HETEROSIS BREEDING EXPLOITING GYNOECY IN CUCUMBER (*Cucumis sativus* L.)

by

AIRINA C. K.

(2011-12-104)

THESIS

Submitted in partial fulfilment of the requirement

for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University, Thrissur

DEPARTMENT OF OLERICULTURE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2013

DECLARATION

I, **Airina C. K. (2011-12-104)**, hereby declare that this thesis entitled **"Heterosis breeding exploiting gynoecy in cucumber (*Cucumis sativus* L.)"** is a *bonafide* record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title of any other University or Society.

Vellanikkara **Airina C. K.**

Date: 05.08.13

CERTIFICATE

Certified that this thesis, entitled **"Heterosis breeding exploiting gynoecy in cucumber (*Cucumis sativus* L.)"** is a *bonafide* record of research work done independently by **Ms Airina C. K. (2011-12-104)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellanikkara

Dr. T. Pradeepkumar
Associate Professor
Department of Olericulture
College of Horticulture
Kerala agricultural University
Vellanikkara, Thrissur, Kerala

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms Airina C. K. (2011-12-104)** a candidate for the degree of **Master of Science in Horticulture**, agree that this thesis entitled **"Heterosis breeding exploiting gynoecy in cucumber (*Cucumis sativus* L.)"** may be submitted by her in partial fulfillment of the requirement for the degree.

Dr.T. Pradeepkumar,
Associate Professor,
Dept. of. Olericulture,
College of Horticulture,
Vellanikkara,Thrissur
(Major Advisor, Advisory Committee)

Dr .T. E. George,
Professor and Head,
Dept. of Olericulture,
College of Horticulture,
Vellanikkara, Thrissur
(Member)

Dr. P.G.Sadhankumar
Professor,
Dept. of Olericulture,
College of Horticulture,
Vellanikkara, Thrissur
(Member)

Mr .S. Krishnan,
Associate Professor
Dept. of Agricultural Statistics,
College of Horticulture,
Vellanikkara ,Thrissur
(Member)

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

The foremost person to be thanked is **Dr. Pradeepkumar, T.** Associate Professor, Department of Olericulture, College of Horticulture, Vellanikkara, and Chairman of my advisory committee for his sustained and valuable guidance, constructive suggestions, unfailing patience, friendly approach, constant support and encouragement during the conduct of this research work and preparation of the thesis. I gratefully remember his knowledge and wisdom, which nurtured this research project in the right direction without which fulfillment of this endeavour would not have been possible.

Words fail to express my indebtedness to **Dr. T.E. George,** Professor and Head, Department of Olericulture, College of Horticulture, Vellanikkara and member of my advisory committee for the valuable guidance, close scrutiny, precious suggestions and everwilling help rendered throughout my study.

I also owe my deep sense of gratitude and sincere thanks to **Dr. P.G. Sadhankumar,** Professor, Department of Olericulture, College of Horticulture, Vellanikkara and member of my advisory committee for his support, untiring interest, suggestions and invaluable guidance throughout the study.

I take this opportunity to express my heartful gratitude to **Mr. S. Krishnan** ,Associate Professor, Department of Agricultural Statistics, College of Horticulture, Vellanikkara and member of my advisory committee for his suggestions, valuable guidance, and accommodating with all facilities for the successful completion of my research work.

Words fall short as I place on record my indebtedness to **all the teachers of Department of Olericulture** for their untiring support and immense help rendered during my course of study.

I also express my gratitude to all the **non-teaching staff members and labourers of Department of Olericulture** for their whole-hearted cooperation and timely assistance.

The encouragement rendered by my friends at various stages of this investigation was invaluable and I thank **Roshna, Uma , Divya** and **Yaha** from the bottom of my heart. My thanks also to all seniors and juniors for their valuable help.

The award of KAU junior fellowship is greatly acknowledged.

Above all, I am forever beholden to **my family members** for their constant prayers, affection, moral support, personal sacrifice and sincere encouragement throughout the period of my studies.

Airina C. K.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

INTRODUCTION

1. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most important and popular cucurbitaceous vegetable crops grown throughout the tropical and subtropical region of the world. De Candolle (1886) considered India as the centre of origin of cucumber. Among the cultivated cucurbits, cucumber is one of the most important vegetables grown throughout India for its high nutritive value and medicinal properties. The fruits and seeds possess cooling, astringent and antipyretic properties and the fruits are good for people suffering from constipation, jaundice and indigestion (Vashista, 1974). It is an ideal summer vegetable crop chiefly grown for its edible tender fruits, preferred as salad ingredient, pickles, and dessert fruit and as a cooked vegetable.

Among the cucurbits, cucumber is distinct with a unique sex mechanism and this feature can easily be manipulated for production of F_1 hybrid seeds. Further, the crop is advantageous in having low inbreeding depression, high heterosis percentage, large number of seeds per fruit and low seed rate requirement per unit area favours commercial exploitation of heterosis in this crop. Hayes and Jones (1916) were the first investigators to report heterosis in cucumber. Considerable heterosis has been manifested in cucumber for various traits such as number of fruits, early and high yield. Heterosis in cucumber has been exploited to maximum advantage in developed countries. The first commercial hybrid (F_1) in vegetables released for cultivation was in cucumber in 1935 in Japan. India, being a native place of cucumber, possesses wide range of genetic variability for qualitative and quantitative characters (Munshi *et al*., 2007). Inspite of this, very little effort has been made for genetic improvement of this crop through exploitation of hybrid vigour.

Utilization of gynoecious lines in breeding programme favoured maximum exploitation of heterosis in cucumber. In Western countries cucumber hybrids are produced commercially using a gynoecious inbred as female parent crossed with monoecious inbred as male and honey bee as pollen vectors. Dominant nature of gynoecious sex expression ensures the development of pistillate flowers in every node of F_1 hybrids. Very high productivity as much as 300t/ha (Sheshadri and More, 2009) in ideal environmental conditions in protected structures has been achieved in U.K. and nearly 500t/ha in Netherlands. Production of hybrid seeds in cucumber using monoecious line is expensive as it involves emasculation and hand pollination. Utilization of a gynoecious line as female parent would be more economical and easier method as it reduces the cost of labour charge for male flower pinching and pollination. Thus F_1 hybrids can be made available to farmers at an affordable cost.

True breeding gynoecious lines in cucumbers are reported from University of Wisconsin, Madison, USA. These lines were used for heterosis breeding programme for developing tropical gynoecious lines and development of F_1 hybrids at IARI, New Delhi and MPKV, Rahuri. However in Kerala no attempt has been made to exploit gynoecy in cucumber. The lack of progress in cucumber breeding might be partially due to the non availability of gynoecious lines and lack of information on combining ability. Cucumber has emerged as a profitable crop in Kerala. Being a high value vegetable crop suitable to both protected and open cultivation, development of gynoecious F_1 hybrids in cucumber will help to boost the production and ensure more return to farmers. No commercial hybrids in cucumber suitable to Kerala have been released so far.

Hence, the present study is undertaken to study the combining ability of gynoecious line with selected monoecious lines in cucumber and to investigate the scope of heterosis breeding exploiting gynoecious line.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In India, cucumber breeding and improvement is on a low key and F_1 hybrids are few and far between. The lack of progress in cucumber might be partially due to the meagre breeding efforts in cucumber relative to other crop species or lack of genetic variability. Available literature on cucumber related to the topic 'Heterosis breeding exploiting gynoecy in cucumber' is reviewed under the following heads:

1. Performance analysis in cucumber
2. Maintenance of gynoecious lines
3. Combining ability
4. Heterosis
5. Heterosis exploiting gynoecy

2.1 PERFORMANCE ANALYSIS IN CUCUMBER

The evaluation of cucumber genotypes is important in breeding programme to select suitable inbreds with significant variability.

Prasad and Singh (1991) evaluated 23 genotypes of cucumber for 13 traits at Ranchi. Genotypes differed considerably in 8 traits and environments. Significant genotype x environment interaction was observed for days to female flower appearance, fruit length, flesh thickness, fruits/plot and yield/plant. CH 15 followed by CH 20 was best in this respect and also produced the highest yield (4.28 kg) over the years.

Eight cucumber genotypes were evaluated for resistance to downy mildew (*Pseudoperonospora cubensis*), fruit yield and quality characteristics (total soluble sugars and bitterness) by Reddy *et al*. (1997). Chitradurga, Poinsette, Poona Kheera and Belgaum produced the highest number of fruits/plot. Poona Kheera and Poinsette yielded 2.8 and 2.64 t/ha, respectively. Local varieties Chitradurga and Belgaum gave yields of 2.8-3.06 t/ha and had the best quality characteristics. Chitradurga and Kuknoor showed resistance to downy mildew.

The performance of cucumber cultivars Poinsette, K-75, K-90, and Green Long under field and greenhouse conditions was studied by Sharma *et al.* (2001) Palampur, Himachal Pradesh during the rainy seasons of 1996, 1997, and 1998. The yield under field conditions was higher by 11.28, 27.08, and 31.69 per cent in 1996, 1997, and 1998. Poinsette and K-75 had higher yields than the other cultivars, which could be attributed to greater fruit length, weight, and yield per plant. In 1996, Poinsette recorded 4.94, 21.57, and 25.39 per cent higher yield than K-75, K-90, and Green Long, respectively.

Das *et al*. (2003) analysed the performance of 18 genotypes of cucumber in Sabour, Bihar, during the summer season and rainy season. Among the genotypes, CHC-20 recorded the maximum fruit yield of 2.74 kg/vine with a fruit weight of 403.11 g and fruit length of 5.19 cm, followed by Pusa Sanyog and PCUC-15. The genotype VRC-11 gave the lowest yield of 0.620 kg/vine.

Twenty six indigenous/exotic cucumber cultivars were evaluated by Kanwar *et al.* (2003) in Solan, Himachal Pradesh for yield and quality parameters. Market Long had the highest yield per plant (2201 g) and total soluble solid content (3.47°Brix). Hermaphrodite-1 required the lowest number of days to first female flower (38.27 days) and registered the highest flesh to seed cavity ratio (0.43), but recorded higher number of days to first picking (55.80 days) and lowest yield per plant (420.67 g). Fazilka Coll-94, a good-yielding cultivar (1694 g per plant), required lower number of days to female flower (39.47) and number of days to first picking (49.87), and recorded the longest harvest duration (21.07 days) and the thickest rind (1.88 mm).

Abraham (2006) reported significant differences for 15 characters studied in 28 genotypes of cucumber collected from different parts of the country. Phule Himangi (20.22 kg/plot) emerged as high yielder followed by AAUC2 (15.11 kg/plot).

Sharma and Sharma (2006) evaluated thirty one genotypes of cucumber and reported that the genotypes Jorji Local, Bengal 60 and Derabassi local were promising with respect to yield per plant and fruit length, while Gyn-2, Gyn-3 and Gyn-4 were superior for number of fruits per plant. However, genotypes Chakkimore local, Farukabad local, Chamoli Local were promising for average fruit weight and fruit breadth.

2.2 MAINTENANCE OF GYNOECIOUS LINES

The underlying principle in the maintenance of a gynoecious line is the induction of staminate flowers phenotypically and resultant production of seeds in isolation. This phenotypic (non-heritable) modification was achieved by exogenous application of growth regulators. The commercial production of gynoecious cucumber seed was made possible only when it was discovered that gynoecious inbreds could self reproduce if a growth regulator is applied to induce male flower formation (Robinson, 1999). Peterson and Anhder (1960) for the first time discovered the effect of giberellic acid (GA_3) on promotion of male flower formation in cucumber. However, due to erratic male flower induction by use of GA_3, application of silver compound such as silver nitrate ($AgNO_3$) is followed to induce male flowers. Silver ions inhibit ethylene action and thus promote male flower formation in gynoecious cucumber plants (Beyer, 1976).

Kalloo and Franken (1978) studied the effect of chemicals in production of staminate flowers in four determinate gynoecious cucumber lines (EsWrD, WLD, ECD and WrD). The lines were sprayed with 100, 500 or 1500 ppm GA_3 , 50, 200 or 500 ppm $AgNO_3$ or 100 or 200 ppm Ethrel [ethephon] when the first true leaf was 2.5 cm long. $AgNO_3$ was superior to GA_3 for the production of male flowers. EsWrD was strongly female and responded less to GA_3 than the other lines. Both $AgNO_3$ and GA_3 were suitable for the production of male flowers to maintain WLD, ECD and WrD.

Nijs *et al*. (1979) reported that treatment with GA_3 or various concentrations of $AgNO_3$ or silver thiosulphate ($[Ag\ (S_2O_3)_2]^3$) induced the formation of male flowers in the gyneocious lines $A_{1,}$ A_2 and G_6 but only $AgNO_3$ was effective in line Fabrio. Application of $AgNO_3$ at 500 ppm gave the highest yield of male flowers in all lines but retarded plant growth and caused crinkling. However, application of $[Ag\ (S_2O_3)_2]^3$ at 500 or 2000 ppm induced male flowers without severe damage to the plants.

Prochazkova and Tronikova (1981) compared the effects of $AgNO_3$ and GA_3 on induction of staminate flowers in 17 gynoecious lines of cucumber. The overall effect of a single treatment with GA_3 in inducing the production of staminate flowers was closely similar to that of $AgNO_{3,}$ but the lines which responded most strongly to the one treatment tended to be among those which were least responsive to the other.

More and Munger (1986) studied gynoecious sex expression and stability in 2 gynoecious cucumber lines and its hybrids. It was observed that genotypic stability varied between treatments and genotypes. The F_1 hybrids generally showed greatest gynoecious stability after one spray of 150 ppm $AgNO_3$ at the one true leaf stage. Two applications of 250 ppm $AgNO_3$ at two-true leaf stage produced the maximum number of male flowers in all genotypes. Plants exposed to light for 10 hrs after $AgNO_3$ application produced fewer male flowers than those exposed to 15 or 20 hours.

More and Sheshadri (1988) used $AgNO_3$ for maintaining gynoecious lines in the heterosis breeding programme. Gynoecious lines do not produce staminate flowers in the absence of an $AgNO_3$ spray. When they are sprayed with $AgNO_3$ (300 ppm. twice) the average node number of first staminate and pistillate flowers ranges from 1.09 to 2.89 and 4.29 to 9.29, respectively.

Chaudhary *et al.* (2001) reported that $AgNO_3$ was superior over $[Ag(S_2O_3)_2]^3$ and GA_3 in terms of flower induction in gynoecious cucumber, although the effects depended on the genotype and environment. Lateral axis application of $AgNO_3$ at 300 and 400 ppm produced the highest sex ratio, hence considered as the best method for maintaining gynoecious lines.

Stankovic and Prodanovic (2002) examined the positive effects of foliar-applied solutions of different $AgNO_3$ concentrations (0.01, 0.02, 0.03 and 0.04%) and the effects of sowing seasons (spring and summer) on sex expression of a gynoecious line and a monoecious inbred. In the gynoecious line, the number of male flowers increased with increasing $AgNO_3$ applications which was more significant in the first sowing season (from 7.35 for 0.01% solution to 36.17 for 0.04%). In both sowing season $AgNO_3$ reduced female flowers compared with the control. In the spring sowing, the optimum sex conversion of gynoecious plants of PMS line was affected by the 0.02 percent $AgNO_3$ solution, whereas in the long-daylight period this effect was achieved by the 0.03 percent $AgNO_3$ solution. $AgNO_3$ did not affect the development of male flowers of monoecious PKTZ cucumber lines. The application of 0.03 and 0.04 percent solutions had negative effects on the total number of flowers.

Hallidri (2004) investigated the effect of $AgNO_3$ concentration (0, 100, 200, 300, 400 and 500 ppm) and number of sprays (once, twice or thrice) on the sex expression of gynoecious, parthenocarpic, cucumbers. The initial sprays were applied at the first true leaf stage of growth, and subsequent treatments were applied at weekly intervals. The induction of staminate flowers depended on the $AgNO_3$ concentration and number of sprays. All treatments sprayed only once and treatments sprayed with 100 ppm $AgNO_3$ failed to induce staminate flowers. The highest number of staminate nodes was produced on plants sprayed twice or thrice with 400-500 ppm $AgNO_3$. Plants showing injury a few days after spraying with 400-500 ppm recovered within 7-10 days.

Nowaczyk and Nowaczyk (2004) induced male flowers on a parthenocarpic gynoecious hybrid cucumber Polonez F_1 using GA_3. GA_3 treatment resulted in increased fruit volume and weight. This was accompanied by a considerable increase in fruit seed yield which was attributable to a statistically nonsignificant increase in the number of seeds per fruit combined with a similar increase in seed size.

Sharma *et al.* (2004) examined the use of $AgNO_3$ and GA_3 for maintaining the gynoecious parent. $AgNO_3$ was sprayed at 250 ppm once at 2-3 leaf stage, and twice at 2-3 and 4-6 leaf stages; and at 600 ppm, sprayed before flowering. GA_3 at 1500 and 2500 ppm was sprayed before flowering. GA_3 at both concentrations failed to induce male flowers in the gynoecious line. Two sprays of $AgNO_3$ at 250 ppm was best for producing the maximum number of male flowers (4 males and 1 female) in gynoecious parent with maximum pollen viability (56.20%). $AgNO_3$ at 600 ppm also induced more male buds but with poor pollen viability.

Zhang *et al.* (2007) recorded male flower inducing effects of $AgNO_3$ in a gynoecious line of cucumber. $AgNO_3$ solution at 0, 100, 200, 300, or 400 mg/litre was used to spray the gynoecious seedlings cucumber inbred line S17 at the two, three, and four leaf stages (at 5 day intervals). Two successive sprays at the two-leaf stage at the rate of 300 mg/litre (w/v) gave the best male flower inducing result. In this treatment, the number of induced male flowers was the maximum (in 20 nodes), the node position of the first male flowers was the lowest and the rate of mortality was the minimum.

Diola *et al*. (2008) evaluated the response of cucumber floral verticils in two cultivars (Wisconsin MR28, gynoecious, and Caipira, monoecious) to IBA application. Cultivar Wisconsin MR28 produced an average of 7636 pollen grains (PG) per flower, with a positive linear response to the increase in IBA concentration. In Caipira (5160 PG), all IBA concentrations reduced PG production. Cultivars did not have significant difference in PG viability (average in vitro germination of 75.4 and 79.9 per cent to cultivars Wisconsin MR28 and Caipira, respectively). In both cultivars, PG viability increased linearly with the increase in IBA concentration The ratio male:female flowers was significantly different between cultivars (4.2:1 and 3.5:1, respectively, in Wisconsin MR28 and Caipira) and responded in a distinct way to IBA concentrations. While in cultivar Caipira, IBA concentrations near to 100 µmol increased the number of male flowers; in cultivar Wisconsin MR28, the same IBA concentration reduced it. The two cultivars had a similar number of female flowers but remained relatively stable in cultivar Caipira in spite of the increase in IBA concentration. There was an increase in the number of female flowers in cultivar Wisconsin MR28, as a result of the rise in IBA concentration.

Susaj and Susaj (2010) observed that the highest number of staminate flowers was taken on plants which were treated twice or three times with 400-500 ppm $AgNO_3$ in seven days intervals. The first node at which the induction of staminate flowers occurred in different plants was significantly influenced by $AgNO_3$ concentrations and the number of treatments (sprays). Plants treated with 200 ppm $AgNO_3$ produced staminate flowers after 3.6 nodes, plants treated with 300 ppm $AgNO_3$ after 3.4 nodes, plants treated with 400 ppm $AgNO_3$ after 2.8 nodes, and plants treated with 500 ppm $AgNO_3$ after 2.2 nodes. On the other hand, all treatments used once were ineffective for producing staminate flowers after tenth node. The anthesis of the first staminate flower (35-38 days after first treatment) resulted not significantly affected by the concentration and the number of treatments or their interaction. In some cases, some days after treatments with 400 and 500 ppm, were observed injuries which were recovered for seven to ten days.

2.3 COMBINING ABILITY

The combining ability analysis gives useful information regarding the selection of parents in terms of the performance of their hybrids. The concept of combining ability in terms of genetic variation was first given by Sprague and Tatum (1942) using single crosses in maize. For improvement of a desirable character, the selected parental line should be of high general combining ability (GCA) value and their F_1 should express high specific combining ability (SCA).

Ananthan and Pappiah (1997) recorded yield and yield components of five parental and 20 F_1 cucumber genotypes for use in combining ability and correlation studies. GCA and SCA were significant for days to first male flowering, days to first female flowering, sex ratio, fruit number per vine, fruit length, fruit girth, seed number per fruit, tender fruit weight per vine and ripe fruit weight per vine.

Two commercial cultivars (Khira 90 and Khira 75), one landrace, one exotic accession (EC173934) and one gynoecious line (Gyn 1) of cucumber were crossed and the 10 resulting hybrids were evaluated for combining ability of several quantitative traits (Dogra *et al.*, 1997). GCA and SCA variances were significant for all characters and non-additive gene action predominated. Gyn1 and Khira 90 were good general combiners for yield and its components. Khira 75 × Gyn1 had the highest SCA estimates and best overall performance.

In a trial on cucumber at KAU, Gayathri (1997) observed that the parents showing higher mean performance for a particular character were generally good combiners for that character. Among the seven parental lines used for producing F_1

hybrids, CS-12 and CS-9 were good general combiners for yield. The hybrids CS-12 × Punerikhira, CS-9 × ARC-1 and BSS-169 × Arc-1 possessed high SCA effects.

Verma *et al.* (2000) estimated combining ability effects in cucumber for seven traits in a line × tester method comprising 21 hybrids obtained by crossing seven lines and three testers. Significant differences were observed among the parents and hybrids/crosses for GCA and SCA, respectively. Parents K27080, LC-3, C-12 and GY2 were found good general combiners for yield and its component traits. High SCA effects for yield and other traits were exhibited by the cross combinations JLG × C-12, K 27080 × C-12 and K 27080 × LC-3.

Wehner *et al.* (2000) tested 761 gynoecious hybrids produced from crosses with a common gynoecious female parent (Gy 14) for early, total, and marketable yield using recommended cultural practices at two locations. Significant differences were observed among cultigens and also between the two locations for all traits evaluated. The interaction of cultigen and location was significant for standardized total yield and standardized corrected total yield. The highest yielding hybrids at both locations were produced using the following cultigens as male (paternal) parents: PI 422185, PI 390253, PI 175120, PI 173889, PI 267087, PI 175686, PI 178888, PI 385967, PI 458851, and PI 171601. The highest and lowest yielding paternal parents from the germplasm screening study were retested, along with check cultigens in a multiple-harvest trial at Clinton. Cultigens were evaluated directly, rather than as hybrids with Gy 14, and fruit number, fruit weight, and sex expression were recorded. Most cultigens performed as expected for the yield traits in the retest study. The exceptions were Wautoma and PI 339250, which were among the low and high yielders in the first test, but were ranked as medium and low, respectively, in the retest study.

Bairagi *et al.* (2001) developed twenty-eight F_1 hybrids from 8 diverse parental lines of cucumber (PCUC-98-25, PCUC-99-5, PCUC-15, C-31, PCUC-28, DC-1, PCUC-98-30 and PCUC-20) and evaluated along with their parents for combining ability for 8 economic traits during the summer season of 2000 in Uttaranchal. Among the hybrids, PCUC-98-25 × C-31 exhibited SCA effects for earliness (days to anthesis of first female flower), fruit length and yield characters, while C-31 × PCUC-28 showed high SCA effects for vegetative characters like number of primary branches per plant and vine length, and also for yield characters.

