GENETIC VARIABILITY AND HETEROSIS IN CUCUMBER (*Cucumis sativus L.*)

By

GAYATHRI. K.

THESIS

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DECLARATION

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

Vellayani
18-09-1997

GAYATHRI. K.

CERTIFICATE

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Dr. M. ABDUL VAHAB
Chairman, Advisory Committee
Associate Professor
Department of Horticulture
College of Agriculture
Vellayani

Vellayani,
18-09-1997

APPROVED BY

Chairman:

Dr. M. ABDUL VAHAB
Associate Professor
Department of Horticulture
College of Agriculture
Vellayani

Members:

Dr. G. SREEKANDAN NAIR
Professor and Head
Department of Plantation Crops and Spices
College of Agriculture
Vellayani

Dr. (Mrs.) P. SARASWATHY
Professor and Head
Department of Agricultural Statistics
College of Agriculture
Vellayani

Dr. S. G. SREEKUMAR
Associate Professor
Department of Plant Breeding and Genetics
College of Agriculture
Vellayani

External Examiner

03/11/97
(Dr. D. VEERARAGAVATHATHAM)
Professor of Horticulture
TNAU Coimbatore 3

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GAYATHRI. K.

DEDICATED TO

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INTRODUCTION

1. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is an important warm season vegetable. Originated in India (De Candolle, 1882) it is now grown throughout the world in tropical and subtropical regions. Being one of the most economical cucurbits, cucumber is grown for its tender fruits which are consumed raw, cooked, pickled or processed in other forms. In India, it is mostly consumed raw or cooked and is sold at premium prices in off season. It contains Vitamins B and C. It also possesses medicinal, cosmetic, cooling, tonic and diuretic properties (CSIR, 1950; Yawalkar, 1969).

Despite its economic, medicinal and nutritional values and extensive cultivation and consumption, lack of improved varieties/hybrids with high yielding ability and acceptable quality attributes is one of the major constraints for cucumber production in the country. There is an imperative need for developing varieties/hybrids suited to the agro-climatic conditions of the country in general and Kerala in particular. This calls for a need based crop improvement programme.

Yielding ability, a quantitative trait is of primary importance in cucumber. Although early yield was improved by the introduction of gynoecious lines (Peterson, 1960), total multiple harvest yield was not improved (Wehner and Miller, 1985). The lack of progress for increased fruiting in cucumber might be partially due to the inadequate breeding effort in cucumber compared to other crops or due to a lack of variability for yield (Wehner *et al*. 1989). Transfer of quantitatively inherited characters into commercially adopted cultivars from available germplasm can be an effective way to obtain greater genetic variation and response to selection (Bliss, 1981). Information on genetic variability and components of variation are basic for any crop improvement programme. Being a cross pollinated crop due to monoecy, there exists considerable scope for exploitation of heterosis in cucumber. Identification of specific parental combinations heterotic for economic characters are very important.

Keeping in view of the above aspects, the present investigation was carried out with the following objectives:

i) To study the genetic variability in cucumber for different characters by estimating phenotypic and genotypic coefficients of variation,

ii) To estimate the heritability and genetic advance for different characters,

iii) To study the association between yield and its components by estimating phenotypic, genotypic and environmental correlation coefficients.

iv) To determine the direct and indirect effects of each components on yield by path coefficient analysis.

v) To generate information on combining ability and

vi) To find out the extent of heterosis for different characters in cucumber.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Cucumbers are grown for their tender fruits which are consumed raw, cooked, pickled or processed in other forms. Cucumber improvement programmes have been in practice for more than half a century, but much of the improvement can be attributed to improved cultural practices and incorporation of better levels of disease resistance. The lack of progress in cucumber might be partially due to the inadequate breeding effort in cucumber compared to other crops. Information on genetic variability and components of variation are basic for any crop improvement. Being a cross pollinated crop due to monoecy, there exists considerable scope for exploitation of heterosis in cucumber. The information available on these aspects in cucumber is reviewed under the following two heads

1. Genetic variability
2. Combining ability and heterosis

2.1 Genetic variability

2.1.1 Genetic variability, heritability and genetic advance

Planning and execution of a breeding programme for the improvement of any crop depend to a great extent upon the magnitude of genetic variability existing in a germplasm. Information on genetic variability among the existing stocks provides an opportunity for selecting the divergent parents for hybridization. Selection of parents will be effective only when major part of the variability of the trait is genetic. The existence of very high variability in respect of many vegetative and productive characters was observed by many workers in cucumber.

Variability available in a population could be partitioned into heritable and nonheritable components with the aid of genetic parameters such as genotypic and phenotypic coefficients of variation (GCV and PCV), heritability (H^2) and genetic advance (GA) which serves as a basis for selection (Johnson *et al.*, 1955a).

Miller and Quisenberry (1976) reported significant variation for days to first female flower opening in cucumber. They also reported high heritability for the same character.

Smith *et al.* (1978) studied several cucumber populations and reported heritability for yield in the range of 0.17 to 0.25. Also, additive variance was observed to be important in phenotypic variation. The results indicated genetic variability for yield sufficient to permit progress.

Solanki and Seth (1980) observed a wide range of variation among 24 genotypes of cucumber for plant height, leaves/plant, internode length, male flowers/plant, days to fruit maturity, female flowers/plant, fruits/plant and yield/ plant. The phenotypic coefficient of variation varied from 10.43 for fruits/plant to 71.80 for plant height. The genotypic coefficient of variation was the lowest for fruits/plant (5.996) and the highest for plant height (69.026), where as the environmental coefficient of variation ranged from 6.896 for days to fruit maturity to 71.202 for yield per plant. High heritability with high expected genetic advance was also observed for the above characters except for fruits/plant while high heritability and low expected genetic advance was recorded for average fruit weight, duration of flowering, primary branches/plant, fruits/plant and secondary branches/plant.

In a collection of cucumber varieties, Korneev (1980) observed significant variation for several characters including bitterness, yield/plant, female flowers/plant, earliness, disease resistance and pickling quality.

Wang and Wang (1980) found narrow sense heritability estimates in the range of 40 to 50 per cent for a number of yield and maturity characters. The values were intermediate (55%) for fruit length, in low intermediate range (2-44%) for fruit weight and lower for single fruit weight.

El Shawaf and Baker (1981) observed variability estimates to range from 0 to 32 per cent for fruits/plant and fruit weight. Fruits/plant was most heritable. Narrow sense heritability for fruits/plant and fruit weight/plant were 53-60 per cent and 32-65 per cent respectively.

The existence of very high variability for vine length, branches/plant and fruit diameter has been reported in cucumber by Joshi *et al*. (1981). High heritability with high genetic advance was also recorded for characters like female flowers/plant, fruit yield and fruits/plant suggesting the role of additive genes in determining these characters which could be improved considerably by selection.

Analysis of generation means and components of variance for fruit size in two cucumber populations by Owens (1983) revealed moderately high broad sense heritability for fruit length and fruit weight.

Choudhary *et al*. (1985) reported significant genotypic variance for several yield components in cucumber. Secondary branches/vine, yield/vine, primary branches/vine, vine length and fruits/vine had high genetic advance along with high heritability. Genetic variance for these characters is probably due to high additive gene effect. They also reported high heritability and low genetic advance for days to first female flower appearance, flowers/vine and fruit length indicating the role of non-additive gene effects.

Owens *et al*. (1985a) recorded significant genetic variability among several lines within a population of cucumber genotypes for fruit length and weight. Heritability was moderately high (0.8) for fruit length and intermediate (0.6) for fruit weight. In another study, heritability for dollar value of the fruit was 0.19 and for fruits/plant 0.17 (Owens *et al.*, 1985b).

Estimates of heritability and genetic advance of yield and five quality traits were made by Strefeler and Wehner (1986) in cucumber. Heritability for fruit yield ranged from 0.03 to 0.25 and for fruit quality traits from 0.00 to 0.30.

Significant variance for seed weight was recorded in cucumber by Globerson *et al.* (1987). They also reported a broad-sense heritability of 26 to 56 percentage for the same.

In a study of 820 cucumber lines of diverse geographical origin, Neykov and Neikov (1988) reported a wide range of variation for characters like yield/plant, harvesting period, disease resistance, dry matter and vitamin C content and growth period.

Prasunna and Rao (1988) reported high degree of both phenotypic and genotypic variation for female flowers/vine, percentage of fruit set, fruits/vine and yield/vine in a collection of cucumber genotypes indicating high genetic variability. They also observed that the GCV were lower ranging from 5.14 to 73.35 per cent while the PCV ranged from 8.52 to 80.13 in a collection of cucumber genotypes. High estimates of heritability for fruits per vine and average fruit weight were also recorded.

Abusaleha and Dutta (1990) examined 75 pure genotypes of cucumber and observed high magnitude of genotypic and phenotypic variance for all the characters studied. Fruit length and fruits per vine were associated with high heritability and genetic advance.

Mariappan and Pappiah (1990) studied 45 diverse cucumber genotypes and reported a wide range of variation for all the traits except for leaves per plant. The PCV was the highest for seeds/fruit followed by weight of seeds/fruit. The difference between PCV and GCV was invariably low for all the characters indicating less environmental influence on the expression of these characters. High heritability associated with high genetic advance was observed for fruit girth, days to first male flower opening, number and weight of seeds per fruit indicating additive gene effect for the expression of these characters.

Rastogi and Deep (1990 a and b) recorded higher PCV and GCV for fruit yield per plant and fruit weight and the lowest for days to fruit maturity. The magnitude of genetic variation nearly approached phenotypic variation in majority of the characters. They also observed high heritability for yield per plant, days to fruit maturity, fruits per vine and fruit weight. Despite high heritability, certain other characters viz. vine length, primary branches per plant, male flowers per plant and days to fruit maturity had only moderate to low genetic gain.

A wide range of variability among 22 cucumber accessions was observed by Satyanarayana (1991) for all the characters excepting branches/vine and flesh thickness. This was confirmed by the wide range of phenotypic and genotypic coefficients of variation observed for all the characters. He also reported high heritability and genetic advance for marketable fruit yield/vine, percentage of deshaped fruit and marketable fruits/vine.

Prasad and Singh (1992) studied 23 genotypes of cucumber and observed wide range of genetic variation. The heritability estimates ranged from 0.02% for fruits/plot to 48% for fruit length. High heritability coupled with high genetic advance was also observed for fruit length, fruit breadth and fruit weight indicating the action of additive genes for the expression of these characters.

Among six monoecious lines of cucumber, yield and its ten components showed significant genetic variance (Prasad and Singh, 1994 a). High heritability and genetic advance for more than 12 growth and yield attributes was also observed in another collection of cucumber (Prasad and Singh, 1994 b).

Considerable variance in respect of yield and earliness was reported among six slicing cucumber cultivars from an observational trial in Kerala. Among the cultivars tested EC 179394 and sheetal were found promising for yield and local preference (KAU, 1996).

Wehner and Cramer (1996) reported genetic variance for total, early and marketable fruits per plot, fruit shape and fruit weight in three slicing cucumber populations. They also reported low to moderate heritability for fruit yield, earliness and quality, but of major importance in cucumbers.

2.1.2 Correlation studies

Yield is the most important and complex character made up of several component characters and the improvement in the former is possible only through selection in the desirable direction, in the latter. Hence, the knowledge of correlation between yield and its component characters and that among the component characters is essential for a rational improvement in yield in any crop.

Hutchins (1940) observed moderate to large positive phenotypic correlation between fruits per plant and lateral branches per plant in cucumber. Fruit length and fruit diameter, and fruit diameter and seed cavity diameter were found to be correlated in cucumber (Imam *et al*., 1977).

Smith *et al*. (1978) measured a genotypic correlation of 1.01 and phenotypic correlation of 0.78 between fruit number and fruit value, where as, Smith and Lower (1978) observed a correlation of 0.64 and 0.85.

Choudhary *et al*. (1985) found that the female flowers/vine, fruit length and fruit diameter and weight were positively associated with yield. They also observed the negative association of days to first female flower opening with fruits/vine and yield/vine.

Haribabu (1985) observed fruit yield to be positively correlated with fruit weight (0.62), fruits/vine (0.18) and vine length (0.19). Vine length was correlated with branches/vine (0.66) and nodes/vine (0.59). In the same study, branches/vine was correlated to nodes/vine (0.69) and fruits/vine (0.58). Also, nodes/vine was correlated with fruits/vine (0.70) and percentage of fruit set (0.49).

Prudek and Wolf (1985) reported significant correlations (0.87-0.95) between yield and its four components in five monoecious lines of cucumber and their hybrids.

Studies on correlation conducted by Choudhary and Mandal (1987) revealed significant genotypic and phenotypic correlation of yield with fruits/plant, female flowers/plant, fruit length, fruit weight and fruit diameter in cucumber.

High positive association was noted for fruit yield with fruit length and fruit number.

Abusaleha and Dutta (1988) reported that magnitude of genotypic correlation coefficients were higher than the corresponding phenotypic coefficients in most of the characters. Positive and significant associations were recorded between yield and fruit length, fruits per vine, fruit girth and flesh thickness. Days to male and female flowering, percentage of deshaped fruits and percentage of unmarketable yield exhibited negative association with yield.

Prasunna and Rao (1989) observed positive correlation of fruit yield with node to first female flower, days to first female flower opening, female flowers/ vine, sex ratio, fruits/vine, average fruit weight and primary branches per vine. A study by Rastogi and Deep (1990 a) with 25 cucumber cultivars also revealed positive correlation of total yield per plant with fruits per plant, fruit weight and fruit length.

Satyanarayana (1991) reported a positive correlation of yield with vine length, nodes/vine, marketable fruits/vine, total fruits/vine and marketable yield/vine and a negative correlation with cavity size and percentage of deshaped fruits. Seed maturity was positively correlated with flesh thickness.

Prasad and Singh (1992) also conducted correlation studies in cucumber and observed a significant and positive correlation of yield per plot with vine length, fruit length, fruit weight, fruit breadth, flesh thickness, and placental thickness.

Studies on correlations carried out in 8 genotypes of cucumber by Saikia *et al*. (1995) showed that yield per plant had strong positive association with main vine length, number of secondary branches, leaf area, fruiting percentage, fruits/plant, fruit weight and fruit length both at genotypic and phenotypic levels.

2.1.3 Path coefficient analysis

Path coefficient analysis specifies the direct and indirect causes of association and allows their indepth understanding and measures the relative importance of each factor.

Path coefficient analysis in 30 diverse genotypes of cucumber revealed fruit number, female flowers per plant, fruit length, fruit weight and fruit diameter as the important characters determining yield (Choudhary and Mandal, 1987).

Abusaleha and Dutta (1988) also reported highest direct effect for fruits per vine and fruit length. They also found direct negative effect of days to female flowering and percentage of unmarketable yield on the total fruit yield. Indirect positive and significant effect of vine length, branches per vine, fruit girth and flesh thickness on yield was also reported.

Prasunna and Rao (1989) conducted path coefficient analysis in cucumber and observed fruits/vine and average fruit weight as the most important yield contributing factors.

A significant positive effect was found between fruits/vine and yield, and branches/vine and yield in cucumber. Harvest period also influenced yield but its degree of association was reduced with increasing vine length (Rajput *et al.*, 1991).

Path analysis of yield and its components in 23 genotypes of cucumber by Prasad and Singh (1992) revealed the positive direct effect of vine length, days to female flower appearance, fruit weight and fruit length on yield. However, the positive direct effects of these components were partially counter balanced by their negative indirect effects.

Solanki and Shah (1992) revealed through path coefficient analysis of 11 yield components in cucumber that internodal length, number of female flowers and days to maturity to have positive and highly significant direct effect on fruit yield.

Chen *et al.* (1994) compared seven monoecious cucumber cultivars for 4 parthenocarpic yield components. There were significant positive direct effects of fruits/vine, female flowers/vine and average fruit yield on yield per plant. Fruits/vine was reported as the most important trait for yield in cucumber.

Path coefficient analysis in 8 genotypes of cucumber by Saikia *et al.* (1995) also revealed fruits per plant to have maximum direct effect on yield followed by fruit weight. These traits were considered important parameters in any selection programme for the yield improvement in cucumber.

2.2 Combining ability and heterosis

2.2.1 Combining ability

Selection of parents and hybrids on the basis of general combining ability (gca) and specific combining ability (sca) are pre-requisites to develop high yielding varieties and hybrids respectively.

Om *et al.* (1978) reported in a half-diallel cross of several varieties of cucumber, significant general and specific combining ability indicating that both additive and non-additive components of genetic variation were important, and the former were the more important for early yield per plant.

Smith *et al.* (1978) observed node to first female flower, female flowers per vine, branches per vine, fruits per vine, average fruit weight, fruit length to diameter ratio and total yield per vine to have high gca variances indicating the role of additive gene action for the expression of these characters.

Solanki and Seth (1980) observed non additive gene effect for characters like average fruit weight, duration of flowering, primary branches/plant, fruits/plant and secondary branches/plant in cucumber as evidenced by high sca variance over gca variances.

Wang and Wang (1980) in a study of 36 combinations involving 16 parents of cucumber found that both gca and sca effects were significant for a number of yield and maturity characters. Additive variance was of importance in phenotypic variation.

Ghaderi and Lower (1981) carried out breeding investigations in cucumber and reported significant additive and/or dominance variances in certain crosses for fruit weight per plant, fruits per plant and average fruit weight.

