GENETIC DIVERSITY AND COMBINING ABILITY IN CUCUMBER (*Cucumis sativus* L.)

by

SUMA. A.

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THESIS

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DEPARTMENT OF PLANT BREEDING AND GENETICS

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DECLARATION

I, hereby declare that this thesis entitled **"GENETIC DIVERSITY AND COMBINING ABILITY IN CUCUMBER (*Cucumis sativus* L.)"** is a bonafide record of research work done by me during the course of research and that this thesis has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"GENETIC DIVERSITY AND COMBINING ABILITY IN CUCUMBER (*Cucumis sativus* L.)"** is a record of research work done independently by Mrs. Suma, A. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Suma. A

LIST OF ABBREVIATIONS

CD	-	Critical Difference
CTAB	-	Cetyl Trimethyl Ammonium Bromide
Df	-	Degrees of Freedom
DMRT	-	Duncan's Multiple Range Test
EDTA	-	Ethylene Diamine Tetra Acetic acid
GCA	-	General Combining Ability
GCV	-	Genotypic Coefficient of Variation
GIS	-	Geographical Information System
HB	-	Heterobeltiosis
LSD	-	Least Square Difference
MI	-	Marker Index
MSS	-	Mean Sum of Squares
NTSYS	-	Numerical Taxonomy and Multivariate Analysis System
PCA	-	Principal Component Analysis
PCV	-	Phenotypic Coefficient of Variation
PDI	-	Per cent Disease Index
PIC	-	Polymorphism Information Content
RH	-	Relative Heterosis
SAHN	-	Sequential Agglomerative Hierarchical and Nested
SCA	-	Specific Combining Ability
SDI	-	Shannon Diversity Index
SH	-	Standard Heterosis
TBE	-	Tris Borate EDTA
UPGMA	-	Unweighted Pair Group Method Algorithm

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Introduction

1. Introduction

Cucumber (*Cucumis sativus* L.) is an important vegetable crop of family Cucurbitaceae with chromosome number 2n=2x=14. *Cucumis hardwickii*, a close relative is considered to be the progenitor of *Cucumis sativus.* The genus *Cucumis* comprises of 52 species (Mabberley, 2008) including cucumber, which is the fourth most important vegetable crop after tomato, cabbage and onion. It is mainly grown for its tender fruits consumed as salads and pickles. It is an important component of cosmetic industry owing to its soothing, cleansing and softening properties (Wang *et al.*, 2007). Recently, in view of the changing food habits and increasing health concern of the people, cucumber is placed as a main component of salad preparations. Despite its economic, medicinal and nutritional values, in-depth study on genetic diversity of this crop is very limited.

Availability of genetic diversity is a pre-requisite for any crop improvement programme. An insight into the magnitude of genetic variability present in a population is of paramount importance to utilize the germplasm in a judicious manner (Abraham, 2012). Systematic characterization and evaluation of genotypes will reveal their genetic potential to use in crop improvement programmes. It is also known that progenies developed from geographically and genetically diverse parents in hybridization programme will be promising in terms of their agronomic performance due to varied combination of genes.

As cucumber is consumed as raw vegetable, preference of the consumer depends on many factors including non-bitterness, crispness and flavour of the fruit. Thus organoleptic qualities are also important factors to be analysed in crop breeding programmes.

In the present scenario, DNA markers have become more popular and effective to study the genetic diversity among genotypes. Simple Sequence Repeats (SSRs) are one of the widely used molecular markers for genetic diversity analysis due to its genomic abundance, high reproducibility, multi-allelic nature

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and high specificity. SSR markers have wide applications in the areas such as gene mapping, marker assisted selection, genetic diversity analysis, cultivar identification and gene pyramiding.

Heterosis breeding is an important tool to enhance the productivity of crops. The exploitation of heterosis is much easier in cross pollinated crops and cucumber being monoecious, with large number of seeds per fruit, provides ample scope for the utilization of heterosis on commercial scale (Singh *et al.*, 2012). Identification of parental combinations that produce hybrids of superior yield and acceptable quality is the most important step in heterosis breeding.