Din and Ahamed (2002) generated 48 F_1 hybrids to study combining ability effects through the line × tester method. Variances due to GCA and SCA effects were significant for all the traits except for nodal position of the first female flower and fruit length.

Lopez-Sese and Staub (2002) evaluated the combining ability for several yield related traits of six F_1 progenies, resulted from a cross between 3 U.S. adapted *Cucumis sativus* var. *sativus* lines and a *C. sativus* var. *hardwickii* (R.) Alef.- derived line. Combining ability was significantly influenced ($p< 0.05$) by year of most of the horticultural traits examined. GCA was significant for all traits in each year. SCA was significant in magnitude and direction for only fruit number and days to anthesis. Data indicate that the *C. sativus* var. *hardwickii*-derived inbred line WI 5551 possessed high SCA for yield component traits.

Rawat (2002) observed significant GCA and SCA among 10 parents and their 45 cucumber hybrids for all the characters studied. On the basis of GCA effects parent P1 (CUC-75-2-10) followed by P2 (Pusa Sheetal) and P8 (Gogunda) were recorded as the best general combiners for most of the characters including yield.

SCA effects of crosses revealed that 16 crosses showed significant SCA effects for total fruit yield per plant and cross P1 x P5 was the best specific combiner.

Kumbhar *et al.* (2005) studied heterosis and combining ability for yield and its components with 28 F_1 hybrids of cucumber obtained by 8×8 diallel among 8 parents. The characters studied were governed by additive and non-additive gene action. There was close agreement between per cent performance of parents and GCA effects for all the characters. The best specific combinations were those involving parents with low and/or high combining ability. Shubhangi and Sheetal were identified as the best combiners for yield. The specific combinations Improved Long Green × Himangi and Poona Khira × Junnar Local were identified as the best hybrids.

Sushir *et al*. (2005) investigated combining ability components using half diallel analysis in cucumber. The mean sum of squares due to GCA was significant for all characters except number of female flowers, whereas mean squares due to SCA were significant for all characters except number of fruits vine. Parents Shubhangi, Sheetal and Talegaon Local were identified as the best general combiners for yield and yield contributing characters. The specific combinations Improved Long Green x Himangi and Poona Khira x Junnar Local were identified as the best hybrids.

Combining ability for yield and its components was studied by Singh and Sharma (2006) following line × tester approach in cucumber. Fifteen cross combinations (5×3) with eight parents were studied for 12 characters. Variance due to SCA was higher than that of GCA for all the characters except fruit length, fruit diameter and TSS, indicating the importance of non-additive gene action. The parents AAUC-2 and Sel. 75-1-10 were good general combiners for marketable yield and component traits. The hybrids Sel. 75-1-10 × K. Paprola and CHC-2 × Sel. 75-2-10 displayed significant SCA effects for marketable yield per plant and marketable fruits per plant.

Yadav *et al.* (2007) analysed the combining ability for yield and its contributing characters in 45 F_1 hybrids of cucumber developed through line x tester technique.The parent 2020 followed by 2017, 2231 and 2336 showed a significant GCA effect. The number of fruits per plant has a positive effect on yield per plant, which ranged from -1.28 to 3.74 in 2227 and 2020 lines, respectively. Based on SCA, 7 superior heterotic crosses, namely 2237×2226, 2237×2238, 2015×2014, 2228×2238, 2028×2238, 2336×2014 and 2229×2226 were selected for yield and yield traits.

A study was carried out by Uddin *et al*. (2009) to assess the combining ability effect of different characters in a line x tester method comprising 24 hybrids produced by crossing eight lines with three testers. Estimates of GCA effects demonstrated M1 parent as good combiner for indeterminate type vine and F8, F5 for determinate vine. The parent F8 was the best for early male and female flower opening. The tester parents M1 was found good combiner for longer vine, more number of fruits, long fruit and higher yield per plant. The parents F7 was found good for average fruit weight. F7 was the best and F1, F8 were also the good general combiners as well to be used in crossing to improve the individual fruit bearing capacity. Hence, F1, M1, F8 and F7 were recognized as the good general combiners to improve fruit yield per plant. F8 x M2 was the best specific combiner to increase the fruit yield per plant. Based on SCA effects the cross combination F8 x M3 was found best combiner for earliness as well as for number of fruits per plant.

Hanchinamani and Patil (2009b) studied 35 F_1 hybrids of cucumber involving 12 parents to work out the combining ability for yield and its contributing traits.

Considering combining ability values, parents BGDL, DWD-2, GBGL and Poinsette found to be superior for total fruit number/vine, parent BGDL, PAU-1,white long, Vejundra Dosa and BGDL for average fruit weight and parents BGDL, PAU-1 AND ARABL for high vigorous plants. The cross BGDL x Hot season showed significant positive SCA for total yield per vine and total number of fruits per vine.

Sarkar and Sirohi (2010) estimated combining ability in cucumber in a 10×10 diallel cross excluding reciprocals for ten important quantitative characters. The mean square due to GCA and SCA were highly significant for all the characters studied. Among 10 parental lines, the parent P1 (DC-1) showed highest GCA for fruit weight, fruit length and total yield per plant and parent P3 (DC-2) exhibited maximum favourable GCA for node number of first female flower and number of fruits per plant. In order of merit, the hybrid P7 × P8 (PCUC-28 × VRC-11-1), P1 × P7 (DC-1 × PCUC-28) and P4 × P6 (CH-20 × Himangi) were found to be the top performing hybrids over top parent for total yield per plant. These F_1 hybrids showed highly significant SCA effects for yield and its important contributing characters.

The combining ability analysis in cucumber by Brar *et al*. (2011) revealed that both GCA and SCA variance were significant for all the characters except equatorial diameter of fruit. Parent EC-27075 was observed to be good general combiner for fruit yield and Poinsette for days to first fruit harvest and fruits per vine. Cross combinations viz. Poinsette × KH-1; Summer Khira × SAKU-6, Sel-97-7 × Summer Khira manifested highest SCA effects for days to first fruit harvest, fruits per vine and fruit yield, respectively.

Eighteen cucumber hybrids and their parents were evaluated by Batakurki *et al.* (2011) to assess the combining ability governing the quality traits. The parents KC-5 and KC-3 were identified as good general combiners for number of leaves per plant, whereas KC-2 and KC-6 were identified as good general combiners for number of branches. The crosses KC-3 × Poinsette and KC-5 × KML exhibited significant SCA effects for flesh thickness and number of seeds per fruit, respectively.

Seven parental lines of cucumber were evaluated in a diallel cross along with their twenty one F_1hybrids (excluding reciprocals) by Khushawa *et al.* (2011) to obtain information about heterosis and combining ability. It was observed that both GCA and SCA variances were significant for all the characters studied. In general, the mean squares for GCA were greater than SCA for all the characters except yield per vine. In most of the cases heterobeltiosis observed was due to high SCA effects. The most promising hybrids were BC-11 x BC-16, BC-15 x Poinsette and BC-13 x BC-14 and these hybrids showed highest SCA effects for yield per vine.

Singh *et al*. (2011) recorded combining ability effects for different characters of cucumber in a line x tester mating design comprising 12 lines and 3 testers and their 36 F_1 hybrids. The result revealed high and significant differences among the parents and hybrids for most of the characters except number of nodes to male flower and female flower and length of fruit. Among the parents, CC-5, BSC-1, and CC-7 were found to be good general combiner for number of primary branches per plant, weight of fruit, number of fruit per plant, fruit yield per plant etc. The cross combination VRC-18 x CC-5, BSC-1 x CC-5 and CC-7 x CHC were found to be good specific combiner for fruit yield and its related contributing characters.

Mule *et al.* (2012) conducted a study on heterosis and combining ability for fruit yield and its components in a set of 27 F_1 hybrids of cucumber obtained from a line x tester method involving twelve diverse parents at Navsari Agricultural University, Navsari. The analysis revealed that none of the parents was found good general combiners for all the traits consistently; however parents CCP-9, Gujarat local and SPP-44 was good combiner for fruit yield and its contributing traits. The hybrids Pilibhit Local x K-90 followed by Sheetal x SPP-44 and Sheetal x CC-9 have exhibited higher heterobeltiosis for fruit yield and its components characters. These crosses involved poor x poor and poor x good combiner parents.

2.4. HETEROSIS

Hayes and Jones (1916) were the first to report heterosis in cucumber. They reported 24-39 per cent yield increase in F_1 over the highest yielding parent. However, heterosis for number of fruits per plant was reported to be 6-27 per cent. Heterosis was reported for various other traits in cucumber by Hutchins (1939), Barnes (1966) and Robinson and Whitaker (1974). Solanki *et al*. (1982) have reported a heterosis of 120.23 per cent for fruit yield plant.

Table 1. Literature on heterosis (Relative heterosis - RH, Heterobeltiosis- HB and Standard heterosis- SH) in cucumber for yield and yield components

Character	Heterosis (%)	Reference
1. Vine length (cm)	22.60 (SH)	Vijayakumari *et al*. (1993)
	58.14 (RH)	Gayathri (1997)
	32.51(HB)	
	25.90 (SH)	
	19.70 (HB)	Bairagi *et al.* (2005)
	19.00 (SH)	
	34.05 (RH)	Yadav *et al*. (2008)
	-56.04 to 30.74 (RH)	Hanchinamani and Patil (2009a)
	-46.02 to 14.52 (HB)	
	21.35 (HB)	Mule *et al*. (2012)
2. Branches per plant	51.41(RH)	Gayathri (1997)
	46.0 (HB)	
	45.9 (SH)	

	9.46 to 21.46 (HB) 15.63 to 68.31(SH) 46.1(HB) 21.0 (SH) 60.88 (RH) 41.67 (HB)	Singh *et al*. (1999a) Bairagi *et al.* (2005) Yadav *et al*. (2008) Mule *et al.* (2012)
3. Days to first male flower anthesis	-16.18 (RH) -15.64 (HB) -11.39 (RH)	Gayathri (1997) Yadav *et al*. (2008)
4. Days to first female flower anthesis	22.2 (HB, Rainy) 14.2 (HB, Summer) 15.5 (SH) -14.29 (RH) -10.29 (HB) -14.41(SH) -15.1(HB) -13 (SH) -11.72 to 82.65 (HB) -17.72 to 65.19 (SH) -7.92 (RH) -0.52 to 16.49 (RH) -1 to -19 (HB) -0.53 to -9.51(HB) -2.89 to -17.84 (SH)	Hormudzi and More (1989) Vijayakumari *et al*. (1993) Gayathri (1997) Bairagi *et al.* (2005) Dogra *et al.* (2007) Yadav *et al*. (2008) Hanchinamani and Patil (2009a) Kumar *et al*. (2010)
5. Node at which first female flower emerged	43.8 (HB, Rainy) 53.2 (HB, Summer) 37.3 (SH)	Hormuzdi and More (1989) Vijayakumari *et al*. (1993)

	53.41(HB) 51.89 (SH)	Dogra *et al.* (1997)
	-27.3 (RH) -38.5 (HB)	Gayathri (1997)
	-13.85 to -33.19 (HB) 0.0 to -21.36 (SH)	Singh *et al*. (1999a)
	-24.7 (HB) 48.0 (SH)	Bairagi *et al.* (2005)
	-40 to 62.5 (HB) -38.46 to 207.69 (SH)	Dogra *et al.*(2007)
	-29.10 (RH)	Yadav *et al*. (2008)
	0 to 46.15 (RH) -9.52 to -47.61(SH)	Hanchinamani and Patil (2009a)
	16.32 (SH)	Singh and Ram (2009)
	-16.31(HB)	Khushawa *et al*. (2011)
	-30.06 (HB)	Mule *et al*. (2012)
6. Days to first harvest	61.71(HB)	Kumbhar *et al.* (2005)
	-10.32 to 74.29 (HB)	Dogra *et al.* (2007)
7. Duration of the crop	-13.81 to 57.46 (SH) -1.92 to 7.06 (HB) -1.50 to 12.54 (SH)	Kumar *et al.* (2010)
	15.15 (RH)) 6.99 (HB)	Gayathri (1997)
8. Fruits per plant	94.8 (SH)	Vijayakumari *et al*. (1993)
	75.80 (RH) 62.38 (HB) 42.32 (SH)	Gayathri (1997)
	67.12 (HB)	Kumbhar *et al.* (2005)

	67.7 (HB)	Bairagi *et al.* (2005)
	22.2 (SH)	
	-45.71 to 15.79 (HB)	Dogra *et al.*(2007)
	-50 to 25.18 (SP)	
	22.2 (RH)	Yadav *et al*. (2008)
	-24.99 to 42.49 (RH)	Hanchinamani and Patil (2009a)
	-37.93 to 27.59 (HB)	
	48.58 (SH)	Singh and Ram (2009)
	0.84 to 25.21(HB)	Kumar *et al.* (2010)
	7.70 to 55.13(SH)	
	110.59 (HB)	Khushawa *et al.* (2011)
	66.7 (HB)	Mule *et al*. (2012)
	-46.3 to 45.5 (HB)	Singh *et al*. (2012)
	-31.90 to 45.07 (SH)	
9. Yield per plant (kg)	247.3 (HB)	Hormuzdi and More (1989)
	51.34 (HB)	Dogra *et al.* (1997)
	51.15 (SH)	
	111.80 (RH)	Gayathri (1997)
	106.92 (HB)	
	146 (RH)	Cramer and Wehner (1999)
	83.1 (HB)	
	32.55 (SH)	Singh *et al.* (1999a)
	187.80 (SH)	Singh *et al.* (1999b)
	88.92 to 147.34 (RH)	Rawat *et al.* (2002)
	62.29 to 136.39 (HB)	
	64.21 to 90.08 (SH)	
	145.9 to184.2 (SH)	More (2002)
	45.5 (HB)	Bairagi *et al*. (2005)

	20.2 (SH) 80.69 (HB) 29.2 -45.0 (SH) -46.07 to 38.79 (HB) -47.97 to 38.25 (SH) -19.03 to 60 (RH) -43.43 to 60.47 (RH) -50.51 to 31.73 (HB) 65.50 (SH) -0.53 to 44.82 (HB) 2.85 to 44.81(SH) 136.49 (HB) 57.96 (HB) 0.87 to 34.45 (HB) 43.77 to 70.81 (SH)	 Kumbhar *et al.* (2005) Munshi *et al.* (2005) Dogra *et al.*(2007) Yadav *et al*. (2008) Hanchinamani and Patil (2009a) Singh and Ram (2009) Kumar *et al.* (2010) Khushawa *et al*. (2011) Mule *et al*. (2012) Singh *et al*. (2012)
10.Average fruit weight (g)	48.78 (RH) 33.19 (HB) 7.1 (RH) 5.4 (HB) 16.2 (HB) 13.9 (SH) -25.44 to 18.75 (HB) -21.74 to 40.99 (SH) 28.39 (RH) 18.9 (SH) -29.12 to 15.33 (RH) -25.69 to 13.28 (SH)	Gayathri (1997) Cramer and Wehner (1999) Bairagi *et al*. (2005) Dogra *et al.*(2007) Yadav *et al*. (2008) Singh and Ram (2009) Hanchinamani and Patil (2009a)

	7.29 to 22.96 (HB) 7.07 to 22.96 (SH) 58.91(HB) 22.68 (HB) -46.5 to 33.3 (HB)	Kumar *et al.* (2010) Khushawa *et al*. (2011) Mule *et al*. (2012) Singh *et al*. (2012)
11. Fruit length (cm)	12.54 (RH) 12.16 (HB) 30.0 (SH) -27.62 to 25.88 (HB) -14.30 to 20.60 (SH) -15.24 to 44.45 (RH) -29.27 to -6.63 (HB) 34.89 (RH) 16.56 (SH) 11.76 to 33.11(HB) 12.32 to 44.70 (SH) 25.22 (HB) 22.35 (HB) -49.25 to 13.39 (HB) -44.24 to 26.60 (SH)	Gayathri (1997) Dogra *et al.*(2007) Hanchinamani and Patil (2009a) Yadav *et al*. (2008) Singh and Ram (2009) Kumar *et al.* (2010) Khushawa *et al*. (2011) Mule *et al*. (2012) Singh *et al*. (2012)
12. Fruit girth (cm)	20.81 (RH) -23.84 to 7.86 (HB) -11.89 to 27.89 (SH) 56.03 (RH) -15.52 to 24.35 (RH) -25.69 to 13.28 (HB)	Gayathri (1997) Dogra *et al.*(2007) Yadav *et al*. (2008) Hanchinamani and Patil (2009a)

	9.52 (SH) 1.26 to 25.18 (HB) 7.07 to 17.97 (SH) 16.0 (HB) 35.94 (HB)	Singh and Ram (2009) Kumar *et al.* (2010) Khushawa *et al*. (2011) Mule *et al*. (2012)
13. Flesh thickness (cm)	-32.93 to 26.67 (HB) -38.75 to 48.44 (SH)	Dogra *et al*. (2007)
14. Seeds per fruit	41(RH) 44.06 (HB) 44.06 (SH)	Gayathri (1997)

2.5. HETEROSIS EXPLOITING GYNOECY

Gynoecious sex form was spotted out as a chance segregant from a Korean gynomonoecious introduction ‘Shogoin’ (PI 220860) (Peterson and Anhder, 1960) and from this source all the gynoecious lines, whether used for slicing or pickling cucumber grown in the glasshouse or open, were developed in U.S.A., Western Europe, Japan, etc. Since then research work has been carried out to exploit the gynoecious trait for crop improvement in cucumber

Three true breeding gynoecious lines under high temperature and long photoperiodic conditions were developed by More and Sheshadri (1988) by transferring gynoecy to different genetical background. They were 304-C, 319-12 and 338 and were renamed as GYC-1, GYC-2 and GYC-3. Further 4 yellow fruit skinned fully parthenocarpic lines (PKG-1-21, PKG-1-23, PKG-1-24) were isolated from a complex cross (Table green 68×sc3 F_2) × Poonakhira) F_3× (GY14 × Table Green 68 F_2) × Poonakhira) F_3. Finally PKG-1 was renamed as GYC-4. Using GYC-2 and GYC-4 as female parents two superior F_1 hybrids, namely 'Phule Prachi' and 'Phule Champa' respectively were released More (2002)

Evaluating 34 and 41 gynoecious F_1 hybrids for horticultural characters during summer and rainy seasons respectively, Vijayakumari *et al.* (1991) recommended promising hybrids for both the season and generalized that the tropical gynoecious hybrids were superior to temperate gynoecious hybrids. The crosses 304 × EC14212 and Gyn. JPL × EC129110 in the summer season and 322-11 × Balam and 304D × RKS295 in the rainy season were good combiners for earliness. In another study of heterosis over better parent and superiority over top parent for earliness, yield and its components, maximum heterosis over better parent with 77.6% and superiority over top parent was evidenced in tropical gynoecious hybrid 304 x RKS 296 (Vijayakumari *et al*., 1993)

Badgujar and More (2004) reported that the gynoecious F_1 hybrids H-13, H-210, H-312 and H-42 had high potential for earliness and yield contributing characters across three seasons. Further the hybrids H-26, H-211, H-36, H-41 and H-411 also had high potential in respect of earliness and yield for two seasons. The prospects of heterosis breeding were found to be promising for days to anthesis of first female flower, node for first female flower, fruits per plant, weight per fruit, total and early yield per plant and vine length.

In a study conducted by Dhillon and Ishiki (1998), 4 gynoecious F_1 hybrids of cucumber were evaluated for 6 years to determine the level of hybrid (G) × year (Y) interaction for fruit number/plant and yield/plant in subtropical field conditions, with the aim of developing efficient field evaluation techniques to maximize yield gain. G × Y interactions were significant for both characters but these were of a lower magnitude for yield/plant and the ranking of the top-performing hybrids was consistent through the years.

Dogra *et al*. (2007) attempted diallel crosses among eight parents of cucumber including two gynoecious lines. G_2 followed by Gyn1 was the best parent. Heterobeltiosis and standard heterosis for earliness were maximum in EC 173934 x LC – 40 and G_2 x Gyn 1 respectively. The cross combination G_2 x Gyn 1 was earliest to produce female flower on lowest node and also to produce early maturity and recorded maximum heterosis over check followed by K-90 x G_2.

Gene action and heterosis studies involving gynoecious lines in cucumber was carried out at Palampur and Hill Agricultural Research and Extension Centre, Bajaura by Sharma (2010). There was wide variation in magnitude and direction of heterosis for all characters studied. Marketable yield per vine, marketable fruits per vine and average fruit weight were the most heterotic characters. Appreciable heterosis over better parent and standard checks was observed for almost all the traits. For marketable yield per vine 51 cross combinations at Palampur, 43 at Bajaura and 50 in pooled environment showed hybrid vigour over better parent. The hybrid vigour was mainly on account of increased, fruit number, weight and size. Based on hybrid vigour, *vis-à-vis* their mean performance and from consumer view point, the combination Plp-Gy-1 x K-pap, Plp-Gy-1 x K-90, G-1 x Summer Green, G-1 x K-pap and G-3 x Sel-75-2-10 were the most promising one.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study 'Heterosis breeding exploiting gynoecy in cucumber (*Cucumis sativus* L.)' was carried out at Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during February-May 2012 and November 2012 to March 2013. Field experiment was conducted at Block 1 of the department (Plate 1).

