HETEROSIS AND COMBINING ABILITY STUDIES IN CUCUMBER (*Cucumis sativus* L.) GENOTYPES

PREETHI, G. P.

UHS15PGM687

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF HORTICULTURE,

UHS CAMPUS, GKVK, BENGALURU- 560 065

UNIVERSITY OF HORTICULTURAL SCIENCES

BAGALKOT - 587 104

JUNE, 2017

HETEROSIS AND COMBINING ABILITY STUDIES IN CUCUMBER (*Cucumis sativus* L.) GENOTYPES

Thesis submitted to the

UNIVERSITY OF HORTICULTURAL SCIENCES, BAGALKOT

In partial fulfillment of the requirements for the

Degree of

MASTER OF SCIENCE (Horticulture)

in

VEGETABLE SCIENCE

By

PREETHI, G. P.

DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE,
UHS CAMPUS, GKVK, BENGALURU- 560 065
UNIVERSITY OF HORTICULTURAL SCIENCES
BAGALKOT - 587 104

JUNE, 2017


Affectionately
Dedicated to
My Beloved
Parents

DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE,
UHS CAMPUS, GKVK, BENGALURU- 560 065
UNIVERSITY OF HORTICULTURAL SCIENCES
BAGALKOT - 587 104

C E R T I F I C A T E

This is to certify that the thesis entitled **"Heterosis and Combining ability studies in Cucumber (*Cucumis sativus* L.) genotypes"** submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **VEGETABLE SCIENCE** to the University of Horticultural Sciences, Bagalkot, is a *bonafide* record of research work carried out by **PREETHI, G.P, UHS15PGM687** under my guidance and supervision and that no part of the thesis has been submitted for the award of any degree, diploma, associateship, fellowship or other similar titles.

Place : Bengaluru

Date : June, 2017

(M. ANJANAPPA)
Chairman

Approved by:

Chairperson: _____
(M. ANJANAPPA)

Members: **1.** _____
(M. PITCHAIMUTHU)

2. _____
(V. DEVAPPA)

3. _____
(R. K. RAMACHANDRA)

4. _____
(R. VENUGOPALAN)

ACKNOWLEDGEMENT

The beatitude and euphoria that accompanies successful completion of any task would be incomplete without expression of appreciation of simple certitude to the people who made it possible to achieve the goal by their encouraging guidance and proper steering. It is still great at this juncture to recall all the faces and spirit in the form of teachers, friends, near and dear ones.

I feel extremely honoured for the opportunity bestowed by Almighty upon me to work under the versatile guidance of ***Dr. Anjanappa, M.*** *Professor, Dept. of Vegetable Science, College of Horticulture, Bengaluru and Chairman of Advisory Committee, for his excellent guidance and encouragement in completion of this thesis. It is my privilege to record a deep sense of gratitude for the valuable guidance, constant inspiration, kind help constructive criticism, unfailing interest and meticulous planning right from suggesting the problem till the completion of this thesis.*

I am very much grateful to my advisory committee members, ***Dr. Pitchaimuthu, M.,*** *Principal Scientist Division of Vegetable Crops, IIHR, Hesaraghatta, Bengaluru,* ***Dr. V. Devappa,*** *Professor and Head, Dept. of Plant Pathology, College of Horticulture Bengaluru,* ***Dr. R.K. Ramachandra,*** *Asst. Professor of GPB, Dept. of Crop improvement and bio technology,* ***Dr. R. Venugopalan,*** *Principle Scientist Division of Statistics, IIHR, Hessaraghatta, Bengaluru , for their constant supervision, valuable guidance and all the facilities extended during the course of this investigation.*

I express my sincere thanks to ***Dr. Jyothi Kattegoudar****, Assistant Professor, Dept. of Vegetable Science, College of Horticulture, Bengaluru,* ***Dr. Prashanth S. J,*** *Assistant Professor, Dept. of Vegetable Science, College of Horticulture, Bengaluru****,*** ***Mrs. Jayashree Ugalat*** *Assistant Professor, Dept. of Crop Improvement and Biotechnology, College of Horticulture, Bengaluru****, Dr. B. Anjenayya reddy,*** *Assistant Professor, Dept. of Plant Pathology, College of Horticulture Bengaluru,* ***Dr. Jayappa,***

Assistant Professor, Dept. of Entomology, College of Horticulture Bengaluru, for their supervision and valuable guidance.

It is my pleasure to thank seniors ***Anand sir, Mahesh sir, Anil sir, Jogi sir, Asha, Pushpalatha, Divya*** *my friends* ***Aswathi, Sushma, Shivaji, Manjunath, Manjesh, Akshatha, Divya, Neelambika, Nandini, Asiya, Kalpana, Chaitra*** *Field Assistant* ***Mr. Shivakumar*** *and many more junior friends for their help and advice during my degree programme.*

One uses the choicest words to acknowledge the invaluable help rendered by someone very close to heart. But, I find such a measure inadequate to quantify the sacrifices, love, affection, support and concern shown to me by my father ***Sri Palaksha G. N,*** *mother* ***Smt. Hemalatha B. V****, and Brother* ***Prathik G. P.*** *Their unselfish struggle towards my wellbeing and attainment of perfection in carrier goals has been boundless and my gratitude is beyond words.*

Above all I am extremely thankful and grateful to ***Almighty God*** *who has blessed me to be what I am today.*

End is inevitable for any kind of work. Though acknowledging is an endless task, I end by saying infinite thanks to all those whom I am able to recall here and also to those whom I might have left unknowingly.

Bengaluru
June, 2017 ***(Preethi G.P.)***

Heterosis and Combining ability studies in Cucumber (*Cucumis sativus* L.) genotypes

PREETHI, G. P.

ABSTRACT

Present investigation on heterosis and combining ability was undertaken at College of Horticulture, Bangalore during 2016-17. Twenty five hybrids developed by crossing five lines with five testers in L × T fashion were evaluated along with the parents in RCBD with two replications. The magnitude of heterosis over the commercial check (Chitra) for vine length (-12.85 to 19.91), number of branches per plant (-7.69 to 25.00), number of nodes per vine (-11.5 to 46.50), node of female flower appearance (-28.95 to 28.07), days to female flower anthesis (-9.67 to -28.46), sex ratio (-20.27 to 34.17), days to first fruit harvest (-3.14 to -23.74), number of fruits per plant (-17.68 to 44.44), Fruit length (-10.05 to 41.94), Fruit yield per plant (-43.16 to 55.79). The hybrid which exhibited maximum heterosis over the commercial check (Chitra) was Green long × Poinsette (55.79 %), Green long × Pusa Uday (54.30 %), Pondicherry 1 × Punjab Naveen (50.47 %) for fruit yield per plant. The crosses Green long × Poinsette and Pondicherry 1 × Punjab Naveen and lines Pondicherry 1 and green long were identified as good specific combiner and general combiner for fruit yield. Among the parents IIHR 341, Green long, Pusa Uday were identified as good general combiners overall 17 characters based on comprehensive study considering gca effects. Non additive component of genetic variance was slightly higher than additive component for all the traits studied.

PREETHI, G. P. — Student

Dr. M. ANJANAPPA — Major Advisor

June, 2017

ಸೌತೆಕಾಯಿ (ಕುಕುಮಿಸ್ ಸಟೈವಸ್ ಎಲ್.) ಜಿನೋಟೈಪ್ಸ್‌ನಲ್ಲಿ ಹೆಟೆರೋಸಿಸ್ ಮತ್ತು ಸಂಯೋಜನಾ ಸಾಮರ್ಥ್ಯದ ಕುರಿತು ಅಧ್ಯಯನ

ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ಹೆಟೆರೋಸಿಸ್ ಮತ್ತು ಸಂಯೋಜನಾ ಸಾಮರ್ಥ್ಯದ ಮೇಲಿನ ಸಂಶೋಧನೆಯನ್ನು 2016-17 ನೇ ಸಾಲಿನಲ್ಲಿ ತೋಟಗಾರಿಕಾ ಮಹಾವಿದ್ಯಾಲಯ, ಜಿಕೆವಿಕೆ, ಬೆಂಗಳೂರಿನಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಐದು ಸಂತತಿಗಳು ಹಾಗೂ ಐದು ಪರೀಕ್ಷಕಗಳನ್ನು ಎಲ್xಟಿ ಮಾದರಿಯಲ್ಲಿ ಕೂಡಿಸಿ 25 ಸಂಕರಣ ತಳಿಗಳನ್ನು ಅಭಿವೃದ್ಧಿಪಡಿಸಿ ಅವುಗಳನ್ನು ಪೋಷಕ ತಳಿಗಳೊಂದಿಗೆ ಮೂರು ಪುನರಾವರ್ತನೆಗಳಲ್ಲಿ ಆರ್.ಸಿ.ಬಿ.ಡಿ. ವಿನ್ಯಾಸದಲ್ಲಿ ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಯಿತು. ಹೆಟೆರೋಸಿಸ್‌ನ ಪ್ರಮಾಣವು ವಾಣಿಜ್ಯ ತಳಿ (ಚಿತ್ರಾ) ಗಿಂತ, ಬಳ್ಳಿಯ ಉದ್ದ (-12.85 ರಿಂದ 19.91), ಪ್ರತಿ ಬಳ್ಳಿಗೆ ಕವಲುಗಳ ಸಂಖ್ಯೆ (-7.69 ರಿಂದ 25), ಪ್ರತಿ ಬಳ್ಳಿಗೆ ಕಣ್ಣುಗಳ ಸಂಖ್ಯೆ (-11.65 ರಿಂದ 46.5), ಹೆಣ್ಣು ಹೂ ಗೋಚರಿಸುವ ಕಣ್ಣುಗಳ ಸಂಖ್ಯೆ (-28.95 ರಿಂದ 28.07), ಹೆಣ್ಣು ಹೂವು ಅರಳಲು ದಿನಗಳು (-9.67 ರಿಂದ -28.46), ಲಿಂಗಾನುಪಾತ (-20.27 ರಿಂದ 34.17), ಮೊದಲ ಬಾರಿ ಕಾಯಿಗಳು ಕಟಾವಿಗೆ ಬರುವ ದಿನಗಳು (-314 ರಿಂದ -23.74), ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಒಟ್ಟು ಕಾಯಿಗಳ ಸಂಖ್ಯೆ (-17.68 ರಿಂದ 44.44), ಕಾಯಿಯ ಉದ್ದ (-10.05 ರಿಂದ 41.94), ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಕಾಯಿಯ ಇಳುವರಿ (-43.16ರಿಂದ 55.79) ರಷ್ಟು ಕಂಡುಬಂದಿತ್ತು. ವಾಣಿಜ್ಯ ತಳಿ (ಚಿತ್ರಾ) ಗಿಂತ ಅತಿ ಹೆಚ್ಚು ಹೆಟೆರೋಸಿಸ್ ಪ್ರಮಾಣವು, ಪ್ರತಿ ಗಿಡದ ಇಳುವರಿಯಲ್ಲಿ ಗ್ರೀನ್‌ಲಾಂಗ್ x ಪೊಯಿನ್‌ಸೆಟ್ಟೆ (ಶೇ. 55.79), ಗ್ರೀನ್‌ಲಾಂಗ್ x ಪೂಸಾ ಉದಯ್ (ಶೇ. 54.30) ಮತ್ತು ಪಾಂಡಿಚೇರಿ-1 x ಪಂಜಾಬ್‌ನವೀನ್ (ಶೇ. 50.47) ದಾಖಲೆಗೊಂಡಿತ್ತು. ಸಂಯೋಗ ವಿನ್ಯಾಸದ ಅಧ್ಯಯನದಿಂದ ತಿಳಿಸುವುದೇನೆಂದರೆ, ಸಂಕರಣ ತಳಿಗಳಿಂದ ಗ್ರೀನ್‌ಲಾಂಗ್ x ಪೊಯಿನ್‌ಸೆಟ್ಟೆ, ಪಾಂಡಿಚೇರಿ-1 x ಪಂಜಾಬ್‌ನವೀನ್‌ಗಳು ಕ್ರಮವಾಗಿ ಪ್ರತಿ ಗಿಡದ ಮಾರಟಕ್ಕೆ ಸೂಕ್ತವಾದ ಅತ್ಯುತ್ತಮವಾದ ಇಳುವರಿ, ನಿರ್ದಿಷ್ಟ ಮತ್ತು ಸಾಮಾನ್ಯ ಕೂಡುವಿಕೆಯ ಕ್ಷಮತೆಯನ್ನು ಹೊಂದಿದ್ದವು. ಎಲ್ಲಾ 17 ಗುಣಗಳು ಜಿ.ಸಿ.ಎ ಪರಿಣಾಮಗಳನ್ನು ಪರಿಗಣಿಸಿ ಮಾಡಿದ ಸಮಗ್ರ ಅಧ್ಯಯನದ ಆಧಾರದ ಮೇಲೆ ಸಾಲುಗಳು ಪಾಂಡಿಚೇರಿ-1 ಮತ್ತು ಗ್ರೀನ್‌ಲಾಂಗ್. ಒಳ್ಳೆಯ ಸಾಮಾನ್ಯ ಸಂಯೋಜಕಗಳಾಗಿ ಗುರಿತಿಸಲಾಗಿದೆ.

ಪ್ರೀತಿ ಜಿ.ಪಿ. **ಡಾ. ಎಂ. ಅಂಜನಪ್ಪ**

ವಿದ್ಯಾರ್ಥಿನಿಯ ಸಹಿ **ಪ್ರಧಾನ ಸಲಹೆಗಾರರು**

ಜೂನ್, 2017

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

I. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most popular vegetable of the family Cucurbitaceae. The “Cucurbit” is a term coined by Liberty Hyde Bailey for cultivated species consisting of 118 genera and 825 species (Jeffrey, 1990). Cucumber is distinct from the other *Cucumis* species as it has got seven pairs of chromosomes 2n=2x=14 a true diploid. India is the centre of origin of many Cucurbitaceous vegetables, where the Cucurbits are capable of thriving and performing well even under the hot summer.

The cucumber has been originated in India. The genus *Cucumis* comprises of about 30 species which is distributed over two distinct geographic areas *viz*., South-East Himalayan an important origin of the Asiatic group with chromosome number of x=7, are distributed in India, China, Myanmar and Korea to which cucumber belongs and African group consisting of species *Cucumis sativus* var. *sativus* and *Cucumis sativus* var. *hardwickii* (Royle) with basic chromosome number x=12. These species are also found in different parts of Africa, Middle East, Sudan, Egypt, Ethiopia and Pakistan. Cucumber has become the fourth important vegetable in the world after tomato, cabbage and onion (Tatilioglee, 1993).

It is an ideal summer vegetable crop which is grown for its edible tender fruits, preferred as a versatile fruit consumed in various ways, salad ingredient, pickles, deserts fruit and as a cooked vegetable. Cucumber has got the cooling effect, so in the eastern countries, fruits were often used as cooling vegetable. It is ideal for the people suffering from jaundice and allied diseases and also very much useful in preventing constipation.

One hundred gram of edible cucumber fruit contain 96g water, 0.6g protein, 0.1g fat, 2.2g carbohydrate, 45 IU Vitamin A, 0.03mg Vitamin B1, B2, 0.3mg Niacin, 12mg vitamin C, 12mg Calcium, 0.3mg Iron, 15mg Magnesium and 24mg Phosphorus (Alcazar, *et al*., 1983). 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). Besides this, the whole fruit is used in cosmetic and soap industries.

Globally cucumber is cultivated in an area of 21,09,651 ha with an annual production of 6,51,34,078 tonnes (FAO, 2012). While, India produces about 6,40,990, tonnes of cucumber from an area of 40,900 hectares with a productivity of 15.98 tonnes per hectare (NHB, 2014). In Karnataka the area under cucumber cultivation is about 6,903 ha with an average production of 1,03,396 mt. The average productivity of cucumber in Karnataka is about 14.98 mt per ha (Anon., 2013).

Cucumber is a monoecious, trailing or climbing vine with angled, hirsute or rough stems. The staminate flowers have three stamens are in clusters with short, slender pedicels. The pistillate flowers contain upto five stigma and are epigynous and hermaphrodite flowers are perigynous. The main stem of monoecious cucumber is usually characterized by three phases of sex expressions. Only staminate flowers are produced in the first phase followed by a phase of irregularly alternating female, male or mixed nodes and finally a phase of only pistillate flowers. Fruits from perigynous flowers are more rounded as opposed to elongated ones from epigynous ones. Sex expression is generally influenced by environment. Under long day and high light intensities staminate flowers predominate, whereas under short day and low light intensities pistillate flower predominate. Anthesis takes place around 5.30 a.m - 7.00 a.m. Anther dehiscence occurs around 4.30 a.m - 5.00 a.m, and pollen fertility is upto 14 hr.

Cucumber it exhibits an considerable heterozygosity in the population and does not suffer much due to the inbreeding depression resulting in natural variability in the population. The demand for the hybrids in cucumber is increasing because of earliness, uniformity and higher yield. Cucumber is a suitable crop for the development of hybrids of commercial importance due to monoecious sex form which eliminates emasculation and large number of seeds per cross, make it more economical.

Heterosis breeding has been recognized as practical tool in providing breeder a means for increasing yield and other economic traits. The hybrid vigour or the superiority of the F_1 hybrids over parents may be manifested in terms of high productivity, uniformity in improved qualities, built in resistance, environmental adoptions, earliness etc. However it never happens that each hybridization is accompanied by manifestation of hybrid vigour. Only certain pair of parents gives heterotic progeny.

Another issue that leads to less yield in cucumber is “Sex ratio”. Efforts have been made by the various researchers in order to increase number of female flowers per plant and eventually yield. Peterson (1960) improved early yield by introducing gynoecious lines. Therefore, development of an effective heterosis breeding in cucumber one needs to elucidate genetic nature and magnitude of quantitatively inherited traits and estimate prepotency of parents in hybrid combinations. Among the variety of biometrical procedures, line x testers analysis proposed by Kempthorne (1957) will provide information in this direction which has received considerable attention to access genetic differences among the parents for quantitative traits. The general combining ability (*gca*) effects and specific combining ability (*sca*) effects in selection of superior hybrids and to understand the nature of gene action involved in the expression of yield and yield contributing characters.

Cucumber has received little attention in crop improvement as compared to other cucurbit vegetables. Therefore exploitation of heterosis involving locally adapted cucumber genotypes for commercial cultivation in priority area of research in improving the productivity, uniformity and fruit quality. Hence, the present study was undertaken with the following objectives:

1. To estimate the heterosis for yield and yield attributing traits in cucumber.
2. To study the combining ability of parents for yield, yield attributing traits in cucumber.

II. REVIEW OF LITERATURE

Cucumber (*Cucumis sativus* L.) is an important Cucurbitaceous vegetable crop grown in tropical and subtropical region. The main goal of any breeding programme is to increase the yielding ability of crop plants. The information on genetic architecture of various traits, particularly of those contribute to yield will be most useful in implementation of the breeding programme. Exploitation of heterosis is an efficient approach for improvement of vegetable crops, where F_1 seed production is economically viable. Nevertheless, for a comparatively less known crop like cucumber, taking stock of the earlier works on the crop improvement aspects with special reference to heterosis breeding on which present investigation is concerned must. Therefore, investigation is carried out to assess the magnitude of heterosis and good combiners for the immense use in breeding programme. The review of literature on heterosis and combining ability for growth, yield and quality parameters of cucumber and other cucurbits are presented under the following headings.

2.1 Heterosis for yield and yield contributing traits in cucumber

Hybrid vigour and heterosis are nearly synonymous. The word heterosis was coined by Shull (1914), which refers to the phenomena in which the F_1 hybrid obtained by crossing the two genetically dissimilar homozygous individuals, shows increased or decreased vigour over the better parent (heterobeltiosis) or best parent value (best-parent heterosis) or commercial check hybrid (standard or true heterosis). Hayes and Jones (1916) were the first investigators to report heterosis in cucumber. They found 24 to 30 per cent increase in yield over the high yielding parents. Heterosis was also reported for various other traits in cucumber by Hutchins (1938). In vegetable crops, heterosis breeding has found useful in the improvement of yield potential of self as well as cross pollinated crops.

The expression of heterosis may be due to factors such as heterozygosity, allelic interaction such as dominance or over-dominance, non-allelic or epistasis and maternal interactions. The degree of heterosis depends upon the number of heterozygous alleles. Higher the number of heterozygous alleles, more is the heterosis expected (East and Hayes, 1912). Various hypothesis have been put forward to know genetic basis of Heterosis. Among them, dominance hypothesis, over-dominance hypothesis and epistasis hypothesis are widely accepted.

Hybrids offer opportunity for increased vigour, earliness, uniformity, size, fruitfulness, resistance to diseases and pests. Considerable degree of heterosis has been documented in cucumber and other cucurbits for various characters. The heterosis of some traits as reported by various scientists is reviewed in the Table 1.

2.2 Combining ability

The concept of combining ability for the evaluation of parents in a crossing programme is of immense important. It has been originated through intensive hybridization work in maize. Hybridization is the most potent technique for breaking yield barriers and evolving varieties having high yielding potential. The selection of suitable parents is one of the most important steps in heterosis breeding. Selection of parents on the basis of phenotypic performance alone is not a sound procedure, since phenotypically superior lines may not lead to expected degree of heterosis. Thus, one of the potential tool for identifying prospective parents for hybridization and shifting productive hybrids from a set of crosses in F_1 generation is the analysis of combining ability (Griffing, 1956). The combining ability concept was first proposed by Sprague and Tatum (1942) in corn.

According to them, the general combining ability (*gca*) is the comparative ability of the line to combine with other lines. It is the deviation of the mean performance of all the crosses involving a parent from overall mean. Specific combining ability (*sca*) was defined as the deviation in the performance of specific cross from the performance expected on the basis of general combining ability effects of parents

involved in the crosses. A positive combining ability (*gca*) indicates a parent that produces above average progeny, whereas parent with negative *gca* produces progeny that performs below average of the population. Specific combining ability (*sca*) can be either negative or positive and *sca* always refers to specific cross and never to a particular parent by itself.

The most commonly design for combining ability studies are line x tester and diallel analysis. Combining ability analysis following the line x tester technique was given by Kempthorne (1957) and Arunachalam (1974). It is also useful for the characterizing the nature and magnitude of gene action involved in controlling the quantitative traits. The general and specific combining ability effects and variances obtained from a set of F_1's enables the breeder to select desirable parents and crosses for each of the quantitative components separately. Sprague and Tatum (1942) from their results concluded that, the general combining ability was largely the result of additive gene action, while the specific combining ability due to dominance, epistasis and genotypic environment interaction. Review of literature on combining ability and gene action in cucumber is presented in Table 2.

Table 1. Review of literature on extent of heterobeltiosis, best parent and standard heterosis for various traits of cucumber

Sl. No.	Character	Crop	No. of hybrids and method	Heterobeltiosis (%)	Best parent (%)	Standard Heterosis (%)	Reference
1	Vine length (cm)	Cucumber	30 L × T	-140.50 to 54.50	-	-	Bairagi *et al.* (2005)
			21 HD	4.18 to -27.93	5.22 to -27.93	-	Jat *et al.* (2015)
		Ridge gourd	28 HD	30.21 to 39.73	-	-	Rao *et al.* (2000a)
			10 Crosses	-17.97 to 54.18	-	-4.03 to 36.27	Mole *et al.* (2001)
			36 Crosses	-44.97 to 54.18	-	1.83 to 75.49	Niyaria and Bhalala (2001)
			45 HD	-32.94 to 37.53	-	-	Shaha and Kale (2003b)
			28 HD	-49.37 to 45.60	-	-40.15 to 29.72	Poshiya *et al.* (2015)
		Bottle gourd	15 HD	-9.32 to 13.09	-	-	Kushwaha and Hariharram (2002)
			36 HD	1.67 to 64.75	-	0.00 to 75.48	Dubey and Maurya (2003)
			30 L × T	-36.50- 49.18	-	-	Sharma *et al.* (2004)
		Bitter gourd	30 HD	2.36 to 33.33	-	9.15 to 43.79	Singh *et al.* (2001)
			25 L × T	-11.05 to 23.60	-	-17.20 to 15.53	Mohan (2005)
			28 HD	-140.50 to 54.50	-	-22.70 to 14.64	Laxuman (2005)
			28 HD	-17.50 to 10.81	-21.74 to 5.37	-	Jadhav *et al.* (2009)
			29 L × T	-24.51 to 2.20	-	-	Yadav *et al.* (2009)
			21 HD	-6.35 to 38.58	-	-	Singh *et al.*(2013)
		Sponge gourd	36 HD	-50.50 to 29.06	-	-38.41 to 75.28	Naliyadhara *et al.* (2007)
		Musk melon	10 HD	-	0.88 to 17.14	-	Kamer *et al.* (2015)
2	Number of branches per plant	Cucumber	28 crosses	-45.50 to 46.10	-	-43.80 to 21.00	Bairagi *et al.* (2005)
			15 FD	-1.86 to 10.83	-	-	Pandey *et al.* (2005)
		Ridge gourd	28 HD	-54.33 to 60.82	-	-	Rao *et al.* (2000a)
			36 crosses	-48.60 to 40.17	-	-24.60 to 57.36	Niyaria and Bhalala (2001)
			10 crosses	-18.41 to 46.26	-	-9.52 to 50.00	Mole *et al.* (2001)
		Bottle gourd	15 HD	-12.39 to 21.04	-	-	Kushwaha and Hariharram (2002)
			36 HD	1.23 to 72.22	-	1.18 to 45.88	Dubey and Maurya (2003)

Sl. No.	Character	Crop	No. of hybrids and method	Heterobeltiosis (%)	Best parent (%)	Standard Heterosis (%)	Reference
			30 L × T	-4.26 to 31.52	-	-20.16 to 11.12	Sharma *et al.* (2004)
		Bitter gourd	28 HD	-18.70 to 23.76	-21.59 to 8.93	-	Jadhav *et al.* (2009)
			24 L × T	-11.21 to 293.65	-	-	Yadav *et al.* (2009)
		Sponge gourd	36 HD	32.28 to 22.78	-	-27.43 to 30.38	Naliyadhara *et al.* (2007)
		Muskmelon	10 HD	-	-13.98 to 7.85	-	Kamer *et al.* (2015)
3	Number of nodes per vine	Cucumber	36 L × T	15 to 37	-	-	Singh *et al.*(2011)
4	Days to first female flower anthesis	Cucumber	28 HD	-11.72 to 82.65	-	-17.72 to 65.19	Dogra *et al.* (2011)
			21 HD	-12.37 to 7.80	-6.08 to -24.24	-	Jat *et al.* (2015)
		Ridge gourd	10 crosses	-21.90 to 76.73	-	-	Rao *et al.* (2000a)
			28 HD	-0.36 to -41.36	-	-42.26 to -1.85	Mole *et al.* (2001)
			45 crosses	-28.93 to 105.69	-	-	Shaha and Kale (2003b)
			28 HD	-14.29 to 17.08	-	-21.77 to 7.94	Poshiya *et al.* (2015)
		Bottle gourd	20 L x T	-31.39 to 43.76	-	-35.94 to 13.00	Singh and Kumar (2002)
			15 FD	-13.42 to 36.43	-	-	Kushwaha and Hariharram (2002)
			36 HD	-1.02 to 38.88	-	-0.85 to 28.21	Dubey and Maurya (2003)
			30 HD	-20.00 to 27.22	-	-	Sharma *et al.* (2004)
			10 HD	-28.26 to 27.53	-	-	Sreevani(2004)
			10 HD		-	-9.93 to 42.00	Upadhyay and Hariharram (2007)
			30 L x T	-3.66 to 16.30	-	-	Singh *et al.* (2012)
		Bitter gourd	21 HD	-14.71 to -27.80	-	-27.80 to -1.44	Singh *et al.* (2000)
			25 L x T	-19.37 to 14.50	-	-7.38 to 12.90	Mohan (2005)
			28 HD	-25.95 to 10.93	-	-19.63 to 15.70	Laxuman (2005)
			56 FD	-50.52 to 45.35	-	-	Sundaram (2007)

Sl. No.	Character	Crop	No. of hybrids and method	Heterobeltiosis (%)	Best parent (%)	Standard Heterosis (%)	Reference
			28 HD	-20.08 to 21.43	-8.60 to 21.43	-	Jadhav *et al.* (2009)
			24 L x T	-2.42 to -41.67	-	-	Yadav *et al.* (2009)
		Pumpkin	28 crosses	-51.9 to 9.70	-	-	Mohanty (2001a)
5	Node to first female flower appearance	Cucumber	28 HD	-40.00 TO 11.11	-	-38.46 to 30.77	Dogra *et al.* (2011)
			21 HD	-10.64-to-37.96	-11.55 to -53.13	-	Jat *et al.* (2015)
		Ridge gourd	10 crosses	-21.90 to 76.73	-	-	Rao *et al.* (2000a)
			28 HD	-0.36 to -41.36	-	-42.26 to -1.85	Mole *et al.* (2001)
			45 crosses	-28.93 to 105.69	-	-	Shaha and Kale (2003b)
			28 HD	-17.08 to 36.97	-	-28.42 to 24.10	Poshiya *et al.* (2015)
		Bottle gourd	20 L x T	-31.39 to 43.76	-	-35.94 to 13.00	Singh and Kumar (2002)
			15 FD	-13.42 to 36.43	-	-	Kushwaha and Hariharram (2002)
			36 HD	-1.02 to 38.88	-	-0.85 to 28.21	Dubey and Maurya (2003)
			30 HD	-20.00 to 27.22	-	-	Sharma *et al.* (2004)
			10 HD	-28.26 to 27.53	-	-	Sreevani(2004)
			10 HD		-	-9.93 to 42.00	Upadhyay and Hariharram (2007)
6	Node to first male flower appearance	Ridge gourd	28 HD	-	-	-	Rao *et al.* (2000a)
			28 HD	-16.19 to 52.44	-	-29.59 to 27.55	Poshiya *et al.* (2015)
		Bottle gourd	30 L × T	-36.10 to 34.25	-	47.49 to 25.61	Singh and Kumar (2002)
			16 HD	-13.42 to 36.43	-		Kushwaha and Hariharram (2002)
		Bitter gourd	21 HD	-21.08 to -41.19	-	-42.97 to -18.57	Singh *et al.* (2000)
			28 HD	-	-	19.1 to 86.4	Chaubey and Hariharram (2004)
		Pumpkin	28 crosses	-43.70 to 15.50	-	-	Mohanty (2001a)
7	No. of fruits per plant	Cucumber	28 crosses	-5.60 to 67.70	-	0.00 to 22.20	Bairagi *et al.* (2005)
			28 HD	-45.71 to 15.79	-	-40.63 to 25.18	Dogra *et al.* (2011)
			21 HD	38.51 to -33.95	141 to 3.55	-	Jat *et al.* (2015)
			15 FD	7.47 to 43.51	-	-	Pandey *et al.* (2005)
		Ridge gourd	28 HD	-64.04 to 76.15	-	-	Rao *et al.* (2000a)

