objective(s) of vegetable breeder and the success of a breeding programme lies in the choice of appropriate parents and the breeding method followed. The common approach of selecting the parents on the basis of per se performance, adaptation and genetic variability does not necessarily lead to useful result. This is because of differential combining ability of parents which depends upon the complex interactions among the genes and cannot be judged by the per se performance alone (Allard, 1960). To effect improvement in polygenic traits like yield and component traits, information about the combining ability of parents and their crosses, the estimates of genetic components of variance and the type of gene action involved are of prime importance to the breeders.

Combining ability studies guide the breeders to select appropriate parents for heterosis and recombination breeding, hence are important in crop improvement studies. Heterosis studies provide information about per cent increase of F_1 over better parent or standard check only and thus help in scoring out the best crosses, but they do not indicate the possible causes for superiority of crosses. The combining ability studies evaluate the parental lines on the basis of their general combining ability (GCA) effects and the performance of these parents in specific cross combinations (SCA). General combining ability effects, being related to additive genetic effects, represent the fixable components of genetic variance and are used to classify the parents for the breeding behavior in hybrid combinations, whereas, specific combining ability effects are related to non-fixable component of genetic variance (Hayman, 1960 and Sprague, 1966). The hybrids, which excel the existing best standard check, are the ultimate choice of the breeders and farmers. In order to realize the maximum gain over a minimum time period, the choice of efficient breeding methodology is inevitable. The most appropriate approach in preliminary screening of material for desirable combining ability is to employ top cross (Inbred x Variety) or line x tester method (Kempthorne, 1957), which has been used in the present study to evaluate sixteen lines, three testers and their forty eight crosses with respect to combining ability. The experimental results pertaining to general combining ability and specific combining ability effects so obtained have been discussed as below:

5.2.1 Estimates of general combining ability (GCA) effects of parents

Development of high yielding varieties/hybrids mainly depend upon the genetically superior parents coupled with suitable breeding methodology. General combining ability (GCA) has immense value in the breeding programmes for the species which are amenable to the development of F_1 hybrids. Since, mean sum of squares due to lines and testers were significant for all the characters, hence general combining ability (GCA) effects have been estimated for all the traits under study and have been discussed as follows:

The experimental results pertaining to significant desirable general combining ability (GCA) effects of 19 parents (16 lines and 3 testers) have been presented in the table 5.5, which revealed that general combining ability was found variable as no single parent has exhibited significant GCA effects for all the traits under study.

A perusal of GCA effects for earliness (days to first female flower appearance, node number bearing first female flower and days to marketable maturity) revealed that LC-1-1, CGN-20953, CGN-19533, Gyne-5, LC-2-2, CGN-20515, CGN-22930 and CGN-20969 among lines and Poinsette and K-75 among testers were found best combiners due to their significant negative GCA effects. Different parents expressing negative general combining ability (GCA) effects for earliness have also been reported earlier by different workers by using different genetic materials and locations (Sharma *et al.,* 2000; Uddin and Ahmed, 2002; Kumbhar *et al.,* 2005; Munshi *et al.,* 2006; Yadav *et al.,* 2007; Hanchinamani *et al.,* 2009; Dogra and Kanwar, 2011 and Kumar *et al.,* 2011).

For marketable yield per plot and per hectare, LC-1-1, CGN-20953, CGN-19533, Gyne-5, CGN-22930 and LC-2-2 among the lines and K-75 and Poinsette among the testers exhibited the highest positive GCA effects. All of these lines and

Table 5.5 Trait wise list of parents (lines and testers) exhibiting significant desirable general combining ability (GCA) effects

Trait	Lines	Testers
Days to first female flower appearance	LC-1-1, CGN-19533, CGN-20953, LC-2-2, Gyne-5,CGN-20969	Poinsette, K-75
Node number bearing first female flower	LC-1-1, CGN-20953, CGN-19533, Gyne-5, LC-2-2, CGN-20515, CGN-22930, CGN-20969	Poinsette, K-75
Days to marketable maturity	LC-1-1, CGN-20953, CGN-19533, Gyne-5, LC-2-2, CGN-20515, CGN-20969	Poinsette, K-75
Fruit length	LC-25-7, LC-1-1, CGN-20953, CGN-19533, Gyne-5, CGN-22930, LC-15-5, LC-28-8, LC-3-3	Japanese Long Green
Fruit breadth	CGN-20515, LC-15-5, LC-1-1, Gyne-5	K-75, Poinsette
Average fruit weight	LC-1-1, LC-25-7, CGN-20953, CGN-19533, Gyne-5, LC-15-5, CGN-22930	K-75
Number of marketable fruits per plant	LC-1-1, CGN-19533, Gyne-5, CGN-20953, LC-2-2, CGN-20515, CGN-20969, CGN-22930	Poinsette, K-75
Harvest duration	LC-1-1, Gyne-5, CGN-19533, CGN-20953, LC-2-2, CGN-20515, CGN-20969, CGN-22930	Poinsette, K-75
Marketable yield per plot and per hectare	LC-1-1, CGN-20953, CGN-19533, Gyne-5, CGN-22930, LC-2-2	K-75, Poinsette
Total soluble solids	CGN-21585, LC-28-8, LC-1-1, CGN-20953, Gyne-5	Japanese Long Green
Cucurbitacin content	CGN-21585, LC-28-8, CGN-20256, CGN-20953, LC-1-1, CGN-22930, CGN-19533	Japanese Long Green, K-75
Fruit fly incidence	LC-3-3, LC-1-1, LC-15-5, LC-2-2, CGN-20953	Poinsette, K-75
Severity of powdery mildew	LC-15-5, CGN-20953, LC-3-3, CGN-20515, LC-1-1, LC-28-8	Poinsette
Severity of downy mildew	CGN-20969, LC-25-7, LC-15-5, LC-3-3, LC-2-2, Gyne-5	Poinsette, K-75
Severity of angular leaf spot	LC-1-1, LC-2-2, CGN-20953, LC-25-7, CGN-20969, LC-12-4	Japanese Long Green
Seed germination	CGN-20953, LC-1-1, CGN-20515, Gyne-5, LC-3-3, LC-15-5	Poinsette
Seed vigour index-I	LC-3-3, CGN-20953, LC-1-1, LC-2-2, LC-15-5	K-75
Seed vigour index-II	LC-1-1, LC-2-2, LC-3-3, LC-15-5, Gyne-5	K-75

testers were also found good combiners for average fruit weight, number of marketable fruits per plant and harvest duration. Beside this, the lines LC-1-1 and Gyne-5 also exhibited significant positive GCA effects for fruit length and breadth, while the testers K-75 and Poinsette were found good combiners for fruit breadth, thereby suggesting close association between GCA of the lines and testers for fruit length and breadth, average fruit weight, number of marketable fruits per plant and harvest duration. The present findings are in line with those of Verma *et al.* (2000), Wehner *et al.* (2000), Wadid *et al.* (2003), Kumbhar *et al.* (2005), Munshi *et al.* (2006), Singh and Sharma (2006), Yadav *et al.* (2007), Hanchinamani and Patil (2009), Dogra and Kanwar (2011), Khuswaha *et al.* (2011) and Kumar *et al.* (2011), who had also reported significant positive GCA effects of different parental material for yield and yield contributing traits in cucumber.

The lines, CGN-21585, LC-28-8, LC-1-1 and CGN-20953 and the tester Japanese Long Green revealed significant desirable GCA effects for total soluble solids and cucurbitacin content. Similar results for significant desirable GCA effects of different parental lines and testers in cucumber had also been reported by Dogra *et al.* (1997), Singh and Sharma (2006), Brar *et al.* (2011) and Dogra and Kanwar (2011) for total soluble solids and Brar *et al.* (2011) for bitterness.

For various biotic stresses, LC-1-1 and CGN-20953 for fruit fly incidence, severity of powdery mildew and angular leaf spot, LC-2-2 for fruit fly incidence, severity of downy mildew and angular leaf spot and LC-3-3 and LC-15-5 for fruit fly incidence, severity of powdery mildew and downy mildew and among the testers, Poinsette for fruit fly incidence, severity of powdery mildew and downy mildew, K-75 for fruit fly incidence and severity of downy mildew and Japanese Long Green for severity of angular leaf spot were found good general combiners as reflected from their consistent performance for desirable negative GCA effects. Significant negative general combining ability effects of different parental material for biotic stresses were also reported by earlier workers *viz.*, Kumar (2006) and Sharma (2010) for fruit fly incidence, Sharma (2010) for severity of powdery mildew and Brar *et al.* (2011) for severity of downy mildew in cucumber.