Dolgikh and Sidorova (1983) while studying the combining ability for 60 F_1 hybrids in cucumber reported general combining ability to be important for early and total yield and for fruit number per plant. They also reported a Line W as promising for producing hybrids with high early yield. Total yield, fruits/plant and fruit weight were controlled mainly by additive genes while early yield was controlled by non-additive genes.

Guseva and Mospan (1984) while studying combining ability in the production of cucumber hybrids found high gca effects for parthenocarpy and disease resistance. Zh L 745 and PML 761 were reported as best combiners for parthenocarpy and high yield.

Analysis of data on the yields of the parental lines and F_1 populations from a 5-line diallel cross by Prudek (1984) showed that both general and specific combining abilities were significant in determining both fruit number and fruit weight per plant, but general combining ability was more important. Specific combining ability was not important with regard to earliness and mean single fruit weight. Line PS 66 was a good combiner for many characters.

Owens *et al*. (1985b) conducted biometrical investigations in cucumber and reported that general and specific combining ability estimates were significant for fruit length and weight indicating the importance of both additive and non-additive effects for trait expression.

Prudek and Wolf (1985) reported lines and crosses with high gca and sca estimates on the basis of a diallel analysis of data on four yield components in crosses involving five lines of cucumber. PS 66 and PS 13 were reported as best combiners for all the characters. Specific combining ability variance was significant for mean fruit weight.

Musmade and Kale (1986) crossed seven cultivars of cucumber in all possible combinations and observed that both gca and sca variances were significant for all the characters studied. In general, the mean squares for gca were greater than that of sca for all the characters except yield per vine.

Frederick and Staub (1989) following evaluation of nine cucumber lines for 6 traits reported significant general combining ability estimates for all the traits. Specific combining ability was significant for days to anthesis. W 12963 and 4H 261 had the highest gca estimates as male and female parents, respectively, for total yield and primary branches, but general combining ability estimate for fruit size was the lowest.

Hormuzdi and More (1989) studied combining ability in cucumber on 9 yield components in 12 genotypes and their F_1 hybrids and reported the genotype SR 551 F as the best combiner for a number of characters. SR 551 F and Japanese Long Green were the best combiners for highest yield.

Rastogi and Deep (1990 a) reported role of non-additive genes for the expression of traits viz. vine length, primary branches per plant, male flowers per plant and days to fruit maturity in cucumber.

Solanki and Shah (1990) revealed significant contribution of gca and sca variances at varied proportions and magnitudes for yield contributing characters in cucumber. Balam Kheera and Hinreka were good combiners. The sca effects were significant for vine length, internodal length, female flowers/plant, fruits/plant and fruit yield/plant in most of the crosses.

Lower *et al*. (1991) following biometrical investigations in cucumber reported Gy 14 and NCSU 19 D_4 as the best combiners for once-over multiple harvest yield.

Satyanarayana (1991) observed significant gca for all the characters except for branches/vine, specific leaf weight, specific leaf area and cavity size in cucumber. Specific combining ability was significant for all the 27 characters studied except for branches/vine. Variance due to sca was more than gca variance indicating the role of non-additive gene effects.

Significant gca effects reported by Prasad and Singh (1994a) suggested existence of genetic differences among the parents selected for hybridization in cucumber. Additive gene action seemed to be responsible for the expression of yield components. Crosses showing maximum sca effects were the resultants of high and poor combinations.

2.2.2 Heterosis

Hayes and Jones (1916) were the first to observe heterosis in cucumber. Hybrid vigour expressed itself in total yield, the increased yield being due to large number of fruits per plant. The highest yielding hybrid out yielded the better parent by 30 per cent.

Jakimovic (1938) noted that hybrids were earlier and gave higher yields and showed an increase in fruit size when compared to the corresponding parents.

Cizov (1945) observed hybrid vigour in respect of earliness, yield and higher fruit weight in cucumber. Carlsson (1952) and Axelsson (1956) also reported heterosis for earliness, increased yield and disease resistance.

Gill *et al*. (1973) developed an F_1 hybrid 'Pusa Sanyog' by crossing a Japanese variety Kaga Aomoga Fushinari with Green Long Naples. This F_1 hybrid out yielded the better parent by 23.05 - 128.78% and was about 10 days earlier.

Heterosis ranged from 15.34 per cent for fruit diameter to 59.22 per cent for fruit shape index in cucumber (Imam *et al*., 1977). Heterobeltiosis was observed for fruit weight per plant and main stem length. Also F_1 deviation from mid-parent was observed for lateral branches per plant (Lower *et al*. 1982).

Solanki *et al*. (1982 a and b) observed heterosis over better parent for primary branches (25.26%), secondary branches (43.60%), female flowers (50.95%), average fruit weight (33.33%), fruits per plant (42.12%) and fruit yield (83.81%). They also observed pronounced heterosis over better parent in a similar study for the above characters. Days to maturity had maximum negative heterosis, while plant height had no heterosis.

Nikulenkova (1984) studied heterosis in cucumber and reported heterosis over standard parent for earliness and fruit yield.

Musmade and Kale (1986) reported heterosis in cucumber. In most of the hybrids, heterosis observed was due to high sca effects. Hybrids P_1 x P_6, P_3 x P_4 and P_5 x P_7 were the most promising since these hybrids showed the highest sca effects and recorded 135.47, 56.42 and 54.72% higher yield per vine over better parent in that order.

Significant relative heterosis and heterobeltiosis for total and marketable yield, earliness and fruit quality traits of cucumber were reported in two varying environments by Rubino and Wehner (1986).

Delaney and Lower (1987) reported significant heterosis of the F_1 over the mean parental values for fruit yield and four plant traits. Heterosis over better parent was observed for average internode length.

Among the progenies from crosses between gynoecious maternal lines and hermaphrodite pollen parents, Aleksandrova (1988) noticed two hybrids, Vikhra (Ts 1x13) and Lora (Ts 3x13) showing significant heterosis for fruit yield, fruit size and other quality traits.

Pyzhenkov *et al*. (1988) reported heterosis for vine length, branches per plant, fruit yield and disease resistance in the F_1 hybrid MOVIR 1 from a cross between line 598 and line 1-29 N.

Hormuzdi and More (1990) reported heterosis for various economic characters except for total yield in crosses involving gynoecious, monoecious and gynomonoecious lines of cucumber in both summer and rainy seasons. Good combinations were W 12757 x RK 5295 and Poinsette x RK 5300 for the rainy season and SR 551 F x Balam, SR 551 F x Japanese Long Green and SR 551 F x Poonakhira for the summer season. Lack of heterosis for total yield was attributed to inability of the F_1 hybrids to sustain production over late period of harvesting.

Satyanarayana (1991) reported a mean heterosis of 61.1 per cent and 52.2 per cent over mid parent and better parent respectively for total fruit yield per vine in a 9x9 diallel analysis in cucumber.

Evaluating 34 and 41 gynoecious F_1 hybrids for horticultural characters during summer and rainy seasons respectively, Vijayakumari *et al*., (1991) recommended promising hybrids for both the seasons and generalised that the tropical gynoecious hybrids were superior to temperate gynoecious hybrids. In another study of heterosis over better parent and superiority over top parent for earliness, yield and its components, maximum heterosis over better parent with 77.6% superiority over top parent was evidenced in tropical gynoecious hybrid 304 x RKS 296. (Vijayakumari *et al*., 1993).

By crossing the line 8232 with line 8129, Wang *et al*. (1993) developed a hybrid having vigorous growth, higher early and total yield, disease resistance and more quality attributes.

Fang *et al*. (1994) developed a hybrid Zhongnong 8 from a cross between line 90271 and line 90211, heterotic over standard variety for early and total yield, vine length, average fruit weight, fruit quality and disease resistance. Heterosis for early and total yield was over 30 per cent.

Musmade *et al*. (1995) evaluated 54 F_1 hybrids along with parents to study the extent of heterosis and observed significant and positive heterosis for yield and its contributing characters. They reported greatest heterosis over better parent for yield and its contributing characters. It was greatest for yield per vine and least for flesh thickness. The percentage of heterosis for yield per vine ranged from -46.79 to 106.37. The hybrid L_6 xT_3 recorded the highest per cent heterosis for yield per vine over better parent.

Ram *et al.* (1995) studied heterosis in cucumber and the promising hybrids were C 8 x C 28, C 13 x C 10 and C 15 x C 28; having higher yield, earliness, uniformity and quality.

3. MATERIALS AND METHODS

The investigations were conducted at the Department of Horticulture, College of Agriculture, Vellayani during the period, 1995-97. Studies were undertaken under the following two major heads.

3.1 Genetic variability in cucumber

3.2 Development of F_1 hybrids and their evaluation for combining ability and heterosis.

3.1 Genetic variability

3.1.1 Experimental materials

The basic material for the study included 22 diverse genotypes of cucumber collected from different parts of the country (Table 1).

3.1.2 Methods

The 22 genotypes were raised in a Randomised Block Design with two replications during August 1996. There were 9 plants per plot. The seeds were sown at a spacing of 1.25x0.30 m. The cultural and management practices were adopted according to the Package of Practices Recommendations of Kerala Agricultural University (KAU, 1993).

Table 1 Source of 22 cucumber genotypes used for the study

Sl.No.	Genotypes	Source
1	Japanese Long Green	IARI Regional Station, Katrain, Himachal Pradesh
2	Spineless Long Green	The Raja Farm and Nursery, Madras
3	Marvel Long	The Raja Farm and Nursery, Madras
4	BSS 169	Bejo Sheetal Seeds, Jalna
5	SC-1	Pune
6	Gangtok Local	Gangtok, Sikkim
7	Batlagundu Local	Saklespur, Karnataka
8	Sel 75-2-10	Mahatma Phule Krishi Vidhyapeeth, Rahuri
9	CS 9	Bejo Sheetal Seeds, Jalna
10	Kasaragod Local	Kasaragod
11	CS 11	Central Horticulture Experiment Station, Ranchi
12	CS 12	Sungro Seeds Pvt. Ltd., Delhi
13	BSS 236	Bejo Sheetal Seeds, Jalna
14	Punerikhira	Nath Seeds, Aurangabad
15	Sheetal	Konkan Krishi Vidhyapeeth, Dapoli
16	ARC-1	Ankur Seeds, Pvt. Ltd, Nagpur
17	Poinsette	NSC, New Delhi
18	Sikkim Sawney	Gangtok, Sikkim
19	White Long	Bangalore
20	BSS 235	Bejo Sheetal Seeds, Jalna
21	Green Long	Mahy Co, Jalna
22	BSS 168	Bejo Sheetal Seeds, Jalna

3.1.3 Observations recorded

Five plants were randomly selected from each plot and tagged for recording the biometrical observations. Observations were recorded on the following characters and the average worked out for further analysis.

3.1.3.1 Days to first male flower opening

The number of days taken from sowing to the opening of the first male flower was recorded.

3.1.3.2 Days to first female flower opening

The number of days taken from sowing to the bloom of the first female flower was recorded.

3.1.3.3 Node to first female flower

The nodes were counted from the lowest to the one at which first female flower opened.

3.1.3.4 Days to first harvest

The number of days taken from sowing to the harvest of first formed fruit in each plant was recorded.

3.1.3.5 Duration of the crop

The number of days from sowing to the harvest of the last fruit from each plant was considered as the duration of the crop.

3.1.3.6 Branches/plant

The number of branches/plant was counted at the full maturity of the plant.

3.1.3.7 Vine length (cm)

Vine length from the collar region to the tip of the main vine at 30 days after sowing was measured and expressed in centimeters.

3.1.3.8 Fruits/plant

The total number of fruits were counted from each plant and the average worked out.

3.1.3.9 Average fruit weight (g)

Weight of the randomly selected fruits from each observational plants were taken and the average worked out and expressed in gram.

3.1.3.10 Fruit Length (cm)

The length of the same fruits used for weight measurements were recorded and the average worked out in centimeters.

3.1.3.11 Fruit girth (cm)

The girth at the middle of the same fruits used for weight measurements were measured and the mean girth worked out in centimeters.

3.1.3.12 Fruit diameter (cm)

Diameter at the middle of the same fruits used for weight measurements were taken and the average worked out in centimeters.

3.1.3.13 Seeds/fruit

The number of seeds in the above five fruits was counted and recorded the average number of seeds/fruit.

3.1.3.14 100 seed weight (g)

A random sample of 100 fully developed seeds per fruit from each genotype were weighed using an electric precision balance and the weight recorded in gram.

3.1.3.15 Yield/plant (kg)

Weight of fruits from observational plants at each harvest was taken using a top loading balance and added to get the total and the average recorded in kilogram.

3.1.4 Statistical analysis

The data collected were subjected to the following statistical analysis.

3.1.4.1 Analysis of variance and covariance

Analysis of variance and covariance were done to test varietal differences for various traits and to estimate variance components and other genetic parameters like heritability, genetic advance, correlation coefficients, etc. as per Singh and Choudhary (1979).

Table 2 represents the analysis of variance/ covariance. From this table other genetic parameters were estimated as follows.

Variance

	X	Y
Environmental variance ($\sigma^2 e$)	$= \sigma^2 ex = E_{xx}$	$\sigma^2 ey = E_{yy}$
Genetic variance ($\sigma^2 g$)	$= \sigma^2 gx = \frac{G_{xx} - E_{xx}}{r}$	$\sigma^2 gy = \frac{G_{yy} - E_{yy}}{r}$
Phenotypic variance ($\sigma^2 p$)	$= \sigma^2 px = \sigma^2 gx + \sigma^2 ex$	$\sigma^2 py = \sigma^2 gy + \sigma^2 ey$

3.1.4.2 Coefficient of variation

Phenotypic and genotypic coefficients of variation (PCV and GCV) were estimated as

$$GCV = \frac{\sigma g(x)}{\bar{X}} \times 100$$

$$PCV = \frac{\sigma p(x)}{\bar{X}} \times 100$$

3.1.4.3 Heritability (Broad sense)

$$H^2 = \frac{\sigma^2 g(x)}{\sigma^2 p(x)} \times 100$$

Table 2 Analysis of variance/covariance

Source	df	Observed mean square XX	Expected mean square XX	Observed mean sum of products XY	Expected mean sum of products XY	Observed mean square YY	Expectd mean square YY
Block	(r-1)	Bxx		Bxy		Byy	
Genotype	(v-1)	Gxx	$\sigma^2 ex + r\sigma^2 gx$	Cxy	$\sigma exy + r\sigma gxy$	Gyy	$\sigma^2 ey + r\sigma^2 gy$
Error	(v-1)(r-1)	Exx		Exy	σexy	Eyy	$\sigma^2 ey$
Total	(rv-1)	Txx		Txy		Tyy	

Hence we have the following estimates

$\sigma^2 g(x) = (Gxx - Exx)/r$ $\sigma^2 e(x) = Exx$

$\sigma^2 g(y) = (Gyy - Eyy)/r$ $\sigma^2 e(y) = Eyy$

$\sigma^2 g(xy) = (Gxy - Exy)/r$ $\sigma^2 e(xy) = Exy$

where

H^2 is the heritability expressed in percentage,

$\sigma^2 g(x)$ is the genotypic variance and

$\sigma^2 p(x)$ is the phenotypic variance (Jain, 1982).

3.1.4.4 Genetic advance as percentage of mean

$$GA = \frac{KH^2 \sigma p}{\bar{X}} \times 100$$ (Miller *et al.*, 1958)

where

K = selection differential = 2.06 at 5 per cent selection and

$\bar{X}$ = mean of the character

3.1.4.5 Correlation

Genotypic correlation coefficient, $$r_{g(xy)} = \frac{\sigma_{g(xy)}}{\sigma_{g(x)} \times \sigma_{g(y)}}$$

Phenotypic correlation coefficient, $$r_{p(xy)} = \frac{\sigma_{p(xy)}}{\sigma_{p(x)} \times \sigma_{p(y)}}$$

Environmental correlation coefficient, $$r_{e(xy)} = \frac{\sigma_{e(xy)}}{\sigma_{e(x)} \times \sigma_{e(y)}}$$

3.1.4.6 Path coefficient analysis

The path coefficients were worked out by the method suggested by Wright (1921). The simultaneous equations which give estimates of path coefficients with k independent characters are

$$\begin{vmatrix} r_{1y} \\ \\ r_{iy} \\ r_{ky} \end{vmatrix} = \begin{vmatrix} 1 & r_{12} & r_{13} \cdots r_{1j} \cdots\cdots & r_{1k} \\ & 1 & r_{23} \cdots\cdots\cdots\cdots & r_{2k} \\ & & r_{ij} \cdots\cdots & r_{ik} \\ & & & 1 \end{vmatrix} \times \begin{matrix} P_1 \\ P_2 \\ P_i \\ P_k \end{matrix}$$

ie. $\underline{Ry} = Rx. \underline{P}$

So that $\underline{P} = Rx^{-1}. \underline{Ry}$

where

r_{ij} is the genotypic correlation between the variables X_i and X_j.

$i, j = 1, 2, \ldots\ldots k$

r_{iy} is the genotypic correlation between X_i and Y and

P_i is the path coefficient of Xi.

The residual factor (R) which measures the contribution of other factors not defined in the causal scheme was estimated by the formula.

$$R = (1 - \sum_{i=1}^{k} P_i \ r_{iy})^{1/2}$$

Indirect effect of i^{th} character via j^{th} character on yield is estimated as $P_i. r_{ij}$.