Sl. No.	Character	Crop	No. of hybrids and method	Heterobeltiosis (%)	Best parent (%)	Standard Heterosis (%)	Reference
			30crosses	-45.40 to 55.4	-	14.12 to 129.00	Mole *et al* (2001)
			10 crosses	-27.78 to 75.44	-	-31.53 to 154.63	Niyaria and Bhalala (2001)
			45 HD	41.64 to 83.33	-	-	Shaha and Kale (2003b)
			45 HD	-0.38 to 75.86	-	0.04 to 80.45	Hedau and Sirohi (2004a)
			28 HD	-37.89 to 57.13	-	-28.81 to 99.60	Poshiya *et al.* (2015)
		Bottle gourd	20 L × T	-39.00 to 86.70	-	-24.00 to 70.00	Singh and Kumar (2002)
			36 HD	7.50 to 143.33	-	6.52 to 95.65	Dubey and Maurya (2003)
			10 HD	-3.81 to 22.95	-	-	Sreevani (2004)
			28 HD	0.87 to 23.49	-	-	Sirohi and Rana (2007)
			10 HD	-59.00 to 4.41	-	-	Upadhyay and Hariharram (2007)
		Bitter gourd	21 HD	13.15 to 130.06	-	25.39 to 86.20	Singh *et al.* (2000)
			30 HD	4.40 to 74.05	-	-	Singh *et al.* (2001)
			25 L × T	-34.34 to 35.57	-	-42.76 to 15.86	Mohan (2005)
			28 HD	-56.02 to 16.69	-	-32.56 to 72.69	Laxuman (2005)
			21 L × T	-17.65 to 131.62	-	-	Singh *et al.* (2007)
			50 FD	-74.14 to 89.36	-	-	Sundaram (2007)
			28 HD	-23.10 to 43.72	-23.10 to 29.54	-	Jadhav *et al.* (2009)
			24 L × T	-38.14 to 1.94	-	-	Yadav *et al.* (2009)
			21 HD	2.51 to 48.75	-	-	Singh *et al.*(2013)
		Sponge gourd	36 HD	-27.54 to 112.58	-	-26.21 to 72.12	Naliyadhara *et al.* (2007)
			28 HD	34.54 to 78.40	-	-	Patel and Desai (2008)
		Musk melon	10 HD	-	-21.14 to 40.6		Kamer *et al.* (2015)
8	Fruit diameter (cm)	Cucumber	28 HD	-23.84 to 7.86	-	-11.81 to 27.99	Dogra *et al.* (2011)
			12 topcross	-6.02 to 19.50	-	-	Airina *et al.* (2013)
			21 HD	15.56 to -18.66	15.56 to -36.63	-	Jat *et al.* (2015)
			15 FD	-10.93 to 13.07	-	-	Pandey *et al.* (2005)
		Ridge gourd	10 crosses	-2.39 to 21.10	-	-2.43 to 19.54	Mole *et al.* (2001)

Sl. No.	Character	Crop	No. of hybrids and method	Heterobeltiosis (%)	Best parent (%)	Standard Heterosis (%)	Reference
			28 HD	-23.52 to 11.52	-	-	Rao and Rao (2002)
			45 HD	-9.67 to 26.43	-	-11.68 to 7.66	Shaha and Kale (2003a)
			28 HD	-9.33 to 12.00	-	-9.93 to 11.26	Poshiya *et al.* (2015)
		Bitter gourd	30 L X T	0.28 to 16.49	-	-	Singh *et al.* (2001)
			25 L X T	-19.78 to 14.35	-	-18.33 to 4.07	Mohan (2005)
			28 HD	-35.48 to 9.09	-	-32.14 to 20.24	Luxuman (2005)
			55 HD	-37.76 to 17.45	-	-	Sundaram (2007)
			21 L X T	-24.91 to 11.39	-	-	Singh *et al.* (2007)
			28 HD	-15.65 to 11.08	-20.68 to 6.05	-	Jadhav *et al.* (2009)
			90 FD	-	-	-13.43 to 25.52	Thangamani *et al.* (2011)
			21 HD	-16.62 to 4.37	-	-	Singh *et al.*(2013)
		Bottle gourd	30 L × T	-25.68 to 19.35	-	-	Sharma *et al.* (2004)
			15 HD	-8.99 to 23.15	-	8.84 to 23.02	Pandey *et al.* (2004)
			30 L x T	11.31 to -14.43	-		Singh *et al.* (2012)
		Sponge gourd	36 HD	-11.43 to 18.63	-	-14.63 to 10.74	Naliyadhara *et al.* (2007)
9	Fruit length (cm)	Cucumber	28 HD	-17.38 to 25.88	-	-14.30 to 20.60	Dogra *et al.* (2011)
			12 Topcross	-24.36 to 13.78	-	-	Airina *et al.* (2013)
			21 HD	15.42 to -13.56	15.42 to -32.03	-	Jat *et al.* (2015)
			15 FD	-60.20 to 9.92	-	-	Pandey *et al.* (2005)
		Ridge gourd	10 crosses	-36.57 to 15.56	-	-48.21 to -7.22	Mole *et al.* (2001)
			36 crosses	-45.10 to 4.67	-	-45.00 to 9.49	Niyaria and Bhalala (2001)
			28 HD	-24.24 to 23.97	-	-	Rao and Rao (2002)
			45 HD	4.91 to 24.66	-	0.38 to 18.56	Hedau and Sirohi (2004a)
			30 L × T	1.40 to 25.46	-	-	Singh *et al.* (2001)
			28 HD	-23.23 to 6.92	-	-39.64 to 7.63	Poshiya *et al.* (2015)
		Bottle gourd	10 L × T	-58.80 to 17.33	-	-54.93 to 26.19	Singh and Kumar (2002)

Sl. No.	Character	Crop	No. of hybrids and method	Heterobeltiosis (%)	Best parent (%)	Standard Heterosis (%)	Reference
			36 HD	7.50 to 143.33	-	6.52 to 95.65	Dubey and Maurya (2003)
			30 L × T	-24.15 to 2.74	-	-	Sharma *et al.* (2004)
			30 L x T	9.79 to -17.38	-	-	Singh *et al.* (2012)
			10 HD	-6.24 to 50.28	-	-	Sreevani (2004)
			28 HD	3.58 to 19.58	-	-	Sirohi and Rana (2007)
		Bitter gourd	25 L × T	-30.44 to 28.18	-	-25.40 to 7.64	Mohan (2005)
			28 HD	-29.45 to 30.31	-	-34.40 to 7.24	Laxuman (2005)
			55 HD	-52.75 to 5.36	-	-	Sundaram (2007)
			28 HD	-36.19 to 13	-36.19 to 6.28	-	Jadhav *et al.* (2009)
			24 L × T	-30.95 to 20.76	-	-	Yadav *et al.* (2009)
			90 FD		-	-59.90 to 2.25	Thangamani *et al.* (2011)
			21 HD	- 19.09 to 30.15	-	-	Singh *et al.*(2013)
10	Days to first harvest	Cucumber	12 topcross	-21.43 to 6.60	-	-	Airina *et al.* (2013)
			21 HD	-7.36 to 17.58	-4.32 to -20.74	-	Jat *et al.* (2015)
		Ridge gourd	36 HD	-11.76 to 17.97	-	-6.25 to 20.12	Niyaria and Bhalala (2001)
			45 HD	-9.79 to 22.74	-	-	Shaha and Kale (2003b)
			45 crosses	-0.34 to -13.03	-9.67 to 1.02	-	Hedau and Sirohi (2004a)
			28 HD	-16.67 to 6.95	-	-18.12 to 5.08	Poshiya *et al.* (2015)
		Bottle gourd	20 L x T	-33.74 to 12.09	-	-5.91 to -37.92	Singh and Kumar (2002)
			15 HD	-7.13 to 11.05	-	-	Kushwaha and Hariharram (2002)
			36 HD	-0.44 to 7.92	-	-0.74 to 11.36	Dubey and Maurya (2003)
			30 L x T	-10.59 to 12.22	-	-	Sharma *et al.* (2004)
			28 HD	-15.21 to 10.25	-	-	Sirohi and Rana (2007)
			30 L x T	-3.57 to16.13	-	-	Singh *et al.* (2012)
		Bitter gourd	21 HD	-6.19 to -22.20	-	-6.20 to 0.00	Singh *et al.* (2000)
			30 HD	-0.47 to 5.97	-	-	Singh *et al.* (2001)
			25 L x T	-20.65 to 10.65	-	-8.04 to 17.09	Mohan (2005)
			28 HD	-14.46 to 9.90	-	10.83 to 13.27	Laxuman (2005)

Sl. No.	Character	Crop	No. of hybrids and method	Heterobeltiosis (%)	Best parent (%)	Standard Heterosis (%)	Reference
			21 L x T	-57.00 to 9.95	-	-	Singh *et al.* (2007)
			28 HD	-16.39 to 11.49	-	-12.67 to 12.02	Jadhav *et al.* (2009)
			90 FD		-	-8.49 to 5.45	Thangamani *et al.* (2011)
		Sponge gourd	36 FD	-6.19 to 21.89	-	-17.56 to 5.6	Naliyadhara *et al.* (2007)
			28 HD	-24.71 to 8.94	-	-	Patel and Desai (2008)
11	Average fruit weight (g)	Cucumber	12 Topcross	-0.18 to 43.36	-	-	Airina *et al.* (2013)
			21 HD	-20.32 to 6.92	-35.20 to 6.92	-	Jat *et al.* (2015)
		Ridge gourd	10 crosses	-35.00 to 3.13	-	-	Mole *et al.* (2001)
			28 HD	-21.56 to 26.41	-	-	Rao and Rao (2002)
			45 HD	-20.80 to 19.99	-	-	Shaha and Kale (2003a)
			45 HD	1.20 to 16.15	-	-	Hedau and Sirohi (2004)
			28 HD	-21.83 to 13.57	-	-32.31 to 13.14	Poshiya *et al.* (2015)
		Bottle gourd	10 L × T	-16.19 to 54.16	-	-16.19 to 66.66	Singh and Kumar (2002)
			15 HD	-32.65	-	41.81	Pandey *et al.* (2004)
			30 L × T	-25.68 to 19.35	-	-	Sharma *et al.* (2004)
			28 HD	0.66 to 39.78	-	-	Sirohi and Rana (2007)
			30 L x T	16.67 to 15.13	-	-	Singh *et al.* (2012)
		Bitter gourd	21 HD	-46.57 to 53.85	-	-	Singh *et al.*(2013)
		Sponge gourd	36 HD	-11.43 to 18.63	-	-14.63 to 10.74	Naliyadhara *et al.* (2007)
		Musk melon	10 HD	-	-27.06	-	Kamer *et al.* (2015)
12	Fruit yield per vine (kg)	Cucumber	12 Topcross	-24.28 to 445.82	-	-	Airina *et al.* (2013)
			21 HD	-1.26 to 45.54	-4.38 to 64.51	-	Jat *et al.* (2015)
		Ridge gourd	45 HD	-14.09 to 50.81	-	-2.26 to 99.71	Mole *et al.*(2001)
			36 crosses	-46.05 to 67.88	-	-18.11 to 121.5	Niyaria and Bhalala (2001)
			28 HD	-41.66 to 200.13	-	-	Rao and Rao (2002)
			45 HD	2.05 to 93.09	-	2.49 to 93.09	Hedau and Sirohi (2004a)
			18 crosses	-27.30 to 57.22	-	-48.85 to 33.10	Ahmed *et al.* (2006)

Sl. No.	Character	Crop	No. of hybrids and method	Heterobeltiosis (%)	Best parent (%)	Standard Heterosis (%)	Reference
			18 crosses	-58.33 to 112.34	-	74.09 to 24.04	Neeraja (2008)
			28 HD	-45.93 to 67.46	-	-52.12 to 80.51	Poshiya *et al*. (2015)
		Bottle gourd	20 L × T	-35.17 to 80.50	-	-10.61 to 72.73	Singh and Kumar (2002)
			15 HD	-40.28 to 69.91	-	-26.60 to 76.19	Kushwaha and Hariharram (2002)
			36 HD	3.11 to 91.02	-	-	Dubey and Maurya (2003)
			30 L × T	-27.46 to 52.16	-	1.86 to 84.47	Sharma *et al.* (2004)
			10 HD	47.89 to 98.12	-	-	Sreevani (2004)
			30 L x T	66.73 to 27.55	-	-	Singh *et al.* (2012)
		Bitter gourd	21 HD	25.85 to 20.00	-	38.13 to 100.00	Singh *et al.* (2000)
			30 L T	4.85 to 95.31	-	-	Singh *et al.* (2001)
			25 L × T	-31.11 to 84.88	-	-50.42 to 25.43	Mohan (2005)
			28 HD	-58.27 to 73.51	-	-56.83 to 23.16	Laxuman (2005)
			56 FD	-41.13 to 94.70	-	-	Sundaram (2007)
			28 HD	-38.91 to 63.14	-38.91 to 41.48	-	Sundaram (2007)
			24 L × T	-10.29 to 58.51	-	-	Jadhav *et al.* (2009)
			90 FD	-	-	-10.61 to 72.73	Thangamani *et al.* (2011)
		Sponge gourd	36 HD	-23.57 to 69.10	-	-25.26 to 53.56	Naliyadhara *et al.* (2007)
			36 HD	23.70 to 51.55	-	-	Patel and Desai (2008)
13	Cavity thickness (cm)	Ridge gourd	45 HD	1.69 to 29.76	-	-	Abusaleha and Dutta (1994)
		Bottle gourd	10 crosses	-5.11 to 34.05	-	-	Sreevani (2004)
		Bitter gourd	28 HD	-38.62 to 38.27	-38.62 to 21.71	-	Jadav *at al*. (2009)
		Sponge gourd	28 HD	1.96 to 15.90	-	-	Abusaleha and Dutta (1995)
		Muskmelon	28 crosses	-	17.37 to 20.33	2.97 to 7.81	Choudary *et al*. (2003)
			15 crosses	-18.84 to 64.92	-	5.00 to 144.60	Vishwanatha (2003)
14.	Flesh thickness (cm)	Cucumber	28 HD	-	-	-32.01 to 11.11	Kaur *et al.* (2016)
			28 HD	-32.93 to 26.67	-	-20.31 to 21.88	Dogra *et al*. (2011)
15.	Rind thickness (mm)	Cucumber	77 L × T	-8.48 to 3.03	-		Pandey *et al*. (2005)

Sl. No.	Character	Crop	No. of hybrids and method	Heterobeltiosis (%)	Best parent (%)	Standard Heterosis (%)	Reference
		Ridge gourd	51 L × T	22.57 to 27.27	-	1.57 to 8.07	Narasannavar *et al*. (2014)

HD- Half diallel FD- Full diallel L × T- Line × tester

Table 2. Review of literature on combining ability and gene action on various traits in cucumber and other cucurbit vegetables

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
1	Vine length (cm)	Cucumber	8 × 8 HD	Highly Significant	-	+	-	Bairagi *et al*.(2001)
			36 L × T	Highly Significant	Highly Significant	+	+	Singh *et al*.(2011)
			8 × 8 HD	Highly Significant	Highly Significant	+	+	Bairagi *et al.* (2013)
		Ridge gourd	8 × 8 FD	Significant	Highly Significant	+	+	Rao *et al.*(2000b)
			10 × 10 HD	Significant	Significant	+	+	Shaha and Kale (2003b)
			8 × 8 FD	Highly Significant	Highly Significant	+	+	Purohit *et al*.(2007)
			18 L × T	Highly Significant	Highly Significant	+	+	Ahmed *et al*.(2006)
			18 L × T	Highly Significant	Highly Significant	+	+	Neeraja (2008)
		Bottle gourd	10 × 10 HD	Highly Significant		-	+	Maurya *et al*.(2004)
			9 × 9 HD	Significant	Significant	+	+	Dubey and Maurya (2006)
			9 × 9 HD	Highly Significant	Highly Significant	-	+	Sharma *et al*.(2007)
		Bitter gourd	10 × 3 L × T	Highly Significant	Highly Significant	+	+	Khattra *et al.*(2000)
			8 × 8 D	Highly Significant	Highly Significant	+	-	Singh *et al*.(2004)
			5 × 5 L × T	Significant	Significant	+	+	Mohan (2005)
			8 × 8 HD	Significant	Significant	+	+	Laxuman (2005)
			9 × 9 HD	Highly Significant	Highly Significant	+	+	Gupta *et al*.(2006)
			8 × 8 FD	Significant	Significant	+	+	Sundaram (2008)

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
			7 × 7 HD	Significant	Significant	+	+	Singh *et al.*(2013)
		Pumpkin	8 × 8 HD	Significant	Significant	+	+	Mohanty (2000 a)
			8 × 8 HD	Significant	Significant	+	+	Mohanty (2000 b)
2	No. of branches	Cucumber	8 × 8 HD	Highly Significant	Highly Significant	+	-	Bairagi *et al.*(2001)
			36 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.*(2011)
			8 × 8 HD	Highly Significant	Highly Significant	+	+	Bairagi *et al.* (2013)
		Ridge gourd	18 L × T	Highly Significant	-	+	-	Ahmed *et al.* (2006)
			8 × 8 FD	Highly Significant	Highly Significant	+	+	Purohit *et al.* (2007)
			18 L × T	Highly Significant	Highly Significant	+	+	Neeraja (2008)
		Bottle gourd	9 × 9 HD	Significant	Significant	+	+	Dubey and Maurya (2003)
			10 × 3 L × T	-	Significant	-	+	Maurya *et al.* (2004)
			9 × 9 HD	Significant	Significant	+	+	Dubey and Maurya (2006)
		Bitter gourd	5 × 5 L × T	Significant	Significant	+	+	Mohan (2005)
			9 × 9 HD	Significant	Significant	+	+	Laxuman (2005)
			8 × 8 HD	Significant	Significant	+	+	Sundaram(2008)
		Sponge gourd	10 × 10 FD	Significant	Significant	+	+	Ram *et al.*(2007)
		Pumpkin	8 × 8 HD	Highly Significant	Highly Significant	+	+	Mohanty (2000 a)
			8 × 8 HD	Significant	-	+	+	Mohanty (2000 b)
3	Number of nodes per vine	Cucumber	36 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.*(2011)
4	Days to first female flower anthesis	Cucumber	5 × 5 HD	Significant	Significant	+	+	Ananthan and Pappiah (2000)
			36 L × T	Highly	Highly	+	+	Singh *et al.*(2011)

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
				Significant	Significant			
			8 × 8 HD		Highly Significant	+	-	Bairagi *et al.* (2001)
			8 × 8 HD	Highly Significant	Highly Significant	+	+	Bairagi *et al.* (2013)
		Ridge gourd	8 × 8 FD	Significant	Highly Significant	+	+	Rao *et al.* (2000b)
			18 L × T	Highly Significant	Highly Significant	+	+	Ahmed (2006)
		Bottle gourd	10 × 3 L × T	Significant	-	+	-	Maurya *et al.* (2004)
			8 × 8 HD	Significant	Significant	+	+	Dubey and Maurya(2006)
			9 × 9 HD	Highly Significant	Highly Significant	+	+	Sharma *et al.* (2007)
			15 × 3 L × T	Significant	-	+	-	Wani *et al.* (2009)
		Bitter gourd	10 × 3 L × T	-	Highly Significant	-	+	Khattra *et al.*(2000)
			8 × 8 HD	Significant	Significant	+	+	Singh *et al.* (2004)
			5 × 5 L × T	Significant	Significant	+	+	Mohan (2005)
			8 × 8 HD	Significant	Significant	+	+	Laxuman (2005)
			9 × 9 HD	Highly Significant	Highly Significant	+	+	Gupta *et al.* (2006)
		Sponge gourd	10 × 10 FD	Significant	Significant	+	+	Ram *et al.* (2007)
		Pumpkin	8 × 8 HD	Significant	Significant	+	+	Mohanty and Mishra (2000)
			8 × 8 HD	Significant	Significant	+	+	Mohanty (2001b)
5	Node to first male flower appearance	Cucumber	36 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.*(2011)
		Ridge gourd	8 × 8 FD	Significant	Highly Significant	+	+	Rao *et al.* (2000 b)
			18 L × T	Highly Significant	Highly Significant	+	+	Ahmed *et al.* (2006)

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
		Bottle gourd	8 × 8 HD	Significant	-	+	-	Maurya *et al.* (2004)
		Bitter gourd	10 × 3 L × T	Significant	Significant	+	+	Singh *et al.* (2004)
6	Node to first female flower appearance	Cucumber	8 × 8 HD	Highly Significant	Highly Significant	+	-	Bairagi *et al.*(2001)
			36 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.*(2011)
			8 × 8 HD	Highly Significant	Highly Significant	+	+	Bairagi *et al.* (2013)
		Ridge gourd	8 × 8 FD	Significant	Highly Significant	+	+	Rao *et al.* (2000 a)
			10 × 10FD	Significant	Significant	+	+	Rao *et al.* (2000 b)
			18 L × T	Highly Significant	Highly Significant	+	+	Ahmed *et al.* (2006)
			18 L × T	Highly Significant	Highly Significant	+	+	Neeraja (2008)
		Bottle gourd	10 × 3 L × T	Significant	-	+	-	Maurya *et al.*(2004)
			9 × 9 HD	Significant	Significant	+	+	Dubey and Maurya (2006)
			15 × 3 L × T	Significant	-	+	+	Wani *et al.* (2009)
		Bitter gourd	8 × 8 HD	Significant	Significant	+	+	Singh *et al.*(2004)
			5 × 5 L × T	Significant	Significant	+	+	Mohan (2005)
			8 × 8 HD	Significant	Significant	+	+	Laxuman (2005)
			9 × 9 HD	Highly significant	Highly significant	+	+	Gupta *et al.*(2006)
			8 × 8 FD	Significant	Significant	+	+	Sundaram (2008)
			10 × 10 FD	Significant	Significant	+	+	Thangamani *et al.*(2011)
		Pumpkin	8 × 8 HD	Significant	Significant	+	+	Mohanty and Mishra(2000)
			8 × 8 HD	Significant	Significant	+	+	Mohanty (2001b)
7	No. of fruits per vine	Cucumber	36 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.*(2011)

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
			8 × 8 HD	Highly Significant	Highly Significant	+	+	Bairagi *et al.* (2013)
		Ridge gourd	10 × 10 H	Significant	Significant	+	+	Shaha and Kale (2003b)
			8 × 8 HD	Significant	Highly Significant	+	+	Rao *et al.* (2000b)
			10 × 10 HD	Significant	Significant	+	+	Hedau and Sirohi (2004b)
			8 × 8 FD	Highly Significant	Highly Significant	+	+	Purohit *et al.*(2007)
			6 × 3L × T	Highly Significant	Highly Significant	+	+	Ahmed *et al.*(2006)
			6 × 3L × T	Highly Significant	Highly Significant	+	+	Neeraja (2008)
		Bottle gourd	9 × 9 HD	Significant	Significant	+	+	Dubey and Maurya (2006)
			15 × 3 L × T	Significant	Significant	+	+	Wani *et al.*(2009)
			30 L x T	Significant	Highly Significant	+	+	Singh *et al.* (2012)
		Bitter gourd	10 × 3 L × T	Highly Significant	Highly Significant	+	+	Khattra *et al.* (2000)
			8 × 8 FD	Significant	Significant	+	+	Singh *et al.*(2004)
			5 × 5 L × T	Significant	Significant	+	+	Mohan (2005)
			8 × 8 HD	Significant	Significant	+	+	Laxuman (2005)
			9 × 9 HD	Significant	Significant	+	+	Gupta *et al.*(2006)
			9 × 9 FD	Significant	Significant	+	+	Sundaram (2008)
			10 × 10 FD	Significant	Significant	+	+	Thangamani *et al.*(2011)
			7 × 7 HD	Significant	Significant	+	+	Singh *et al.*(2013)
		Pumpkin	8 × 8 HD	Significant	-	+	+	Mohanty (2000a)
			8 × 8 HD	Significant	Significant	+	+	Mohanty (2000b)
		Watermelon	8 × 8 HD	Highly Significant	Highly Significant	+	+	Sapovadiya *et al.*(2014)

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
8	Fruit diameter (cm)	Cucumber	36 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.*(2011)
			8 × 8 HD	Highly Significant	Highly Significant	+	+	Bairagi *et al.* (2013)
		Ridge gourd	8 × 8 FD	Significant	Highly Significant	+	+	Rao *et al.*(2000 b)
			10 × 10 HD	Significant	Significant	+	+	Shaha and Kale (2003b)
			10 × 10 HD	Highly Significant	-	+	-	Hedau and Sirohi (2004b)
			6 × 3 L × T	Highly Significant	Highly Significant	+	+	Ahmed *et al.* (2006)
			6 × 3 L × T	Highly Significant	Highly Significant	+	+	Neeraja (2008)
		Bottle gourd	15 × 3 L × T	Significant	-	+	-	Wani *et al.* (2009)
		Bitter gourd	30 L x T	Significant	Highly Significant	+	+	Singh *et al.* (2012)
			5 × 5 L × T	Significant	Significant	+	+	Mohan (2005)
			8 × 8 HD	Significant	Significant	+	+	Laxuman (2005)
			9 × 9 HD	Highly Significant	Highly Significant	+	+	Gupta *et al.*(2006)
			8 × 8 FD	Significant	Significant	+	+	Sundaram (2008)
			10 × 10 FD	Significant	Significant	+	+	Thangamani *et al*. (2011)
			7 × 7 HD	Significant	Significant	+	+	Singh *et al.*(2013)
9	Fruit length (cm)	Cucumber	36 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.*(2011)
			8 × 8 HD	Highly Significant	Highly Significant	+	+	Bairagi *et al.* (2013)
		Ridge gourd	8 × 8 FD	Highly Significant	Significant	+	+	Rao *et al.*(2000 b)

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
			10 × 10 HD	Significant	Significant	+	+	Hedau and Sirohi (2004b)
			6 × 3 L × T	Highly Significant	Highly Significant	+	+	Ahmed *et al.*(2006)
			8 × 8 FD	Highly Significant	Highly Significant	+	+	Purohit *et al.*(2007)
			6 × 3 L × T	Highly Significant	Highly Significant	+	+	Neeraja (2008)
		Bottle gourd	10 × 3 L × T	Significant	-	+	-	Maurya *et al.* (2004)
			9 × 9 HD	Significant	Significant	+	+	Dubey and Maurya (2007)
			15 × 3 L × T	Significant	-	+	-	Wani *et al.*(2009)
			30 L x T	Significant	Highly Significant	+	+	Singh *et al.* (2012)
		Bitter gourd	10 × 3 L × T	Highly Significant	Highly Significant	+	+	Khattra *et al.*(2000)
			8 × 8 HD	Significant	Significant	+	+	Singh *et al.*(2004)
			5 × 5L × T	Significant	Significant	+	+	Mohan (2005)
			8 × 8 HD	Significant	Significant	+	+	Laxuman (2005)
			9 × 9 HD	Highly Significant	Highly Significant	+	+	Gupta *et al.*(2006)
			8 × 8 FD	Significant	Significant	+	+	Sundaram (2008)
			10 × 10 FD	Significant	Significant	+	+	Thangamani *et al.* (2011)
			7 × 7 HD	Significant	Significant	+	+	Singh *et al.*(2013)
		Sponge gourd	8 × 8 HD	-	Highly Significant	+	+	Patel and Desai (2008)
10	Days to first harvest	Cucumber	36 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.*(2011)
			8 × 8 HD	Highly Significant	Highly Significant	+	+	Bairagi *et al.* (2013)
		Ridge gourd	10 × 10 FD	Significant	Significant	+	+	Shaha and Kale (2003b)

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
			18 LXT	Highly Significant	Highly Significant	+	+	Ahmed *et al.*(2006)
			8 × 8 FD	Highly Significant	Highly Significant	+	+	Purohit *et al.*(2007)
		Bottle gourd	9 × 9HD	Significant	Significant	+	+	Samadia and Khandelwal (2002)
			10 × 3 L × T	Significant	-	+	-	Maurya *et al.*(2004)
			9 × 9 HD	Highly Significant	Highly Significant	+	+	Dubey and Maurya (2006)
			9 × 9 HD	Highly Significant	Highly Significant	+	+	Sharma *et al.*(2007)
			15 × 3 L × T	Significant	-	+	-	Wani *et al*. (2009)
			30 L x T	Significant	Highly Significant			Singh *et al.* (2012)
			30 L x T	Significant	Highly Significant	+	+	Singh *et al.* (2012)
		Bitter gourd	10 × 3 L × T	Highly Significant	Highly Significant	-	+	Khattra *et al.* (2000)
			6 × 6 HD	-	Highly Significant	-	+	Bahve *et al.*(2004)
			7X 3 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.*(2006)
			5 × 5 L × T	Significant	Significant	+	+	Mohan (2005)
			8 × 8 HD	Significant	Significant	+	+	Laxuman (2005)
			9 × 9 HD	Highly Significant	Highly Significant	+	+	Gupta *et al.*(2006)
			8 × 8 FD	Significant	Significant	+	+	Sundaram (2008)
			10 × 10 FD	Significant	Significant	+	+	Thangamani (2011)
			7 × 7 HD	Significant	Significant	+	+	Singh *et al.*(2013)
11	Average fruit weight (g)	Cucumber	36 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.*(2011)