For seed traits, lines LC-1-1, LC-3-3 and LC-15-5 for seed germination, seed vigour index-I and II, LC-2-2 for seed vigour index-I and II, CGN-20953 for seed germination and seed vigour index-I and Gyne-5 for seed germination, seed vigour

Table 5.6 Elite lines and testers identified on the basis of overall performance for general combining ability (GCA) effects

Parents	Character
Lines	
LC-1-1	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length and breadth, average fruit weight, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, total soluble solids, cucurbitacin content, fruit fly incidence, severity of powdery mildew and angular leaf spot, seed germination and seed vigour index-I and II.
CGN-20953	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length, average fruit weight, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, total soluble solids, cucurbitacin content, fruit fly incidence, severity of powdery mildew and angular leaf spot, seed germination and seed vigour index-I.
Gyne-5	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length and breadth, average fruit weight, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, total soluble solids, severity of downy mildew, seed germination, seed vigour index-II.
LC-2-2	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, fruit fly incidence, severity of downy mildew and angular leaf spot and seed vigour index-I and II.
CGN-19533	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length, average fruit weight, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare and cucurbitacin content.
Testers	
K-75	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit breadth, average fruit weight, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, cucurbitacin content, fruit fly incidence, severity of downy mildew and seed vigour index-I and II.
Poinsette	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit breadth, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, fruit fly incidence, severity of powdery mildew and downy mildew and seed germination.

index-II and testers Poinsette for seed germination and K-75 for seed vigour index-I and II exhibited significant positive GCA effects. No information is available in the literature regarding the combining ability of cucumber for seed germination, seed vigour index-I and II.

Additive parental effects as measured by GCA effects are of practical use to the plant breeders, since non-allelic interactions are unpredictable. On the basis of present investigations for GCA effects, it may be concluded that the parents *viz.,* LC-1-1, CGN-20953, Gyne-5, LC-2-2 and CGN-19533 among the lines and K-75 and Poinsette among the testers were found good general combiners for yield and its component traits (Table 5.6) and may be utilized in hybridization programmes for getting superior hybrids or transgressive segregants.

5.2.2 Estimates of specific combining ability (SCA) effects of crosses

Specific combining ability effect helps in identifying the best cross combinations for various traits. These effects arise due to non-additive gene interactions. Since, mean sum of squares due to lines x testers interactions were significant for all the characters, hence specific combining ability (SCA) effects have been estimated for all the traits under study and have been discussed as below:

The trait-wise list of best five hybrid combinations exhibiting significant desirable SCA effects have been presented in Table 5.7. No single cross revealed the significant SCA for all the traits under study. The cross combinations, CGN-20953 x Poinsette, CGN-19533 x K-75, LC-1-1 x K-75, Gyne-5 x K-75 and LC-2-2 x Poinsette due to their significant negative SCA effects were found as best specific combiners for earliness. All of these crosses involved the parents with good x good GCA effect, hence revealed the additive x additive type of gene action operating for earliness. Therefore, these crosses can be exploited to isolate transgressive segregants or single plant selection can be effective in advanced segregating generations. Kushawha *et al.* (2011) had also reported that additive x additive components had predominant role in influencing the earliness in cucumber. Hence developing superior lines from such crosses will be worthwhile to improve earliness in cucumber.

Specific combining ability effect for marketable yield per plot and per hectare were found significantly high for CGN-19533 x K-75 (good x good), LC-25-7 x Japanese Long Green (average x poor), CGN-20953 x Poinsette (good x good), LC-1-

1 x K-75 (good x good) and Gyne-5 x K-75 (good x good). Beside this, above cross combinations also revealed significant SCA effects of yield contributing traits *viz.*, fruit length, average fruit weight, number of marketable fruits per plant and harvest duration. These results indicated that out of these crosses four involved the parents with good x good and one with average x poor GCA effect, hence indicated the importance of additive x additive and additive x dominance type of gene action, respectively controlling these traits as reported by Ghadheri and Lower (1979), Dolgibh and Sidorova (1983), Hanchinamani and Patil (2009) and Dogra and Kanwar (2011). The crosses which involved good x good combiners includes positive alleles from both the parents and thus can be fixed in the subsequent generations for effective selection of desirable lines, if no repulsion phase linkage is present, whereas crosses which involved average x poor combiners may be used for exploitation of heterosis in F_1 generations. Different crosses expressing high desirable SCA in respect to yield and its contributing traits had also been reported by different workers (Musmade and Kale, 1986; Prasad and Singh, 1992; Li *et al.*, 1995; Dogra *et al.*,1997; Sharma *et al.*, 2000; Singh and Sharma, 2006; Kushawha *et al.*, 2011and Dogra and Kanwar, 2011).

For total soluble solids, hybrid combination CGN-21585 x Japanese Long Green (good x good), followed by LC-1-1 x K-75 (good x average), LC-28-8 x K-75 (good x average), Gyne-5 x Poinsette (good x poor) and LC-1-1 x Poinsette (good x poor) revealed significant positive SCA effects. While, cross combination LC-28-8 x K-75 (good x good), CGN-21585 x Japanese Long Green (good x good), CGN-20256 x Japanese Long Green (good x good), LC-28-8 x Poinsette (good x poor) and LC-1-1 x K-75 (good x good) recorded significantly high negative SCA effects for cucurbitacin content. The best crosses with significant desirable SCA effect for quality traits had the parents with either good x good or good x average or good x poor GCA effects. The interactions between positive and positive alleles in the crosses, which involved good x good general combiners indicated the importance of additive gene action and can be fixed in the subsequent generations for effective selection. However, desirable performance of combinations like good x average or good x poor may be ascribed to interactions between dominant alleles from the good combiners and recessive alleles from the poor/average combiners (Dubey, 1975). These cross combinations indicated the presence of both additive and non-additive gene action, which may be used for exploiting F_1 hybrids. Brar *et al.* (2011) and

Table 5.7: List of top five hybrids exhibiting significant desirable specific combining ability (SCA) effects for different traits in cucumber

Traits	Top five hybrid combinations
Days to first female flower appearance	CGN-20953 x Poinsette, CGN-19533 x K-75, LC-1-1 x K-75, Gyne-5 x K-75 and LC-2-2 x Poinsette
Node number bearing first female flower	CGN-19533 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75, Gyne-5 x K-75 and LC-2-2 x Poinsette.
Days to marketable maturity	CGN-20953 x Poinsette, CGN-19533 x K-75, LC-2-2 x Poinsette, LC-1-1 x K-75 and Gyne-5 x K-75.
Fruit length	LC-25-7 x Japanese Long Green, CGN-20953 x Poinsette, CGN-19533 x K-75, LC-1-1 x K-75 and Gyne-5 x K-75.
Fruit breadth	CGN-20515 x Japanese Long Green, LC-15-5 x Poinsette, Gyne-5 x Japanese Long Green, CGN-22930 x K-75 and LC-12-4 x Poinsette.
Average fruit weight	LC-25-7 x Japanese Long Green, CGN-20953 x Poinsette, CGN-19533 x K-75, LC-3-3 x Poinsette and LC-1-1 x K-75.
Number of marketable fruits per plant	CGN-19533 x K-75, Gyne-5 x K-75, LC-1-1 x K-75, CGN-20953 x Poinsette and LC-2-2 x Poinsette.
Harvest duration	CGN-19533 x K-75, Gyne-5 x K-75, LC-1-1 x K-75, CGN-20953 x Poinsette and LC-2-2 x Poinsette.
Marketable yield per plot and per hectare	CGN-19533 x K-75, LC-25-7 x Japanese Long Green, CGN-20953 x Poinsette, LC-1-1 x K-75 and Gyne-5 x K-75.
Total soluble solids	CGN-21585 x Japanese Long Green, LC-1-1 x K-75, LC-28-8 x K-75, Gyne-5 x Poinsette and LC-1-1 x Poinsette.
Cucurbitacin content	LC-28-8 x K-75, CGN-21585 x Japanese Long Green, CGN-20256 x Japanese Long Green, LC-28-8 x Poinsette and LC-1-1 x K-75.
Fruit fly incidence	LC-1-1 x K-75, CGN-20953 x K-75, LC-15-5 x Poinsette, LC-3-3 x Poinsette and LC-2-2 x K-75.
Severity of powdery mildew	LC-15-5 x K-75, CGN-20953 x K-75, Gyne-5 x Poinsette, LC-1-1 x K-75 and LC-3-3 x K-75.
Severity of downy mildew	CGN-20969 x Japanese Long Green, CGN-19533 x K-75, CGN-22930 x Poinsette, LC-25-7 x Japanese Long Green and LC-15-5 x Japanese Long Green.
Severity of angular leaf spot	CGN-20953 x K-75, LC-1-1 x K-75, LC-25-7 x K-75, CGN-20969 x Japanese Long Green and LC-2-2 x Poinsette
Seed germination	LC-1-1 x K-75, LC-3-3 x Japanese Long Green, CGN-20515 x K-75, CGN-19533 x Poinsette and CGN-20953 x Poinsette.
Seed vigour index-I	LC-1-1 x K-75, CGN-20953 x Poinsette, LC-2-2 x Poinsette, LC-15-5 x Poinsette and LC-3-3 x K-75.
Seed vigour index-II	LC-1-1 x K-75, LC-2-2 x Poinsette, LC-3-3 x K-75, LC-15-5 x Poinsette and CGN-20953 x Japanese Long Green.