3.1.4.7 Selection index

The selection index developed by Smith (1937) using discriminant function of Fisher (1936) was used to discriminate the genotypes based on eight characters viz. node to first female flower, days to first harvest, fruits per plant, average fruit weight, fruit length, fruit girth, fruit diameter and yield/plant.

The selection index is described by the function

$$I = b_1 X_1 + b_2 x_2 + \ldots\ldots\ldots + b_7 x_7$$

and the merit of a plant is described by the function

$$H = a_1 G_1 + a_2 G_2 + \ldots\ldots\ldots + a_7 G_7$$

where X_1, X_2, ... X_7 are the phenotypic values and G1, G2, ... G7 are the genotypic worth of the plant with respect to characters X_1, X_2 ..... X_7.

The b coefficients are determined such that the correlation between H and I is maximum. It is also assumed that the economic weight assigned to each character is equal to unity.

ie. $a_1 = a_2 = \ldots = a_7 = 1$

The expected genetic advance was also estimated at a given intensity of selection as follows

Expected genetic advance,

$$\Delta G = \underline{a}.\ \underset{\sim}{G}.\ \underline{b}' \ /\ (\underline{b}'.\ \underset{\sim}{P}.\underline{b})^{1/2}$$

where G = genotypic variance covariance matrix

P = phenotypic variance covariance matrix

$\underline{a}$ = vector of economic weightage and

$\underline{b}$ = vector of b-coefficients.

3.2 Development of F_1 hybrids and their evaluation for combining ability and heterosis

3.2.1 Experimental materials

Seven parents viz. CS 12, CS 9, Punerikhira, Green long, BSS 169, ARC-1 and Japanese Long Green which were originally included in the variability studies were selected based on selection index. These parental lines were crossed in all possible combinations excluding reciprocals in a 7x7 diallel to develop 21 F_1 hybrids during January-April, 1997. For crossing, male and female flowers to be used in pollination were identified the day before they open and covered with butter paper bags. On the next day morning, the selected female flowers were pollinated using pollen from selected male flowers. The artificially pollinated flowers were suitably labelled and again covered with butter paper bags. The fruits of each cross were collected separately, seeds extracted, cleared, dried and used for evaluation.

The 21 F_1 hybrids and their seven parents were evaluated in a Randomised Block Design with 2 replications during April-July, 1997. There were nine plants/ genotype/ replication.

3.2.2 Observations recorded

Five plants each were marked at random for all the 21 F_1 hybrids and seven parents in both replications. Observations were recorded on days to first male flower opening, days to first female flower opening, node to first female flower, days to first harvest, duration of the crop, branches/plant, vine length (cm), fruits/plant, average fruit weight (g), fruit length (cm), fruit girth (cm), fruit diameter (cm), seeds/fruit, 100 seed weight (g) and yield/plant (kg). Average of five plants were worked out for statistical analysis.

3.2.3 Statistical analysis

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

3.2.3.1 Combining ability analysis

The mean data were subjected to combining ability analysis according to Method II, Model I of Griffing's approach (1956).

The gca effects of parents and sca effects of hybrids were estimated as follows.

General combining ability effect of i^{th} parent,

$$g_i = \frac{1}{p + 2} (Y_{i.} + Y_{ii}) - \frac{2Y_{..}}{p}$$

Specific combining ability effect of i x j cross

$$s_{ij} = Y_{ij} - \frac{1}{p+2} (Y_{i.} + Y_{ii}) + (Y_{.j} + Y_{jj}) + \frac{2Y_{..}}{(p+1)\ (p+2)}$$

where Y_{ij} is the mean value with respect to i x j cross

$Y_{i.} = {}_j Y_{ij}$, $Y_{.j} = {}_i Y_{ij}$ and $Y_{..} = {}_{ij} Y_{ij}$

The significance of gca effects of parents and their within differences, sca effects of crosses and their within differences were tested using 't' test as given below.

Effect	't'	SE
gca		
g_i	g_i / SE (g_i)	$(p-1)\ Me/p(n+2)^{1/2}$
$g_i - g_j$	$g_i - g_j$ /SE ($g_i - g_j$)	$2Me/(p+2)^{1/2}$
sca		
s_{ij}	s_{ij} /SE(s_{ij})	$2(p-1)Me/(p+1)(p+2)^{1/2}$
$s_{ij} - s_{ik}$	$s_{ij} - s_{ik}$ /SE($s_{ij} - s_{kl}$)	$2(p+1)Me/(p+2)^{1/2}$
$s_{ij} - s_{kl}$	$s_{ij} - s_{kl}$ /SE($s_{ij} - s_{kl}$)	$2pMe / (n+2)^{1/2}$

where Me = mean square error

3.2.3.2 Estimation of genetic components of variance

$$\sigma^2 gca = \frac{(1+F)^2}{4} \sigma^2_a$$

$$\sigma^2 sca = \frac{(1+F)^2}{2} \sigma^2_d$$

where $\sigma^2 gca = \sigma^2_a$

$\sigma^2 sca = \sigma^2_d$

F = coefficient of inbreeding

σ^2_a = additive genetic variance

σ^2_d = dominance genetic variance

3.2.3.3 Heterosis

Heterosis was calculated as the deviation of the mean performance of F_1s ($\overline{F_1}$) from their mid parent ($\overline{MP}$), better parent ($\overline{BP}$) and the standard parent ($\overline{SP}$) for each cross combination expressed as the percentage of the mean respectively as suggested by Hayes <u>et al</u>. (1955) and Briggle (1963).

$$\text{Relative heterosis} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Heterobeltiosis} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis} = \frac{\overline{F_1} - \overline{SP}}{\overline{SP}} \times 100$$

The significance of heterosis over MP, BP and SP were compared using the following critical difference (CD) values

$$CD\ (0.05) = t \ \frac{3}{2r} \ Me \quad \text{(for relative heterosis)}$$

$$CD\ (0.05) = t \ \frac{2}{r} \ Me \quad \text{(for heterobeltiosis and standard heterosis)}$$

where Me is the estimated error variance with respect to each character.

The parent selected as best from the variability study is considered as standard parent for standard heterosis.

RESULTS

4. RESULTS

4.1 Genetic variability

4.1.1 Variability, heritability and genetic advance

Analysis of variance showed significant differences among the 22 genotypes of cucumber for all the 15 characters studied (Table 3). The mean values are given in Table 4. The population mean range, genotypic and phenotypic coefficients of variation, heritability and genetic advance for all the 15 characters are given in Table 5.

Days to first male flower opening

Significant genotypic differences were observed for days to first male flower opening. The genotype Punerikhira (Plate 1) was the earliest which took 28.6 days for the first male flower anthesis. Kasaragod Local took the maximum days for the same (51.0 days). The mean was 36.51 days. The PCV was 14.5 and the GCV 11.20. This character had comparitively low heritability (60%) and genetic advance (17.94%).

Days to first female flower opening

The performance of the genotypes with respect to the opening of female flowers was similar to that of male flower. It ranged from 32.2 days in Punerikhira (Plate 1) to 52.5 days

Table 3 Analysis of variance for 15 characters in 22 genotypes of cucumber

Source of variation	df	Mean square: Days to first male flower opening	Days to first female flower opening	Node to first female flower	Days to first harvest	Duration of the crop	Branches/ plant	Vine length	Fruits/ plant	Fruit weight	Fruit length	Fruit girth	Fruit diameter	Seeds/ fruit	100 seed weight	Yield/ plant
Replication	1	26.01	10.86	2.21	7.82	9.78	0.87	298.13	0.13	89.00	0.30	0.59	6.88	992.00	4.60	1.82
Genotypes	21	44.87**	49.51**	18.16**	80.24**	209.57**	4.34**	1305.06**	37.62**	19061.86**	26.97**	14.05**	1.38**	46186.17**	0.57**	4.03**
Error	21	11.21	7.41	0.79	2.30	6.09	0.30	103.48	3.35	366.05	1.17	1.69	0.17	266.14	0.01	0.12

** Significant at 1% level

Table 4 Mean value of 15 biometrical characters for 22 cucumber genotypes

Genotypes	Days to first male flower opening	Days to first female flower opening	Node to first female flower	Days to first harvest	Duration of the crop (days)	Branches/ plant	Vine length (cm)	Fruits/ plant	Fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Fruit diameter (cm)	Seeds/ fruit	100 seed weight (g)	Yield/ plant (kg)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Japanese Long Green	37.00	41.63	4.00	49.00	69.13	9.00	120.20	3.60	90.00	27.00	8.75	2.79	420.50	2.30	0.28
2. Spineless Long Green	36.35	38.34	6.50	52.50	49.00	4.00	101.25	3.60	111.00	16.25	10.75	3.43	796.00	2.84	0.18
3. Marvel Long	39.98	40.67	4.92	51.50	57.75	4.50	76.57	3.13	112.50	15.50	17.00	5.41	713.00	1.79	0.23
4. BSS 169	37.50	39.50	2.63	44.00	61.25	7.50	61.00	7.50	192.50	15.00	16.50	5.26	360.50	2.13	1.21
5. SC-1	34.40	35.88	4.75	43.00	48.63	5.75	106.38	5.97	169.34	13.50	16.50	5.24	340.50	2.02	0.91
6. Gangtok Local	31.40	32.80	3.90	41.75	53.00	5.50	106.20	11.13	162.79	11.98	16.34	5.20	562.50	2.33	1.43
7. Batlagundu Local	33.05	36.00	7.50	43.00	71.50	5.00	91.46	3.00	214.50	12.63	15.50	4.89	626.50	1.17	0.58
8. Sel 75-2-10	36.10	36.57	3.74	44.67	61.25	4.17	70.50	8.14	145.00	13.13	13.25	4.23	258.00	2.06	1.89
9. CS 9	32.20	32.30	2.70	40.80	55.50	5.00	123.28	13.65	248.50	13.88	17.38	5.49	371.50	2.58	2.44
10 Kasaragod Local	51.00	52.50	13.00	63.00	88.50	3.50	55.00	3.00	127.50	13.75	14.50	4.60	298.50	1.94	0.73
11. CS 11	36.50	33.97	4.44	44.00	81.25	6.5	73.10	9.52	267.00	20.00	16.59	5.26	259.50	2.40	3.22

Table 4 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
12. CS 12	34.00	37.33	3.73	43.50	78.63	5.63	128.42	15.57	534.34	18.84	20.34	6.48	363.00	2.25	6.23
13. BSS 236	35.80	39.15	3.80	46.50	68.00	6.00	94.60	5.50	102.50	17.00	16.75	5.33	359.50	2.71	0.57
14. Punerikhira	28.60	32.20	3.60	42.48	69.00	4.50	109.77	12.55	210.63	14.35	16.27	5.18	512.50	1.99	2.07
15. Sheetal	34.10	36.35	3.75	43.00	68.00	7.13	155.50	10.58	75.00	21.13	19.50	6.08	267.50	2.91	2.98
16. ARC-1	34.90	39.03	3.93	46.00	68.25	5.75	92.98	12.00	185.63	14.11	16.53	5.25	253.00	2.79	1.45
17. Poinsette	36.10	33.78	3.93	42.00	55.00	4.00	90.80	15.80	164.00	17.25	15.25	4.86	521.00	2.06	2.95
18. Sikkim Sawney	45.00	48.50	11.50	61.50	56.75	3.00	118.50	2.50	72.50	16.50	16.25	5.13	317.50	1.61	0.19
19. White Long	38.75	41.50	11.50	57.50	71.00	7.25	145.75	4.50	101.00	13.00	11.00	3.51	520.50	1.49	0.52
20. BSS 235	32.84	34.25	4.25	46.50	65.00	6.50	102.67	8.50	162.50	12.00	15.50	4.99	296.50	2.76	1.22
21. Green Long	36.88	36.84	4.25	45.50	71.75	7.00	118.25	5.60	215.50	20.50	15.75	4.98	363.50	3.51	1.33
22. BSS 168	40.75	40.50	8.75	51.00	67.75	5.25	110.77	3.50	126.50	18.25	16.00	5.13	415.00	2.54	0.53
SE (±M)	3.35	2.72	0.89	1.64	2.47	0.55	10.17	1.83	19.13	1.08	1.29	0.41	16.31	0.10	0.35
CD (0.05)	6.96	5.66	1.85	3.42	5.13	1.14	21.16	3.81	39.80	2.24	2.69	0.86	33.93	0.21	0.72
CD (0.01)	9.48	7.70	2.52	4.64	6.99	1.56	28.79	5.18	54.16	3.06	3.65	1.16	46.17	0.28	0.99

Table 5 Range, mean, PCV, GCV, heritability and genetic advance as per cent of mean for 15 characters in cucumber

Characters	Range	Mean±SE	PCV (%)	GCV (%)	Heritability (%)	Genetic advance as percentage of mean
1. Days to first male flower opening	28.60-51.00	36.51±2.37	14.5	11.2	60.0	17.94
2. Days to first female flower opening	32.20-52.50	38.16±1.93	14.0	12.0	74.0	21.30
3. Node of first female flower	2.63-13.00	5.50±0.63	56.0	53.6	92.0	105.61
4. Days to fruit harvest	40.80-63.00	47.40±1.16	13.6	13.1	93.0	26.16
5. Duration of the crop (days)	48.63-88.50	65.27±1.74	15.9	15.5	94.0	30.92
6. Branches/plant	3.00-9.00	5.56±0.39	27.4	25.5	87.0	49.06
7. Vine length (cm)	55.00-155.50	102.41±7.19	25.9	23.9	85.0	45.54
8. Fruits/plant	2.50-15.80	7.67±1.29	59.0	53.9	84.0	101.72
9. Fruit weight (g)	72.50-534.34	172.31±13.53	57.2	56.1	96.0	113.39
10. Fruit length (cm)	11.98-27.00	16.16±0.76	23.2	22.2	92.0	43.87
11. Fruit girth (cm)	8.75-20.34	15.55±0.91	18.0	16.0	79.0	29.25
12. Fruit diameter (cm)	2.79-6.48	4.94±0.29	17.9	15.8	78.0	28.75
13. Seeds/Fruit	253-796	418.02±11.54	36.5	36.3	99.0	74.24
14. 100 seed weight (g)	1.17-3.51	2.28±0.07	23.7	23.3	96.0	46.91
15. Yield/plant (kg)	0.18-6.23	1.50±0.25	95.8	92.9	94.0	186.33

in Kasaragod Local, with a mean of 38.16 days. The PCV was 14.0 and the GCV was 12.0. The character recorded a moderate heritability (74%) and genetic advance (21.30%).

Node to first female flower

The node to first female flower ranged from 2.63 in BSS 169 (Plate 2) to 13.00 in Kasaragod Local with a general mean of 5.50. This trait exhibited a phenotypic coefficient of variation of 56.00 and genotypic coefficient of variation of 53.60, resulting in high estimates of heritability (92%) and genetic advance (105.61%).

Days to first harvest

The first fruit was harvested within 40.8 days in CS 9 which was closely followed by Gangtok Local (41.75 days) and Poinsette (42 days). Kasaragod Local took maximum days to first fruit harvest (63 days). The variation for the trait was mainly genetical (PCV, 13.60; GCV, 13.14) as evidenced by high heritability (93%). The estimate for genetic advance was low (26.16%).

Duration of the crop

Duration of the crop ranged from 48.63 days (SC 1) to 88.5 days (Kasaragod Local) with general mean of 65.27 days. It recorded a PCV of 15.9 and GCV of 15.5. It showed high

Plate 1.

Punerikhira, the earliest flowering genotype

Plate 2.

BSS 169, the genotype which produces female flowers in the lowest node

heritability (94%) and comparitively low genetic advance (30.92%).

Branches/plant

Branches/plant was maximum for Japanese Long Green (9.0) and minimum in Sikkim Sawney (3.0) with a mean of 5.56. The PCV was 27.4 and GCV 25.5. Heritability was 87 percentage and genetic advance 49.06 percentage.

Vine length

The main vine length ranged from 55.00 to 155.50 cm with a general mean of 102.41 cm. The genotype Kasaragod Local was the shortest (55.00 cm) while Sheetal (Plate 3) had longest vine (155.50 cm). It had a PCV of 25.9 and GCV of 23.9. Heritability was 85 percentage and genetic advance was 45.54 percentage.

Fruits/plant

The genotype Poinsette produced maximum fruits per plant (15.8) closely followed by CS 12 (15.57) while genotype Sikkim Sawney had the minimum number (2.50). Fruit number showed high PCV and GCV (59.0 and 53.9 respectively) with a heritability of 84 percentage. It also indicated high genetic advance (101.72%).

Average fruit weight

Average fruit weight exhibited a wide range of variation from 72.50 g in Sikkim Sawney to 534.34 g in CS 12 (Plate 4) with a general mean of 172.31 g. The difference in fruit weight was mainly genetical (PCV, 57.2; GCV, 56.1) as evidenced by high heritability (96%) and genetic advance (113.39%).

Fruit length

The fruits of Japanese Long Green were the longest (27.00 cm) where as those of Sikkim Sawney were the shortest (11.98 cm). The over all mean was 16.16 cm. Major part of the variation was genetic (PCV, 23.2; GCV, 22.2) as evidenced by high estimate of heritability (92%). The genetic advance was moderate for fruit length (43.87%).