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
			8 × 8 HD	Highly Significant	Highly Significant	+	+	Bairagi *et al.* (2013)
		Ridge gourd	8 × 8 FD	Significant	Highly Significant	+	+	Rao *et al.*(2000b)
			10 × 10HD	Significant	Significant	+	+	Shaha and Kale (2003b)
			8 × 8 FD	Highly Significant	Highly Significant	+	+	Purohit *et al.*(2007)
			6 × 3 L × T	Highly Significant	Highly Significant	+	+	Ahmed *et al.*(2006)
			6 × 3 L × T	Highly Significant	Highly Significant	+	+	Neeraja (2008)
		Bottle gourd	10 × 3 L × T	Highly Significant	-	+	-	Maurya *et al.* (2004)
			15 × 3 L × T	Significant	-	+	-	Wani *et al.*(2009)
			30 L x T	Significant	Highly Significant	+	+	Singh *et al.* (2012)
		Bitter gourd	10 × 3 L × T	Highly Significant	Highly Significant	+	-	Khattra *et al.* (2000)
			5 × 5 L × T	Significant	Significant	+	+	Mohan (2005)
			7 × 3 L × T	Highly Significant	Highly Significant	+	+	Singh *et al.* (2006)
			8 × 8 HD	Significant	Significant	+	+	Sundaram (2008)
			10 × 10 HD	Significant	Significant	+	+	Thangamani *et al.* (2011)
			7 × 7 HD	Significant	Significant	+	+	Singh *et al.*(2013)
		Pumpkin	8 × 8 HD	Significant	Significant	+	+	Mohanty (2000a)
			8 × 8 HD	Significant	Significant	+	+	Mohanty (2000b)
		Watermelon	8 × 8 HD	Highly Significant	Highly Significant	+	+	Sapovadiya *et al.*(2014)
12	Fruit yield per plant (kg)	Cucumber	8 × 8L × T	Highly Significant	Highly Significant	+	-	Bairagi *et al.*(2001)

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
			8 × 8 HD	Highly Significant	Highly Significant	+	+	Bairagi *et al.* (2013)
		Ridge gourd	8 × 8 FD	Significant	Highly Significant	+	+	Rao *et al.* (2000 b)
			10 × 10 HD	Significant	Significant	+	+	Shaha and Kale (2003b)
			10 × 10 HD	Significant	Significant	+	+	Hedau and Sirohi (2004b)
			6 × 3 L × T	Significant	Significant	+	+	Ahmed *et al.* (2006)
			8 × 8 FD	Highly Significant	Highly Significant	+	+	Purohit *et al.* (2007)
			6 × 3 L × T	Significant	Highly Significant	-	+	Neeraja (2008)
		Bottle gourd	10 × 3 L × T	Significant	-	+	-	Maurya *et al.* (2004)
			9 × 9 HD	Significant	Significant	+	+	Dubey and Maurya (2007)
			9 × 9 HD	Highly Significant	Highly Significant	+	+	Sharma *et al.* (2007)
			30 L x T	Significant	Highly Significant	+	+	Singh *et al.* (2012)
		Bitter gourd	10 × 3 L × T	Highly Significant	Highly Significant	+	+	Khattra *et al.*(2000)
			5 × 5 L × T	Significant	Significant	+	+	Mohan (2005)
			8 × 8 HD	Significant	Significant	+	+	Laxuman (2005)
			9 × 9HD	Highly Significant	Highly Significant	+	+	Gupta *et al.* (2006)
			8 × 8 FD	Significant	Significant	+	+	Sundaram (2008)
			10 × 10 FD	Significant	Significant	+	+	Thangamani (2011)
			7 × 7 HD	Significant	Significant	+	+	Singh *et al.*(2013)
		Sponge gourd	10 × 10FD	Significant	Significant	+	+	Ram *et al.* (2007)
		Pumpkin	8 × 8 HD	Significant	Significant	+	+	Mohanty (2000 a)

Sl. No.	Character	Crop	Material and Method used	Combining ability		Gene action		Reference
				GCA	SCA	Additive	Non-additive	
			8 × 8 HD	Significant	Significant	+	+	Mohanty (2000 b)
		Watermelon	8 × 8 HD	Highly Significant	Highly Significant	+	+	Sapovadiya *et al.*(2014)
13	Cavity thickness (cm)	Cucumber	8 × 8 HD	Significant	-	+	+	Ananthan and Pappiah (2000)
			36 L × T	Significant	Significant	+	+	Singh *et al.*(2011)
		Pumpkin	8 × 8 HD	Significant	Significant	+	+	Mohanty (2000 a)
			8 × 8 HD	Significant	Significant	+	+	Mohanty (2000 b)
14	Rind thickness (mm)	Muskmelon	8 × 8 HD	Highly Significant	Highly Significant	+	+	Vashisht *et al.* (2010)
			5 × 5 FD	Highly Significant	Highly Significant	+	+	Bayoumy *et al.* (2014)

HD- Half diallel FD- Full diallel L × T- Line × tester

III. MATERIAL AND METHODS

The present study was carried out to assess heterosis and combining ability in cucumber was undertaken during the year 2016-17. The details of experiment, materials used and techniques adopted in the present investigation are presented in this chapter.

3.1 Experimental site

The experiment was conducted in the Research Block of the Department of Vegetable Science, College of Horticulture, UHS campus, GKVK, Bengaluru-65.

3.2 Location and climate

The experimental plot is located at an altitude of 930 m above the mean sea level and that comes under the Eastern dry zone of Karnataka. It is situated at 12°58' latitude north and 77°11' longitude east. The soil texture was red sandy loam, friable, good water holding capacity and slightly acidic in nature (pH 5). The climatic conditions were moderate and suitable for cucumber cultivation. The details of the meteorological data on weather conditions that prevailed during the experimentation period are presented in Appendix-I.

3.3 Experimental materials

The experimental materials consisted of 5 Lines and 5 Testers of cucumber collected from the germplasm maintained by the Department of Vegetable Science, College of Horticulture, UHS Campus, GKVK, and Bengaluru. Their 25 F_1's were developed by crossing them in Line X Tester mating design. In the present study the following are the parental lines and testers along with their sources are listed below in Table 3. Among the 10 genotypes, 5 collections were used as lines and the remaining 5 genotypes were selected as testers based on their yield and its contributing characters.

Table 3. Details of cucumber parental lines with their sources

Sl. No.	Genotypes	Source
	Lines	
1	IIHR-285	IIHR, Bengaluru
2	IIHR-341	IIHR, Bengaluru
3	IIHR-304	IIHR, Bengaluru
4	Green Long	College of Horticulture, Bengaluru
5	Pondicherry-1	PAJANCOA, Puducherry
	Testers	
7	Poinsette	College of Horticulture, Bengaluru
8	Phule Shubhangi	MPKV, Rahuri, PAU, Ludhiana
9	Punjab Naveen	College of Horticulture, Bengaluru
10	Pusa Uday	IARI, New Delhi
11	Kerala-1	College of Horticulture, Bengaluru

3.4 Methods

3.4.1 Development of F_1 hybrids

The investigation consisted of a field experiment conducted during *Kharif* season of 2016 for attempting crosses in Line X Tester fashion. All the recommended cultivation practices were followed to raise a good crop.

3.4.2 Crossing technique

A day before anthesis or on the previous day of anthesis, fully matured buds of male parent and female flower buds of seed parent were bagged using butter paper bags. On the next day, between 6 and 8 am the pollen grains from the male flowers of male parent were collected and dusted on to the stigmatic surface of the female flowers of the female parent. The pollinated flowers were labelled and covered with butter paper bags.

Plate 1: Fruits of Lines and Testers

3.5 Studies on heterosis and combining ability

3.5.1 Evaluation of F_1's, along with parents and a commercial check

Experiment was undertaken in *Kharif* season of 2016-17 at Research Block of the Department of Vegetable Science, College of Horticulture, Bengaluru under open field condition. Other details of experiment are given below.

Mating design : Line X Tester

Experiment design : Randomized Complete Block Design

No. of replications : 2

Spacing : 1.5 m×1 m

No. of genotypes : Lines-5

Testers-5

No. of crosses : 25

Commercial Check : Chitra

Total : 36

3.5.2 Cultural operations

3.5.2.1 Land preparation

The experimental field ploughed, harrowed and made into a fine tilth. Well decomposed farm yard manure at the rate of 25 tonnes per hectare was applied along with the commercial fertilizer dose of 60:50:80 kg NPK per hectare. According to the fertilizer application schedule full doses of phosphorous, potassium and half dose of nitrogen was applied as basal dose and the remaining half of nitrogen was top dressed after 30 days of transplanting.

3.5.2.2 Nursery raising and transplanting

Seeds were sown into protrays filled with coir pith. Necessary plant protection measures were taken up before and after seed sowing. The 12 days old seedlings were transplanted into main field. The experimental plot was irrigated uniformly just before transplanting and thereafter at an interval of two days depending upon the soil and climate condition.

Plate 2 : General view of the crossing block (L × T) at field.

Plate 3: General view of the crossing block (L × T) at poly house

3.5.2.3 Intercultural operations

All necessary care was taken to establish a healthy cucumber crop. Plots were kept free from weeds by hand weeding at regular intervals and prophylactic sprays taken against pest and diseases at different intervals. Other intercultural practices were undertaken such as earthing up, drenching, staking, irrigation as per the package of practices for horticultural crops given by University of Horticultural Sciences, Bagalkot.

3.5.3 Observations recorded

Each treatment was replicated twice consisting 10 plants in individual replication. Five representative plants from each treatment were selected randomly, tagged and observations were recorded on these plants. The data recorded on five plants from each treatment was averaged and used for statistical analysis. The details of observations recorded and techniques for recording observations were as follows.

3.5.3.1 Growth parameters

3.5.3.1.1 Vine length (cm)

The length of the vine from the collar to the tip was measured in all the five representative plants in each treatment at final harvest. Mean was calculated and expressed in centimetres.

3.5.3.1.2 Number of branches per plant

The total number of branches was counted at final harvest in all the five representative plants in each treatment at final harvest and mean was calculated.

3.5.3.1.3 Number of nodes per vine

The number of nodes per vine on the main stem was counted at final harvesting in all the five representative plants in each treatment at final harvest and mean was calculated.

3.5.3.1.4 Node of first female flower appearance

The node number from the cotyledonary leaves at which the first female flower appeared was recorded in all the five representative plants in each treatment and mean was calculated.

3.5.3.1.5 Node of first male flower appearance

The node number from the cotyledonary leaves at which the first male flower appeared was recorded in all the five representative plants in each treatment and mean was calculated.

3.5.3.1.6 Days to first female flower anthesis

Number of days taken from the date of transplanting to the appearance of the first female flower on the vine was recorded in all the five representative plants in each treatment and mean was calculated.

3.5.3.1.7 Days to first fruit harvest

Number of days taken from the date of transplanting to first fruit harvest was recorded in all the five representative plants in each treatment and mean was calculated.

3.5.3.2 Yield parameters

3.5.3.2.1 Number of fruits per plant

The number of fruits per vine upto the last harvest were counted in all the five representative plants in each treatment and mean was calculated.

3.5.3.2.2 Average fruit weight (g)

The weight of five individual fruits harvested at the edible stage was recorded. The average weight of the fruit was calculated and expressed in gram.

3.5.3.2.3 Fruit yield per plant (kg)

The weight of all the fruits per vine was recorded in all the five representative plants in each treatment. Mean was calculated and expressed in kilo gram.

3.5.3.2.4 Fruit length (cm)

Length of five fruits harvested at edible maturity was recorded from base to the apex of fruit in all the five representative plants in each treatment. Mean was calculated and expressed in centimetre.

3.5.3.2.5 Fruit diameter (cm)

Diameter of the five fruits selected for recording the length, was measured in centimetre with the help of Vernier calliper. Mean was calculated and expressed in centimetre.

3.5.3.3 Quality parameters

3.5.3.3.1 Fruit rind thickness (mm)

The rind thickness was measured by Vernier calliper. Mean was calculated and expressed in milimetre.

3.5.3.3.2 Fruit flesh thickness (cm)

The fruit flesh thickness was measured by Vernier calliper. Mean was calculated and expressed in centimetre.

3.5.3.3.3 Fruit cavity at harvesting (cm)

The flesh thickness without the skin was measured using Vernier calliper by cutting the fruit in equatorial plane. Mean was calculated and expressed in centimetre.

Plate 4: General view of the experimental plot of F_1 hybrids

3.5.3.3.4 Shelf life (days)

To study the shelf life of fruits, five fruits were collected after harvest from each treatment and kept at room temperature. Fruits were observed for retention of freshness and firmness. Number of days the fruits were looking fresh was recorded based on visual observation and expressed in days.

3.5.3.3.5 Color of the fruit

Color of the fruit was recorded according to visual observation. DUS guideline that is Creamy white, Yellow, Light green, Dark green are presented in Appendix-II.

3.5.3.3.6 Spines on the fruit surface

Spines on the fruit surface were recorded according to DUS guidelines are presented in Appendix-II.

3.5.4 Statistical and biometrical analysis

3.5.4.1 Analysis of variance

Analysis of variance was carried out separately for all the characters. The population mean for each of the replication was calculated for 36 entries from five plants in each entries. The model of analysis of variance adopted is given below.

Source of variation	Degrees of freedom (d.f.)	Sum of squares (SS)	Mean sum of squares (MSS)	F value
Replication	r-1	**SSr**	Mr	Mr / Me
Treatments	t-1	**SSt**	Mt	Mt / Me
Error	(r-1) (t-1)	**SSe**	Me	
Total	(rt-1)			

Where,

r = Number of replications
t = Number of treatments
MSS = Sum of squares/ d.f.
Mr = Mean sum of square due to replication
Mt = Mean sum of square due to treatments
Me = Mean sum of square due to error

3.5.4.1 Estimation of heterosis

The mean of all the replications for each parents, hybrids and check for each of the characters was computed and used in estimation of heterosis. Heterosis was calculated as the

percentage increase or decrease of mean $\bar{F}_1$ performance ($\bar{F}_1$) over the means of better parent ($\overline{BP}$), the best parent ($\overline{BTP}$) and the commercial check ($\overline{CC}$).

1) Heterosis over better parent (%) (Heterobeltiosis) = $\frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100$

Where, $\overline{BP}$ is the mean of better parent involved in development of respective F_1.

2) Heterosis over best parent (%) = $\frac{\bar{F}_1 - \overline{BTP}}{\overline{BTP}} \times 100$

Where, $\overline{BTP}$ is the superior parent involved in the development of respective F_1.

3) Heterosis over commercial check (%) (Standard Heterosis) = $\frac{\bar{F}_1 - \overline{CC}}{\overline{CC}} \times 100$

Where, $\overline{CC}$ is the mean of commercial checks.

3.5.4.2 Combining ability

Information about general combining ability (GCA) and specific combining ability (SCA) were obtained by subjecting the data to line x tester analysis as outlined by Kempthorne (1957).

ANOVA for combining ability

Sources	Degrees of freedom	Mean sum of squares	Expected mean sum of squares
Replication	(r - 1)		
Genotype	(*l* + t + *l*t - 1)	Mg	
Parents	(*l* + t - 1)	Mp	
Parents Vs crosses	1	Mpc	
Crosses	(*l*t - 1)	Mc	
Lines	(*l* - 1)	M_1	σ^2 + rCov(F.S) – 2Cov (F.S.)+ lrCov (H.S.)
Testers	(t - 1)	M_2	σ^2 + rCov (F.S) – 2Cov (F.S.) + trCov(H.S.)
Line x tester	(*l* - 1) x (t - 1)	M_3	σ^2 + rCov(F.S) – 2Cov(F.S.)
Error	(*l* + t + *l*t - 1) (r - 1)	M_4	$\sum^2$
Total	(*l*tr-1)		

Where

r = number of replications
l = number of lines
t = number of testers
Cov(FS) = Covariance of full sibs
Cov(HS) = Covariance of half sibs

For the expectations of the mean sum of squares the following estimates were worked out.

$$\sigma^2_{gca} = Cov\ HS = \frac{1}{r(2lt - 1 - t)}\left[\frac{(l-1)M_1 + (t-1)M_2}{l+t+2} - M_3\right]$$

$$\sigma^2_{gca} = \frac{M_3 - M_4}{r}$$

Variance due to GCA= Cov (HS)

Variance due to SCA = Cov (FS) – 2 Cov (HS)

$$\text{GCA variance for lines} = \frac{(M_1\text{-}M_3)}{rm}$$

$$\text{GCA variance for testers} = \frac{(M_2\text{-}M_3)}{rf}$$

$$\text{SCA variance for hybrids} = \frac{(M_2\text{-}M_3)}{r}$$

Where,

M_1 = Mean sum of square of males
M_2 = Mean sum of square of females
M_3 = Mean sum of square of males and females interaction
M_4 = Error mean sum of squares

Estimation of combining ability effects

The model adopted to estimate *gca* and *sca* effects of ijk observations was as follows.

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

Where μ = population mean
g_i = *gca* effects of i^{th} line
g_j= *gca* effects of j^{th} tester
S_{ij}= *sca* effects of i x j cross
e_{ijk}= error associated with observation ijk

The *gca* effects of parents and *sca* effects of crosses (hybrids) were estimated as indicated below.

General combining ability effects

$$(a)\ \textbf{Line}: \mathbf{g_i} = \frac{x_{i..}}{t \times r} - \frac{x\ ...}{l \times t \times r}$$

$$(b)\ Testers: \mathbf{g}_j = \frac{x_{.j.}}{l \times r} - \frac{x..}{l \times t \times r}$$

Specific combining ability effects

$$S_{ij} = \frac{x_{ij}}{r} - \frac{x_{i..}}{t \times r} - \frac{x_{.j.}}{l \times r} - \frac{x \ldots}{l \times t \times r}$$

Where *l* = number of lines
t = number of testers
r = number of replications
g_i = gca of i^{th} line
$x_{i..}$= total of i^{th} line over all the testers
x.. = total of all the crosses
g_j = gca of j^{th} testers
$x_{j..}$= total of j^{th} testers over all lines and replications
S_{ij} = sca effects of i x j crosss
$x_{.j.}$ = total of cross i x j over all replications

Standard errors of *gca* and *sca* effects

SE (GCA) for lines = $\sqrt{\frac{\text{Error variance}}{t \times r}}$

SE (GCA) for testers = $\sqrt{\frac{\text{Error variance}}{l \times r}}$

SE (SCA) = $\sqrt{\frac{Error\ variance}{r}}$

r = Number of replications
t = Number of treatments
Mr=replication mean square
Mt=treatment mean square
Me=error mean square

IV. EXPERIMENTAL RESULTS

To estimate the heterosis and combining ability studies in cucumber was conducted at college of horticulture, UHS campus. In this experiment twenty five crosses were obtained by crossing five testers and five lines. All the parents and their crosses were evaluated for assessing the magnitude of heterosis to identify the good combiners. The results obtained in the investigation are presented under the following headings.

4.1 Analysis of variance

4.2 *Per se* performance and magnitude of heterosis

4.3 Combining ability study

4.1 Analysis of variance

The analysis of variance for 17 characters under the study results are summarized in Table 4 and presented under different headings as components of variance.

4.1.1 Genotypes

The variance due to genotypes (crosses and parents) was highly significant (at p=0.01) for all the growth, earliness, yield parameters, *viz.,* vine length (cm), number of branches, number of nodes per vine, node at first female flower appearance, node at first male flower appearance, days to first fruit harvest , sex ratio, days to female flower anthesis, number of fruits per vine , fruit length (cm), fruit diameter (cm), average fruit weight (g), fruit yield per plant(kg),shelf life (days),cavity thickness (cm), flesh thickness (cm) and rind thickness (mm) .

4.1.2 Parents

Parents differed significantly at p=0.01 among themselves for vine length (cm), number of nodes per vine, node at first female flower appearance, node at first male flower appearance, sex ratio, number of fruits per vine, fruit length (cm), fruit diameter (cm), average fruit weight (g), flesh thickness and rind thickness (mm) and parents differ significantly at p= 0.05 for number of branches, days to female flower anthesis and cavity thickness. Whereas the variance were non-significant for number of female flowers per plant, days to first fruit harvest.

Table 4. Analysis of variance (mean sum of squares) of line × tester analysis for various characters in cucumber

Sl. No.	Character	Replications	Genotypes	Parents	Parents vs Crosses	Crosses	Lines	Testers	Line × Tester	Error
	Degree of freedom	1	34	9	1	24	4	4	16	34
1	Vine length (cm)b	12.85	1037.40**	538.52**	0.02**	553.01**	1580.53*	834.32*	225.81**	15.59
2	No. of branches per vine	0.25	0.71**	0.27*	10.90**	0.46**	1.83 **	0.33 NS	0.15 NS	0.09
3.	No. of nodes per vine	0.01	32.80**	5.14**	439.64**	26.22**	102.38**	8.46 NS	11.63**	0.23
4.	Node of female flower appearance	0.13	1.59**	1.34**	4.95**	1.55**	3.71*	1.60 NS	1.00**	0.05
5.	Node of male flower appearance	0.04	0.74**	0.48**	0.10 NS	0.87 **	1.69 NS	0.73 NS	0.70**	0.01
6.	Days to first fruit harvest	0.08	30.24**	4.93 NS	367.65**	25.68**	101.38**	5.32 NS	11.84*	5.06
7.	Sex ratio	0.01	1.34**	0.40**	25.31**	0.70**	2.54**	0.38 NS	0.32**	0.06
8.	Days to female flower anthesis	0.03	27.91**	10.05*	429.94**	17.86**	33.92 NS	17.58 NS	13.91**	3.86
9.	Number of fruits per plant	0.192	2.04**	0.92**	0.23 NS	2.54**	7.29*	0.16 NS	1.95**	0.07
10.	Fruit diameter (cm)	0.19	0.78**	0.32**	6.77**	0.71**	3.21**	0.04 NS	0.25*	0.09
11.	Fruit length (cm)	0.684	20.55**	4.38**	241.05**	17.42**	82.62**	5.05 NS	4.21**	0.23
12.	Average fruit weight (g)	92.20	48485.31**	28037.32**	141301.39**	52285.98 **	231923.90 **	19514.9	15569.3**	62.78
13.	Fruit yield per plant (kg)	0.03	2.11**	0.42 NS	15.92 NS	2.17*	9.71**	1.92**	0.35 NS	0.89
14.	Shelf life (days)	1.76	1.38**	0.76 NS	12.17 NS	1.16*	5.03**	0.87*	0.26 NS	0.50
15.	Cavity thickness (cm)	0.06	0.04**	0.01*	1.23**	0.003 NS	0.006 NS	0.002 NS	0.003 NS	0.006
16.	Flesh thickness (cm)	0.02	0.14**	0.26**	0.19**	0.10 **	0.07 NS	0.19 NS	0.08 ***	0.01
17.	Rind thickness (mm)	0.001	0.009**	0.012**	0.005**	0.009**	0.023**	0.009*	0.002**	0.00

*and ** indicate significance of values at p=0.05 and p=0.01, respectively, NS: Non significant

4.1.3 Parent versus crosses

The variance due to parent vs. crosses was found to be significant at p=0.01 for vine length (cm), number of branches, number of nodes per vine, node at first female flower appearance, days to first fruit harvest, sex ratio, days to female flower anthesis, fruit length (cm), fruit diameter (cm), average fruit weight (g), cavity thickness (cm), flesh thickness (cm), rind thickness (mm) and it was not significant for all other parameters variance due to parent vs. crosses.

4.1.4 Crosses

There was highly significant (p=0.01) difference among the crosses for 14 characters and significant (p=0.05) difference was observed in fruit yield per plant and shelf life. However, variance due to crosses was non- significant for cavity thickness.

4.1.5 Lines

Lines differ significantly for vine length (cm), node at first female flower appearance and number of fruits per vine at p=0.05, whereas variance due to lines was highly significantly for number of branches, number of nodes per vine, days to first fruit harvest, sex ratio, fruit length (cm), fruit diameter (cm), average fruit weight (g), fruit yield per plant (kg), shelf life (days) and rind thickness (mm). For all other traits variance due to lines was not significant.

4.1.6 Testers

Variance due to testers was found to be significant at only p=0.05 for vine length (cm), shelf life and rind thickness (mm), whereas variance due to testers was highly significant at p=0.01 for fruit yield per plant (kg). However, testers did not significantly differ for all other characters studied, among themselves.

Table 5. Per se performance of parents and crosses for earliness, growth and yield parameters in cucumber

Sl. No.	Genotypes	Vine length (cm)	No. of branches per vine	No. of nodes per vine	Node of female flower appearance	Node of male flower appearance	Days to first fruit harvest	Sex ratio	Days to female flower anthesis
1.	IIHR 285 × Poinsette	194.30	5.10	26.10	5.10	2.30	49.75	4.17	42.65
2.	IIHR 285 × Phule Shubhangi	180.35	5.30	19.30	5.80	3.65	50.80	4.23	44.8
3.	IIHR 285 × Punjab Naveen	214.15	5.30	24.50	4.40	2.30	53.10	4.36	44.95
4.	IIHR 285 × Pusa Uday	223.13	5.10	25.30	4.95	2.45	52.55	4.39	45.05
5.	IIHR 285 × Kerala-2	211.10	5.10	22.10	4.85	1.95	51.60	4.31	45.60
6.	IIHR 341× Poinsette	175.30	5.70	20.68	5.20	2.15	49.40	3.74	41.90
7.	IIHR 341 × Phule Shubhangi	212.10	6.00	26.80	4.80	3.25	58.30	3.74	44.10
8.	IIHR 341 × Punjab Naveen	217.10	5.50	26.30	4.75	3.40	51.65	3.68	45.65
9.	IIHR 341 × Pusa Uday	219.00	5.50	27.30	4.50	1.95	48.75	4.31	48.85
10.	IIHR 341 × Kerala-2	214.40	5.50	22.25	4.40	1.90	53.15	3.94	45.10
11.	IIHR 304 × Poinsette	206.15	5.00	18.45	5.35	3.25	50.80	4.32	43.35
12.	IIHR 304 × Phule Shubhangi	184.15	5.15	17.70	5.25	1.85	52.25	4.71	47.10
13.	IIHR 304 × Punjab Naveen	211.65	4.80	21.40	5.75	1.80	49.40	4.95	42.80
14.	IIHR 304 × Pusa Uday	219.35	5.30	18.70	6.80	1.75	53.65	4.81	45.20
15.	IIHR 304 × Kerala -2	211.25	5.50	19.30	5.55	2.25	54.55	4.65	50.00
16.	Green Long × Poinsette	221.30	5.40	24.60	4.05	2.55	46.10	4.07	39.60
17.	Green Long × Phule Shubhangi	226.10	6.50	24.30	4.60	3.45	54.75	4.44	48.75
18.	Green Long × Punjab Naveen	233.00	6.30	22.60	4.70	3.25	55.15	4.55	45.80
19.	Green Long × Pusa Uday	241.20	6.20	26.70	4.50	2.40	46.25	4.67	41.45
20.	Green Long × Kerala -2	223.25	5.60	28.40	4.40	2.50	54.00	4.64	49.50
21.	Pondicherry- 1 × Poinsette	228.50	5.75	27.70	5.35	3.50	57.60	4.93	47.85

Table 5. Contd…

22.	Pondicherry- 1 × Phule Shubhangi	231.00	6.30	29.30	4.20	2.55	58.55	4.97	44.00
23.	Pondicherry- 1 × Punjab Naveen	234.50	6.35	28.60	4.60	3.65	46.35	4.82	41.00
24.	Pondicherry- 1 × Pusa Uday	226.00	6.20	29.00	7.30	3.30	56.35	5.22	43.50
25.	Pondicherry- 1 × Kerala 2	223.15	5.60	24.50	7.25	3.40	55.75	5.27	51.55
	Lines								
26.	IIHR 285	182.60	4.50	17.70	6.10	2.20	60.45	5.69	54.10
27.	IIHR 341	186.00	4.05	18.55	4.75	2.10	58.35	5.46	48.05
28.	IIHR 304	148.60	4.38	16.50	6.15	2.70	59.35	5.43	49.80
29.	Green Long	180.80	4.85	18.33	4.35	2.35	56.85	5.93	51.05
30.	Pondicherry- 1	205.20	5.30	20.55	7.15	3.15	55.45	5.86	54.20
	Testers								
31.	Poinsette	163.25	4.82	20.55	5.35	2.45	56.15	6.15	47.55
32.	Phule Shubhangi	169.93	4.50	18.25	5.50	3.40	56.15	6.83	50.40
33.	Punjab Naveen	186.10	4.90	15.75	6.15	2.45	57.45	5.37	49.85
34.	Pusa Uday	186.10	5.05	19.20	5.40	2.45	56.65	5.69	49.80
35.	Kerala-2	197.50	4.95	19.90	6.35	3.45	58.10	6.24	52.10
	Check								
36.	Chitra	201.50	5.20	20.00	5.70	3.45	60.45	4.75	55.35
	S.Em+_	3.94	0.30	0.48	0.24	0.12	2.24	0.26	1.96
	CD at 5%	8.15	0.62	1.00	0.50	0.26	4.64	0.53	4.05
	CD at 1%	11.04	0.84	1.36	0.68	0.35	6.29	0.72	5.49

4.1.7 Line x tester

Variance due to line x tester interaction was significant at p=0.05 only for days to first fruit harvest and fruit diameter (cm). Variance was not significant for number of branches, fruit yield per plant (kg), shelf life, cavity thickness. Variance for other 12 character it was highly significant due to line x tester interaction.