Dogra and Kanwar (2011) had also reported significant negative and positive GCA estimates for bitterness and total soluble solids in cucumber, respectively.

Among all the hybrids, five best crosses *viz.,* LC-1-1 x K-75 (good x good), CGN-20953 x K-75 (good x good), LC-15-5 x Poinsette (good x good), LC-3-3 x Poinsette (good x good) and LC-2-2 x K-75 (good x good) for fruit fly incidence; LC-15-5 x K-75 (good x poor), CGN-20953 x K-75 (good x poor), Gyne-5 x Poinsette (average x good), LC-1-1 x K-75 (good x poor) and LC-3-3 x K-75 (good x poor) for severity of powdery mildew; CGN-20969 x Japanese Long Green (good x poor), CGN-19533 x K-75 (poor x good), CGN-22930 x Poinsette (poor x good), LC-25-7 x Japanese Long Green (good x poor) and LC-15-5 x Japanese Long Green (good x poor) for severity of downy mildew; CGN-20953 x K-75 (good x poor), LC-1-1 x K-75 (good x poor), LC-25-7 x K-75 (good x poor), CGN-20969 x Japanese Long Green (good x good) and LC-2-2 x Poinsette (good x average) for Severity of angular leaf spot revealed significant negative SCA effects. Most of the above crosses have the parents with good x poor GCA effects, which indicated the involvement of both additive and non-additive gene action. Such type of cross combinations are most desirable for genetic improvement of any crop through heterosis breeding. The other crosses had the involvement of either good x good or average x good combiners, which indicated the presence of additive x additive or additive x dominance type of gene interactions. Significant negative estimates of heterosis with the involvement of parents with different GCA effect hve also been reported earlier by Brar *et al.* (2011) for severity of downy mildew and Kumar (2006) for fruit fly incidence in cucumber.

For seed traits *viz.,* LC-1-1 x K-75 (good x poor), LC-3-3 x Japanese Long Green (good x average), CGN-20515 x K-75 (good x poor), CGN-19533 x Poinsette (average x good) and CGN-20953 x Poinsette (good x good) for seed germination; LC-1-1 x K-75 (good x good), CGN-20953 x Poinsette (good x average), LC-2-2 x Poinsette (good x average), LC-15-5 x Poinsette (good x average) and LC-3-3 x K-75 (good x good) for Seed vigour index-I and LC-1-1 x K-75 (good x good), LC-2-2 x Poinsette (good x average), LC-3-3 x K-75 (good x good), LC-15-5 x Poinsette (good x average) and CGN-20953 x Japanese Long Green (average x poor) for seed vigour index-II, recorded significantly high positive SCA effects among all the hybrids under study. These crosses revealed the involvement of either good x good or good x average or good x poor combiners, thus indicated the role of both additive and non-additive gene action for improvement of seed traits.

Table 5.8 Top five hybrid combinations (F_1's) identified on the basis of specific combining ability (SCA) effects

Hybrids	Trait
LC-1-1 x K-75	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length, average fruit weight, number of marketable fruits per plant, severity of angular leaf spot, seed germination, seed vigour index-I, seed vigour index-II, harvest duration, marketable yield per plot and per hectare, total soluble solids, cucurbitacin content, fruit fly incidence and severity of powdery mildew
CGN-20953 x Poinsette	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length, average fruit weight, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, seed germination and seed vigour index-I
CGN-19533 x K-75	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length, average fruit weight, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare and severity of downy mildew
Gyne-5 x K-75	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length, number of marketable fruits per plant, harvest duration and marketable yield per plot and per hectare
LC-25-7 x Japanese Long Green	Fruit length, average fruit weight, marketable yield per plot and per hectare and severity of downy mildew

Specific combining ability effects for different horticultural traits revealed that, all cross combinations exhibiting desirable SCA effects had atleast one of the parents as good or average general combiner. The combinations exhibiting high SCA effects derived from good or average general combiners will be of main interest as they are certainly going to perform better and respond to selection in advanced generations to isolate desirable lines for a particular trait. Similarly, other cross combinations involving one good and other poor or average combiner may give desirable transgressive segregants in the later generations if the additive effect of one parent and complementary epistatic effects (if present in the cross) act in same direction and maximize the desirable plant attributes as reported by Sharma (1999). However, Singh *et al.* (1985) concluded that the best crosses involving at least one parent with good combining ability may produce transgressive segregants. Similar views have also been expressed by earlier researchers (Prasad and Singh, 1992; Sharma *et al.,* 2000; Singh and Sharma, 2006; Munshi *et al.,* 2006; Yadav *et al.,* 2007 and Kushwaha *et al.,* 2011).

A comparison of the SCA effects of the crosses and GCA effects of the parents involved indicated that in most of the cases GCA effects were reflected in the SCA effects of the cross combination. It is apparent that in almost all the hybrids which showed the best SCA effects, the parental lines involved were at least one of the outstanding parental lines for particular character, which also had high GCA effects for one or more characters contributing towards yield. This indicated that there was strong tendency of transmission of higher gain from the parents to the offspring. The present findings corroborated the earlier work of Verma *et al.* (2000), Bairagi *et al.* (2001), Navazio and Simon (2001), Gulamuddin *et al.* (2002), Shushir *et al.* (2005), Munshi *et al.* (2006), Sarkar and Sirohi (2006) and Kumar *et al.,* (2011) in cucumber.

On the basis of overall performance, the cross combinations LC-1-1 x K-75, CGN-20953 x Poinsette, CGN-19533 x K-75, Gyne-5 x K-75 and LC-25-7 x Japanese Long Green were found as five best hybrids (Table 5.8). Among these crosses, LC-1-1 x K-75, CGN-20953 x Poinsette, CGN-19533 x K-75 and Gyne-5 x K-75 can be exploited to isolate transgressive segregants in early generations as they involve both parents with high GCA effects for earliness and marketable yield per plot and per hectare, respectively. While, cross combination LC-25-7 x Japanese Long Green (average x poor) may give desirable transgressive segregants in the later segregating generations.

5.3 GENE ACTION

5.3.1 Estimates of genetic components of variance

After the identification of appropriate parents and potential crosses, the next important step in a dynamic breeding programme is to adopt suitable breeding methodology for the purposeful management of generated variability which largely depends upon the type of gene action in the population for the traits under genetic improvement (Cockerham, 1961 and Sprague, 1966). Among various designs developed for this purpose, the line x tester (Kempthorne, 1957) not only evaluates parents and crosses for combining ability but also provides information on the nature of gene action controlling the traits under consideration. The nature of gene action predicted from the different estimates of GCA and SCA variances. The mean sum of squares due to GCA and SCA were highly significant for all the traits under study, indicating the importance of both additive and non-additive genetic components of variance. Further, the mean sum of squares due to GCA and SCA were used to estimate the variances for GCA and SCA, respectively, based on which nature of gene action has been worked out.

A perusal of the data indicated that the estimates of σ^2sca were higher in magnitude as compared to σ^2gca (average) for all the traits under study *viz.*, days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length and breadth, average fruit weight, number of marketable fruits per plant, harvest duration, yield per plot and per hectare, total soluble solids, cucurbitacin content, severity of powdery mildew, downy mildew and angular leaf spot, seed germination, seed vigour index-I and II, except for fruit fly incidence, thereby indicating predominant role of non-additive gene action governing these traits. Thus, hybrid vigour could better be exploited for these traits. Similar findings have also been reported by Singh *et al.* (1973) and Bhateria *et al.* (1995).