Experiment site was located at an altitude of 22.5m above MSL between10°32'N latitude and 75°16' longitude. The location experienced warm humid climate. Soil of experimental site was textured class of sandy loam and was acidic in pH (5.7)

3.A. EXPERIMENTAL MATERIALS AND METHODS

3.A.1 Experimental Materials

Experimental materials consisted of 12 monoecious cucumber (*Cucumis sativus* L.) genotypes, collected from different parts of the country (Plate 2) and a stable gynoecious inbred introduced from USA (Plate 3). Source and morphological description of genotypes are presented in Table 2.**Table 2. List of cucumber accessions/varieties collected from different parts of the country**

Sl.No	Accession/ Variety	Source
1.	CS-127 (Green long)	National Seed Corporation, Bangalore
2.	IC 527427	National Bureau of Plant Genetic Resources, New Delhi

Plate 1. Field layout

2a. CS 127

2b. IC 527427

2c. IC 410617

2d. IC 410638

Plate 2. General view of monoecious cucumber genotypes

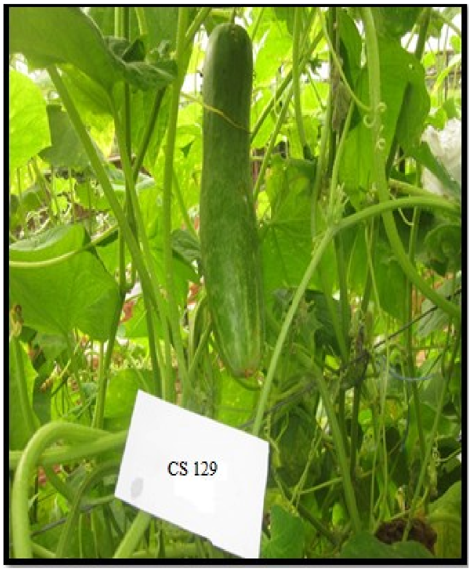
2e. IC 538155

2f. 527431

2g. IC 538186

2h. CS 128

Plate 2. General view of monoecious cucumber genotypes



2i. CS 129

2j. CS 25

2k. CS 121

2l. CS 123

Plate 2. General view of monoecious cucumber genotypes

Plate 3. Field view of gynoecious cucumber line

3.	IC 410617	National Bureau of Plant Genetic Resources, New Delhi
4.	IC 410638	National Bureau of Plant Genetic Resources, New Delhi
5.	IC 538155	National Bureau of Plant Genetic Resources, New Delhi
6.	IC 527431	National Bureau of Plant Genetic Resources, New Delhi
7.	IC 538186	National Bureau of Plant Genetic Resources, New Delhi
8.	CS-128	G.B. Pant University of Agriculture and Technology, Uttaranchal
9	CS-129	G.B. Pant University of Agriculture and Technology, Uttaranchal
10	CS-25	Assam Agricultural University, Jorhat
11	CS-121	Kerala Agricultural University, Thrissur
12	CS-123	Kerala Agricultural University, Thrissur
13	EC 709119	University of Wisconsin, USA

3.A.2. Experimental methods

a. Topcrossing

During first season 12 monoecious cucumber genotypes were crossed in a top cross fashion with gynoecious inbred (EC 709119) as female parent. Well developed female buds of gynoecious inbred were selected and covered with butter paper bags at evening hours on the day before anthesis. In the same way, the male buds of the monoecious parents were selected and covered. Anthesis takes place at 5.30 - 7.00 am and maximum of pollen grain viability is up to noon. Stigmatic receptivity is reported only for a short period and hence pollination was conducted within two hours after anthesis. At this time, pollen collected from covered male buds were brushed over the stigma of covered female flowers of female parent and tagged. The crossed female flowers were kept covered for 2 more days till the fruit developed to avoid pollen contamination. The developed fruits were covered with perforated polythene bags to protect from the fruit fly damage. Hybrid seeds from 12 topcrosses were collected from the female parent at seed maturity and stored. The parents were selfed simultaneously to produce adequate seeds.

b. Maintenance of gynoecious parent

The gynoecious parent was maintained by spraying 200 ppm silver thiosulphate at three true-leaf stage. Solution of 200 ppm silver thiosulphate sulphate was prepared as follows.

Materials required:

Sodium thiosulphate (NaS_2O_3 $5H_2O$) – 11.905 g
Silver nitrate ($AgNO_3$) – 1.02 g
Double distilled water – 1L

Procedure: NaS_2O_3 $5H_2O$ was dissolved in 250ml double distilled water in a volumetric flask. It was then poured into a 1L container. The flask was rinsed with 250 ml double distilled water and was poured into the container. $AgNO_3$ was dissolved in 250 ml double distilled water in a separate volumetric flask and was poured into the jar containing NaS_2O_3 $5H_2O$ solution. The flask was rinsed with 250 ml double distilled water and poured into the container.

Application: For spraying cucumber plant, the solution was diluted with double distilled water in the ratio 1:1. The plants were sprayed at three to six trueleaf stage with 2 applications per week.

b. Evaluation of F_1 hybrids

In the second season, 12 hybrids along with their parents were evaluated in a randomized block design (RBD) with three replications. There were five plants/genotype/replication with an area of 15m^2 per plot. Seedlings raised in protrays were transplanted after 14th day on raised beds covered with polythene mulch (B/W 25 micron) at a spacing of 2 x 1.5 m. FYM was applied at the rate of 20 kg/m^2 during the preparation of bed. Fertilizer was applied at the rate of 120: 100: 160 kg/ha (IIHR, 2012) through fertigation. 20 per cent of N and K and entire quantity of P were applied as basal dosage. Fertigation was given through inline dripper starting from 3rd week after transplanting at a frequency of twice a week. During cropping period various plant protection measures were adopted as per KAU Package of Practices (2011).

3.B. PLANT CHARACTERS STUDIED

Observations on important vegetative, fruit and yield characters were recorded in five randomly selected plants. Procedures followed for recording observations on quantitative and qualitative traits are furnished below.

3.B.1. Quantitative characters

Fruit characters were recorded in five randomly selected fruits in the plant.

1. Length of main vine (cm): Plants were pulled out after final harvest and length of the vine was measured from the collar region up to the tip of main vine.

2. Branches per plant: Number of branches originating from the main vine was counted at final harvest.

3. Days to first male flower anthesis: Number of days was counted from the date of sowing to the date when first male flower opened.

4. Days to first female flower anthesis: No of days was counted from the date of sowing to the date when first female flower opened.

5. Node at which first female flower emerged: Nodes were counted from the lowest to the one at which the first female flower emerged.

6. Days to first harvest: Number of days taken from sowing to the harvest of first formed fruit at tender in each plant was recorded.

7. Duration of the crop: Days were counted from date of sowing to the date of last harvest for five plants in each variety.

8. Number of harvests: total number of harvests made from each plant till the end of the crop.

9. Fruits per plant: Number of tender fruits in five selected plants was counted at different harvest and added to get total fruits per plant.

10. Yield per plant (kg): Weight of fruits harvested from five selected plants at different dates was recorded separately. These were added to get total yield/plant.

11. Average fruit weight (g): Weight of five fruits from five selected plants at third harvest was recorded and average was calculated.

12. Fruit length (cm): Length of five fruits from five selected plants at third harvest was recorded separately and average was calculated.

13. Fruit girth (cm): Girth of five fruits from five selected plants at third harvest was recorded separately and average was calculated.

14. Flesh thickness (cm): Flesh thickness of fruits at central part from five selected plants after cutting vertically was recorded separately and average was calculated.

15. Number of seeds per fruit: The fruits were harvested after full maturity and number of seeds per fruit was counted.

3.B.2. Qualitative Characters

Five plants randomly selected from each plot and were considered for recording the following fruit characters NBPGR (2002).

1. Density of prickles at harvestable maturity: Prickles present on the fruit surface at harvestable maturity (dense/sparse).

2. Sex form: Androecious/ gynoecious/ andromonoecious/ gynomonoecious/ hermaphrodite.

3. Colour of prickles on fruit at emergence and senescence: (brown/ black).

4. Stem pubescence: Plant surface, i.e., stem and leaves (pubescent/ non-pubescent).

5. Colour of rind at tender harvestable maturity: Colour of fruit rind after seven days of emergence, i.e., tender harvestable stage (cream/ yellow/ light green/ green/ dark green).

6. Colour of rind at mature stage: Colour of rind after attaining physiological maturity (dark green/ orange/ pink/ brown/ others).

7. Presence or absence of cavity: Cavity present at the centre of fruit at harvestable maturity (present/ absent).

8. Presence of bitterness: Organoleptic evaluation of fruits at different stages of harvest (present/absent).

9. Presence of crispness: Organoleptic evaluation of fruits at single harvest based on 0-5 hedonic scale (very crisp/crisp/moderately crisp/ soft/very soft).

10. Incidence of pest and diseases: Various diseases and pests like downy mildew, mosaic, serpentine leaf miner, etc. and their occurrence in various genotypes (severe/ moderate/ mild/ very low/ nil).

3.C. STATISTICAL ANALYSIS

Data recorded from the parents and hybrids were initially subjected to analysis of variance to detect the genotypic differences if any.

3.C.1. Combining Ability analysis

The mean data were subjected to combining ability analysis according to top cross method developed by Sprague and Tautum (1942). The simple analysis of variance for parents and topcrosses is carried out based on the skeleton of ANOVA (Table 3).

Table 3. Skeleton of topcross ANOVA

Sl No	Sources of variation	d.f.	SS	MSS
i.	Replication (r)	(r-1)	rSS	rMS
ii.	Entries (g)	(g-1)	gSS	gMS
iii.	Parents (p)	(p-1)	pSS	pMS
iv.	Top crosses (c)	(c-1)	cSS	cMS
v.	p *vs* c	(p-1) - (c-1)	pcSS	pcMS
vi.	Error (e)	(g-1) (r-1)	eSS	eMS
vii.	Total	(gr-1)	TSS	

CF (correction factor) = GT^2/N

(i) $rSS = \sum_{j}^{r} Tr_j^2 / g - CF$

$rMS = rSS / (r-1)$

(ii) $gSS = \sum_{i}^{g} T^2_{gi} / r - CF$

$gMS = gSS / (g-1)$

(iii) $pSS = \sum_{i}^{p} T^2_{gi} / r - T^2_p / pr$

$pMS = pSS (p-1)$

(iv) $cSS = \sum_{i}^{c} T^2_{gi} / r - T^2_c / cr$

$cMS = cSS / (c-1)$

(v) $pcSS = T_p^2 / pr + T_c^2 / cr - CF$

(vi) $TSS = \sum_{i}^{g} \sum_{j}^{r} x_{ij}^2 - CF$

(vii) $eSS = TSS - gSS - rSS$

$eMS = eSS/(g-1)(r-1)$

Breeding value (A) represents the GCA effect of the individual test inbred in topcross analysis. Larger the size of A, greater is the GCA effect (fixable component). Breeding value was calculated as per the standard normal deviate procedure (Sharma, 1988)

$$A = A'_i / SD\,(A')$$

$$= (\bar{c}_i - \bar{c}) / SD\,(A')$$

Where, SD – Standard deviation

As the statistic computed is a Z statistic, the area under normal curve lying between 2 ordinates was taken as a measure to calculate significant deviation. The significant deviation is the significant deviation from Z=0 or the significant difference between two GCA effects.

3.C.2. Heterosis

Heterosis was calculated as the deviation of the mean performance of F_1s ($\bar{F}_1$) from their mid parent ($\overline{MP}$), better parent ($\overline{BP}$) and the standard parent ($\overline{SP}$) for each cross combination expressed as the percentage of the mean respectively as suggested by Hayes *et al*. (1965) and Briggle (1963). A commercial hybrid of cucumber, Navya (Jaison seeds) was taken as standard parent to estimate standard heterosis.

$$\text{Relative heterosis} = \frac{\bar{F}_1 - \overline{MP}}{\overline{MP}}$$

$$\text{Heterobeltiosis} = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}}$$

$$\text{Standard heterosis} = \frac{\overline{F_1} - \overline{SP}}{\overline{SP}}$$

To test the significance of difference of F_1 mean over mid and better parents, critical difference (CD) was worked out. CD was calculated from the standard error of difference as given below. (Briggle, 1963).

To test the significance over mid-parent

$$CD\ (0.05) = te'\ (0.05) \times \sqrt{\frac{3MSE}{2r}}$$
$$= te'\ (0.05) \times SE$$

To test the significance over better parent and standard parent

$$CD(0.05) = te'\ (0.05) \times \sqrt{\frac{2MSE}{r}}$$
$$= te'\ (0.05) \times SE$$

Where, te' - critical value of t statistic at 5 % level of significance

MSE - Error mean square

r - Number of replications

SE - Standard error of difference between two means

RESULTS

4. RESULTS

Results obtained from the study 'Heterosis breeding exploiting gynoecy in cucumber (*Cucumis sativus* L.)' is presented under the following heads.

4.1. Analysis of variance

The analysis of variance was conducted by topcross method. The analysis of variance for 15 characters in 25 genotypes showed significant variability for 9 characters among the genotypes (Table 4). There was no significant differences for the characters like length of main vine, branches/plant, node at which first female flower emerged, number of harvests, duration of the crop, length of fruit and number of seeds/fruit.

4.2. Combining ability analysis

Breeding value (A) which represents the GCA effect of the individual test inbred in topcross analysis was estimated. The general combining ability effects were significant for the characters viz., vine length, branches/plant, days to first female flower anthesis, node at which first female flower emerged, days to first harvest, number of harvests, duration of the crop, fruits per plant, yield per plant, average fruit weight, fruit length, fruit girth, flesh thickness and number of seeds per fruit. The GCA was not significant for days to first male flower anthesis. The GCA effects of the parents and their percentage level of significance was estimated (Table 5). The significant deviation was estimated as the significant deviation from Z=0.

Table 4. Topcross ANOVA for 15 characters in thirteen genotypes of cucumber and their 12 hybrids

Source of variation	df	Length of main vine (cm)	Branches/ plant	Days to first male flower anthesis	Days to first female flower anthesis	Node at which first female flower emerged	Days to first harvest	Number of harvests
Replications	1	3232.08	0.61	0.96	6.13	0.41	0.4	0.005
Entries	24	10067.81	181.75	209.45	95.70	0.71	53.66	12.437
Parents	12	11836.89**	11.72**	403.91**	102.51**	0.78	49.98**	12.44*
Topcrosses	11	8440.89*	3.74	5.52	8.89	0.62	21.50	10.01
p *vs* c	1	6735.07	0	119.39*	968.85**	0.74	451.68**	6.76
Error	24	65626.67	3.16	21.25	22.78	0.81	11.81	103.96**

*Significant at 5% level
**Significant at 1% level

Table 4. Continued

Source of variation	df	Duration of the crop	Fruits/plant	Yield/ plant (kg)	Average fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Flesh thickness	Number of seeds/fruit
Replication	1	7.605	7.22	1.014	112.5	0.09	0.54	0.01	153.83
Entries	24	32.79	375.52	31.36	7450.92	11.49	6.59	0.16	11105.11
Parents	12	46.046*	339.16**	29.87**	8800.80**	18.91**	8.04**	0.16**	15270.83**
Topcrosses	11	13.91	280.28*	23.89**	5667.05*	4.05**	3.26**	0.18**	7465.62**
p *vs* c	1	81.64	1787.53**	131.36**	10874.88*	4.46	25.74**	0.06*	1150.77
Error	24	20.08	109.62	7.54	1714.58	1.19	0.74	0.01	854.81

*Significant at 5% level
**Significant at 1% level

Length of main vine (cm)

Highest GCA effect for vine length was observed for CS-123 (2.86). CS-123 has the probability of increasing the vine length by 49.74 per cent. All other parents exhibited non-significant GCA effect.

Branches per plant

The genotype CS-123 (2.30) exhibited significant GCA for branches per plant. This genotype has the potential of increasing the number of branches by 48.93 per cent in cross combinations. No other genotypes showed significant GCA for the character.

Days to first male flower anthesis

The GCA effect was not significant in any of the parents.

Days to first female flower anthesis

The highest negative GCA effect was shown by genotype CS-128 (-1.76) followed by IC 538186 (-1.56). The genotype CS-128 has the potential to reduce the number of days to first female flower anthesis by 43.32 per cent.

Node at which first female flower emerged

The genotype IC 538186 (-1.49) exhibited highest negative GCA effect. The genotype has the probability of decreasing the node at which first female flower emerged by 43.32 per cent. No other genotypes showed significant GCA effect.

Days to first harvest

The highest negative GCA effect was observed for CS-128 (-2.76). It has 49.74 per cent probability in decreasing the number of days to first harvest. All other genotypes exhibited non significant GCA effect.

Table 5. Estimate of GCA effect of 12 cucumber genotypes for 15 characters

Characters	CS-127	IC 527427	IC 410617	IC 410638	IC 538155	IC 527431
Length of main vine(cm)	-1.12 (-36.43)	-0.53 (-19.15)	0.11(3.98)	0.08 (3.98)	-0.50 (-19.15)	-0.01 (0)
Branches/ plant	-0.62 (-22.57)	-1.36 (-40.32)	-0.26 (-7.93)	-1.17 (-38.49)	1.02 (34.13)	0.11 (3.98)
Days to first male flower anthesis	-0.78 (-25.80)	1.63 (44.52)	-1.23 (-38.49)	0.28 (11.79)	0.88 (31.59)	-0.78 (-28.81)
Days to first female flower anthesis	0.49 (19.15)	-0.22 (-7.93)	-0.45 (-15.54)	0.14 (3.98)	0.26 (11.79)	1.44 (41.92)
Node at which first female flower emerged	-0.60 (-22.57)	-1.05 (-34.13)	-0.15 (-15.54)	2.09 (48.21)	1.20 (38.49)	0.30 (11.79)
Days to first harvest	-0.01(0)	-0.17 (-7.93)	-0.01(0)	-0.17 (-7.93)	1.05 (34.13)	-0.01 (0)
Number of harvests	-0.69 (-25.80)	-1.51(-43.32)	0.94 (31.59)	0.40 (15.54)	-0.01(0)	-0.01 (0)
Duration of the crop	-0.76 (-28.81)	-0.76 (-25.80)	-0.09 (-3.98)	-0.09 (-3.98)	-0.09 (-3.98)	-0.76 (-28.81)
Fruits per plant	-0.94 (-31.59)	-0.77 (-25.80)	0.82 (28.81)	0.37 (15.54)	0.10 (3.98)	0.35 (15.54)
Yield per plant (kg)	-0.68 (-25.80)	-0.67 (-25.80)	0.67 (25.8)	0.84 (28.80)	-0.28 (-7.93)	0.03 (0)
Average fruit weight (g)	2.00 (47.72*)	0.02 (0)	0.45 (15.54)	-0.63 (-22.57)	-0.68 (-25.8)	-0.49 (-19.15)
Fruit length (cm)	2.37 (49.18*)	-0.30 (-11.79)	0.19 (7.93)	-1.00 (-34.13)	-0.58 (-22.57)	-0.09 (-3.98)
Fruit girth (cm)	1.69 (44.52*)	0.45 (19.15)	0.38 (15.54)	-0.49 (-19.15)	-0.21 (-7.93)	-0.45 (-15.54)
Flesh thickness (cm)	-0.44 (-15.54)	0.93 (31.59)	-1.22 (-38.49)	1.00 (31.59)	1.33 (40.32*)	-0.15 (-3.98)
Number of seeds per fruit	-0.64 (-22.57)	-1.67 (-44.52)	-0.37 (-37.29)	-0.22 (-7.93)	0.96 (31.59)	-0.59 (-22.57)

Value in parantheses represents per cent significance of GCA (*Significant at 5% level)

Table 5. Continued

Characters	IC 538186	CS-128	CS-129	CS-25	CS-121	CS-123
Length of main vine (cm)	-0.75 (-25.8)	-0.32 (-11.79)	0.39 (15.54)	-0.42 (-15.54)	0.20 (7.93)	2.86 (49.74*)
Branches/ plant	-0.62 (-22.57)	0.29 (11.79)	-0.26 (-11.79)	0.66 (28.81)	-0.08 (-3.98)	2.30 (48.93*)
Days to first male flower anthesis	-0.63 (-22.57)	-0.93 (-31.57)	-0.78 (-25.8)	0.43 (15.54)	0.28 (11.79)	1.63 (44.52)
Days to first female flower anthesis	-1.52 (-43.32*)	-1.76 (-46.41*)	-0.81 (-28.81)	0.38 (15.54)	0.97 (34.13)	1.09 (36.43)
Node at which first female flower emerged	-1.49 (-43.32*)	-0.15 (-3.98)	0.30 (11.79)	0.30 (11.79)	-1.05 (-34.13)	0.30 (11.79)
Days to first harvest	1.05 (36.43)	-2.76 (-49.74*)	-0.01 (0)	-0.01 (0)	1.05 (36.43)	-0.01 (0)
Number of harvests	-0.96 (-31.59)	-0.83 (-28.81)	0.12 (3.98)	-0.56 (-22.57)	1.08 (36.43)	2.03 (47.72*)
Duration of the crop	-0.76 (-28.81)	0.57 (22.57)	0.57 (22.57)	-1.33 (-40.32)	1.99 (47.72)	1.52 (43.32*)
Fruits per plant	-1.30 (-38.49)	-0.56 (-19.15)	-0.56 (-19.15)	-0.11 (-3.98)	0.08 (0)	2.51 (49.38*)
Yield per plant (kg)	-1.41 (-41.90)	-0.35 (-11.79)	-0.42 (-15.54)	-0.25 (-7.93)	-0.02 (0)	2.55 (49.38*)
Average fruit weight (g)	-0.49 (-19.15)	1.95 (47.13*)	-0.07 (0)	-1.10 (-36.43)	-0.49 (-19.15)	-0.45 (-15.54)
Fruit length (cm)	-0.30 (-11.79)	0.72 (25.8)	1.17 (38.49)	-1.14 (-36.43)	-0.72 (-25.8)	-0.30 (-11.79)
Fruit girth (cm)	-1.27 (-40.32)	1.61 (44.52*)	0.53 (19.15)	-1.51 (-43.32)	0.02 (0)	-0.76 (-28.81)
Flesh thickness (cm)	-1.24 (-38.49)	1.00 (34.13)	-0.80 (-28.81)	0.83 (28.81)	1.33 (40.32*)	0.18 (7.93)
Number of seeds per fruit	0.23 (7.93)	-1.05 (-34.13)	1.52 (43.32)	0.68 (25.8)	-0.36 (-15.54)	1.52 (43.32*)

Value in parantheses represents per cent significance of GCA (*Significant at 5% level)

Number of harvests

The genotype which exhibited maximum GCA effect was CS-123 (2.03). It has the probability of increasing the number of harvests by 49.74 per cent. No other parents showed significant GCA effect.

Duration of the crop

The highest GCA effect was shown by CS-121 (1.99) followed by CS-123 (1.52). CS-121 and CS-123 have the probability to increase the duration of the crop by 47.72 and 43.32 percent respectively.

Fruits per plant

The parent CS-123 (2.51) exhibited maximum GCA effect. It has the probability of increasing the fruits per plant by 49.38 per cent when combined with another parent. All the other parents showed non-significant GCA effect.

Yield per plant (kg)

The genotype which exhibited maximum GCA effect was CS-123 (2.55). It has the probability of increasing the number of harvests by 49.38 per cent. No other parents showed significant GCA effect.

Average fruit weight (g)

The genotype CS-127 (2.00) showed maximum GCA effect followed by CS-128 (1.95). CS-127 and CS-128 have the probability of increasing the average fruit weight by 47.72 and 47.13 respectively.

Fruit length (cm)

The highest GCA effect was observed for CS-127 (2.17). The probability of CS-127 in increasing fruit length is 49.18. All the other parents showed non-significant GCA effect.

Fruit girth (cm)

The highest GCA effect was shown by CS-127 (1.69) followed by CS-128 (1.61). CS-121 and CS-123 have the probability of increasing the fruit girth by 44.52 per cent.

Flesh thickness (cm)

The genotypes IC 538155(1.33) and CS-121(1.33) exhibited maximum GCA effect with a probability to increase the flesh thickness by 40.32 per cent.

Number of seeds per fruit

The highest GCA effect was observed for the genotypes CS-129 (1.52) and CS-123 (1.52). The probability of increasing the number of seeds per fruit is 43.32 per cent.

4.3. Estimation of heterosis

The estimation of heterosis for yield and its contributing characters will help to identify the best hybrid combination. Twelve hybrids (Plate 4) were produced by crossing gynoecious inbred with selected pollen parents. The hybrids were EC 709119 x CS-127, EC 709119 x IC 527427, EC 709119 x IC 410617, EC 709119 x IC 410638, EC 709119 x IC 538155, EC 709119 x IC 527431, EC 709119 x IC 538186, EC 709119 x CS-128, EC 709119 x CS-129, EC 709119 x CS-25, EC 709119 x CS-121 and EC 709119 x CS-123. Relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for all the characters were estimated (Table 6). A popular commercial hybrid Navya (Plate 5) was taken as a standard hybrid for calculating standard heterosis. Table 7 contains the estimated values of range, mean in parents, heterosis and percentage superiority. Significant heterosis was observed for all the characters studied except for average fruit weight.