4.2 *Per se* performance and magnitude of heterosis

The *per se* performance of parents, hybrids and their heterosis was worked out over better parent, the best parent and the commercial check hybrid (Chitra) are presented. The hybrid 'Chitra' were selected as standard check, since it is commercially and widely popular grown variety.

4.2.1 Vine length (cm)

For the vine length among the lines, IIHR 304 showed the lowest (148.60cm) and the highest (205.20 cm) *per se* values was observed in Pondicherry 1. The vine length for tester was ranges from 163.25 cm (Poinsette) to Kerala- 2 (197.50 cm). Among F_1, the lowest mean value (180.35 cm) was recorded in IIHR 285 x Phule Shubhangi and the highest (241.20 cm) was recorded in the cross Green Long x Pusa Uday (Table 5). The magnitude of heterosis over better parent, the best parent and the commercial check was highly significant in both the directions. The maximum heterosis was observed in the cross IIHR 304 × Poinsette (26.28 %) over the better parent, while the cross Pondicherry 1 × Pusa Uday exhibited highest heterosis over the best parent (33.41 %) and over the commercial check Green Long × Pusa Uday (19.91 %). Twenty three crosses exhibited significantly positive heterosis over better parent, twenty one crosses exhibited positively significant heterosis over the best parent and the thirteen crosses over the commercial check for vine length.

4.2.2 Number of branches

Genotypes differed significantly among themselves for number of branches. Number of branches ranged from 4.50 (Phule Shubhangi) to 5.05 (Pusa Uday) ranges among testers, 4.05 (IIHR 341) to 5.30 (Pondicherry -1) ranges among lines and 4.80 (IIHR 304 × Punjab Naveen) to 6.50 (Green Long × Phule Shubhangi) among crosses. Maximum positive and significant heterobeltiosis was observed in the cross Green long × Phule Shubhangi (34.02 %) and the cross Green Long × Phule Shubhangi exhibited highly significant heterosis over the best (34.02 %) and the commercial check (25.00%). Among the crosses, 11 crosses over better parent and seven crosses over the commercial check exhibited positive and significant heterosis.

Table 6. Heterosis (%) over better parent, the best parent and the commercial check for Vine length, No. of branches /vine, No. of nodes / vine in cucumber

Sl. No.	Cross	Vine length (cm)			No. of branches per vine			No.of nodes per vine		
		BP	BTP	CC	BP	BTP	CC	BP	BTP	CC
1.	IIHR 285 × Poinsette	6.41**	7.47**	-3.41	5.92	5.15	-1.92	27.01**	42.43**	30.50**
2.	IIHR 285 × Phule Shubhangi	-1.23	-0.25	-10.34**	17.78*	9.28	1.92	5.75*	5.32	-3.50
3.	IIHR 285 × Punjab Naveen	15.07**	18.45**	6.46	8.27	9.28	1.92	38.42**	33.70**	22.50**
4.	IIHR 285 × Pusa Uday	19.90**	23.41**	10.92**	0.99	5.15	-1.92	31.77**	38.06	26.50**
5.	IIHR 285 × Kerala-2	6.89**	16.76**	4.95	3.03	5.15	-1.92	11.06**	20.60**	10.50**
6.	IIHR 341× Poinsette	-5.75**	-3.04	-12.85**	18.38**	17.53**	9.62	0.61	12.82**	3.38
7.	IIHR 341 × Phule Shubhangi	14.03**	17.31**	5.44	33.33**	23.71**	15.38*	44.47**	46.25**	34.00**
8.	IIHR 341 × Punjab Naveen	16.66**	20.08**	7.93	12.36	13.40*	5.77	41.78**	43.52**	31.50**
9.	IIHR 341 × Pusa Uday	17.68**	21.13**	8.87*	8.91	13.40*	5.77	42.19**	48.98**	36.50**
10.	IIHR 341 × Kerala-2	8.56**	18.58**	6.59	11.11	13.40*	5.77	11.81**	21.42**	11.25**
11.	IIHR 304 × Poinsette	26.28**	14.02**	2.49	3.84	3.09	-3.85	-10.22**	0.68	-7.75**
12.	IIHR 304 × Phule Shubhangi	8.37**	1.85	-8.45*	14.44*	6.19	-0.96	-3.01	-3.41	-11.5**
13.	IIHR 304 × Punjab Naveen	13.73**	17.06**	5.22	-1.94	-1.03	-7.69	29.70**	16.78**	7.00**
14.	IIHR 304 × Pusa Uday	17.87**	21.32**	9.05*	4.95	9.28	1.92	-2.60	2.05	-6.50*
15.	IIHR 304 × Kerala -2	6.96**	16.84**	5.02	11.11	13.40*	5.77	-3.02	5.32	-3.50
16.	Green Long × Poinsette	22.40**	22.40**	10.02*	11.34	11.34	3.85	19.71**	34.24**	23.00**
17.	Green Long × Phule Shubhangi	25.06**	25.06**	12.40**	34.02**	34.02**	25.00**	32.61**	32.61**	21.50**
18.	Green Long × Punjab Naveen	25.20**	28.87	15.83**	28.70**	29.90**	21.15**	23.33**	23.33**	13.00**
19.	Green Long × Pusa Uday	17.54**	33.41**	19.91**	22.77**	27.84**	19.23**	39.06**	45.70**	33.50**
20.	Green Long × Kerala -2	13.04**	23.48**	10.99*	13.13*	15.46*	7.69	42.71**	54.98**	42.00**
21.	Pondicherry- 1 × Poinsette	11.35**	26.38**	13.60**	8.49	18.56**	10.58	34.79**	51.16**	38.50**
22.	Pondicherry- 1 × Phule Shubhangi	12.57**	27.77**	14.84**	18.87**	29.90**	21.15**	42.58**	59.89**	46.50**
23.	Pondicherry- 1 × Punjab Naveen	14.28**	29.70**	16.58**	19.81**	30.93**	22.12**	39.17**	56.07**	43.00**
24.	Pondicherry- 1 × Pusa Uday	21.44**	25.00**	12.35**	16.98**	27.84**	19.23**	41.12**	58.25**	45.00**
25.	Pondicherry- 1 × Kerala 2	8.75**	23.42**	10.94*	5.66	15.46*	7.69	19.22**	33.70**	22.50**
	S.Em+_	3.94	3.94	3.94	0.30	0.30	0.30	0.48	0.48	0.48
	CD at 5%	8.15	8.15	8.15	0.62	0.62	0.62	1.00	1.00	1.00
	CD at 1%	11.04	11.04	11.04	0.84	0.84	0.84	1.36	1.36	1.36

*and ** indicate significance of values at p=0.05 and 0.01, respectively.

BP- Heterosis over better parent BTP- Heterosis over the best parent (Green Long) CC- Heterosis over the commercial check (Chitra)

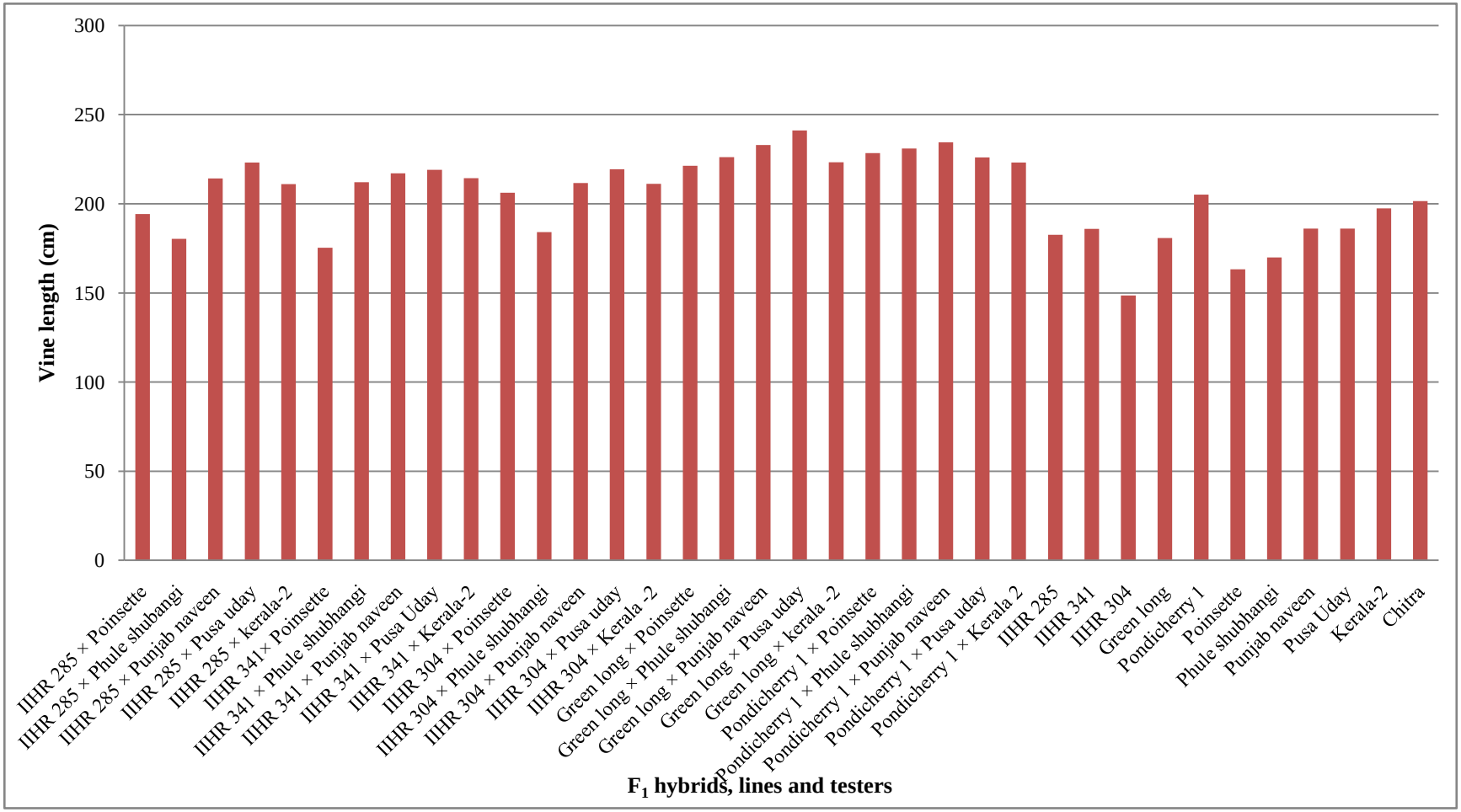

Fig. 1: Vine length (cm) of F_1 hybrids, lines and testers in cucumber

Table 7. Heterosis (%) over better parent, the best parent and the commercial check for Node of female flower appearance, Node of male flower appearance, Days to first harvest

Sl. No.	Cross	Node of female flower appearance			Node of male flower appearance			Days to first fruit harvest		
		BP	BTP	CC	BP	BTP	CC	BP	BTP	CC
1.	IIHR 285 × Poinsette	-3.77**	17.24**	-10.53*	-6.12	-2.13	-33.33 **	-11.32**	-12.49**	-17.70**
2.	IIHR 285 × Phule Shubhangi	5.45	33.33**	1.75	7.35	55.32**	5.80	-9.45**	-10.64*	-15.96**
3.	IIHR 285 × Punjab Naveen	-27.87**	1.15	-22.81**	-6.12	-2.13	-33.33 **	-7.49	-6.60	-12.16**
4.	IIHR 285 × Pusa Uday	-8.33**	13.79**	-13.16**	0.01	4.26	-28.99 **	-7.16	-7.56	-13.07**
5.	IIHR 285 × kerala-2	-20.49**	11.49	-14.91**	-43.48**	-17.02 **	-43.48 **	-11.19**	-9.23*	-14.64**
6.	IIHR 341× Poinsette	20.93	19.54**	-8.77	-12.24*	-8.51	-37.68 **	-11.94**	-13.10**	-18.28**
7.	IIHR 341 × Phule Shubhangi	2.13	10.34	-15.79**	-4.41	38.30**	-5.80	5.23	2.55	-3.56
8.	IIHR 341 × Punjab Naveen	1.06	9.20	-16.67**	38.78**	44.68**	-1.45	-10.02**	-9.15*	-14.56**
9.	IIHR 341 × Pusa Uday	-4.26	3.45	-21.05**	-20.41**	-17.02 **	-43.48 **	-13.87	-14.25**	-19.35**
10.	IIHR 341 × Kerala-2	-6.38**	1.15	-22.81**	-44.93**	-19.15 **	-44.93 **	-5.26	-6.51	-12.08**
11.	IIHR 304 × Poinsette	0.94	22.99**	-6.14	20.37**	38.30**	-5.80	-9.45**	-10.64*	-15.96**
12.	IIHR 304 × Phule Shubhangi	-4.55	20.69**	-7.89	-45.59**	-21.28 **	-46.38 **	-6.86	-8.09	-13.56**
13.	IIHR 304 × Punjab Naveen	-5.74**	32.18**	0.88	-33.33**	-23.40 **	-47.83 **	-13.94**	-13.10**	-18.28**
14.	IIHR 304 × Pusa Uday	25.93	56.32**	19.3**	-35.19**	-25.53 **	-49.28 **	-5.21	-5.63	-11.25**
15.	IIHR 304 × Kerala -2	-9.02**	27.59**	-2.63	-34.78**	-4.26	-34.78 **	-6.11	-4.05	-9.76**
16.	Green Long × Poinsette	-5.81	-6.90	-28.95**	4.08	8.51	-26.09 **	-20.65**	-18.91**	-23.74**
17.	Green Long × Phule Shubhangi	6.98	5.75	-19.30**	1.47	46.81**	0.00	-2.41	-3.69	-9.43**
18.	Green Long × Punjab Naveen	9.30	8.05	-17.54**	32.65**	38.30**	-5.80	-3.92	-2.99	-8.77**
19.	Green Long × Pusa Uday	-10.64**	-3.45	-26.32**	-2.04	2.13	-30.43 **	-18.29**	-18.65**	-23.49**
20.	Green Long × Kerala -2	-24.59**	5.75	-19.30**	-27.54**	6.38	-27.54 **	-7.06	-5.01	-10.67**
21.	Pondicherry- 1 × Poinsette	0.94	22.99**	-6.14	11.11**	48.94**	1.45	3.97	1.32	-4.71
22.	Pondicherry- 1 × Phule Shubhangi	-18.18**	3.45	-21.05**	-25.00**	8.51	-26.09 **	5.69	2.99	-3.14
23.	Pondicherry- 1 × Punjab Naveen	2.33	1.15	-22.81**	15.87**	55.32**	5.80	-17.38**	-18.47**	-23.33**
24.	Pondicherry- 1 × Pusa Uday	35.19	67.82**	28.07**	4.76	40.43**	-4.35	1.71	-0.88	-6.78
25.	Pondicherry- 1 × Kerala- 2	15.08	66.67**	27.19**	-1.45	44.68**	-1.45	0.63	-1.93	-7.78**
	S.Em+_	0.24	0.24	0.24	0.12	0.12	0.12	2.24	2.24	2.24
	CD at 5%	0.50	0.50	0.50	0.26	0.26	0.26	4.64	4.64	4.64
	CD at 1%	0.68	0.68	0.68	0.35	0.35	0.35	6.29	6.29	6.29

*and ** indicate significance of values at p=0.05 and 0.01, respectively.

BP- Heterosis over better parent BTP- Heterosis over the best parent (Green Long) CC- Heterosis over the commercial check (Chitra)

4.2.3 Number of nodes per vine

Number of nodes per vine ranged from 15.75 (Punjab Naveen) to 20.55 (Poinsette) among testers, 16.50 (IIHR 304) to 20.55 ((Pondicherry- 1) among lines and 17.07(IIHR 304 × Phule Shubhangi) to 29.30 (Pondicherry 1 × Phule Shubhangi) among crosses. Magnitude of heterosis was highly significant over better parent, the best parent and the commercial check in both the directions. The cross IIHR 341 × Phule Shubhangi exhibited highly significant heterosis over better parent (44.47 %), the best parent (59.89%) Pondicherry 1 × Phule Shubhangi and the commercial check 46.50 % (Pondicherry 1 × Phule Shubhangi). Among the 25 crosses, 21 over better parent, 20 crosses over the best parent and 22 crosses over the commercial check exhibited positive and significant heterosis.

4.2.4 Node at first female flower appearance.

Genotypes differed significantly among themselves for node at first female flower appearance and ranged from 5.35 (Poinsette) to 6.35 (Kerala -2) among testers, 4.35 (Green Long) to 7.15 (Pondicherry 1) lines and 4.05 (Green Long × Poinsette) among crosses. The magnitude of heterosis was significant in both directions over better parent and the commercial check. The maximum and significantly negative heterosis over the better parent was observed in the cross IIHR 285× PunjabNaveen (-27.87 %). Green Long × Poinsette exhibited significant and negative heterosis over the commercial check (-28.95 %).

Table 8. Heterosis (%) over better parent, the best parent and the commercial check for Sex ratio, Days to female flower anthesis, Number of fruits per plant

Sl. No.	Cross	Sex ratio			Days to female flower anthesis			Number of fruits per plant (kg)		
		BP	BTP	CC	BP	BTP	CC	BP	BTP	CC
1.	IIHR 285 × Poinsette	-27.10**	-29.62**	-12.85*	-10.21	-16.36**	-22.85**	-39.63**	-19.05 **	-17.68**
2.	IIHR 285 × Phule Shubhangi	-18.46	-28.44**	-11.39*	-10.40**	-12.34**	-19.15**	-30.89**	-0.95	-14.14*
3.	IIHR 285 × Punjab Naveen	-23.60**	-26.33**	-8.78	-8.27	-11.95**	-18.79**	-14.05**	34.29**	5.05
4.	IIHR 285 × Pusa Uday	-28.47**	-32.15**	-15.99**	-8.06	-11.75**	-18.61**	11.90**	15.71**	42.42**
5.	IIHR 285 × kerala-2	-33.30**	-35.61**	-20.27**	-12.31**	-10.68*	-17.62**	0.41	44.76**	22.73**
6.	IIHR 341× Poinsette	-31.91**	-36.79**	-21.73**	-10.85	-17.92**	-24.30**	6.29	55.24**	53.54**
7.	IIHR 341 × Phule Shubhangi	-30.64**	-35.61**	-20.27**	-8.13**	-13.61**	-20.33**	13.99**	40.95**	64.65**
8.	IIHR 341 × Punjab Naveen	-29.64**	-34.68**	-19.12**	-4.90	-10.58*	-17.52**	3.50	35.24**	49.49**
9.	IIHR 341 × Pusa Uday	-26.36**	-31.65**	-15.36**	-0.31	-4.31	-11.74**	-0.70	38.10**	43.43**
10.	IIHR 341 × Kerala-2	-9.82	-16.29**	3.66	-4.04	-11.66**	-18.52**	1.40	20.95**	46.46**
11.	IIHR 304 × Poinsette	-10.19	-21.18**	-2.40	-8.74**	-15.08**	-21.68**	-5.93	36.19**	28.28**
12.	IIHR 304 × Phule Shubhangi	-15.87	-26.16**	-8.57	-3.88	-7.74	-14.91**	16.26**	0.95	44.44**
13.	IIHR 304 × Punjab Naveen	-11.06	-13.50**	7.11	-12.65**	-16.16**	-22.67**	-2.75	-15.24 **	7.07
14.	IIHR 304 × Pusa Uday	-12.21	-22.95**	-4.60	-7.76	-11.46**	-18.34**	-29.37**	-9.52	-10.10
15.	IIHR 304 × Kerala -2	-15.38	-25.65**	-7.94	2.04	-2.06	-9.67**	-11.21**	0.95	-4.04
16.	Green Long × Poinsette	-29.21**	-31.73**	-15.46**	-17.50**	-22.43**	-28.46**	-21.48**	0.95	7.07
17.	Green Long × Phule Shubhangi	-20.09**	-22.70**	-4.28	-2.50	-4.51	-11.92**	-13.82**	3.81	7.07
18.	Green Long × Punjab Naveen	-19.30	-21.35**	-2.61	-6.53	-10.28*	-17.25**	0.00	20.95**	10.10
19.	Green Long × Pusa Uday	-17.54	-20.17**	-1.15	-13.65**	-18.81**	-25.11**	0.79	20.95**	28.28**
20.	Green Long × Kerala -2	-20.18**	-22.87**	-4.49	-2.94	-3.04	-10.57**	18.69**	17.14**	28.28**
21.	Pondicherry- 1 × Poinsette	-14.04	-16.03**	3.97	1.81	-6.27	-13.55**	-8.89**	18.10**	24.24**
22.	Pondicherry- 1 × Phule Shubhangi	-11.40	-14.68**	5.64	-12.00**	-13.81**	-20.51**	0.81	36.19**	25.25**
23.	Pondicherry- 1 × Punjab Naveen	-14.04	-16.62**	3.24	-16.33**	-19.69**	-25.93**	31.19**	-1.90	44.44**
24.	Pondicherry- 1 × Pusa Uday	-7.89	-10.89*	10.34	-11.22**	-14.79**	-21.41**	-18.25**	0.00	4.04
25.	Pondicherry- 1 × Kerala- 2	11.40	8.35	34.17**	-0.87	0.98	-6.87	-1.87	-9.52	6.06
	S.Em+_	0.26	0.26	0.26	1.96	1.96	1.96	0.26	0.26	0.26
	CD at 5%	0.53	0.53	0.53	4.05	4.05	4.05	0.55	0.55	0.55
	CD at 1%	0.72	0.72	0.72	5.49	5.49	5.49	0.74	0.74	0.74

*and ** indicate significance of values at p=0.05 and 0.01, respectively.

BP- Heterosis over better parent BTP- Heterosis over the best parent (Green Long) CC- Heterosis over the commercial check (Chitra)

4.2.5 Node at first male flower appearance

Nodes at first male flower appearance varied among the genotypes which ranged from 2.45 (Poinsette) to 3.45 (Kerala -2) among testers, 2.1 (IIHR 341) to 3.15 (Pondicherry 1) among lines and among crosses 1.75 (IIHR 304 × Pusa Uday) to 3.65 (Pondicherry 1 × Punjab Naveen) and also (IIHR 285 × Phule Shubhangi). The magnitude of heterosis was significant in both the directions over better parent and the commercial check, whereas heterosis over the best parent significant only in positive direction. In the cross (IIHR 304 × Phule Shubhangi) -45.59 % followed by the cross IIHR 341 × Kerala-2 (-44.93%) the maximum and significantly negative heterosis over better parent was observed.

4.2.6 Days to first fruit harvest

Days to first harvest varied significantly among the genotypes. It ranged from 56.15 (Poinsette and Phule Shubhangi) to 58.10 (Kerala-2) among testers, 55.45 (Pondicherry 1) to 60.45 (IIHR 285) among lines and 46.10 (Green long × Poinsette) to 58.55 (Pondicherry 1 × Phule Shubhangi) among crosses. The magnitude of heterosis over the better parent was significant in both the directions, whereas heterosis over the best parent and the commercial check was significant in the negative direction. The significant negative heterosis in the desirable direction was observed in the cross (-20.65 %) Green Long × Poinsette over better parent, (-18.91 %) over best parent and also (-23.74 %) over commercial check.

4.2.7 Sex ratio

For the sex ratio significant difference was observed among the genotypes and it varied from 5.37 (Punjab Naveen) to 6.83 (Phule Shubhangi) among testers, among lines 5.43 (IIHR 304) to 5.93 (Green long). Among crosses 3.68 (IIHR 341 × Punjab Naveen) to 5.27 (Pondicherry- 1 × Kerala -2). The cross IIHR 341× Poinsette (-21.73 %) were showed significant heterosis over check. The magnitude of heterosis over better parent and the commercial check was found to be highly significant in both the directions. The cross IIHR 285 × Kerala-2 (-33.30 %) exhibited maximum and significantly negative heterosis over the better parent .

Table 9. Per se performance of parents and crosses for yield and fruit quality parameters in cucumber

Sl. No.	Genotypes	Number of fruits per plant	Fruit diameter (cm)	Fruit length (cm)	Avg. fruit weight (g)	Fruit yield per plant (kg)	Fruit yield per ha (t)	Shelf life (days)	Cavity thickness (cm)	Flesh thickness (cm)	Rind thickness (mm)
1.	IIHR 285 × Poinsette	4.07	4.35	18.35	256.35	1.35	9.00	4.10	1.75	1.85	0.71
2.	IIHR 285 × Phule Shubhangi	4.25	4.70	19.25	260.60	1.40	9.33	5.70	1.86	1.60	0.74
3.	IIHR 285 × Punjab Naveen	5.20	5.00	20.36	386.05	1.59	10.60	5.20	1.85	1.65	0.91
4.	IIHR 285 × Pusa Uday	7.05	4.50	21.75	415.15	2.80	18.67	4.65	1.86	1.55	0.74
5.	IIHR 285 × Kerala-2	6.07	5.25	20.75	520.65	3.10	20.67	5.65	1.84	1.70	0.77
6.	IIHR 341× Poinsette	6.60	5.30	18.13	292.75	3.10	20.67	5.25	1.78	1.60	0.76
7.	IIHR 341 × Phule Shubhangi	8.15	5.50	24.10	278.80	2.75	18.33	5.35	1.90	1.70	0.69
8.	IIHR 341 × Punjab Naveen	7.40	5.35	20.36	403.05	3.45	23.00	5.35	1.82	1.85	0.72
9.	IIHR 341 × Pusa Uday	7.10	5.35	22.05	522.30	3.15	21.00	5.75	1.88	1.35	0.73
10.	IIHR 341 × Kerala-2	7.25	4.85	21.65	358.15	3.65	24.33	6.30	1.88	1.95	0.75
11.	IIHR 304 × Poinsette	6.35	5.00	18.70	293.65	2.00	13.33	5.70	1.87	1.45	0.75
12.	IIHR 304 × Phule Shubhangi	7.15	4.36	19.35	327.05	1.75	11.67	5.50	1.87	1.35	0.75
13.	IIHR 304 × Punjab Naveen	5.30	5.05	20.04	250.80	1.55	10.33	6.15	1.86	1.25	0.75
14.	IIHR 304 × Pusa Uday	6.20	4.21	19.93	369.30	2.75	18.33	5.45	1.87	1.55	0.75
15.	IIHR 304 × Kerala -2	4.75	4.15	20.70	515.70	2.35	15.67	6.20	1.90	1.85	0.75
16.	Green Long × Poinsette	7.50	4.80	27.87	557.05	4.65	31.00	6.70	1.88	1.85	0.77
17.	Green Long × Phule Shubhangi	5.30	5.30	24.75	670.70	2.70	18.00	6.80	1.81	1.40	0.78
18.	Green Long × Punjab Naveen	5.45	5.00	26.27	601.75	3.35	22.33	6.95	1.80	1.30	0.78
19.	Green Long × Pusa Uday	6.35	5.60	28.60	698.65	4.63	30.87	7.15	1.82	1.50	0.91
20.	Green Long × Kerala -2	6.35	5.40	25.06	599.20	4.05	27.00	7.15	1.79	1.60	0.94
21.	Pondicherry- 1 × Poinsette	3.20	6.40	23.67	717.65	2.25	15.00	6.00	1.88	2.00	0.95
22.	Pondicherry- 1 × Phule	5.20	5.90	24.01	747.75	3.95	26.33	5.75	1.88	1.89	0.78

Table 9. Contd…

Sl. No.	Genotypes	Number of fruits per plant	Fruit diameter (cm)	Fruit length (cm)	Avg. fruit weight (g)	Fruit yield per plant (kg)	Fruit yield per ha (t)	Shelf life (days)	Cavity thickness (cm)	Flesh thickness (cm)	Rind thickness (mm)
	Shubhangi										
23.	Pondicherry- 1 × Punjab Naveen	7.15	5.95	25.25	699.25	4.50	30.00	6.15	1.88	1.25	0.79
24.	Pondicherry- 1 × Pusa Uday	5.15	6.00	24.33	683.85	3.75	25.00	6.70	1.84	1.35	0.79
25.	Pondicherry- 1 × Kerala- 2	5.25	5.85	22.65	547.65	4.40	29.33	6.55	1.89	1.55	0.81
	Lines										
26.	IIHR 285	6.05	4.11	16.40	202.75	2.05	13.67	4.25	2.05	2.15	0.69
27.	IIHR 341	7.15	4.29	16.50	206.10	2.10	14.00	4.65	2.02	2.37	0.72
28.	IIHR 304	5.25	4.32	16.20	344.80	2.25	15.00	4.55	2.21	1.85	0.69
29.	Green Long	5.25	4.55	19.01	480.75	2.55	17.00	5.85	2.32	1.59	0.70
30.	Pondicherry- 1	5.35	5.05	20.66	515.70	2.68	17.87	6.10	2.24	1.65	0.94
	Testers										
31.	Poinsette	5.10	4.20	18.21	330.70	1.25	8.33	4.50	2.12	1.22	0.71
32.	Phule Shubhangi	5.25	4.15	19.24	377.90	1.75	11.67	4.90	2.11	1.85	0.77
33.	Punjab Naveen	5.45	4.10	18.15	376.75	1.60	10.67	4.65	2.04	1.71	0.82
34.	Pusa Uday	5.30	4.85	19.55	405.70	1.58	10.53	5.45	2.15	1.28	0.83
35.	Kerala-2	5.35	5.15	18.18	402.85	1.63	10.87	5.15	2.17	1.45	0.87
	Check										
36.	Chitra	5.95	5.15	20.15	510.35	3.00	20.00	5.50	2.1	1.45	0.7
	S.Em±	0.26	0.30	0.48	7.92	0.94	4.34	0.70	0.08	0.11	0.01
	CD at 5%	0.55	0.62	1.01	16.35	1.95	8.64	1.46	0.16	0.24	0.02
	CD at 1%	0.74	0.84	1.36	22.16	2.65	11.48	1.98	0.22	0.35	0.03

4.2.8 Days to female flower anthesis.

The *per se* performance of parents and hybrids revealed that testers took 47.55 (Poinsette) to 52.10 (Kerala -2) days and lines took 48.05 (IIHR 341) to 54.20 (Pondicherry 1) days for the production of first female flower. However, the crosses took 39.60 (Green Long × Poinsette) to 51.55 (Pondicherry 1 × Kerala -2) days for the first female flower production . The magnitude of heterosis over better parent was significant in both the directions, whereas heterosis over the best parent and the commercial check was significant in the positive direction. The maximum and significant negative heterosis over better parent and also over check was found in the cross Green Long × Poinsette (-17.50%) and (-25.93%) Pondicherry 1 × Punjab Naveen.