The results of analysis of variance for combining ability were also confirmed from the study of additive (σ^2g) and dominant (σ^2s) components of variance. In all the traits studied, where SCA variances were higher than GCA values, dominant components of variance (σ^2s) were also higher than the additive components (σ^2g), indicating the role of non-additive gene action. Further the variance ratio was found less than one for all the traits except for fruit fly incidence, for which it was recorded higher than one. Again this confirmed the role of non-additive gene action controlling almost all the traits in cucumber. The results of present study are in accordance with the earlier workers for the traits related to earliness (Munshi *et al.*, 2006; Dogra and Kanwar, 2011 and Kumar *et al.*, 2011), fruit length and breadth and average fruit weight (Munshi *et al.,* 2006; Dogra and Kanwar, 2011 and Kumar *et al.*, 2011), number of fruits per plant (Sharma *et al.*, 2000; Singh and Sharma, 2006; Munshi *et al.*, 2006; Yadav *et al.*, 2007, Dogra and Kanwar, 2011 and Kumar *et al.*, 2011), marketable yield (Sharma *et al.*, 2000; Singh and Sharma 2006; Munshi *et al.*, 2006; Yadav *et al.*, 2007; Dogra and Kanwar, 2011; and Kumar *et al.*, 2011) and total soluble solids (Dogra and Kanwar, 2011), cucurbitacin content and fruit fly incidence (Kumar, 2006).

In conclusion, it may be stated that non-additive gene action governed the almost all the traits under study, hence hybrid vigour could better be exploited for these traits in cucumber. Alternatively exploitation of reciprocal recurrent selection, which capitalizes on both additive and non-additive variances, might be more effective for the characters, which had either high or equal dominant (σ^2s) components of variance to that of additive (σ^2g) components (Ghaderi and Lower, 1979a; Lower *et al.*, 1982 and Musmade and Kale, 1986).

The hybrids in cucumber are likely to dominate on account of the gynoecious lines and the relatively ease in producing hybrid seed commercially. The inclusion of gynoecious lines in heterosis and gene action study may lead to conclusion quite contrary to the ones obtained with mostly monoecious lines. This view lends credence from the finding of Wehner and Miller (1985) and Sharma (2010), who reported that gynoecious x monoecious hybrids were significantly higher yielding than monoecious x monoecious hybrids.

5.3.2 Proportional contribution of lines, testers and their interactions (%)

Proportional contribution of lines was found higher than the individual contribution of testers and lines x testers interactions for total soluble solids, fruit length, average fruit weight, severity of angular leaf spot, cucurbitacin content, seed vigour index-II, seed vigour index-I, severity of powdery mildew and seed germination. The contribution of testers was found higher in fruit fly incidence, harvest duration, node number bearing first female flower, number of marketable fruits per plant, days to marketable maturity, days to first female flower appearance and severity of downy mildew as compared to individual contribution of lines and lines x testers interactions. The proportional contribution of lines x tester interactions was found higher than the individual contribution of lines and testers interactions for fruit breadth, yield per plot and per hectare. Present studies revealed that the contribution of lines was the highest followed by individual contribution of testers and then line x tester interaction. The present studies contradict finding of Sharma (2010), who have reported that the contribution of line x tester interaction was the highest followed by individual contribution of testers and then lines. This may be due to the difference in the experimental material used for the study.

5.4 HETEROSIS STUDIES

Heterosis breeding has played a pivotal role in improving the yield and component traits of self as well as cross-pollinated species. In contrast to the consistency of evidence of superiority of heterozygotes in cross-pollinated species, the evidence for inbreeding species has been conflicting. Commercial exploitation of heterosis in self (Rick, 1945; Bishop, 1954; Allard and Workman, 1963; Athwal and Borlaug, 1967 and Singh and Singh, 1978) and cross (Hutchins, 1939 and Rao, 1968) pollinated species suggests that they are essentially similar in their heterotic response and use of heterosis should carefully be considered in all the crop plants irrespective of the breeding system. With the availability of breeding methods for the exploitation of non-additive genetic component of variability, it is desirable to assess the magnitude of exploitable heterosis to obtain consistency of hybrid vigour and to identify the best cross combination.

Globally, the heterosis was first reported by Hayes and Jones (1916) in cucumber but at national level, the first report of hybrid vigour appeared in 1933 in chilli at IARI. The first commercial F_1 hybrid of cucumber was made available in 1935 in Japan and in 1945 in USA, whereas in India the first F_1 hybrid of cucumber, ‘Pusa Sanyog’ was released in 1973 by IARI, Katrain , by crossing gynoecious line, isolated from a Japanese variety ‘Kaga Aomoga Fushinavi’ with Green Long of Naples, an Italian variety. Though the first gynoecious F_1 hybrid, ‘Spartan Dawn’ was introduced in 1962 in USA.

Mohanty and Mishra (1999) have advocated that heterosis breeding is one of the most important tools to exploit genetic diversity in cucumber. In literature, most of the research work on heterosis refers to average heterosis and heterobeltiosis only. However, it is the standard heterosis, which is of practical interest to the breeders as well as growers. Therefore, the present study was carried out to find out the superior heterotic cross combinations in comparison to average heterosis, heterobeltiosis and standard heterosis over, KH-1 (Standard check-I) and Pusa Sanyog (Standard check-

II). The heterotic response of best F_1 hybrids for various traits under study has been presented in the table 5.9 and discussed as below:

In cucumber, days to first female flower appearance (Miller and Quisenberry, 1976), node number bearing first female flower (El-Shawaf and Baker, 1981a) and days to marketable maturity are considered as good indices of earliness. This may be on the fact that early female flower appearance at lower node leads to early development and maturity of fruits. In the present studies, with regard to earliness, ample number of hybrids showed their superiority over mid parent, better parent and standard check 1 and 2. The cross combination, CGN-19533 x K-75, CGN-20953 x Poinsette, CGN-21585 x Poinsette, LC-1-1 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75 revealed the significant negative values for all the estimates of heterosis for earliness. This may be attributed to the fact that out of these best crosses, maximum hybrid combinations produced form gynoecious x monoecious parents. Gynoecious lines are said to be early in maturity than the normal monoecious types (Peterson, 1960) and thus ensure early picking. El-Shawaf and Baker (1981b) also recorded hybrid vigour for earlier flowering (8 days) and earlier pistillate node (0.7 nodes) in a study of 20 F_1 hybrids created by crossing four gynoecious lines with five hermaphrodite lines. Early flowering, fruit maturity and harvest may also be attributed to quicker establishment of hybrid plants and their faster growth and development. The present findings with respect to earliness are in close agreement with many researchers (Dogra *et al.,* 1997; Bairagi *et al.,* 2005; Kumbhar *et al.,* 2005; Sudhakhar *et al.,* 2005; Yadav *et al.,* 2008; Hanchinamani and Patil, 2009; Kumar *et al.,* 2010; Singh *et al.,* 2010, Dogra and Kanwar, 2011 and Khushwaha *et al.,* 2011).