Fruit girth

The differences for fruit girth were significant and it ranged widely from 8.75 cm in Japanese Long Green to 20.34 cm in CS 12 (Plate 4) with a general mean of 15.55 cm. It recorded a PCV of 18.0 and GCV of 16.0 with moderate heritability (79%) and genetic advance (29.25%).

Fruit diameter

Fruit diameter was maximum (6.48 cm) in genotype CS 12 (Plate 4) and minimum (2.79 cm) in Japanese Long Green with a mean of 4.94 cm. It recorded a PCV of 17.9 and GCV of 15.8. This character had a moderate estimate of heritability (78%) and genetic advance (28.75%).

Seeds/fruit

Seeds/fruit ranged widely from 253 (ARC-1) to 796 (Spineless Long Green) with a general mean of 418.02. The genotypic variation contributed mostly to seeds/fruit. The PCV was 36.5 and GCV 36.3, resulting in high heritability (99%) and genetic advance (74.24%).

100 seed weight

100 seed weight was maximum in Green Long (3.51 g) and minimum in Batlagundu Local (1.17 g) with an over all mean of 2.28 g. The phenotypic and genotypic coefficients of variation were 23.7 and 23.3 respectively resulting in high heritability (96%). The genetic advance was 46.91 percentage.

Yield/plant

Wide variation existed among genotypes for yield/ plant. Yield was highest (6.23 kg) in CS 12 (Plate 4) followed by CS 11 (3.22 kg). Lowest yielder was Spineless Long Green (0.18 kg). The average yield was 1.50 kg. Yield/plant was found to be genetically controlled (PCV, 95.8; GCV, 92.9) as evidenced from very high estimate of heritability (94%) and genetic advance (186.33%).

Plate 3.

Sheetal, the genotype with longest vines

Plate 4.

CS 12, the genotype with highest yield and fruit weight, girth and diameter


SHEETAL

4.1.2 Correlation studies

The phenotypic, genotypic and environmental correlations among yield and its components have been estimated and the results are presented in Table 6, 7 and 8.

The characters which significantly contributed to yield were days to first male flower opening, days to first female flower opening, node to first female flower, days to first harvest, fruits/plant, average fruit weight, fruit girth, fruit diameter and seeds/fruit. Fruits/plant exhibited the highest positive and significant correlation with fruit yield (r_p = 0.8078, r_g = 0.8336, r_e = 0.6960) followed by average fruit weight (r_p = 0.7879, r_g = 0.8329, r_e = -0.1061), fruit girth (r_p = 0.5485, r_g = 0.6147, r_e = 0.0714) and fruit diameter (r_p = 0.5474, r_g = 0.6176, r_e = 0.1582). Days to first harvest exhibited significant negative correlation with fruit yield (r_p = -0.5054, r_g = -0.5238, r_e = -0.2256) followed by node to first female flower (r_p = -0.4306, r_g = -0.4425, r_e = -0.2797).

Intercorrelation among yield components

Days to first male flower opening exhibited negative correlation with yield through fruits/plant, average fruit weight, branches/plant and vine length (r_g = -0.6704, -0.3910, -0.3591 and -0.3538 respectively). High positive correlation

Table 6 Phenotypic correlation coefficients (r_p) among yield and its components in cucumber

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
Days to first male flower opening (X_1)		0.8135	0.7161	0.7956	0.2451	-0.2429	-0.3073	-0.5402	-0.3181	0.0656	-0.2086	-0.2091	-0.1187	-0.2073	-0.3531
Days to first female flower opening (X_2)			0.7106	0.8786	0.3083	-0.1948	-0.1653	-0.5797	-0.3371	0.0602	-0.2441	-0.2468	-0.1099	-0.2603	-0.4077
Node to first female flower (X_3)				0.8496	0.2658	-0.3352	-0.0044	-0.5937	-0.3347	-0.1765	-0.2803	-0.2828	0.0955	-0.4588	-0.4306
Days to first harvest (X_4)					0.2186	-0.2839	-0.0813	-0.6358	-0.4324	-0.0282	-0.3782	-0.3766	0.0653	-0.2825	-0.5054
Duration of the crop (X_5)						0.2042	-0.0855	-0.0409	0.3093	0.2475	0.0712	0.0700	-0.3927	-0.0129	0.2757
Branches/plant (X_6)							0.3118	-0.0056	0.0162	0.4603	-0.1559	-0.1566	-0.2238	0.2977	0.0465
Vine length (X_7)								0.1605	0.0230	0.2815	0.0403	0.0264	0.0044	0.1795	0.1971
Fruits/plant (X_8)									0.5465	-0.0279	0.4871	0.4896	-0.2305	0.2351	0.8078
Fruit weight (X_9)										0.0056	0.4749	0.4848	-0.1337	0.0506	0.7879
Fruit length (X_{10})											-0.0757	-0.0868	-0.1380	0.3671	0.1738
Fruit girth (X_{11})												0.9988	-0.3070	0.1587	0.5485
Fruit diameter (X_{12})													-0.3019	0.1570	0.5474
Seeds/fruit (X_{13})														-0.2754	-0.3190
100 seed weight (X_{14})															0.1371
Yield/plant (X_{15})															

Table 7 Genotypic correlation coefficients (r_g) among yield and its components in cucumber

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
Days to first male flower opening (X_1)		1.8937	0.8379	0.9680	0.3951	-0.3591	-0.3538	-0.6704	-0.3910	0.1485	-0.2206	-0.2276	-0.1593	-0.2442	-0.3949
Days to first female flower opening (X_2)			0.8480	0.9408	0.3465	-0.2179	0.2244	-0.7213	-0.3876	0.1596	-0.2744	-0.2812	-0.1299	-0.2939	-0.4614
Node to first female flower (X_3)				0.9203	0.3068	-0.3953	0.0128	-0.6439	-0.3498	-0.1810	-0.3451	-0.3500	0.0909	-0.4740	-0.4425
Days to first harvest (X_4)					0.2307	-0.3000	-0.0636	-0.7187	-0.4578	-0.0061	-0.4315	-0.4357	0.0655	-0.2926	-0.5238
Duration of the crop (X_5)						0.2391	-0.1179	-0.0451	0.3172	0.2710	0.1147	0.1137	-0.3978	-0.0056	0.2810
Branches/plant (X_6)							0.3544	0.0118	0.0418	0.5114	-0.1503	-0.1560	-0.2527	0.3550	0.0436
Vine length (X_7)								0.1669	0.0256	0.3252	0.0934	0.0807	0.0149	0.2193	0.1904
Fruits/plant (X_8)									0.6273	-0.0926	0.4988	0.5058	-0.2404	0.2429	0.8336
Fruit weight (X_9)										0.0056	0.5119	0.5242	-0.1378	0.0487	0.8329
Fruit length (X_{10})											-0.1890	-0.2057	-0.1507	0.3699	0.1730
Fruit girth (X_{11})												0.9997	-0.3542	0.1390	0.6147
Fruit diameter (X_{12})													-0.3514	0.1385	0.6176
Seeds/fruit (X_{13})														-0.2856	-0.3160
100 seed weight (X_{14})															0.1793
Yield/plant (X_{15})															

Table 8 Environmental correlation coefficients (r_e) among yield and its components in cucumber

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
Days to first male flower opening (X_1)		0.2627	0.5185	0.4366	-0.3480	0.0726	-0.2233	-0.2545	-0.1702	-0.2451	-0.1951	-0.1799	0.0589	-0.1783	-0.3681
Days to first female flower opening (X_2)			0.0841	0.7404	0.1556	-0.1091	0.0659	-0.0603	-0.1019	-0.4845	-0.1475	-0.1385	0.0214	-0.1249	-0.1839
Node to first female flower (X_3)				-0.0333	-0.2841	0.1716	-0.1419	-0.2561	-0.1106	-0.1271	-0.0969	-0.0983	0.2909	-0.2419	-0.2797
Days to first harvest (X_4)					0.0310	-0.1452	-0.2504	-0.0021	0.0359	-0.3076	-0.0677	-0.0361	0.0872	-0.0990	-0.2256
Duration of the crop (X_5)						-0.1442	0.2222	-0.0085	0.1528	-0.0672	0.2531	-0.2493	-0.3371	-0.1674	0.1891
Branches/plant (X_6)							0.0467	-0.1076	-0.3145	0.0338	-0.1896	-0.1663	0.2728	-0.3971	0.0806
Vine length (X_7)								0.1257	-0.0016	-0.0555	-0.2052	-0.2197	-0.2255	-0.2654	-0.2862
Fruits/plant (X_8)									-0.2073	0.4570	0.4411	0.4271	-0.2738	0.2214	0.6960
Fruit weight (X_9)										0.0060	0.3268	0.3355	0.0337	0.1005	-0.1061
Fruit length (X_{10})											0.6400	0.6434	0.1786	0.3523	0.1874
Fruit girth (X_{11})												0.9958	0.1120	0.4274	0.1714
Fruit diameter (X_{12})													0.1338	0.4125	0.1582
Seeds/fruit (X_{13})														0.1629	-0.5463
100 seed weight (X_{14})															-0.2968
Yield/plant (X_{15})															

was observed between days to first male flower opening and days to first harvest (0.9680), days to first female flower opening (0.8937) and node to first female flower (0.8379).

Days to first female flower opening had high negatve correlation with fruits/plant (-0.7213) and average fruit weight (-0.3876). Days to first harvest (0.9408), node to first female flower (0.8480) and days to first female flower opening exhibited high positive correlation with days to first female flower opening.

Node to first female flower exhibited high negative correlation with fruits/plant (-0.6439) and 100 seed weight (-0.4740). Node to first female flower had high positive correlation with days to first male flower opening, days to first female flower opening and days to first harvest (0.9203).

Days to first harvest was negatively correlated with fruits/plant (-0.7187) followed by average fruit weight (-0.4578), fruit diameter (-0.4357) and fruit girth (-0.4315). Days to first harvest had positive correlation with days to first male flower opening, days to first female flower opening and node to first female flower.

Duration of the crop had high positive correlation with days to first male flower opening (0.3951), days to first female flower opening (0.3465), average fruit weight (0.3172) and node to first female flower (0.3068). Seeds/fruit (-0.3978) showed negative association with duration of the crop.

Branches/plant showed positive association with fruit length (0.5114), 100 seed weight (0.3550) and vine length (0.3544). Node to first female flower (-0.3953) and days to first male flower opening (-0.3591) were negatively corelated with branches/plant.

Vine length exhibited positive correlation with branches/plant and fruit length (0.3252). Days to first male flower opening had negative correlation with vine length.

Fruits/plant had a high positive association with yield through average fruit weight (0.6273), fruit diameter (0.5058) and fruit girth (0.4988). Days to first female flower opening, days to first harvest, days to first male flower opening and node to first female flower were negatively correlated with fruits/plant.

Average fruit weight showed high positive correlation with yield through fruits/plant, fruit diameter (0.5242) and fruit girth (0.5119). Days to first harvest, days to first male flower opening, days to first female flower opening and node to first female flower (-0.3498) were negatively correlated with fruit weight.

Fruit length had positive correlation with branches/ plant, 100 seed weight (0.3699) and vine length.

Fruit girth exhibited high positive correlation with yield through fruit diameter (0.9997), average fruit weight and fruits/plant. Days to first harvest and seeds/fruit (-0.3542) negatively correlated with fruit girth.

Fruit diameter had high positive association with yield through fruit girth, average fruit weight and fruit diameter. Days to first harvest, node to first female flower and seeds/fruit (-0.3514) were negatively correlated with fruit diameter.

Seeds/fruit showed high negative association with duration of the crop, fruit girth and fruit diameter.

100 seed weight was positively correlated with fruit length and branches/plant. Negative association was noticed between node to first female flower and 100 seed weight.

4.1.3 Path coefficient analysis

The genotypic correlations among yield and its component characters were partitioned into different components to find out the direct and indirect contribution of each character on fruit yield (Table 9, Fig. 1). The characters viz. fruits/plant, average fruit weight, fruit length, fruit

Table 9 Direct and indirect effects of five yield components on fruit yield in cucumber

Characters	Fruits/ plant	Fruit weight	Fruit length	Fruit girth	Fruit diameter	Total correlation
Fruits/plant	0.491	0.617	0.027	14.342	-14.645	0.832
Fruit weight	0.308	0.984	-0.002	14.719	-15.177	0.832
Fruit length	-0.045	0.006	-0.291	-5.435	5.938	0.173
Fruit girth	0.245	0.504	0.055	28.754	-28.944	0.614
Fruit diameter	0.248	0.516	0.060	28.745	-28.953	0.616

Residual effect (R) = 0.1681

(Underlined, diagonal values indicate direct effects) girth and fruit diameter which showed significant correlation with yield alone were selected for path coefficient analysis.

The path analysis revealed that fruit girth had the maximum positive direct effect on fruit yield (28.754) followed by average fruit weight (0.984) and fruits/plant (0.491). The direct effect of fruit diameter was high and negative (-28.953) and that of fruit length was negligible.

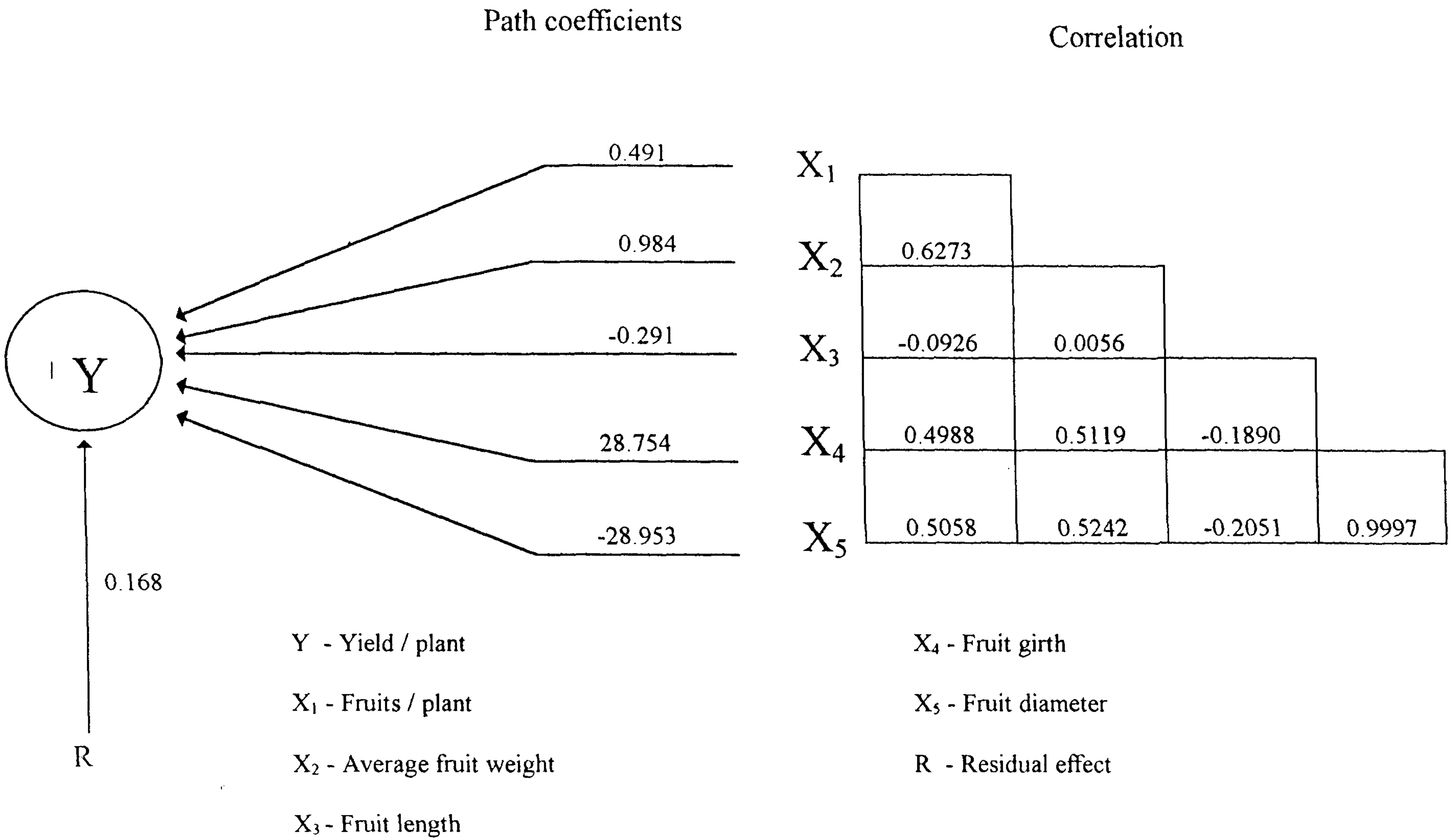
Though the direct effect of fruits/plant on fruit yield was low in magnitude it exerted high and positive indirect effect through fruit girth (14.342) and fruit weight (0.617). The indirect effect of fruits/plant on fruit yield through fruit diameter was high and negative (-14.645). The indirect effect through fruit length was low in magnitude.

Average fruit weight exerted a positive and high indirect effect through fruit girth (14.719) and a negative and high indirect effect through fruit diameter. The indirect effect through fruits/plant was positive but low and that through fruit length was negligible.

Fruit length exerted a positive indirect effect through fruit diameter (5.938) and negative indirect effect through fruit girth (-5.435). However, the indirect effects through other characters were negligible.

