DEVELOPMENT OF TROPICAL GYNOECIOUS LINES IN CUCUMBER (*Cucumis sativus* L.)

By

Karthika A. K.

(2013-12-101)

THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Science in Horticulture

(OLERICULTURE)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Olericulture

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR – 680656

KERALA, INDIA

2016

DECLARATION

I hereby declare that the thesis entitled **"Development of tropical gynoecious lines in cucumber (*Cucumis sativus* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara

Date: 18/03/2016

Karthika A.K.

(2013-12-101)

CERTIFICATE

Certified that thesis entitled **"Development of tropical gynoecious lines in cucumber (*Cucumis sativus* L.)"** is a bonafide record of research work done independently by **Karthika A. K. (2013-12-101)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

Vellanikkara

Date: 18/03/2016

Dr. T. Pradeepkumar
Chairperson (Advisory Committee)
Associate Professor
Department of Olericulture

CERTIFICATE

We, the undersigned members of the advisory committee of **Karthika A. K. (2013-12-101)**, a candidate for the degree of **Master of Science in Horticulture**, with major field in **Olericulture**, agree that the thesis entitled **"Development of tropical gynoecious lines in cucumber (*Cucumis sativus* L.)"** may be submitted by her in partial fulfillment of the requirement for the degree.

Dr. T. Pradeepkumar
Associate Professor
Department of Olericulture
College of Horticulture
Vellanikkara - 680656

Dr. Salikutty Joseph
Professor and Head
Dept. of Olericulture
College of Horticulture
Vellanikkara, Thrissur - 680656

Dr. P.G.Sadhankumar
Professor
Department of Olericulture
College of Horticulture
Vellanikkara, Thrissur - 680656

Dr. S. Krishnan
Associate Professor and Head
Department of Agricultural Statistics
College of Horticulture
Vellanikkara, Thrissur - 680656

19/03/2016

External examiner

Dr. K. P.Prasanna

Professor (Retd)

Department of Olericulture, Thrissur

ACKNOWLEDGEMENT

First and foremost I bow my head before the ***Almighty God*** *for enlightening and making me confident and optimistic throughout my life and enabled me to successfully complete the thesis work, ahead of all the difficulties I faced.*

It is with immense pleasure I avail this opportunity to express my deep sense of whole hearted gratitude and indebtedness to my major advisor ***Dr.T. Pradeepkuamr****, Associate Professor and Major advisor, Department of Olericulture, for expert advice, inspiring guidance, valuable suggestions, constructive criticisms, and above all, the extreme patience, understanding and wholehearted co-operation rendered throughout the course of my study.. I gratefully remember his knowledge and wisdom without which fulfillment of this endeavour would not have been possible.*

I consider it as my privilege to express my deep-felt gratitude to ***Dr.Salikutty Joseph,*** *Professor and Head, Dept. of Olericulture, for her constant support, valuable suggestions and critical scrutiny of the manuscript. I sincerely thank* ***Dr.P.G.Sadhankumar,*** *Professor, for his generous support , constructive criticisms and valuable suggestions during my entire study which helped in successful completion of this work. I express my gratitude to* ***Dr. S. Krishnan,*** *Professor and Head, Dept. of Agricultural Statistics, College of Horticulture, for his valuable assistance, immense help and guidance during the statistical analysis of the data.*

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 kindly acknowledge my sincere heartfelt gratitude to all the non teaching staff, labourers, research associates of the Department of Olericulture especially ***Geethu chechi, Divya chechi, Varun chettan, Shali chechi, Rekha chechi,Teena chechi, Unni chettan*** *for their whole hearted cooperation and timely assistance.*

I duly acknowledge the encouragement, moral support, precious suggestions and timely persuasions by my dear classmtes, ***Arunkumar and Nithya*** *not only in my research work, but also throughout my PG programme. I thank my dear friends* ***Thanuja, Divya,Sameera, Neshva, Razia, Remya, Nazia Deepthi, Arya, Litty, Mithra ,Tincy, Sarath, Deepika, Neethu chechi, Suma chechi*** *for their affection ,prayers and empathy which gave me enough mental strength and perseverance to get through all odds and tedious circumstances .I have infinite pleasure to express whole hearted thanks to my loving juniors* ***Nimisha, Ningappa, Reshma, Miriam*** *for their love, innumerable help and support .*

I am in dearth of words to express my love towards ***my beloved Parents, Parents – in - laws*** *and* ***my all time loving and inspiring husband Shravan*** *for their boundless affection, moral support, eternal love, deep concern, prayers and personal sacrifices which sustains peace in my life.*

I express my deep sense of gratitude to Kerala Agricultural University, Horticulture library and Central library for informational,financial and technical support for persuasion of my study and research work.

It would be impossible to list out all those who have helped me in one way or another in the successful completion of this work. I once again express my heartful thanks to all those who helped me in completing this venture.

KARTHIKA A. K.

CONTENTS

LIST OF TABLES

LIST OF PLATES

INTRODUCTION

1. INTRODUCTION

Cucumber (*Cucumis sativus* L., 2n = 2x = 14), belongs to the genus *Cucumis* of the family Cucurbitaceae. It is grown all over the world and is one of the members of the economically important Cucurbitaceae family (Jeffrey,1980;). Cucumber is thought to be indigenous to India, the evidence being more of a circumstantial nature, as cucumber is never been found in a wild state. According to Decandolle (1886) cucumber has been cultivated for over 3000 years in India, which has been corroborated by Seshadri and More (2009), that the antiquity of cucumber in India being very old. Diversification in cucumber occurred possibly in two directions viz., the tropical course in India, which characterises the adaptation to high temperature and high humidity conditions; and another subtropical course in the China-Korea-Japan region, which tolerates subtropical and temperate low temperatures (Seshadri and More, 2009). Being an internationally acclaimed warm season vegetable, it is used as salad, pickles, dessert and even cooked.

Among the cucurbitaceous group, cucumber is peculiar with a unique sex mechanism and this feature can easily be manipulated for production of F_1 hybrid seeds. Utilization of gynoecious lines in breeding programme favoured maximum exploitation of heterosis in cucumber. True breeding gynoecious lines used for heterosis breeding produce exclusively pistillate flowers and hence modification of this sex form in reverse direction, to produce male flowers is necessary in order to maintain the gynoecious genetic stock by hand pollination (More, 2002). True breeding gynoecious lines in cucumber are reported from University of Wisconsin, Madison, USA. At Indian Agricultural Research Institute, New Delhi, More and Seshadri (1988), attempted the transfer of gynoecy into tropical varieties of cucumber and thus four stable tropical gynoecious lines viz., 87-304-6, 87-316, 87-319-12 and 87-338-15 were established. These stocks were developed from the crosses involving

temperate gynoecious lines like WI 2757, SR 551F, Tablegreen 68 and SC3 of USA origin and Indian origin monoecious parent. These tropical gynoecious lines were used in the development of tropical F_1 hybrids in cucumber at the Indian Agricultural Research Institute, New Delhi and at Mahatma Phule Agricultural University, Rahuri. It is further observed that gynoecious sex expression in the parents was found to be stable in the tropical genetic background, under high temperature conditions (Vijayakumari *et al.*,1991;1993). This was substantiated by the development of parthenocarpic tropical gynoecious cucumber lines (PKG-1 series) in Poona Khira background (More and Munger, 1986). One of these lines were used as female parent for developing tropical gynoecious lines and development of F_1 hybrids at IARI, New Delhi and MPKV, Rahuri (More, 2002). Temperate gynoecious line GY-14 was successfully exploited in the development of two hybrids *viz.*, Hira and Shubhra from Kerala Agricultural University (KAU News, 2015). However, when temperate gynoecious lines were grown in tropical countries like India under high temperature and long photoperiodic conditions, gynoecy was not found to be stable and there was heavy incidence of powdery mildew and downy mildew. Hence gynoecy in cucumber did not receive much attention in the tropical countries (More, 2002). Development of stable tropical gynoecious line is the only alternative for exploiting the potential of gynoecy in India. Being a high value vegetable crop suitable for both rainshelter and open cultivation, development of tropical gynoecious lines will be helpful in generating high yielding F_1 hybrids in cucumber. 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.

Hence the present study was undertaken to develop stable tropical gynoecious lines in salad cucumber through evaluation of F_2 population generated from the selfing of predominantly gynoecious F_1 hybrids.

2. REVIEW OF LITERATURE

The available reviews of literature concerning the research topic are presented under the following headings:

2.1 . Development of tropical gynoecious lines in cucumber

2.2 . Maintenance of gynoecious lines in cucumber

2.3 . Inheritance studies in cucumber

2.4 . Genetic variability and heritability studies in cucumber

2.5. Varieties or hybrids released exploiting gynoecy

2.1. Development of tropical gynoecious lines in cucumber

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.

Kubicki in 1969 indicated the possibility of the use of female and monoecious lines in the production of heterotic hybrids. Female plants can be easily reproduced by crossing with a hermaphrodite plant. The F_1S of monoecious x female lines were either monoecious or almost completely female.

According to Yang in 1980, F_1 crosses between gynoecious and hermaphrodite lines gave only gynoecious or subgynoecious plants which flowered a few days earlier than the gynoecious parent.

Promising new lines of the gynoecious type (5-1, Zh3, Vzh8-7-2, 6-4) have been bred in Bulgaria and used in the production of small-fruited F_1 hybrid varieties. The best of which were Pobeda (Zh3 X K2) and Druzhba (Vzh X E1), both giving high yields of fruit 3-12 cm long from once-over harvesting (Mikhov *et al.*, 1981).

The gynoecious inbred lines GY14-2 and GY2, and 4 hybrids derived from crosses between these lines and both a monoecious determinate line (M20-2) and a monoecious indeterminate line (M11) were grown at densities of 1, 2 and 4 plants per hill, all at populations of 84000 plants/ha. Increasing numbers of plants/hill reduced the percentage of pistillate nodes/plant in all hybrids, the number of flowering nodes in both gynoecious inbred lines and their hybrids, and the percentage of gynoecious plants in both gynoecious inbred lines, and their hybrids with the determinate line M20-2 (Nienhuis *et al.*, 1984).

Meshchervov and Malychenko in 1984 at the Volgograd Experimental Station has developed 2 forms *viz.*, 257 and 301 with parthenocarpy and resistance to powdery mildew without bitterness. Derived from crosses between gynoecious and hermaphrodite lines, they are gynoecious and gynomonoecious and are propagated by natural pollination. They are high yielding, producing fruits suitable for pickling. Form 257 can be grown outdoors or under cover, while 301 is suited to greenhouse cultivation without the need for bee pollination.

Hybrids from crosses between 3 female (gynoecious) parents and 2 genetically similar male parents were evaluated at 3 sites to determine whether bisexual (phenotypically andromonoecious) parents reduce yield or quality. Bisexual pollen parents developed by 8 successive backcrosses to recurrent gynoecious lines

gave hybrids that were indistinguishable from those obtained using near-isogenic gynoecious male parents with pollen production induced by silver nitrate treatment. Hybrids involving the original 2 near-isogenic pollen parents did not differ in yield, fruit shape, defects, brining quality or sex expression. Deficiencies, generally attributed to bisexual parents were corrected by adequate backcrossing to establish bisexual lines (Staub *et al*., 1986).

Brar *et al.* (1986) conducted an experiment at the Agricultural College Farm, Dharwad, using the foundation seeds of the parents of cucumber cv. Picklingham. The female parent was completely gynoecious and the male parent was monoecious. Two lines of the gynoecious parent and one line of the monoecious parent were sown side by side. Ultimately only one plant/basin was maintained. Treatments consisted of 5 sowing dates (1 Dec., 15 Dec., 1 Jan., 15 Jan and 30 Jan.) and plant growth regulators (seed treatment with 100 ppm MH, foliar application of 200 ppm MH, foliar application of 200 ppm ethephon and a water spray (control)). Fruit and seed yield increased with later sowing dates and highest yields were obtained with sowing on 30 Jan. The number of pistillate flowers and fruits/plant differed significantly only among the plant growth regulators. The best results were obtained with a foliar spray of 200 ppm ethephon (24.7 pistillate flowers/plant and 4.9 fruits/plant). The highest fruit yield (899 g/plant) and seed yield (13.76 g/plant) were obtained with sowing on 30 Jan. and foliar application of 200 ppm ethephon. The germination percentage of the seeds differed significantly due to the sowing date and was generally higher in the December sowings.

Fang *et al* in 1995 developed a series of gynoecious cucumber lines suited to subtropical conditions with different ripening habit. They were bred by crossing and

backcrossing superior foreign gynoecious hybrids from Japan and the Netherlands with the northern type Chinese varieties which had good disease resistance.

Thirty cucumber hybrids were developed by crossing 10 inbred lines, i.e. Poona Khira, Gynoecious line, Paprola Local, Pacer, Cus 450, Cus-78, Shimla Local, Sheetal, Sel. 72-5 and Swarnapurna, with 3 testers, i.e. Poinsette, K-75 and K-90.These were evaluated for fruit yield and quality under 3 environments, i.e. spacing of 1.5×1.0 m (E-I and E-III) and 1.50×0.50 m (E-II), in Palampur and Jachh, Himachal Pradesh, India. In E-I and E-II, the control cultivar Pusa Sanyog was found superior to all hybrids, except Sheetal × K-90, with regard to fruit yield. In E-III, however, majority of the hybrids recorded higher yields than the control. Pooled results over the 3 environments indicated that 6 hybrids, i.e. Sheetal × K-90, Sheetal × K-75, Sheetal × Poinsette, Gynoecious Line × K-90, Poona Khira × K-75 and Sel. 72-5 × Poinsette, exhibited higher level of homeostasis than the control. The hybrids Sheetal × K-90 (73.08 q/ha) in E-1, Sel. 72-5 × Poinsette (214.23 q/ha) in E-II and Sel. 72-5 × K-90 (128.03 q/ha) in E-III registered the highest fruit yields. The superiority of the 6 hybrids were consistent across environments in relation to fruit size, low count of cull fruits, fruit number, earliness and smaller seed cavity. (Sharma and Vidyasagar, 2001).

Seven tropical parthenocarpic gynoecious cucumber lines *viz.*, PKG 1-2, PKG 1-11, PKG 1-12, PKG 1-15 (Yellow skinned fruits) and PKG 1-21, PKG 1-23 and PKG 1-24 (Green skinned fruits) with 100% parthenocarpy were evaluated for their horticutural performance in plastic green house. PKG 1-12, PKG 1-15 and PKG 1-24 produced first female flower at a lower node, thus noticed earliness. The two lines namely PKG 1-15 and PKG 1-21 recorded higher yield compared to other lines

studied. These lines could be utilized as female line in the development of parthenocarpic gynoecious cucumber hybrids (Budgujar and More, 2002).