4a. EC709119 x CS 127

4b. EC 709119 x IC 527427

4c. EC 709119 x IC 410617

4d. EC 709119 x IC 410638

Plate 4. General view of F_1 hybrids

4e. EC 709119 x IC 538155

4f. EC 709119 x IC 527431

4g. EC 709119 x IC 538186

4h. EC 709119 x CS 128

Plate 4. General view of F_1 hybrids

4i. EC 709119 x CS 129

4j. EC 709119 x CS 25

4k. EC 709119 x CS 121

4l. EC 709119 x CS 123

Plate 4. General view of F_1 hybrids

5a. Field view of Navya

5b. Fruits of Navya

Plate 5. Navya (standard hybrid)

Length of main vine (cm)

Length of main vine ranged from 116.00 to 348.75 cm in parents and 202.00 to 460.25 cm in hybrids. Hybrid EC 709119 x CS-123 (102.98%) and EC 709119 x IC 538155 (96.95%) exhibited significant positive heterosis over mid parent with respect to this trait. But not a single cross expressed significant heterosis over better parent and standard parent. Range of heterosis over standard parent was -34.84 to 48.47 percent.

Branches per plant

With respect to branches per plant, F_1 means ranged from 4.5 - 9.5. All the hybrids except one exhibited highly significant positive relative heterosis. Six hybrids showed heterobeltiosis and eight hybrids showed standard heterosis in the positive direction. Maximum relative heterosis, heterobeltiosis and standard heterosis was observed for hybrids EC 709119 x IC 538155 (100.00%), EC 709119 x IC 538186 (37.5%) and EC 709119 x CS-123 (72.73%) respectively. The values were highly significant.

Days to first male flower anthesis

Days to first male flower, which is an indication of earliness ranged from 38.75 to 43.5. None of the hybrids showed significant negative heterosis over mid parent and standard parent. But there was significant negative heterosis over better parent. The highest significant heterosis over better parent in negative direction was exhibited by EC 709119 x IC 538186 (-27.73%) followed by EC 709119 x IC 538155 (-25.88%) and the values were highly significant.

Days to first female flower anthesis

Earliness, which is also indicated by days to first female flower anthesis ranged from 37.5 to 44.25. The highest negative relative heterosis was observed in hybrid, EC 709119 x IC 538186 (-22.05%) which is highly significant. However, none of the hybrids exhibited heterobeltiosis and standard heterosis in negative direction. The range of standard heterosis was 2.74 to 21.23.

Table 6. Mean values of parents and F_1 hybrids and percentage heterosis

Parents	Length of main vine (cm)	Crosses	Length of main vine (cm)			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	305.00	EC 709119 x CS-127	202.00	-4.04	-33.77	-34.84
IC 527427	285.00	EC 709119 x IC 527427	240.00	19.70	-15.79	-22.58
IC 410617	197.25	EC 709119 x IC 410617	281.75	79.89	42.84	-9.11
IC 410638	205.00	EC 709119 x IC 410638	280.00	74.45	36.59	-9.68
IC 538155	130.00	EC 709119 x IC 538155	242.25	96.95*	86.35	-21.85
IC 527431	348.75	EC 709119 x IC 527431	273.75	17.81	-21.51	-11.69
IC 538186	180.00	EC 709119 x IC 538186	226.00	52.70	25.56	-27.10
CS-128	276.25	EC 709119 x CS-128	253.75	29.38	-8.14	-18.15
CS-129	311.25	EC 709119 x CS-129	300.00	40.43	-3.61	-3.23
CS-25	280.00	EC 709119 x CS-25	247.00	24.75	-11.79	-20.32
CS-121	294.50	EC 709119 x CS-121	287.25	39.95	-2.46	-7.34
CS-123	337.50	EC 709119 x CS-123	460.25	102.98*	36.37	48.47
EC 709119	116.00					
Navya (Check)	251.27					
SE				46.39	53.57	53.57
CD (0.05)				95.56	110.35	110.35
CD (0.01)				129.43	149.45	149.45

*Significant at 5% level

**Significant at 1% level

Table 6. continued

Parents	Branches/plant	Crosses	Branches/plant			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	7.50	EC 709119 x CS-127	5.50	15.79**	-26.67**	0.00
IC 527427	4.75	EC 709119 x IC 527427	4.50	33.33**	-5.26**	-18.18**
IC 410617	4.50	EC 709119 x IC 410617	6.00	84.62**	33.33**	9.09**
IC 410638	4.50	EC 709119 x IC 410638	4.75	46.15**	5.56**	-13.64**
IC 538155	5.75	EC 709119 x IC 538155	7.75	100.00**	34.78**	40.91**
IC 527431	11.25	EC 709119 x IC 527431	6.50	-1.89	-42.22**	18.18**
IC 538186	4.00	EC 709119 x IC 538186	5.50	83.33**	37.50**	0.00
CS-128	8.75	EC 709119 x CS-128	6.75	25.58**	-22.86**	22.73**
CS-129	7.50	EC 709119 x CS-129	6.00	26.32**	-20.00**	9.09**
CS-25	6.75	EC 709119 x CS-25	7.25	65.71**	7.41**	31.82**
CS-121	7.25	EC 709119 x CS-121	6.25	35.14**	-13.79**	13.64**
CS-123	8.00	EC 709119 x CS-123	9.50	90.00**	18.75**	72.73**
EC 709119	2.00					
Navya (Check)	6.35					
SE				1.31	1.52	1.52
CD (0.05)				2.71	3.13	3.13
CD (0.01)				3.67	4.23	4.23

*Significant at 5% level
**Significant at 1% level

Table 6. continued

Parents	Days to first male flower anthesis	Crosses	Days to first male flower anthesis			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	41.00	EC 709119 x CS-127	39.50	92.68**	-3.66*	14.49**
IC 527427	53.00	EC 709119 x IC 527427	43.50	64.15**	-17.92**	26.09**
IC 410617	46.75	EC 709119 x IC 410617	38.75	65.78**	-17.11**	12.32**
IC 410638	40.75	EC 709119 x IC 410638	41.25	102.45**	1.23	19.57**
IC 538155	57.00	EC 709119 x IC 538155	42.25	48.25**	-25.88**	22.46**
IC 527431	51.75	EC 709119 x IC 527431	39.50	52.66**	-23.67**	14.49**
IC 538186	55.00	EC 709119 x IC 538186	39.75	44.55**	-27.73**	15.22**
CS-128	48.00	EC 709119 x CS-128	39.25	63.54**	-18.23**	13.77**
CS-129	44.25	EC 709119 x CS-129	39.50	78.53**	-10.73**	14.49**
CS-25	45.75	EC 709119 x CS-25	41.50	81.42**	-9.29**	20.29**
CS-121	43.75	EC 709119 x CS-121	41.25	88.57**	-5.71**	19.57**
CS-123	43.00	EC 709119 x CS-123	43.50	102.33**	1.16	26.09**
EC 709119	0					
Navya (Check)	43.85					
SE				1.42	1.64	1.64
CD (0.05)				2.92	3.38	3.38
CD (0.01)				3.96	4.57	4.57

*Significant at 5% level
**Significant at 1% level

Table 6. continued

Parents	Days to first female flower anthesis	Crosses	Days to first female flower anthesis			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	45.75	EC 709119 x CS-127	42.25	-0.59	7.64*	15.75**
IC 527427	58.50	EC 709119 x IC 527427	40.75	-16.62**	3.82	11.64**
IC 410617	47.25	EC 709119 x IC 410617	40.25	-6.94*	2.55	10.27**
IC 410638	44.00	EC 709119 x IC 410638	41.50	-0.30	5.73	13.70**
IC 538155	61.00	EC 709119 x IC 538155	41.75	-16.71**	6.37	14.38**
IC 527431	61.00	EC 709119 x IC 527431	44.25	-11.72**	12.74**	21.23**
IC 538186	58.25	EC 709119 x IC 538186	38.00	-22.05**	-3.18	4.11
CS-128	47.50	EC 709119 x CS-128	37.50	-13.54**	-4.46	2.74
CS-129	46.25	EC 709119 x CS-129	39.50	-7.60**	0.64	8.22*
CS-25	48.00	EC 709119 x CS-25	42.00	-3.72	7.01*	15.07**
CS-121	44.50	EC 709119 x CS-121	43.25	3.28	10.19**	18.49**
CS-123	49.00	EC 709119 x CS-123	43.50	-1.42	10.83**	19.18**
EC 709119	39.25					
Navya (Check)	50.01					
SE				2.83	3.26	3.26
CD (0.05)				5.82	6.72	6.72
CD (0.01)				7.88	9.10	9.10

*Significant at 5% level
**Significant at 1% level

Table 6. continued

Parents	Node at which first female flower emerged	Crosses	Node at which first female flower emerged			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	3.75	EC 709119 x CS-127	3.75	0.00	0.00	25.00**
IC 527427	4.00	EC 709119 x IC 527427	3.50	-9.68**	-12.50**	16.67**
IC 410617	5.75	EC 709119 x IC 410617	4.00	-15.79**	-30.43**	33.33**
IC 410638	4.25	EC 709119 x IC 410638	5.25	31.25**	23.53**	75.00**
IC 538155	4.00	EC 709119 x IC 538155	4.75	22.58**	18.75**	58.33**
IC 527431	4.75	EC 709119 x IC 527431	4.25	0.00	-10.53**	41.67**
IC 538186	4.00	EC 709119 x IC 538186	3.25	-16.13**	-18.75**	8.33**
CS-128	3.75	EC 709119 x CS-128	4.00	6.67**	6.67**	33.33**
CS-129	4.00	EC 709119 x CS-129	4.25	9.68**	6.25**	41.67**
CS-25	4.75	EC 709119 x CS-25	4.25	0.00	-10.53**	41.67**
CS-121	5.25	EC 709119 x CS-121	3.50	-22.22**	-33.33**	16.67**
CS-123	4.25	EC 709119 x CS-123	4.25	6.25**	0.00	41.67**
EC 709119	3.75					
Navya (Check)	4.33					
SE				0.77	0.89	0.89
CD (0.05)				1.59	1.83	1.83
CD (0.01)				2.15	2.48	2.48

*Significant at 5% level
**Significant at 1% level

Node at which first female flower emerged

The F_1 means ranged from 3.25 to 5.25 for node at which first female flower emerged. Highly significant heterosis over mid parent and better parent in the negative direction was observed for many hybrids. EC 709119 x CS-121 exhibited maximum relative heterosis (-22.22%) and heterobeltiosis (-33.3%) in the negative direction. Standard heterosis for all the hybrids was in the positive direction.

Days to first harvest

The mean values for days to first harvest ranged from 44.00 to 56.50. There was significant negative relative heterosis and heterobeltiosis for many hybrids. Highest relative heterosis and heterobeltiosis in the negative direction was exhibited by the cross EC 709119 x CS-128. (-22.98% and -21.43% respectively). However, all the hybrids recorded significant positive standard heterosis, indicating lateness of the crop.

Number of harvests

The number of harvests of F_1 hybrids ranged from 7.5 to 14. All the F_1 hybrids exhibited significant relative heterosis in positive direction. EC 709119 x IC 410617 exhibited maximum relative heterosis of 113.33%. All the hybrids except EC 709119 x CS-128 showed significant positive heterosis over better parent and maximum heterobeltiosis was observed for EC 709119 x IC 538186 (112.50%). EC 709119 x CS-123 exhibited maximum heterosis over standard parent (64.71%) followed by EC 709119 x CS-121 (44.12%).

Duration of the crop

The mean values for duration of the crop ranged from 114.5 to 121.75. Maximum relative heterosis was expressed by EC 709119 x CS-121(6.80%). None of the hybrids showed significant heterobeltiosis but all the F_1 hybrids exhibited superior standard heterosis. EC 709119 x CS-121 recorded the highest standard heterosis of 19.36 per cent.

Fruits per plant

The number of fruits per plant in the F_1 hybrids ranged from 18.75 to 63.75. All the hybrids exhibited heterosis in positive direction and EC 709119 x IC 538155 (347.62%) exhibited maximum relative heterosis. The maximum positive and significant heterobeltiosis (271.05%) was exhibited by the cross EC 709119 x IC 538155. All the hybrids expressed highly significant standard heterosis except the cross EC 709119 x IC 538186. Hybrid, EC 709119 x CS-123 recorded maximum standard heterosis of 244.59 per cent.

Yield per plant (kg)

The yield per plant of F_1 hybrids ranged from 4.26 to 17.96 kg. Mid parent heterosis was found highly significant for all the hybrids. Hybrid, EC 709119 x IC 538155 exhibited maximum relative heterosis of 560.73 per cent and maximum heterobeltiosis of 445.52 per cent. All the hybrids showed significant standard heterosis in the positive direction except EC 709119 x IC 538186. The hybrids EC 709119 x CS-123 and EC 709119 x IC 410638 exhibited highly significant standard heterosis of 309.93 per cent and 174.54 per cent respectively.

Average fruit weight (g)

The relative heterosis, heterobeltiosis and standard heterosis were not significant in any of the hybrids.

Fruit length (cm)

The F_1 means for fruit girth ranged from 15.1 to 20.1 cm. Relative heterosis and heterobeltiosis were significant for fruit length. Maximum relative heterosis of 13.24 per cent was recorded for EC 709119 x CS-128 followed by EC 709119 x IC 527427 (11.07 %). Heterobeltiosis was also maximum in EC 709119 x CS-128. Standard heterosis values for all the hybrids were negative.

Table 6. continued

Parents	Days to first harvest	Crosses	Days to first harvest			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	57.00	EC 709119 x CS-127	53.00	-6.19**	-5.36*	26.19**
IC 527427	63.75	EC 709119 x IC 527427	52.50	-12.32**	-6.25**	25.00**
IC 410617	59.00	EC 709119 x IC 410617	53.00	-7.83**	-5.36*	26.19**
IC 410638	53.00	EC 709119 x IC 410638	52.50	-3.67*	-0.94	25.00**
IC 538155	69.50	EC 709119 x IC 538155	56.50	-9.96**	0.89	34.52**
IC 527431	67.50	EC 709119 x IC 527431	53.00	-14.17**	-5.36*	26.19**
IC 538186	53.00	EC 709119 x IC 538186	56.50	3.67*	6.60**	34.52**
CS-128	58.25	EC 709119 x CS-128	44.00	-22.98**	-21.43**	4.76*
CS-129	58.50	EC 709119 x CS-129	53.00	-7.42**	-5.36*	26.19**
CS-25	56.50	EC 709119 x CS-25	53.00	-5.78**	-5.36*	26.19**
CS-121	58.25	EC 709119 x CS-121	56.50	-1.09	0.89	34.52**
CS-123	57.50	EC 709119 x CS-123	53.00	-6.61**	-5.36*	26.19**
EC 709119	56.00					
Navya (Check)	59.06					
SE				1.77	2.04	2.04
CD (0.05)				3.64	4.21	4.21
CD (0.01)				4.93	5.70	5.70

*Significant at 5% level
**Significant at 1% level

Table 6. continued

Parents	Number of harvests	Crosses	Number of harvests			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	5.25	EC 709119 x CS-127	9.00	94.59**	71.43**	5.88**
IC 527427	5.75	EC 709119 x IC 527427	7.50	53.85**	30.43**	-11.76**
IC 410617	7.25	EC 709119 x IC 410617	12.00	113.33**	65.52**	41.18**
IC 410638	7.50	EC 709119 x IC 410638	11.00	91.30**	46.67**	29.41**
IC 538155	6.00	EC 709119 x IC 538155	10.25	105.00**	70.83**	20.59**
IC 527431	8.00	EC 709119 x IC 527431	10.25	70.83**	28.13**	20.59**
IC 538186	4.00	EC 709119 x IC 538186	8.50	112.50**	112.50**	0.00
CS-128	9.50	EC 709119 x CS-128	8.75	29.63**	-7.89**	2.94**
CS-129	10.00	EC 709119 x CS-129	10.50	50.00**	5.00**	23.53**
CS-25	7.00	EC 709119 x CS-25	9.25	68.18**	32.14**	8.82**
CS-121	9.50	EC 709119 x CS-121	12.25	81.48**	28.95**	44.12**
CS-123	11.25	EC 709119 x CS-123	14.00	83.61**	24.44**	64.71**
EC 709119	4.00					
Navya (Check)	7.31					
SE				0.92	1.07	1.07
CD (0.05)				1.90	2.19	2.19
CD (0.01)				2.57	2.97	2.97

*Significant at 5% level
**Significant at 1% level

Table 6. continued

Parents	Duration of the crop	Crosses	Duration of the crop			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	118.00	EC 709119 x CS-127	114.50	1.55	-2.97	12.25**
IC 527427	112.00	EC 709119 x IC 527427	114.50	4.33	2.23	12.25**
IC 410617	111.75	EC 709119 x IC 410617	116.25	6.04*	4.03	13.97**
IC 410638	118.00	EC 709119 x IC 410638	116.25	3.10	-1.48	13.97**
IC 538155	112.00	EC 709119 x IC 538155	116.25	5.92*	3.79	13.97**
IC 527431	112.00	EC 709119 x IC 527431	114.50	4.33	2.23	12.25**
IC 538186	109.00	EC 709119 x IC 538186	114.50	5.77*	5.05	12.25**
CS-128	113.75	EC 709119 x CS-128	118.00	6.67**	3.74	15.69**
CS-129	113.75	EC 709119 x CS-129	118.00	6.67**	3.74	15.69**
CS-25	109.25	EC 709119 x CS-25	113.00	4.27	3.43	10.78**
CS-121	120.50	EC 709119 x CS-121	121.75	6.80**	1.04	19.36**
CS-123	123.75	EC 709119 x CS-123	120.50	4.22	-2.63	18.14**
EC 709119	107.50					
Navya (Check)	113.94					
SE				2.34	2.70	2.70
CD (0.05)				4.82	5.56	5.56
CD (0.01)				6.52	7.53	7.53

*Significant at 5% level

**Significant at 1% level

Table 6. continued

Parents	Fruits per plant	Crosses	Fruits per plant			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	15.00	EC 709119 x CS-127	23.00	116.47**	53.33**	24.32**
IC 527427	11.75	EC 709119 x IC 527427	25.00	177.78**	112.77**	35.14**
IC 410617	17.50	EC 709119 x IC 410617	43.75	268.42**	150.00**	136.49**
IC 410638	38.75	EC 709119 x IC 410638	38.50	71.11**	-0.65	108.11**
IC 538155	9.50	EC 709119 x IC 538155	35.25	347.62**	271.05**	90.54**
IC 527431	25.50	EC 709119 x IC 527431	38.25	140.94**	50.00**	106.76*
IC 538186	5.00	EC 709119 x IC 538186	18.75	233.33**	200.00**	1.35
CS-128	39.25	EC 709119 x CS-128	27.50	20.88*	-29.94**	48.65**
CS-129	32.00	EC 709119 x CS-129	27.50	43.79**	-14.06	48.65**
CS-25	20.25	EC 709119 x CS-25	32.75	147.17**	61.73**	77.03**
CS-121	23.00	EC 709119 x CS-121	35.00	139.32**	52.17**	89.19**
CS-123	43.75	EC 709119 x CS-123	63.75	155.00**	45.71**	244.59**
EC 709119	6.25					
Navya (Check)	22.16					
SE				9.25	10.69	10.69
CD (0.05)				19.06	22.01	22.01
CD (0.01)				25.81	29.81	29.81

*Significant at 5% level
**Significant at 1% level

Table 6. continued

Parents	Yield per plant (kg)	Crosses	Yield per plant (kg)			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	7.48	EC 709119 x CS-127	6.78	60.47**	-9.30**	54.79**
IC 527427	1.69	EC 709119 x IC 527427	6.83	412.20**	303.85**	55.82**
IC 410617	3.04	EC 709119 x IC 410617	11.45	470.82**	277.10**	161.30**
IC 410638	10.89	EC 709119 x IC 410638	12.03	102.61**	10.37**	174.54**
IC 538155	1.50	EC 709119 x IC 538155	8.16	560.73**	445.82**	86.30**
IC 527431	5.76	EC 709119 x IC 527431	9.25	174.54**	60.50**	111.07**
IC 538186	1.84	EC 709119 x IC 538186	4.26	202.66**	131.52**	-2.74
CS-128	10.48	EC 709119 x CS-128	7.94	38.54**	-24.28**	81.16**
CS-129	9.93	EC 709119 x CS-129	7.68	40.83**	-22.67**	75.23**
CS-25	5.11	EC 709119 x CS-25	8.27	172.04**	62.00**	88.81**
CS-121	6.81	EC 709119 x CS-121	9.05	132.50**	32.89**	106.62**
CS-123	11.10	EC 709119 x CS-123	17.96	197.39**	61.76**	309.93**
EC 709119	0.98					
Navya(Check)	5.90					
SE				2.27	2.62	2.62
CD (0.05)				4.68	5.40	5.40
CD (0.01)				6.33	7.31	7.31

*Significant at 5% level
**Significant at 1% level

Table 6. continued

Parents	Average fruit weight (g)	Crosses	Average fruit weight (g)			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	437.5	EC 709119 x CS-127	407.5	23.02	-6.86	35.83
IC 527427	162.5	EC 709119 x IC 527427	302.5	56.13	34.44	0.83
IC 410617	282.5	EC 709119 x IC 410617	325.0	28.08	15.04	8.33
IC 410638	320.0	EC 709119 x IC 410638	267.5	-1.83	-16.41	-10.83
IC 538155	200.0	EC 709119 x IC 538155	265.0	24.71	17.78	-11.67
IC 527431	245.0	EC 709119 x IC 527431	275.0	17.02	12.24	-8.33
IC 538186	275.0	EC 709119 x IC 538186	275.0	10.00	0.00	-8.33
CS-128	282.5	EC 709119 x CS-128	405.0	59.61	43.36	35.00
CS-129	282.5	EC 709119 x CS-129	297.5	17.24	5.31	-0.83
CS-25	307.5	EC 709119 x CS-25	242.5	-8.92	-21.14	-19.17
CS-121	235.0	EC 709119 x CS-121	275.0	19.57	17.02	-8.33
CS-123	277.5	EC 709119 x CS-123	277.0	10.25	-0.18	-7.67
EC 709119	225.0					
Navya (Check)	271.1					
SE				39.19	45.25	45.25
CD (0.05)				80.73	93.22	93.22
CD (0.01)				109.34	126.26	126.26