The indirect effect of fruit girth on fruit yield through fruit diameter were high and negative (-28.944) even

Fig .1 Path diagram showing direct effect and genotypic correlation in cucumber



though it had the maximum direct effect. The indirect effect of fruit girth through other characters were positive but low.

Though the direct effect of fruit diameter on fruit yield was high and negative, the correlation coefficient was high and positive, according to the fact that the high and positive indirect effect of fruit girth (28.745) was responsible for this.

The residual effect due to the unknown causal factors influencing yield was 0.17 indicating that the five characters considered in path analysis contributed to about eighty three per cent of the fruit yield.

4.1.4 Selection index (discriminant function)

Selection index is used to discriminate the genotypes based on major components of yield, viz. node to first female flower, days to first harvest, fruits/plant, average fruit weight, fruit length, fruit girth, fruit diameter and yield/plant. The selection index prepared based on yield/plant and other characters are presented in Table 10. The merit of each character explained in terms of b-coefficients in the discriminant function

$$I = b_1x_1 + b_2x_2 + \ldots\ldots + b_7x_7$$

Table 10 Selection index (score) for twenty two different genotypes of cucumber

Sl.No	Genotypes	Selection index
1.	CS 12	1036.34
2.	CS 11	504.41
3.	CS 9	450.39
4.	Punerikhira	376.39
5.	Green Long	370.46
6.	Batlagundu Local	355.12
7.	BSS 169	322.53
8.	Poinsette	317.97
9.	ARC-1	316.79
10.	SC-1	277.61
11.	Gangtok Local	277.13
12.	BSS 235	271.31
13.	Sel. 75-2-10	264.09
14.	Kasaragod Local	208.28
15.	BSS 168	194.68
16.	Spineless Long Green	170.31
17.	White Long	163.38
18.	Marvel Long	158.45
19.	Sheetal	156.99
20.	BSS 236	149.27
21.	Japanese Long Green	138.75
22.	Sikkim Sawney	94.56

Character		b - coefficient
Node to first female flower	=	0.4252
Days to first harvest	=	-0.0832
Fruits/plant	=	-0.0767
Average fruit weight	=	0.8794
Fruit length	=	-0.0087
Fruit girth	=	4.5263
Fruit diameter	=	-17.9015
Yield/plant	=	12.1309

The highest index was recorded by the genotype CS 12 (1036.34) followed by CS 11 (504.41), CS 9(450.39), Punerikhira (376.39), etc. in that order.

4.2 Combining ability and heterosis

4.2.1 Combining ability analysis

The analysis of variance showed significant differences among 28 genotypes for all the fifteen characters (Table 11). Analysis of variance for combining ability revealed that the variance due to gca and sca were significant for all the traits (Table 12). Estimate of gca effect of parents and sca effects of hybrid combinations are presented in Tables 13 and 14 respectively.

Table 11 Analysis of variance for 15 characters in 28 genotypes of cucumber

Source of variation	df	Mean square: Days to first male flower opening	Days to first female flower opening	Node to first female flower	Days to first harvest	Duration of the crop	Branches/ plant	Vine length	Fruits/ plant	Fruit weight	Fruit length	Fruit girth	Fruit diameter	Seeds/ fruit	100 seed weight	Yield/ plant
Replication	1	0.02	0.49	0.01	5.84	14.25	0.01	162.96	0.05	4.72	0.01	0.00	0.16	0.16	0.03	0.01
Genotypes	27	50.48**	51.85**	9.12**	53.66**	62.68**	7.40**	1078.95**	49.05**	18343.17**	24.11**	17.53**	2.15**	16833.08**	0.42**	3.36**
Error	27	5.77	5.29	0.30	4.03	3.38	0.18	84.85	0.30	598.92	0.53	1.54	0.15	489.09	0.05	0.01

** Significant at 1% level

Table 12 Analysis of variance for combining ability in a 7x7 diallel in cucumber

Source of variation	df	Mean square														
		Days to first male flower opening	Days to first female flower opening	Node to first female flower	Days to first harvest	Duration of the crop	Branches/ plant	Vine length	Fruits/ plant	Fruit weight	Fruit length	Fruit girth	Fruit diameter	Seeds/ fruit	100 seed weight	Yield/ plant
gca	6	55.28**	52.30**	20.58**	35.18**	55.23**	11.74**	421.96**	65.78**	21462.03**	22.00**	26.31**	2.90**	10060.08**	0.09**	4.20**
sca	21	16.65**	18.39**	102.48**	24.45**	24.51**	88.11**	573.05**	12.74**	5660.03**	9.21**	3.75**	0.56**	7946.95**	0.25**	0.96**
Error	27	2.88	2.65	8.02	2.02	1.69	4.78	42.43	0.15	299.46	0.26	0.77	0.08	244.54	0.02	0.00

** Significant at 1% level

Days to first male flower opening

Significant gca and sca variance were observed for days to first male flower opening. Punerikhira possessed the highest negative gca effect (-3.61) followed by CS 9 (-3.24). BSS 169 x Japanese Long Green had highest negative sca effect (-5.84) followed by CS 12 x Japanese Long Green (-3.50) and CS 12 x Punerikhira (-2.61).

Days to first female flower opening

Significant gca and sca variances were observed for this character also. Maximum negative gca effect was noticed with CS 9 (-3.84) followed by Punerikhira (-2.88). The cross BSS 169 x Japanese Long Green had maximum sca effect (-5.68) followed by CS 12 x Punerikhira (-4.15) and Punerikhira x ARC-1 (-3.76).

Node to first female flower

Both gca and sca effects were highly significant for node to first female flower. CS 9 possessed the maximum negative gca effect (-0.63) followed by CS 12 (-0.45). The hybrid combination CS 12 x BSS 169 had the maximum negative sca effect for node to first female flower (-2.05) followed by Punerikhira x ARC-1 (-1.88) and CS 9 x BSS 169 (-1.75).

Days to first harvest

CS 9 showed significant gca effect for days to first harvest (-1.97) followed by Punerikhira (-1.79). Maximum negative sca effect was recorded with CS 12 x Japanese Long Green (-5.51).

Duration of the crop

Significant gca and sca variances were observed for duration of the crop also. Punerikhira recorded the maximum gca effect (2.55) followed by CS 12 (1.58). CS 9 showed the lowest gca effect (-4.48). The cross BSS 169 x Japanese Long Green had the highest sca value (9.52) followed by CS 9 x ARC-1 (9.32).

Branches/plant

Highest value of gca effect for branches/plant was observed in ARC-1 and Punerikhira (0.72 and 0.46) where as highest sca effects were recorded in the cross CS 12 x CS 9 (2.52) followed by BSS 169 x ARC-1 (1.68).

Vine length

The gca and sca effects were highly significant for this character. Punerikhira possessed maximum gca effect (11.10) followed by CS 12 (5.51) and CS 9 (2.47). Maximum sca effects were observed in CS 12 x Japanese Long Green (48.19) followed by CS 9 x ARC-1 and Punerikhira x ARC-1 (35.79 and 35.78).

Fruits/plant

Fruits/plant exhibited highly significant gca and sca variances. The parents with high gca effects were CS 9 (2.60) followed by ARC-1 (2.24). High sca effects were shown by Punerikhira x ARC-1 (7.74) followed by CS 9 x BSS 169 (4.04).

Average fruit weight

The gca and sca variances were highly significant for average fruit weight. The genotype CS 12 had the maximum gca effect (90.43) followed by Punerikhira (23.49) and CS 9 (8.68). The cross CS 9 x ARC-1 recorded the maximum sca effect followed by CS 12 x Punerikhira (90.94).

Fruit length

Significant gca and sca variances were observed for fruit length also. Maximum gca effect was shown by Japanese Long Green (2.20) followed by Green Long (1.61) where as CS 12 x Japanese Long Green (3.54) showed the highest sca effect followed by Punerikhira x BSS 169 (2.68).

Fruit girth

Fruit girth also exhibited significant gca and sca variances. The genotype CS 12 recorded the highest gca effect (1.24) followed by CS 9 (0.90) where as the crosses BSS 169 x Japanese Long Green, CS 9 x Japanese Long Green and CS 9 x Green Long exhibited the highest sca values (3.08, 2.78 and 1.98).

Fruit diameter

Highly significant gca and sca variances were observed for fruit diameter. Among the parents CS 12 had the maximum gca value (0.34) followed by BSS 169 (0.32). Among the crosses, Punerikhira x BSS 169 exhibited the highest sca effect (1.42) followed by CS 9 x Japanese Long Green (1.41).

Seeds/fruit

The gca and sca variances for seeds/fruit were highly significant. The parent CS 12 had the highest gca value (56.42). Maximum sca effect was shown by the cross CS 12 x BSS 169 (112.21) followed by CS 9 x Japanese Long Green (72.71) and CS 12 x Punerikhira (70.54).

100 seed weight

Both gca and sca variances were highly significant for 100 seed weight also. The parents with high gca effects were ARC-1 and Green Long (0.15 and 0.05). Hybrids with

Table 13 Estimate of gca effects of seven cucumber genotypes for 15 characters

Parental lines	Days to first male flower opening	Days to first female flower opening	Node to first female flower	Days to first harvest	Duration of the crop	Branches/ plant	Vine length	Fruits/ plant	Fruit weight	Fruit length	Fruit girth	Fruit diameter	Seeds/ fruit	100 seed weight	Yield/ plant
CS 12	1.42*	1.44*	-0.45*	-0.72	1.58*	0.00	5.51*	1.73*	90.43*	0.92*	1.24*	0.34*	56.42*	0.03*	0.98*
CS 9	-3.24*	-3.84*	-0.63*	-1.97*	-4.48*	-0.18	2.47	2.60*	8.68	-1.72*	0.90*	0.26*	15.81*	0.03*	0.43*
Punerikhira	-3.61*	-2.88*	0.34*	-1.79*	2.55*	0.46*	11.10*	1.26*	23.49*	-1.52*	0.46	0.18*	-0.30	-0.06*	0.39*
Green Long	2.52*	1.51*	1.18*	3.69*	0.42	-0.58*	-6.71*	-0.83*	-26.71*	1.61*	0.29	0.22*	-45.30*	0.05*	-0.37*
BSS 169	2.10*	2.10*	0.12	-0.30	-2.26*	-0.46*	-2.88	-2.40*	-11.79*	-0.88*	0.85*	0.32*	11.03*	-0.05*	-0.56*
ARC-1	0.07	-0.07	-0.38*	-0.34	1.31*	0.72*	-1.34	2.24*	-18.46*	-0.62*	0.03	-0.07	-32.80*	0.15*	0.15*
Japanese Long Green	0.74	1.74*	-0.18*	1.42*	0.88*	0.05	-8.15*	-4.59*	-65.65*	2.20*	-3.77*	-1.25*	-4.86	-0.15*	-1.01*
SE (g_i)	0.51	0.50	0.10	0.43	0.40	0.10	2.01	0.10	5.34	0.17	0.26	0.08	4.82	0.01	0.01
SE (g_i-g_j)	0.80	0.76	0.17	0.66	0.60	0.14	3.07	0.17	8.15	0.24	0.41	0.12	7.37	0.07	0.07

* Significant at 1% level

Table 14 Estimate of sca effects of 21 F_1 hybrids of cucumber for 15 characters

Crosses	Days to first male flower opening	Days to first female flower opening	Node to first female flower	Days to first harvest	Duration of the crop	Branches/ plant	Vine length	Fruits/ plant	Fruit weight	Fruit length	Fruit girth	Fruit diameter	Seeds/ fruit	100 seed weight	Yield/ plant
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CS 12 x CS 9	-1.33	-1.68	1.66*	0.13	-6.45*	-1.14*	-11.85*	1.45*	-111.75*	0.46	-1.72*	0.19	-41.57*	0.00	-0.36*
CS 12 x Punerikhira	-2.61	-4.15*	-1.43*	-0.30	3.52*	2.52*	-10.57	1.38*	90.94*	-0.99*	-0.04	-0.23	70.54*	0.66*	1.44*
CS 12 x Green Long	4.96*	3.97*	1.35*	14.47*	-2.23	-1.62*	-0.01	2.09*	-6.36	-0.87	0.89	1.15*	-23.96	-0.80*	-0.66*
CS 12xBSS 169	11.58*	13.04*	-2.05*	2.46	3.33*	-2.10*	2.66	-5.59*	-153.78*	-2.38*	-3.55*	-1.16*	112.21*	0.07	-1.80*
CS 12xARC-1	-0.20	0.65	0.46	-2.00	-5.11*	0.97*	-25.63*	-5.77*	-77.11*	1.11*	0.40	0.27	38.54*	-0.25	-1.73*
CS 12xJapanese Long Green	-3.50*	-3.56*	-0.19	-5.51*	-5.81*	0.25	48.19*	2.17*	35.08*	3.54*	-1.06	-0.68*	25.60	0.00	0.36*
CS 9 x Punerikhira	1.05	0.04	2.97*	-1.05	-3.92*	1.16*	2.22	-0.75*	45.19*	0.65	0.68	0.35	-106.85*	-0.41*	0.45*
CS 9 x Green Long	-3.01*	-0.33	-1.63*	3.22*	3.70*	-0.77*	-16.72*	1.22*	-14.61	0.02	1.98*	0.19	5.65	-0.44*	-0.42*

Table 14 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CS 9xBSS 169	-0.26	-0.84	-1.75*	-0.29	-0.61	-0.80*	-17.64*	4.04*	-42.03*	-0.25	-1.58*	-0.29	15.32	0.09	0.05
CS 9xARC-1	-1.61	-0.04	-0.39	-0.25	9.32*	1.27*	35.79*	-1.56*	99.64*	0.49	-1.51	-0.90*	57.65*	-0.09	1.33*
CS 9xJapanese Long Green	-1.50	0.15	0.64	2.99*	-1.25	-0.57*	26.48*	-4.23*	31.83*	-5.07*	2.78*	1.41*	72.71*	0.09	-0.71*
Punerikhira x Green Long	0.39	0.20	-0.81*	-0.26	0.18	-0.24	-11.98*	-0.57	3.08	1.82*	0.91	0.01	-65.74*	-0.14	0.20*
Punerikhira x BSS 169	-1.29	2.36	5.00*	5.53*	-1.64	-1.81*	11.41	-4.21*	33.16*	2.68*	1.55*	1.42*	-51.07*	-0.33*	-1.02*
Punerikhira x ARC-1	-2.11	-3.76*	-1.88*	-4.02*	4.79*	0.63*	35.78*	7.74*	34.83*	0.80	-0.17	-0.07	0.26	0.25	0.78*
Punerikhira x Japanese Long Green	2.84	5.30*	-0.33	6.31*	-0.03	-0.79*	-36.03*	-2.93*	-117.98*	-7.85*	-1.66*	-0.64*	-177.68*	-0.20	-0.83*
Green Long x BSS 169	-0.18	-2.69	2.03*	-3.45*	-4.02*	-1.15*	0.38	-2.28*	35.86*	0.18	-0.97	-0.37	-68.57*	0.41*	-0.27*
Green Long x ARC-1	5.51*	4.98*	4.15*	4.59*	-5.59*	-1.83*	16.34*	2.33*	-97.48*	-1.91*	-1.91*	-0.24	26.26	-0.79*	0.16*
Green Long x Japanese Long Green	2.71	0.42	-1.04*	-1.67	-2.66*	-1.55*	-12.68*	-0.99*	-22.78	-1.39*	-3.36*	-0.68*	-106.18*	-0.55*	-0.02

Table 14 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
BSS 169xARC-1	-1.82	-3.21*	-1.54*	0.58	-0.91	1.68*	18.13*	2.23*	47.61*	1.40*	1.04	0.72*	-36.07*	0.17	1.33*
BSS 169 x Japanese Long Green	-5.84*	-5.68*	2.89*	-2.68*	9.52*	-1.78*	6.97	0.73*	72.30*	-2.16*	3.08*	0.85*	-3.01	-0.61*	0.19*
ARC-1 x Japanese Long Green	1.08	-1.75	-0.36	1.86	-3.55*	-3.46*	4.62	-3.83*	-11.03	-1.42*	-0.85	-0.39	-58.18*	0.24	-0.44*
SE(s_{ij})	1.52	1.45	0.34	1.27	1.16	0.26	5.84	0.34	15.53	0.45	0.78	0.24	14.03	0.14	0.05
SE($s_{ij}-s_{ik}$)	2.26	2.17	0.50	1.89	1.73	0.40	8.68	0.50	23.07	0.68	1.16	0.36	20.85	0.20	0.07
SE ($s_{ij}-s_{kl}$)	2.11	2.02	0.47	1.76	1.62	0.37	8.12	0.47	21.51	0.64	1.09	0.34	19.50	0.17	0.07

* Significant at 1% level

highest sca effects were CS 12 x Punerikhira (0.66) and Green Long x BSS 169 (0.41).

Yield/plant

Yield/plant recorded highly significant values for gca and sca variances. Maximum gca effect was in parent CS 12 (0.98) followed by CS 9 (0.43). Maximum sca effect was shown by hybrid CS 12 x Punerikhira (1.44) followed by hybrids CS 9 x ARC-1 and BSS 169 x ARC-1 with same sca effects (1.33).