2.2. Maintenance of gynoecious lines in cucumber

Different chemical combinations for maintenance of gynoecious lines in cucumber are as follows in Table 1:

Table 1: Chemicals and their concentrations for maintenance of gynoecious lines in cucumber

S. No.	Chemicals with concentration and stage	Authors
1.	Use of GA_3 and Silver nitrate	Peterson and Anhder(1960)
2.	100, 500 or 1500 ppm GA_3 / 50, 200 or 500 ppm $AgNO_3$ /100 or 200 ppm Ethrel [ethephon] at first true leaf stage	Kalloo and Franken (1978)
3.	$AgNO_3$ at 500ppm, $[Ag(S_2O_3)_2]^3$ at 500 or 2000 ppm	Nijs *et al* (1979)
4.	Silver nitrate at 100, 200 and 400 ppm	Tolla and Peterson (1979)
5.	One spray of 150ppm $AgNO_3$ at the one true leaf stage and two applications of 250ppm $AgNO_3$ at two-true leaf stage	More and Munger (1986)
6.	$AgNO_3$ (300 ppm twice)	More and Sheshadri(1988)
7.	$AgNO_3$ (250 ppm) twice, $AgNO_3$ (300 ppm. twice)	More and

		Sheshadri(1988)
8.	A single spray with silver thiosulphate or silver nitrate at 500 ppm when the first true leaf appeared induced both male and hermaphrodite flowers in gynoecious plants in the ratio 1.4:1 (range from 1.1:1 to 2.6:1) in the case of silver thiosulphate and 2.6:1 (range from 0.7:1 to 2.75:1) in the case of silver nitrate	Scurtu and Scurtu(1995)
9.	Lateral axis application of $AgNO_3$ at 300 and 400 ppm	Chaudhary *et al* (2001)
10.	0.02 percent $AgNO_3$ solution on short day light conditions; 0.03 percent $AgNO_3$ solution on long day light conditions	Stankovic and Prodanovic (2002)
11.	Twice or thrice with 400-500 ppm $AgNO_3$ at first true leaf stage	Hallidri (2004)
12.	Two sprays of $AgNO_3$ at 250 ppm	Sharma *et al* (2004)
13.	Two successive sprays at the two-leaf stage at the rate of 300 mg/litre	Zhang *et al* (2007)
14.	Twice or three times with 400-500 ppm $AgNO_3$ in seven days intervals	Susaj and Susaj (2010)
15.	Silver nitrate solution @250 mg/kg and GA solution @ 500 mg/kg	Das *et al* (2013)

2.3. Inheritance studies in cucumber

Shawaf and Baker in 1981 obtained F_1 hybrids from crosses between four gynoecious lines and five hermaphroditic lines, additive genetic variance was greater than non additive for yield and associated components, except for gynoecious expression, where non additive variance was more important. The general combining ability (GCA) effects for time to harvest, gynoecious expression and yield of the female parents were greater than that of the male parents. The converse was true for days to flowering. Complete dominance was indicated for early flowering and over dominance for gynoecious expression. Narrow-sense heritability estimates of half sibs for fruit number and fruit weight per plant were 53-60% and 32-65%, respectively. Genotypic and phenotypic correlations for nodal position of the first pistillate flower with flowering time and with parthenocarpic yield were high.

Robinson (1987) studied progeny of over 100 self-pollinated 'Lemon' plants with opposite leaves, all segregated for alternate vs. opposite leaf arrangement showing single recessive gene with incomplete penetrance. The proportion of seedlings with opposite leaves were significantly less than 25% in each of 26 F_2 populations. The combined segregation ratio was 875, alternate to 86 opposite linkage, was detected between opposite leaf arrangement and two genes known to be on the same chromosome. Genes of 'Lemon' for sex expression *(m)* and five fruit locules *(l)* were linked (2), and were associated with opposite leaves in segregating generations.

According to Staub and Peterson in 1986, multi-branched habit did not follow any single-gene inheritance pattern, so can be considered as a quantitative trait. On the other hand, the little leaf trait of the cultivar 'Little John' was controlled by a single recessive gene. Some of the plants were misclassified due to environmental variability for leaf size. Thus, little leaf can be considered a good marker, already

named *ll*, where 'Little John' carries the recessive mutant allele, and WI 2757 cultivar carries the dominant, wild-type allele.

A complete M x N mating pattern between five non parthenocarpic monoecious and four parthenocarpic gynoecious inbred lines were used to estimate general combining abilities (GCA) for fruit firmness. Non- parthenocarpic lines were used as males and parthenocarpic lines were used as females to produce 20 F_1 hybrids for evaluation. On studying the inheritance of whole fruit firmness, a quantitative fashion was noticed. Inheritance appears additive, though some dominance for firmness was present as F_1's consistently exceeded midparent values. (Kanwar *et al.*, 1994)

Zhang *et al* in 2007 adopted the classical genetic method to study female segregation of the F_1, F_2, and BC_1 of cucumber by crossing gynoecious lines with monoecious lines and andromonoecious lines, and crossing sub-gynoecious lines with monoecious lines and gynoecious lines. Results indicated that the sex of cucumber was determined by both the two major loci *F* and *M* and another female gene which is recessive to monoecious lines. The recessive gene is closely linked with the dominant gene which determines female sex expression. Sex expression of the sub-gynoecious phenotype is different from the gynoecious phenotype. The former had a high degree type of pistillate sex expression, while the latter were all female.

The inheritance of sub gynoecious traits in cucumber plants were investigated with that of the inbred sub gynoecious cucumber lines (*C. sativus* L. var *sativus* cv 97-17 and S-2-98) . Genetic analysis have shown that the two sub gynoecious inbred lines were controlled by a pair of recessive gene and pair of incompletely dominant gene, which were designated presently as mod-F2 and Mod-F1, respectively. Furthermore, the mod-F2 and Mod-F1 loci, which enhance the intensity of femaleness, also inherited independently with F and M genes (Chen *et al.*, 2011).

2.4. Genetic variability and heritability studies in cucumber

Field performance, variability, characters association and genetic divergence of 58 long type cucumber accessions were studied in Bangladesh Agricultural University. Wide variability was found for the plant characteristics of days to seed germination, vine length harvest, petiole length and yield contributing characters namely, days to first male and female flowering, number of fruits per plant, average fruit weight, fruit length and fruit diameter. The highest GCV was recorded in yield per plant (42.75%) where number of fruits per plant (33.41%), fruit length (27.57%), number of lateral shoots (24.19%), average fruit weight (22.14%), petiole length (16.10%), node order at which male and female flower opened (13.28% and 12.62%) were recorded.(Mohammad *et al*., 2010).

Kumar *et al* in 2009 estimated the magnitude of heritable and non-heritable component of variation and genetic parameters such as genotypic coefficient of variation, heritability and genetic advance in twenty diverse cucumber genotypes. The GCV, which gives a picture of extent of genetic variability in the population ranged from 6.54 (days to first fruit harvest) to 214.53 (number of days to first female flower anthesis). The GCV values were considerably high for characters such as number of days to first female flower anthesis, number of primary branches per plant at maturity, number of nodes bearing female flower per plant, cavity of fruit at edible stage, while the lowest coefficient of variability were observed for days to first fruit harvest followed by number of daysto first male flower anthesis. Moderate coefficient ofvariability were observed for number of fruits per plant. The heritability estimate (%) were maximum for fruit length at edible stage, node number bearing first male flower and fruit weight at edible stage (g) while the minimum heritability was observed for number of days to first female flower anthesis followed by number of days to germination (50%).

Kumar *et al* in 2009 studied on variability, heritability, genetic gains, correlation coefficients and path coefficients in twenty five diverse cucumber genotypes was carried out for fruit yield and yield attributing traits. The genotypes exhibited significant differences for all the traits under study. A wide range of variability along with estimates of PCV and GCV was observed for days to 1st female flower anthesis, number of primary branches/plant, number of fruits/plant, number of node bearing female flowers/plant, fruit length, fruit weight, cavity of fruit at edible stage and fruit yield/plant. High heritability and high expected genetic gain were observed for days to 1st female flower anthesis, number of primary branches/plant, number of fruits/plant, fruit length and fruit diameter, 100-seed weight,cavity of fruit at edible stage and fruit yield/plant indicate that these characters had additive gene effect and therefore, these are more reliable for effective selection.

Analysis of variance revealed significant differences among entries for all the characters. The estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for yield per plant, fruits per plant, fruit weight and fruit length. Broad sense heritability estimates for various traits ranged from 42.26 to 89.55%. Fruit yield per plant showed high significant positive correlation with fruits per plant, fruit weight, flesh thickness, fruit diameter and leaves per plant. Fruit weight, fruits per plant, fruit length and days to flowering were shown to have high to moderate genotypic variance, high heritability and greater genetic gain. (Ullah *et al.*, 2010)

High GCV and PCV were obtained for characters like number of nodes per vine ,dry weight of fruits, marketable fruit yield per vine and total fruit yield per vine. High heritability was observed for most of the characters studied, except days to first female flower and number of unmarketable fruits per vine. Among the various characters studied high heritability coupled with high GAM was noticed for days to first male flower, number of nodes at which first female flower appears, days to first fruit harvest, vine length and dry weight of fruit. It indicates that a simple selection

scheme for these traits would be sufficient to bring genetic improvement in the desired direction. (Hanchinamani *et al.*, 2011)

Arunkumar *et al* in 2011 studied the genetic variability, correlation and path analysis in F_2 of BGDL x Hot Season. High variability was observed for number of female flowers per vine, number of male flowers per vine, number of branches per vine, average fruit weight, number of good fruits per vine, total number of fruits per vine and total fruit yield per vine. High PCV and GCV were recorded for number of misshaped fruits per vine whereas, moderate PCV and GCV were observed for number of good fruits per vine, total number of fruits per vine, fruit diameter and total fruit yield per vine. Higher variability coupled with moderate to low genetic gain was noticed for days to first male flower, days to first female flower, vine length, number of nodes per vine, number of branches per vine, number of female flowers per vine, number of male flowers per vine, days to first fruit harvest, fruit length, fruit diameter, average fruit weight, number of good fruits per vine and total fruit yield per vine.

Kumar *et al* in 2012 collected thirty diverse genotypes of cucumber collected from different indigenous sources. High heritability coupled with moderate genetic gain was observed for fruit length, fruit breadth and average fruit weight, indicated that these characters are under non-additive gene effects. The genotype LC-1 gave maximum mean value for fruit weight and yield per plot. Among the horticultural traits, comparatively wide range was observed for node number bearing first female flower (3.53-13.53) and days to marketable maturity.

Fifty two cucumber (*Cucumis sativus* L.) genotypes were evaluated for genetic variability, heritability and genetic advance. Moderate to high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed for number of fruits per plant and fruit yield per vine. High heritability coupled with high genetic advance over mean was observed for number of fruits per

vine, fruit yield per vine (g), and number of seeds per fruit.(Basavarajeshwari *et al.*, 2014).

2.5. Varieties and hybrids developed through exploitation of gynoecy

Varieties and hybrids developed through exploitation of gynoecy in different parts of the world are as follows in Table 2:

Table 2. Varieties or hybrids developed through exploitation of gynoecy

S. No.	Name of gynoecious line / hybrid/variety	Main characteristics	Reference
1.	WI1983G (98-100% gynoecious) and WI1983A (andromonoecious).	Multiple disease resistance, seedless fruits with no bitterness	Peterson *et al* (1986)
2.	Wautoma	White spined, multiple disease resistance,indeterminate habit	Peterson *et al* (1986)
3.	Kecskeméti Livmé	Non- bitter, good yielder, good quality	Diola *et al* (1986)
4.	Linda	Parthenocarpic non bitter gynoecious F_1 hybrid, early ripener	Diola *et al* (1986)
5.	Vikhra, Lora	Gynoecious variety, uniform cylindrical fruits, zero bitterness	Aleksandrova, (1988)
6.	Renesansa	Gynoecious hybrid, suitable for protected cultivation and field condition	Stankovic *et al.*, 1992
7.	304 × EC14212 and Gyn. JPL × EC129110 ; 322-11 × Balam and 304D × RKS295	Tropical gynoecious hybrids	Vijaykumari *et al.*,1991

8.	Wonye 501, Wonye 502	Gynoecious lines with good fruit shape and field resistance to downy mildew [*Pseudoperonospora cubensis]*	Om *et al.*, 1992
9.	81066 × TR, T × B81 and 81066 × B81	Gynoecious type with a growth period of 43-46 days and resistance to powdery mildew	Khristova,1995
10.	K75	Best general combiner	Dogra *et al.*, 1997
11.	GYC-1, GYC-2 and GYC-3	True breeding gynoecious lines under high temperature and long photoperiodic conditions	More, 2002
12.	Phule Prachi, Phule Champa	Superior F_1 hybrids	More, 2002
13.	H-13, H-210, H-312 and H-42	Earliness, high yield	Badgujar and More (2004)
14.	'Zhongnong 19'	Crispy sweet fruits, tolerant to low temperature, good disease resistance	Fang, 2006
15.	'Biyu No. 2'	European gynoecious cucumber hybrid	Jun *et al.*, 2009
16.	'Zhongnong 29'	Resistant to scab, fusarium, powdery mildew and downy mildew. It is tolerant to low temperature and weak light, suitable for protected cultivation	Fang *et al.*, 2010
17.	'Dongnong 807'	Highly resistant to Fusarium wilt and bacterial augular leaf spot disease, resistant to downy	Fang *et al.*, 2010

		mildew and powdery mildew	
18.	'Lvyuan No.4'	F_1 hybrid, resistant to cucumber mosaic virus and bacterial augular leaf spot disease, mid-resistant to downy mildew, early maturing	Feng *et al.*, 2011
19	'Shenlv03'	Gynoecious parthenocarpic, smooth and non-warty straight fruit, short fruit stalk, high powdery mildew and downy mildew resistance	Le *et al.*, 2013
20.	'Yuexiu No. 3'	Gynoecious hybrid highly resistant to powdery mildew, medium resistant to downy mildew and fusarium wilt	Gen *et al.*, 2014
21.	'Jingyan 207'	Resistant to downy mildew, powdery mildew, and CMV, tolerant to low temperature and weak light. It is suitable for greenhouse cultivation in spring, plastic tunnel cultivation in spring and autumn	Jun *et al.*, 2014

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study 'Development of tropical gynoecious lines in cucumber (*Cucumis sativus* L.)' was carried out at Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 2014-15 (August-May). The field experiment was conducted at Block 2 of the department.