4.2.9 Number of fruits per vine

In the genotypes the number of fruits per vine varied significantly , which ranged from 5.10 (Poinsette) to 5.45 (Punjab Naveen) among testers, 5.25 (IIHR 304 and Green Long) to 7.15 (IIHR 341) among lines and 3.20 (Pondicherry-1 × Poinsette) to 8.15 (IIHR 341 × Phule Shubhangi) among crosses. Heterosis over better parent, the best parent and the commercial check was highly significant in both the directions. The maximum and positively significant heterosis was observed in the cross Green long × Kerala -2 over better parent (18.69 %), over the best parent (55.24 %) IIHR 341× Poinsette and over the commercial check 64.65 % (IIHR 341 × Phule Shubhangi) .Out of 25 crosses, 5 crosses over better parent, 15 crosses over the best parent and 14 crosses over the commercial check exhibited positive significant heterosis.

4.2.10 Fruit diameter (cm)

The genotypes differed significantly among themselves for fruit diameter which ranged from 4.10 (Punjab Naveen) to 5.15 (Kerala -2) among testers, 4.11 (IIHR 285) to 5.05 (Pondicherry-1) among lines and 4.15 (IIHR 304 × Kerala -2) to 6.00 (Pondicherry 1 × Pusa Uday) among crosses. Heterosis over better parent, the best parent and the commercial check was highly significant in both the directions. The cross IIHR 341 × Phule Shubhangi exhibited negative and highly significant heterosis over better parent (-28.35 %). Maximum and positively significant heterosis over the best parent (-19.42%) IIHR 304 × Kerala -2 and over the commercial check (-19.42 %) also. Two crosses over better parent, five cross over the best parent and five crosses over the commercial check showed the significant and negative heterosis for fruit diameter.

Table 10. Heterosis (%) over better parent, the best parent and the commercial check for Fruit diameter, Fruit length, Average fruit weight

Sl. No.	Cross	Fruit diameter (cm)			Fruit length (cm)			Avg. fruit weight (g)		
		BP	BP	BP	BP	BTP	CC	BP	BTP	CC
1.	IIHR 285 × Poinsette	3.57	3.57	3.57	0.77	-3.45	-8.93 **	-22.48**	6.21**	-49.77 **
2.	IIHR 285 × Phule Shubhangi	13.25	13.25	13.25	0.08	1.29	-4.47	35.12**	-19.70 **	0.05
3.	IIHR 285 × Punjab Naveen	21.80**	21.8**	21.80**	12.15**	7.10*	1.02	-9.75**	-13.65 **	-24.36 **
4.	IIHR 285 × Pusa Uday	-7.22	-7.22	-7.22	11.25**	14.44**	7.94	-17.91**	8.30**	-18.65 **
5.	IIHR 285 × Kerala-2	1.94	1.94	1.94	14.14**	9.18**	2.98	3.54*	-39.11 **	2.02
6.	IIHR 341× Poinsette	23.69**	23.69**	23.69**	-0.47	-4.63	-10.05**	-11.48**	-42.01 **	-42.64 **
7.	IIHR 341 × Phule Shubhangi	-28.35**	28.35**	28.35**	25.29**	26.81**	19.6**	-26.22**	-16.16 **	-45.37 **
8.	IIHR 341 × Punjab Naveen	24.85**	24.85**	24.85**	12.15**	7.10*	1.02	-5.77**	8.64**	-21.02 **
9.	IIHR 341 × Pusa Uday	10.31	10.31	10.31	12.79**	16.02**	9.43**	3.28*	-25.50 **	2.34
10.	IIHR 341 × Kerala-2	-5.83	-5.83	-5.83	19.09**	13.92**	7.44**	-28.78**	-38.92 **	-29.82 **
11.	IIHR 304 × Poinsette	15.87*	15.87*	15.87*	2.69	-1.60	-7.20 **	-14.83**	-31.97 **	-42.46 **
12.	IIHR 304 × Phule Shubhangi	0.93	0.93	0.93	0.60	1.82	-3.97	-13.46**	-47.83 **	-35.92 **
13.	IIHR 304 × Punjab Naveen	17.03*	17.03*	17.03*	10.41**	5.45*	-0.55	-41.37**	-23.18 **	-50.86 **
14.	IIHR 304 × Pusa Uday	-13.30*	-13.30*	-13.30*	1.94	4.87	-1.09	-26.97**	7.27**	-27.64 **
15.	IIHR 304 × Kerala -2	-19.42**	-19.42**	-19.42**	13.86**	8.92**	2.73	2.56	15.87**	1.05
16.	Green Long × Poinsette	5.49	5.49	5.49	46.65**	46.65**	38.31**	15.87**	39.51**	9.15
17.	Green Long × Phule Shubhangi	16.48*	16.48*	16.48*	28.67**	30.23**	22.83**	39.51**	25.17**	31.42**
18.	Green Long × Punjab Naveen	9.89	9.89	9.89	38.23**	38.23**	30.37**	25.17**	45.33**	17.91**
19.	Green Long × Pusa Uday	15.46*	15.46*	15.46*	46.29**	50.49**	41.94**	38.16**	24.64**	36.90**
20.	Green Long × Kerala -2	4.85	4.85	4.85	31.86**	31.86**	24.37**	19.16**	49.28**	17.41**
21.	Pondicherry- 1 × Poinsette	26.73**	26.73**	26.73**	14.55**	24.52**	17.44**	39.16**	55.54**	40.62**
22.	Pondicherry- 1 × Phule Shubhangi	16.83**	16.83**	16.83**	16.21**	26.34**	19.16**	45.00**	45.45**	46.52**
23.	Pondicherry- 1 × Punjab Naveen	17.82**	17.82**	17.82**	22.22**	32.86**	25.31**	35.59**	42.25**	37.01**
24.	Pondicherry- 1 × Pusa Uday	18.81**	18.81**	18.81**	17.74**	27.99**	20.72**	32.61**	13.92**	34.00**
25.	Pondicherry- 1 × Kerala= 2	13.59*	13.59*	13.59*	9.63**	19.18**	12.41**	6.20**	6.21**	7.31**
	S.Em+_	0.30	0.30	0.30	0.48	0.48	0.48	7.92	7.92	7.92
	CD at 5%	0.62	0.62	0.62	1.01	1.01	1.01	16.33	16.33	16.33
	CD at 1%	0.84	0.84	0.84	1.36	1.36	1.36	22.16	22.16	22.16

*and ** indicate significance of values at p=0.05 and 0.01, respectively.

BP- Heterosis over better parent BTP- Heterosis over the best parent (Green Long) CC- Heterosis over the commercial check (Chitra)

4.2.11 Fruit length (cm)

In the genotypes significant differences were observed for the character fruit length and it varied from 18.18 (Kerala -2) to 19.55 (Pusa Uday) among testers, 16.40 (IIHR 285) to 20.66 (Pondicherry 1) among lines and 18.13 (IIHR 285 × Kerala-2) to 28.60 (Green long × Pusa Uday) among crosses. The magnitude of heterosis was significant in both the directions over better parent, the best parent and the commercial check. The cross Green Long × Poinsette showed maximum and positive significant heterosis over better parent (46.65 %), over the best parent (50.49%) Green long × Pusa Uday and over the commercial check (41.94 %) by Green long × Pusa Uday. Out of 25 crosses, 19 crosses over better parent, 20 crosses over best parent and 13 cross over commercial check recorded positive and significant heterosis for fruit length.

4.2.12 Average fruit weight (g)

The genotypes differed significantly among themselves for average fruit weight which ranged from 330.70 (Poinsette) to 405.70 (Pusa Uday) among testers, 202.5 (IIHR 285) to 515.00 (Pondicherry- 1) among lines and 250.80 (IIHR 304 × Punjab Naveen) to 747.75 (Pondicherry 1 × Phule Shubhangi) among crosses. The magnitude of heterosis over better parent and the commercial check was significant in both the directions. Maximum positive and significant heterosis over better parent was observed in the cross Green long × Phule Shubhangi (39.51 %) and (55.54 %) Pondicherry- 1 × Poinsette over best parent. The cross Pondicherry- 1 × Phule Shubhangi (46.52 %) showed maximum and positively significant heterosis over the commercial check. Among 25 crosses, 13 over better parent and 9 over the commercial check showed positive and significant heterosis.

Table 11. Heterosis (%) over better parent, the best parent and the commercial check for Fruit yield per plant, Shelf life, Cavity thickness

Sl. No.	Cross	Fruit yield per plant (kg)			Fruit yield per ha (t)			Shelf life (days)		
		BP	BTP	CC	BP	BTP	CC	BP	BTP	CC
1.	IIHR 285 × Poinsette	-34.15	-47.06**	-55.16**	-52.19	49.63	-25.00**	-8.89	-29.91 *	-25.45
2.	IIHR 285 × Phule Shubhangi	-31.95	-45.29**	-53.26**	-54.63	47.76	-26.67**	16.33	-2.56	3.64
3.	IIHR 285 × Punjab Naveen	-22.68	-37.84**	-47.26**	-63.89	40.67	-33.00**	11.83	-11.11	-5.45
4.	IIHR 285 × Pusa Uday	36.59**	9.80	-6.60	-122.92	-4.48	-73.33	-14.68	-20.51	-15.45
5.	IIHR 285 × kerala-2	51.22**	21.57	3.53	-137.55	-15.67	-83.33	9.71	-3.42	2.73
6.	IIHR 341× Poinsette	47.62**	21.57	3.53	-133.63	-15.67	-83.33	12.9	-10.26	-4.55
7.	IIHR 341 × Phule Shubhangi	30.95	7.84	-8.30	-116.96	-2.61	-71.67	9.18	-8.55	-2.73
8.	IIHR 341 × Punjab Naveen	64.29**	35.29**	13.30*	-150.30*	-28.73*	-95.00*	15.05	-8.55	-2.73
9.	IIHR 341 × Pusa Uday	50.00**	23.53**	5.30	-136.01*	-17.54*	-85.00*	5.50	-1.71	4.55
10.	IIHR 341 × Kerala-2	63.81**	43.14**	21.60**	-159.82	-36.19*	101.67**	22.33	7.69	14.55
11.	IIHR 304 × Poinsette	-11.11	-21.57	-33.33**	-73.90	25.37	-46.67*	25.27	-2.56	3.64
12.	IIHR 304 × Phule Shubhangi	-22.22	-31.37**	-41.60**	-62.78	34.70**	-38.33**	12.24	-5.98	0.00
13.	IIHR 304 × Punjab Naveen	-31.11	-39.22**	-48.30**	-53.89	42.16**	-31.67**	32.26*	5.13	11.82
14.	IIHR 304 × Pusa Uday	22.22	7.84	-8.30	-107.23	-2.61	-71.67	0.00	-6.84	-0.91
15.	IIHR 304 × Kerala -2	4.44	-7.84	-21.60**	-89.45	12.31	58.33**	20.39	5.98	12.73
16.	Green Long × Poinsette	68.22**	61.57**	55.79**	165.36**	73.51**	135.00**	14.53	14.53	21.82
17.	Green Long × Phule Shubhangi	5.88	5.88	-10.00	-88.89	-0.75	-70.00	16.24	16.24	23.64
18.	Green Long × Punjab Naveen	31.37**	31.37**	11.60	-114.38*	-25.00*	-91.67	18.80	18.80	26.36
19.	Green Long × Pusa Uday	66.47**	66.47**	54.30**	-164.58*	-72.76*	-134.33*	22.22	22.22	30.00*
20.	Green Long × Kerala -2	58.82**	58.82**	35.53**	141.83**	51.12**	115.00**	22.22	22.22	30.00*
21.	Pondicherry- 1 × Poinsette	-11.76	-11.76	-25.26**	-66.09	16.04	-55.00**	-1.64	2.56	9.09
22.	Pondicherry- 1 × Phule Shubhangi	47.66**	54.90**	31.32**	-129.53**	-47.39*	-111.67*	-5.74	-1.71	4.55
23.	Pondicherry- 1 × Punjab Naveen	55.79**	62.35**	50.47**	150.05**	67.91**	130.00**	0.82	5.13	11.82
24.	Pondicherry- 1 × Pusa Uday	47.06**	47.06**	35.89**	122.06**	-39.93*	105.00*	9.84	14.53	21.82
25.	Pondicherry- 1 × Kerala- 2	4.47	9.80	-6.60	-146.32	-64.18	-126.67	7.38	11.97	19.09
	S.Em+_	0.94	0.94	0.94	4.34	4.34	4.34	0.70	0.70	0.70
	CD at 5%	1.95	1.95	1.95	8.64	8.64	8.64	1.46	1.46	1.46
	CD at 1%	2.65	2.65	2.65	11.48	11.48	11.48	1.98	1.98	1.98

*and ** indicate significance of values at p=0.05 and 0.01, respectively.

BP- Heterosis over better parent BTP- Heterosis over the best parent (Green Long) CC- Heterosis over the commercial check (Chitra)

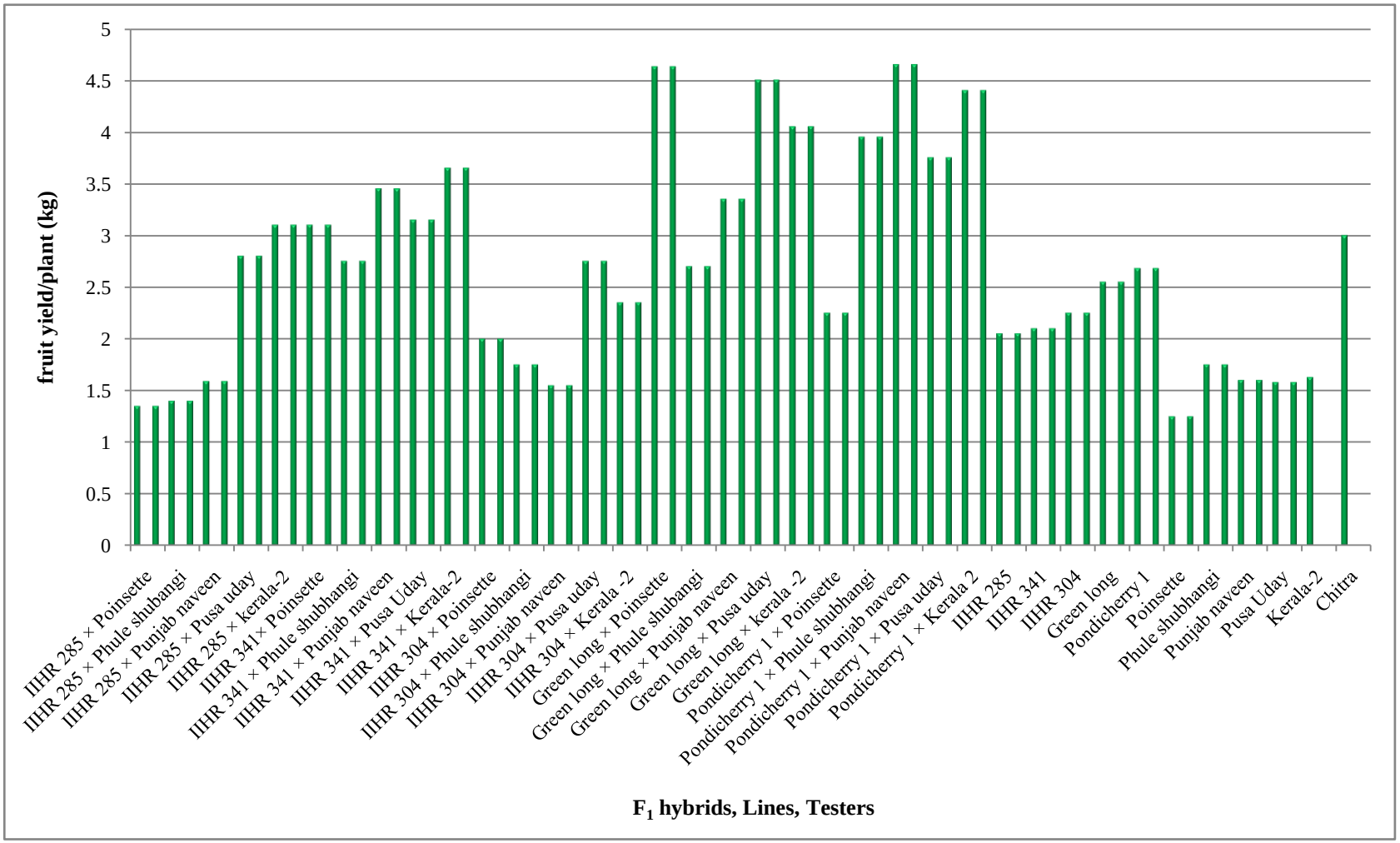

Fig. 2: Fruit yield (kg) of F_1 hybrids, lines and testers in cucumber

4.2.13 Fruit yield per plant (kg)

Genotypes differed significantly among themselves for fruit yield per vine which ranged from 1.25 (Poinsette) to 1.75 (Phule Shubhangi) among testers, 2.10 (IIHR 285) to 2.68 (Pondicherry 1) among lines and 1.35 (IIHR 285 × Poinsette) to 4.65 (Green Long × Poinsette) among crosses. The magnitude of heterosis over better parent, the best parent and the commercial check was significant in both the directions. The maximum and positively significant heterosis over commercial check exhibited by the cross 55.79 % (Green long × Poinsette), 54.3 % (Green Long × Pusa Uday) followed by the cross 50.47 % (Pondicherry 1 × Punjab Naveen) .

4.2.14 Shelf life (days)

The genotypes differed significantly among themselves for shelf life which ranged from 4.50 (Poinsette) to 5.45 (Pusa Uday) among testers, 4.25 (IIHR 285) to 6.10 (Pondicherry 1) among lines and 4.10 (IIHR 285 × Poinsette) to 7.15 (Green Long × Pusa Uday and Green long × Kerala -2) among crosses. The magnitude of heterosis over better parent, the best parent and the commercial check was significant in both the directions. The maximum heterosis over better parent was exhibited in the cross IIHR 304 × Punjab Naveen (32.26%) and over the commercial check 30.00 % (Green Long × Pusa Uday and Green long × Kerala -2.

4.2.15 Cavity thickness (cm)

Cavity thickness differed significantly among the genotypes which ranged from 2.04 (Punjab Naveen) to 2.17 (Kerala-2) among testers, 2.02 (IIHR 341) to 2.24 (Pondicherry- 1) among lines and 1.78 (IIHR 341× Poinsette) to 1.90 (IIHR 304 × Kerala -2 and IIHR 341 × Phule Shubhangi) among crosses. The magnitude of heterosis over better parent, the best parent and the commercial check was significant in both the directions. The maximum and significant heterosis over better parent was observed in the cross (-14.29%) Green Long × Punjab Naveen and over the commercial check (-15.24%) IIHR 341× Poinsette.

Table 12. Heterosis (%) over better parent, the best parent and the commercial check for Flesh thickness, Rind thickness

Sl. No.	Cross	Cavity thickness (cm)			Flesh thickness (cm)			Rind thickness (mm)		
		BP	BTP	CC	BP	BTP	CC	BP	BTP	CC
1.	IIHR 285 × Poinsette	-12.25**	-24.35 **	-16.43**	-13.95	15.99**	27.59**	-8.39**	-3.40	-0.70
2.	IIHR 285 × Phule Shubhangi	-7.00	-19.83 **	-11.43**	-25.58**	0.31	10.34	-11.38**	0.68	3.50
3.	IIHR 285 × Punjab Naveen	-7.50	-20.26 **	-11.90**	-23.26**	3.45	13.79	5.85**	23.13**	26.57**
4.	IIHR 285 × Pusa Uday	-7.00	-19.83 **	-11.43**	-27.91**	-2.82	6.90	-4.52*	0.68	3.50
5.	IIHR 285 × kerala-2	-7.75	-20.47 **	-12.14**	-20.93	6.58	17.24*	-7.78**	4.76*	7.69**
6.	IIHR 341× Poinsette	-11.00**	-23.28 **	-15.24**	-32.63**	0.31	10.34	-10.53**	4.08	6.99**
7.	IIHR 341 × Phule Shubhangi	-5.00	-18.10	-9.52	-28.42**	6.58	17.24*	-10.32**	-5.44**	-2.80*
8.	IIHR 341 × Punjab Naveen	-9.00	-21.55 **	-13.33**	-22.11**	15.99*	27.59**	-14.37**	2.72	0.01
9.	IIHR 341 × Pusa Uday	-6.00	-18.97	-10.48	-43.16**	-15.36*	-6.90	-14.62**	-0.68	2.10
10.	IIHR 341 × Kerala-2	-6.00	-18.97	-10.48	-17.89	22.26**	34.48**	-3.23	2.04	4.90*
11.	IIHR 304 × Poinsette	-10.95	-19.40 **	-10.95	-21.62**	-9.09	0.00	-9.58**	2.72	5.59**
12.	IIHR 304 × Phule Shubhangi	-10.71	-19.18 **	-10.71	-27.03**	-15.36*	-6.90	-11.70**	2.72	5.59**
13.	IIHR 304 × Punjab Naveen	-11.43**	-19.83 **	-11.43**	-32.43**	-21.63**	-13.79	-3.87*	1.36	4.20**
14.	IIHR 304 × Pusa Uday	-10.95	-19.40 **	-10.95	-16.22	-2.82	6.90	-10.18**	2.04	4.90**
15.	IIHR 304 × Kerala -2	-9.52	-18.10	-9.52	0.00	15.99*	27.59**	-9.94**	4.76*	7.69**
16.	Green Long × Poinsette	-10.24	-18.75	-10.24	15.99*	15.99*	27.59**	-0.65	4.76*	7.69**
17.	Green Long × Phule Shubhangi	-13.81**	-21.98 **	-13.81**	-24.32**	-12.23	-3.45	-5.99**	6.80**	9.79**
18.	Green Long × Punjab Naveen	-14.29**	-22.41 **	-14.29**	-24.20**	-18.50*	-10.34	-8.19**	6.80**	27.27**
19.	Green Long × Pusa Uday	-13.10**	-21.34 **	-13.10**	-5.96	-5.96	3.45	0.55	23.81**	31.47**
20.	Green Long × Kerala -2	-14.52**	-22.63 **	-14.52	0.31	0.31	10.34	3.87*	27.89**	32.87**
21.	Pondicherry- 1 × Poinsette	-10.48	-18.97	-10.48	21.21**	25.39**	37.93**	4.97**	29.25**	9.79**
22.	Pondicherry- 1 × Phule Shubhangi	-10.24	-18.75	-10.24	2.16	18.5*	30.34**	1.29	6.80**	10.43**
23.	Pondicherry- 1 × Punjab Naveen	-10.48	-18.97	-10.48	-27.11**	-21.63**	-13.79	-5.39**	7.48**	11.19**
24.	Pondicherry- 1 × Pusa Uday	-12.38**	-20.69 **	-12.38**	-18.18	-15.36*	-6.90	-7.02**	8.16**	12.59**
25.	Pondicherry- 1 × Kerala- 2	-9.76	-18.32	-9.76	-6.06	-2.82	27.59**	-8.00**	9.52**	15.38**
	S.Em+_	0.08	0.08	0.08	0.11	0.11	0.24	0.01	0.01	0.01
	CD at 5%	0.16	0.16	0.16	0.24	0.24	0.32	0.02	0.02	0.02
	CD at 1%	0.22	0.22	0.22	0.32	0.32	27.59**	0.03	0.03	0.03

*and ** indicate significance of values at p=0.05 and 0.01, respectively.

BP- Heterosis over better parent BTP- Heterosis over the best parent (Green Long) CC- Heterosis over the commercial check (Chitra)

4.2.16 Flesh thickness (cm)

Flesh thickness differed significantly among the genotypes which ranged from 1.22 (Poinsette) to 2.17 (Kerala -2) among testers, 1.59 (Green Long) to 2.37 (IIHR 341) among lines and 1.30 (Green long × Punjab Naveen) to 1.89 (Pondicherry 1 × Phule Shubhangi) among crosses. The magnitude of heterosis over better parent, the best parent and the commercial check was significant in both the directions. The maximum and significant heterosis over better parent was observed in the cross Pondicherry-1 × Poinsette (21.21 %) and showed the maximum and significant heterosis over the best parent (25.39%) Pondicherry-1 × Poinsette and over the commercial check (37.93 %) Pondicherry-1 × Poinsette. Out of 25 crosses, 2 crosses over better parent, and 10 crosses over the commercial check exhibited the positive and significant heterosis for flesh thickness.

4.2.17 Rind thickness (mm)

Rind thickness differed significantly among the genotypes. It varied from 0.71 (Poinsette) to 0.87 (Kerala -2) among testers, 0.69 (IIHR 285 and IIHR 304) among lines and 0.69 (IIHR 341 × Phule Shubhangi) to 0.95 (Pondicherry 1 × Poinsette) among crosses. The magnitude of heterosis over better parent, over the best parent and the commercial check was observed in both the directions. The maximum negative and significant heterosis over better parent (-14.62 %) IIHR 341 × Pusa Uday , over the best parent (-5.44%) IIHR 341 × Phule Shubhangi and over the commercial check (-2.80 %) IIHR 341 × Phule Shubhangi. Among crosses, 15 over better parent, 1 over the best parent and 2 over the commercial check exhibited positive and significant heterosis.

4.3 Combining ability

The variance due to general combining ability (GCA), specific combining ability (SCA) and GCA to SCA ratio for various characters are presented in Table 13. GCA to SCA ratio was higher than unity for vine length (1.13), number of branches (3.18), days to first fruit harvest (1.42), sex ratio (1.07), fruit length (2.19), fruit diameter (1.84), average fruit weight (1.62), shelf life (2.10) and rind thickness (1.30). Low GCA to SCA ratio was observed for the ratio was near to unity for number of nodes per vine (0.96), node at first female flower appearance (0.55), node at first male flower appearance (0.34) ,days to female flower anthesis (0.45), number of fruits per vine (0.38), fruit yield per plant(0.63), cavity thickness (0.14), flesh thickness (0.33), indicating predominance of non-additive gene action and hence these traits can be improved through recurrent selection for specific combining ability or heterosis. There is a great scope for heterosis breeding to exploit non-additive variance observed for yield and yield components.

Table 13. Variance due to general and specific combining ability for different characters in cucumber

Sl. No.	Character	GCA	SCA	GCA:SCA
1	Vine length (cm)	119.18	105.11	1.13
2	No. of branches per plant	0.09	0.03	3.18
3	No. of nodes per vine	5.51	5.69	0.96
4	Node of female flower appearance	0.26	0.47	0.55
5	Node of male flower appearance	0.11	0.34	0.34
6	Days to first fruit harvest	4.83	3.39	1.42
7	Sex ratio	0.14	0.13	1.07
8	Days to female flower anthesis	2.18	5.02	0.43
9	Number of fruits per plant	0.36	0.93	0.38
10	Fruit diameter (cm)	0.15	0.08	1.84
11	Fruit length (cm)	4.36	1.98	2.19
12	Average fruit weight (g)	12565.66	7753.24	1.62
13	Fruit yield per plant (kg)	0.03	0.05	0.63
14	Shelf life (days)	0.24	0.11	2.10
15	Cavity thickness (cm)	0.00	0.002	0.14
16	Flesh thickness (cm)	0.01	0.03	0.33
17	Rind thickness (mm)	0.0013	0.0010	1.30

4.3.1 Vine length (cm)

For vine length, there was significant *gca* effects in both the direction. Maximum positive and significant *gca* effects was observed in the lines Pondicherry- 1 and Green Long (10.67). The testers also exhibited significant *gca* effects like Pusa Uday (10.47). Among crosses, seven crosses showed positively significant *sca* effects. Maximum *sca* effects (9.78) was exhibited by the cross IIHR 304 x Poinsette followed by Pondicherry 1 x Poinsette (6.79).

4.3.2 Number of branches

Two lines exhibited significant *gca* effects in positive direction, which is desirable. Maximum *gca* effects was observed in the line Pondicherry- 1 (0.43) followed by Green Long (0.39). The testers showed significant *gca* effects in (0.24) Phule Shubhangi. Among the crosses, two crosses showed positive and significant *sca* effects. Maximum positive *sca* effects was observed in the cross IIHR 304 × Kerala -2 (0.42) followed by IIHR 341× Poinsette (0.27).

4.3.3 Number of nodes per vine

For number of nodes per vine, maximum positive and significant *gca* effects was observed in the line (3.75) Pondicherry 1 and testers exhibited positive and significant *gca* effects in (1.35) Pusa Uday. Among the crosses only cross (2.73) IIHR 341 × Phule Shubhangi was exhibited positive and significant *sca* effects which is desirable.