Analysis of combining ability has been used in practical crop improvement programmes to determine the relative importance of general combining ability (GCA) of the parents and specific combining ability (SCA) of the crosses. The GCA effects helps in selection of superior parents and SCA effects helps in selection of superior hybrids. The information generated from the *per se* performance, combining ability and heterosis studies will be helpful in identifying promising F_1 hybrids.

ICAR-National Bureau of Plant Genetic Resources, New Delhi maintains diverse genotypes of cucumber collected from different parts of the country. The detailed characterization of these genotypes has not been attempted so far. Hence, the present study was envisaged

1. to explore genetic diversity in cucumber genotypes using morphological and molecular markers
2. to study combining ability in selected genotypes

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Review of literature

2. Review of literature

2.1. Morphological characterization

The success of any breeding programme depends on the magnitude of genetic variability present in the population. The unambiguous, reliable, fast and cost effective assessment of genetic diversity is important for conservation and further evaluation of genetic resources (Reddy, 2008). The amount of genetic variability present in the population can be assessed at morphological level and molecular level. The variability at morphological level is influenced by environment in which they are grown.

Solanki and Seth (1980) evaluated 24 varieties of cucumber and found significant difference between genotypes for the characters namely plant height, number of leaves per plant, number of male flowers per plant and days to fruit maturity. Genetic parameters like phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) also ranged between low to moderate to high in different characters studied.

Twenty varieties of cucumber were evaluated by Joshi *et al.* (1981) and reported that GCV was high for characters namely node number at which first fruit appeared, number of fruits per plant, fruit circumference, and fruit length indicating a scope for improvement in these traits.

Significant differences with respect to vegetative characters, reproductive characters and yield and yield components in cucumber were reported by Patil and Patil (1985a). In their study cucumber genotypes, showed high degree of variability for fruit number, fruit yield and fruit weight. They observed that earliness in fruiting did not directly correlate with high number of fruits and high yield. Least number of fruit productions was attributed to fewer female flowers produced and fruit set (Patil and Patil, 1985b).

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Choudhary *et al.* (1985) recorded maximum range of variation for vine length ranging from 1.76 m to 3.16 m. In their study, fruit diameter ranged from 4.96 cm to 5.60 cm. High heritability and low genetic advance for days to first female flower appearance, number of flowers per vine and fruit length were observed.

Mariappan and Pappiah (1990) assessed the performance of 45 genotypes of cucumber and found that traits like number of fruits per plant and fruit weight exhibited high PCV and GCV, and suggested that since GCV being the heritable portion of variation, it is more useful for assessment of variability.

Genetic variability assessment in 23 genotypes of cucumber by Prasad and Singh (1992) reported high values of PCV in conjunction with GCV for characters like yield and number of fruits per plant followed by node number at which first male and female flower appeared in cucumber. Heritability estimates ranging from 0.02 per cent to 48.00 per cent was observed in number of fruits and fruit length respectively. They suggested that low heritability values for number of fruits and yield per plot may be attributed to environmental effects on the total phenotypic variation.

Saikia *et al.* (1995) recorded high variability for yield per plant followed by node number at which first female flower appeared and number of leaves per plant. They reported highest PCV for yield per plant and lowest in days to first picking. GCV also followed similar trend.

Rao *et al.* (1999) observed high heritability and genetic advance for traits namely fruit weight, number of fruits per plant and node at which first female flower appeared. They suggested that characters with high heritability along with high genetic advance would respond better towards selection.

Das *et al.* (2003) observed high heritability along with high genetic advance for fruit yield per vine, vine length, number of primary branches, number of fruits per vine, fruit length, fruit diameter and fruit weight. They suggested that these characters were more reliable for selection.

Hochmuth *et al.* (2004) studied the genetic variability in twelve greenhouse beit-alpha cucumber varieties and two growing systems. No significant difference in fruit width was found among the twelve cucumber varieties with all means between 26.40 to 27.70 mm in diameter. Fruit length ranged from 136.00 to 178.00 mm per fruit. Variety 'Tenor' had recorded the longest fruits at 178 mm, followed by '4419' at 167 mm, and 'Ilas' with 157 mm.