Experimental site was located at an altitude of 22.5m above MSL between 10°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

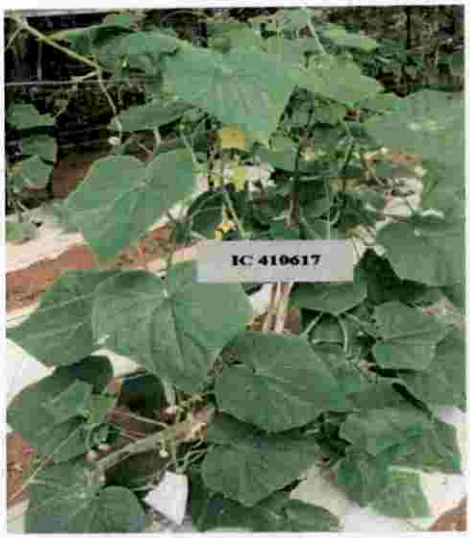
3.A.1. Experimental Materials

Experimental materials consisted of 12 monoecious cucumber (*Cucumis sativus* L.) genotypes, collected from different parts of the country and a stable gynoecious inbred introduced from University of Wisconsin. Name and source of genotypes are presented in Table 3.

Table 3. List of cucumber accessions/varieties collected from various 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
3.	IC 410617	National Bureau of Plant Genetic Resources, New Delhi
4.	IC 410638	National Bureau of Plant Genetic

1a. CS 129



1b. IC 410617

1c . IC 527431

1 d. CS 25

Plate 1: General view of monoecious cucumber genotypes

1e . CS 121

1f . CS 128

1g. CS 123

1h. CS 127

Plate 1: General view of monoecious cucumber genotypes

1i. IC 527427

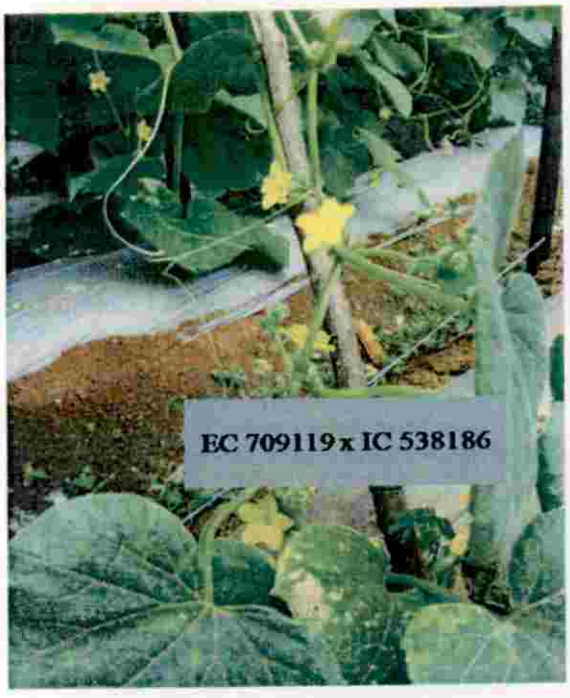
1j. IC 410638

1k. IC 538155

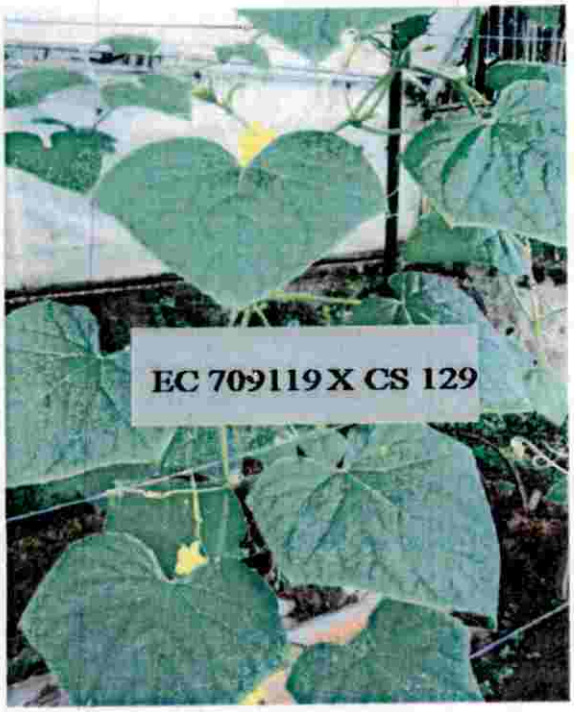
1l. IC 538186

Plate 1: General view of monoecious cucumber genotypes

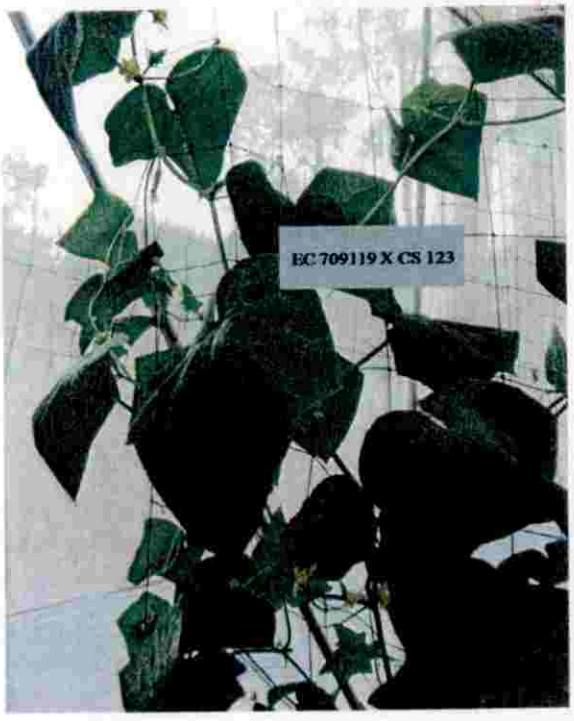
2a. EC 709119 x IC 527427



2b. EC 709119 x IC 538186



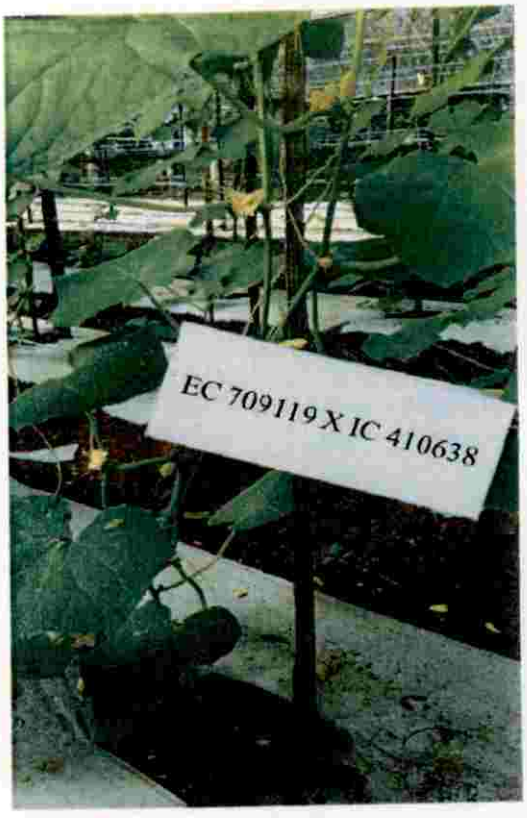
2c. EC 709119 x CS 129



2d. EC 709119 x CS 123

Plate 2 : General view of F_1 hybrids

2e. EC 709119 x CS121

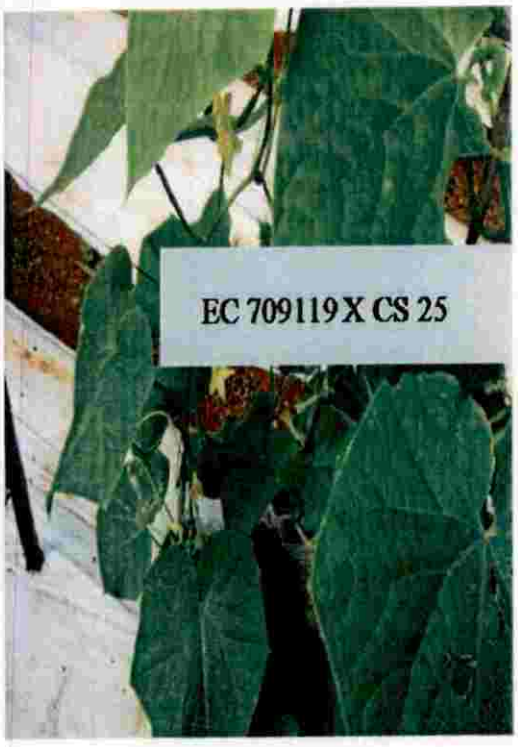


2f. EC 709119 x IC 410638

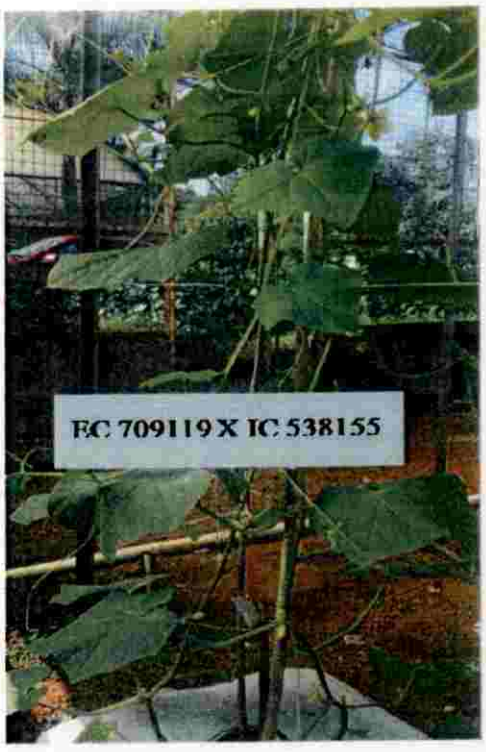
2g. EC 709119 x CS 127

2h. EC 709119 X CS 128

Plate 2 : General view of F_1 hybrids



2i. EC 709119 X CS 25



2j. EC 709119 X IC 538155

Plate 2 : General view of F_1 hybrids

		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 (PSK-1)	G.B. Pant University of Agriculture and Technology, Uttaranchal
9	CS-129 (PK-1)	G.B. Pant University of Agriculture and Technology, Uttaranchal
10	CS-25(AAUC-2)	Assam Agricultural University, Jorhat
11	CS-121 (Kuruppanthara local)	Kerala Agricultural University, Thrissur
12	CS-123	Kerala Agricultural University, Thrissur
13	EC 709119	University of Wisconsin, USA

3.A.2. Experimental methods

a. Evaluation of F_1 hybrids for gynoecious sex expression

During first season, 12 hybrids were produced by crossing gynoecious inbred line (EC 709119) with selected tropical monoecious pollen parents. These hybrids were evaluated for gynoecy under rainshelter. The gynoecious parent (EC 709119) was maintained by spraying silver thiosulphate @ 200ppm at 3 true-leaf stage. Solution of 200 ppm silver thiosulphate was freshly 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 – 1litre

Procedure: NaS_2O_3 $5H_2O$ was dissolved in 250ml double distilled water in a volumetric flask. It was then poured into a 1litre container. The flask was rinsed with 250 ml double distilled water and was poured into the above 1 litre 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 was poured into the jar. For spraying cucumber plant, the solution was diluted with double distilled water in the ratio 1:1. The plants were sprayed at 3-6 leaf stage with 2 applications per week.

b. Selfing of F_1 hybrids exhibiting gynoecy

F_1 hybrids were selfed to generate F_2 population. Well developed female buds 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 same parents were selected and covered. Anthesis takes place at 5.30 - 7.00 am and maximum pollen grain viability was observed 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 on to the stigma of covered female flowers and tagged. The selfed female flowers were kept covered for two more days, till the fruit developed to avoid foreign pollen contamination. The developed fruits were covered with perforated polythene bags to protect from the fruit fly damage. Seeds from 12 F_1 hybrids were collected at seed maturity and stored.

c. Evaluation of F_2 population

F_2 population was evaluated along with gynoecious inbred EC 709119 for expression of gynoecious characters, *viz.*, days taken for female flower anthesis, node at which first female flower emerged and total number of female flowers. Selected genotypes exhibiting high gynoecy were selfed as well as back crossed with EC 709119 for future studies.

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. Days to first male flower anthesis: Number of days was counted from the date of sowing to the date when first male flower opened.
2. Days to first female flower anthesis: No of days was counted from the date of sowing to the date when first female flower opened.
3. Node at which first female flower emerged: Nodes were counted from the lowest to the one at which the first female flower emerged.
4. Node at which first female flower: Nodes were counted from the lowest to the one at which the first female flower emerged.
5. Total number of male flowers: Male flowers were counted from the date of first anthesis and on 3 days interval.
6. Total number of female flowers: Female flowers were counted from the date of first anthesis and on 3 days interval.
7. Average fruit weight (g): Weight of five fruits from five selected plants at third harvest was recorded and the average was calculated.

8. Fruit length (cm): Length of five fruits from five selected plants at third harvest was recorded separately and the average was calculated.
9. Fruit girth (cm): Girth of five fruits from five selected plants at third harvest was recorded separately and the average was calculated.
10. Flesh thickness (cm): Flesh thickness of fruits at central part from five selected plants after cutting vertically were recorded separately and the average was calculated.

3.B.2. Qualitative Characters

Five plants were 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. 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).

10. Fruit cracking: Present/ absent

3.C. STATISTICAL ANALYSIS

Data recorded from the parents and hybrids were initially subjected to analysis of variance to detect the genotypic variability among them.

3.C.1 Analysis of variance (ANOVA)

Anova was conducted on the F_1 population for both parents and hybrids involved. Calculated value, greater than table F value at error degrees of freedom at a default significance level will reflect significant variation among treatments. A significant variation will necessitate computation of critical difference (Sharma, 1988).

3.C.2. Estimation of variability among the genotypes

The mean of the values observed for 13 parents and 12 hybrids as well as 20 plants in F_2 population were taken for statistical analysis. The data thus obtained were processed for analysis of variance, range, standard deviation, genotypic and phenotypic variance, genotypic and phenotypic coefficient of variance, genetic advance, genetic gain, heritability etc.