*Significant at 5% level
**Significant at 1% level

Table 6. continued

Parents	Fruit length (cm)	Crosses	Fruit length (cm)			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	23.35	EC 709119 x CS-127	20.10	2.81**	-13.92**	-7.59**
IC 527427	13.60	EC 709119 x IC 527427	16.30	11.07**	3.49**	-25.06**
IC 410617	18.05	EC 709119 x IC 410617	17.00	0.59	-5.82**	-21.84**
IC 410638	17.35	EC 709119 x IC 410638	15.30	-7.55**	-11.82**	-29.66**
IC 538155	14.25	EC 709119 x IC 538155	15.90	6.00**	0.95	-26.90**
IC 527431	17.55	EC 709119 x IC 527431	16.60	-0.30	-5.41**	-23.68**
IC 538186	21.55	EC 709119 x IC 538186	16.30	-12.60**	-24.36**	-25.06**
CS-128	15.60	EC 709119 x CS-128	17.75	13.24**	13.78**	-18.39**
CS-129	18.50	EC 709119 x CS-129	18.40	7.45**	-0.54	-15.40**
CS-25	20.05	EC 709119 x CS-25	15.10	-15.64**	-24.69**	-30.57**
CS-121	12.75	EC 709119 x CS-121	15.70	10.18**	-0.32	-27.82**
CS-123	16.90	EC 709119 x CS-123	16.30	-0.15	-3.55**	-25.06**
EC 709119	15.75					
Navya (Check)	17.33					
SE				0.96	1.11	1.11
CD (0.05)				1.98	2.28	2.28
CD (0.01)				2.68	3.09	3.09

*Significant at 5% level

**Significant at 1% level

Table 6. continued

Parents	Fruit girth (cm)	Crosses	Fruit girth (cm)			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	21.80	EC 709119 x CS-127	20.48	7.34**	-6.08**	50.00**
IC 527427	14.50	EC 709119 x IC 527427	18.90	22.53**	15.60**	38.46**
IC 410617	18.60	EC 709119 x IC 410617	18.80	7.58**	1.08*	37.73**
IC 410638	15.60	EC 709119 x IC 410638	17.70	10.80**	8.26**	29.67**
IC 538155	13.65	EC 709119 x IC 538155	18.05	20.33**	10.40**	32.23**
IC 527431	16.75	EC 709119 x IC 527431	17.75	7.25**	5.97**	30.04**
IC 538186	16.05	EC 709119 x IC 538186	16.70	3.09**	4.05**	22.34**
CS-128	17.05	EC 709119 x CS-128	20.38	22.01**	19.50**	49.27**
CS-129	18.25	EC 709119 x CS-129	19.00	9.83**	4.11**	39.19**
CS-25	17.45	EC 709119 x CS-25	16.40	-2.96**	-6.02**	20.15**
CS-121	16.50	EC 709119 x CS-121	18.35	11.72**	11.21**	34.43**
CS-123	16.95	EC 709119 x CS-123	17.35	4.20**	2.36**	27.11**
EC 709119	16.35					
Navya (Check)	16.88					
SE				0.93	1.07	1.07
CD (0.05)				1.92	2.21	2.21
CD (0.01)				2.59	2.99	2.99

*Significant at 5% level
**Significant at 1% level

Table 6. continued

Parents	Flesh thickness (cm)	Crosses	Flesh thickness (cm)			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	2.30	EC 709119 x CS-127	1.56	-25.71**	-32.17**	4.00**
IC 527427	1.20	EC 709119 x IC 527427	1.98	27.74**	4.21**	32.00**
IC 410617	1.35	EC 709119 x IC 410617	1.32	-18.77**	-30.53**	-12.00**
IC 410638	1.63	EC 709119 x IC 410638	2.00	13.48**	5.26**	33.33**
IC 538155	1.48	EC 709119 x IC 538155	2.10	24.26**	10.53**	40.00**
IC 527431	1.93	EC 709119 x IC 527431	1.65	-13.73**	-14.29**	10.00**
IC 538186	1.50	EC 709119 x IC 538186	1.32	-22.65**	-30.79**	-12.33**
CS-128	1.55	EC 709119 x CS-128	2.00	15.94**	5.26**	33.33**
CS-129	1.81	EC 709119 x CS-129	1.45	-21.83**	-23.68**	-3.33**
CS-25	1.88	EC 709119 x CS-25	1.95	3.17**	2.63**	30.00**
CS-121	1.70	EC 709119 x CS-121	2.10	16.67**	10.53**	40.00**
CS-123	1.81	EC 709119 x CS-123	1.75	-5.66**	-7.89**	16.67**
EC 709119	1.90					
Navya (Check)	1.69					
SE				0.09	0.10	0.10
CD (0.05)				0.18	0.21	0.21
CD (0.01)				0.24	0.28	0.28

*Significant at 5% level
**Significant at 1% level

Table 6. continued

Parents	Number of seeds per fruit	Crosses	Number of seeds per fruit			
	Mean		Mean	RH (%)	HB (%)	SH (%)
CS-127	184.90	EC 709119 x CS-127	222.25	37.40	20.20	-20.77
IC 527427	239.85	EC 709119 x IC 527427	159.40	-15.76	-33.54	-43.17
IC 410617	305.25	EC 709119 x IC 410617	238.40	7.42	-21.90	-15.01
IC 410638	305.40	EC 709119 x IC 410638	247.80	11.62	-18.86	-11.66
IC 538155	166.00	EC 709119 x IC 538155	320.05	110.14*	92.80*	14.10
IC 527431	362.05	EC 709119 x IC 527431	225.00	-10.12	-37.85	-19.79
IC 538186	210.55	EC 709119 x IC 538186	275.15	57.61	30.68	-1.91
CS-128	411.20	EC 709119 x CS-128	196.90	-28.37	-52.12	-29.80
CS-129	323.15	EC 709119 x CS-129	353.90	53.29	9.52	26.17
CS-25	290.00	EC 709119 x CS-25	302.70	41.25	4.38	7.91
CS-121	146.35	EC 709119 x CS-121	238.90	67.68*	63.24	-14.83
CS-123	187.25	EC 709119 x CS-123	353.75	117.12*	88.92*	26.11
EC 709119	138.60					
Navya (Check)	251.58					
SE				31.27	36.10	36.10
CD (0.05)				64.41	74.37	74.37
CD (0.01)				87.23	100.73	100.73

*Significant at 5% level
**Significant at 1% level

Fruit girth (cm)

Fruit girth of F_1 hybrids ranged from 16.7 to 20.48 cm. Relative heterosis was maximum and positive in the cross EC 709119 x IC 527427 (22.53%). Heterobeltiosis was significant and maximum in EC 709119 x CS-128 (19.50%). All the hybrids expressed significant and positive standard heterosis and maximum heterosis of 50.00 per cent was recorded for EC 709119 x CS-127 followed by EC 709119 x CS-128 (49.27%).

Flesh thickness (cm)

Flesh thickness ranged from 1.32 to 2.1cm in hybrids. Significant and maximum relative heterosis was recorded for EC 709119 x IC 527427 (27.74%). Maximum and significant heterobeltiosis was shown by EC 709119 x IC 538155 and EC 709119 x CS-121 (10.53%, 40.00%). The same hybrids exhibited maximum standard heterosis of 10.53 per cent and 40.00 per cent respectively.

Number of seeds per fruit

The number of seeds per fruit in the F_1 hybrids ranged from 159.40 to 353.95. Maximum relative heterosis was shown by EC 709119 x CS-123 (117.12%) followed by EC 709119 x IC 538155 (110.12%). Maximum and significant heterobeltiosis was observed for EC 709119 x IC 538155 (92.80%) followed by EC 709119 x CS-123 (88.92%). None of the hybrids showed significant standard heterosis.

4.4. Qualitative characters

Qualitative characters also have an important role in the selection of superior genotypes in a breeding programme. Important characters which exhibited variation among genotypes were density of prickles at harvestable maturity, colour of rind at harvestable maturity and presence of crispness (Table 8 and 9).

All the accessions/hybrids produced caducous prickles on fruit surface. Most of the genotypes were sparsely prickled (<5/cm^2). Among parents, IC 410617, IC 527431, CS-128, CS129, CS-25 and CS-121 were densely prickled. The hybrids, EC 709119 x IC 410617, EC 709119 x IC 527431, EC 709119 x CS-128, EC 709119 x CS129, EC 709119 x CS-25 and EC 709119 x CS-121 were densely prickled.

Fruits of majority of the genotypes had black prickles at tender harvestable stage. The parents CS-127 and EC 709119 produced white prickles at harvestable maturity stage which turned brown at maturity. Also the hybrid EC 709119 x CS-127 had white prickles which turned brown at maturity. In hybrids EC 709119 x IC 527431 and CS-128 prickles were borne on slight protuberances while in remaining accessions they were on smooth surfaces.

All the male parents were monoecious and produced male and female flowers on the same plant. The female parent, EC 709119 was gynoecious in nature and produced female flowers only. All the hybrids were predominantly gynoecious in nature which produced more number of female flowers at each node.

At tender maturity stage, fruits were green with slight dark green tinge at the pedicel end and short white stripes at the blossom end in IC 410617, IC 410638, IC 538186, CS-128, CS-129 and CS-123. The intensity of green tinge was more at pedicel end and fade towards lower side. IC 527431 produced dark green fruits with white patches and darker pedicellar end. Dark green fruits with white stripes at lower side were borne on IC 538155. In CS-127 and CS-25, fruits were light green with green tinge on pedicel end. Fruits of CS-121 were uniformly greenish white in colour. Fruits of the hybrids EC 709119 x 410617, EC 709119 x IC 410638, EC 709119 x IC 538186, EC 709119 x CS-128, EC 709119 x CS-25, EC 709119 x CS-129 and EC 709119 x CS-123 were green in colour with slight dark green tinge at the pedicel end and white stripes at the blossom end. In EC 709119 x IC 538186 the fruits had prominent long white stripes. EC 709119 x

IC 527431 and EC 709119 x IC 538155 had dark green fruits with darker pedicel end and slight white stripes at the lower side. The fruits were light green with dark green tinge at the pedicel end in EC 709119 x CS-127 and EC 709119 x CS-121.

After harvestable maturity stage, majority of the fruits turned orange in colour with white stripes turning yellow or orange initially. The colour change started from lower side and gradually progressed to the pedicel end. In CS-128 the fruits had prominent brown patches after maturity. IC 410617 and IC 538186 gradually turned brown in colour. Fruits of the parents, CS127, EC 709119, CS-25, CS-121and CS123 turned yellow colour during post maturity phase. Among hybrids, fruits of EC 709119 x CS-127, EC 709119 x CS-25 EC 709119 x CS-121 and EC 709119 x CS-123 were yellow after maturity. All other hybrids turned orange after maturity.

No significant variation was observed for stem pubescence. All the parents as well as hybrids had hairs on the stem. Seed cavity was present in all the parents as well as hybrids and showed little variation.

Wide variation was observed for bitterness in parents as well as hybrids (Table 10 and 11). Bitterness was not present in any of the parents or hybrids during initial harvests. After five to six harvests, bitterness was observed in some fruits of IC 538155, CS-128 and CS-25. Though the parents, IC 538155, CS 128 and CS 125 exhibited bitterness during mid harvests, the crosses involving these parents *viz*, EC 709119 x IC 538155, EC 709119 x CS 128 and EC 709119 x CS 125 were bitter free during mid harvests. However, the gynoecious parent, EC 709119 was bitter free during all the harvests. The hybrids, EC 709119 x CS-129, EC 709119 x CS-127 and EC 709119 x IC 538186 exhibited bitterness during mid harvests. However, parents of these hybrids were bitter free during mid harvests. During later harvests slight bitterness was observed in all the genotypes except EC 709119. But the bitterness was not consistent and was not observed in all harvested fruits of a single variety or hybrid. Also the bitterness was not evenly distributed in a bitter fruit. Bitterness was mostly concentrated near the rind portion of fruit and near to the pedicel end. The standard hybrid 'Navya' yielded some bitter fruits at later harvests.

Presence of crispness was also evaluated among the parents and hybrids. They were ranked according to the scores obtained by organoleptic evaluation based on 0-5 hedonic scale. Mean values and their ranks are depicted in table 12. The range of the scores of the parents with respect to crispness was 2 to 3.36.
The hybrid range was 2.25 to 4.75. EC 709119 x IC 538155 (4.75) was ranked as most crisp among all the parents and hybrids followed by EC 709119 x CS-128 (3.64). Parent with highest crispness was CS-128 (3.36). The hybrids were crisper than parents. Majority of the parents and hybrids were moderately crisp and none of them were soft or very soft.

Variation on incidence of pest and diseases were also observed (Table 13 and 14) among parents and hybrids. Important pests' occurred in the field were fruit fly, serpentine leaf miner, red pumpkin beetle and aphids. But none of the pests crossed economic threshold level.

CS-128 showed moderate susceptibility to serpentine leaf miner. All other parents had mild infestation of serpentine leaf miner which occurred during initial stage of the crop. Symptoms appeared as characteristic white serpentine markings on leaf lamina. All the hybrids showed mild susceptibility to leaf miner.

Mild infestation of red pumpkin beetle was there at initial stages of the crop. Parents IC 410617, CS-128, CS-129 and CS-123 had very low infestation. Mild infestation was noticed in all hybrids.

EC 709119 and CS-127 had mild infestation of aphids. No other genotypes were affected by aphids. EC 709119 x IC 527427 and EC 709119 x CS-25 were moderately susceptible to aphids. Severely affected leaves dried off later.

Fruit fly attack was mild on all hybrids and parents. Affected fruits were non marketable or rotten. Varietal variation was not observed on the incidence of the fruit fly.

Mild infections of leaf spot disease characterized by grayish spots on the leaf margin were observed at later stages. Leaves dried off completely at later stage of infection. IC 538186 showed moderate infection. Majority of the genotypes showed very low infection to leaf spot. CS-128 and CS-129 were not affected by the disease.

CS-129 was moderately affected by fungal wilt. Symptoms include drooping of leaves, drying of branches followed by slow wilting. Vascular discolouration was also observed. Moderate infection was noticed in EC 709119 x CS-25. EC 709119 x CS-129 and EC 709119 x CS-127 were mildly affected. The disease occurred at the later stage of the crop.

Phyllody, characterized by reduction in internodal length, luxuriant vegetative growth at each node and production of leafy flowers were observed in EC 709119 x CS-127 and EC 709119 x IC 410638 during final stage of the crop.

Table 7. Range of mean in parents and F_1 hybrids, heterosis and percentage superiority

Particulars	Length of main vine (cm)	Branches/plant	Days to first male flower anthesis
Parent range	116.00 - 348.75	2.00 - 11.25	40.75 - 57
Hybrid range	202.00 - 460.25	4.50 - 9.5	38.75 - 43.5
Best performing parent	IC 527431 (348.75)	IC 527431(11.25)	IC 410638 (40.75)
Best performing hybrid	EC 709119 x CS-123 (460.25)	EC 709119 x CS-123 (9.5)	EC 709119 x IC 410617 (38.75)
Number of heterotic hybrids over better parent	0	6	10
Number of heterotic hybrids over standard parent	0	8	0
Range of percentage superiority over better parent	-21.51 to 86.35	-42.22 to 37.50	-27.73 to 1.23
Range of percentage superiority over standard parent	-34.84 to 48.47	-18.18 to 72.73	12.32 to 26.09
Hybrids with highest percentage superiority over better parent	EC 709119 x IC 538155 (86.35)	EC 709119 x IC 538155 (37.50)	EC 709119 x IC 538186 (-27.73)
Hybrids with highest percentage superiority over standard parent	EC 709119 x CS-123 (48.45)	EC 709119 x CS-123 (72.73)	EC 709119 x IC 410617 (12.32)

Table 7. continued

Particulars	Days to first female flower anthesis	Node at which first female flower emerged	Days to first harvest
Parent range	39.25 - 61.00	3.75 -5.75	53 - 69.5
Hybrid range	37.5 - 44.25	3.25 - 5.25	44 -56.5
Best performing parent	EC 709119 (39.25)	CS-127, CS-128, EC 709119 (3.75)	IC 538186, IC 410638 (53.00)
Best performing hybrid	EC 709119 x CS-128 (37.50)	EC 709119 x IC 538186 (3.25)	EC 709119 x CS-128 (44.00)
Number of heterotic hybrids over better parent	0	6	8
Number of heterotic hybrids over standard parent	0	0	0
Range of percentage superiority over better parent	-4.46 to 12.74	-33.33 to 23.53	-21.43 to 6.6
Range of percentage superiority over standard parent	2.74 to 21.23	8.33 to 75.00	4.76 to 34.52
Hybrids with highest percentage superiority over better parent	EC 709119 x CS-128 (-4.46)	EC 709119 x CS-121 (-33.33)	EC 709119 x CS-128 (-21.43)
Hybrids with highest percentage superiority over standard parent	EC 709119 x CS128 (2.74)	EC 709119 x IC 538186 (8.33)	EC 709119 x CS-128 (4.76)

Table 7. Continued

Particulars	Number of harvests	Duration of the crop	Fruits per plant
Parent range	4.00 - 11.25	107.50 - 123.75	5.00 - 43.75
Hybrid range	7.50 - 14.00	114.5 - 121.75	18.75 - 63.75
Best performing parent	CS-123 (11.25)	CS-123 (123.75)	CS-123 (43.75)
Best performing hybrid	EC 709119 x CS-123 (14.00)	EC 709119 x CS-121 (121. 75)	EC 709119 x CS-123 (63.75)
Number of heterotic hybrids over better parent	11	0	9
Number of heterotic hybrids over standard parent	10	12	11
Range of percentage superiority over better parent	-7.89 to 112.5	-1.48 to 5.05	-29.94 to 271.05
Range of percentage superiority over standard parent	-11.76 to 64.71	10.78 to 19.36	1.35 to 244.59
Hybrids with highest percentage superiority over better parent	EC 709119 x IC 538186 (112.5)	EC 709119 x IC 538186 (5.05)	EC 709119 x IC 538155 (271.05)
Hybrids with highest percentage superiority over standard parent	EC 709119 x CS-123 (64.71)	EC 709119 x CS-121 (19.36)	EC 709119 x CS-123 (244.59)

Table 7. Continued

Particulars	Yield per plant (kg)	Average fruit weight (g)	Fruit length (cm)
Parent range	0.98 - 11.10	162.50 - 437.50	12.75 - 23.35
Hybrid range	4.26 - 17.96	242.50 - 407.50	15.10 - 20.10
Best performing parent	CS123 (11.1)	CS-127 (437.5)	CS-127 (23.35)
Best performing hybrid	EC 709119 x CS123 (17.96)	EC 709119 x CS-127 (407.50)	EC 709119 x CS-127 (20.10)
Number of heterotic hybrids over better parent	9	0	2
Number of heterotic hybrids over standard parent	11	0	0
Range of percentage superiority over better parent	-24.28 to 445.82	-21.14 to 43.36	-24.69 to 13.78
Range of percentage superiority over standard parent	-2.74 to 309.93	-19.17 to 35.83	-30.57 to -7.59
Hybrids with highest percentage superiority over better parent	EC 709119 x IC 538155 (445.82)	EC 709119 x IC 538155 (43.36)	EC 709119 x CS-128 (13.78)
Hybrids with highest percentage superiority over standard parent	EC 709119 x CS123 (309.93)	EC 709119 x CS123 (35.83)	EC 709119 x CS-127 (-7.59)

Table 7. Continued

Particulars	Fruit girth (cm)	Flesh thickness (cm)	Number of seeds per fruit
Parent range	13.65 - 21.80	1.2 - 2.3	138.60 - 411.20
Hybrid range	16.7 - 20.48	1.32 - 2.1	159.40 - 353.90
Best performing parent	CS-127 (21.80)	CS-127 (2.3)	CS-128 (411.20)
Best performing hybrid	EC 709119 x CS-127 (20.48)	EC 709119 x IC 538155 (2.1)	EC 709119 x CS-129 (353. 90)2
Number of heterotic hybrids over better parent	9	6	2
Number of heterotic hybrids over standard parent	12	9	0
Range of percentage superiority over better parent	-6.08 to 19.5	-32.17 to 10.53	-52.12 to 92.80
Range of percentage superiority over standard parent	-20.15 to 50	-12.33 to 40.00	-43.17 to 26.17
Hybrids with highest percentage superiority over better parent	EC 709119 x CS-128 (49.27)	EC 709119 x IC 538155, EC 709119 x CS-121 (10.53)	EC 709119 x IC 538155 (92.80)
Hybrids with highest percentage superiority over standard parent	EC 709119 x CS-127 (50.00)	EC 709119 x IC 538155, EC 709119 x CS-121 (40.00)	EC 709119 x CS-129 (26.17)

Table 8. Qualitative characters of parents

Parents	Density of prickles at harvestable maturity	Sex form	Colour of prickles at		Stem pubescence	Colour of rind at tender harvestable maturity	Colour of rind at mature stage	Presence / absence of cavity
			emergence	senescence				
CS-127	Sparse	Monoecious	White	Brown	Present	Light green	Yellow	Present
IC 527427	Sparse	Monoecious	Black	Black	Present	Green	Orange	Present
IC 410617	Dense	Monoecious	Black	Black	Present	Green	Orange	Present
IC 410638	Sparse	Monoecious	Black	Black	Present	Green	Orange	Present
IC 538155	Sparse	Monoecious	Black	Black	Present	Dark green	Orange	Present
IC 527431	Dense	Monoecious	Black	Black	Present	Dark green	Orange	Present
IC 538186	Sparse	Monoecious	Black	Black	Present	Green	Orange	Present
CS-128	Dense	Monoecious	Black	Black	Present	Green	Orange	Present
CS-129	Dense	Monoecious	Black	Black	Present	Green	Orange	Present
CS-25	Dense	Monoecious	Black	Black	Present	Light Green	Orange	Present
CS-121	Dense	Monoecious	Black	Black	Present	Greenish white	Yellow	Present
CS-123	Sparse	Monoecious	Black	Black	Present	Green	Yellow	Present
EC 709119	Sparse	Gynoecious	White	Brown	Present	Light Green	Yellow	Present

Table 9. Qualitative characters of hybrids

Hybrids	Density of prickles at harvestable maturity	Sex form	Colour of prickles on fruit at		Stem pubescence
			emergence	senescence	
EC 709119 x CS-127	Sparse	Monoecious	White	Brown	Present
EC 709119 x IC 527427	Sparse	Monoecious	Black	Black	Present
EC 709119 x IC 410617	Dense	Monoecious	Black	Black	Present
EC 709119 x IC 410638	Sparse	Monoecious	Black	Black	Present
EC 709119 x IC 538155	Sparse	Monoecious	Black	Black	Present
EC 709119 x IC 527431	Dense	Monoecious	Black	Black	Present
EC 709119 x IC 538186	Sparse	Monoecious	Black	Black	Present
EC 709119 x CS-128	Dense	Monoecious	Black	Black	Present
EC 709119 x CS-129	Dense	Monoecious	Black	Black	Present
EC 709119 x CS-25	Dense	Monoecious	Black	Black	Present
EC 709119 x CS-121	Dense	Monoecious	Black	Black	Present
EC 709119 x CS-123	Sparse	Monoecious	Black	Black	Present

Table 9. Continued

Hybrids	Colour of rind at tender harvestable maturity	Colour of rind at mature stage	Presence or absence of cavity
EC 709119 x CS-127	Light green	Yellow	Present
EC 709119 x IC 527427	Green	Orange	Present
EC 709119 x IC 410617	Green	Orange	Present
EC 709119 x IC 410638	Green	Orange	Present
EC 709119 x IC 538155	Dark green	Orange	Present
EC 709119 x IC 527431	Dark green	Orange	Present
EC 709119 x IC 538186	Green	Orange	Present
EC 709119 x CS-128	Green	Orange	Present
EC 709119 x CS-129	Green	Orange	Present
EC 709119 x CS-25	Green	Yellow	Present
EC 709119 x CS-121	Light green	Yellow	Present
EC 709119 x CS-123	Green	Yellow	Present