A fairly good number of cross combinations exhibited significant positive heterosis for fruit size (fruit length and breadth) and average fruit weight over the mid parent, better parent, standard check-I and standard check-II. The cross combinations, CGN-19533 x K-75, LC-1-1 x K-75 and Gyne-5 x K-75 for fruit length, CGN-20515 x Japanese Long Green, LC-1-1 x K-75 and LC-15-5 x Poinsette for fruit breadth and CGN-19533 x K-75, CGN-20953 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75 and Gyne-5 x K-75 for average fruit weight were found best heterotic crosses which recorded significant positive values for all the estimates of heterosis. These results are at variance with the earlier findings. Kartalov (1966) reported that hybrids of cucumber were intermediate in fruit length. Singh *et al.* (1970) reported that all the F_1

Table 5.9: Trait-wise list of top hybrids exhibiting significant desirable heterotic response for different estimates of heterosis in cucumber

Traits	Best heterotic hybrid combinations
Days to first female flower appearance	CGN-19533 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75 and LC-2-2 x Poinsette
Node number bearing first female flower	CGN-21585 x Poinsette, LC-1-1 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75
Days to marketable maturity	CGN-19533 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75 and LC-2-2 x Poinsette
Fruit length	CGN-19533 x K-75, LC-1-1 x K-75 and Gyne-5 x K-75
Fruit breadth	CGN-20515 x Japanese Long Green, LC-1-1 x K-75 and LC-15-5 x Poinsette
Average fruit weight	CGN-19533 x K-75, CGN-20953 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75 and Gyne-5 x K-75
Number of marketable fruits per plant	CGN-19533 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75
Harvest duration	CGN-19533 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75
Marketable yield per plot and per hectare	CGN-19533 x K-75, CGN-20953 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75, LC-2-2 x Poinsette, LC-3-3 x Poinsette, and Gyne-5 x K-75
Total soluble solids	LC-1-1 x K-75 and LC-28-8 x K-75
Cucurbitacin content	CGN-20953 x Japanese Long Green, CGN-21585 x Japanese Long Green, LC-1-1 x K-75 and LC-28-8 x K-75
Fruit fly incidence	CGN-20953 x Poinsette, LC-1-1 x K-75, LC-3-3 x Poinsette, LC-15-5 x K-75 and Gyne-5 x K-75
Severity of powdery mildew	CGN-20515 x Poinsette, CGN-20953 x K-75, LC-3-3 x Poinsette, LC-15-5 x K-75 and Gyne-5 x Poinsette
Severity of downy mildew	LC-3-3 x K-75
Severity of angular leaf spot	CGN-20969 x Japanese Long Green and LC-1-1 x K-75
Seed germination	CGN-20953 x Poinsette and LC-1-1 x K-75
Seed vigour index-I	LC-1-1 x K-75
Seed vigour index-II	LC-1-1 x K-75, LC-2-2 x Poinsette, LC-3-3 x K-75, LC-15-5 x Poinsette and Gyne-5 x K-75

hybrids produced smaller fruits as compared to their respective mean of parents and standard cultivar (Japanese Long Green). The deviation could be on account of the variation in genotypes used in hybrid combinations and also in environments under which these were evaluated. The present findings are in conformity with Sudhakar *et al.* (2005), Singh and Sharma (2006) and Yadav *et al.* (2008), Hanchinamani and Patil (2009), Kumar *et al.* (2010), Singh *et al.* (2010), Dogra and Kanwar (2011), Khushwaha *et al.* (2011) and Singh *et al.* (2012).

Similarly, for number of marketable fruits per plant, harvest duration and marketable yield per plot and per hectare number of hybrids revealed significant positive heterosis over the mid parent, better parent, standard check-I and standard check-II. The cross combinations, CGN-19533 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75 had reported significant positive values for all the estimates of heterosis, hence designated as best heterotic crosses among all the 48 F_1 hybrids under study. The high consistent performance of these hybrids for marketable yield may be attributed to their hybrid vigour for increased fruit size, weight and number recorded in the present study. Significant heterosis for all these traits have also been reported earlier by Bairagi *et al.* (2005), Singh and Sharma (2006) and Yadav *et al.* (2008), Hanchinamani and Patil (2009), Kumar *et al.* (2010), Singh *et al.* (2010), Dogra and Kanwar (2011), Khushwaha *et al.* (2011) and Singh *et al.* (2012).

Relatively higher total soluble solids (TSS) and low cucurbitacin content is desirable in cucumber, since this may be associated with better taste and quality. Ample number of cross combinations revealed hybrid vigour for total soluble solids. The crosses, LC-1-1 x K-75 and LC-28-8 x K-75 for TSS and CGN-20953 x Japanese Long Green, CGN-21585 x Japanese Long Green, LC-1-1 x K-75 and LC-28-8 x K-75 for cucurbitacin content, recorded significant desirable values for all the estimates of heterosis. Earlier workers *viz.,* Kumar (2006), Sharma (2010) and Brar *et al.* (2011), have also reported significant desirable heterosis for TSS and cucurbitacin content in cucumber.

Cucumber is attacked mainly by red pumpkin beetle, *Aulacophora foveicollis* (Lucas) during the early plant growth stages and later on its fruiting stage is ravaged by fruit flies, *Bactrocera* (*Dacus*) *cucurbitae* (Coquillett). The melon fly has a wide distribution throughout south East Asia and attacks fruits of a wide range of plant species including vegetables, horticultural fruits and even beans (Narayan and Batra, 1960; Chawla, 1966 and Syed, 1970). It causes severe damage to the crop which results in considerable reduction in yield and market value of the fruits (Srinivasan and Swamy, 1961). According to Mote (1975), losses in India due to *B. cucurbitae* may be as high as 40-80 per cent. Nearly 50 per cent of cucurbits are reported partially or completely damaged by the pest every year in India (Aggarwal *et al.*,1987). In the present study, number of the crosses revealed the significant negative heterosis for fruit fly incidence. But, the hybrid combinations CGN-20953 x Poinsette, LC-1-1 x K-75, LC-3-3 x Poinsette, LC-15-5 x K-75 and Gyne-5 x K-75 were rated as best heterotic crosses due to their significant negative values for all the estimates of heterosis under study. Kumar (2006) and Sharma (2010) had also reported negative heterosis for fruit fly incidence in cucumber.

Cucumber is vulnerable to the attack of a number of fungal, bacterial and viral diseases of which powdery mildew, downy mildew and angular leaf spot are the most destructive disease in Himachal Pradesh. In the present studies, ample of the crosses recorded the significant negative heterosis for severity of these diseases. But, CGN-20515 x Poinsette, CGN-20953 x K-75, LC-3-3 x Poinsette, LC-15-5 x K-75 and Gyne-5 x Poinsette for severity of powdery mildew, LC-3-3 x K-75 for severity of downy mildew and CGN-20969 x Japanese Long Green and LC-1-1 x K-75 for severity of angular leaf spot, revealed significant negative values for all the estimates of heterosis. Significant negative heterosis for severity of powdery mildew and downy mildew was also reported by Sharma (2010) and Brar *et al.* (2011), respectively.

For seed traits, few crosses revealed significant heterosis for average heterosis, heterobeltiosis and standard heterosis over KH-1 and Pusa Sanyog. But, CGN-20953 x Poinsette and LC-1-1 x K-75 for seed germination, LC-1-1 x K-75 for seed vigour index-I and LC-1-1 x K-75, LC-2-2 x Poinsette, LC-3-3 x K-75, LC-15-5 x Poinsette and Gyne-5 x K-75 for seed vigour index-II, reported significant positive values for all the estimates of heterosis under study. No reports pertaining to heterotic effect of seed traits are available in the literature. But, heterotic effect of these traits might be attributed to the greater fruit size and weight in these crosses, which ultimately lead to development of vigorous seeds and hence the better seed germination and seed Vigour.

Table 5.10 Top five hybrid combinations (F_1's) identified on the basis of heterosis studies

Parents	Character
LC-1-1 x K-75	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length and breadth, average fruit weight, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, total soluble solids, cucurbitacin content, fruit fly incidence, severity of angular leaf spot, seed germination and seed vigour index-I and II.
CGN-20953 x Poinsette	Days to first female flower appearance, days to marketable maturity, average fruit weight, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, fruit fly incidence and seed germination.
Gyne-5 x K-75	Node number bearing first female flower, fruit length, average fruit weight, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, fruit fly incidence and seed vigour index-II.
LC-2-2 x Poinsette	Days to first female flower appearance, node number bearing first female flower, days to marketable maturity, number of marketable fruits per plant, harvest duration, marketable yield per plot and per hectare, seed vigour index-II
CGN-19533 x K-75	Days to first female flower appearance, days to marketable maturity, fruit length, average fruit weight, number of marketable fruits per plant, harvest duration and marketable yield per plot and per hectare.

On the basis of overall all performance heterosis studies revealed that LC-1-1 x K-75, CGN-20953 x Poinsette, Gyne-5 x K-75, LC-2-2 x Poinsette, CGN-19533 x K-75 revealed the significantly high heterotic values for yield and its contributing traits, quality and seed characters and tolerance to various biotic stresses. Hence, hybrid vigour may be exploited commercially for improvement in cucumber.