Standard deviation

$$SD = \sqrt{var}$$

Standard error

$$SE = \frac{SD}{\sqrt{n}}$$

Where n = number of families involved in the population

Coefficient of variation

The formula for C.V. was suggested by Snedecor and Cochran (1968)

$$C.V. = \frac{SD}{Mean} \times 100$$

Phenotypic, genotypic and environmental variance

The variance components were estimated using the formula suggested by Burton (1952).

Phenotypic variance (V_p) = $V_g + V_e$

Where,

V_g – genotypic variance

V_e - environmental variance

Genotypic variance (V_g) = $(V_T - V_E)/N$

Where,

V_T – mean sum of squares due to treatments

V_E – mean sum of squares due to error

N - number of replications

Environmental variance, $V_e = V_E$

Phenotypic and genotypic coefficient of variation

The phenotypic and genotypic coefficients of variation were calculated by the formula suggested by Burton and Devane (1953).

Phenotypic coefficient of variation (pcv) = $(V_p^{1/2} / \bar{X}) \times 100$

Where,

V_p = Phenotypic variance

$\bar{X}$ = Mean of character under study

Genotypic coefficient of variation (gcv) = $(V_g^{1/2} / \bar{X}) \times 100$

Where,

V_g = Genotypic variance

$\bar{X}$ = Mean of character under study

Heritability

Heritability in broad sense is estimated by the formula suggested by Burton and Devane (1953). Heritability in broad sense,

$$H = (V_g / V_p) \times 100$$

Where,

V_p = Phenotypic variance

V_g = Genotypic variance

Expected genetic advance

The genetic advance expected for the genotype at five percent selection pressure was calculated using the formula by Lush (1949) and Johnson *et al.* (1955) with the value of constant K as given by Allard (1960).

Expected genetic advance, $GA = (V_g / V_p) \times K$

Where,

V_p = Phenotypic variance

V_g = Genotypic variance

$K = 2.04$

Genetic Gain (genetic advance as percentage of mean)

Genetic Gain (GG) = $(GA/\bar{X}) \times 100$

Where,

GA = genetic advance

$\bar{X}$ = Mean of character under study

Gene action governing gynoecy was worked out based on the evaluation of F_2 population using Chi – square test after classifying the population as monoecious and gynoecious.

The value of the test statistic is

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

Where

X^2 = Pearson's cumulative test statistic, which asymptotically approaches a X^2 distribution

45

O_i = an observed frequency

E_i = an expected frequency, asserted by null hypothesis

N= number of cells in the table

Highest, middle and lowest values were recorded for F_2 population and highest values were only recorded for F_1 population.

$$\text{Sex ratio} = \frac{\text{Total number of female flowers}}{\text{Total number of male flowers}}$$

Based on the percentage of leaf area affected for downy mildew, disease intensity was calculated using the following formula (Wheeler, 1969)

$$\text{Percentage of disease intensity (PDI)} = \frac{\text{Sum of all numerical ratings}}{\text{Total number of leaves assessed}} \times \frac{100}{\text{Maximum disease category}}$$

Based on above formula, the genotypes were grouped into five categories as adopted by Rajkumar *et al* (1995)

Disease intensity (%)	Category
0	Immune
1-10	Highly resistant
10.1- 25	Moderately resistant
25.1- 50	Moderately susceptible
Above 50	Highly susceptible

RESULTS

4. RESULTS

Results obtained in three experiments are presented under the following headings:

4.1. Evaluation of parents

Thirteen parents differed significantly for all the characters studied (Table 4). The results of each character are briefly described as follows:

a. Days to male flower anthesis

Parents varied significantly for this character and the range was 0 – 29.75 (Table 6). CS 129 was the first to produce male flower (17.25 days) and IC 527427 was very late to produce male flowers (29.75 days). No male flowers were observed in the gynoecious line EC 709119. The GCV and PCV for the character were 36.10 and 36.24 respectively. Genetic gain and genetic advance were found to be 66.09 and 14.37 respectively with heritability values of 88.51.

b. Days to female flower anthesis

Parents shown significant difference for the character and the range was 14.50 – 32.25 (Table 6). EC 709119 was the first to produce female flowers ie., 14.50 days where as IC 410617 took almost 32.25 days to produce first female flower. The GCV and PCV were found to be 18.30 and 20.29 respectively. Genetic gain and Genetic advance were 34.02 and 9.37 respectively with heritability values of 81.39.

c. Node at which first male flower emerged

Significant difference was noticed for this character among the parents (Table 4). No male flower was observed for EC 7091119 and CS 123 recorded maximum number of nodes (12.25) for male flower emergence. The GCV and PCV were high (38.49 and 44.15) respectively. Genetic gain and Genetic

advance were 69.13 and 5.65 respectively with high heritability values of 76.00.

d. Node at which first female flower emerged

Significant difference was noted among the parents (Table 4). Highest value was obtained in CS 121(19.75) and the least was found in EC709119 (5.75) for female flower emergence. The GCV and PCV were found to be 31.05 and 34.10 respectively. Genetic gain and Genetic advance were 58.24 and 6.88 respectively with high heritability values of 82.91.

e. Total number of male flowers

Parents differed significantly for this character (Table 4). CS 129 recorded highest number of total male flowers (64.25) whereas CS 25 recorded lowest number of total male flowers (36.75). The GCV and PCV were found to be 35.34 and 35.97 respectively. Genetic gain and Genetic advance were 40.65 and 33.47 respectively with high heritability values of 96.54.

f. Total number of female flowers

Significant difference was observed among the parents for total number of female flowers (Table 4).IC 527431 recorded lowest number of female flowers of value (30.4) and highest value was observed for EC 709119 (67.75). The GCV and PCV were found to be 21.61 and 22.27 respectively. Genetic gain and Genetic advance were found to be 43.22 and 19.45 respectively with high heritability values of 94.21.

g. Average fruit weight

Average fruit weight ranged from (87.46 to 150.85) (Table 6). EC 527427 and EC 709119 recorded the highest average value (150) whereas IC 538155 recorded the lowest value *i,e*, 87.46. The GCV and PCV were found to be 16.02 and 16.49 respectively. Genetic gain and Genetic advance were 32.08 and 37.68 respectively with high heritability values of 94.43.

h. Fruit length

Significant difference was observed between the parents and the fruit length ranged from 10.44 to 18.83 (Table 6). Highest value was shown by IC 410617 (18.83) and the lowest value was observed for IC 538186 (10.44). The GCV and PCV were found to be 16.40 and 17.23 respectively. Genetic gain and Genetic advance were 32.14 and 4.44 respectively with high heritability values of 90.51.

i. Fruit girth

The range lies between 10.76 and 15.87 (Table 4). IC 527427 recorded highest value of 15.87 and CS 129 recorded the lowest value of 10.76. The GCV and PCV were found to be 12.42 and 13.35 respectively. Genetic gain and Genetic advance were 23.82 and 3.18 respectively with high heritability values of 86.60.

j. Flesh thickness

Most of the parents showed significant difference and it ranged between 1.00 - 2.09 (Table 6). EC 709119 was noted with high flesh thickness (2.09) and CS 25 yielded lowest flesh thickness (1.00). The GCV and PCV were found to be 22.14 and 23.16 respectively. Genetic gain and Genetic advance were 43.60 and 0.53 respectively with high heritability values of 91.39.

Table 4. Analysis of variance (ANOVA) for quantitative characters in parents

Treatments	Days to male flower anthesis	Days to female flower anthesis	Node at which first male flower emerged	Node at which first female flower emerged	Total number of male flowers	Total number of female flowers	Average fruit weight(g)	Fruit length(cm)	Fruit girth(cm)	Flesh thickness(cm)
Treatment	227.20**	107.63**	42.72**	56.72**	1103.95**	384.33**	1438.34**	21.12**	11.48**	0.29**
Error	6.75	6.13	3.12	2.78	12.64	5.94	21.49	0.70	0.44	0.007
CV	11.94	8.98	21.35	14.11	7.60	5.42	3.94	6.06	4.96	6.94

*significant at 5% level ** significant at 1% level

Table 5: Biometric characters of parents

Treatments	Days to male flower anthesis	Days to female flower anthesis	Node at which first male flower emerged	Node at which first female flower emerged	Total number of male flowers
CS 127	25.75 (5.07)	31.00	11.25 (3.48)	12.75	50.50 (7.16)
IC 527427	29.75 (5.45)	31.25	9.25 (3.20)	15.25	58.50 (7.71)
IC 410617	26.50 (5.14)	32.25	4.50 (2.31)	11.50	48.75 (7.05)
IC 410638	27.25 (5.22)	30.50	7.75 (2.95)	7.75	38.50 (6.28)
IC 538155	27.25 (5.22)	28.25	9.00 (3.16)	10.25	42.75 (6.61)
IC 527431	19.75 (4.44)	24.00	6.75 (2.77)	7.75	61.25 (7.88)
IC 538186	21.75 (4.66)	20.50	11.25 (3.49)	10.00	52.75 (7.32)
CS 129	17.25 (4.15)	29.75	9.75 (3.27)	12.50	64.25 (8.07)
CS 128	25.25 (5.02)	31.25	6.25 (2.69)	9.00	60.00 (7.80)
CS 25	22.25 (4.71)	31.25	9.50 (3.21)	13.00	36.75 (6.13)
CS 121	22.25 (4.71)	27.25	8.75 (3.07)	19.25	41.75 (6.53)
CS 123	18.25(4.27)	26.50	12.25 (3.64)	16.75	52.5 (7.31)
EC 709119	0.00 (1.00)	14.50	0 (1.00)	5.75	0 (1.00)
Mean	21.75	27.55	8.17	11.65	46.78
CD (0.01)	4.97 (2.22)	4.74	3.92 (0.41)	3.19	6.88 (0.35)
CD (0.05)	3.71	3.54	2.92	2.38	5.14

Table 5 continued

Treatments	Total number of female flowers	Average fruit weight(g)	Fruit length(cm)	Fruit girth(cm)	Flesh thickness(cm)
CS- 127	32.75	124.37	14.36	14.89	1.14
IC 527427	35.25	150.14	15.04	15.87	1.18
IC 410617	44.50	116.75	18.83	10.91	1.10
IC 410638	53.00	126.90	11.78	11.65	1.13
IC 538155	35.75	87.46	11.60	14.84	1.21
IC 527431	30.40	113.94	15.73	11.64	1.09
IC 538186	33.80	119.61	10.44	13.46	1.20
CS 129	54.25	102.07	13.63	10.76	1.03
CS 128	40.75	96.50	13.16	13.05	1.08
CS 25	46.50	120.82	14.52	13.76	1.00
CS 121	42.40	119.60	13.61	14.35	1.14
CS 123	41.25	97.81	11.16	13.43	1.09
EC 709119	67.75	150.85	12.71	15.30	2.09
Mean	42.95	117.45	13.58	13.38	1.19
CD (0.01)	4.67	8.87	1.60	1.27	0.16
CD (0.05)	3.48	6.63	1.20	0.95	0.12

52

Table 6 : Range, mean, standard deviation, standard error, genotypic coefficient of variation, phenotypic coefficient of variation, heritability, genetic advance and genetic gain of parents

Treatments	Range	Mean	SD	SE	GCV	PCV	Heritability(%)	Genetic gain(%)	Genetic advance
Days to male flower anthesis	0 - 29.75	23.50	1.47	1.88	36.10	36.24	88.51	66.09	14.37
Days to female flower anthesis	14.50 – 32.25	27.65	0.98	1.70	18.30	20.29	81.39	34.02	9.37
Node at which first male flower emerged	0 - 12.25	8.173	1.93	1.25	38.49	44.15	76.00	69.13	5.65
Node at which first female flower emerged	5.75 - 19.25	11.65	1.69	1.25	31.05	34.10	82.91	58.24	6.88
Total number of male flowers	0 - 64.25	46.78	3.07	2.21	35.34	35.97	96.54	40.65	33.47
Total number of female flowers	32.75 - 67.75	42.95	6.18	1.70	21.61	22.27	94.21	43.22	19.45
Average fruit weight(g)	87.46-150.85	117.45	3.96	3.23	16.02	16.49	94.43	32.08	37.68
Fruit length(cm)	10.44- 18.83	13.53	1.27	0.51	16.40	17.23	90.51	32.14	4.44
Fruit girth(cm)	10.76-15.87	13.38	0.63	0.46	12.42	13.35	86.60	23.82	3.18
Flesh thickness (cm)	1.00-2.09	1.19	0.10	0.05	22.14	23.16	91.39	43.6	0.53

4.2. Evaluation of hybrids

12 hybrids differed significantly for all the characters studied (Table 7). Details are given below:

a. Days to male flower anthesis

Significant difference was observed for character and the range was between 15.50 – 28.50 (Table 9). Highest value was observed for EC 709119 X CS 128(28.50) and the lowest was observed for EC 709119 X CS 127 (15.50). Heritability value was 87.96 along with genetic gain of 33.16 and genetic advance of 6.46.

b. Days to female flower anthesis

EC 709119 X CS 129 and EC 709119 X CS 128 were observed with lowest values for female flower anthesis (32.25) and the highest values were observed for EC 709119 x IC 527427 (19.25). The range lies between 19.25– 32.25. Heritability value was 77.20. Genetic gain and genetic advance were 27.16 and 6.52 respectively.

c. Node at which first male flower emerged

The character range lies between 2.25 – 9.5 (Table 9). EC 709119 X IC 410638 recorded lowest value of 2.25 whereas EC 709119 X IC 538186 was observed with highest value of 9.5. The GCV and PCV were found to be 53.33 and 58.37 respectively. Genetic gain and Genetic advance were 100.39 and 3.59 respectively with high heritability values of 83.49.

d. Node at which first female flower emerged

The range for node at which first female flower emerged lies between 3.25 to 15.75 (Table 9). The highest value was observed for EC 709119 X CS 127(15.75) and EC 709119 X IC 527427. EC 709119 X IC

538155 recorded the lowest value of 3.25. Genetic gain and genetic advance for the character were 100.75 and 7.76 respectively. The heritability value was 90.33. The GCV and PCV were found to be 51.46 and 54.14 respectively.

e. Total number of male flowers

Total number of male flowers produced was in the range of 30.25-55.5 (Table 9). EC 709119X CS 25 was noted with lowest number of male flowers whereas EC 709119 X IC 538155 observed higher number of male flowers. Genetic gain and genetic advance for the character were 32.86 and 14.84 respectively. The heritability value was 78.43. The GCV and PCV were found to be 18.01 and 20.33 respectively.

f. Total number of female flowers

Significance was observed for this character and the range lies between 24 - 52.25. EC 709119 X IC 527427 was observed with lowest value for total number of female flowers and EC 709119 X IC 527431was noted for the highest value of 52.25. GCV was 16.96 and PCV was 20.69. High heritability value was observed for this character (67) with a genetic gain of 23.6 and genetic advance of 12.32.

g. Average fruit weight

Fruit weight of the hybrids ranged between 80.83-205.45 (Table 9). The GCV and PCV were found to be 21.69 and 21.80 respectively. Genetic gain and Genetic advance were 44.2 and 6.92 respectively with high heritability values of 98.98.

h. Fruit length

Significance was observed for this character and the range lies between13.18 -18.67(Table 9). EC 709119 X IC 410638 was observed

with lowest value for fruit length and EC 709119 X CS 128 was noted for the highest value of 18.67. GCV and PCV values were comparatively lower (9.05 and 13.41 respectively) with medium heritability value (45) and genetic gain of 12.54 and genetic advance of 1.52.

i. Fruit girth

The character range lies between12.38-21.25(Table 9). EC 709119 X IC 410617 recorded lowest value of 12.38 whereas EC 709119 X CS 127 was observed with highest value of 21.25. The GCV and PCV values were found to be 14.04 and 15.79 respectively. Genetic gain and Genetic advance were 25.7 and 4.41 respectively with heritability values of 79.05.

j. Flesh thickness

Significant difference was observed for character and the range was between 1.27 to 2.23. Highest value was observed for EC 709119 X IC 527427 and the lowest was observed for EC 709119 X CS 127. Heritability value was 80.81 along with genetic gain of 39.17 and genetic advance of 0.61.