Table 10. Presence of bitterness in parents

Parents	During initial harvests (1st - 5th)	During mid harvests (5th - 8th)	During final harvests (8th - 12th)
CS-127	Absent	Absent	Present
IC 527427	Absent	Absent	Present
IC 410617	Absent	Absent	Present
IC 410638	Absent	Absent	Present
IC 538155	Absent	Present	Present
IC 527431	Absent	Absent	Present
IC 538186	Absent	Absent	Present
CS-128	Absent	Present	Present
CS-129	Absent	Absent	Present
CS-25	Absent	Present	Present
CS-121	Absent	Absent	Present
CS-123	Absent	Absent	Present

Table 11. Presence of bitterness in hybrids

Hybrids	During initial harvests (1^{st} - 5^{th})	During mid harvests (5^{th} - 8^{th})	During final harvests (8^{th} - 12^{th})
EC 709119 x CS-127	Absent	Present	Present
EC 709119 x IC 527427	Absent	Absent	Present
EC 709119 x IC 410617	Absent	Absent	Present
EC 709119 x IC 410638	Absent	Absent	Present
EC 709119 x IC 538155	Absent	Absent	Present
EC 709119 x IC 527431	Absent	Absent	Present
EC 709119 x IC 538186	Absent	Present	Present
EC 709119 x CS-128	Absent	Absent	Present
EC 709119 x CS-129	Absent	Present	Present
EC 709119 x CS-25	Absent	Absent	Present
EC 709119 x CS-121	Absent	Absent	Present
EC 709119 x CS-123	Absent	Absent	Present
Navya (Check)	Absent	Absent	Present

Table 12. Ranked means of crispness in parents and genotypes

Parents	Mean	Hybrids	Mean
CS-127	2.75^{fghij}	EC 709119 x CS-127	3.19^{bcdef}
IC 527427	3.10^{cdefg}	EC 709119 x IC 527427	2.25^{jk}
IC 410617	2.36^{ijk}	EC 709119 x IC 410617	2.26^{jk}
IC 410638	2.63^{ghij}	EC 709119 x IC 410638	3.56^{bc}
IC 538155	2.81^{efghi}	EC 709119 x IC 538155	4.75^{a}
IC 527431	2.48^{hijk}	EC 709119 x IC 527431	3.53^{bc}
IC 538186	2.71^{fghij}	EC 709119 x IC 538186	3.46^{bc}
CS-128	2.56^{hij}	EC 709119 x CS-128	3.64^{b}
CS-129	2.90^{defgh}	EC 709119 x CS-129	3.08^{cdefg}
CS-25	3.36^{bcd}	EC 709119 x CS-25	2.64^{ghij}
CS-121	2.40^{hijk}	EC 709119 x CS-121	3.29^{bcde}
CS-123	2.00^{k}	EC 709119 x CS-123	2.50^{hijk}
EC 709119	2.00^{k}	Navya (Check)	2.75^{ijk}

Table 13. Incidence of pest and diseases in parents

Parents	Serpentine leaf miner	Red pumpkin beetle	Fruit fly	Aphids	Leaf spot	Fungal wilt
CS-127	Mild	Mild	Mild	Very low	Very low	Nil
IC 527427	Mild	Mild	Mild	Nil	Very low	Nil
IC 410617	Mild	Very low	Mild	Nil	Very low	Nil
IC 410638	Mild	Mild	Mild	Nil	Mild	Nil
IC 538155	Mild	Mild	Mild	Nil	Very low	Nil
IC 527431	Mild	Mild	Mild	Nil	Very low	Nil
IC 538186	Nil	Mild	Mild	Nil	Moderate	Nil
CS-128	Moderate	Very low	Mild	Nil	Nil	Nil
CS-129	Nil	Very low	Mild	Nil	Nil	Moderate
CS-25	Mild	Mild	Mild	Nil	Very low	Nil
CS-121	Mild	Mild	Mild	Nil	Mild	Nil
CS-123	Mild	Very low	Mild	Nil	Very low	Nil
EC 709119	Mild	Mild	Mild	Mild	Very low	Mild

Table 14. Incidence of pest and diseases in hybrids

Hybrids	Serpentine leaf miner	Red pumpkin beetle	Fruit fly	Aphids	Leaf spot	Fungal wilt
EC 709119 x CS-127	Mild	Mild	Mild	Nil	Very low	Mild
EC 709119 x IC 527427	Mild	Mild	Mild	Moderate	Very low	Nil
EC 709119 x IC 410617	Mild	Mild	Mild	Nil	Very low	Nil
EC 709119 x IC 410638	Mild	Mild	Mild	Nil	Mild	Mild
EC 709119 x IC 538155	Mild	Mild	Mild	Nil	Very low	Nil
EC 709119 x IC 527431	Mild	Mild	Mild	Nil	Very low	Nil
EC 709119 x IC 538186	Mild	Mild	Mild	Nil	Very low	Nil
EC 709119 x CS-128	Mild	Mild	Mild	Nil	Very low	Nil
EC 709119 x CS-129	Mild	Mild	Mild	Nil	Very low	Nil
EC 709119 x CS-25	Mild	Mild	Mild	Moderate	Moderate	Moderate
EC 709119 x CS-121	Mild	Mild	Mild	Nil	Very low	Nil
EC 709119 x CS-123	Mild	Mild	Mild	Nil	Very low	Nil

DISCUSSION

5. DISCUSSION

In cucumber, there are a number of sex forms occurring as a result of differences in frequency and distribution of staminate, pistillate and hermaphrodite flowers. The main sex forms occurring in cucumber are monoecious, androecious, gynoecious, and hermaphrodite plants. Of the various sex forms, gynoecious and monoecious are important from hybrid seed production point of view.

Gynoecy, condition where all the flowering nodes produce only pistillate flowers, is important in heterosis breeding of cucumber. It is an important economic character for improving yield and economizing F_1 hybrid production. Dominance of gynoecy over monoecy made the exploitation of hybrid vigour advantageous in cucumber. Gynoecious sex form was spotted as a chance segregate from a Korean gynomonoecious introduction 'Shogoin' (PI 220860) (Peterson and Anhder, 1960) and from this source all the gynoecious lines, whether used for slicing or pickling cucumber, grown in the glasshouse or open were developed in USA, Western Europe, Japan etc. Temperate gynoecious hybrids showed thermo specificity for gynoecy at or above 30°C temperature (More and Munger, 1987). Not much work has been done in gynoecy of cucumber in India.

In the present study, a temperate gynoecious inbred, EC 709119, direct introduction from University of Wisconsin, USA was used as the female parent. The combining ability analysis helps to identify suitable monoecious parents which can be hybridized with gynoecious parent to exploit heterosis. The F_1 hybrids along with their parents were evaluated to obtain information on combining ability and heterosis. The major findings are discussed under the following headings.

5.1 Maintenance of gynoecious line

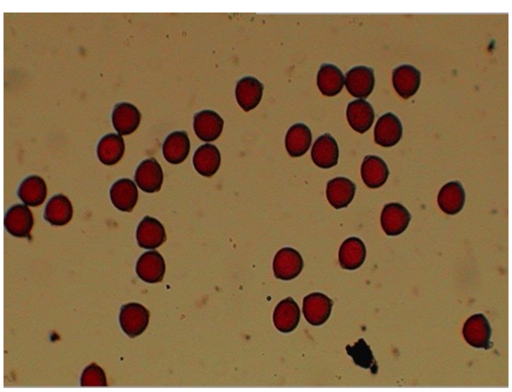
The underlying principle in the maintenance of gynoecy is the induction of staminate flowers phenotypically and resultant production of seeds in isolation. In this experiment, maleness was successfully induced in the gynoecious line (EC 709119) by spraying silver thiosulphate @ 200 ppm (Plate 6) as reported by earlier workers (Nijs and Visser,1979; Chaudhary *et al*., 2001). The flower production on sprayed plants was not uniform. Hermaphrodite flowers were produced initially followed by male flowers. The male flowers produced were uniform and normal as monoecious cultivars and pollen fertility was on par with them (Plate 7). Inspite of the temperate origin, the gynoecious character was stable throughout the life span.

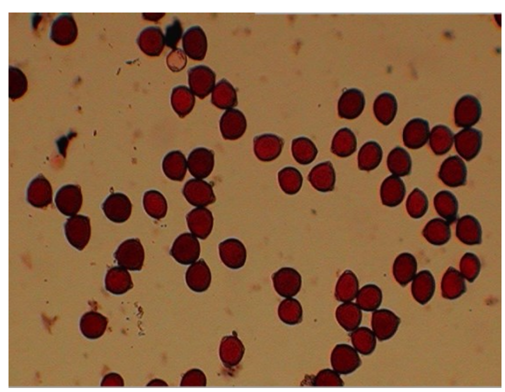
5.2. Combining ability

In a heterosis breeding programme, selection of parents is an important step for getting good results. In the present study, 12 parents were crossed with a temperate gynoecious inbred by topcross method to obtain 12 F_1 hybrids. Evaluation of combining ability for 15 characters recorded significant GCA effects for all the characters except days to first male flower anthesis. The estimates of GCA effects revealed that none of the parents exhibited good GCA for all the characters together because the combining ability effects were not consistent for the yield components viz. number of fruits per vine, number of harvests and average fruit weight, possibly because of negative association among the characters (Solanki and Seth, 1990; Mule *et al.*2012). This shows that genes for desirable characters would have to be combined from different sources (Nehe *et al.*2007). Among 12 parents, CS-123 was the good general combiner for fruit yield per vine. It also showed significant GCA effects for various characters like length of main vine, branches per plant, number of harvests, duration of the crop, fruits per plant and number of seeds per fruit.

The GCA effect for vine length was maximum in CS-123. The best general combiner with high positive GCA effect for the number of branches per plant was

Plate 6. Maleness induced in EC 709119 by spraying STS





7a. Pollen stainability of EC 709119

7b. Pollen stainability of control

Plate 7. Comparison of pollen fertility

CS-121 followed by CS-123. Genotypic difference with respect to GCA for number of branches were reported by Rawat (2002), Singh *et al*. (2011) and Mule *et al.* (2012) in monoecious lines of cucumber.

The genotype CS-128 had the maximum GCA effect for days to first female flower followed by IC 538186 indicating that these are the good combiners for earliness. None of the parents exhibited significant GCA effect for days to first male flower anthesis. The maximum negative GCA effects for node at which first female flower emerged were shown by IC 538186. For the character, days to harvest, which contributes to earliness was found highest for CS-128. Thus CS-128 and IC 538186 were general good combiners for earliness as reported by Rawat (2002) in monoecious lines of cucumber.

CS-123 exhibited maximum GCA effect for number of harvests. The GCA effect for duration of the crop was highest in CS-121 followed by CS-123. So CS-123 as well as CS-121 can be considered as general good combiners for extended duration of the crop. This genotype had the highest GCA effect for number of fruits per plant and yield per plant indicating its potential in improving the yield. Similar results were recorded in monoecious lines of cucumber by Ananthan and Pappiah (1997), Sarkar and Sirohi (2006), Hanchinamani and Patil (2009b), Singh *et al.* (2011), Kushawa *et al.* (2011) and Mule *et al.* (2012).

The genotype CS-127 showed maximum GCA effect for average fruit weight, fruit length and fruit girth suggesting it as the best combiner for these characters. High GCA effect for fruit length, weight and girth in monoecious lines of cucumber was reported by Rawat (2002), Khushawa *et al*. (2011) and Mule *et al*. (2012).

The GCA effect for flesh thickness was maximum in IC 538155 and CS-121. Similar reports were given by Rawat (2002) in monoecious cucumber lines. The highest GCA effect for number of seeds per fruit was shown by CS 129 and CS-123 indicating both the parents as general good combiners for the character. Significant

GCA effect for flesh thickness and number of seeds in monoecious lines of cucumber was reported by Brar *et al*. (2011).

5.3. Heterosis

The relative heterosis, heterobeltiosis and standard heterosis of 12 F_1 hybrids for 15 characters were estimated in the experiment. Significant heterosis was observed for all the characters studied except for average fruit weight.

A desirable degree of vegetative growth is essential for realizing high fruit yield. Regarding the vine length, only relative heterosis was exhibited in the different F_1s studied. EC 709119 x CS-123 (102.98%) was proved to be the best hybrid with respect to vine length. This is due to high GCA effect of the parent CS-123. Similar results were reported by Badgujar (1999) and Sharma (2010) in crosses involving gynoecious lines of cucumber. High heterosis for the character has been reported in crosses involving monoecious lines of cucumber by Gayathri (1997), Bairagi *et al*. (2005) Yadav *et al.* (2008) and Hanchinamani and Patil (2009a).

The character that contributes to vegetative growth such as branches per plant expressed significant relative heterosis, heterobeltiosis and standard heterosis among many hybrids. The three best hybrids for this character were EC 709119 x IC 538155, EC 709119 x IC 538186 and EC 709119 x CS-123. High standard heterosis for the cross EC 709119 x CS-123 can be attributed to the high GCA effect of the parent CS-123. Heterosis for branches per plant was reported by Sharma (2010) in gynoecious cultivars of cucumber. Wide range of heterosis for branches per plant is an established phenomena in monoecious cultivars as reported by Gayathri (1997), Bairagi *et al*. (2005), Yadav *et al.* (2008) and Mule *et al.* (2012).

Earliness, indicated by 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. The number of days to first male flower anthesis showed significant negative heterobeltiosis. EC 709119 x IC 538186 followed by EC 709119 x IC 538155 were the best crosses. All the F_1 hybrids were late in production of male flower when compared to standard parent indicating non significant standard heterosis. This can be attributed to the non significant GCA effect exhibited by the parents for the trait. However, Gayathri (1997) and Yadav *et al*. (2008) have reported significant negative heterosis for the character in monoecious cucumber cultivars.

Days to first female flower anthesis and nodal position of female flower is a good index of earliness. For days to first female flower anthesis, the highest negative relative heterosis was noticed in the cross, EC 709119 x IC 538186 (-22.05%). All the hybrids recorded standard heterosis in the positive direction which shows that none of the F_1 hybrids were earlier than standard variety. Maximum relative heterosis and heterobeltiosis for node at which first female flower emerged was recorded for the cross EC 709119 x CS-121 (-22.21% and -33.3% respectively). All hybrids showed standard heterosis in the positive direction which indicates the occurrence of first female flower at higher nodes in F_1 hybrids. In accordance with the present findings, Vijayakumari *et al*. (1993), Badgujar (1999), Dogra *et al*. (2007) and Sharma (2010) also observed heterosis for earliness in crosses involving gynoecious lines of cucumber. Wide range of heterosis was reported for earliness in monoecious cultivars by many workers (Gayathri, 1997, Bairagi *et al.*, 2005, Yadav *et al.*, 2008 and Hanchinamani and Patil, 2009a).

For days to first harvest, EC 709119 x CS-128 exhibited maximum and significant negative relative heterosis and heterobeltiosis. This may be due to negative GCA effect of the parent CS-128. But significant standard heterosis in the positive direction shows that none of the F_1 hybrids were earlier than standard parent. Significant standard heterosis for days to first harvest, in crosses involving gynoecious lines of cucumber were also observed by Dogra *et al*. (2007) and Sharma (2010).

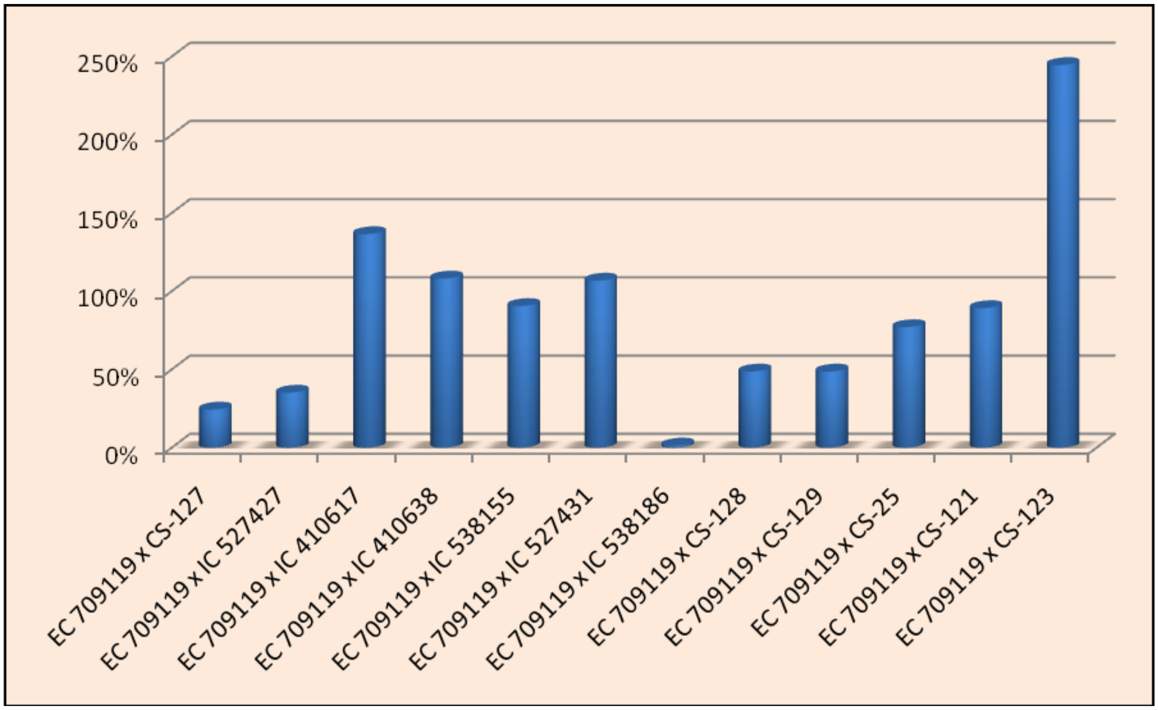


Figure 1. Standard heterosis of number of fruits per plant

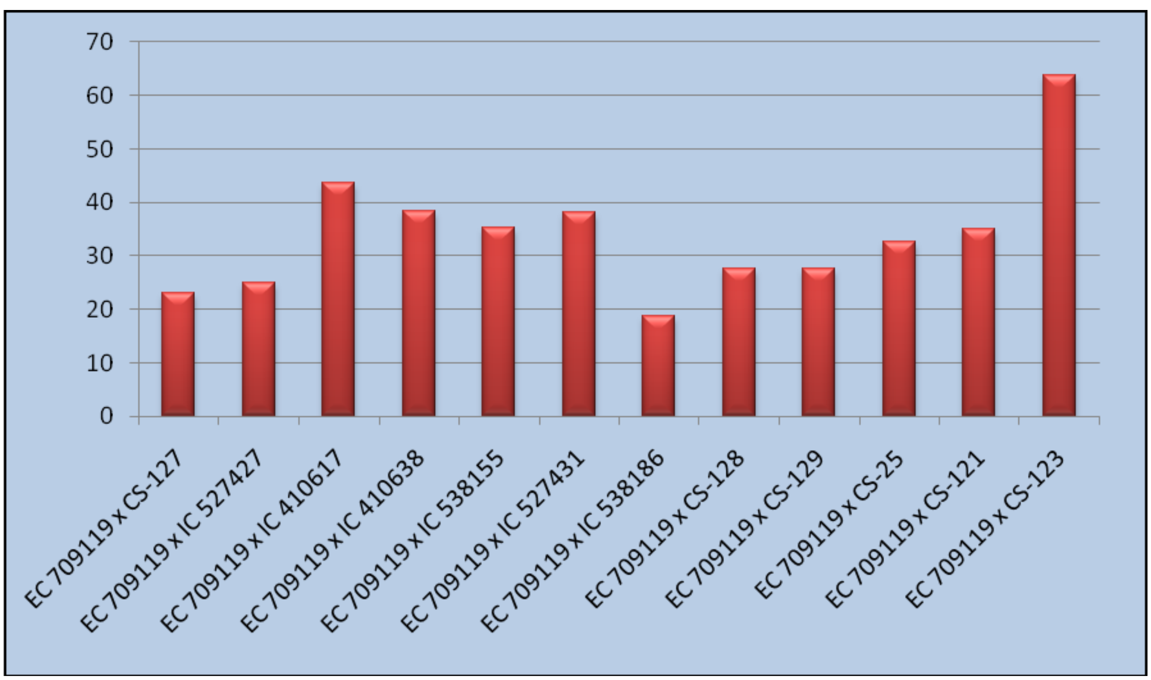


Figure 2. Mean values of number of fruits per plant among hybrids

Number of harvests exhibited significant relative heterosis for all the hybrids and maximum relative heterosis was noticed for EC 709119 x IC 410617 (113.33%). Maximum heterobeltiosis was observed for EC 709119 x IC 538186 (112.5%) and the maximum standard heterosis was recorded for EC 709119 x CS-123 (64.71%). The highest standard heterosis exhibited in EC 709119 x CS-123 may be due to high GCA effect of the parent CS-123. Superior standard heterosis was expressed by all the F_1 hybrids for duration of the crop. EC 709119 x CS-121 recorded the highest standard heterosis and relative heterosis. Sharma (2010) also reported significant heterosis for duration of the crop in gynoecious crosses of cucumber.

Number of fruits per plant is an important trait which contributes to yield, hence positive and significant heterosis effect would be highly desirable. The heterosis data pertaining to number of fruits per plant revealed that all the crosses manifested significant relative heterosis, all in desirable direction. The best heterotic hybrid was EC 709119 x IC 538155 (347.62%) followed by EC 709119 x IC 410617 (268.42%). It is noteworthy that these hybrids also registered significant superiority over better parent, with EC 709119 x IC 538155 (271.05%) recording highest significant heterobeltiosis. Eleven hybrids expressed superior standard heterosis and EC 709119 x CS-123 (244.59) was significantly high heterotic over the check cultivar. Heterosis ranged from -29.94 to 271.05 per cent over better parent and 1.35 to 244.59 over standard parent as shown in the figure 1 and 2. Vijayakumari *et al*. (1993), Badgujar (1999), Dogra *et al*. (2007) and Sharma (2010) also reported significant heterosis among crosses involving gynoecious cucumber combinations. Similar findings were also reported in monoecious cultivars of cucumber by many workers (Gayathri, 1997; Hanchinamani and Patil., 2009a; Kumar *et al*., 2010; Khushawa *et al*., 2011 and Singh *et al*., 2012).