4.2.2. Heterosis in cucumber

Analysis of variance for seven parents and 21 hybrids showed significant difference among the genotypes for all the characters studied (Table 12). The relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) calculated are presented in Tables 15, 16, 17, 18 and 19.

Days to first male flower opening

Highly significant relative heterosis was shown by the cross BSS 169 x Japanese Long Green (-16.18%) followed by CS 9xJapanese Long Green (-8.45%). Out of the 21 F_1 hybrids, eight hybrids expressed significant positive and negative heterobeltiosis, but only one (BSS 169 x Japanese Long Green) showed heterobeltiosis in the desired direction (-15.64%).

Table 15 Heterosis for days to first male flower opening, days to first female flower opening and node to first female flower in cucumber

Genotypes	Days to first male flower opening				Days to first female flower opening				Node of first female flower			
Parents/cross	Mean (No.)	RH (%)	HB (%)	SH (%)	Mean (No.)	RH (%)	HB (%)	SH (%)	Mean (No.)	RH (%)	HB (%)	SH (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
CS 12	34.30				37.83				4.12			
CS 9	32.75				32.75				2.91			
Punerikhira	29.55				33.33				3.84			
Green Long	35.75				38.83				5.25			
BSS 169	39.00				41.80				2.88			
ARC-1	35.62				40.50				3.95			
Japanese Long Green	39.50				45.12				3.75			
CS 12 x CS 9	32.75	-2.31	0.00	-4.52	35.00	-0.83	6.87	-7.48	5.50	56.25**	88.68**	33.50**
CS 12 x Punerikhira	31.10	-2.58	5.25	-9.33	33.50	-5.85	0.51	-11.45*	3.38	-15.20	-11.99	-17.96
CS 12 x Green Long	44.80	27.91**	30.61**	30.61**	46.00	19.99**	21.58**	21.60**	7.00	49.33**	69.70**	69.90**
CS 12xBSS 169	51.00	39.15**	48.69**	48.68**	55.67	39.80**	47.13**	47.16**	2.54	-27.43*	-11.65	-38.35**

Table 15 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13
CS 12 x ARC-1	37.20	6.40	8.45	8.45	41.10	4.93	8.63	8.64	4.55	12.69	15.19	10.44
CS 12xJapanese Long Green	34.56	-6.33	0.77	0.76	38.70	-6.70	2.29	2.30	4.10	4.13	9.33	-0.49
CS 9 x Punerikhira	30.10	-3.37	1.86	-12.24	32.40	-1.94	-1.01	-14.35*	7.60	125.19**	160.72**	84.47**
CS 9 x Green Long	32.17	-6.09	-1.79	-6.21	36.42	1.74	11.19	-3.72	3.84	-6.06	31.56	-6.80
CS 9x BSS 169	34.50	-3.83	5.34	0.58	36.50	-2.08	11.45	-3.52	2.66	-7.94	-7.30	-35.44**
CS 9 x ARC-1	31.12	-8.96	-4.96	-9.27	35.12	-4.10	7.25	-7.16	3.53	2.69	20.93	-14.32
CS 9xJapanese Long Green	31.90	-11.70*	-2.60	-7.00	37.12	-4.65	13.36**	-1.88	4.75	42.54**	62.95**	15.29
Punerikhira x Green Long	35.20	7.81	19.12*	2.62	37.92	5.08	13.76**	0.24	5.62	23.83**	46.68**	36.41**
Punerikhira x BSS 169	33.10	-3.43	12.01	-3.50	40.67	8.25	22.01**	7.51	10.38	209.24**	260.87**	151.94**
Punerikhira x ARC-1	30.25	-7.17	2.37	-11.81	32.38	-12.30*	-2.87	-14.41*	3.00	-22.93	-21.77	-27.18*
Punerikhira x Japanese Long Green	35.88	3.91	21.40**	4.61	43.25	10.25*	29.76**	14.33*	4.75	25.25	26.67	15.29
Green Long x BSS 169	40.33	7.92	12.83*	17.58**	40.00	-0.79	3.00	5.74	8.25	103.08**	186.46**	100.24**

Table 15 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13
Green Long x ARC-1	44.00	23.29**	23.51**	28.28**	45.50	14.70**	17.16**	20.27**	9.88	114.67**	150.00**	139.81**
Green Long x Japanese Long Green	41.88	11.30*	17.13**	22.10	42.75	1.83	10.08	13.01*	4.88	8.33	30.00*	18.45
BSS 169xARC-1	36.25	-2.85	1.77	5.69	37.90	-7.90	-6.42	0.19	3.12	-8.42	8.77	-24.27
BSS 169 x Japanese Long Green	32.90	-16.18**	-15.64**	-4.08	37.25	-14.29**	-10.89*	-1.53	7.75	133.96**	169.57**	88.11**
ARC-1 x Japanese Long Green	37.80	0.63	6.11	-10.20	39.00	-8.91	-3.70	3.09	4.00	3.90	6.67	-2.91
SE m±	2.40	2.00	2.13	2.13	2.30	1.95	2.08	2.08	0.54	0.47	0.53	0.53
CD (0.05)	4.92	4.10	4.37	4.37	4.72	4.00	4.27	4.27	1.11	0.96	1.09	1.09
CD (0.01)	6.65	5.54	5.90	5.90	6.37	5.40	5.76	5.76	1.50	1.30	1.47	1.47

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

Standard heterosis was observed in 10 hybrids for days to first male flower opening was not in the desired direction.

Days to first female flower opening

Significant relative heterosis, heterobeltiosis and standard heterosis were expressed for days to first female flower opening. Maximum relative heterosis was shown by BSS 169 x Japanese Long Green (-14.29%). Punerikhira x ARC-1 (Plate 5) also had high relative heterosis (-12.30%). Heterobeltiosis also was the highest in BSS 169 x Japanese Long Green (-10.89%). Highly significant negative standard heterosis (-14.41%) was shown by the cross Punerikhira x ARC-1 followed by CS 9 x Punerikhira (-14.35%).

Node to first female flower

Maximum relative heterosis and standard heterosis was shown by CS 12xBSS 169 (-27.43%, -38.35%). None of the hybrids showed significant heterobeltiosis. Other hybrids with standard heterosis were CS 9xBSS 169 (-35.44%) and Punerikhira x ARC-1 (-27.18%).

Days to first harvest

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

Table 16 Heterosis for days to first harvest, duration of the crop and branches/plant in cucumber

Genotypes	Days to first harvest				Duration of the crop				Branches/plant			
Parents/cross	Mean (No.)	RH (%)	HB (%)	SH (%)	Mean (Days)	RH (%)	HB (%)	SH (%)	Mean (No.)	RH (%)	HB (%)	SH (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
CS 12	42.50				77.38				5.25			
CS 9	42.25				58.50				4.75			
Punerikhira	41.88				71.50				4.88			
Green Long	47.50				74.00				7.12			
BSS 169	46.88				60.50				6.75			
ARC-1	47.50				71.00				6.50			
Japanese Long Green	50.75				71.50				8.75			
CS 12 x CS 9	46.00	8.55*	8.88	8.24	58.50	-13.89**	-24.39**	-24.39**	3.38	-32.50**	-35.71**	-35.71**
CS 12 x Punerikhira	45.75	8.44*	9.25*	7.65	75.50	1.43	-2.42	-2.42	7.66	51.41**	46.00**	46.00**
CS 12 x Green Long	66.00	46.67**	55.29**	55.29**	67.62	-10.65**	-12.60**	-12.60**	2.50	-59.60**	-64.91**	-52.38**
CS 12xBSS 169	50.00	11.89**	17.65**	17.65**	70.50	2.27	-8.89**	-8.89**	2.12	-64.58**	-68.52**	59.62**

Table 16 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13
CS 12xARC-1	45.50	1.11	7.06	7.06	65.62	-11.54**	-15.19**	-15.19**	6.38	8.51	-1.92	21.52*
CS 12xJapanese Long Green	43.75	-6.17	2.94	2.94	64.50	-13.35**	-16.64**	-16.64**	5.00	-28.57**	-42.86**	-4.76
CS 9 x Punerikhira	43.75	4.01	4.48	2.94	62.00	-4.62	-13.29**	-19.75**	6.12	27.27**	25.64**	16.57*
CS 9 x Green Long	53.50	19.22**	26.63**	25.88**	67.50	1.89	-8.78**	-12.69**	3.16	-46.69**	-55.58**	-39.81**
CS 9 x BSS 169	46.00	3.23	8.88	8.24	60.50	1.68	0.00	-21.81**	3.25	-43.48**	-51.85**	-38.10**
CS 9xARC-1	46.00	2.51	8.88	8.24	74.00	14.29**	4.23	-4.37	6.50	15.56*	0.00	23.81**
CS 9 x Japanese Long Green	51.00	9.68*	20.71**	20.00**	63.00	-3.08	-11.89**	-18.53**	4.00	-40.74**	-54.29**	-23.81**
Punerikhira x Green Long	50.20	12.34**	19.88**	18.12**	71.00	-2.41	-4.05	-8.25**	4.34	-27.75**	-39.16**	-17.33**
Punerikhira x BSS 169	52.00	17.18**	24.18**	22.35**	66.50	0.76	-6.99*	-14.06**	2.88	-50.54**	-57.41**	-45.14**
Punerikhira x ARC-1	42.42	-5.09	1.29	-0.19	76.50	7.37**	6.99**	-1.14	6.50	14.29**	0.00	23.81**
Punerikhira x Japanese Long Green	54.50	17.68**	30.15**	28.24**	71.25	-0.35	-0.35	-7.92**	4.41	-35.19**	-49.54**	-16.00

Table 16 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13
Green Long x BSS 169	48.50	2.78	3.47	14.12**	62.00	-7.81**	-16.22**	-19.88**	2.50	-63.96**	-62.96**	-52.38**
Green Long x ARC-1	56.50	18.95**	18.95**	32.94**	64.00	-11.72**	-13.51**	-17.29**	3.00	-55.96**	-53.85**	-42.86**
Green Long x Japanese Long Green	52.00	5.85	9.47*	22.35**	66.50	-8.59**	-10.14**	-14.06**	2.62	-66.93**	-70.00**	-50.10**
BSS 169xARC-1	48.50	2.78	3.47	14.12**	66.00	0.38	-7.04*	-14.71**	6.62	0.00	1.92	26.10**
BSS 169 x Japanese Long Green	47.00	-3.71	0.27	10.59*	76.00	15.15**	6.29*	-1.78	2.50	-67.74**	-71.43**	-52.38**
ARC-1 x Japanese Long Green	51.50	4.83	8.42	21.18**	66.50	-6.67**	-6.99*	-14.06**	2.00	-73.77**	-77.14**	-61.90**
SE m±	2.01	1.71	1.86	1.86	1.84	1.58	1.91	1.91	0.42	0.37	0.42	0.42
CD (0.05)	4.12	3.51	3.82	3.82	3.78	3.24	3.92	3.92	0.86	0.76	0.86	0.86
CD (0.01)	5.56	4.73	5.15	5.15	5.09	4.37	5.29	5.29	1.16	1.02	1.16	1.60

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

Duration of the crop

Maximum relative heterosis was shown by BSS 169 x Japanese Long Green (15.15%) followed by CS 9 x ARC-1 (Plate 6) having 14.29 percentage relative heterosis. Heterobeltiosis was highest in Punerikhira x ARC-1 (6.99%) followed by BSS 169 x Japanese Long Green (6.29%). The standard heterosis expressed by several hybrids was not in the desired direction.

Branches/plant

Highly significant positive heterosis was observed for branches/plant. The hybrid CS 12 x Punerikhira had the maximum positive value for relative heterosis, heterobeltiosis and standard heterosis (51.41, 46.00 and 45.90%).

Vine length

Relative heterosis, heterobeltiosis and standard heterosis were significant for vine length. Eight hybrids showed significant positive relative heterosis. Highest relative heterosis (58.14%) was shown by the cross CS 9 x ARC-1 (Plate 6) followed by CS 12 x Japanese Long Green (49.39%). Heterobeltiosis also was maximum (32.51%) in CS 9 x ARC-1 followed by ARC-1 x Japanese Long Green (31.59%). Maximum positive standard heterosis value of 25.59% was recorded in two hybrids viz. CS 12 x Japanese Long Green and Punerikhira x ARC-1.

Table 17 Heterosis for vine length, fruits/plant and average fruit weight in cucumber

Genotypes	Vine length				Fruits/plant				Fruit weight			
Parents/cross	Mean (cm)	RH (%)	HB (%)	SH (%)	Mean (No.)	RH (%)	HB (%)	SH (%)	Mean (g)	RH (%)	HB (%)	SH (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
CS 12	140.33				13.35				510.00			
CS 9	126.50				12.88				230.88			
Punerikhira	157.50				9.95				220.00			
Green Long	129.62				5.20				215.38			
BSS 169	114.00				5.50				197.50			
ARC-1	85.50				11.66				182.50			
Japanese Long Green	95.62				3.12				92.62			
CS 12 x CS 9	126.83	-4.93	-9.62	-9.62	13.54	3.26	1.42	1.42	205.00	-44.66**	-59.80**	-59.80**
CS 12 x Punerikhira	136.75	-8.17	-13.17	-2.55	12.12	4.08	-9.18	-9.18	422.50	15.75**	-17.16**	-17.16**
CS 12 x Green Long	129.50	-4.06	-7.72	-7.72	10.75	15.90**	-19.48**	-19.48**	275.00	-24.18**	-46.08**	-46.08**
CS 12xBSS 169	136.00	6.95	-3.09	-3.09	1.50	-84.08**	-88.76**	-88.76**	142.50	-59.72**	-72.06**	-72.06**
CS 12xARC-1	109.25	-3.25	-22.15**	-22.15**	5.96	-52.35**	-55.36**	-55.36**	212.50	-38.63**	-58.33**	-58.33**

Table 17 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13
CS 12xJapanese Long Green	176.25	49.39**	25.59**	25.59**	7.07	-14.11**	-47.00**	-47.00**	277.50	-7.90	-45.59**	-45.59**
CS 9 x Punerikhira	146.50	3.17	-6.98	4.40	10.88	-4.71	-15.53**	-18.50**	295.00	30.86**	27.77**	-42.16**
CS 9 x Green Long	109.75	-14.30**	-15.33*	-21.79**	10.75	18.95**	-16.50**	-19.48**	185.00	-17.09	-19.87**	-63.73**
CS 9xBSS 169	112.67	-6.31	-10.94	-19.71**	12.00	30.61**	-6.80	-10.10*	172.50	-19.46*	-25.28**	-66.18**
CS 9xARC-1	167.62	58.14**	32.51**	19.45**	11.04	-10.02*	-14.25**	-17.30**	307.50	48.78**	33.19**	-40.29**
CS 9xJapanese Long Green	151.50	36.41**	19.76*	8.00	1.54	-80.75**	-88.04**	-88.46**	192.50	19.01	-16.62	-62.25**
Punerikhira x Green Long	123.12	-14.24*	-21.83**	-12.26	7.62	0.66	-23.37**	-42.92**	217.50	-0.09	-1.14	-57.35**
Punerikhira x BSS 169	150.35	10.76	-4.54	7.14	2.41	-68.74**	-75.73**	-81.95**	262.50	25.75*	19.32	-48.53**
Punerikhira x ARC-1	176.25	45.06**	11.90	25.59**	19.00	75.80**	62.88**	42.32**	257.50	27.95**	17.05	-49.51**
Punerikhira x Japanese Long Green	97.62	-22.86**	-38.02**	-30.44**	1.50	-77.06**	-84.92**	-88.76**	57.50	-63.21**	-73.86**	-88.73**
Green Long x BSS 169	121.50	-0.26	-6.27	-13.42	2.25	-57.94**	-59.09**	-83.15**	215.00	4.15	-0.17	-57.84**

Table 17 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13
Green Long x ARC-1	139.00	29.23**	7.23	-0.95	11.50	36.38**	-1.41	-13.86**	75.00	-62.30	-65.18**	-85.29**
Green Long x Japanese Long Green	103.17	-8.40	-20.41**	-26.48**	1.35	-67.57**	-74.04**	-89.89**	102.50	-33.44*	-52.41**	-79.90**
BSS 169xARC-1	144.62	44.99**	26.86**	3.05	9.84	14.59*	-15.69	-26.29**	235.00	23.68*	18.99	-53.92**
BSS 169 x Japanese Long Green	126.65	20.83*	11.10	-9.75	1.50	-65.22**	-72.73**	-88.76**	212.50	46.49**	7.59	-58.33**
ARC-1 x Japanese Long Green	125.83	38.95**	31.59	-10.33	1.59	-78.57**	-86.41**	-88.09**	122.50**	-10.95	-32.88**	-75.98**
SE m±	9.21	8.11	9.58	9.58	0.54	0.50	0.61	0.61	24.47	20.28	20.84	20.84
CD (0.05)	18.89	16.64	19.65	19.65	1.10	1.02	1.25	1.25	50.21	41.61	42.76	42.76
CD (0.01)	25.52	22.47	26.54	26.54	1.49	1.38	1.69	1.69	67.80	56.19	57.74	57.74

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

Plate 5.

Punerikhira x ARC-1, the hybrid heterotic for days to first female flower opening and fruits/plant

Plate 6.