Table 7. Biometric characters in hybrids

Treatments	Days to male flower anthesis	Days to female flower anthesis	Node at which first male flower emerged	Node at which first female flower emerged	Total number of male flowers
EC 709119 X CS- 127	15.00	25.75	2.75	15.75	41.75
EC709119 X IC 527427	16.75	19.25	2.50	15.75	34.00
EC 709119 X IC 410617	17.75	23.75	3.25	9.50	51.50
EC 709119 X IC 410638	20.50	23.00	2.25	4.25	36.40
EC 709119 X IC 538155	19.25	25.75	4.50	3.25	55.50
EC 709119 X IC 527431	19.25	24.75	2.50	6.50	48.00
EC 709119 X IC 538186	21.50	21.50	9.50	6.25	40.25
EC 709119 X CS 129	20.25	20.25	3.00	5.75	53.50
EC 709119 X CS 128	28.50	32.25	3.50	5.75	56.00
EC 709119 X CS 25	20.00	20.25	3.00	4.75	30.25
EC 709119 X CS 121	23.75	28.50	3.50	5.00	47.50
EC 709119 X CS 123	18.00	23.25	2.75	13.25	30.60
Mean	20.04	24.02	3.58	7.97	43.77
CD (0.01)	1.82	2.95	1.66	2.84	8.22
CD (0.05)	2.45	2.2	1.24	2.12	6.13

Table 7 continued.....

Treatments	Total number of female flowers	Average fruit weight(g)	Fruit length(cm)	Fruit girth(cm)	Flesh thickness(cm)
EC 709119 X CS- 127	36.75	205.45	17.60	21.25	1.27
EC709119 X IC 527427	24.00	164.00	15.42	18.69	2.23
EC 709119 X IC 410617	42.40	179.88	13.97	12.38	1.40
EC 709119 X IC 410638	36.75	80.83	13.12	15.36	1.55
EC 709119 X IC 538155	54.00	180.94	15.79	17.97	1.97
EC 709119 X IC 527431	52.25	101.84	14.81	16.24	1.44
EC 709119 X IC 538186	32.40	183.89	14.58	15.10	1.29
EC 709119 X CS 129	41.50	163.98	16.84	19.94	1.41
EC 709119 X CS 128	50.50	119.17	18.67	17.54	2.08
EC 709119 X CS 25	31.80	161.71	14.68	15.94	1.36
EC 709119 X CS 121	43.25	142.82	14.29	19.63	1.35
EC 709119 X CS 123	37.75	158.91	16.11	15.83	1.30
Mean	40.27	153.62	15.49	17.16	1.55
CD (0.01)	9.822	6.481	3.24	2.40	0.30
CD (0.05)	7.326	4.834	2.42	1.79	0.22

Table 8. Analysis of variance for quantitative characters of hybrids

Treatments	Days to male flower anthesis	Days to female flower anthesis	Node at which first male flower emerged	Node at which first female flower emerged	Total number of male flowers	Total number of female flowers	Average fruit weight	Fruit length	Fruit girth	Flesh thickness
Treatment	48.94**	55.83**	15.33**	64.62**	282.97**	238.77**	4577.7**	10.23**	24.76**	0.46**
Error	1.61	3.83	0.75	2.19	18.27	26.09	11.36	2.85	1.55	0.02
CV	10.55	9.67	24.16	19.21	9.46	11.88	2.16	10.90	7.27	10.15

*significant at 5% level **significant at 1% level

Table 9 : Range, mean, standard deviation, standard error, genotypic coefficient of variation, phenotypic coefficient of variation, heritability, genetic advance and genetic gain of hybrids

Treatments	Range	Mean	SD	SE	GCV	PCV	Heritability (%)	Genetic gain	Genetic advance
Days to male flower anthesis	15.00-23.75	20.04	1.07	0.90	17.16	18.30	87.96	33.16	6.46
Days to female flower anthesis	19.25 – 32.25	24.02	1.71	1.38	15.01	17.08	77.20	27.16	6.52
Node at which first male flower emerged	2.25-9.5	3.58	0.71	0.60	53.33	58.37	83.49	100.39	3.59
Node at which first female flower emerged	3.25-15.75	7.70	1.29	0.91	51.46	54.14	90.33	100.75	7.76
Total number of male flowers	30.25-55.5	45.16	6.42	3.01	18.01	20.33	78.43	32.86	14.84
Total number of female flowers	24-52.25	43.00	9.36	3.60	16.96	20.69	67.22	28.65	12.32
Average fruit weight(g)	80.83-205.45	155.74	7.78	2.41	21.69	21.80	98.98	44.46	69.24
Fruit length(cm)	13.12-18.67	15.49	1.62	1.08	9.059	13.41	45.58	12.59	1.95
Fruit girth(cm)	12.38-21.25	17.16	1.19	0.87	14.04	15.79	79.05	25.71	4.41
Flesh thickness(cm)	1.27-2.23	1.55	0.13	0.11	21.15	23.53	80.81	39.17	0.61

4. 3. Sex ratio of parents, F_1 hybrids and F_2 population

61

Sex ratio of parents, F_1 hybrids and F_2 population was presented in Table No.10.Among parents, highest sex ratio was observed for IC 410638(1.37) followed by CS 25 (1.26) and CS 121(1.26). Lowest sex ratio was observed for IC 527427 (0.6). EC 709119 x IC 538186 exhibited high sex ratio (1.21) among hybrids followed by EC 709119 x CS 25(1.11). The lowest value among hybrids was shown by EC 709119 x CS 129 (0.77).

For F_2 population, highest sex ratio was observed for EC 709119 x IC 527427 (2.00) followed by EC 709119 x IC 410638 and EC 709119 x CS 127 (1.47) in the highest category. In the middle category, EC 709119 x IC 410617 and EC 709119 x IC 410638 exhibited high sex ratio (1.37) whereas the lowest value was given by EC 709119 x CS 129 (0.63). In the lowest category, highest sex ratio was observed in EC 709119 x IC 527431 (0.87) whereas lowest value was observed in EC 709119 x CS 129 (0.44).

4.4. Range of selected characters in F_2 population

Range of selected characters in F_2 population are presented in Table No.11.Days to female flower anthesis, node at which first female flower emerged, total number of male and female flowers were observed for the F_2 population. Among 12 populations, EC 709119 x IC 538186 was found to be promising in producing minimum number of days for female flower anthesis (16-21 days), with minimum number of nodes for female flower emergence (2-9) and with low number of male flowers (21-42) and high number of total female flowers (45-62). Other promising populations were EC 709119 x IC 527431 and EC 709119 x CS 25 which follows the above population.

4.5. Chi- square analysis of promising F_2 populations for gynoecious character

Chi – square analysis was done and presented in Table No.12. Chi – square analysis was done for 4 F_2 populations *viz.*, EC 709119 x CS 127, EC 709119 x IC 410638, EC 709119 x IC 538155 and EC 709119 x CS 129 for 3:1 monohybrid ratio. Among the 12 F_2 populations, only four of them segregated for monoecious and gynoecious character. Hence these populations were subjected to chi – square analysis with a a monohybrid ratio of 3:1 being monoecy dominant over gynoecy. Chi square analysis indicated that, 2 populations *viz.*, EC 709119 x CS 127 anD EC 709119 x IC 410638 fitted to the monohybrid ratio of 3:1 while other 2 populations *viz.*, EC 709119 x IC 538155 and EC 709119 x CS 128 failed to fit into 3:1 ratio.

4.6. Qualitative characters of parents and hybrids

Qualitative characters of parents and hybrids were presented in Table No. 13 and 14. Among the qualitative characters, the character of prime importance were colour of rind at tender harvestable maturity and the presence of bitterness. In parents, the preferred dark green colour of cucumber fruit were shown by IC 538155 and IC 527431 whereas others exhibited in the colour range of light green-green (Table No.13). Cavity was present among all the parents and the sex form of the parents were all monoecious.

For hybrids, the sex form observed was all monoecious and the rind colour of the fruits at harvest maturity ranged from dark green (EC 709119 x IC 538155 and EC 709119 x IC 527431) to light green. Cavity was also present among all the hybrids.

Bitterness was observed variably among parents and hybrids. At initial harvests, bitterness was present among the parents *viz.*, IC

527427,CS 129 and CS 123 whereas none of the hybrids exhibited bitterness during initial harvests. During mid harvests, IC 527427, IC 410638, IC 538155, CS 129 exhibited bitterness. For hybrids in the mid harvests, EC 709119 x IC 538155 and EC 709119 x CS 129 were observed with presence of bitterness. In the later harvests, most of the parents as well as hybrids exhibited bitterness.

4.7. Percentage Disease Intensity for downy mildew disease

Percentage Disease Intensity (PDI) was calculated and presented in Table No.16. PDI was calculated for the parents and F_1 hybrids. Moderate resistance (10.1-25 %) was observed for the parents IC 410617, IC 538155, IC 527431, IC 538186, CS 129 and CS 121(Table No. 17).Among hybrids, EC 709119 x CS 127, EC 709119 X IC 410617, EC 709119 X IC 538155, EC 709119 X IC 538186 and EC 709119 X CS 129 were moderately resistant to downy mildew.

4.8. Incidence of pests and diseases

Incidence of other pests and diseases for parents and hybrids were recorded in Table No.18 and 19. Mild incidence of serpentine leaf miner (*Liriomyza trifoli*) was observed in parents IC 410617,IC 410638 , CS 129, CS 128, CS 121 and CS 123. Incidence caused by fruitfly (*Bactrocera cucurbitae*) was observed to be mild among the parents IC 410617, IC 410638, IC 538155, IC 527431, IC 538186 and CS 129, CS 128, CS 25 and CS 123. Among diseases, leaf spot incidence caused by *Alternaria alternata* was found to be moderate in IC 527431 whereas all other parents exhibited very low incidence.

For hybrids, mild incidence of serpentine leaf miner was observed in EC 709119 x IC 410617, EC 709119 x IC 410638, EC709119 x CS 129, EC 709119 x CS 128, EC709119 x CS 121 and EC 709119 x CS 123. Fruit fly incidence among hybrids were found to be mild in 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 129, EC 709119 x CS 128, EC 709119 x CS 25 and EC 709119 x CS 123. For leaf spot incidence, there was very low incidence among hybrids.

Table 10 : Analysis of sex ratio of parents, F_1 hybrids and F_2 population

Treatments				F_2 population			
Parents	Sex ratio	Hybrids	Sex ratio	Hybrids	Highest	Middle	Lowest
CS 127	0.64	EC 709119 X CS 127	0.88	EC 709119 X CS 127	1.47	1.12	0.60
IC 527427	0.60	EC 709119 X IC 527427	0.88	ECC 709119 X IC 527427	2.00	1.25	0.61
IC 410617	0.91	EC 709119 X IC 410617	1.02	EC 709119 X IC 410617	1.19	1.37	0.59
IC 410638	1.37	EC 709119 X IC 410638	0.80	EC 709119 X IC 410638	1.47	1.37	0.62
IC 538185	0.83	EC 709119 X IC 538155	0.97	EC 709119 X IC 538155	1.45	1.12	0.67
IC 527431	0.62	EC 709119 X IC 527431	1.08	EC 709119 X IC 527431	1.21	1.03	0.87
IC 538186	0.80	EC 709119 X IC 538186	1.21	EC 709119 X IC 538186	2.01	0.78	0.56
CS 129	0.84	EC 709119 X CS 129	0.77	EC 709119 X CS 129	0.83	0.63	0.44
CS 128	0.67	EC 709119 X CS 128	0.90	EC 709119 X CS 128	1.43	1.21	0.75
CS 25	1.26	EC 709119 X CS 25	1.11	EC 709119 X CS 25	0.99	0.78	0.48
CS 121	1.26	EC 709119 X CS 121	0.91	EC 709119 X CS 121	0.83	0.77	0.46
CS 123	0.78	EC 709119 X CS 123	0.98	EC 709119 X CS 123	0.85	0.55	0.51

Table 11 : Range of selected characters in F_2 population

F_2 population	Days to female flower anthesis	Node at which first female flower emerged	Total number of male flowers	Total number of female flowers
EC 709119 X CS 127	18 – 26	3 -12	35 - 40	33 - 50
EC 709119 X IC 527427	16 - 25	9 - 18	23 – 61	20 -52
EC 709119 X IC 410617	18 – 25	6 - 13	30 - 56	32 - 50
EC 709119 X IC 410638	18 - 24	2 - 15	25 - 58	36 - 49
EC 709119 X IC 538155	19 - 26	5 - 17	21 - 61	35 - 59
EC 709119 X IC 527431	18 - 24	3 - 17	30 - 59	31 - 60
EC 709119 X IC 538186	16 - 21	2 - 9	21 - 42	45 - 62
EC 709119 X CS 129	19 - 25	9 -21	23 - 54	27 - 44
EC 709119 X CS 128	18 - 25	9 - 18	21 - 58	32 - 54
EC 709119 X CS 25	16 - 24	4 - 16	27 - 60	41 - 60
EC 709119 X CS 121	18 – 25	10-18	31 - 54	30 - 40
EC 709119 X CS 123	16 - 25	10-18	29 - 50	37 - 61