Table 14. General combining ability effects for growth and earliness parameters in cucumber

Sl. No.	Parents	Vine length	No. of branches per plant	No.of nodes per vine	Node of female flower appearance	Node of male flower appearance	No. of male flowers per plant	No. of female flowers per plant	Days to first fruit harvest	Sex ratio
	Lines									
1	IIHR 285	-10.65 **	-0.42**	-0.61**	-0.11	-0.14**	-1.46	1.92**	-0.86	-0.41**
2	IIHR 341	-7.67 **	0.03	0.59**	-0.60**	-0.14**	0.99	2.95**	-3.97**	-0.45**
3	IIHR 304	-8.74 **	-0.45**	-4.96**	0.60**	-0.49**	-4.24*	-1.68**	-0.29	0.09
4	Green Long	10.67**	0.39**	1.24**	-0.54**	0.16**	-2.30	-0.63*	0.23	-0.02
5	Pondicherry- 1	10.67**	0.43**	3.74**	0.66**	0.61**	7.01**	-2.54**	4.88**	0.79**
	Testers									
1	Poinsette	-10.14 **	-0.21*	-0.57**	-0.19*	0.08	-3.16*	0.44	-0.28	-0.21*
2	Phule Shubhangi	-8.51**	0.24*	-0.59**	-0.14	0.28**	-2.18	0.08	0.11	-0.12
3	Punjab Naveen	6.82**	0.04	0.60**	-0.42**	0.21**	1.48	-0.04	1.09	0.05
4	Pusa Uday	10.47**	0.05	1.32**	0.61**	-0.30**	1.44	0.28	-0.91	-0.09
5	Kerala-2	1.37	-0.14	-0.76**	0.15	-0.27**	2.41	-0.75*	-0.02	0.29**
	S.Em±	1.24	0.09	0.15	0.07	0.04	1.53	0.30	0.71	0.08
	CD at 5%	2.57	0.19	0.31	0.15	0.08	3.16	0.16	1.46	0.17
	CD at 1%	3.4	0.26	0.43	0.21	0.11	4.28	0.83	1.98	0.23

*and ** indicate significance of values at p=0.05 and 0.01, respectively

4.3.4 Node at first female flower appearance

For number of nodes at first female flower, two lines exhibited negative and significant *gca* effects like (-0.60) IIHR 341 and (-0.54) Green long and two testers exhibited significantly negative *gca* effects. Among the 25 crosses only five crosses exhibited negative and significant *sca* effects which is desirable. Maximum negative *sca* effects was observed in the cross Pondicherry- 1 × Punjab Naveen (-0.77 %) .

4.3.5 Node at first male flower appearance

For nodes up to first male flower, three lines had negatively significant *gca* effects and two line had positively significant *gca* effects. Maximum negative *gca* effects was observed in the lines (-0.49) IIHR 304 .Among the testers, (-0.30) Pusa Uday showed significant and negative *gca* effects. Among the crosses, 11 crosses exhibited significant and negative *sca* effects and 9 cross exhibited significant and positive *sca* effects. Maximum negative *sca* effects was observed in the cross Pondicherry 1 × Phule Shubhangi (-1.01).

4.3.6 Days to first fruit harvest

Among 5 lines, two lines each exhibited significant *gca* effects in both the directions. The highest *gca* effects was observed in the line (-3.97) IIHR 341. Among the testers, there was no significant *gca* effects. Among the crosses, two crosses each exhibited significant *sca* effects in both the directions. The highest *sca* effects was observed in the cross Green Long × Pusa Uday (-5.49).

4.3.7 Sex ratio

For sex ratio, lines IIHR 341 (-0.45) and IIHR 285(-0.41) showed negative and significant *gca* effects and other lines exhibited significant positive *gca* effects. Among the testers, Poinsette (-0.21) exhibited significant and negative *gca* effects. Among 25 crosses, four crosses exhibited significant in desirable direction (negative) and three cross exhibited the positive and significant *sca* effects. The highest negative and significant *sca* effects was observed in the cross (-0.60) IIHR 285 × Kerala-2.

Table 15. General combining ability effects for yield and quality parameters in cucumber

Sl. No.	Parent	Days to female flower anthesis	Number of fruits per plant	Fruit diameter (cm)	Fruit length (cm)	Avg. fruit weight (g)	Fruit yield per plant (kg)	Shelf life (days)	Cavity thickness (cm)	Flesh thickness (cm)	Rind thickness (mm)
	Lines										
1	IIHR 285	-0.59	-0.70**	-0.40 **	-2.22 **	-71.19 **	-0.95**	-0.86 **	-0.01	0.07	-0.003
2	IIHR 341	-2.66**	1.46**	0.10	-1.06**	-117.94 **	0.22	-0.32	0.00	0.09*	-0.030**
3	IIHR 304	0.48	-0.43**	-0.61 **	-2.57 **	-137.65 **	-0.91**	-0.12	0.02	-0.10**	-0.035**
4	Green long	2.39**	-0.28*	0.05	4.19	136.51**	0.22	1.02**	-0.02	-0.06	-0.033**
5	Pondicherry- 1	0.37	-0.05	0.85	1.66	190.27**	1.42**	0.30	0.02	0.01	-0.008
	Testers										
1	Poinsette	-1.02	-0.13	0.00	-0.97 **	-65.46 **	-0.33	-0.37	-0.01	0.15**	0.145**
2	Phule Shubhangi	0.53	0.17*	-0.01	-0.02	18.02**	-0.48	-0.10	0.01	-0.01	0.002
3	Punjab Naveen	-1.16	0.06	0.10	0.13	-20.77 **	-0.08	0.03	-0.01	-0.13**	-0.020**
4	Pusa Uday	-0.39	-0.01	-0.03	1.01**	48.89**	0.39	0.01	0.00	-0.13**	0.023**
5	Kerala-2	2.04*	-0.09	-0.06	-0.15	19.31**	0.51	0.44	0.01	0.13**	0.0031
	S.Em±	0.62	0.08	0.09	0.15	2.50	0.29	0.22	0.02	0.03	0.003
	CD at 5%	1.28	0.17	0.19	0.31	5.17	0.61	0.46	0.05	0.07	0.006
	CD at 1%	1.73	0.23	0.26	0.43	7.00	0.83	0.62	0.07	0.10	0.008

*and ** indicate significance of values at p=0.05 and 0.01, respectively

4.3.8 Days to female flower anthesis

Among 5 lines, one line exhibited negative and significant *gca* effects and one line showed positively significant *gca* effects. The only line IIHR 341 (-2.66) exhibited negative and significant *gca* effects. Among the testers, Kerala-2 (2.04) showed significantly positive *gca* effects. Among the 25 crosses, two crosses exhibited significant and negative *sca* effects and three crosses exhibited significantly positive *sca* effects. Maximum negative and significant *sca* effects was observed in the cross (-4.98) Green Long × Poinsette.

4.3.9 Number of fruits per vine

Among 5 lines, only one line exhibited positive and significant *gca* effects. The highest *gca* effects was observed in the line (1.46) IIHR 341. The tester (0.17) Phule Shubhangi exhibited positive and significant *gca* effects. The eight crosses exhibited significant *sca* effects for number of fruits per vine. The highest was (1.37) IIHR 304 × Phule Shubhangi.

4.3.10 Fruit length (cm)

For fruit length, none of the lines had shown positive and significant *gca* effects and three lines had significantly negative *gca* effects. Among crosses, only one cross showed significantly positive *sca* effects (1.05) Pusa Uday and one cross showed significantly negative *sca* effects. Among crosses six exhibited significantly positive *sca* effects. The highest positive and significant *sca* effects was exhibited by the cross (2.33) Green Long × Poinsette

4.3.11 Fruit diameter (cm)

Among 5 lines, none of the lines exhibited significant *gca* effects for fruit diameter. Among testers, there was no significant *gca* effects. Among the crosses, two cross exhibited positive and significant *sca* effects. Maximum and significant *sca* effects was observed in the cross (0.55) IIHR 285 × Kerala-2.

Table 16. Specific combining ability effects for growth and earliness parameters in cucumber

Sl. No.	Cross	Vine length (cm)	No. of branches per plant	No. of nodes per vine	Node of female flower appearance	Node of male flower appearance	Days to first fruit harvest	Sex ratio	Days to female flower anthesis	Number of fruits per plant
1.	IIHR 285 × Poinsette	-0.15	0.13*	3.21**	0.27	-0.31**	-1.52	0.26	-0.88	-1.11**
2.	IIHR 285 × Phule Shubhangi	-15.73**	-0.12	-3.56**	0.92**	0.84**	-0.87	0.24	-0.39	-1.25**
3.	IIHR 285 × Punjab Naveen	2.72	0.07	0.43	-0.19	-0.44**	0.44	0.18	1.50	-0.19
4.	IIHR 285 × Pusa Uday	8.04**	-0.13*	0.51	-0.68**	0.22*	1.90	-0.09	0.83	1.73**
5.	IIHR 285 × Kerala-2	5.72*	0.06	-0.59	-0.32	-0.31**	0.06	-0.60**	-1.05	0.84**
6.	IIHR 341× Poinsette	-22.13**	0.27**	-3.42**	-0.01	-0.46**	1.23	-0.12	0.38	0.23
7.	IIHR 341 × Phule Shubhangi	13.03**	0.11	2.73**	0.41*	0.44**	-0.10	-0.14	1.02	0.47*
8.	IIHR 341 × Punjab Naveen	2.69	-0.18**	1.03**	0.64**	0.66**	2.10	-0.27	4.27**	-0.16
9.	IIHR 341 × Pusa Uday	0.94	-0.19**	1.31**	-0.64**	-0.28**	1.21	-0.02	1.64	-0.38
10.	IIHR 341 × Kerala-2	5.76*	0.00	-1.65**	-0.28**	-0.36**	0.77	0.57**	-1.47	-0.15
11.	IIHR 304 × Poinsette	9.78**	0.06	-0.09	-0.19	0.99**	-1.04	0.25	-1.31	0.88**
12.	IIHR 304 × Phule Shubhangi	-13.84**	-0.24**	-0.81*	-0.34	-0.61**	0.01	-0.12	0.87	1.37**
13.	IIHR 304 × Punjab Naveen	-1.68	-0.39	1.68**	0.43*	-0.59**	-3.82*	0.44*	-1.72	-0.36
14.	IIHR 304 × Pusa Uday	2.36	0.09	-1.73**	0.44*	-0.13**	2.43	-0.05	-0.09	-1.13**
15.	IIHR 304 × Kerala -2	3.36	0.49**	0.95*	-0.34	0.34**	2.44	-0.51**	2.26	-0.75**
16.	Green Long × Poinsette	5.51*	-0.38**	-0.15	-0.11	-0.36**	-2.32	-0.25	-4.98**	-0.33
17.	Green Long × Phule Shubhangi	8.68**	0.25**	-0.42	0.15	0.34**	1.97	0.18	0.61	-0.62**
18.	Green Long × Punjab Naveen	0.24	0.25**	-3.32**	0.30	0.21**	1.39	0.08	-0.63	-0.38
19.	Green Long × Pusa Uday	-10.40**	0.14*	0.05	-0.13	-0.13	-5.49**	0.22	-0.69	0.61**
20.	Green Long × Kerala -2	-4.05	-0.25**	3.84**	-0.34	-0.06	1.32	-0.24	-0.14	0.69**
21.	Pondicherry- 1 × Poinsette	6.97**	-0.07	0.45	-0.25	0.14	0.57	-0.14	3.29*	0.30
22.	Pondicherry- 1 × Phule Shubhangi	7.84**	0.01	2.07**	-1.15**	-1.01**	1.12	-0.15	-2.11	0.04
23.	Pondicherry- 1 × Punjab Naveen	-3.91	0.26**	0.17	-0.77**	0.16	-2.21	-0.44*	-3.41*	1.10**
24.	Pondicherry- 1 × Pusa Uday	-0.94	0.10	-0.14	0.88**	0.32**	-0.04	-0.05	-1.68	-0.81**
25.	Pondicherry- 1 × Kerala -2	-9.89 **	-0.29**	-2.55**	1.29**	0.39**	-1.53	0.79**	3.92**	-0.63**
	S.Em±	2.79	0.06	0.34	0.17	0.09	1.59	0.18	1.38	0.18
	CD at 5%	5.76	0.13	0.71	0.35	0.18	3.28	0.38	2.86	0.39
	CD at 1%	7.81	0.17	0.96	0.48	0.25	4.44	0.51	3.88	0.52

*and ** indicate significance of values at p=0.05 and 0.01, respectively

4.3.12 Average fruit weight (g)

Five of each lines exhibited significant *gca* effects in both the directions among the lines. Maximum and positive *gca* effects was observed in the line (190.20) Pondicherry- 1 followed by (136.50) Green Long. Three of the testers exhibited the significant and positive *gca* effects. Among the crosses, 10 crosses exhibited positive and significant *sca* effects. Maximum and significant *sca* effects was observed in the cross (145.00) IIHR 304 × Kerala -2 followed by (102.30) IIHR 341 × Pusa Uday.

4.3.13 Fruit yield per plant (kg)

For fruit yield per vine , one line showed significant and positive *gca* effects, the highest was observed in the line (1.48) Pondicherry-1 and two lines showed significantly negative *gca* effects. Among testers there was no significant and positive *gca* effects. Among crosses, seven crosses exhibited positively *sca* effects. Maximum and positively significant *sca* effects was observed in the cross (0.54) Green Long × Poinsette.

4.3.14 Shelf life (days)

Among 5 lines, one line exhibited significant *gca* effects for shelf life . The highest positive *gca* effects was exhibited by the line (1.02) Green Long . Among testers, there was no positive and significant *gca* effects. Among the crosses, there was no significant *sca* effects .

4.3.15 Cavity thickness (cm)

For cavity thickness, none of the lines and testers showed significant *gca* effects None of the testers exhibited significant *gca* effects. Among the crosses, there was no significant *sca* effects.

4.3.16 Flesh thickness (cm)

For flesh thickness, only line (0.09) IIHR 341 exhibited positive and significant *gca* effects. Among the testers, (0.15) Poinsette and (0.13) Kerala -2 exhibited positive and significant *gca* effects. Among the crosses, four crosses exhibited positive and significant *sca* effects. Maximum and significant *sca* effects was observed in the cross (0.29) Pondicherry -1 × Phule Shubhangi.

Table 17. Specific combining ability effects for yield and quality parameters in cucumber

Sl. No.	Cross	Fruit diameter (cm)	Fruit length (cm)	Avg. fruit weight (g)	Fruit yield per plant (kg)	Shelf life (days)	Cavity thickness (cm)	Flesh thickness (cm)	Rind thickness (mm)
1.	IIHR 285 × Poinsette	-0.41	-0.76*	-95.94**	-0.36	-0.58	-0.06	0.02	-0.05**
2.	IIHR 285 × Phule Shubhangi	-0.04	-0.81*	74.81**	-0.16	0.74	0.01	-0.06	-0.04**
3.	IIHR 285 × Punjab Naveen	0.13	0.12	-10.93	-0.38	0.10	0.02	0.11	0.09**
4.	IIHR 285 × Pusa Uday	-0.22	0.64	-51.50**	0.36	-0.42	0.02	0.01	0.001
5.	IIHR 285 × Kerala-2	0.55 *	0.81*	83.57**	0.54	0.14	0.01	-0.10	0.015
6.	IIHR 341× Poinsette	0.02	-2.15**	-12.79*	0.21	0.02	-0.05	-0.24**	-0.013
7.	IIHR 341 × Phule Shubhangi	0.24	2.86**	-110.23**	0.01	-0.14	0.03	0.02	0.002
8.	IIHR 341 × Punjab Naveen	-0.02	-1.03**	52.81**	0.31*	-0.28	-0.02	0.29**	0.004
9.	IIHR 341 × Pusa Uday	0.11	-0.22	102.39**	-0.46	0.13	0.02	-0.20**	-0.006
10.	IIHR 341 × Kerala-2	-0.35	0.54	-32.17**	-0.08	0.25	0.01	0.12	0.017
11.	IIHR 304 × Poinsette	0.44 *	-0.07	7.81	0.25*	0.27	0.01	-0.19*	0.004
12.	IIHR 304 × Phule Shubhangi	-0.18	-0.37	-42.27**	0.15	-0.19	-0.01	-0.13	-0.021*
13.	IIHR 304 × Punjab Naveen	0.39	0.15	-79.72**	-0.44	0.31	-0.00	-0.10	0.010
14.	IIHR 304 × Pusa Uday	-0.31	-0.82*	-30.89**	0.13	-0.36	-0.00	0.19*	-0.002
15.	IIHR 304 × Kerala -2	-0.33	1.11**	145.08**	-0.24	-0.04	0.01	0.22**	-0.008
16.	Green Long × Poinsette	-0.42	2.33**	-2.95	0.53**	0.12	0.08	0.16	0.010
17.	Green Long × Phule Shubhangi	0.09	-1.73**	27.20**	-0.03	-0.04	-0.02	-0.12	0.008
18.	Green Long × Punjab Naveen	-0.32	-0.37	-2.94	0.31*	-0.03	-0.01	-0.09	-0.018
19.	Green Long × Pusa Uday	0.41	1.07**	24.28**	0.31**	0.18	-0.01	0.10	-0.003
20.	Green Long × Kerala -2	0.24	-1.29**	-45.58**	0.27	-0.24	-0.03	-0.06	0.009
21.	Pondicherry- 1 × Poinsette	0.37	0.65	103.88**	-0.63**	0.14	0.02	0.24**	-0.006
22.	Pondicherry- 1 × Phule Shubhangi	-0.10	0.05	50.49**	0.01	-0.37	-0.05	0.29**	0.015
23.	Pondicherry- 1 × Punjab Naveen	-0.17	1.13**	40.79**	0.30**	-0.11	0.01	-0.22**	0.003
24.	Pondicherry- 1 × Pusa Uday	0.01	-0.67	-44.27**	-0.31	0.45	-0.03	-0.12	-0.018
25.	Pondicherry- 1 × Kerala -2	-0.10	-1.17**	-150.89**	-0.53	-0.12	0.08	-0.19*	0.003
	S.Em±	0.21	0.34	5.60	0.09	0.50	0.05	0.08	0.009
	CD at 5%	0.44	0.71	11.56	0.19	1.03	0.11	0.17	0.019
	CD at 1%	0.59	0.96	15.67	0.26	1.40	0.15	0.22	0.025

*and ** indicate significance of values at p=0.05 and 0.01, respectively

4.3.17 Rind thickness (mm)

For rind thickness, only three line showed negative and significant *gca* effects and two line showed negative and significant *gca* effects. One of the tester exhibited significant *gca* effects. Among the crosses, only three cross exhibited negative and significant *sca* effects. The maximum was found in (-0.04) IIHR 285 × Phule Shubhangi.

Table 18. Per cent contribution of lines, tester and line × tester for different characters in cucumber

Sl. No.	Character	Line	Tester	Line × Tester
1.	Vine length (cm)	47.63	25.14	27.22
2.	Number of branches per plant	65.92	11.87	22.19
3.	Number of nodes per vine	65.05	5.37	29.56
4.	Node of female flower appearance	39.79	17.20	42.99
5.	Node of male flower appearance	32.25	13.90	53.84
6.	Days to first fruit harvest	65.79	3.45	30.74
7.	Sex ratio	60.03	9.04	30.92
8.	Days to female flower anthesis	31.64	16.40	51.94
9.	Number of fruits per plant	47.80	1.05	51.13
10.	Fruit diameter (cm)	74.92	0.96	24.11
11.	Fruit length (cm)	79.03	4.83	16.13
12.	Average fruit weight (g)	73.92	6.22	19.85
13.	Fruit yield per plant (kg)	74.30	14.75	10.93
14.	Shelf life (days)	72.02	12.56	15.41
15.	Cavity thickness (cm)	30.34	10.02	59.62
16.	Flesh thickness (cm)	12.09	31.70	56.20
17.	Rind thickness (mm)	78.70	7.15	14.13

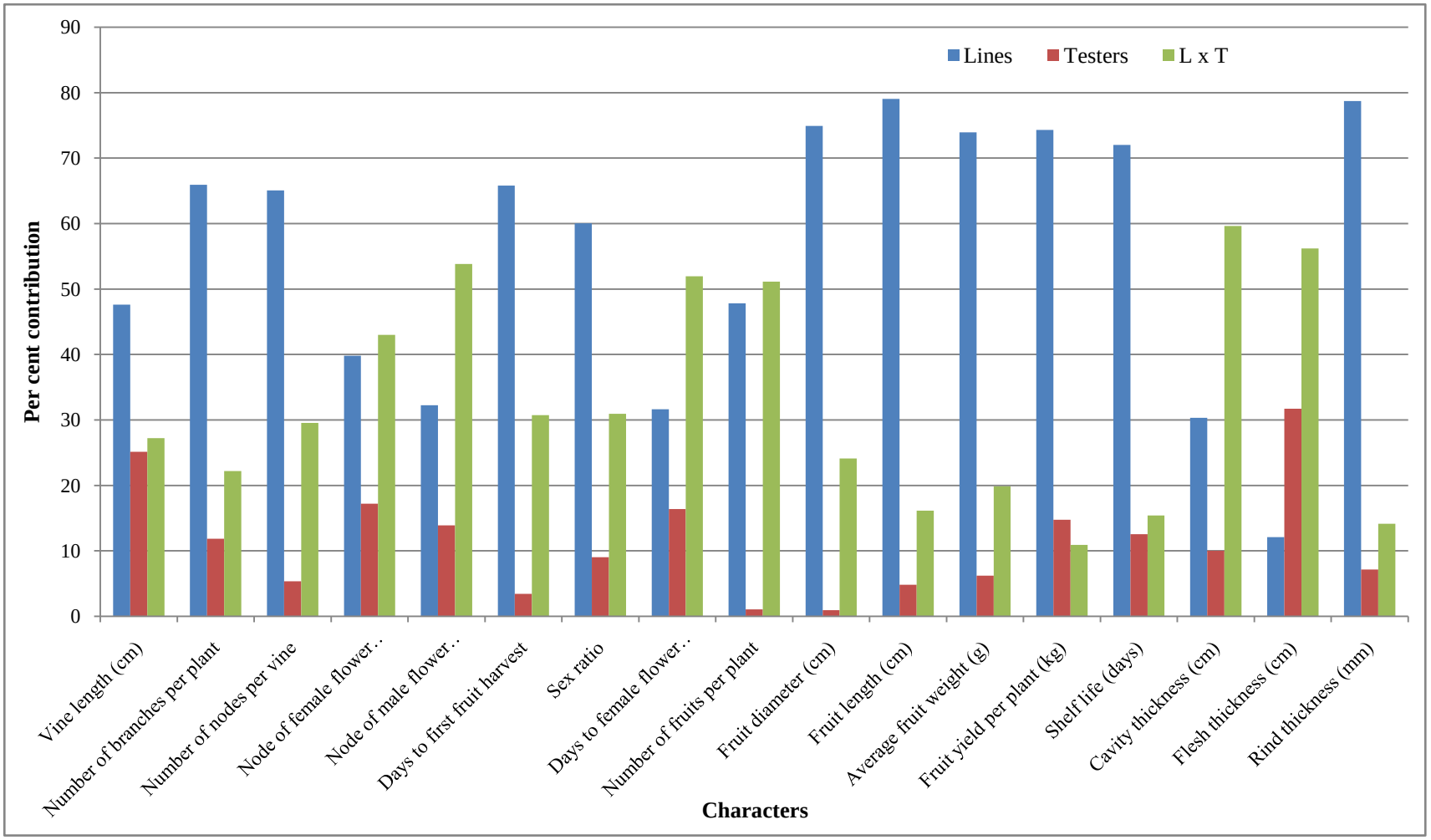

Fig. 3: Per cent contribution of lines, testers and line × tester for different characters in cucumber

V. DISCUSSION

Cucumber is the one of the important crop grown in India. It is regarded as home of cucumber and greater range of variability is available in cucumber. Hence, there is a wide scope to exploit heterosis. Hybridization is one of the means of obtaining increased yield and exploitation of heterosis and is an efficient approach for crop improvement. Heterosis can be defined as superiority of F_1 over its parents and F_1 hybrids derived from crossing of pure lines are uniform in growth and development and possess better adaptability to changing and adverse environmental conditions and give early as well as higher total yield. In practical plant breeding, superiority of the F_1 over mid parent is of little value, since it does not offer any advantage to exploit it commercially. The commercial usefulness of the hybrid would depend on its performance in comparison to the best available hybrid. Hence, heterosis over the better parent, best parent and the standard check was worked out in the present investigation for identification of superior hybrids in cucumber.

The line x tester analysis is one of the technique where a large number of genotypes could be tested for their combining ability. This method was developed by Kempthrone (1957) which has been used in the present study for estimating combining ability and other genetic parameters. Heterosis and combining ability for growth, earliness, yield and quality parameters are discussed in this chapter.

For a systematic breeding programme, it is essential to identify the parents, as well as crosses which could be exploited. This is important in order to bring about further genetic improvement in economic characters. For exploitation of heterosis, the information on *gca* should be supplemented with *sca* and hybrid performance. Heterosis in F_1 indicates operation of non-additive gene effects, but it cannot give any idea about the relative magnitude of non-additive (dominance + epistasis) and additive gene action. Hence analysis of combining ability is one of the potential tools for identifying prospective parents to develop commercial F_1 hybrids (Griffing, 1956). General and specific combining ability effects and variances obtained from a set of F_1's would enable a breeder to select desirable parents and crosses for each of the quantitative components.

General combining ability effects of parents and specific combining ability effects of crosses were highly significant for the characters studied. From the present investigation, it is evident that *gca* or *sca* effects in parents and crosses are in desirable direction for some characters and in undesirable direction for some other traits. Therefore, it is important to ascertain the status of parent or hybrid with respect to combining ability effects over a number of component characters (Arunachalam and Bandopadhay, 1979).

The best cross combinations for most of the characters generally involved one good and one poor general combiner with high *sca* effects. It may be due to a complementary gene action, which can be fixed in the segregating generation. On the contrary, crosses with high *sca* effects involving low (negative) x low (negative) combiners parents may be used for exploring hybrids as the non-additive, non-fixable genes seems to play a major role (Brar *et al*., 2011).

Among the parents involved at least one parent as poor or average combiner. These results indicated that high frequency of highly heterotic hybrids could be obtained from parental combinations with high (positive) x low (negative) or low (negative) x average general combining ability which clearly indicates that, the parental contribution to the heterosis is mainly through non-additive gene effects. Complement the epistatic effects present in the cross, which would finally result in higher *sca* effects. Hence, exploitation of heterosis appears to be an appropriate strategy for improvement in cucumber.

With the main aim of increasing the yield of the crop an ideotype has to be developed. The ideotype in cucumber should have more vine length, more number of branches and early flowering, greater fruit length, high fruit weight, more number of fruits per vine and highest fruit yield per vine. Therefore, the present study is conducted to find out the magnitude of heterosis in the cross combinations and to make use of line x tester analysis to estimate the combining ability keeping an ideotype in view.

5.1 Analysis of variances for parents and hybrids

Genetic diversity is prerequisite for getting high magnitude of heterosis. In this present investigation, variance due to genotypes was highly significant for all growth, earliness, and yield parameters except days to first harvest. Variance due to parents was highly significant for majority of characters studied (Table 4) indicating, the presence of diversity among parents used in the study. The mean sum of squares of hybrids were significant for all characters. The significance indicates the divergence among themselves. The contribution to the total hybrid variance was found to be higher in female parents than the male parents for all the characters under study as female parents were genetically diverse than male parents.

5.2 Heterosis and its attributing characters

5.2.1 Vine length (cm)

In the present study, most of the hybrids recorded heterosis in positive direction. The vine length was measured at time of harvest and the parent range of vine length was 148.60 cm to 205.60 cm. The vine length of the crosses ranged from 175.30 cm to 241.20 cm. The maximum vine length was exhibited by the hybrid Pondicherry -1 × Pusa Uday (241.20 cm).

Green Long × Pusa Uday (19.91%) followed by Pondicherry 1 × Punjab Naveen (16.58 %) exhibited the significant positive standard heterosis over check Chitra. Vine length is positively correlated with yield hence, this hybrids also exhibited the significant standard heterosis for yield. The increased vine length, it is a desirable trait to realize higher yield provided the environmental conditions are otherwise conducive for growth and fruiting over a longer period. From the productivity point of view, vine length is an important growth parameter which was reported by several workers, to be an important yield component as it was significantly associated with fruit yield. This results in line with the findings of Ojha *et al.* (2009), Sharma *et al*. (2012), Arya and Singh (2014) and Jat *et al.* (2015).

5.2.2 Number of branches per vine

Branches are the important growth parameters contributing to productivity. For realizing high fruit yield, desirable degree of vegetative growth is essential (Mule *et al*., 2012). The parents had the range of 4.05 to 5.30 branches per vine. The maximum *per se* performance of parent was observed in Pondicherry 1 (5.30), while the hybrids had the range of 4.80 to 6.50 and maximum *per se* performance was observed in the cross Green long × Phule Shubhangi (6.50) followed by Pondicherry 1 × Punjab Naveen (6.35).

Green long × Phule Shubhangi (25.00 %) followed by Pondicherry 1 × Punjab Naveen (22.12 %) exhibited the significant standard heterosis over check Chitra. This results in line with findings of Sharma *et al.* (2012) and Narasannavar *et al.* (2014). Similar results with significant heterosis for number of branches were reported by Aravindkumar *et al*. (2005), Bairagi *et a.l* (2005), Pandey *et al.* (2005), Jadhav *et al*. (2009), Ojha *et al.* (2009), Yadav *et al.* (2009), Shaik *et al.* (2011) and Sarkar *et al*. (2015).