CS 9 x ARC-1, the hybrid heterotic for crop duration, vine length and fruit weight

Fruits/plant

Significant and positive relative heterosis of 75.80% was shown by the cross Punerikhira x ARC-1 (Plate 5) followed by Green Long x ARC-1 (36.38%). Punerikhira x ARC-1 also expressed the highest positive values for heterobeltiosis and standard heterosis (62.38 and 42.32%).

Average fruit weight

Significant and positive relative heterosis was observed in seven hybrids. Highest positive relative heterosis (48.78%) was recorded with CS 9 x ARC-1 (Plate 6) followed by BSS 169 x Japanese Long Green (46.49%). The cross CS 9 x ARC-1 also recorded the maximum positive heterobeltiosis (33.19%). Standard heterosis observed in all the hybrids was negative.

Fruit length

Significant and positive relative heterosis, heterobeltiosis and standard heterosis were observed for fruit length. Maximum positive relative heterosis was recorded in Punerikhira x BSS 169 (12.54%) followed by BSS 169 x ARC-1 (9.50%). Punerikhira x BSS 169 expressed the highest heterobeltiosis also (12.16%). The standard heterosis was highest (30.00%) in the hybrid CS 12 x Japanese Long Green (Plate 7).

Table 18 Heterosis for fruit length, fruit girth and fruit diameter in cucumber

Genotypes	Fruit length				Fruit girth				Fruit diameter			
Parents/cross	Mean (cm)	RH (%)	HB (%)	SH (%)	Mean (cm)	RH (%)	HB (%)	SH (%)	Mean (cm)	RH (%)	HB (%)	SH (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
CS 12	17.50				20.60				6.12			
CS 9	14.50				17.08				5.25			
Punerikhira	14.50				15.88				5.15			
Green Long	20.38				17.40				5.62			
BSS 169	14.60				17.50				5.26			
ARC-1	14.62				17.15				5.38			
Japanese Long Green	27.67				8.59				2.78			
CS 12 x CS 9	15.75	-1.56	-10.00*	-10.00*	16.00	-15.06**	-22.33**	-22.33**	6.00	5.49	-2.04	-2.04
CS 12 x Punerikhira	14.50	-9.38*	-17.14**	-17.14**	17.25	-5.41	-16.26**	-16.26**	5.50	-2.44	-10.20	-10.20
CS 12 x Green Long	17.75	-6.27	-12.88**	1.43	18.00	-5.26	-12.62*	-12.62*	6.93	17.87**	13.06*	13.06*
CS 12xBSS 169	13.75	-14.33**	-21.43**	-21.43**	14.12	-25.85**	-31.43**	31.43**	4.71	-17.30**	-23.10**	-23.10**
CS 12xARC-1	17.50	8.95*	0.00	0.00	17.25	-8.61	-16.26**	-16.26**	5.75	0.00	-6.12	-6.12

Table 18 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13
CS 12xJapanese Long Green	22.75	0.74	-17.77**	30.00**	12.00	-17.77*	-41.75**	-41.75**	3.62	-18.54*	-40.82**	-40.82**
CS 9 x Punerikhira	13.50	-6.90	-6.90	-22.86	17.62	6.98	3.22	-14.47*	6.00	15.38*	14.29	-1.96
CS 9 x Green Long	16.00	-8.24*	-21.47**	-8.57	18.75	8.77	7.76	-8.98	5.88	8.05	4.44	-3.92
CS 9xBSS 169	13.25	-8.93	-9.25	-24.29**	15.75	-8.89	-10.00	-23.54**	5.50	4.61	4.46	-10.13
CS 9 x ARC-1	14.25	-2.15	-2.56	-18.57**	15.00	-12.34*	-12.54	-27.18**	4.50	-15.29*	-16.28*	-26.47**
CS 9xJapanese Long Green	11.50	-45.45**	-58.43**	-34.39**	15.50	20.81*	-9.22	-24.76**	5.62	4.41	0.00	-8.17
Punerikhira x Green Long	18.00	3.23	-11.66**	2.86	17.25	3.68	-0.86	-16.26**	5.62	4.41	0.00	-8.17
Punerikhira x BSS 169	16.38	12.54**	12.16*	-6.40	18.45	10.56	5.43	10.44	7.12	36.82**	35.33**	16.34
Punerikhira x ARC-1	14.75	1.29	0.85	-15.71**	15.91	-3.62	-7.20	-22.77**	5.25	-0.24	-2.33	-14.21**
Punerikhira x Japanese Long Green	8.91	-57.71**	-67.78**	-49.09**	10.62	-13.12	-33.07**	-48.45**	3.50	-11.67	-32.04**	-42.81
Green Long x BSS 169	17.00	-2.79	-16.56**	-2.85	15.75	-9.74	-10.00	-23.54**	5.38	-1.29	-4.44	-12.09*

Table 18 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13
Green Long x ARC-1	15.16	-13.34**	-25.57**	-13.37**	14.00	-18.96**	-19.54**	-32.04**	5.12	-6.82	-8.89	-16.34
Green Long x Japanese Long Green	18.50	-22.98**	-33.13**	5.71	8.75	-32.65**	-49.71**	-57.52**	3.50	-16.67*	26.13	-42.81**
BSS 169xARC-1	16.00	9.50	9.40	-8.57	17.50	1.01	0.00	-15.05	6.18	16.07	14.88	-0.98
BSS 169 x Japanese Long Green	15.25	-27.84**	-44.88**	-12.86**	15.75	20.76*	-10.00	-23.54**	5.12	27.49**	-2.66	-16.34*
ARC-1 x Japanese Long Green	16.25	-23.15**	-41.26**	-7.14	11.00	-14.51	-35.86**	-46.60**	3.50	-14.11	-34.88**	42.81**
SE m±	0.73	0.65	0.77	0.77	1.24	1.00	1.12	1.12	0.39	0.34	0.39	0.39
CD (0.05)	1.49	1.33	1.58	1.58	2.54	2.05	2.29	2.29	0.80	0.69	0.80	0.80
CD (0.01)	2.02	1.80	2.13	2.13	3.43	2.77	3.10	3.10	1.08	0.94	1.08	1.08

* Significant at 5% level

** Significant at 1% level

Plate 7.

CS 12 x Japanese Long Green, the hybrid with maximum standard heterosis for fruit length

Plate 8.

Punerikhira x BSS 169, the hybrid heterotic for fruit diameter

Fruit girth

A maximum and significant positive relative heterosis was observed in CS 9 x Japanese Long Green (20.81%) followed by BSS 169 x Japanese Long Green (20.76%). Though many hybrids recorded significant heterobeltiosis and standard heterosis, all the values were negative.

Fruit diameter

Significant and positive relative heterosis was shown by CS 9 x Japanese Long Green (40.19%). Punerikhira x BSS 169 (Plate 8) also recorded high relative heterosis (36.82%). Heterobeltiosis and standard heterosis recorded were maximum (35.33 and 16.34%) in the cross Punerikhira x BSS 169.

Seeds/fruit

Relative heterosis, heterobeltiosis and standard heterosis were significant for seeds/fruit. Maximum relative heterosis of 41.00% was recorded by CS 12 x BSS 169 followed by CS 12 x ARC-1 (29.69%). Heterobeltiosis was also maximum in CS 12 x BSS 169 (44.06%) Standard heterosis was also maximum in the same combination (44.06%) followed by CS 12 x Punerikhira (29.23%).

100 Seed weight

Relative heterosis was maximum and positive in the cross CS 12 x Punerikhira (23.42%). None of the hybrids showed

Plate 9.

BSS 169 x ARC-1, the hybrid heterotic for yield/plant

positive significant heterobeltiosis. Standard heterosis was also significant and maximum in CS 12 x Punerikhira (16.94%).

Yield/plant

Significant positive relative heterosis was shown by seven hybrids. Maximum positive relative heterosis (111.80%) was expressed by BSS 169xARC-1 (Plate 9) followed by CS 9xARC-1 (104.87%). Five hybrids which were relatively heterotic expressed larger values for heterobeltiosis also. BSS 169xARC-1 showed the highest heterobeltiosis (106.92%). None of the hybrids expressed significant positive standard heterosis for yield/plant.

Table 19 Heterosis for seeds/fruit, 100 seed weight and yield/plant in cucumber

Genotypes	Seeds/fruit				100 seed weight				Yield/plant			
Parents/cross	Mean (No.)	RH (%)	HB (%)	SH (%)	Mean (g)	RH (%)	HB (%)	SH (%)	Mean (kg)	RH (%)	HB (%)	SH (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
CS 12	357.50				2.42				4.89			
CS 9	365.50				2.64				2.25			
Punerikhira	500.00				2.16				1.83			
Green Long	361.00				3.46				1.32			
BSS 169	373.00				2.19				1.19			
ARC-1	255.00				2.75				1.14			
Japanese Long Green	449.00				2.42				0.26			
CS 12 x CS 9	366.00	1.24	0.14	2.38	2.26	-10.63	-14.42	-6.61	2.61	-26.84**	-46.60**	-46.60**
CS 12 x Punerikhira	462.00	7.76	-7.60	29.23**	2.83	23.42**	16.84	16.94*	4.37	30.18**	-10.54**	-10.54**
CS 12 x Green Long	322.50	-10.23	-10.66	-9.79	1.48	-49.62**	-57.21**	-38.84**	1.51	-51.43**	-69.16**	-69.16**
CS 12xBSS 169	515.00	41.00**	38.07**	44.06**	2.24	2.77**	-7.31	-7.44	0.18	-94.16**	-96.37**	-96.37**
CS 12xARC-1	397.50	29.69**	11.19	11.19	2.13	-17.52*	-22.48**	-11.98	0.95	-68.46**	-80.56**	-80.56**

Table 19 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13
CS 12xJapanese Long Green	412.50	2.29	-8.13	15.38*	2.07	-14.22	-14.23	-14.46	1.88	-26.80**	-61.43**	-61.43**
CS 9 x Punerikhira	244.00	-43.62**	-51.20**	-31.75**	1.76	-26.60**	-33.30**	-27.27**	2.83	38.93**	26.03**	-42.13**
CS 9 x Green Long	311.50	-14.25*	-13.71*	-12.87*	1.84	-39.65**	-46.78**	-23.97**	1.20	-32.87**	-46.72**	-75.46**
CS 9xBSS 169	377.50	2.23	1.21	5.59	2.27	-5.97	-13.98	-6.20	1.48	-13.81**	-34.04**	-69.73**
CS 9xARC-1	376.00	21.10	2.87	5.17	2.30	-14.78*	-16.42	-4.96	3.47	104.87**	54.28**	-29.04**
CS 9x Japanese Long Green	419.00	2.89	-6.68	17.20**	2.17	-14.04	-17.70*	-10.33	0.27	-78.69	-88.10**	-94.48**
Punerikhira x Green Long	224.00	-47.97**	-55.20**	-37.34**	2.05	-27.23**	-40.90**	-15.29	1.78	13.17**	-2.60	-63.50**
Punerikhira x BSS 169	295.00	-32.42**	-41.00**	-17.48**	1.75	-19.57*	-20.16	-27.68**	0.37	-75.35**	-79.64**	-92.43**
Punerikhira x ARC-1	302.50	-19.92**	-39.50**	-15.38*	2.54	3.31	-7.75	4.95	2.88	93.77**	57.10**	-41.10**
Punerikhira x Japanese Long Green	152.50	-67.86**	-69.50**	-57.34**	1.79	-22.01**	-26.15**	-27.69**	0.11	-89.73**	-94.13**	-97.75**
Green Long x BSS 169	232.50	-36.65**	-37.67**	-34.97**	2.61	-7.65	-24.57**	7.85	0.35	-71.94**	-73.30**	-92.84**

Table 19 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13
Green Long x ARC-1	283.50	-8.03	-21.47**	-20.70**	1.61	-48.06**	-53.40**	-33.47**	1.50	21.87**	13.45**	-69.33**
Green Long x Japanese Long Green	179.00	-55.80**	-60.13**	-49.93**	1.56	-47.05**	-55.03**	-35.54**	0.15	-81.04**	-88.64**	-96.93**
BSS 169xARC-1	277.50	-11.69	-25.60**	-22.38**	2.47	-0.21	-10.31	2.07	2.47	111.80**	106.92**	-49.49**
BSS 169 x Japanese Long Green	338.50	-17.64**	-24.61**	-5.31	1.39	-39.63**	-42.44**	-42.56**	0.17	-76.29**	-85.53**	-96.52**
ARC-1 x Japanese Long Green	239.50	-32.01**	-46.66**	-33.00**	2.44	-5.51	-11.20	0.83	0.25	-63.93**	-77.80**	-94.89**
SE m±	22.12	18.86	20.61	20.61	0.22	0.19	0.22	0.22	0.08	0.07	0.09	0.09
CD (0.05)	45.39	38.70	42.29	42.29	0.45	0.39	0.45	0.45	0.16	0.14	0.18	0.18
CD (0.01)	61.29	52.26	57.11	57.11	0.60	0.52	0.60	0.60	0.22	0.19	0.24	0.24

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

DISCUSSION

5. DISCUSSION

Cucumber (*Cucumis sativus* L.) is regarded as an economic crop in India, grown through out the year in one or other parts of the country due to varied agro-climatic conditions since long. They are grown for their immature fruits which are consumed raw, cooked, pickled or processed in other forms. The present status of the crop is spelt through the modified cultural practices and plant protection measures. Evidence to show the genetic improvement in yield is comparatively less in the country and ways to push back the yield or productivity barriers is still a need. The first step for achieving genetic improvement is understanding the genetic parameters, viz. variability, heritability, genetic advance and correlation between characters. The second step being, selection of genotypes with desired genetic background and its involvement in a definite procedural pattern. The third step would be the analysis of the results obtained through the procedural handling of the genotypes with desired genetic background. The last step would be charting out breeding programmes based on the information on combining ability, gene action and heterosis patterns, obtained through the analysis of the resultant data. Hence, the present study is contemplated to investigate the genetic variability, correlation among yield and yield contributing characters, combining ability and heterosis and to identify F_1 hybrids heterotic for various economic characters.

5.1 Genetic variability

5.1.1 Variability, heritability and genetic advance

An insight into the magnitude of genetic variability present in a crop species is of utmost importance in any successful crop improvement programme. Estimates of heritability coupled with genetic advance are more useful than any one of the two alone, in the choice of proper selection methods (Johnson *et al.*, 1955 a).

Cucumber breeders althrough have observed limited variability in the germplasm. However, it sounds pertinent to look into the available germplasm for variability. Hallauer and Miranda (1982) opine, the choice of germplasm, either fortuitous or planned to play an important role in any breeding programme, whether an applied programme for inbred development or population improvement or a selection study comparing breeding methods. There are certainly differences among breeding populations and the particular choice of germplasm deciding the ultimate success or failure of selection. In the present study, the components of variation due to phenotype and genotype of 22 accessions from different parts of the country were evaluated.

Analysis of variance revealed significant differences among the 22 cucumber genotypes for all the fifteen characters, viz. days to first male flower opening, days to first female flower opening, node to first female flower, days to first harvest, duration of the crop, branches/plant, vine length, fruits/plant, average fruit weight, fruit length, fruit girth, fruit diameter, seeds/fruit, 100 seed weight and yield/plant. The existence of considerable variation indicated enough scope for improving the population. Cucumber being a cross pollinated crop, there exists much variation and therefore the present observation is quite rational as reported earlier by Miller and Quisenberry (1976), Solanki and Seth (1980), Joshi *et al.* (1981), Choudhary *et al.* (1985), Globerson *et al.* (1987), Prasunna and Rao (1988), Mariappan and Pappiah (1990), Satyanarayana (1991), KAU (1996) and Wehner and Cramer (1996) in cucumber. The genotype CS 12 recorded maximum yield per plant (6.23 kg). The highest number of fruits/plant was in Poinsette (15.80) closely followed by CS 12 (15.57). Average fruit weight, fruit girth and fruit diameter were also maximum in CS 12 (534.34 g, 20.34 cm and 6.48 cm respectively). Japanese Long Green had the longest fruit (27.00 cm). Punerikhira was the earliest flowering genotype (32.2 days).

The genotypic coefficient of variation (GCV) resulting in high heritability was of higher magnitude for yield/plant, fruits/plant and average fruit weight. This indicated low impact of environment on the expression of these characters. The reports by Prasunna and Rao (1988) and Rastogi and Deep (1990 b) supports this view. Days to first male flower opening and days to first female flower opening had the lowest values of GCV and heritability indicating greater impact of environment on these characters. Alternations in sex expression, flower number and type in cucumbers are subject to environmental influence due to changes in auxin concentration (Galun, 1959). The estimated phenotypic coefficient of variation for different characters followed a similar trend as that of GCV. Mariappan and Pappiah (1990) reported similar results in cucumber. Furthermore, the coefficient of variability revealed that the magnitude of genetic variation nearly approached the phenotypic variation in all the characters indicating that the selection on phenotypic basis will hold good for genotypic basis too. This observation was in confirmation with the findings of Rastogi and Deep (1990b) in cucumber.