Heterosis for yield is a culmination of contributing factors such as fruit number, number of harvests and average fruit weight. Considering overall performance with respect to fruit yield per vine, most promising hybrids were EC

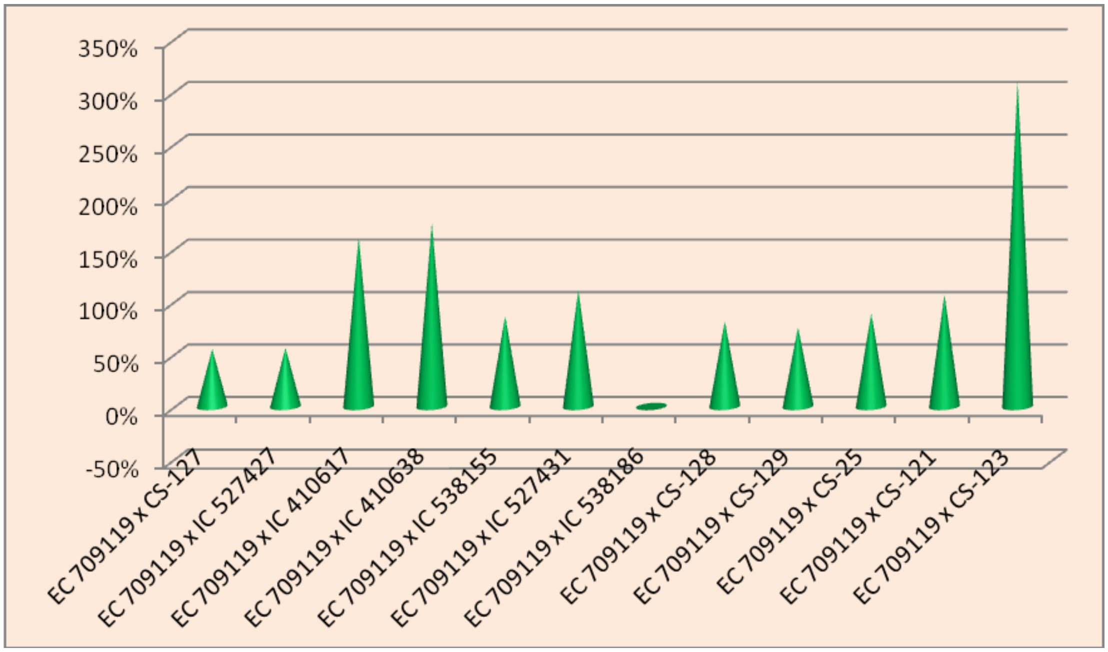


Figure 3. Standard heterosis of yield per plant

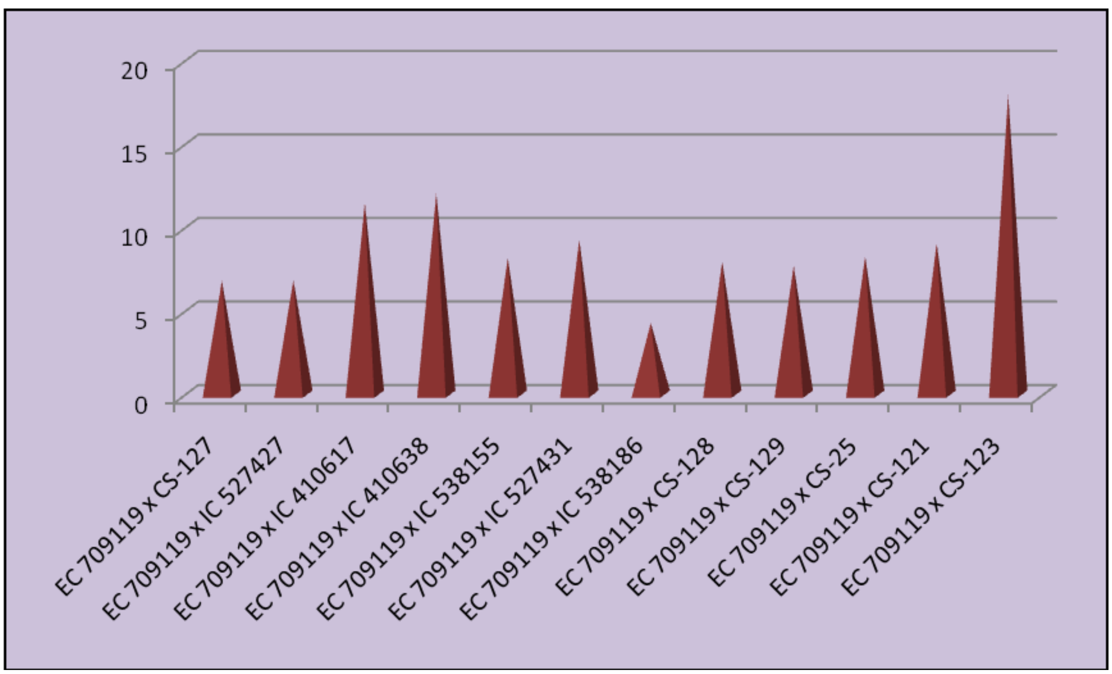


Figure 4. Mean values of yield per plant among hybrids

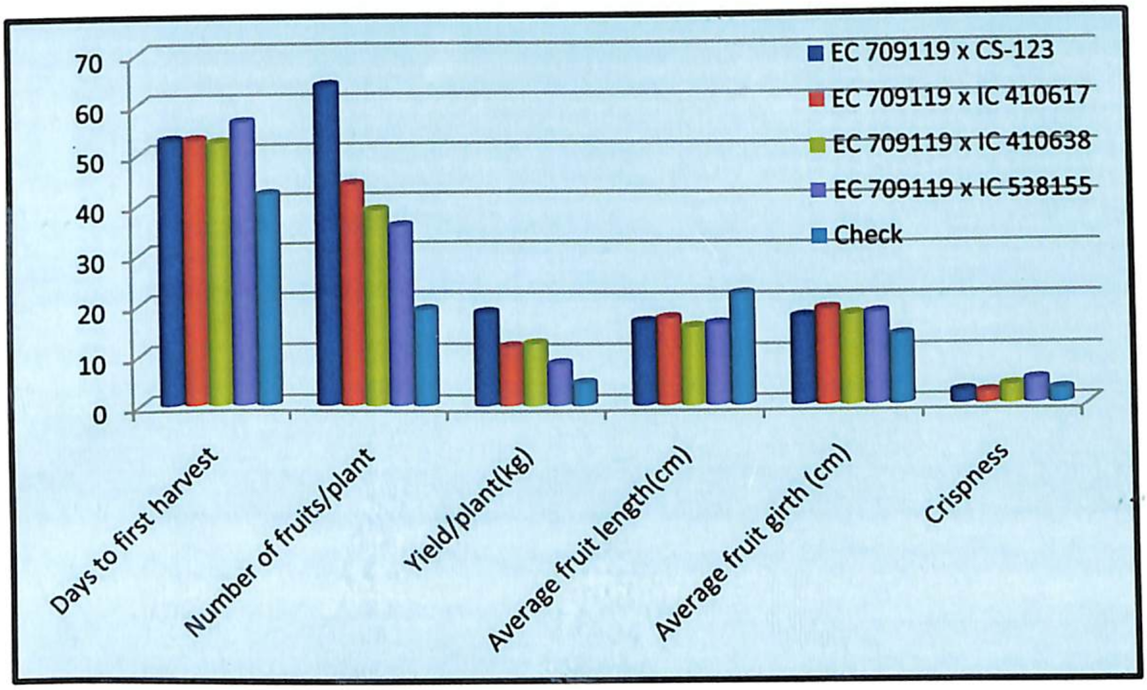


Figure 5. Mean values of best four hybrids and check for different characters

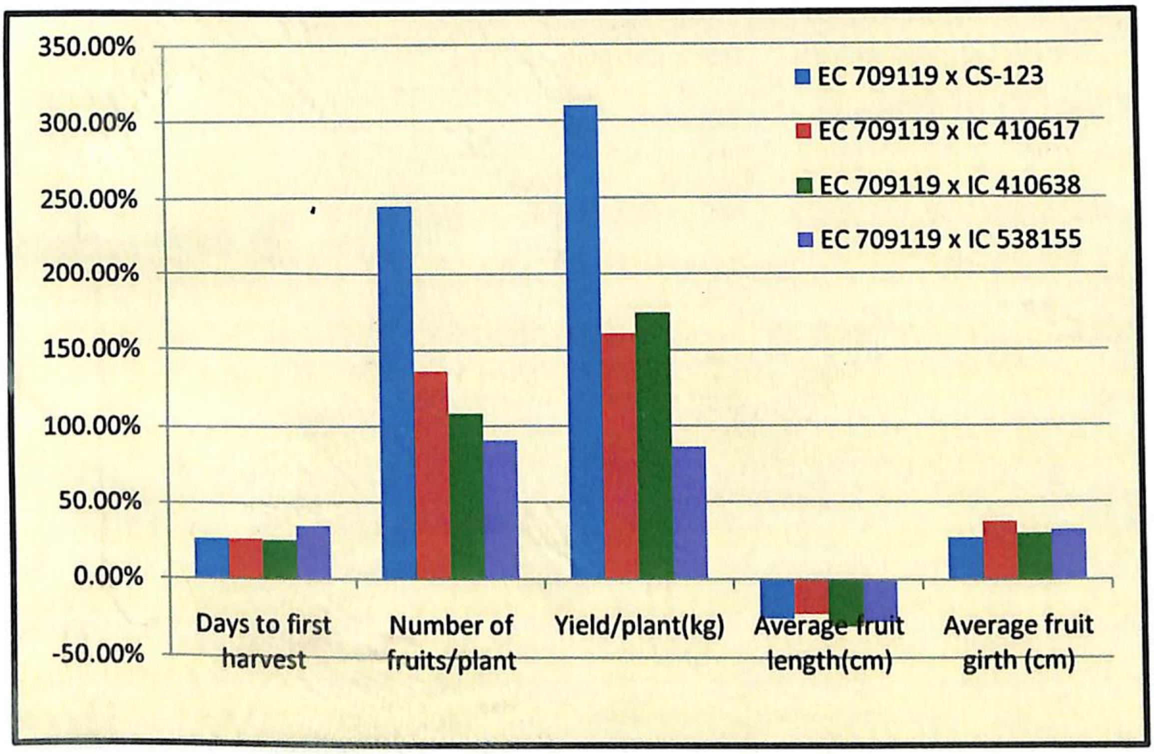


Figure 6. Standard heterosis of best four hybrids for different characters

709119 x CS-123 and EC 709119 x IC 538155. High standard heterosis was exhibited by EC 709119 x CS-123 (309.93%) and it may be due to the high GCA of the parent CS-123 for the trait. EC 709119 x IC 538155 expressed maximum relative heterosis (560.73%) and heterobeltiosis (445.52%) for yield per plant, though the parents had low GCA effects. For both the crosses, number of fruits per vine contributed to the heterotic effect in the yield per plant. Range of heterosis was -24.28 to 445.82 per cent (heterobeltiosis) and -2.74 to 309.93 per cent (standard heterosis) as depicted in the figure 3 and 4. These results were akin to the findings of Vijayakumari *et al*. (1993), Badgujar (1999), More (2002), Dogra *et al*. (2007) and Sharma (2010). Wide range of heterosis has been reported in monoecious cultivars of cucumber by Gayathri, (1997), Hanchinamani and Patil. (2009a) Kumar *et al.* (2010), Khushawa *et al*., (2011) and Singh *et al*. (2012).

Though significant GCA was observed for parents with respect to average fruit weight, none of the crosses exhibited significant heterosis for fruit weight which is contrasting. But reports of significant negative heterosis for fruit weight had been given by Solanki *et al*. (1982) and Singh *et al*. (2012). Fruit appearance manifested by its length and girth is an important aspect from the consumer point of view. With respect to fruit length, EC 709119 x CS-128 followed by EC 709119 x IC 527427 exhibited maximum relative heterosis and heterobeltiosis. But none of the hybrids expressed superior heterotic effect over standard parent. Regarding fruit girth, all the hybrids showed superior positive standard heterosis and highest heterotic effect was noticed in EC 709119 x CS-127. It is probably due to the highest GCA observed in parent, CS-123. Two other crosses EC 709119 x IC 527427 and EC 709119 x CS-128 showed superior relative heterosis and heterobeltiosis for fruit girth. These crosses also expressed superior heterosis for fruit length. Significant heterobeltiosis was reported for fruit length and girth in gynoecious crosses of cucumber by Dogra *et al.* (2007) and Sharma (2010). Similar results were obtained in monoecious crosses of cucumber by Gayathri, (1997), Hanchinamani and Patil (2009a) Kumar *et al.* (2010), Khushawa *et al*., (2011), Mule *et al*. (2011) and Singh *et al*. (2012).

Crosses exhibited significant positive relative heterosis, heterobeltiosis and standard heterosis for flesh thickness, which contributes to the girth of the fruit. Maximum relative heterosis was observed in EC 709119 x IC 527427. Highest significant and positive heterobeltiosis and standard heterosis was recorded for two crosses, EC 709119 x IC 538155 and EC 709119 x CS-121. Standard heterosis for flesh thickness was reported by Dogra *et al.* (2007) in crosses involving gynoecious liness of cucumber. The number of seeds per fruit is important in seed production. The crosses, EC 709119 x CS-123 and EC 709119 x IC 538155 were the best with respect to number of seeds per fruit. None of the hybrids were superior to check variety. Similar results were in observed by Gayathri (1997) in monoecious of cucumber.

From the above results, it is apparent that almost all the hybrids 1 significantly higher number of fruits per plant which contributed to increase in total yield. For vegetative characters like vine length and number of branches and for yield and yield contributing characters such as number of fruits and number of harvests, EC 709119 x CS-123 was proved to be the best cross. It also produced maximum number of seeds per fruit. The next best crosses with respect to number of fruits per plant and yield per plant were EC 709119 x IC 410638 and EC 709119 x IC 410617. Further, the cross EC 709119 x IC 538155 was superior for most of the characters including earliness, yield per plant and seeds per fruit. The superiority of these best crosses can be clearly understood from the figure 5 and 6.

5.4. Qualitative characters

Qualitative traits such as spine colour, colour of rind, crispness, bitterness etc are of great importance, because they are related to the fruit's commercial value directly and acceptance of F_1 hybrid.

All the accessions/hybrids produced caducous prickles on fruit surface. Fifty per cent of the parents had sparse spines on the fruit surface and the rest of them had dense spines. The gynoecious parent possessed sparse spines. The crosses with sparse spine x sparse spine resulted in production of fruits having sparse spines and combination of sparse spine x dense spine fruits yielded fruits with dense spines indicating dominance of dense spines. Regarding spine colour, all the monoecious parents except CS-127 and were black in colour. The gynoecious inbred, EC 709119 and CS-127 possessed white spines at harvestable maturity stage. Though the female parent, EC 709119 has white spines, all the hybrids wore black spines except EC 709119 x CS-127. This shows that black spine colour is dominant over white spine colour in cucumber as reported by Pyzhenkov (1986).

The primary differences among the cucumber types are the appearance of the fruit, such as the shape and color (Shetty and Wehner 1998). Among the parents, the colour of rind at harvestable maturity ranged from light green to dark green. The gynoecious parent was characterized by light green rind colour. When hybridized with light green gynoecious parent, the combination of light green x light green produced light green fruits as in EC 709119 x CS-127 and EC 709119 x CS-12. But the cross EC 709119 x CS-25 produced green fruits whose parents were light green in colour. The crosses involving light green fruits and green colour fruits yielded green colour fruits. Similarly light green x dark green crosses produced dark green fruits. After maturity fruits with light green colour rind changed to yellow colour. Fruits with green colour turned either yellow or orange in colour after maturity. All dark green colour fruits turned orange in colour after maturity.

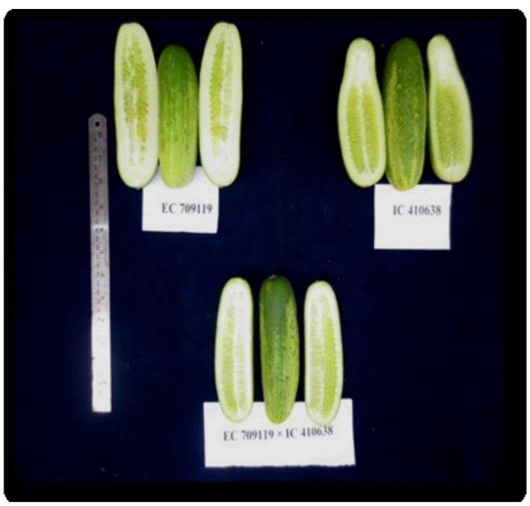
Bitterness in cucumber is a major constraint for fresh consumption. Bitterness in cucumber is mainly due to presence of cucurbitacin C (Balkema-Boomstra *et al*., 2003). The extent of bitterness in the fruits depends on genetic character of the cultivars as well as the growing conditions (Pitchaimuthu *et al.,* 2012). All the parents as well as hybrids were bitter free during initial harvests. After five to six harvests, bitterness was observed in some fruits of monoecious parents viz, IC 538155, CS-128 and CS-25. But the crosses involving these parents were not bitter during mid harvests. The gynoecious inbred, EC 709119 were bitter free throughout the harvests. It was significant that nine of the 12 hybrids derived from the cross between gynoecious inbred and monoecious parents were free from bitterness during initial harvests. This shows the potential of gynoecious inbred, EC 709119 as a source of breeding bitter free cucumber. During later harvests slight bitterness was experienced in all the genotypes except EC 709119. This may be attributed to increase in temperature towards the end of growing period. Klosin'ska *et al*. (2001) observed variation in bitterness among cucumber due to fluctuation in temperature during the growing season. But the bitterness was not consistent and was not observed in all harvested fruits of a single variety or hybrid. Also the bitterness was not evenly distributed in a bitter fruit. It was observed that bitterness was mostly concentrated near the rind portion of fruit and near to the pedicel end as observed by Huang (1964).

The crispness of parents and hybrids varied from very crisp to slightly crisp. None of them were soft. Hybrid, EC 709119 x IC 538155 (4.75) was ranked as most crisp among all the parents and hybrids followed by EC 709119 x CS-128 (3.64). Parent with highest crispness was CS-128 (3.36). Significant variation in crispness of cucumber cultivars was observed by Shimomura *et al.* (2012).

Incidence of pest and diseases occurred in the field during the growing period but none of them were serious. Important pests occurred were fruit fly,

8a. EC 709119 x CS 123

8b. EC 709119 x IC 410617



8c. EC 709119 x IC 410638

8d. EC 709119 x IC 538155

Plate 8. Four best crosses

serpentine leaf miner, red pumpkin beetle and aphids. Pest infestation was mild to moderate among the parents and hybrids. Mild to moderate disease infections of leaf spot and fungal wilt was observed among the parents and hybrids. CS-128 and CS-129 were found resistant to leaf spot disease.

The best four crosses (Plate 8) with respect to quantitative characters were EC 709119 x CS-123 (Plate 8a), EC 709119 x IC 410638 (Plate 8b), EC 709119 x IC 410617 (Plate 8c) and EC 709119 x IC 538155 (Plate 8d). The performance of these hybrids with respect to qualitative characters viz, free from bitterness and crispness was also good. Among the 12 crosses, the cross EC 709119 x IC 538155 was highly crisp. Rest of the three best crosses was moderately crisp. Four crosses bore bitter free fruits up to mid harvest stage. Fruits of all the three crosses except, EC 709119 x IC 538155 was green in colour at harvestable maturity stage. The cross, 709119 x IC 538155 bore dark green fruits which have great consumer preference now-a-days. The characters of the best four crosses are summarized in table 15. Hence, these hybrids can be advanced for testing under different agroclimatic conditions for commercial exploitation of hybrid vigour. The performance of these hybrids under protected structures like polyhouses and rain shelters need to be evaluated. The scope of incorporating parthenocarpy in F_1 hybrids should be explored. Further studies should be conducted for elucidating the physiology of bitterness in cucumber so that bitter free genotypes and suitable management practices for evading bitterness can be developed.

Table 15. Characters of best four hybrids and check

Characters	EC 709119 x CS 123		EC 709119 x IC 410617		EC 709119 x IC 410638		EC 709119 x IC 538155		Navya (Check)
	Mean	SH (%)	Mean	SH (%)	Mean	SH (%)	Mean	SH (%)	Mean
Days to first harvest	53.00	26.19	53.00	26.19	52.50	25.00	56.5	34.52	59.06
Number of fruits/plant	63.75	244.59	43.75	136.49	38.50	108.11	35.25	90.54	22.16
Yield/plant (kg)	17.96	309.93	11.45	161.30	12.03	174.54	8.16	86.30	5.90
Average fruit length (cm)	16.30	-25.06	17.00	-21.84	15.30	-29.96	15.9	-26.90	17.33
Average fruit girth (cm)	17.35	27.11	18.80	37.73	17.70	29.67	18.05	32.23	16.88
Crispness	2.50	-	2.26	-	3.56	-	4.75	-	2.75
Colour of rind at harvestable maturity	Green		Green		Green		Dark green		Green

SUMMARY

SUMMARY

Among the cucurbits, cucumber is distinct with a unique sex mechanism and this feature can easily be manipulated for production of F_1 hybrid seeds. Considerable heterosis has been manifested in cucumber for various traits such as number of fruits, early and high yield. Gynoecy, condition where all the flowering nodes produce only pistillate flowers, can be exploited for improving yield and economizing F_1 hybrid production.

In India, only few works utilizing gynoecious lines in heterosis breeding programme of cucumber have been reported. Hence, the present study is undertaken to study the combining ability of gynoecious line with selected monoecious lines in cucumber and to investigate the scope of heterosis breeding exploiting gynoecious line.

The experiment was carried out at Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during February-May 2012 and November 2012 to March 2013. Experimental material consisted of 12 monoecious cucumber (*Cucumis sativus* L.) genotypes, collected from different parts of the country and a gynoecious inbred (EC 709119) introduced from USA. During first season 12 monoecious cucumber genotypes were crossed in a top cross fashion with gynoecious inbred (EC 709119) as female parent.

In the second season, 12 hybrids along with their parents were evaluated in a randomized block design (RBD) with three replications to obtain information on combining ability and heterosis. The data were subjected to combining ability analysis according to top cross method. Heterosis was calculated as the deviation of the mean performance of F_1s ($\overline{F}_1$) from their mid parent (MP), better parent (BP) and the standard parent (SP) for each cross combination expressed as the percentage of the mean respectively. A commercial hybrid of cucumber, Navya (Jaison seeds, Bangalore) was taken as standard check to estimate standard heterosis.

In this experiment, maleness was successfully induced in the gynoecious line (EC 709119) by spraying silver thiosulphate @ 200 ppm. The male flowers produced were uniform and normal as monoecious cultivars and pollen fertility was on par with them. Inspite of the temperate origin of EC 709119, the gynoecious character was stable throughout the life span.

Evaluation of combining ability for 15 characters recorded significant GCA effects for all the characters except days to first male flower anthesis. The estimates of GCA effects revealed that none of the parents exhibited good GCA for all the characters together. Among 12 parents, CS-123 was the good general combiner for fruit yield per vine, length of main vine, branches per plant, number of harvests, duration of the crop, fruits per plant and number of seeds per fruit.