5.2.3 Number of nodes per vine

To increase the productivity, nodes play a very important role. The parents had the range of 15.75 to 20.55 nodes per vine. The maximum *per se* performance of parent was observed in Pondicherry- 1 and Poinsette (20.55), while the hybrids had the range of 17.70 to 29.30 and maximum *per se* performance was observed in the cross Pondicherry 1 × Phule Shubhangi (29.30) followed by Pondicherry 1 × Pusa Uday (29.00).

Pondicherry- 1 × Phule Shubhangi (46.50 %) followed by Pondicherry 1 × Pusa Uday (45.00 %) exhibited the significant standard heterosis over check Chitra. This results are in line with findings of Singh *et al.* (2011).

5.2.4 Node of female flower appearance.

The prime objective is that the appearance of first female flower at the lower node for development of early hybrid. Among parents, the node at which the first female flower appeared is in the Green Long (4.35) and relatively higher in Pondicherry 1 (7.15). With respect to hybrids, Green Long × Poinsette (4.05) recorded the first female flower at lower node and it indicated the earliness.

For the development of early fruiting, genotypes with negative heterosis is desirable for node number at which first female flower appear (Arya and Singh., 2014). The crosses IIHR 285 × Punjab Naveen (-27.87 %) and Pondicherry 1 × Punjab Naveen (-24.59%) exhibited the significant heterobeltiosis in negative direction. This is in accordance with the research findings of Bairagi *et al.* (2005), Hanchinamani and Patil (2009), Kumar *et al.* (2010), Singh *et al*. (2010) and Singh *et al.* (2015). The crosses exhibited the positive standard heterosis over superior Check and similar findings was reported by Dogra *et al*. (2011) in cucumber.

5.2.5 Node of male flower appearance

For earliness flowering at lower node is an indication. In cucurbits male flower appear at the lower node, usually 6-7 days before the female flower open. Hence, appearance male flower is related with earliness. Among the parents, IIHR 341 (2.10) showed flowering at lower nodes while Kerala -2 (3.45) showed first male flower at higher node.

Heterosis in negative direction was desirable for this trait, the cross IIHR 304 × Pusa Uday (-49.28%) exhibited the significant negative heterosis over check. Similar standard heterosis was recorded by Singh and Ram (2009) in cucumber. Five crosses *viz.,* IIHR 304 × Phule Shubhangi (-45.59 %), IIHR 341 × Kerala-2 (-44.93 %), IIHR 285 × Kerala-2 (-43.48 %), IIHR 304 × Kerala -2 (-34.78 %) exhibited the significant negative heterobeltiosis. This result is in line with research findings of Singh *et al*. (2010), Mule *et al.* (2012) and Singh *et al.* (2015) in cucumber.

5.2.6 Days to first fruit harvest

For days to first harvest negative estimates of heterosis is a well-recognized and prime objective of any breeding programme as it helps the grower to earn a good early market price (Airina *et al*., 2013). Among parent Pondicherry 1 (55.45) shows the early harvest while IIHR 285 (60.45) shows more days to first harvest.

Heterosis in negative direction is desirable for days to first harvest. The cross Green long × Poinsette exhibited the significant negative heterobeltiosis (-20.65%) as well as standard heterosis (-23.74 %) over the check Chitra. This is in line with the research findings with Kumar *et al.* (2010) and Jat *et al.* (2015) in cucumber.

5.2.7 Sex ratio

For sex ratio, out of 25 crosses, 10 crosses over better parent and 9 crosses over commercial check exhibited significant negative heterosis. The cross IIHR 341 × Punjab Naveen (-29.64 %)had showed maximum and significant heterosis over better parent which is low as compared to -80.14 per cent reported by Sundaram (2007) in bitter gourd. The cross IIHR 341× Poinsette (-21.73 %) exhibited the maximum and negative heterosis over the commercial check and is comparable with earlier report -29.90 per cent by Thangamani *et al*. (2011) in bitter gourd.

5.2.8 Days to female flower anthesis

Heterosis in negative direction is preferred for earliness. The parent Poinsette (47.55) showed significant negative heterosis. The crosses Green Long × Poinsette (39.60) and Pondicherry 1 × Punjab Naveen (41.00) exhibited the significant negative heterosis. The reason for significant negative heterosis may be due to the presence of dominant loci in different directions leading to cancellation of effects (Pandey *et al.,* 2005). Most of the crosses shown significant negative heterosis over commercial check and few crosses exhibited the significant negative heterosis over better parent. The crosses showing no heterosis indicated that the parent involved in the cross do not differ in the gene frequency with respect character under study (Pandey *et al.,* 2005).

5.2.9 Number of fruits per plant

Number of fruits is important parameter which directly contributes to the yield. The more number of fruits was recorded in the parents like IIHR 341 (7.15) followed by Poinsette (6.75).

Hayes and Jones (1916) reported the first generation crosses in cucumber frequently exhibited the high parent heterosis due to increased fruit number per plant. The crosses viz., IIHR 341 × Phule Shubhangi (8.15), IIHR 341 × Punjab Naveen (7.40), IIHR 341 × Kerala-2 (7.25), Pondicherry 1 × Punjab Naveen (7.15), IIHR 341× Poinsette (6.6) exhibited the significant standard heterosis . The crosses like *viz.*, IIHR 341 × Phule Shubhangi (64.65%), IIHR 341× Poinsette (53.54 %), IIHR 341 × Punjab Naveen (49.49 %), IIHR 341 × Kerala-2 (46.46 %), Pondicherry 1 × Punjab Naveen (44.44 %) exhibited the significant standard heterosis over the check. Significant and desirable heterosis in aforesaid crosses is due to dominance and dominance x dominance type of interaction, Singh *et al*. (2012). Higher heterobeltiosis for number of fruits was observed in Pondicherry 1 × Punjab Naveen (31.19 %) , Green Long × Kerala -2 (18.69 %) similar result was reported by Hanchinamani and Patil (2009), Kushwaha *et al.* (2002), Mule *et al*. (2012), Singh *et al*. (2012), Airina *et al.* (2013) and Singh *et al.* (2015).

5.2.10 Fruit diameter (cm)

For the fresh consumption less fruit diameter is preferred (Arya and Singh., 2014). Hence, negative direction of heterosis consider to be an desirable. Among parent lesser fruit diameter is observed in Punjab Naveen (4.10 cm) with respect to crosses lesser fruit diameter was observed in IIHR 304 × Kerala -2 (4.15) .

Most of the crosses exhibited the significant positive heterosis for this trait it is in accordance with the research findings of Kumar *et al*. (2010). IIHR 304 × Kerala -2 exhibited the significant negative heterosis over better parent (-19.42%) and over the check Chitra (-19.42%). It is in line with the research findings of Hanchinamani and Patil (2009), Dogra *et al*. (2011), Kushwaha *et al*. (2002), Mule *et al*. (2012), Singh *et al.* (2012), Arya and Singh (2014), Jat *et al.* (2015) and Singh *et al*. (2015) in cucumber.

5.2.11 Fruit length (cm)

Heterosis in positive direction is desirable for fruit length, which is an important traits, contribute towards yield and Highest significant positive heterosis was recorded in the crosses Green long × Pusa Uday (41.94 %), Green long × Poinsette (38.31 %), Green Long × Punjab Naveen (30.37 %) over the check it is in line with Dogra *et al*. (2011), Singh *et al*. (2012), Arya and Singh (2014) and Jat *et al*. (2015) in cucumber.

5.2.12 Average fruit weight (g)

Fruit weight is an important component which ultimately results in higher fruit yield. The maximum average fruit weight was recorded in Pondicherry- 1 (515.50 g) among parents and Pondicherry- 1 × Phule Shubhangi (747.75 g) with respect to hybrids. The heterosis in positive direction is desirable for this trait. Positive heterobeltiosis was reported by Hanchinamani and Patil

(2009), Kushwaha *et al.* (2002), Mule *et al*. (2012), Singh *et al*. (2012), Airina *et al*. (2013) and Singh *et al.* (2015) in cucumber.

Similarly, in this study significant posistive heterobeltiosis was recorded in Green long × Phule Shubhangi (39.51 %), Pondicherry 1 × Poinsette (39.16 %), Green Long × Pusa Uday (38.16 %), Pondicherry 1 × Punjab Naveen (35.59 %),Pondicherry 1 × Pusa Uday (32.61 %). More number of crosses exhibited the significant Positive standard heterosis over check Chitra and maximum was recorded in Pondicherry 1 × Phule Shubhangi (46.52 %) . It is in line with the findings of Dogra *et al*. (2011) Arya and Singh (2014) and Jat *et al*. (2015) in cucumber.

5.2.13 Fruit yield per vine (kg)

Increase in the fruit yield per vine is an important criteria to increase the productivity. Pondicherry- 1 (2.68) and Pondicherry- 1 × Punjab Naveen (4.65 kg) exhibited the maximum yield potential among parents and hybrids respectively. Hanchinamani and Patil (2009) reported that the maximum yield attributed to increase in average fruit weight and total number of fruits per plant.

For yield and yield attributing characters heterosis in positive direction is desirable. Only 16 crosses exhibited the significant standard heterosis over the check Chitra. Among 25 crosses, 13 crosses exhibited the significant positive heterobeltiosis and maximum was observed in Green Long × Pusa Uday (68.22 %). Similar results were reported by Hanchinamani and Patil (2009), Kushwaha *et al.* (2002), Mule *et al*. (2012), Singh *et al*. (2012), Airina *et al*. (2013) and Singh *et al*. (2015). The cross Pondicherry- 1 × Punjab Naveen (55.79 %) exhibited the significant positive heterosis over the check. It is in line with the research findings of Kumar *et al*. (2010), Dogra *et al*. (2011), Singh *et al.* (2012), Arya and Singh (2014) and Jat *et al*. (2015) in cucumber.

5.2.14 Shelf life (days)

For fruit shelf life positive heterosis is desirable in cucumber. Among parents maximum shelf life was observed in Pondicherry-1 (6.10) and less shelf life was observed in IIHR 285 (4.25). Low genotypic and phenotypic coefficients of variation were recorded for fruit moisture per cent. Most of the crosses under study show the positive heterosis it is in line with the findings of Pushpalatha *et al*. (2015) in cucumber.

5.2.15 Cavity thickness (cm)

The negative heterosis is desirable for fruit cavity thickness in cucumber. Among parents maximum cavity thickness was observed in Pondicherry-1 (2.24) and thin cavity was observed in IIHR 341 (2.02). Most of the crosses under study show the positive heterosis it is in line with the findings of Vishwanatha *et al*. (2003) in muskmelon.

The crosses IIHR 285 × Poinsette (-16.43 %) exhibited the negative direction heterosis over the commercial check which is desirable. Similar result reported by Choudary *et al*. (2003).

5.2.16 Flesh thickness (cm)

For flesh thickness, out of 25 crosses, 22 crosses over better parent, two crosses over the best parent and 10 crosses over the commercial check exhibited positive and significant heterosis. The cross Pondicherry- 1 × Poinsette exhibited 21.21 % of heterosis over better parent. The cross Pondicherry- 1 × Poinsette showed 37.93 % of heterosis over the commercial check and is very low as compared to 144.60 per cent in musk melon reported by Vishwanath (2003).

5.2.17 Rind thickness (mm)

For fruit rind thickness negative heterosis is desirable in cucumber which is reported by Pandey *et al*. (2005). Among parents maximum rind thickness was observed in Pondicherry 1 (0.94) and thin rind was observed in IIHR 304 (0.64). Most of the crosses under study shows the positive heterosis it is in line with the findings of Narasannavar *et al*. (2014) in ridge gourd.

The crosses IIHR 341 × Pusa Uday (-14.62%) exhibited the heterobeltosis in negative direction which is desirable. Similar result reported by Pandey *et al*. (2005).

5.3 Combining ability

Estimation of combining ability effects is done to assess the relative ability of a genotype to transmit its desirable performance to its crosses. Combining ability analysis provides information about the components of genetic variance involved in the expression of various polygenic characters and thus helps in the selection of desirable parents for hybridization and also in deciding the breeding procedure for the genetic improvement of such characters. The knowledge of gene action and combining ability helps in identifying the best combiners which may be hybridized either to exploit heterosis or to accumulate fixable genes through selection. For developing a new variety through conventional breeding programme, selection of potential parents based on their combining ability and few special attributes under consideration is most important. The combining ability analysis is an indication of the variances due to *gca* and *sca* which represents a relative measure of the additive and non-additive gene action, respectively. The variance component due to *gca* and *sca* are used to derive conclusions regarding the gene action that is prevalent in determining any trait.

General combing ability is the average performance of a strain in a series of hybrid combination, which reflects the additive gene effects of parents. Specific combining ability indicates the deviation in the performance of specific cross from the performance expected on the basis of general combining ability effects of parents involved in the crosses. It is an indication of non-additive gene action. A positive general combining ability (*gca*) indicates a parent that produces above average progeny, whereas parent with negative *gca* produces a progeny that performs below average of the population. Specific combining ability (*sca*) can be either negative or positive and *sca* always refers to a specific cross. Some of them manifested positive heterosis while others exhibited negative heterosis mainly due to varying extent of genetic diversity between parents of different cross combination for the component characters. The manifestation of negative heterosis observed in some of the crosses for different traits may be due to the combination of the unfavourable genes of the parents.

5.3.1 Vine length

Both positive and negative significant *gca* effect was recorded for vine length among the parents. Green Long and Pondicherry 1 exhibited the significant positive *gca* effect, it is in line with the research findings of Mule *et al*. (2012), Bairagi *et al*. (2013) and Pati *et al.* (2015).

Among 25 crosses, 7 crosses exhibited the positive *sca* effect but 4 crosses showed the negative effect. It is in accordance with the research findings of Bairagi *et al*. (2013) in cucumber.

5.3.2 Number of branches per plant

Among the parents, Pondicherry- 1 exhibited the significant positive *gca* effect for number of branches , it is in line with Dubey and Maurya (2006), Singh and Singh (2009) in bitter gourd, Reddy *et al.* (2013) and Sarkar *et al*. (2015) in ridge gourd. Similar findings were reported by Bairagi *et al*. (2013) in cucumber, Purohit *et al*. (2007) and Neeraja (2008) in ridge gourd.

The cross IIHR 304 × Kerala -2 exhibited the significant positive *sca* effect it is in accordance with the research findings of Dubey and Maurya (2006), Singh and Singh (2009) in bitter gourd, Reddy *et al*. (2013) and Sarkar *et al*. (2015) in ridge gourd. Most of the crosses exhibited the non-significant *sca* effect for number of branches per vine (Mule *et al*., 2012) in cucumber.

5.3.3 Number of nodes per vine

Among the parents, Pondicherry- 1 exhibited the significant positive *gca* effect for number of branches. The cross Green Long × Kerala -2 exhibited the significant positive *sca* effect. Most of the crosses exhibited the significant *sca* effect for number of nodes per vine (Singh *et al*., 2011) in cucumber.

5.3.4 Node of female flower appearance

Among lines Pondicherry-1 and tester Punjab Naveen recorded highly significant negative *gca* effect. It is in line with the research findings of Kumar *et al.* (2011), Mule *et al.* (2012), Bairagi *et al.* (2013) and Pati *et al.* (2015).

Out of 25 crosses, 5 crosses exhibited the negative *sca* effect for node at first female flower appear. It is in agreement with the research findings of Maurya *et al.* (2004) and Wani *et al.* (2009) in bottle gourd.

5.3.5 Node of male flower appearance

Among lines IIHR 304 and tester Pusa Uday exhibited the significant negative *gca* effect. It is in accordance with the research findings Rao *et al.* (2000b) in ridge gourd, Maurya *et al.* (2004) , Sreevani (2005) and and Vegad *et al*. (2011) in bottle gourd. Among hybrids, IIHR 304 × Phule Shubhangi exhibited the significant *sca* it is in line with the research findings of Sreevani (2005) and Vegad *et al.* (2011) in bottle gourd.

5.3.6 Days to first fruit harvest

Among parents, IIHR 341 exhibited the significant *gca* effect for days to first harvest. It is in line with research findings of Laxuman (2005) and Mohan (2005) in bitter gourd. Wani *et al*. (2009), Singh and Singh (2009) in bottle gourd.

Out of 25 crosses, four crosses exhibited the negative *sca* effect for days to first harvest and only cross Green long × Pusa Uday exhibited the significant negative *sca* effect, it is in line with the research findings of Sundaram (2008), Yadav *et al.* (2008), Kushwaha and Maurya (2009), Dey *et al.* (2010), Thangamani (2011) and Kumara *et al*. (2013) in bitter gourd.

5.3.7 Sex ratio

The line IIHR 341 exhibited maximum and significant *gca* effects for sex ratio in desirable direction. For these characters significant *gca* effects was reported by Sreevani (2005) in bottle gourd.

5.3.8 Days to female flower anthesis.

IIHR 341 (1ine) and Punjab Naveen (tester) exhibited highly significant negative *gca* effect. It is in line with the earlier studies of Kumar *et al*. (2011), Mule *et al*. (2012) , Bairagi *et al.* (2013) and Pati *et al*. (2015).

Out of 25 cross combinations, two crosses exhibited the negative *sca* effect and none of the crosses recorded significant *sca* effect. It is in line with the research findings of Mourya *et al.* (2004) in muskmelon and Wani *et al.* (2009) in bottle gourd.

5.3.9 Number of fruits per plant

Among the lines, IIHR 341 and in tester Phule Shubhangi exhibited the significant positive *gca* effect it is in line with research findings of Kumara *et al*. (2013) and Singh *et al*. (2013). Similar of

significant *gca* effect for number of fruits was observed by Mule *et al*. (2012), Bairagi *et al*. (20 1 3), Kumara *et al*. (2013) and Pati *et al*. (2015) in cucumber.

Out of 25 crosses, eight crosses exhibited highly significant positive *sca* effect for number of fruits. This superiority of *sca* effects may be due to complementary type of gene action or involvement of non-allelic interaction of fixable and non-fixable genetic variance Purohit (2007). The present findings are in congruence with reports of Mule *et al*. (2012), Bairagi *et al*. (2013), Kumara *et al*. (2013) and Pati *et al*. (2015) in cucumber.

5.3.10 Fruit diameter (cm)

Among parents IIHR 304 exhibited the highly significant negative *gca* effect for fruit diameter. It is in accordance with the research findings of Pati *et al*. (2015) in cucumber. Out of 25 crosses, 2 exhibited the positive *sca* effect and none of the cross exhibited the significant *sca* effect it is in line with the research findings of Bairagi *et al*. (2013) in cucumber and Wani *et al*. (2009) in bottle gourd.

5.3.11 Fruit length (cm)

Among parents, Pusa uday exhibited the highly significant positive *gca* effect for fruit length and similar result was found by Mule *et al*. (2012), Bairagi *et al*. (2013), Kumara *et al.* (2013) and Pati *et al*. (2015) in cucumber

Both positive and negative *sca* effect was observed for this trait and four of the cross combinations exhibited the significant *sca* effect for fruit length, it is in line with the earlier findings of Maurya *et al*. (2004) and Wani *et al*. (2009) in bottle gourd.

5.3.12 Average fruit weight (g)

The lines Green Long and Pondicherry- 1 exhibited the highly significant positive *gca* effect. Similar highly significant *gca* was recorded by Mule *et al*. (2012), Kumara *et al*. (201 1) and Pati *et al.* (2015) in cucumber.

Out of 25 crosses, ten crosses exhibited the highly significant positive *sca* effect for average fruit weight, it is in line with the research findings of Mule *et al*. (2012), Kumara *et al.* (2011) and Pati *et al*. (2015). Pondicherry 1 × Poinsette and IIHR 304 × Kerala -2 exhibited the positive significant *sca* effect, it is in line with the research findings of Sreevani (2005) and Wani *et al*. (2009) in bottle gourd.

5.3.13 Yield per plant (kg)

Among 10 parents only one exhibited the highly significant positive *gca* effect for yield per vine it is in line with the research findings of Mule *et al*. (2012), Bairagi *et al*. (2013), Kumara *et al.* (2013) and Pati *et al*. (2015) in cucumber. Green long × Poinsette , Green Long × Pusa Uday and Pondicherry 1 × Punjab Naveen exhibited the highly significant positive *sca* effect it is in line with the research findings of Singh *et al*. (2011), Mule *et al*. (2012), Bairagi *et al.* (2013), Kumara *et al.* (2013) and Pati *et al*. (2015) in cucumber.

5.3.14 Shelf life (days)

For fruit shelf life positive *gca* and *sca* is desirable in cucumber. Among parents maximum *gca* for shelf life was observed in green long and less *gca* for shelf life was observed in IIHR 285. Most of the crosses under study show the maximum *sca* it is in line with the findings of Pushpalatha *et al*. (2015) in cucumber.

5.2.15 Cavity thickness (cm)

The *gca* effects for cavity thickness were reported by Vishwanatha *et al*. (2003) in muskmelon. Most of the parents does not exhibited significant *gca* for this character and among the crosses also does not exhibited significant *sca* effects.

5.3.16 Flesh thickness (cm)

The significant *gca* effects for flesh thickness were reported by Sreevani (2005) and Singh *et al.* (2006) in bottle gourd. Only one line exhibited significant *gca* for this character and among the crosses only five exhibited significant *sca* effects.

5.3.17 Rind thickness (mm)

Among 10 parents, four showed the highly significant *gca* effect it is in line with_the research findings of Vashisht *et al*. (2010) and Bayoumy *et al*. (2014) in muskmelon. The crosses viz., IIHR 285 × Poinsette , IIHR 285 × Phule Shubhangi , IIHR 304 × Phule Shubhangi exhibited the highly significant *sca* effect for fruit rind thickness. Similar result was found by Vashisht *et al*. (2010) and Bayoumy *et al*. (2014) in muskmelon.

Table 19. Top three crosses based on high mean performance and percent heterosis for important economic traits

Sl. No.	Cross combinations	Mean performance	Heterosis over	
			BP	SC
Node at first female flower appearance				
1.	Green long × Poinsette	4.05	-5.81	-28.95**
2.	Green long × Pusa Uday	4.20	-10.64**	-26.32**
3.	Pondicherry 1 × Punjab Naveen	4.40	2.33	-22.81**
Days to first female flower appearance				
1.	Green long × Poinsette	39.60	-17.50**	-28.46**
2.	Pondicherry 1 × Punjab Naveen	41.00	-16.33**	-25.93**
3.	Green long × Pusa Uday	41.45	-13.65**	-25.11**
Days at first fruit harvest				
1.	Green long × Poinsette	46.1	-20.65**	-23.74**
2.	Pondicherry 1 × Punjab Naveen	46.25	-17.38**	-23.33**
3.	Green long × Pusa Uday	46.35	-18.29**	-23.49**
Number of fruits				
1.	IIHR 341 × Phule Shubhangi	8.15	13.99**	64.65**
2.	IIHR 341× Poinsette	6.60	6.29	53.54**
3.	IIHR 341 × Punjab Naveen	7.40	3.50	49.49**
Fruit length (cm)				
1.	Green long × Pusa Uday	28.60	46.29**	41.94**
2.	Green long × Poinsette	27.87	46.65**	38.31**
3.	Green long × Punjab Naveen	26.27	38.23**	30.37**
Fruit diameter (cm)				
1.	IIHR 304 × Kerala -2	4.15	-19.42**	-19.42**
2.	IIHR 304 × Pusa Uday	4.20	-13.3*	-18.35**
3.	IIHR 304 × Phule Shubhangi	4.30	0.93	-15.44*
Average fruit weight (g)				
1.	Pondicherry 1 × Phule Shubhangi	747.75	45**	46.52**
2.	Pondicherry 1 × Poinsette	717.65	39.16**	40.62**
3.	Pondicherry 1 × Punjab Naveen	699.25	35.59**	37.01**
Fruit yield per plant (kg)				
1.	Pondicherry 1 × Punjab Naveen	4.65	53.83**	55.79**
2.	Green long × Poinsette	4.63	61.57**	54.35**
3.	Green long × Pusa Uday	4.50	68.22**	50.47**

Green long × Poinsette

Green long × Pusa Uday

Pondicherry 1 × Punjab Naveen

Plate 5: Fruits of top three F_1 hybrids

Table 20. Heterosis range over better parent and standard check for different characters in cucumber

Sl. No.	Characters	BP	SC
1.	Vine length (cm)	-5.75 to 26.28	-12.85 to 19.91
2.	No. of branches per plant	-1.94 to 34.02	-7.69 to 25.00
3.	No. of nodes per vine	-10.22 to 44.47	-11.5 to 46.50
4.	Node of female flower appearance	-27.87 to 25.93	-28.95 to 28.07
5.	Node of male flower appearance	-45.59 to 20.37	-49.28 to 5.80
6.	Days to first fruit harvest	-20.65 to 5.69	-3.14 to -23.74
7.	Sex ratio	-33.30 to 11.40	-20.27 to 34.17
8.	Days to female flower anthesis	-17.50 to 2.04	-9.67 to -28.46
9.	Number of fruits per plant	-39.63 to 31.19	-17.68 to 44.44
10.	Fruit diameter (cm)	-19.42 to 28.35	-19.42 to 24.27
11.	Fruit length (cm)	-0.47 to 46.65	-10.05 to 41.94
12.	Average fruit weight (g)	-26.22 to 39.51	-45.37 to 46.52
13.	Fruit yield per plant (kg)	-34.15 to 68.22	-55.16 to 55.79
14.	Shelf life (days)	-14.68 to 32.26	-15.45 to 11.82
15.	Cavity thickness (cm)	-12.38 to -5.00	-15.24 to -12.38
16.	Flesh thickness (cm)	-32.63 to 21.21	10.34 to 37.93
17.	Rind thickness (mm)	-14.62 to 5.85	2.10 to 26.57

VI. SUMMARY

The present investigation on heterosis and combining ability studies in cucumber (*Cucumis sativus* L.) was undertaken at College of Horticulture, UHS Campus, GKVK, Bengaluru during *Kharif* (2016) and *rabi* (2017) seasons. The diversed group of ten genotypes (five lines and five testers) of cucumber and one check cultivar (Chitra) were used to fulfil the objective such as to estimate the general combining ability (*gca*) and specific combining ability (*sca*) for yield and yield attributing traits to estimate the magnitude and direction of heterosis for the yield and yield attributing traits, to identify the highly heterotic combination. Twenty five crosses were developed by crossing with five lines with each of five testers. All the crosses were evaluated along with the parents in Randomized Complete Block Design with two replications. Here are some of the salient features obtained from present investigations have been summarized as below.

All the parameters recorded were subjected to line x tester analysis. Some of the parameters manifested positive heterosis while others exhibited negative heterosis mainly due to varying extent of genetic diversity between parents of different cross combinations for the component characters. In the this present study, the estimation of the best parent, better parent and standard check were found to be highly variable in direction and magnitude among crosses for all the characters under study.

The variance due to parents was significant for all the characters studied except days to first harvest, fruit yield per plant, shelf life. Variance due to parents vs. crosses was significant for vine length, number of branches per plant, number of nodes per vine, node of female flower appearance, days to female flower anthesis, fruit diameter, fruit length, average fruit weight, shelf life, cavity thickness, rind thickness and it was not significant for node of male flower appearance, days to first fruit harvest and number of fruits per plant.

The magnitude of heterosis over the standard check (Chitra) for important earliness, growth and yield parameters ranges from for vine length -12.85 to 19.91, node at first female flower appearance -12.85 to 19.91, node of male flower appearance -49.28 to 5.8, days to first fruit harvest -3.14 to -23.74, sex ratio -20.27 to 34.17, days to female flower anthesis -9.67 to -28.46, number of fruits per plant -17.68 to 44.44, fruit length -10.05 to 41.94, average fruit weight -45.37 to 46.52 and fruit yield per plant -53.16 to 55.79.

Green long × Poinsette , Green long × Pusa Uday , Pondicherry 1 × Punjab Naveen these hybrids exhibited the maximum significant standard heterosis over the check (Chitra) for yield per vine and same cross combination exhibited maximum significant standard heterosis for fruit length, average fruit weight, number of fruits per vine over standard check. The results indicated the importance of heterosis breeding for the effective utilization of non-additive genetic variance which had a predominant role in the improvement of yield attributing traits.

The crosses have higher *sca* effects due to involvement of poor (negative) x poor (negative) and poor (negative) x good (positive) parents. The higher *sca* effect observed in poor (negative) x poor (negative) general combiners cross might be due to non-additive gene effects and such could be exploited through the hybridization, which is possible in the crop due to monoecious nature of flowers. The cross involved poor (negative) x good (positive) general combiners can produce good transgressive segregants in later generation. The parents *viz.,* Green Long, Poinsette, Pusa Uday, Pondicherry- 1, Punjab Naveen are the good general combiner for yield and yield attributing traits. For earliness character the parent Green Long, Poinsette, Pusa Uday, Punjab Naveen, IIHR 341 exhibited the good *gca* effect. These parents were superior for most of the traits, an inter mating population involving all possible crosses among themselves subjected to biparental mating in early generation will be expected to offer the maximum promise in breeding for yield and earliness in cucumber.

The combining ability studies indicated that the high proportions of *sca* variances than *gca* variances. Study on combing ability variance revealed that non-additive gene action for node at first female flower appear, fruit length (cm) average fruit weight (g), yield per vine (kg). This could be attributed to dominance, over dominance and or the epistatic components such as additive x dominance and dominance x dominance type of gene interaction. Green Long × Poinsette, Green Long × Pusa Uday, Pondicherry 1 × Punjab Naveen exhibited the significant positive *sca* effect for yield attributing

traits. However keeping the basic objective of the investigation in view, the cross Green Long × Poinsette was exhibited the highly significant *sca* effects for yield contributing traits. This hybrid also exhibited maximum significant and positive heterosis over the checks for total fruit yield per plant.