Chapter-6

SUMMARY AND CONCLUSION

Chapter-6

Summary and Conclusion

The present investigations entitled "Genetic studies on yield and quality traits in cucumber (*Cucumis sativus* L.)" were carried out at the Experimental Research Farm of the Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during 2011 and 2012 to assess mean performance, combining ability, nature and magnitude of gene action and to ascertain best heterotic combination(s) for marketable yield and quality traits. The experimental material for the present investigation was comprised of 16 lines and 3 testers. The crosses were attempted during the year 2011 as per Line x Tester design as suggested by Kempthrone (1957). The F_1 population of 48 crosses so obtained was evaluated along with parents and standard check cultivars (KH-1 and Pusa Sanyog) during the year 2012. The observations were recorded on days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length and breadth (cm), average fruit weight (g), number of marketable fruits per plant, harvest duration (days) marketable yield per plot (kg) and per hectare (q), total soluble solids (^{o}B), cucurbitacin content (µg/100g), fruit colour, fruit fly incidence (%), severity of powdery mildew (%), downy mildew (%) and angular leaf spot (%), seed germination (%) and seed vigour index-I and II. The experimental results so obtained have been summarized as under:

6.1 Mean performance

- The wide variations were observed among all parents and hybrid combinations for horticultural traits. The genotype, CGN-20953, CGN-19533 and CGN-20969 and the cross combination CGN-20953 x K-75, LC-1-1 x K-75 and CGN-19533 x K-75 were found superior for earliness. Highest average fruit weight was recorded in the genotype Japanese Long Green and the cross combination LC-25-7 x Japanese Long Green followed by LC-1-1 x K-75. The genotype, Gyne-5 recorded maximum number of marketable fruits per plant, followed by LC-1-1, CGN-20515 and Poinsette, while among the hybrids, it was recorded maximum in the cross combination CGN-20953 x Poinsette, LC-1-1 x K-75, CGN-19533 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75. Amongst the parents, highest marketable yields were observed in the genotype LC-1-1, CGN-20953 and Japanese Long Green, while among the hybrids LC-1-1 x K-75, CGN-19533 x K-75 and CGN-20953 x Poinsette recorded highest marketable yields.

- Maximum total soluble solids (TSS) were recorded in the genotype CGN-21585 and cross combination CGN-21585 x Japanese Long Green. The genotype CGN-21585 recorded minimum cucurbitacin content followed by CGN-20256 and CGN-20969, while among hybrids significantly minimum cucurbitacin content was reported in the cross combination CGN-21585 x Japanese Long Green.
- Lowest fruit fly incidence was recorded in the genotype LC-2-2, followed by LC-1-1 and the cross combination LC-1-1 x K-75 followed by LC-3-3 x Poinsette and LC-15-5 x Poinsette. Minimum severity of powdery mildew was recorded in the genotypes LC-15-5, Poinsette, LC-21-6, CGN-20953 and Japanese Long Green, while hybrid combinations LC-15-5 x K-75, CGN-20515 x Poinsette, LC-3-3 x Poinsette, Gyne-5 x Poinsette and CGN-20953 x K-75 recorded least severity of powdery mildew. The genotype CGN-20969 recorded minimum severity of downy mildew followed by Poinsette, K-75 and LC-3-3. Among the crosses, minimum response to severity of downy mildew was reported in LC-3-3 x K-75 followed by CGN-20969 x Japanese Long green, LC-2-2 x Poinsette and LC-15-5 x K-75. Minimum severity of angular leaf spot was observed in the genotype LC-1-1 and similar response was noticed in CGN-20969, LC-12-4 and CGN-20953, while among the different hybrid combinations, LC-1-1 x K-75 followed by CGN-20969 x Japanese Long Green, LC-2-2 x Poinsette and CGN-20953 x K-75 recorded minimum severity of angular leaf spot.
- Highest seed germination of was recorded in the genotype CGN-20953 and cross combination CGN-20953 x Poinsette, which was followed by LC-1-1 x K-75. The genotype LC-3-3 recorded highest seed vigour index-I (2960.67) followed by LC-2-2 (2786.93), while among the hybrids maximum seed vigour index-I was recorded in the hybrid combination LC-1-1 x K-75 followed by CGN-20953 x Poinsette. Highest seed vigour index-II was observed in the genotype LC-3-3 followed by LC-2-2 and LC-1-1, whereas among crosses, hybrid combination LC-1-1 x K-75 recorded highest seed vigour index-II followed by LC-3-3 x K-75.

On the basis of mean performance it is concluded that Parents LC-1-1, CGN-20953, LC-15-5, Gyne-5, LC-25-7 (Lines), Japanese Long Green, Poinsette (Testers) exceled for most of the horticultural and quality traits. These lines/testers can be selected for hybrid seed production. Among the hybrids LC-1-1 x K-75, CGN-20953 x Poinsette, CGN-19533 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75 were found most promising and these hybrids after multilocation testing can be adopted for commercial cultivation.

6.2 Combining ability studies

- A perusal of GCA effects for earliness revealed that LC-1-1, CGN-20953, CGN-19533, Gyne-5, LC-2-2, CGN-20515, CGN-22930 and CGN-20969 among lines and Poinsette and K-75 among testers were found best combiners due to their significant negative GCA effects. For marketable yield per plot and per hectare, LC-1-1, CGN-20953, CGN-19533, Gyne-5, CGN-22930 and LC-2-2 among the lines and K-75 and Poinsette among the testers exhibited the highest positive GCA effects. All these lines and testers were also found good combiners for average fruit weight, number of marketable fruits per plant and harvest duration.
- The lines, CGN-21585, LC-28-8, LC-1-1 and CGN-20953 and the tester Japanese Long Green revealed significant desirable GCA effects for total soluble solids and cucurbitacin content.
- For various biotic stresses, LC-1-1 and CGN-20953 for fruit fly incidence, severity of powdery mildew and angular leaf spot, LC-2-2 for fruit fly incidence, severity of downy mildew and angular leaf spot and LC-3-3 and LC-15-5 for fruit fly incidence, severity of powdery mildew and downy mildew and among the testers, Poinsette for fruit fly incidence, severity of powdery mildew and downy mildew, K-75 for fruit fly incidence and severity of downy mildew and Japanese Long Green for severity of angular leaf spot were found good general combiners.
- For seed traits, lines LC-1-1, LC-3-3 and LC-15-5 for seed germination, seed vigour index-I and II, LC-2-2 for seed vigour index-I and II, CGN-20953 for seed germination and seed vigour index-I and Gyne-5 for seed germination, seed vigour index-II and testers Poinsette for seed germination and K-75 for seed vigour index-I and II exhibited significant positive GCA effects.
- On the basis of GCA studies, the parents *viz.*, LC-1-1, CGN-20953, Gyne-5, LC-2-2 and CGN-19533 among the lines and K-75 and Poinsette among the testers were found good general combiners for yield and its component traits and may be utilized in hybridization programmes for getting superior hybrids or transgressive segregants.
- The cross combinations, CGN-20953 x Poinsette, CGN-19533 x K-75, LC-1-1 x K-75, Gyne-5 x K-75 and LC-2-2 x Poinsette due to their significant negative SCA effects were found as best specific combiners for earliness.
- Specific combining ability effect for marketable yield per plot and per hectare were found significantly high for CGN-19533 x K-75, LC-25-7 x Japanese Long

Green, CGN-20953 x Poinsette, LC-1-1 x K-75 and Gyne-5 x K-75. Beside this, above cross combinations also revealed significant SCA effects of yield contributing traits *viz.,* fruit length, average fruit weight, number of marketable fruits per plant and harvest duration. Majority of the crosses exhibiting good SCA effects had atleast one of the parents as good or average general combiners.

- For total soluble solids, hybrid combination CGN-21585 x Japanese Long Green, followed by LC-1-1 x K-75, LC-28-8 x K-75, Gyne-5 x Poinsette and LC-1-1 x Poinsette revealed significant positive SCA effects. While, cross combination LC-28-8 x K-75, CGN-21585 x Japanese Long Green, CGN-20256 x Japanese Long Green, LC-28-8 x Poinsette and LC-1-1 x K-75 recorded significantly high negative SCA effects for cucurbitacin content.
- Among all the hybrids, five best crosses *viz.,* LC-1-1 x K-75, CGN-20953 x K-75, LC-15-5 x Poinsette, LC-3-3 x Poinsette and LC-2-2 x K-75 for fruit fly incidence; LC-15-5 x K-75, CGN-20953 x K-75, Gyne-5 x Poinsette, LC-1-1 x K-75 and LC-3-3 x K-75 for severity of powdery mildew; CGN-20969 x Japanese Long Green, CGN-19533 x K-75, CGN-22930 x Poinsette, LC-25-7 x Japanese Long Green and LC-15-5 x Japanese Long Green for severity of downy mildew; CGN-20953 x K-75, LC-1-1 x K-75, LC-25-7 x K-75, CGN-20969 x Japanese Long Green and LC-2-2 x Poinsette for severity of angular leaf spot revealed significant negative SCA effects.
- For seed traits *viz.,* LC-1-1 x K-75, LC-3-3 x Japanese Long Green, CGN-20515 x K-75, CGN-19533 x Poinsette and CGN-20953 x Poinsette for seed germination; LC-1-1 x K-75, CGN-20953 x Poinsette, LC-2-2 x Poinsette, LC-15-5 x Poinsette and LC-3-3 x K-75 for Seed vigour index-I and LC-1-1 x K-75, LC-2-2 x Poinsette, LC-3-3 x K-75, LC-15-5 x Poinsette and CGN-20953 x Japanese Long Green for seed vigour index-II, recorded significantly high positive SCA effects among all the hybrids under study.