99

Table 12 : Chi – square analysis of promising population for gynoecy

Treatments	Observed (3:1)		Expected (3:1)		Chi square value		Total
	Monoecious	Gynoecious	Monoecious	Gynoecious	Monoecious	Gynoecious	
EC 709119 X CS -127	17	3	15	5	1.66	0.8	2.46
EC 709119 X IC 410638	18	2	15	5	0.66	1.8	2.46
EC 709119 X IC 538186	10	10	15	5	1.06	3.2	4.26
EC 709119 X CS -128	{9	1	15	5	1.06	3.2	4.26

Table 13. 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 or 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 129	Dense	Monoecious	Black	Black	Present	Green	Orange	Present
CS 128	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	Monoecious	White	Brown	Present	Light green	yellow	Present

Table 14. Qualitative characters of hybrids

Hybrids	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 or absence of cavity
			emergence	senescence				
EC 709119 X CS- 127	Sparse	Monoecious	White	Brown	Present	Light green	yellow	present
EC709119 X IC 527427	sparse	Monoecious	Black	Black	Present	Green	orange	Present
EC 709119 X IC 410617	Dense	Monoecious	Black	Black	Present	Green	Orange	Present
EC 709119 X IC 410638	Sparse	Monoecious	Black	Black	Present	Green	Orange	Present
EC 709119 X IC 538155	sparse	Monoecious	Black	Black	Present	Dark green	Orange	Present
EC 709119 X IC 527431	Dense	Monoecious	Black	Black	Present	Dark green	Orange	Present
EC 709119 X IC 538186	Sparse	Monoecious	Black	Black	Present	Green	Orange	Present
EC 709119 X CS 129	Dense	Monoecious	Black	Black	Present	Green	Orange	Present
EC 709119 X CS 128	Dense	Monoecious	Black	Black	Present	Green	Orange	Present
EC 709119 X CS 25	Dense	Monoecious	Black	Black	Present	Light green	orange	Present
EC 709119 X CS 121	Dense	Monoecious	Black	Black	Present	Greenish white	yellow	Present
EC 709119 X CS 123	Sparse	Monoecious	Black	Black	Present	Green	yellow	Present

Table 15 : Presence of bitterness in parents and hybrids

Parents	Initial harvests(1^{st} – 7^{th})	Mid harvests(8^{th}-11^{th})	Final harvests(from 11^{th})
CS- 127	Absent	Absent	Present
IC 527427	present	Present	Present
IC 410617	Absent	Absent	Absent
IC 410638	Absent	Present	Present
IC 538155	Absent	Present	Absent
IC 527431	Absent	Absent	Absent
IC 538186	Absent	Absent	Present
CS 129	Present	Present	Present
CS 128	Absent	Absent	Absent
CS 25	Absent	Absent	Absent
CS 121	Absent	Absent	Absent
CS 123	Present	Absent	Present
EC 709119 X CS- 127	Absent	Absent	Present
EC709119 X IC 527427	Absent	Absent	Present
EC 709119 X IC 410617	Absent	Absent	Absent
EC 709119 X IC 410638	Absent	Absent	Present
EC 709119 X IC 538155	Absent	Present	Absent
EC 709119 X IC 527431	Absent	Absent	Absent
EC 709119 X IC 538186	Absent	Absent	Present
EC 709119 X CS 129	Absent	Present	Absent
EC 709119 X CS 128	Absent	Absent	Absent
EC 709119 X CS 25	Absent	Absent	Absent
EC 709119 X CS 121	Absent	Absent	Absent
EC 709119 X CS 123	Absent	Absent	Present

Table 16. Percentage Disease Intensity (PDI) of downy mildew in cucumber

Parents		F_1 hybrids	
Genotype	PDI	Hybrid	PDI
CS- 127	89	EC 709119 X CS- 127	23
IC 527427	47	EC709119 X IC 527427	35
IC 410617	13	EC 709119 X IC 410617	12
IC 410638	29	EC 709119 X IC 410638	29
IC 538155	13	EC 709119 X IC 538155	14
IC 527431	17	EC 709119 X IC 527431	27
IC 538186	12	EC 709119 X IC 538186	12
CS 129	24	EC 709119 X CS 129	25
CS 128	45	EC 709119 X CS 128	35
CS 25	33	EC 709119 X CS 25	87
CS 121	20	EC 709119 X CS 121	39
CS 123	34	EC 709119 X CS 123	42

Table 17: Moderately resistant parents and hybrids(10.1- 25%) for downy mildew disease 72

Parents	F_1 hybrids
IC 410617	EC 709119 X CS 127
IC 538155	EC 709119 X IC 410617
IC 527431	EC 709119 X IC 538155
IC 538186	EC 709119 X IC 538186
CS 129	EC 709119 X CS 129
CS 121	

Table 18 : Incidence of pests and diseases in parents

Parents	Serpentine leaf miner	Fruit fly	Leaf spot
CS- 127	Severe	Severe	Very low
IC 527427	Severe	Moderate	Very low
IC 410617	Mild	Mild	Very low
IC 410638	Mild	mild	Very low
IC 538155	Moderate	Mild	Very low
IC 527431	Moderate	Mild	Moderate
IC 538186	Moderate	Mild	Very low
CS 129	Mild	Mild	Very low
CS 128	Mild	Mild	Very low
CS 25	Moderate	Mild	Very low
CS 121	Mild	moderate	Very low
CS 123	Mild	mild	Very low
EC 709119	Severe	severe	Very low

Table 19: Incidence of pests and diseases in hybrids

Parents	Serpentine leaf miner	Fruit fly	Leaf spot
EC 709119 X CS- 127	Severe	Severe	Very low
EC709119 X IC 527427	Severe	Moderate	Very low
EC 709119 X IC 410617	Mild	Mild	Very low
EC 709119 X IC 410638	Mild	mild	Very low
EC 709119 X IC 538155	Moderate	Mild	Very low
EC 709119 X IC 527431	Moderate	Mild	Moderate
EC 709119 X IC 538186	Moderate	Mild	Very low
EC 709119 X CS 129	Mild	Mild	Very low
EC 709119 X CS 128	Mild	Mild	Very low
EC 709119 X CS 25	Moderate	Mild	Very low
EC 709119 X CS 121	Mild	moderate	Very low
EC 709119 X CS 123	Mild	mild	Very low

74

DISCUSSION

5. DISCUSSION

Among the cucurbitaceous group, cucumber is a model for sex expression studies and this feature can easily be manipulated for production of F_1 hybrid seeds. Utilization of gynoecious lines in breeding programme favoured maximum exploitation of heterosis in cucumber. True breeding gynoecious lines used for heterosis breeding produce exclusively pistillate flowers and F_1 very often produces more number of female flowers which resulted in high yield.

True breeding gynoecious lines in cucumbers are reported from University of Wisconsin, Madison, USA. At Indian Agricultural Research Institute, New Delhi, More and Seshadri (1988), attempted to transfer gynoecy into tropical varieties of cucumber and four stable tropical gynoecious lines viz., 87-304-6, 87-316, 87-319-12 and 87-338-15 were generated. These lines were further used in the development of tropical F_1 hybrids at IARI and MPKV Rahuri. Two hybrids viz., Heera and Shubhra were also released from Kerala Agricultural University exploiting gynoecy. In tropical conditions, gynoecy in cucumber did not get much attention due to the unstable nature of temperate gynoecious lines along with heavy incidence of downy mildew.

In the present study, F_1 hybrids were generated by crossing temperate gynoecious line (EC 709119) with monoecious genotypes and F_2 generations were evaluated to develop tropical gynoecious lines in salad cucumber. Three gynoecious characters *viz*., days to female flower anthesis, node at which first female flower emerged and total number of female flowers were taken as a standard to identify and select the gynoecious lines. Sex ratio, heritability studies and chi-square analysis were done to identify true breeding and stable tropical gynoecious lines suitable for high temperature and long photo periodic conditions. The main details of each experiment were as follows:

5.1. Evaluation of parental F_1 and F_2 population

Parents and F_1 hybrids were subjected to analysis of variance and significant differences were observed for all the quantitative characters. Airina *et*

al (2013) also observed significant difference between characters among parents and F_1 hybrids of salad cucumber. Parents exhibited wide range (0-29.75) for days to male flower anthesis compared to hybrids (15.00-23.75). GCV and PCV values were lower for hybrids. High heritability and genetic gain values for this character indicate the scope of improving the character through selection. Kumar *et al* in 2008 also reported improvement in earliness of male flower production through selection.

Days to female flower anthesis is an important trait governing gynoecy and early flowering types are preferred in the breeding programme. As in the case of male flower anthesis, here also parents exhibited wide range (14.5 – 32.25) when compared to hybrids (19.25-32.25). GCV and PCV values were comparatively lower. But the heritability value with moderate genetic gain indicates the scope of selection which is akin to the observations made by Kumar *et al* (2012). None of the hybrids exhibited earliness to female flower when compared to gynoecious line EC 709119.

Node at which first male flower emerged is yet another important character in the selection for true gynoecious line. There was wide range for this character among parents and hybrids. GCV and PCV values were comparatively lower among parents and hybrids. But high heritability value along with high genetic gain was noted as observed by Kumar *et al.*, (2013). Hybrids initiated early male flower compared to parents which is not a preferable trait in developing gynoecious line. No male flower was observed in the gynoecious line EC 709119.

Early node to form first female flower contribute to gynoecy. In parents, female flower emerged at the nodes in the range of 5.75- 19.25, which was very late as compared to hybrids (5-15.75). High GCV and PCV along with high heritability was observed for this trait according to the observations made by Kumar *et al.* (2013). The gynoecious line produced female flowers at minimum number of nodes as compared to other parents as well as hybrids.

Total number of male flowers were observed to be nil in the case of gynoecious line EC 709119. But among parents, CS 129 exhibited highest number (64) of male flowers as an indication of monoecy. Whereas in hybrids, the number of male flowers were observed to be low in comparison to parents. This observation was found to be true to the findings of Hossain *et al.* (2012). High heritability was noticed for this character in both parents and hybrids.

Total number of female flowers is a strong indicator of gynoecy present among these treatments. Highest number (67) of female flowers were noted in the gynoecious line EC 709119 among parents and hybrids. GCV and PCV values were moderate for this character for hybrids as well as parents in concordance with the observations of Arunkumar *et al.* (2011). Heritability values were high indicating chances of selection for improving the trait which was in line with the finding of Zhang *et al.*(2003).

Average fruit weight exhibited high heritability with moderate genetic advance as observed by Zhang *et al.*,(1997). GCV and PCV values were moderate among parents and hybrids. Fruit weight was more in CS 121 and EC 709119, which were on par (150.5). High heritability was observed for this character with high genetic advance which indicates scope for improvement through selection.

Fruit length was observed with high heritability (86.60) with moderate genetic advance. Low GCV and PCV values were observed for parents in this character with moderate genetic gain which implies the action of additive gene action as recorded by Kumar *et al.*,(2008).

Fruit girth and flesh thickness was observed with moderate heritability as compared to parents. Hybrids exhibited more flesh thickness with respect to fruit length and weight. Moderate GCV and PCV values were indicative of non additive gene action which can be improved through heterosis breeding.

Promising fruit character for salad cucumber from consumer perspective is found to be 150-200 g average fruit weight and 15-20 cm length fruit weight

coupled with green fruit rind at harvestable stage. These favourable characters were reported in parents *viz.*, IC 527427 and EC 709119. Among hybrids, the promising ones were EC 709119 x CS 127, EC 709119 x IC 527427, EC 709119 x IC 410617, EC 709119 x IC 538155, EC 709119 x IC 538186, EC 709119 x CS 129 and EC 709119 x CS 123.

5.2. Evaluation of F_2 population for gynoecious character

F_2 population was evaluated for the character governing gynoecy *viz.*, days to female flower anthesis, node at which first female flower emerged, total number of male flowers and total number of female flowers produced. A true gynoecious line should produce only female flowers throughout the growth period as well as should produce female flowers early with minimum node (Hanchinamani *et al.*, 2011). The F_2 population EC 709119 x IC 538186 was observed as most promising with respect to these characters and some of the plants in F_2 population produced upto 62 female flowers.

Among the 12 F_2 populations, the most promising population was found to be EC 709119 x IC 538186, where some of the plants took only 21 days to form female flower (Table 11).The same population also took minimum number of nodes to form female flower (2). Some of the populations took upto 21 nodes for forming female flower (EC 709119 x CS 129). Maximum number of female flowers were also produced by the population (EC 709119 X IC 538186) and the range was found to be 45- 62. The same population produced minimum number of male flowers which was found to be in the range of 21- 42.

5.3. Analysis of sex ratio of parents, F_1 hybrids and F_2 population

Among the monoecious parents used in the crossing programme, parent IC 538186 exhibited highest sex ratio (1.376) whereas IC 527427 recorded the lowest sex ratio of 0.67. Among the F_1 hybrids, EC 709119 x IC 538186 exhibited highest sex ratio and the lowest (0.8) one was exhibited by EC 709119 x IC 410638. The F_2 population was classified into 3 groups based on sex ratio *viz.*,highest, middle and lowest for each population. The highest sex expression

among the F_2 population found to be exhibited by EC 709119 x IC 538186 (2.01). Much variation was observed among 12 F_2 population for the range of sex ratio and in the highest class, lowest sex expression was expressed by two populations *viz.*, EC 709119 x CS 129 and EC 709119 x CS 121(0.83). The lowest sex expression values were found to be in the range of 0.44 to 0.87. Variation for the sex ratio was found to be minimum for the F_2 population EC 709119 x IC 527431.

Sex ratio is an important trait in controlling gynoecy and plants with high sex ratio is always preferred in breeding programme (Basavarajeshwari *et al.*, 2014**).** The parents having high sex ratio failed to transmit the same to its hybrids. However, parent IC 538186 which was having a moderate sex ratio of 0.8 produced high value in F_1 hybrid (1). In F_2, the progenies of the same cross surpasses all the population. High heritability values were reported for number of female flower produced in cucumber **(**Basavaraajeshwari *et al.*, 2014**).** A total of 4 crosses exhibited a sex ratio above 1 and in the F_2 population, 2 populations *viz.*, EC 709119 X IC 527427 and EC 709119 x IC 538186 exhibited a sex ratio of more than 2, which indicates the scope of improvement of sex ratio through selection in advanced generations.