Since heritability estimates fluctuate in interaction with the environment as well as genetic background, it should be studied along with genetic advance for characters in concern for effective and a pin point selection (Johnson *et al*. 1955b). In the present study, characters such as yield/plant, fruits/ plant, average fruit weight and node to first female flower had high heritability along with high genetic advance. It shows variation for these characters to be due to high additive gene effect and consequently the scope for improving yield through selection. This result is in line with the earlier reports of Solanki and Seth (1980), Joshi *et al.* (1981), Prasunna and Rao (1988), Rastogi and Deep (1990 b) and Prasad and Singh (1992). Though heritability was high for days to first harvest, duration of the crop and fruit length, the genetic advance was of moderate to low magnitude, indicating the action of non-additive genes for expression of these characters, suggesting selection based on these characters to be less effective. This observation is in confirmation with the results of Choudhary *et al.* (1985) and Satyanarayana (1991). Thus it implies that high heritability is not always an indication of high genetic advance (Johnson *et al.*, 1955a).

5.1.2 Correlation studies

A knowledge of the relationship of yield and its component characters is essential for the simultaneous improvement of yield components and in turn yield to be effective. In the present investigation, fruits/plant, average fruit weight, fruit girth and fruit diameter were the characters which exerted the highest positive and significant association with yield (Table 6, 7 and 8). Many earlier reports of positive association of yield and its component characters such as number, girth, diameter and weight of the fruits in cucumber are in support of the present result

(Choudhary, *et al*., 1985; Haribabu, 1985; Prasunna and Rao, 1989; Rastogi and Deep, 1990 b; Prasad and Singh, 1992 and Chen *et al*., 1994). Days to first harvest showed significant negative association with yield. In crops like cucumber harvesting tender fruits will stimulate production of further female flowers and fruits in the vines. Hence, the earliest the fruits are ready for harvesting, the more will be the number and yield of the fruits (Seshadri, 1986).

In general, magnitude of genotypic correlation coefficients were higher than the corresponding phenotypic correlations which indicated that environment had small and similar effects on these characters. Genotypic correlation was also reported to be higher than the phenotypic correlation by Solanki and Seth (1980) and Rastogi and Deep (1990a) in cucumber.

5.1.3 Path coefficient analysis

Path coefficient analysis provides a knowledge of paths through which a component character influences the expression of economic character like yield. Fruit yield is influenced by its components directly as well as indirectly. In the present study, among the direct effects, fruit girth exhibited maximum positive effect on fruit yield followed by average fruit weight. The results were in confirmation with earlier reports of Choudhary and Mandal (1987), Prasunna and Rao (1989), Abusaleha and Dutta (1990) and Prasad and Singh

(1992). Fruits/plant though exhibited positive and significant association with yield, their direct effect on yield was low. The direct effect of fruit diameter was high and negative, but the positive correlation of the character with yield may be due to high and positive indirect effect through fruit girth. The direct effect of fruit length on yield was negligible.

In this study the residual effect noticed was of very low magnitude (0.17) indicating that almost 83 per cent of the variation in fruit yield was attributable to factors considered in this study.

Correlation simply measures the mutual association without caring for casuation, while path analysis specifies the causes and measures the relative importance of causal factors. This could be the reason for the variation observed between correlation and path coefficient analysis.

Results of genetic variability, correlation and path analysis indicated that the characters such as fruit diameter, average fruit weight, fruits/plant, fruit girth and days to first harvest are to be considered in developing high yielding genotypes in cucumber.

5.2 Combining ability and heterosis

5.2.1 Assessment of combining ability of parents

In a heterosis breeding programme for evolving high yielding hybrids, the breeder is often confronted with problem of choice of parents. The common approach of selecting parents on the basis of *per se* performance does not necessarily lead to the best result in hybridization programme (Allard, 1960) as a high yielding inbred may not necessarily be able to transmit its superiority in cross combinations. Selection of the best parents based on complete genetic information and knowledge of combining ability leads to fruitful results in the identification of promising F_1 hybrids. Sprague and Tatum (1942) emphasised that estimates of general combining ability (gca) and specific combining ability (sca) are relative to and dependent on the particular set of parents included in the hybrids under test, an important principle that is often forgetten.

In this study, seven parental lines selected based on selection index were used to study the combining ability, in a diallel experiment. They were crossed in all possible combinations without reciprocals to obtain 21 F_1 hybrids. These hybrids along with their parents were evaluated to obtain information on combining ability and heterosis.

The study revealed significant variances due to gca and sca for all the characters considered. The significance of general combining ability and specific combining ability variances indicated the role of additive as well as non-additive gene action in the control of most of the characters. Significance of gca and sca were observed by many workers in cucumber which support the present findings (Om *et al.*, 1978; Wang and Wang, 1980; Owens *et al.*, 1985b; Musmade and Kale, 1986 and Satyanarayana, 1991).

The mean squares for the genotypes in the analysis of variance for combining ability were significant for all the vegetative and productive characters indicating the presence of adequate variability which could be exploited by selection. Report by Musmade and Kale (1986) supports this view. The magnitude of gca variance was much higher than that of sca variance in eleven out of the 15 traits considered indicating the preponderence of additive type of gene action for these characters. The reports by Prudek (1984) and Prasad and Singh (1994a) supports this view. Higher sca variances than gca variances were observed for characters viz. node to first female flower, branches/plant, vine length and 100 seed weight, indicating non-additive gene effect. Solanki and Seth (1980) observed non-additive gene effect for characters like branches/plant, average fruit weight and duration of flowering in cucumber.

The variation in the gca effect of parents can be attributed to genetic as well as geographic diversity among the parents. Prasad and Singh (1994a) had similar findings. High sca effect observed for different characters may be helpful for sorting out outstanding parents with favourable alleles in heterosis breeding.

It was observed in the present study that the parents showing high gca effect for yield and other characters also gave good *per se* performance for most of the characters. This suggests that the combining ability of parents was related to the *per se* performance as well. Parents showing higher mean performance for a particular character were generally good combiners for that character. General combining ability studies revealed that among the seven parental lines, CS 12 and CS 9 were good combiners for yield.

CS 12 x Punerikhira (1.44) was the best combination for yield followed by CS 9xARC-1 and BSS 169 x ARC-1 with same sca effects (1.33). The parent CS 12 showed high gca effect for average fruit weight, fruit girth, fruit diameter and yield. CS 12 x Punerikhira and Punerikhira x ARC-1 flowered significantly earlier. In these two crosses the common parent Punerikhira was a good general combiner for early flowering, which was manifested in its combinations.

In the present study, for all the characters under consideration, additive as well as non-additive gene actions were significant, suggesting reciprocal recurrent selection and biparental mating as effective tool in handling the population. This is in confirmation with reports of Satyanarayana (1991) and Prasad and Singh (1994 a).

5.2.2. Heterosis

Extent of heterosis was estimated for yield and its 14 components in a 7x7 diallel experiment. Significant differences were observed among the genotypes for all the characters studied.

Heterosis (relative heterosis, heterobeltiosis and standard heterosis) have been considered in conjunction with significant general and specific combiners. In the present study, it was observed that parents producing heterotic crosses for a trait had high and significant sca effect for that trait in their crosses in all the characters considered. Musmade and Kale (1986), Solanki and Shah (1990) and Satyanarayana (1991) had similar results.

Significant and negative relative heterosis and heterobeltiosis were observed for days to first male flower opening in cucumber. High relative heterosis and standard heterosis observed in BSS 169 x Japanese Long Green could be attributed to high genetic distance between the parents. The same cross was heterotic for days to first female flower opening also. Other combinations Punerikhira x ARC-1 and CS 9 x Punerikhira also showed high relative heterosis and standard heterosis. These significant heterosis can be attributed to the high gca effects of the parents, Punerikhira and CS 9. This result was in agreement with the reports of Gill *et al.* (1973), Nikulenkova (1984) and Vijayakumari *et al.* (1993).

Maximum and negative relative heterosis and standard heterosis for node to first female flower was shown by CS 12 x BSS 169. Other hybrids with high standard heterosis were CS 9 x BSS 169 and Punerikhira x ARC-1. This result could be attributed to the involvement of a good general combiner as one of the parents. The sca effects and *per se* performance of the hybrids were also high, which are in line with the findings of Satyanarayana (1991).

The relative heterosis, heterobeltiosis and standard heterosis were not significant in any of the hybrids for days to first harvest. This was contrary to the results obtained by Solanki *et al.* (1982a). Rubino and Wehner (1986) and Ram *et al.* (1995) in cucumber. This indicates that despite earliness in flowering, the behaviour of the hybrids and parents were almost similar in the days taken for fruit maturing.

Significant relative heterosis and heterobeltiosis were observed for duration of the crop. BSS 169 x Japanese Long Green had maximum relative heterosis followed by CS 9 x ARC-1. It is observed that atleast one of the parents involved in the above crosses had positive gca effect. Maximum hetero-beltiosis observed in Punerikhira x ARC-1 could be attributed to the high gca and sca effects of the parents and hybrids respectively.

For branches/plant, high and positive relative heterosis, heterobeltiosis and standard heterosis were shown by the cross CS 12 x Punerikhira which can be attributed to the high and positive gca effect of punerikhira and the high sca effect of the cross. Lower *et al*. (1982), Solanki *et al* (1982 a and b) and Pyzhenkov (1988) got similar results.

Heterosis was significant for vine length also. The cross exhibiting high relative heterosis were CS 9 x ARC-1 and CS 12 x Japanese Long Green. Those exhibiting high hetero-beltiosis were CS 9 x ARC-1 and ARC-1 x Japanese Long Green. The crosses CS 12 x Japanese Long Green and Punerikhira x ARC-1 showed maximum standard heterosis. It is observed that atleast one of the parents involved in these crosses had high gca effects which gave significant heterosis. The genetic distance between these parents could be another factor for heterosis in vine length. This result was in agreement with the reports of Lower *et al*. (1982), Pyzhenkov *et al*. (1988) and Satyanarayana (1991) in cucumber.

Maximum relative heterosis, heterobeltiosis and standard heterosis were shown by Punerikhira X ARC-1 for fruits/plant. The parents were good general combiners and the combination exhibited high sca effect for fruits/plant. Besides, the *per se* performance of the cross was also good. The observed heterosis for fruits/plant has been in line with the findings of Solanki *et al*. (1982 a and b).

Several hybrids exhibited high relative heterosis and heterobeltiosis, the maximum being in CS 9 X ARC-1 for average fruit weight. In all those combinations the sca effects were high which is supported by reports of Cizov (1945), Solanki *et al*. (1982a and b), Satyanarayana (1991) and Fang *et al*. (1994).

Significant and positive relative heterosis and heterobeltiosis for fruit length were shown by Punerikhira x BSS 169. The cross showed high sca effect and also good *per se* performance. The high standard heterosis shown by CS 12 x Japanese Long Green can be attributed to the high gca effects of parents and also the genetic distance between them. Heterosis for fruit length was reported earlier by Lebedeva (1984) and Li and Zhu (1995).

Significant and maximum relative heterosis and heterobeltiosis for fruit girth was observed in the cross CS 9 x Japanese Long Green closely followed by BSS 169 x Japanese Long Green. This is due to the positive gca effect of atleast one of the parents and the genetic distance between the parents involved in the crosses.

Heterosis was significant for fruit diameter also. The cross CS 9 x Japanese Long Green had the maximum relative heterosis which is attributed to the high genetic distance between the parents. Punerikhira x BSS 169 showed the maximum heterobeltiosis and standard heterosis. They were good general combiners for fruit diameter. Similar result was also reported by Imam *et al*. (1977).

Heterosis for seeds/fruit was high and significant in the cross CS 12 x BSS 169 where the parents were good general combiners and the cross had high sca effect. Highest relative and standard heterosis for 100 seed weight observed in CS 12 x Punerikhira is due to the high gca effect of CS 12.

In the present study, relative heterosis was significant in seven and heterobeltiosis in five hybrids as far as yield/plant is concerned. The crosses BSS 169 x ARC-1, CS 9 x ARC-1 and Punerikhira X ARC-1 were significantly heterotic over mid and better parents. It is clear from the combining ability studies that in crosses with significant heterosis atleast one of the parents involved was a good general combiner. It is also evident that heterotic crosses had higher values of sca effects. Relative heterosis and heterobeltiosis in cucumber were also reported by Rubino and Wehner (1986), Satyanarayana (1991) and Musmade *et al*. (1995). However, in the present diallel crosses, none of the hybrids possessed standard heterosis. This is because the standard heterosis was worked out in comparison with the best genotype (CS 12) included in the variability studies since there is no standard cucumber variety in the State. Despite the heterosis for earliness, standard heterosis was not manifested for yield/plant in any of the hybrids. This lack of standard heterosis for total yield could also be attributed to the inability of F_1 hybrids to sustain production over late period of harvesting. Thus cucumber improvement is to be viewed through a) inclusion of more genetically diverse genotypes b) increasing early component of total yield and c) Sustaining production through out the harvesting period. Therefore, early flowering genotypes with long harvesting period can be considered in cucumber breeding programme.

SUMMARY

6. SUMMARY

The present investigation 'Genetic variability and heterosis in cucumber (*Cucumis sativus* L.)' was conducted at the Department of Horticulture, College of Agriculture, Vellayani during 1995-97. The objectives of the study were estimation of genetic variability, heritability and genetic advance, studying the association among yield and its components, assessing the direct and indirect effects of the component characters on yield by path analysis and identification of heterotic F_1 hybrids in cucumber.

The extent of genetic variability in 22 genotypes were assessed. From these genotypes, seven parents were selected based on selection index and 21 F_1 hybrids developed. These hybrids were evaluated along with their parents for the esitmation of combining ability and heterosis.

The genotypes showed significant difference for all the characters studied, viz. days to first male flower opening, days to first female flower opening, node to first female flower, days to first harvest, duration of the crop, branches/plant, vine length, fruits/plant, average fruit weight, fruit length, fruit girth, fruit diameter, seeds/fruit, 100 seed weight and yield/plant.

The genotype CS 12 was first for yield/plant (6.23 kg), average fruit weight (534.34 g), fruit girth (20.34 cm) and fruit diameter (6.48 cm) and second for fruits/plant (15.57). The earliest flowering genotype was Punerikhira (32.2 days).

The genotypic coefficient of variation resulting in high heritability along with genetic advance was of high magnitude for yield/plant, fruits/plant average fruit weight and node to first female flower. Days to first harvest, duration of the crop and fruit length had high heritability but moderate to low genetic advance. Days to first male flower opening and days to first female flower opening had the lowest values of GCV and heritability. The magnitude of genetic variation nearly approached the phenotypic variation in all the characters.

In general, the genotypic correlations were higher than phenotypic correlations. The characters like fruits/ plant, average fruit weight, fruit girth and fruit diameter were highly correlated with yield. Fruit girth exerted the maximum direct positive effect on yield, followed by average fruit weight and fruits/plant.

Analysis of variance for combining ability showed significant gca and sca variances for all the characters indicating the role of both additive and non additive gene action for the control of most of the characters.

It was observed that the parents showing higher mean performance for a particular character were generally good combiners for that character. Among the seven parental lines CS 12 and CS 9 were good general combiners for yield. The hybrids CS 12 x Punerikhira, CS 9 x ARC -1 and BSS 169 x ARC-1 possessed high sca effects.

In general, heterosis was observed for most of the characters. Significant relative heterosis, heterobeltiosis and standard heterosis were expressed for days to first female flower opening. Punerikhira x ARC -1 and CS 9 x Punerikhira flowered significantly earlier than the standard variety CS 12.

Relative heterosis was significant in seven and heterobeltiosis in five hybrids for yield/plant. None of the hybrids exceeded the standard parent. The hybrids BSS 169 x ARC-1, CS-9 x ARC-1 and Punerihira x ARC-1 were significantly heterotic over mid and better parents.

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GENETIC VARIABILITY AND HETEROSIS IN CUCUMBER (*Cucumis sativus* L.)

By

GAYATHRI. K.

ABSTRACT OF THE THESIS

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ABSTRACT

The present investigation on 'Genetic variability and heterosis in cucumber (*Cucumis sativus* L.)' was conducted at the College of Agriculture, Vellayani, Trivandrum during 1995-97. Twenty two genotypes of cucumber collected from different parts of the country were grown in randomised block design with two replications and assessed the genetic variability of fifteen characters. The genetic parameters like variability, heritability, genetic advance, correlation coefficients and direct and indirect effects of the component traits on yield were estimated. Seven parents were selected based on selection index, crossed in all possible combinations without reciprocals in a 7x7 diallel and produced 21 F_1 hybrids. These F_1 hybrids were evaluated along with their parents and derived information on general and specific combining ability and heterosis.

Significant differences were observed among the 22 genotypes for all the fifteen characters studied. Yield/plant, fruits/plant, average fruit weight and node to first female flower had the highest genotypic coefficient of variation with high heritability and genetic advance. Fruits/plant, average fruit weight, fruit girth and fruit diameter were highly correlated with yield. Fruit girth exerted the maximum

positive effect on yield followed by average fruit weight and fruits/plant.

Significant gca and sca variances were observed for all the traits. CS 12 and CS 9 were good general combiners for yield. The hybrids CS 12 x Punerikhira, CS 9 x ARC-1 and BSS 169 x ARC-1 possessed high sca effects for yield.

Significant heterosis were observed for most of the traits. Relative heterosis, heterobeltiosis and standard heterosis were significant for days to first female flower opening. Punerikhira x ARC-1 and CS 9 x Punerikhira were significantly earlier than the standard variety CS 12. Relative heterosis and heterobeltiosis were observed for yield/plant. None of the hybrids exceeded the standard parent. The hybrids BSS 169 x ARC-1, CS 9 x ARC-1 and Punerikhira x ARC-1 showed significant relative heterosis and heterobeltiosis for yield/plant.