On the basis of overall all SCA performance, the cross combinations LC-1-1 x K-75, CGN-20953 x Poinsette, CGN-19533 x K-75, Gyne-5 x K-75 and LC-25-7 x Japanese Long Green were found as five best hybrids . Among these crosses, LC-1-1 x K-75, CGN-20953 x Poinsette, CGN-19533 x K-75 and Gyne-5 x K-75 can be exploited to isolate transgressive segregants in early generations as they involve both parents with high GCA effects for earliness and marketable yield per plot and per hectare, respectively.

Early fruit set

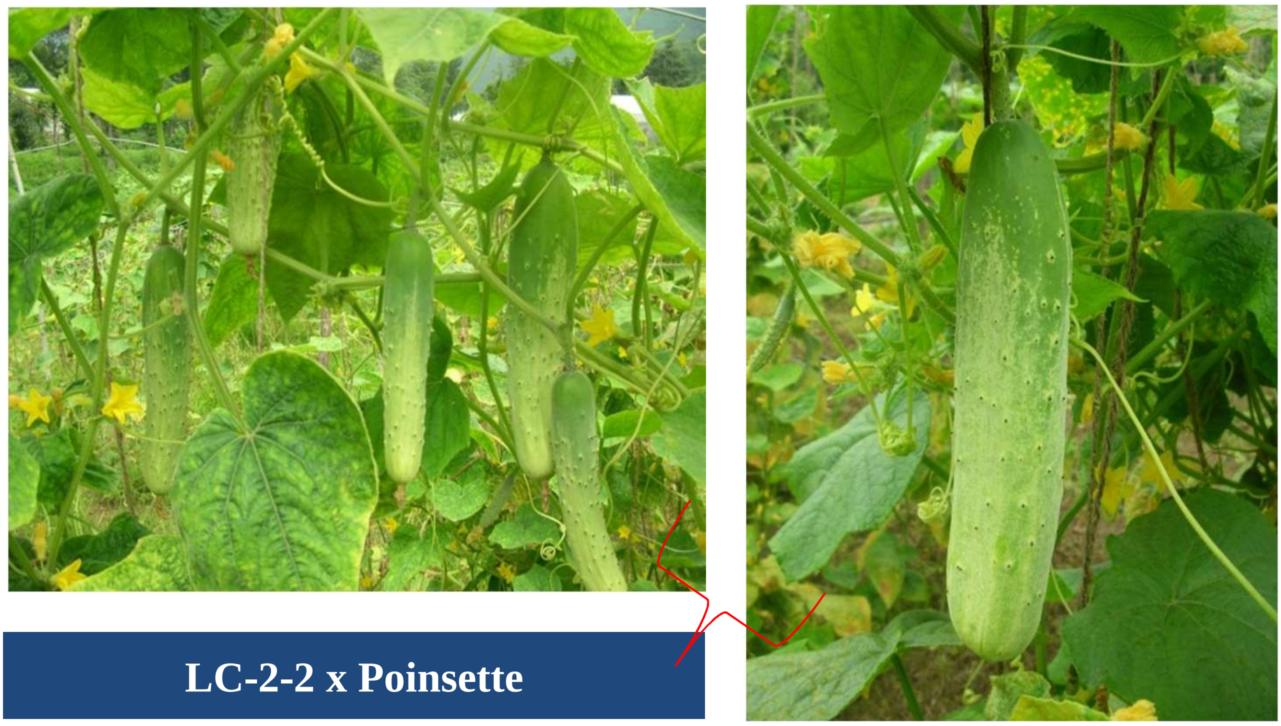
Quality fruit

More number of fruits per plant

Less severity of diseases

LC-1-1 x K-75

Figure 6.1: Best hybrids identified on the basis of overall performance



LC-2-2 x Poinsette

CGN-20953 x Poinsette

Figure 6.2: Best hybrids identified on the basis of overall performance

CGN-19533 x Poinsette

Gyne-5 x K-75

Figure 6.3: Best hybrids identified on the basis of overall performance

6.3 Gene action

- Gene action studies indicated that the estimates of σ^2sca were higher in magnitude as compared to σ^2gca (average) for all the traits under study except for fruit fly incidence, thereby indicating predominant role of non-additive gene action governing these traits. Thus, hybrid vigour could better be exploited for these traits.
- In all the traits studied, where SCA variances were higher than GCA values, dominant components of variance ($\sigma^2$2s) were also higher than the additive components ($\sigma^2$2g), indicating the role of non-additive gene action. Further variance ratio was found less than one for all the traits except for fruit fly incidence, for which it was recorded higher than one. Again this confirmed the role of non-additive gene action controlling almost all the traits in cucumber.
- Proportion contribution of lines, testers and lines x testers interactions, revealed that the variability among the crosses was mainly due to higher contribution of lines as compared to individual contribution of testers and line x tester interactions.

6.4 Heterosis studies

- Heterosis studies revealed that the cross combinations *viz.,* CGN-19533 x K-75, CGN-20953 x Poinsette, CGN-21585 x Poinsette, LC-1-1 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75 revealed the significant negative values for all the estimates of heterosis for earliness. Whereas, the cross combinations, CGN-19533 x K-75, LC-1-1 x K-75 and Gyne-5 x K-75 for fruit length, CGN-20515 x Japanese Long Green, LC-1-1 x K-75 and LC-15-5 x Poinsette for fruit breadth and CGN-19533 x K-75, CGN-20953 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75 and Gyne-5 x K-75 for average fruit weight were found best heterotic crosses. Similarly, for number of marketable fruits per plant, harvest duration and marketable yield per plot and per hectare, CGN-19533 x K-75, CGN-20953 x Poinsette, LC-1-1 x K-75, LC-2-2 x Poinsette and Gyne-5 x K-75 had reported significant positive values for all the estimates of heterosis.
- Ample number of cross combinations revealed significant desirable heterosis for quality traits. The crosses, LC-1-1 x K-75 and LC-28-8 x K-75 for TSS and CGN-20953 x Japanese Long Green, CGN-21585 x Japanese Long Green, LC-1-1 x K-

75 and LC-28-8 x K-75 for cucurbitacin content, recorded significant desirable values for all the estimates of heterosis.

- The hybrid combinations CGN-20953 x Poinsette, LC-1-1 x K-75, LC-3-3 x Poinsette, LC-15-5 x K-75 and Gyne-5 x K-75 for fruit fly incidence, CGN-20515 x Poinsette, CGN-20953 x K-75, LC-3-3 x Poinsette, LC-15-5 x K-75 and Gyne-5 x Poinsette for severity of powdery mildew, LC-3-3 x K-75 for severity of downy mildew and CGN-20969 x Japanese Long Green and LC-1-1 x K-75 for severity of angular leaf spot, revealed significant negative values for all the estimates of heterosis.
- For seed traits, CGN-20953 x Poinsette and LC-1-1 x K-75 for seed germination, LC-1-1 x K-75 for seed vigour index-I and LC-1-1 x K-75, LC-2-2 x Poinsette, LC-3-3 x K-75, LC-15-5 x Poinsette and Gyne-5 x K-75 for seed vigour index-II, reported significant positive values for all the estimates of heterosis under study.

On the basis of overall all performance heterosis studies revealed that LC-1-1 x K-75, CGN-20953 x Poinsette, Gyne-5 x K-75, LC-2-2 x Poinsette, CGN-19533 x K-75 revealed the significantly high heterotic values for yield and its contributing traits, quality and seed characters and tolerance to various biotic stresses. Hence, hybrid vigour may be exploited commercially for improvement in cucumber.