5.4. Genetic analysis of gynoecy based on chi- square test

In cucumber, seven sex types were reported *viz.*, androecious(only male flowers), gynoecious(only female flowers), monoecious(male flowers at the base and female flowers at the top of the main stem), hermaphroditic(only bisexual flowers), andromonoecious (male and bisexual flowers), gynomonoecious (female and bisexual flowers) and trimonoecious (male, female and bisexual flowers) (Shifriss,1961 and Liu *et al.*, 2008). Several authors described dominant as well as recessive genes in controlling sex determination in cucumber **(**Mibus and Tatlioglu, 2004; Witkowicz *et al., 2003***).** 'F', 'M', 'A' are major genes controlling sex expression in cucumber plants. The gene F/f controls the gynoecious trait with F gene being dominant. However, interaction of A gene and F gene regulates the expression of monoecious character. In the present study, all the F_1 hybrids were

found to be monoecious in nature though degree of monoecy with respect to the number of female and male flowers produced varied across the hybrids. Predominant monoecious trait in F_1 hybrids indicates the dominant nature of monoecious character and recessive nature of gynoecious character.

The 12 F_2 population evaluated for gynoecious trait were classified into monoecious and gynoecious trait. Only four F_2 population produced gynoecious plants and subjected to chi- square test. Since the F_1 were all monoecious, the F_2 population was subjected to chi square test with monohybrid ratio of 3:1. Among the four population tested, 2 populations fit to the 3:1 ratio of monoecious vs gynoecious character (Table 12). Absence of goodness of fit to the 3: 1 ratio of other two populations may be due to the low number of F_2 plants used for evaluation or the different kind of genetic control governing gynoecy inherited from the male parent. Among the F_2 population, EC 709119 x IC 538186 produced maximum number of true gynoecious plants (10) whereas eight F_2 populations failed to produce even one true gynoecious plant.

Expression of monoecy by all the F_1 hybrids indicate the dominant nature of monoecious character in salad cucumber. However, varying frequency of monoecious and gynoecious plants in the F_2 population indicate the different nature of gene interaction which essentially depends on the type of male genotypes involved. Presence of recessive gene governing gynoecy (gy) is already reported in cucumber (Kubicki, 1974). The population derived from the cross, EC 709119 x IC 538186 could be selected for developing true breeding stable gynoecious line for future breeding programme.

5.5. Analysis of parents, F_1 hybrids and F_2 population for downy mildew incidence

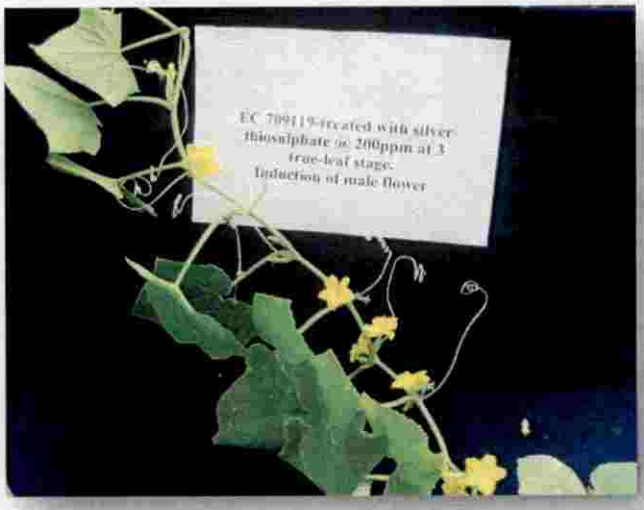
Downy mildew incidence in cucumber was scored according to the procedure adopted by earlier workers (Pitchaimuthu *et al.*, 2012)

Parents, F_1 hybrids and F_2 population were analysed under natural infection for downy mildew incidence and PDI was estimated and presented in

Table 16. Among the parents, EC 709119 X IC 538186 exhibited minimum infection (12) which falls under the category of moderate resistance. EC 709119 x IC 410617, EC 709119 x IC 538155, EC 709119 x IC 527431 and EC 709119 x CS 121 were found to be moderately resistant to downy mildew under natural infection. Among the F_1 hybrids, EC 709119 x CS 127, EC 709119 x IC 410617, EC 709119 x IC 538155 and EC 709119 x IC 538186 were found to be moderately resistant.

5.6. Analysis of qualitative characters

Parents as well as hybrids were evaluated for important qualitative characters including sex form as well as presence or absence of bitterness. Bitterness is an important quality character which was absent in most of the parents except three during initial harvest. However during later harvests, five parents were found to be bitter indicating the role of physiological stage and maturity in controlling the bitterness of cucumber. The crosses involving parents prone to bitterness were found to be bitter during later harvest, though all crosses were free of bitterness during initial stage.



Induction of male flowers in temperate gynoecious line EC 709119 treated with silver thiosulphate

Plate 3 : Temperate gynoecious line EC 709119 grown under rainhelter

Plate 4 : Promising F_2 population EC 709119 x IC 538186 with early female flowers

SUMMARY

Cucumber belonging to Cucurbitaceae family is popularly known for its peculiar sex mechanism which can be profitably utilized for the production of F_1 hybrids. Utilizing gynoecious lines has made the efforts fruitful in generating maximum vigour associated with hybrids. True breeding gynoecious lines produce pistillate or female flowers only at every node is the necessary condition for female parents in F_1 hybrid seed production. Several temperate and tropical gynoecious lines were used in the production of F_1 hybrids successfully at various institutes.

The quantum of work done on this behalf in India was optimum but the unavailability, unstable nature of these lines and susceptibility to different fungal diseases by the temperate gynoecious lines like EC 709119 prompt for development of more stable gynoecious lines suitable for tropical and humid conditions. Being a high value vegetable, development of tropical gynoecious lines can be effective for development of hybrids suitable for both rainshelter and polyhouse conditions.

The present study 'Development of tropical gynoecious lines in cucumber (*Cucumis sativus* L.) was carried out at Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during August - November 2014 to February – May 2015 to evaluate the F_1 hybrids and their F_2 population for identifying stable tropical gynoecious lines of salad cucumber.

Experimental material consisted of 12 monoecious cucumber genotypes, collected from different parts of the country and a gynoecious inbred EC 709119 introduced from USA. During the first season, evaluation of F_1 hybrids and their parents were conducted under rainshelter conditions. In this experiment, maleness was induced on the temperate gynoecious line EC 709119 by spraying silver thiosulphate @ 200 ppm at 3 true leaf stage. Selfing of the F_1 hybrids were done to generate the F_2 population.

In the second season, evaluation of F_2 population generated by selfing F_1 hybrids were evaluated along with 12 F_1 hybrids and 13 parents including the temperate gynoecious line EC 709119. Three gynoecious characters viz., days to female flower anthesis, node at which first female flower emerged and total number of female flowers were recorded to identify gynoecious lines along with assessment of different diseases and pests to notify resistance.

Significant difference was observed for all the characters observed in F_1 hybrids and parents. High heritability with moderate genetic advance was noted for all the characters observed except for fruit parameters like fruit length, fruit girth and flesh thickness. Among the monoecious parents used in the crossing programme, parent IC 538186 exhibited highest sex ratio whereas IC 527427 recorded the lowest sex ratio. The gynoecious line EC 709119 produced some male flowers during summer months which is an indicator of its unstable nature of gynoecious sex expression. Among the F_1 hybrids, EC 709119 x IC 538186 exhibited highest sex ratio and the lowest one was exhibited by EC 709119 x IC 410638. The F_2 population was classified into 3 groups based on sex ratio *viz.*, highest, middle and lowest for each population. The highest sex expression among the F_2 population was exhibited by the population generated from the cross EC 709119 x IC 538186. Variation for the sex ratio was found to be minimum for the F_2 population from EC 709119 x IC 527431.

EC 709119 x IC 538186 was the most promising F_2 population evaluated for gynoecious characters. Few of the plants produced female flowers at minimum number of days. Maximum number of female flowers and minimum number of male flowers were also produced by the population EC 709119 x IC 538186.

Out of 12, only 4 F_2 populations produced gynoecious plants and these were subjected to chi- square test with monohybrid ratio of 3:1 hypothesising monoecy dominant over gynoecy. Out of the 4 populations, 2 populations fitted to the 3:1 ratio of monoecy vs gynoecy. Other two populations did not follow 3:1 ratio. Among the F_2 populations, EC 709119 x IC 538186 produced maximum

number of true gynoecious plants. Eight F_2 populations failed to produce a single true gynoecious plant indicating the dominance of monoecious trait in cucumber.

The varying frequency of monoecy and gynoecy among the F_2 populations indicates different gene interaction involved. This involves the dependence of male monoecious parents. Predominant monoecious trait in F_1 hybrids indicates the dominant nature of monoecious character and recessive nature of gynoecious character. Present study confirms the recessive nature of gynoecious expression in cucumber. The population derived from the cross, EC 709119 x IC 538186 can be selected for developing as a true and stable gynoecious lines for future studies.

Downy mildew incidence for different parents and hybrids were noted and PDI was calculated. Among the parents, IC 538186 exhibited minimum infection which falls under the category of moderate resistance. The hybrids, EC 709119 x IC 410617, EC 709119 x IC 538155, EC 709119 x IC 527431 and EC 709119 x CS 121 were found to be moderately resistant to downy mildew under natural infection.

Parents as well as hybrids were evaluated for important qualitative characters including sex form as well as presence or absence of bitterness. Bitterness is an important quality character which was absent in most of the parents except three of them during initial harvest. However during later harvests, five parents were found to be bitter indicating the role of physiological stage and maturity in controlling the bitterness of cucumber. The crosses involving parents prone to bitterness were found to be bitter during later harvest, though all crosses were free of bitterness during initial stage. Fruit cracking was found to be absent. Present investigation proved the scope of developing tropical gynoecious line from temperate lines by crossing with potential monoecious lines and making selection in advance segregating generations for gynoecy.

REFERENCES

Airina,C.K., Pradeepkumar, T., George,T.E., Sadhankumar, P.G. and Krishnan, S. 2013. Heterosis breeding exploiting gynoecy in cucumber (*Cucumis sativus* L.). *J. Trop. Agri.* 51 (1-2) : 144-148.

Aleksandrova, M. 1988. Results of breeding heterotic hybrid varieties of greenhouse cucumber. *Rasteniev"dni Nauki* . 25(5) pp. 60-63

Aleksandrova, M., Ovoshcharstvo,V. and Gradinarstvo, I. 1988. Bulgarian heterotic greenhouse cucumber varieties . *Konservna Promishlenost.* 69 (3) pp. 19

Allard, R.W. 1960. *Principles of plant breeding.* John wilye and sons Inc., NewYork. 89 – 98 p.

Arunkumar K.H., Patil, M.G., Hanchinamani,C.N., Shanker Goud,I and Hiremath, S. V. 2011.Genetic relationship of growth and development traits with fruit yield in F_2 population of BGDL x Hot season of cucumber (*Cucumis sativus* L.) *Karnataka J. Agric. Sci.*, 24 (4) : 497-500.

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

Barnes, W. C. 1987. Development of disease resistant hybrid cucumbers. *Proc. Amer. Soc. Hort. Sci.* 89 : 390 -393.

Basavarajeshwari., Mulge, R., Nagaraja, K. S., Srikanth, L. G., Raveendra, Y. C.,Mahamad Toufeeq Husain Naik And Harsha Vardhan Gowda, V.2014.Genetic Variability, Heritability and Genetic Advance for Yield and Yield Parameters and Fruit and Seed Quality Parameters in Cucumber (*Cucumis sativus* L.).*Trends in Biosciences* .7(15): 1965-1967.

Brar, P.S., Singh, G., Singh, M. And Batth, G. S. 1986. Combining ability for yield and its attributing traits in cucumber. *Crop Improv.* 38 : 189 – 190.

Budgujar, C. D. And More, T.A. 2002. Offseason performance of selected tropical gynoecious cucumber hybrids grown under different regimes. *S. Indian Hort.* 52: 97-103.

Budgujar, C. D.; More, T. A. 2004. Estimation of average degree of dominance of genes for yield and its components in cucumber (*Cucumis sativus* L.). *S. Indian Hort.*e 52 (1/6) pp. 89-96.

Burton, G.W. 1952. Quantitative inheritance in grasses. *6th Int. Grassld. Cong. Proc.* 1: 277 – 283.

Burton, G.W. and Devane, E.M. 1953. Estimation of heritability in tall fescue (*Festica arundinaceae*) from replicated clonal material. *Agron. J.* 45 : 478-481

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.

Chen. H. M., Tian, Y., Lu, X. G., and Liu, X. H. 2011. The inheritance of two novel subgynoecious genes in cucumber (*Cucumis sativus* L.). *Scientia Hort.* 127: 464-467.

Das, S., Maurya, K. R. And Choudhary, D. N. 2013. Performance of cucumber genotypes under summer and rainy seasons. *J. Appl. Biol.* 13 : 51 -53.

Decandolle, A. 1886. Origin of cultivated plants. New York, USA.268 p.

Diola, V., Orth, A. I. And Guerra, M.P. 1986. Reproductive biology and varietal performance of Kecskeméti Livmé and Linda varieties. *Horticultura Brasileira.* 26 : 30 – 34.

Dogra, B. S., Rostogi, K.B. and Kumar, A. 1997. Exploiation of hybrid vigour in cucumber (*Cucumis sativus* L.). *Indian J. Hort.* 54 : 261 -264.

Fang, J. M. 2006. Sex determination in the monoecious species cucumber is confined to specific floral whorls. *Plant Cell* . 13: 481–493.

Fang. G. X., Ping, Z.S., Ye, W., and Qing, X.C. 2010. A new cucumber hybrid 'Zhongnong 29'. *Acta Hort.* 37 (10) : 1709-1710.

Feng, S. T., Hui, F., Li, L. Y., and Yong, Z. J. 2011. A new cucumber F_1 hybrid - 'Lvyuan No.4' . *China Vegetables.* 10 : 97-99.

Gen, G. Z., Zhi, Y. G., Wei, Y., and Hua.Y. L. 2014. A new fruit cucumber F_1 hybrid - 'Yuexiu No. 3'. *China Vegetables* . 8: 47-48.