Significant heterosis was observed among the 12 F_1 hybrids for all the 15 characters studied except for average fruit weight. All the hybrids produced significantly higher number of fruits per plant which contributed to increase in total yield. For vegetative characters like vine length and number of branches and for yield and yield contributing characters such as number of fruits and number of harvests, EC 709119 x CS-123 was proved to be the best cross. It also produced maximum number of seeds per fruit. The next best crosses with respect to number of fruits per plant and yield per plant were EC 709119 x IC 410638 and EC 709119 x IC 410617. Further, the cross EC 709119 x IC 538155 was superior for most of the characters including earliness, yield per plant and seeds per fruit. The performance of these hybrids regarding qualitative characters was also good. Among the 12 crosses,the cross EC 709119 x IC 538155 was highly crisp. Rest of the three best crosses was moderately crisp. Bitterness, a limiting factor in commercial production of cucumber was also estimated. Bitterness was not observed in any of the parents or hybrids during initial harvests. After five to six harvests, bitterness was observed in some fruits of EC 709119 x CS-129, EC 709119 x CS-127 and EC 709119 x IC 538186. Also the parents, IC 538155, CS-128 and CS-25 showed bitterness in some of the fruits. During later harvests some degree of bitterness was experienced in all the genotypes. But the bitterness was not consistent and was not observed in all harvested fruits of a single variety or hybrid.

Four crosses *viz.* EC 709119 x CS-123, EC 709119 x IC 410638, EC 709119 x IC 410617 and EC 709119 x IC 538155 were proved to be the best with respect to quantitative characters and qualitative characters including crispness and free from bittreness. Hence, these hybrids can be advanced for testing under different agroclimatic conditions for commercial exploitation of hybrid vigour. The performance of these hybrids under protected structures like polyhouses and rain shelters need to be evaluated. The scope of incorporating parthenocarpy in F_1 hybrids should be explored. Further studies should be conducted for elucidating the physiology of bitterness in cucumber so that bitter free genotypes and suitable management practices for avoiding bitterness can be developed.

REFERENCE

REFERENCE

Abraham, S. 2006. Divergence studies in salad cucumber (*Cucumis sativus* L.). M.Sc Hort. Thesis, Kerala Agricultural University, Thrissur, 86p.

Ananthan, M. and Pappiah, C. M. 1997. Combining ability and correlation studies in cucumber (*Cucumis sativus* L.). *S. Indian Hort*., 45: 57-58.

Badgujar, C. D. 1999. Exploitation of gynoecy in cucumber (*Cucumis sativus* L.). PhD Ag. Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, 190p.

Badgujar, C. D. and More, T. A. 2004. Off season performance of selected tropical gynoecious cucumber hybrids grown under different regimes. *S. Indian Hort.* 52: 97-103.

Bairagi, S. K., Singh, D. K., Ram, H. H. 2001. Diallel analysis of combining ability in cucumber (*Cucumis sativus* L.). *Prog. Hort*. 33: 178-183.

Bairagi, S. K., Ram, H. H., Singh, D. K. and Maurya, S. K. 2005. Exploitation of hybrid vigour for yield and attributing traits in cucumber. *Indian J. Hort*. 62: 41-45.

Balkema-Boomstra, A. G., Zijlstra, S., Verstappen, F. W. A., Inggamer, H. and Mercke, P. 2003. Role of cucurbitacin C in resistance to spider mite (*Tetranychus urticae*) in cucumber (*Cucumber sativus* L.). *J. Chem. Ecol.* 29: 225-235.

Barnes, W. C. 1966. Development of disease resistant hybrid cucumbers. *Proc. Amer. Soc. Hort. Sci*. 89:390-393.

Batakurki, I., Mulge, R., Aradiguddi, M. K., and Ghasti, V. D. 2011. Heterosis and combining ability studies for growth and quality parameters in cucumber (*Cucumis sativus* L.). *Green Farming* 2: 521-523.

Beyer, E.M. Jr. 1976. Silver ion : A potent antiethylene agent in cucumber and tomato. *Hort. Sci*. 11: 195-196.

Brar, P. S., Singh, G., Singh, M. and Batth, G. S. 2011. Combining ability for yield and its attributing traits in cucumber. *Crop Improv*. 38: 189-190.

Briggle, L. M. 1963. Heterosis in wheat- a review. *Crop Sci*. 3: 407-412.

Cramer, C. S. and Wehner, T. C. 1999. Little heterosis for yield and yield components in hybrids of six cucumber inbreds. *Euphytica* 110: 99-108.

Chaudhary, B. N., Piluek, K., Taychasinpitak, T. and Sagwansupyakorn, C. 2001. Development and maintenance of gynoecious lines of cucumber (*Cucumis sativus* L.). *Kasetsart J. Nat. Sci.* 35: 242-250.

Das, S., Maurya, K. R. and Choudhary, D. N. 2003. Performance of cucumber genotypes during summer and rainy seasons. *J. Appl. Biol*. 13: 51-53.

De Candolle, A. 1886. *Origin of Cultivated Plants*. New York, USA. 268 p.

Dhillon, N. P. S. and Ishiki, K. 1998. Yield stability of gynoecious F_1 hybrids of cucumber in subtropical field conditions. *Adv. Hort. Sci*. 12: 183-185.

Din, G. U and Ahamed, N. 2002. Studies on combining ability in cucumber (*Cucumis sativus* L.). *J. App. Biol. Res*. 4: 31-38

Diola, V., Orth, A. I. and Guerra, M. P. 2008. Reproductive biology in monoecious and gynoecious cucumber cultivars as a result of IBA application. *Horticultura Brasileira*. 26: 30-34.

Dogra, B. S., Rostogi, K. B. and Kumar, A. 1997. Exploitation of hybrid vigour in cucumber (*Cucumis sativus* L.). *Indian J. Hort*. 54: 261-64.

Dogra, B. S., Kanwar, M. S. and Bhardwaj, R. K. 2007. Heterosis for yield and horticultural traits in cucumber (*Cucumis sativus* L.). *Haryana J. Hort. S*ci. 36: 92-94.

Gayathri, K. 1997. Genetic variability and heterosis in cucumber (*Cucumis sativus* L.). M.Sc Hort. Thesis, Kerala Agricultural University, Thrissur, 94p.

Hallidri, M. 2004. Effect of silver nitrate on induction of staminate flowers in gynoecious cucumber line (*Cucumis sativus* L.). *Acta Hort*. 637: 149-154.

Hanchinamani, E. N. and Patil, M. G. 2009a. Heterosis in cucumber (*Cucumis sativus* L.). *Asian J. Hort*. 4: 21-24.

Hanchinamani, E. N. and Patil, M. G. 2009b. Combining ability through line x tester analysis in cucumber (*Cucumis sativus* L.). *Asian J. Hort*. 4: 70-73

Hayes, H. K. and Jones, D. F. 1916. First generation crosses in cucumber. *Conn. Agric. Exp. Stn. Ann. Rept. pp. 319-22.*

Hayes, H. K., Immer, I. R. and Smith, D. C. 1955. *Methods of Plant Breeding* (2nd Ed.). Mc Graw Hill Company Inc., New York. 535p.

Hormuzdi, S. J. and More, T. A. 1989. Heterosis studies in cucumber. (*Cucumis sativus* L.) *Indian J. Hort*. 46: 73-79.

Huang, H. 1964. Studies on bitterness in cucumbers. *Tai-wan Ta-hsueh Nung-hsuehyuan Yen-chiu Pao-kao/Mem. Coll. Agric.* 8: 120-32.

Hutchins, A. E. 1939. Some example of heterosis in cucumber (*Cucumis sativus* L). *Proc. Amer. Soc. Hort. Sci*. 36: 660-664.

IIHR [Indian Institute of Horticultural Research]. 2012. IIHR home page [online]. Available: http://www.iihr.ernet.in. [01 Nov. 2012].

Kalloo, G. and Franken, S. 1978. Chemical induction of staminate flowers in four determinate gynoecious lines of pickling cucumber. *Gartenbauwssenschaft* 43: 280-282.

Kanwar, M. S., Korla, B. N. and Kumar, S. 2003. Evaluation of cucumber genotypes for yield and qualitative traits. *Himachal J. Agric. Res*. 29: 43-47.

KAU [Kerala Agricultural University]. 2011. Package of Practices Recommendations: Crops (14th Ed.). Kerala Agricultural University, Thrissur, 360p.

Kłosin´ska, U., Kozik, E. U., Łakowska-Ryk, E. and Doruchowski, R. W. 2001. Evaluation of bitterness trait of selected pickling cucumber genotypes (*Cucumis sativus* L.). *Veg. Crops Res. Bulletin.* 55: 5-9.

Kumar, J., Munshi, A. D., Kumar, R. and Sureja, A. K. 2010. Studies on heterosis in slicing cucumber. *Indian J. Hort*. 67: 197-201.

Kumbhar, H. C., Dumbre, A. D. and Patil, H. E. 2005. Heterosis and combining ability studies in cucumber (*Cucumis sativus* L.). *J. Maharashtra Agric. Univ*. 30: 272-75.

Kushwaha, M. L., Yadav, L. B. and Maurya R. P. 2011. Heterobeltiosis and Combining ability in cucumber (*Cucumis sativus* L.) under mid hilly area of Uttrakhand. *Prog. Agric*. 11: 103-107.

Lopez-Sese, A. I. and Staub, J. 2002. Combining ability analysis of yield components in cucumber. *J. Am. Soc. Hort. Sci.* 127: 931- 937.

More, T. A., and Munger, H. M. 1986. Gynoecious sex expression and stability in cucumber (*Cucumis sativus* L.). *Euphytica* 35: 899-903.

More, T. A and Munger, H. M. 1987. Effect of temperature and photoperiod on gynoecious sex expression in cucumber. *Veg. Sci*. 14: 42-50.

More, T. A. and Seshadri, V. S. 1988. Development of tropical gynoecious lines in cucumber. *Cucurbit Genet. Coop. Rep*. 11: 17-18.

More, T. A. 2002. Development and exploitation of tropical gynoecious lines in F_1 hybrid of cucumber. *Acta Hort*. 588: 261-267.

Mule, P. N., Khandelwal, V., Lodam, V. A., Shinde, D. A., Patil, P. P. and Patil, A. B. 2012. Heterosis and combining ability in cucumber (*Cucumis sativus* L.). 99: 420-423.

Munshi, A. D., Kumar, R. and Panda, B. 2005. Heterosis for yield and its components in cucumber (*Cucumis sativus* L.). *Veg. Sci*. 32: 133-35.

Munshi, A. D., Panda., B., Behera, T. K., Kumar, R. and Bist, I. S. 2007. Genetic variability in *Cucumis sativus* var. *hardwickii* R. (Alef.) germplasm. *Cucurbit Genet. Coop. Rept.* 30: 5-10.

NBPGR [National Bureau of Plant Genetic Resources]. 2002. *Minimal Descriptor of Agri-horticultural Crops*. Pusa campus, New Delhi, 800p.

Nehe, A. S., Banger, N. D. and Chavan, B. H. 2007. Combining Ability study in cucumber (*Cucumis sativus* L.). *J. Maharashtra Agric. Univ*. 32: 340-342.

Nijs den A. P. M. and Visser, D. L. 1979. Induction of male flowering in gynoecious cucumber (*Cucumis sativus* L.) by silver ion. *Euphytica*. 29: 273-280.

Nowaczyk, L. and Nowaczyk, P. 2004. Cucumber fruit size and seed yield affected by growth regulators. In: *Progress in cucurbit genetics and breeding research. Proceedings of Cucurbitaceae 2004, the 8th EUCARPIA Meeting on Cucurbit Genetics and Breeding;* 12-17 July, 2004, Olomouc, Czech Republic, pp. 45-49.

Peterson, C. E. and Anhder, L. D. 1960. Inducation of staminate flowers on gynoecious cucumber with gibberellin GA3. *Science*. 131: 1673-1674.

Pitchaimuthu, M., Dutta, O. P., Swamy, K. R. M. and Souravi, K. 2012. Mode of inheritance of bitterness and spine colour in cucumber fruits (*Cucumis sativus* L.). Sari, Solmaz and Aras (eds) In: *Proceedings of the Xth EUCARPIA meeting on genetics and breeding of Cucurbitaceae* , 15-18th October 2012, Antalya (Turkey), pp. 70-74.

Prasad, V. S. R. K. and Singh, D. P. 1991. Genotype performance and their interactions with the environment in cucumber (*Cucumis sativus* L*.). Indian J. Hort.* 48: 346-350.

Prochazkova, A. and Tronikova, E. 1981. Comparison of the effects of GA3 and AgNO3 applications to gynoecious lines of pickling cucumbers. 1. The effect on the induction of male flowering in various gynoecious lines. *Zahradnictvi*. 8: 105-116.

Pyzhenkov, V. I. 1986. Inheritance of spine colour and type of fruit surface in cucumber. *Sbornik Nauchnykh Trudov po Prikladnoĭ Botanike, Genetike i Selektsii.* 101: 33-38.

Rawat, T. S. 2002. Studies on heterosis and combining ability in cucumber (*Cucumis sativus* Roxb.). Ph. D. Thesis. Rajasthan College of Agriculture, Udaipur. 125p.

Reddy, B. S., Thammaiaha, N., Patil, R. V., Nandihalli, B. S. and Patil, D. R. 1997. Evaluation of cucumber genotype and resistance to downy mildew disease. *Adv. Agric. Res. India*. 7: 175-177.

Robinson, R. W. and Whitaker, J. W., 1974, Cucumis. In: King R. C. (ed.), *Handbook of Genetics*, Plemum Press, New York, pp.145-150.

Robinson, R.W. 1999. Rationale and methods for producing hybrid cucurbit seed. *J. New Seeds*. 1: 1-47.

Sarkar, M. and Sirohi, P. S. 2006. Gene action of quantitative characters including yield in cucumber (*Cucumis sativus* L.). *Indian J. Hort*. 63: 341-342.

Sarkar, M. and Sirohi, P. S. 2010. Combining ability analysis for yield and its contributing characters in cucumber. *Indian J. Hort*. 67: 525-530.

Sharma, J. R. 1988. *Statistical and Biometrical Techniques in Plant Breeding*. New Age International (P) Ltd., Publishers, New Delhi. 430p.

Sharma, V. K., Goel, A. K. and Kumar, R. 2001. Performance of cucumber varieties under protected cultivation. *Himachal J. Agric. Res*. 26: 175-177.

Sharma, R. K., Pathania, N., Joshi, A. K. 2004. Studies on hybrid seed production in cucumber. *Seed Res*. 32: 103-104.

Sharma, H. R. and Sharma, D. 2006. Genetic divergence for yield and yield-contributing traits in cucumber (*Cucumis sativus* L.). *J. Hort. Sci.* 1: 141-143.

Sharma, M. 2010. Gene action and heterosis studies involving gynoecious lines in cucumber (*Cucumis sativus* L.). M.Sc Hort. Thesis. CSK, Himachal Pradesh Krishi Vishvavidyalaya, Palampur. 192p.

Sheshadri, V. S. and More, T. A. 2009. *Cucurbit Vegetables [Biology, Production and Utilization]*. Studium Press Pvt. Ltd., New Delhi. 482p.

Shimomura, K., Yoshioka Y. and Sugiyama M. 2012. Fruit texture variation among Beit Alpha, European greenhouse and Japanese cucumbers (*Cucumis sativus*). Sari, Solmaz and Aras (eds) In: *Proceedings of the Xth EUCARPIA meeting on genetics and breeding of Cucurbitaceae*, 15-18th October 2012, Antalya (Turkey), pp. 571-574.

Singh, A. K., Gautam, N. C. and Singh. R. D. 1999a. Heterosis in cucumber (*Cucumis sativus* L.). *Veg. Sci*. 26: 126-28.

Singh, R. V., Verma, T. S. and Thakur, P. C. 1999b. Relative heterosis in cucumber in temperate region. *Himachal J. Agri. Res*. 24: 49-54.

Singh, Y. and Sharma, S. 2006. Combining ability through line x tester analysis in Cucumber (*Cucumis sativus* L.). *Crop Res*. 31: 110-115.

Singh, A. and Ram, H. H., 2009. Standard heterosis for yield and its attributing characters in cucumber (*Cucumis sativus* L.). *Pantnagar J. Res*. 1: 81-84.

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: 49-52.

Singh, R., Singh, A. K., Kumar, S. and Singh, B. K. 2012. Heterosis and inbreeding depression for fruit characters in cucumber. *Indian J. Hort*. 69: 200-204.

Solanki, S. S., Seth, J. N. and Lal, S. D. 1982. Heterosis and inbreeding depression in cucumber (*Cucumis sativus* L.) *Prog. Hort*. 14: 136-140.

Solanki, S. S. and Shah, A. 1990. Line x Tester analysis of combining ability for yield and its components in cucumber (*Cucumis sativus* L.). *Prog. Hort*. 22: 87-91.

Sprague, G. F. and Tatum, L. A., 1942. General *vs* specific combining ability in single crosses of corn. *J. Am. Soc. Agron*. 34: 923-932.

Stankovic, L and Prodanovic, S. 2002. Silver nitrate effects on sex expression in cucumber. *Acta Hort.* 579: 203-206.

Susaj, E. and Susaj, L. 2010. Induction of staminate flowers in gynoecious cucumber lines (*Cucumis sativus* L.) using silver nitrate In: *Proceedings – 21st Scientific-Expert Conference of Agriculture and Food Industry*, Neum 2010. pp. 407-412.

Sushir, K. V., Dumbre, A. D., Patil, H. E., Kamdi, S. R. and Saitwal. V. M. 2005. Combining ability studies in cucumber (*Cucumis sativus* L.). *J. Soils Crops*. 15: 72-75.

Uddin, M. N., Hossain, M., Rahman, M. M., Ahmad, S. and Quamruzzaman. A. K. M. 2009. Combining ability and gene action in cucumber (*Cucumis sativus* L.). *SAARC J. Agri*., 7: 63-71.

Vashista, P. C. 1974. *Taxonomy of Angiosperms*. P. B. M. Press, New Delhi, 599p.

Verma, T. S., Singh, R. V. and Sharma, S. C. 2000. Line × tester analysis for combining ability in cucumber. *Indian J. Hort*. 57: 144-147.

Vijayakumari, P., More, T. A. and Sheshadri, V. S. 1991. Evaluation of gynoecious F_1 hybrids for horticultural characters in cucumber. *Veg. Sci*. 18: 167-76.

Vijayakumari, P., More, T. A. and Shesadri, V. S. 1993. Heterosis in tropical and temperate gynoecious hybrids in cucumber. *Veg. Sci*. 20: 152-57.

Wehner, T. C., Shetty, N. V. and Clark, R. L. 2000. Screening the cucumber germplasm collection for combining ability for yield. *Hortscience*. 35: 1141-1150.

Yadav, J. R., Singh, S. P., Parihar, N. S., Yadav, J. K., Mishra, G., Kumar, S. and Yadav, A. 2007. Combining ability for yield and its contributing characters in cucumber (*Cucumis sativus* L.). *Prog. Hort*. 7: 116-118.

Yadav, J. R., Singh, S. P., Singh, N. and Singh, P. B. 2008. Heterosis in cucumber (*Cucumis sativus* L.). *Prog. Hort*. 3: 87-88

Zhang, C., He, P., Qu, Z., Zhou, X., Zhang, Z., Ji, H., Gaio, S., and Li, J. 2007. Male flower-inducing effects of silver nitrate in a cucumber (*Cucumis sativus* L.) gynoecious line. *J. S. W. Agric. Univ*. 29: 49-52.

APPENDIX I

Data on weather change in COH, Vellanikkara campus from 03/11/12 to 15/03/13									
Week		Temperature (°C)		Humidity (%)		Wind speed (km/h)	Rainfall (mm)	Evaporation (mm)
No	Date	Max	Min	I	II			
1	03/11-09/11	32.6	23.1	92	59	1.8	0	2.7
2	10/11-16/11	32.8	22.5	78.3	47.9	3.1	0	3.5
3	17/11-23/11	33.12	22.6	93.4	54.4	2.3	0.5	3.1
4	24/11-30/11	23.3	22.7	74.9	45.0	5.0	0	4.7
5	01/12-07/12	33.18	23.1	76.1	42.6	5.7	0.9	4.9
6	08/12-14/12	33.71	21.9	79.9	41.6	4.5	0	4.4
7	15/12-21/12	31.6	23.8	62.9	45.0	10.5	0	6.3
8	22/12-28/12	33.0	23.4	70.9	42.0	6.5	0	5.3
9	29/12-04/01	34.1	23.6	80.0	41.4	4.4	1.9	4.1
10	05/01-12/01	34.2	23.3	77.0	38.6	4.4	0	4.1
11	12/01-18/01	33.4	21.3	66.4	31.9	6.0	0	5.2
12	19/01-25/01	34.2	22.2	63.1	32.6	6.2	0	5.5
13	26/01-01/02	34.4	23.0	63.8	27.5	4.2	0	5.5
14	02/02-08/02	34.5	22.9	75	37	1.3	0	4.6
15	09/02-15/02	35.1	24.4	70	37	0	0	6.2
16	16/02-22/02	33.4	23.5	86	49	0	0.1	3.8
17	23/02-/01/03	35.9	22.2	76	24	1.35	0	5.5
18	02/03-08/03	33.5	24.2	61	34	0	0	5.9
19	09/03-15/03	34.7	24.5	89	56	0	0.1	4.25

HETEROSIS BREEDING EXPLOITING GYNOECY IN CUCUMBER (*Cucumis sativus* L.)

by

AIRINA C. K.

(2011-12-104)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement

for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University, Thrissur

DEPARTMENT OF OLERICULTURE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2013

ABSTRACT

The present study 'Heterosis breeding exploiting gynoecy in cucumber (*Cucumis sativus* L.)' was carried out at Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during February-May 2012 and November 2012 to March 2013 to study the combining ability of gynoecious line with selected monoecious lines in cucumber and to investigate the scope of heterosis breeding exploiting gynoecious line.

Twelve monoecious cucumber genotypes were collected from different parts of the country and was crossed in a topcross manner with a stable gynoecious inbred introduced from USA (EC 709119) as female parent. Observations on important 15 quantitative characters and 10 qualitative characters were recorded in five randomly selected plants. The F_1 hybrids along with their parents were evaluated to obtain information on combining ability and heterosis.

In this experiment, maleness was successfully induced in the gynoecious line (EC 709119) by spraying silver thiosulphate @ 200 ppm. The male flowers produced were uniform and normal as monoecious cultivars with high pollen fertility. Inspite of the temperate origin, the gynoecious character was stable throughout the life span.

The data were subjected to combining ability analysis according to top cross method. Significant GCA effects were observed for all the characters except days to first male flower anthesis. Among 12 parents, CS-123 was observed as the good general combiner for fruit yield per vine, length of main vine, branches per plant, number of harvests, duration of the crop, fruits per plant and number of seeds per fruit.

Heterosis values were estimated over mid, better and standard parents. Significant heterosis was observed for all the characters studied except average fruit weight. Almost all the hybrids produced significantly higher number of fruits per

plant which contributed to increase in total yield. For vegetative characters and yield contributing characters like vine length, number of branches, number of fruits and number of harvests, EC 709119 x CS-123 was proved to be the best cross. The next best crosses with respect to quantitative characters were EC 709119 x IC 410638, EC 709119 x IC 410617 and EC 709119 x IC 538155). The performance of these hybrids with respect to qualitative characters viz, free from bitterness and crispness was also good. Hence, these hybrids can be advanced for testing under different agroclimatic conditions for commercial exploitation of hybrid vigour.