FUTURE LINE OF WORK

1. The hybrids Green Long × Poinsette , Green Long × Pusa Uday , Pondicherry 1 × Punjab Naveen are the top most hybrids in order of merit for yield potentiality and can also be commercially exploited.
2. It is suggested to test the superior hybrids in multilocation trial to confirm their potentiality and stability over different agro climatic conditions.
3. Selected parents with desirable *per se* and combining ability effect can be used in multiple crossing schemes to recombine different productive components.
4. These hybrids can be subjected for selection in segregating generation to identify their superior lines which will be useful for future breeding programme.
5. Population involving parents *viz.*, Green Long, Poinsette, Pusa Uday , Pondicherry 1, Punjab Naveen can be constituted to create a promising gene pool for future breeding programmes as these lines and testers are good general combiners over all traits studied.

VII. REFERENCES

ABUSALEHA AND DUTTA, O. P., 1994, Manifestation of heterosis in ridge gourd. *Indian J. Hort*., **51**(4): 389-392.

ABUSALEHA AND DUTTA, O. P., 1995, Studies on heterosis in sponge gourd. *Indian J. Hort*., **52**(3): 222-225.

AHMED, A. M. I., REDDY, P. AND NEERAJA, G., 2006, Combining ability and heterosis for yield and yield components in ridge gourd (*Luffa acutangula* L.). *J. Res. Angrau*., **34**(1): 15-20.

AIRINA, C.K., PRADEEPKUMAR, T., GEORGE, T.E., SADHANKUMAR, P.G. AND KRISHNAN, S., 2013, Heterosis breeding exploiting gynoecy in cucumber (*Cucumis sativus* L.). *J. Trop. Agric.,* **51**(1-2): 144-148.

ALCAZAR, E.J.T. AND GULICK, P.J. 1983. Genetic resources of cucurbitaceae-a global report, Rome, International Board for Plant Genetic Resources, Rome. pp 101. analysis in bitter gourd. *Indian J. Hort*., **67** (3): 399-401.

ANANTHAN, M. AND PAPPIAH, C. M., 2000, Combining ability and correlation studies in cucumber (*Cucumis sativus* L.). *South Indian Hort*., **45**(1-2): 57 -58.

ANONYMOUS, 2012. *FAO Year Book Production,* **42** (88), FAO, UN Rome.

ANONYMOUS, 2013, Crop wise statistics of Horticultural crops in Karnataka state 2011-12, Government of Karnataka, Directorate of Horticulture, Department of Horticulture, Lalbagh, Bangalore, pp: 52.

ANONYMOUS, 2014, Indian Horticulture Database-2013, area and production of fruits and vegetables-all India (2013-14), Ministry of Agriculture, Government of India.

ARAVINDAKUMAR, J. S., PRABHAKAR, M., PITCHAIMUTHU, M., AND NARASEGOWDA, N.C., 2005, Heterosis and combining ability studies in musk melon (*Cucumis melo* L.) for earliness and growth parameters. *Karnataka J. Agric. Sci*., **1**(4): 12-19.

ARUNACHALAM, V. AND BANDOPADHAY, A., 1979, Arc multiple cross pollen – an answer for productivity population in *Brassica campestris* var. Brown Sarson. *Theor. Appl. Genet*., **54**: 203-207.

ARUNACHALAM, V., 1974, The fallacy behind the use of modified line x tester design. *Indian J. Genet.,* **34**: 280-287.

ARYA, K. AND SINGH, D. K., 2014, Exploitation of Heterosis among parthinocarpic and monoecious genotypes of cucumber (*Cucumis sativus* L.) under polyhouse*. Int. J. Basic and applied Agri. Resc.,* **12**(1): 68-71.

BAIRAGI, S. K., HARIHARRAM, SINGH, D. K. AND MAURYA, S. K., 2005, Exploitation of hybrid vigour for yield and attributing traits in cucumber. *Indian J. Hort*., **62**(1): 41-45.

BAIRAGI, S. K., RAM, H. H. AND SINGH, D. K., 2013, Analysis of combining ability in cucumber (*Cucumis sativus* l.) through half diallel mating system. *Ann. Horti* ., **6**(2) : 308-314.

BAIRAGI, S. K., SINGH, D. K. AND HARIHARRAM, 2001, Diallel analysis of combining ability in cucumber (*Cucumis sativus* L.). *Prog. Hort*., **33**(2): 178-183.

BAYOUMY, A. M., MONA, M., YOUSRY AND GAMAL, A. M. E., 2014, Combining ability and sensory evaluation for some hybrids of melon (*Cucumis melo* L.). *Middle East J. Agric. Res*., **3**(3): 398-411.

BHAVE, S. G., BENDALE, V. W., PETHE, U. B., DHER, H. D. AND MEHTA, J. L., 2004, Combining ability in bitter gourd (*Momordica charantia* L.). *Hort. J*., **19**(2): 112-115.

BRAR, P. S., SINGH, G., SINGH, M. AND BATTH, G. S., 2011, Genetic analysis for quality traits and reaction to downy mildew in cucumber (*Cucumis sativus* L.). *J. Res. Punjab Agric. Univ*. **48**(1): 28-33.

CHAUBEY, A. AND HARIHARRAM, 2004, Heterosis for fruit yield and its component in bitter gourd (*Momordica charantia* L.). *Veg. Sci*. **31**(1): 51-53.

CHOUDHARY, B. R., DHOKA, R. S. AND FAGERIO, M. S., 2003, Heterosis for yield and yield related attributes in muskmelon (*Cucumis melo* L.). *Indian J. Genet.*, **63**(1): 91-92.

DEY, S. S., BEHERA, T. K., MUNSHI, A. D. AND PAL, A., 2010, Combining ability analysis in bitter gourd (*Momordica charantia* L*.)*. *Hort. J*., **19**(2): 112-115.

DOGRA, B. S. AND KANWAR, M.S., 2011, Exploiting Heterosis for Yield and Horticultural Traits in Cucumber (*Cucumis sativus* L.). *Indian J. Plant Genet. Resour* .,**24**(3): 332–339.

DUBEY, S. K. AND MAURYA, I. B., 2003, Studies on heterosis and combining ability studies in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Indian J. Genet*., **63**(2): 148-152.

DUBEY, S. K. AND MAURYA, I. B., 2006, Combining ability studies in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Indian J. Hort*., **63**(2): 178-181.

DUBEY, S. K. AND MAURYA, I. B., 2007, Combining ability for characters related to yield and earliness in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Indian J. Agric. Res*., **41**(1):59-62.

EAST, E. M. AND HAYES, H. K., 1912, Heterosis in evolution and in plant breeding.

GRIFFING, B., 1956, Concept of general combining ability in relation to diallel crossing system. Australian *J. Biol. Sci*., **9**: 463-493

GUPTA, V., KISHORE, N. AND PRATAP, P. B., 2006, Diallel analysis for combining ability in bitter gourd (*Momordica charantia* L.). *Crop Res*., **32**(3): 406-410.

HANCHINAMANI, E. N. AND PATIL, M. G., 2009, Heterosis in cucumber (*Cucumis sativus* L.) *Asian J. Hort*., **4**:21-24.

HAYES, H.K. AND JONES, D.F. 1916. First generation crosses in cucumber. *Cann. Agric. Stu*. *Newsletter* 3:34-35.

HEDAU, N. K. AND SIROHI, P. S., 2004a, Heterosis studies in ridge gourd. *Indian J. Hort*., **61**(3): 236-239.

HEDAU, N. K. AND SIROHI, P. S., 2004b, Combining ability for yield and its contributing characters in ridge gourd. *Prog. Hort*., **36**(1): 91-93.

HUTCHINS, A.E. 1938. Some examples of heterosis in cucumber (*Cucumis sativus* L.). *Proc. Amer. Soc. Hort. Sci.* 36: 660-664.

JADHAV, K. A., GARAD, B. V., DAHMAL, S. S., KASHIRSAGAR, D. B., PATIL, B. T. AND SHINDE, K. G., 2009, Heterosis in bitter gourd (*Momordica charantia* L.). *Agric. Sci. Digest*., **29**(1): 7-11.

JAT, G. S., MUNSHI, A. D., BEHERA, T.K., CHOUDHARY, H. AND DEV, B., 2015, Exploitation of heterosis in cucumber for earliness, yield and yield components utilizing gynoecious lines. *Indian J. Hort*., **72**(4): 494-499.

JEFFREY, C. 1990. SYSTEMATIC OF THE CUCURBITACEAE: AN OVERVIEW. *IN:* BATES, D.M., ROBINSON, R.W. AND JEFFERY, C. eds. Biology and Utilization of the Cucurbitaceae. Ithaca, New York, Cornell University Press. pp. 3-9.

KAMER, A., MONA, M.E., YOUSRY, M. AND GAMAL, A.M., 2015, Heterosis and heritability studies for fruit character and yield in melon (*Cucumis melo* L.). *Middle East J. Appl. Sci.*, **5**(1): 262-273.

KAUR, K., DHALL, R. K. AND CHAWALA, N., 2016, Heterosis and combining ability for quality attributing traits in cucumber (*Cucumis sativus* L.). *Agric. Res. J.,* **53** (4): 475-479.

KEMPTHORNE, O., 1957, An introduction to genetic statistics. John Wiley and Sons, New York, pp. 408-711.

KHATTRA, A. S., SINGH, R. AND THAKUR, J. C., 2000, Combining ability studies in bitter gourd in respect of line x tester crossing system. *Veg. Sci*., **28**(1): 60-63.

KUMAR, J., MUNSHI, A.D., KUMAR, R. AND SURELIA, A.K., 2010, Studies on Heterosis in slicing cucumber. *Indian J. Hort*. **67**(2) : 197-201.

KUMAR, S. B., PUTTARAJU, T. B., HONGAL, S., PRAKASH, K., JAINAG, K. AND SUDHEESH, N. K., 2011, Combining ability studies in bitter gourd (*Momordica charantia* L.) for quantitative characters. *Asian J. Hort*., **6**(1): 135-140.

KUMARA, S. B. AND HONGAL, S., 2013, Combining ability studies in bitter gourd (*Momordica charantia* L.) for quantitative characters . *J. Hort. Sci*., **84**: 342-348.

KUSHWAHA, M. L. AND HARIHARRAM, 2002, Heterosis in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Prog. Hort*., **34**(2): 174-178.

LAXUMAN, 2005, Studies on diversity, heterosis and combining ability in bitter gourd (*Momordica charantia* L.). M.Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad.

MAURYA, S. K., HARIHARRAM, AND SINGH, D. K., 2004, Combining ability analysis in bottle gourd. *Prog. Hort*., **36**(1): 67-72.

MAURYA, S. K., RAM, H. H AND SINGH, D. K., 2004, Combining ability analysis in bottle gourd. *Prog. Hort*., **36**(1): 67-72.

MOHAN, 2005, Heterosis and combining ability in bitter gourd (*Momordica charantia* L.). M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad.

MOHANTY, B. K. AND MISHRA, R. S., 2000, Studies on combining ability for flowering traits in pumpkin. *Haryana J. Hort. Sci*., **20**(3-4): 220-222.

MOHANTY, B. K., 2000a, Combining ability for yield components in pumpkin. J. *Genet. Pl.Breed*.,**60**(3):373-379

MOHANTY, B. K., 2000b, Quantitative inheritance in pumpkin- a combining ability analysis. *Indian J. Hort*., **57**(2): 160-163.

MOHANTY, B. K., 2001a, Manifestation of heterosis in flowering attributes in pumpkin. *J. Maharashtra Agric. Univ*., **26**(3): 284-287.

MOHANTY, B. K., 2001b, Genetic control of flowering characters in pumpkin. *J. Maharashtra Agril. Univ*., **26**(3): 247-249.

MOLE, T. J., NIRMALADEVI, S., RAJAN, S. AND SADHANKUMAR, P. B., 2001, Heterosis and combining ability in ridge gourd *(Luffa acutangula* Roxb.). *Veg. Sci*., **28**(2): 156-167.

MULE , P. N., KHANDELWAL, V., LODAM, V. A., SHINDHE, D. A., PATIL, P. P. AND PATIL, A. B., 2012, Heterosis and combining ability in cucumber (*Cucumis sativus* L.). *Madras Agri. J*., **99**(7-9): 420-423.

NALIYADHARA, M. V., DHADUK, L. K., BARAD, A. V., PUROHIT, V. L. AND VACHHANI, J. H., 2007, Heterosis for fruit yield and its components in sponge gourd (*Luffa cylindrica* (ROEM.) L.). *Natnl. J. Pl. Improv*., **9**(2): 132-135.

NARASANNAVAR, A. R., GASTHI, V. D., SHANTAPPA, T., MULGE, R., ALLOLLI, T. B. AND THAMMAIAH, N., 2014, Heterosis studies in ridge gourd (*Luffa acutangula* (Roxb.). *Karnataka J. Agric. Sci*., **27**(1): 47-51

NEERAJA, P. B., 2008, Combining ability and heterosis for fruit yield and yield components in ridge gourd (*Luffa acutangula* L.). *J. Res. Angrau*., **36**(4): 24-32.

NEHE, A. S., BANGER, N. D. AND CHAVAN, B. H. 2007, Combining ability study in cucumber (*Cucumis sativus* L.). *J. Maharastra Agric. Univ*., **32**: 340-342.

NIYARIA, R. AND BHALALA, M. K., 2001, Heterosis and combining ability in ridge gourd. *Indian J. Pl. Genet. Resour*., **14**: 101-102.

OJHA, M. D., PANDEY, V.S. AND SINGH ,G., 2009, Heterosis and combining ability studies in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). *Veg. Sci*., **36**(1): 55-59.

PANDEY, S. K., SHRIVASTAVA, B. P., SHRIVASTAVA, S. B. L. AND SHRIVASTAVA, J. P., 2004, Heterosis and inbreeding depression for fruit characters in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Indian J. Hort*., **61**(120): 146-149.

PANDEY, S., SINGH, B., SINGH, M. AND RAI, M., 2005, Heterosis in cucumber (*Cucumis sativus* L.). *Veg. Sci*., **32**(2) : 143-145.

PATEL, S. R. AND DESAI, D, T., 2008, Heterosis and combining ability studies in sponge gourd (*Luffa cylindrica* (Roem.) L.]. *Veg. Sci*. **35**(2): 199-200.

PATI, K., MUNSHI, A. D., BEHERA, T. K., KUMAR, R. AND KARMAKAR, P., 2015, Estimating combining ability for yield and yield contributing traits in cucumber. *Indian J. Hort*. **72**(1): 49-53.

PETERSON, C.E., 1960. A gynoecious inbred line of cucumbers *Michigan Agriculture Experiment Station Quarter Bulletin*, **43**: 40-42.

POSHIYA, S. C., DHADUK, L. K. AND MEHTA, D. R., 2015, Heterosis study in ridge gourd (*Luffa acutangula* L.).*Electron. J. Pl. Breed*., **6**(2): 581-585.

PUROHIT, V. L., MEHTA, D. R., DHADUK, L. K. AND GAJIPARA, N. N., 2007, Combining ability for fruit yield and its attributes in ridge gourd [*Luffa acutangula* (Roxb.) L.]. *Veg. Sci*., **34**(1): 84-85.

PUSHPALATHA N., 2015, Genetic variability and heritability for growth, yield and selected qualitative traits in cucumber (*Cucumis sativus* l.) genotypes, M. Sc. (Hort) Thesis, Univ. Agric. Sci., Bengaluru.

RAM, D., KUMAR, V., RAI, M., SINGH, T. B., KUMAR, A. AND CHAUBEY, T., 2007, Combining ability studies of quantitative traits in sponge gourd (*Luffa cylindrica* (Roem.) L.) *Veg. Sci*., **32**(2): 170-172.

RAO, B. N. AND RAO, P. V., 2002, Heterosis in ridge gourd (*Luffa acutangula* (Roxb.) L.). *J. Res. Angrau*., **30** (1): 11-18.

RAO, B. N., RAO, P. V. AND REDDY, B. M., 2000a, Heterosis in ridge gourd [*Luffa acuangula* (Roxb.) L.]. *Haryana J. Hort. Sci*., **29**(1-2): 96-98.

RAO, B. N., RAO, P. V. AND REDDY, Y. N., 2000b, Combining ability studies in ridge gourd [*Luffa acutangula* (Roxb.) L.]. *Intl. J. Trop. Agric*., **18**(2): 141-146.

REDDY, P. K., REDDY , V. S. K AND PADMA, V. S. S., 2013, Performance of parents and hybrids for yield and yield attributing characters in ridge gourd (*Luffa acutangala* (Roxb.)L.). *The Bioscan*, **8**(4): 1373-1377.

ROBINSON, R.W. AND DECKER-WALTER, D.S., 1999, *Cucurbits*. Cab International, University Press, Cambridge.

SAMADIA, D. K. AND KHANDELWAL, R. C., 2002, Combining ability in bottle gourd. *Indian J. Hort.,* **50**(1-3): 82-90**.**

SAPOVADIYA, M. H., MEHTA, D. R., DHADUK, H. L. AND BABARIYA, C. A., 2014, Combining ability in watermelon (*Citrullus lanatus* (Thunb.) Mansf.) . *Electron. J. Pl. Breed*., **5**(3): 327-330.

SARKAR, M., SINGH, D. K., LOHANI, M., DAS, A. K. AND OJHA, S., 2015, Exploitation of heterosis and combining ability for earliness vegetative traits in ridge gourd (*Luffa acutangala* (Roxb.)L.). *Int. J. of Agric., Environ and Biotechnol.,*, **8**(1): 153-161

SHAHA, S. R. AND KALE, P. N., 2003a, Heterosis studies in ridge gourd. *J. Maharashtra Agric. Univ*., **28**(3): 334-336.

SHAHA, S. R. AND KALE, P. N., 2003b, Diallel analysis for combining ability in ridge gourd. *J. Maharastra Agril. Univ*., **28**(3): 252-254.

SHAIKH, J. A., KATHIRIA, K. B. AND ACHARYA, R. R., 2011, Heterosis and combining ability for fruit yield and its component traits in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Veg. Sci*., **38** (2): 169-175.

SHARMA, N., SHARMA, N. K. AND MALIK, Y. S., 2007, Combining ability studies for earliness in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Haryana J. Hort. Sci*., **36** (1-2): 190-191.

SHARMA, N., MALIK, Y. S. AND SHARMA, N. K., 2004, Heterobeltiotic effects in long- fruited bottle gourd. *Haryana J. Hort. Sci*., **33**(1-2): 109-112.

SHARMA, D.R., CHOUDHARY, M.R., JAKHAR, M.L AND DADHEECH S., 2012, Heterosis in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). *Int. J. Life Sci*., **1**(3): 212-216.

SHULL, G.H. 1914. Duplicate gene for capsul form in Bursa burcapastoris. Zeitcher Induki Abst. V. Verecurra, 12:97-149.

SINGH, A. K., HARIHARRAM, AND SINGH, J. P., 2004, Combining ability in bitter gourd (*Momordica charantia* L.). *Prog. Hort*., **36**(1): 107-112.

SINGH, A. K., PANDEY, U. B. AND SINGH, M., 2000, Studies on heterosis in bitter gourd. *Veg. Sci*., **27**(2): 158-161.

SINGH, A.K., PAN, R. S. AND BHAVANA, P., 2013, Heterosis and combining ability analysis in bitter gourd (*Momordica charantia* L.). *The Bioscan.,* **8**(4): 1533-1536.

SINGH, B., SINGH, S. K., RAM, D., PANDEY, S. AND RAI, M., 2006, Combining ability analysis in bitter gourd (*Momordica charantia* L.*)*. *Hort. J*., **19**(2): 112-115.

SINGH, D. K. AND KUMAR, R., 2002, Heterosis in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Prog. Hort*., **32** (2): 204-207.

SINGH, N. J., KHATTRA, A. S. AND THAKUR, J. C., 2001, Studies on heterosis in bitter gourd (*Momordica charantia* L.). *Haryana J. Hort. Sci*., **30**(3-4): 224-227.

SINGH, P. P. AND SINGH, S. P., 2009, Combining ability analysis in relation to heterosis for yield and its components in bottle gourd. *Veg. Sci*., **36**(1): 98-99.

SINGH, R., SINGH, A. K., KUMAR, S., SINGH, B. K. AND SINGH. S. P., 2011, Combining ability studies in cucumber (*Cucumis sativus* L.). *Veg. Sci*., **38**(1) : 49-52 .

SINGH, S. K., KISHOR, G. R. AND SRIVASTAVA, J. P., 2010, Commercial exploitation of hybrid vigour in cucumber. *Prog. Agric*. (Special Issue), **10**: 266-269.

SINGH, S. K., SINGH, B., KUMAR, U. AND RAI, M., 2007, Heterosis analysis in bitter gourd through line × tester design. *Veg. Sci*., **34**(1): 95.

SINGH, S. K., SINGH, S. V. AND SRIVASTAVA, J. P., 2015, Studies on Heterosis and inbreeding depression in cucumber (*Cucumis sativus* L.) *Agriways*, **3**(2): 107-111.

SINGH, S.K., UPADHYAY, A. K., PANDEY, J. AND PANDEY, A.K., 2012, Studies on heterosis and combining ability in bottle gourd (*Lagenaria siceraria*(Mol.) Standl.) for yield traits. *Ann. Horti.,* **5**(2): 246-251.

SIROHI, S. AND RANA, S. C., 2007, Heterosis studies in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Haryana J. Hort. Sci*., **36**(3&4): 363-364.

SPRAGUE, G.F. AND TATUM, L.A. 1942. General vs specific combining ability in single cross corn. *J. American Soc. Agron.* **34**: 923-32.

SREEVANI, P. G., 2005, Studies on exploitation of heterosis in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Madras Agric. J*., **91**(4-6): 311-313.

SUNDARAM, V., 2007, Studies on hybrid vigour in bitter gourd (*Momordica charantia* L.) under salinity. *Asian. J. Hort*., **2**(2): 151-156.

SUNDARAM, V., 2008, Studies on combining ability in bitter gourd (*Momordica charantia* L.). *Crop Res*., **38**(1 -2): 46-51.

TATILIOGLEE, T., 1993, Cucumber (*Cucumis sativus* L.). Genetic improvement of Indian Vegetable crops. Kalloo, G. and Bergh, B.O. (eds.). Pergamon Press, Oxford, pp: 197-233.

THANGAMANI, C., PUGALENDHI, L., SUMATHI, T., KAVITA, C. AND RAJASHREE, V., 2011, Estimation of combining ability and heterosis for yield and quality character in bitter gourd (*Momordica charantia* L.). *Electron. J. Pl. Breed*., **2**(1):62-66.

UPADHYAY, M. AND HARIHARRAM, 2007, Hybrid versus pure line breeding in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Pantnagar J. Res*., **5**(1): 113-117.

VASHISHT, V. K., GURESH, S., TARSEM AND AMIT, K. G., 2010, Combining ability for yield and yield attributing traits in musk melon (*Cucumis melo* L.). *J. Crop improve*., **37**(1): 36-40.

VEGAD, P. M., VADDORIA, M. A., MEHTA, D. R. AND NAGHERA, Y. V., 2011, Combining ability analysis in bottle gourd. *Crop Improv*., **38**(1): 13-17.

VERMA, V. K. AND BEHERA, T. K., 2007, Heterosis studies in ash gourd [*Benincasa hispida* (Thomb.) (Ogn.)] for yield and related traits*. J. Trop. Agric.,* **45**(1-2): 51-54.

VISHWANATHA, P. D., 2003, Genetic variability and heterosis studies in muskmelon (*Cucumis melo* L.). M. Sc. (Hort.) Thesis, Univ. Agric. Sci., Dharwad.

WANI, P. K., AHMED, N., AFROZA, B. AND HUSSAIN, K., 2009, Line × tester analysis for combining ability in bottle gourd under temperate conditions of Kashmir valley. *Indian J. Hort*.. **66**(4): 476-482.

YADAV, M., CHAUDHARY, R. AND SINGH, D. B., 2009, Heterosis in bitter gourd (*Momordica charantia* L.). *J. Hort. Sci*., **4**(2): 170-173.

YADAV, M., CHAUDHARY, R. AND SINGH, D. B., 2008, Combining ability in bitter gourd (*Momordica charantia* L.). *Indian J. Hort*., **65** (2): 163-166.

APPENDIX I

Meteorological data recorded during the period of experimentation (2016-17)

Month	Rainfall		Temperature (^{o}C)		Relative humidity (%)	
	mm	days	Maximum	Minimum	Maximum	Minimum
Aug	20.3	2	27.5	19.4	91.9	60.1
Sep	50.7	4	27.4	19.3	92.1	59.3
Oct	0.2	0	30.8	18.0	83.3	49.8
Nov	2.4	0	28.9	17.0	86.2	33.2
Dec	63.8	3	26.2	20.7	88.7	43.7

* UHS Campus (RHREC & COH), Bengaluru

APPENDIX II

Type of spines, fruit shape, fruit color, fruit at blossom end, fruit ribs, fruit creasing in cucumber. genotypes as for DUS guidelines

Genotypes	Type of vesture/ spines	Fruit shape	Fruit color	Fruit shape @ blossom end	Fruit ribs	Fruit creasing
Lines						
IIHR 285	Prickles	Cylindrical	Light green	Trunket	Absent	Absent
IIHR 341	Prickles	Cylindrical	Dark green	Round	Absent	Absent
IIHR 304	Prickles	Cylindrical	Dark green	Trunket	Absent	Absent
Green long	Prickles	Cylindrical	Light green	Round	Absent	Absent
Pondicherry 1	Hairy	Elongate	Dark green	Round	Present	Present
Testers						
Poinsette	Prickles	Elongate	Light green	Round	Absent	Absent
Phule shubhangi	Prickles	Elongate	Dark green	Round	Absent	Absent
Punjab Naveen	Prickles	Elongate	Dark green	Round	Absent	Absent
Pusa uday	Prickles	Cylindrical	Light green	Round	Absent	Absent
kerala 2	Prickles	Oblong	Light green + Yellow patches	Trunket	Present	Present
Crosses						
IIHR 285 × Poinsette	Prickles	Cylindrical	Yellow	Round	Absent	Absent
IIHR 285 × Phule shubangi	Prickles	Cylindrical	Light green	Round	Absent	Absent
IIHR 285 × Punjab naveen	Prickles	Cylindrical	Light green	Round	Absent	Absent
IIHR 285 × Pusa uday	Prickles	Cylindrical	Dark green	Round	Absent	Absent
IIHR 285 × kerala-2	Prickles	Cylindrical	Light green	Round	Absent	Present
IIHR 341× Poinsette	Prickles	Elongate	Light green	Round	Absent	Absent
IIHR 341 × Phule shubhangi	Prickles	Cylindrical	Light green	Round	Present	Absent
IIHR 341 × Punjab naveen	Prickles	Cylindrical	Light green	Obtuse	Absent	Absent
IIHR 341 × Pusa Uday	Prickles	Cylindrical	Light green	Round	Absent	Absent
IIHR 341 × Kerala-2	Prickles	Elongate	Dark green	Round	Absent	Present

Genotypes	Type of vesture/ spines	Fruit shape	Fruit color	Fruit shape @ blossom end	Fruit ribs	Fruit creasing
IIHR 304 × Poinsette	Prickles	Elongate	Dark green	Round	Absent	Absent
IIHR 304 × Phule shubhangi	Prickles	Cylindrical	Yellow	Round	Absent	Absent
IIHR 304 × Punjab naveen	Prickles	Cylindrical	Light green	Round	Absent	Absent
IIHR 304 × Pusa uday	Prickles	Cylindrical	Light green	Round	Absent	Absent
IIHR 304 × Kerala -2	Prickles	Cylindrical	Dark green	Round	Absent	Present
Green long × Poinsette	Prickles	Elongate	Light green	Round	Absent	Absent
Green long × Phule shubangi	Prickles	Cylindrical	Dark green	Round	Absent	Absent
Green long × Punjab naveen	Prickles	Elongate	Light green	Round	Absent	Absent
Green long × Pusa uday	Prickles	Cylindrical	Light green	Obtuse	Present	Absent
Green long × kerala -2	Prickles	Elongate	Dark green	Obtuse	Absent	Present
Pondicherry 1 × Poinsette	Hairy	Elongate	Light green	Round	Absent	Present
Pondicherry 1 × Phule Shubhangi	Hairy	Elongate	Yellow	Round	Absent	Present
Pondicherry 1 × Punjab naveen	Hairy	Elongate	Light green	Round	Absent	Present
Pondicherry 1 × Pusa uday	Hairy	Elongate	Dark green	Round	Absent	Present
Pondicherry 1 × Kerala 2	Hairy	Oblong	Dark green	Trunket	Absent	Present
Chitra	Prickles	Elongate	Dark green	Obtuse	Present	Absent

APPENDIX III

LIST OF ABBREVATIONS

Abbreviations		Descriptions
%	:	Per cent
/	:	Per
Anon.	:	Anonymous
BP	:	Better parent
BTP	:	Best parent
CC	:	Commercial check
cm	:	Centimeter
°C	:	Degree centigrade
CD	:	Critical difference
DAS	:	Days after sowing
df	:	Degrees of freedom
gca	:	General combining ability
et al.	:	Co- authours
EMSS	:	Error mean sum of squares
E. df	:	Error degrees of freedom
Fig	:	Figure
g	:	Gram
ha	:	Hectare
kg	:	Kilo gram
mm	:	Mili meter
MP	:	Mid parent
MSL	:	Mean sea level
SC	:	Standard check
sca	:	Specific combining ability
SD	:	Standard deviation
S. Em	:	Standard error mean
Sl. No.	:	Serial number
viz.,	:	Namely