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, C.N., Patil M. G., Dharmatti, P.R. and Mokashi, A.N. 2011. Studies on heritability and genetic advance in cucumber (*Cucumis sativus* l.). *Crop Res.* 41 (1, 2 and 3): 160-163.

Hossain, M. F., Rabbani, M.G., Hakim, M.A., Amanullah, A.S.M., and Ahsanullah, A.S.M. 2010. Study on variability character association and yield performance of cucumber (*Cucumis sativus* L.*) Bangladesh Res. Publi. J.* 4(3): 297-311.

Jeffrey, C. 1980. A review of the Cucurbitaceae. *Botanical J. Linnean Soc.* 81(3):23-247.

Johnson, H. W., Robinson, H.F. and Comstock R.E. 1955. Estimate of genetic and environmental variability in soyabean. *Agron. J.* 47: 314-318.

Joseph, H. Kirkbride. 1993. *Biosystematic Monograph of the Genus Cucumis(Cucurbitaceae): Botanical Identification of Cucumbers and Melons.* Parkway publishers Inc. 159 p.

Juan, F.X., Yan, Y., Xu, H., and Fang, G.X .1994. Breeding the new cucumber cultivar Zhong Nong 2. *China Vegetables* . 6: pp. 1-3.

Juan., F. X., Yan, Y., Xu, H., and Fan, G. X. 1995. Selection of gynoecious lines and their hybrids with different ecotypes in cucumber (*Cucumis sativus*). *Acta Hort.* 13: 392-397.

Jun, M, I., Jian, W.Y., Rong, Z.L., and Long, W. C. 2014. A new cucumber F_1 hybrid - 'Jingyan 207'. *China Vegetables* . 11: 45-47.

Jun.H. J., Di. C. B and Ping, D. 2009. A new European type fruit cucumber F1 hybrid - 'Biyu No. 2'. *China Vegetables* . 2 : 74-75.

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. 1994. Evaluation of cucumber genotypes for yield and qualitative traits. *Himachal J. Agric. Res.* 29 : 43-47.

KAU News [Kerala Agricultural University]. 2015. KAU press, Mannuthy, 8pp.

Khristova, B., 1993. Sex determination in cucumber (*Cucumis sativus*) as a model system for molecular biology. *Plant Sci.* 80: 39–47.

Kubicki, B. 1969. Investigation on sex determination in cucumber (*Cucumis sativus* L.). *Genet Pol.* 10: 69-86.

Kubicki, B., 1974. New sex types in cucumber and their uses in breeding work. In: Able, S.T. (Ed.), XIX *International Horticultural Congress*. 1974 September 11–18, Warszawa, pp. 475–485.

Kumar, A., Kumar, S., and Kumar, A. P. 2008. Genetic variability and characters association for fruit yield and yield traits in cucumber. *Indian J. Hort.* 65(4): 423-428.

Kumar, R., Thakur, K.S., Dogra, B. S., Kumar, S., and Dharminder Kumar. 2012. Estimation of Genetic Variability and Divergence for Fruit Yield and Quality

Traits in Cucumber (*Cucumis Sativus* L.) in North-Western Himalayas. *Universal J. Plant Sci*. 1(2): 27-36.

Le.H. H., Run, C., and Song, P. J. 2013. Breeding of new cucumber F_1 hybrid "Shenlv03". *J. Sanghai Jiaotong University – Agri. Scie* . 31 (2): 30-33.

Lush, J. L. 1949. *Animal breeding plans*. Lown state University Press, Annes, 473 p.

Meshcherov, Ė. T. And Malychenko, P. 1984. New cucumber forms. *L. Imeni N. I. Vavilova*. 140 :71-73.

Mibus, H., and Tatlioglu, T., 2004. Molecular characterization and isolation of the F/fgene for femaleness in cucumber (*Cucumis sativus* L.). *Theor. Appl. Genet.* 109: 1669–1676.

Mikhov, A. S., Aleksandrova, M. P. And Petkkova, T. 1981. Breeding varieties of small-fruited cucumber for mechanical harvesting. *Kartofel' i Ovoshchi* .11 : 35-36.

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

More, T.A. and Seshadri, V. S. 1988. Development of tropical gynoecious lines in cucumber. *Cucubt. 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.

More, T. A., Budgujar, C. D., Nishimura, S., Ezura, H., Matsuda, T., and Tazuke, A. 2002. Isolation of parthenocarpic tropical gynoecious lines in Cucumber (*Cucumis sativus*). *Acta Hort*. 588: 255-260

NBPGR [National Bureau of Plant Genetic Resources]. 2002. *Minimal Descriptor of Agri – Horticultural Crops.* Pusa Campus, New Delhi, 800 p.

Nienhuis, J., Lower, R. L., Pharr, D. M. 1979. The effect of various graft combinations of gynoecious and monoecious cultivars of *Cucumis sativus* on the flowering response of *Cucumis hardwickii*. *Hort. Sci*.14 (3) : 435p.

Nienhuis, J., Lower, R. L., Miller, C. H .1984. Effects of genotype and within-row spacing on the stability of sex expression in cucumber. *Hort Sci.* 19(2) 273-274pp.

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.

Om, Y. H., Hong, K. H., Oh, D. G., and Kwack, S. N. 1992. Breeding of gynoecious cucumber inbreds 'Wonye 501' and 'Wonye 502'. *Acta Hort.* 34 (1) : 1-4

Peterson, C.E. and Anhder, L. D. 1960. Induction of staminate flowers on gynoecious cucumber with gibberelin. *Science.* 131 : 1673 – 1674.

Peterson, C. E., Staub, J. E., Palmer, M., and Crubaugh, L.1986. Wisconsin 2843, a multiple disease resistant cucumber population. *Hort. Sci.* 20 (2): 309-310.

Pitchaimuthu, M., Souravi, K., Ganeshan, G., Sonthosh kumar, G., and Pushpalatha. R. 2012. Identification of sources of resistance to powdery and downy mildew diseases in Cucumber [*Cucumis sativus* (L.). *Pest Managt. in Horti. Ecosystems.* 18(1): 105-107.

Rajkumar, G., Kalloo, G., and Pandey, P. K. 1995. Resistance in cowpea to *Pseudocercospora. Paper presented in National symposium on Recent Developments in Vegetable Improvement.* p 23.

Robinson, R.W. 1987. Morphactin-induced parthenocarpy in the cucumber. *Science.* 171: 1251–1252.

Sanjay Kumar, Yadav,Y. C., Bisen, B., and Dixit, S. K .2009. Genetic variability, heritability and genetic advance for some traits in cucumber (*Cucumis sativus* L.). *Veg. Sci.* 36(2) : 220-221.

Scurtu, M. And Scurtu, I. 1995. Utilization of sex expression in cucumber for the production of F_1 hybrids. *Acta Hort.* 13 : 59-66.

Sharma, J. R. 1988. *Statistical and biometrical techniques in plant breeding.* New Age International Ltd., NewDelhi. 430 p.

Sharma, A. K. and Vidyasagar . 2001. Development and evaluation of cucumber hybrids in the hills of Himachal Pradesh. *J. Hill Res.* 14 (2): 101-103 ,

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

Shawaf, I., and Baker, L. R.1981. Inheritance of yield in parthenocarpic hybrid pickling cucumbers. *HortSci.* 13 (3): pp 355.

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

Shifriss, O., 1961. Sex control in cucumbers. *J. Hered.* 52: 5–12.

Snedecor, G. W., and Cocharan, W. G. 1968. *Statistical methods.* Oxford and IBH publishing Co. 593p.

Stankovic, D. J., Pharr, D.M., Lower, R.L., 1992. Some morphogenic differences between monoecious and gynoecious cucumber seedlings as related to ethylene production. *Plant Physiol.* 55: 352–355.

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

Staub, J. E. and Peterson, C. E. 1986. Comparisons between bacterial wilt resistant and susceptible gynoecious cucumber lines and F1 progeny. *Hort. Sci.* 21(6) : 1428-1430.

Staub, J. E., Bacher, J., and Crubaugh, L. 1986. Problems associated with the selection of determinate cucumber (*Cucumis sativus* L.) plant types in a multiple lateral background.*Cucurbit Genet. Coop. Rpt.* 18:7-9.

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. 30: 407 – 412.

Tazeen M., Nadia K. And Farzana, N.N. 2009. Heritability, phenotypic correlation and path coefficient studies for some agronomic characters in synthetic elite lines of wheat. *J. Food, Agri. Environ.* 7(3-4): 278-282.

Tolla, G. E. and Peterson, C. E. 1979. Comparison of gibberellin A4/A7 and silver nitrate for induction of staminate flowers in a gynoecious cucumber line.. *HortSci.* 14 (4) : 542-544.

Ullah, M. Z., Hasan, M. J., Chowdhury, K. A., Saki, I. and Rahman, M.A. 2010. Genetic variability and correlation in exotic cucumber(*Cucumis sativus* L.) varieties. *Bangladesh J. Pl. Breed. Genet.* 25(1): 17-23.

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

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.

Wheeler, B. E. J, 1969. *An introduction to Plant Disease*. John wiley and Sons Ltd, London, p.301.

Witkowicz, J., Czyk-Wochniak, U, E., Przybecki, Z., 2003. AFLP marker polymorphism in cucumber (*Cucumis sativus* L.) near isogenic lines differing in sex expression. *Cell. Mol. Biol. Lett.* 8: 375–381.

Yan, Z. X., Wei, Q. Z., Ming, X., Ju, Z.Y., Tao, W., and Guo, W. X. 2013. A new cucumber F_1 hybrid - 'Dongnong 810'. *China Vegetables.* 24 : 73-75.

Yang, S. F. 1980. Regulation of ethylene biosynthesis. *Hort. Sci.* 15: 238-243.

Zhang, C. E., Knopf, R.R., and Trebitsh, T., 2003. The female-specific Cs-ACS1G gene of cucumber: Acase of gene duplication and recombination between the non-sex-specific 1-aminocyclopropane-1-carboxylate synthase gene and a branched-chain aminoacid transaminase gene. *Plant Cell Physiol.* 47: 1217–1228.

Zhang, C. E., Qu, P., Zhou, Z., Zhang, X., Ji, Z., 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.

91

DEVELOPMENT OF TROPICAL GYNOECIOUS LINES IN CUCUMBER (*Cucumis sativus* L.)

By

Karthika A. K.

(2013-12-101)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Science in Horticulture

(OLERICULTURE)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Olericulture

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR – 680656

KERALA, INDIA

2016

Abstract

The present study 'Development of tropical gynoecious lines in cucumber (*Cucumis sativus* L.) was carried out at Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during August - November 2014 and February – May 2015 to evaluate the F_1 hybrids and their F_2 population for identifying stable tropical gynoecious lines of salad cucumber.

Twelve hybrids produced by crossing gynoecious line EC 709119 with selected tropical monoecious parents were evaluated for gynoecy under rainshelter. Observations on important quantitative and qualitative characters were recorded. These hybrids were selfed to generate F_2 population. F_2 population was evaluated for expression of gynoecious character, *viz.*, days taken for female flower anthesis, node at which first female flower emerged and total number of female flowers. The data was subjected to analysis of variance and variability among the genotypes was calculated. Most of the characters exhibited high heritability except for fruit parameters like fruit length, fruit girth and flesh thickness.

For gynoecy F_2 population from the cross EC 709119 x IC 538186 was observed as the most promising one. This population took only minimum days to form female flower and took minimum number of nodes to form female flower with highest number of female flowers and minimum male flowers. Sex ratio was estimated for parents, F_1 hybrids and F_2 population. Some of the parents having high sex ratio failed to transmit the same to its hybrid progenies. Among the parents, IC 538186 exhibited highest sex ratio. The highest sex ratio among the F_2 population was for EC 709119 x IC 538186. Two populations viz., EC 709119 x IC 527427 and EC 709119 X IC 538186 exhibited a sex ratio of more than 2.

The 4 F_2 population evaluated for gynoecious trait were classified into monoecious and gynoecious character and tested for goodness of fit based on chi square test with monohybrid ratio of 3:1 being monoecy dominant over gynoecy. Out of the 4 populations, 2 populations were found

to express significant value and fit in 3:1 ratio for dominant monoecious trait. The other 2 populations failed to fit in the 3:1 ratio.

Bitterness was an important quality character which was absent in most of the parents except three of them during initial harvest. The crosses involving parents prone to bitterness were found to be bitter during later harvest, though all crosses were free of bitterness during initial stage. During later harvests, five parents were found to be bitter.

Downy mildew incidence on parents and F_1 hybrids were analyzed and Percentage of Disease Intensity (PDI) was estimated. Among parents, IC 538186 exhibited minimum infection and falls under the category of moderate resistance. Hybrid, EC 709119 x IC 538186 exhibited minimum infection and falls under the category of moderate resistance.

Among 12 F_2 populations, EC 709119 x IC 538186 produced maximum number of true gynoecious plants whereas eight F_2 populations failed to produce even one true gynoecious plant. This population also exhibited moderate resistance against downy mildew disease and could be selected for developing true breeding stable gynoecious line for future breeding programme. Present investigation proved the scope of developing tropical gynoecious line from temperate lines by crossing with potential monoecious lines and making selection in advance segregating generations for gynoecy.

APPENDIX 1

100

Data on weather change in COH, Vellanikkara campus from 03/08/14 to 15/12/15

S. No.	Date	Maximum Temperature	Minimum temperature	Humidity	Wind speed(km/h)
1	03/08 – 09/08	33.8	23.1	91	1.9
2	10/08 – 16/08	34.2	22.7	85	3.7
3	17/08 – 23/08	33.12	22.6	78	2.5
4	24/08- 30/08	23.8	21.03	86	5.5
5	01/09-07/09	34.15	22.36	85	4.3
6	08/09- 14/09	31.20	24.8	73	4.0
7	15/09- 21/09	31.8	27.8	91	2.3
8	22/09-28/09	30.2	26.33	90	5.1
9	29/09- 04/10	30.5	21.23	88	5.3
10	05/10-12/10	30.8	23.6	84	4.2
11	12/10-18/10	28.9	24.7	82	4.01
12	19/10-25/10	32.2	30.2	74	3.98
13	26/10-01/11	31.6	30.6	77	3.3
14	02/11-08/11	31.2	29.5	78	2.5
15	09/11-15/11	30.8	28.7	92	2.7
16	16/11-22/11	30.87	25.6	90	1.9
17	23/11-01/12	29.2	24.78	90	1.8
18	02/12-08/12	28.4	22.31	85	1.00
19	09/12-15/12	28.78	24.38	84	1.28