Conclusion

The present studies concluded that five lines *viz.*, LC-1-1, CGN-20953, LC-2-2, CGN-19533 and Gyne-5 and two testers *viz.*, K-75 and Poinsette were found superior on the basis of mean performance and general combining ability studies. Five cross combination *viz.*, LC-1-1 x K-75, LC-2-2 x Poinsette, CGN-19533 x K-75, Gyne-5 x K-75 and CGN-20953 x Poinsette were found best on the basis of mean performance, specific combining ability and heterosis studies. Hence, these hybrid combinations can be tested further at multilocations before releasing as a substitute of already exiting hybrid varieties of cucumber.

Chapter-7

REFERENCES

Chapter-7

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ABSTRACT

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Department of Vegetable Science

Title of Thesis : **“Genetic studies on yield and quality traits in cucumber (*Cucumis sativus* L.)”**
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Year of Award of Degree : 2013
No. of pages in Thesis : 190 + III
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ABSTRACT

The present studies entitled “Genetic studies on yield and quality traits in cucumber (*Cucumis sativus* L.)” were carried out at the Experimental Research Farm of the Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the years 2011 and 2012. The experimental material for the present study comprised of F_1 population of forty eight crosses, developed by crossing 16 lines and 3 testers. All the parents (16 lines and 3 testers) and their hybrids (48) along with the standard checks (KH-1 and Pusa Sanyog) were planted in a Randomized Complete Block Design for their comparative evaluation. The observations were recorded on days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length (cm), fruit breadth (cm), average fruit weight (g), fruit colour, number of marketable fruits per plant, harvest duration (days), marketable yield per plot (kg) & per hectare (q), total soluble solids (^{o}B), cucurbitacin content (μg/100g), incidence of fruit fly (%), severity of powdery mildew (%), downy mildew (%) and angular leaf spot (%), seed germination (%) and seed vigour index-I and II. The analysis of variance indicated highly significant differences among the genotypes for all the traits studied. Experimental results revealed that five lines *viz.*, LC-1-1, CGN-20953, LC-2-2, CGN-19533 and Gyne-5 and two testers *viz.*, K-75 and Poinsette were found superior on the basis of mean performance and general combining ability studies. Five cross combination *viz.*, LC-1-1 x K-75, LC-2-2 x Poinsette, CGN-19533 x K-75, Gyne-5 x K-75 and CGN-20953 x Poinsette were found best on the basis of mean performance, specific combining ability and heterosis studies. Hence, these hybrid combinations can be tested further at multilocations before releasing as a substitute of already exiting hybrid varieties of cucumber in Himachal Pradesh and in India as well.

Signature of Major Advisor **Signature of the student**

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APPENDICES

APPENDIX-I

AGRO-METEOROLOGICAL DATA DURING GROWING PERIOD

Month	Temperature (^oC)			Relative humidity (%)	Rainfall (mm)
	Minimum	Maximum	Mean		
			2011		
May, 2011	16.55	32.31	24.43	46.35	31.70
June, 2011	17.68	29.09	23.38	65.92	178.20
July, 2011	19.23	27.35	23.29	80.24	263.60
August, 2011	19.21	27.92	23.56	79.87	189.80
			2012		
May, 2012	15.34	32.21	23.78	40.47	2.60
June, 2012	18.84	34.15	26.49	48.28	19.30
July, 2012	19.48	28.84	24.16	70.74	316.10
August, 2012	18.84	26.99	22.92	84.06	269.80

Source: Meteorological Observatory, Department of Environmental Sciences, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP, 173 230

APPENDIX-II

Analysis of variance for various traits in cucumber

Source Character	Mean Sum of Squares			
	Replications	Genotypes	Errors	Total
df	2	68	136	206
Days to first female flower appearance	0.88	46.42*	1.08	48.38
Node number bearing first female flower	0.01	12.82*	0.22	13.05
Days to marketable maturity	1.92	49.41*	0.85	52.18
Fruit length (cm)	3.35	16.24*	0.67	20.25
Fruit breadth (cm)	0.01	1.16*	0.03	1.20
Average fruit weight (g)	855.80	4531.99*	190.73	5578.51
Number of marketable fruits per plant	0.18	11.99*	0.11	12.28
Harvest duration (days)	0.02	90.36*	1.42	91.81
Marketable yield per plot (kg)	3.30	403.66*	4.42	411.38
Marketable yield per hectare (q)	146.64	17958.49*	196.72	18301.85
Total soluble solids (°B)	0.002	0.232*	0.01	0.245
Cucurbitacin content (µg/100g)	2.74	101.84*	2.56	107.14
Fruit fly incidence (%)	1.14	50.19*	0.66	51.99
Severity of powdery mildew (%)	0.07	0.81*	0.04	0.92
Severity of downy mildew (%)	1.30	66.31*	1.85	69.46
Severity of angular leaf spot	9.23	51.04*	1.85	62.12
Seed germination (%)	3.06	21.14*	1.60	25.80
Seed vigour index-I	38548.01	223409.78*	16288.99	278246.78
Seed vigour index-II	14922.56	201311.79*	12651.19	228885.53

*Significant at 5% level of significance

APPENDIX-III

Analysis of variance for Line x Tester analysis including parents in cucumber

Source	**Mean Sum of Squares**								
Character	**Replications**	**Treatments**	**Parents**	**P vs C**	**Crosses**	**Lines**	**Testers**	**Line x Testers**	**Error**
df	2.00	66.00	18.00	1.00	47.00	15.00	2.00	30.00*	132
Days to first female flower appearance	0.92	46.39*	38.39*	36.48*	49.66*	35.71*	497.81*	26.75*	1.11
Node number bearing first female flower	0.01	13.04*	11.57*	34.88*	13.13*	7.28*	7.37*	143.46*	0.22
Days to marketable maturity	1.98	49.40*	38.42*	63.15*	53.31*	37.46*	538.38*	28.89*	0.86
Fruit length (cm)	3.52	16.34*	22.35*	110.69*	12.03*	26.29*	20.08*	4.37*	0.68
Fruit breadth (cm)	0.01	1.17*	0.25*	0.83*	1.32*	0.82*	10.88*	0.91*	0.03
Average fruit weight (g)	920.10	4626.37*	4914.27*	35239.07*	3864.78*	8044.47*	4663.69*	1721.68*	194.235
Number of marketable fruits per plant	0.20	11.94*	5.78*	65.22*	13.17*	7.14*	143.82*	7.47*	0.11
Harvest duration (days)	0.01	89.99*	38.76*	391.22*	103.20*	54.30*	1139.81*	58.55*	1.44
Marketable yield per plot (kg)	3.53	408.32*	105.46*	3789.56*	452.37*	457.92*	3002.83*	279.57*	4.46
Marketable yield per hectare (q)	157.00	18165.86*	4691.95*	168593.33*	20125.50*	20372.26*	133592.67*	12437.64*	198.63
Total soluble solids (°B)	0.01	0.24*	0.27*	0.14*	0.23*	0.51*	0.35*	0.07*	0.01
Cucurbitacin content (μg/100g)	3.16	102.34*	114.65*	54.59*	98.65*	183.49*	216.95*	48.34*	2.59
Fruit fly incidence (%)	2.32	105.70*	31.13*	27.02*	135.93*	43.80*	2530.74*	22.34*	1.40
Severity of powdery mildew (%)	4.47	55.64*	41.52*	5.72*	62.11*	85.62*	377.52*	29.33*	2.42
Severity of downy mildew (%)	2.09	141.36*	177.46*	151.33*	127.32*	133.31*	1074.19*	61.20*	3.51
Severity of angular leaf spot	12.78	93.62*	119.97*	29.94*	84.88*	163.67*	291.57*	31.71*	3.14
Seed germination (%)	5.55	44.77*	58.74*	8.54*	40.19*	54.79*	211.69*	21.45*	3.37
Seed vigour index-I	35110.86	215944.34*	189796.50*	56077.11*	229359.83*	351978.62*	367490.77*	158841.70*	16534.67
Seed vigour index-II	15482.13	206364.98*	153366.01*	148972.62*	227883.58*	357430. 59*	628839.52*	136379.67*	12780.91

*Significant at 5% level of significance

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Whether sponsored by some State/ Central Govt./Univ./SAARC	:	No
Scholarship/Stipend/Fellowship/ or any other financial assistance received during the study period	:	University merit scholarship during PhD programme

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