Evaluation of 11 exotic and six indigenous cultivars of cucumber were undertaken by Afangideh and Uyoh (2007) for yield and quality characteristics. The fruit yield was significantly higher in indigenous cultivars than the exotic lines. However, exotic cultivars like Ashley, Addis and Regal recorded high vine length and fewer days to flowering. In their study, PCV was greater than GCV for all the characters studied. High heritability was recorded for days to flower initiation and days to 50 per cent flowering.

Kumar *et al.* (2008) evaluated genetic variability in 25 cucumber genotypes for yield and yield contributing characters. High PCV and GCV were observed for days to first female flower anthesis, number of primary branches per plant, number of fruits per plant, node number bearing female flower, fruit length, fruit weight and fruit yield per plant. High heritability and genetic gain were observed for all the characters, indicating the additive gene effects controlling these characters.

Yadav *et al.* (2009) characterized 20 cucumber genotypes for assessing the genetic variability, heritability and genetic advance for different traits. The results revealed existence of considerable amount of genetic variation for all the traits except fruit cavity at edible stage. Highest value for PCV and GCV were observed for number of days to first female flower anthesis.

Study on variability assessment, character association and yield performance of 58 cucumber genotypes was undertaken by Hossain *et al.* (2010). High GCV for characters like yield per plant, number of fruits per plant, fruit length, number of lateral shoots, average fruit weight, petiole length and node number at which first male and female flower appeared were observed.

Morphological traits namely fruit length, fruit circumference, days to 50 per cent male and female flowering, number of fruits per plant were recorded for six promising varieties of cucumber (Dissanayaka *et al.*, 2011). Qualitative traits namely fruit shape, skin colour, stem end and blossom end shape were also recorded. Based on the analysis on both quantitative and qualitative characters, they have identified the variety which performed best in the study.

Al-Rawahi *et al.* (2011) studied the diversity of 24 cucumber accessions in Oman to evaluate the genetic diversity based on morphological traits. The Shannon-Weaver diversity index (SDI) analysis revealed the presence of genetic variability among the accessions. Among the traits considered, tendril lobe had the highest diversity index followed by large leaf length, male flowers, plant length after 60 days. Lowest diversity index was for large leaf width, indicating less diverse nature of the character.

Genetic variability studies in cucumber by Gaikwad *et al.* (2011) reported that GCV was slightly less than PCV indicating the effect of environment in the expression of traits considered. However, high PCV and GCV were observed for fruit length, number of fruits per vine, fruit weight and node number at which first female flower appeared. High heritability coupled with high genetic advance was recorded for vine length and fruit weight.

Genetic variation in 20 genotypes of cucumber was assessed by Golabadi *et al.* (2012) and the results revealed significant differences between the genotypes for the traits considered. Genotypes with high total fruit yield also showed high fruit number per plant with the exception of genotype Green Majic with low total fruit yield. They observed that low fruit length and fruit diameter caused yield reduction in this cultivar. Fruit number was found to be more stable measure of productivity than fruit weight for cucumber.

Zhang *et al*., (2012) studied 18 *Cucumis* genotypes (nine *Cucumis sativus* and nine *C. melo*) collected from three South Asian countries namely India, China and Nepal and characterised for nine quantitative and 23 qualitative characteristics. In their study, fruit weight displayed the maximum divergence among the nine quantitative traits and much variation was displayed in twenty-three qualitative traits among eighteen accessions.

Genetic variation among 44 cucumber accessions was assessed using morphological traits (Pandey *et al*., 2013). High genetic variability was observed for days to 50 per cent female flowering (37-46 days from sowing), number of fruits per plant (1.4-6.0), individual fruit weight (0.04-0.552 kg) and root length (14.25-32.8 cm). The accession from Madhya Pradesh and Uttar Pradesh were diverged from the accessions of other parts of India.

Khan *et al.* (2015) evaluated 24 genotypes of cucumber to find out their similarities and differences based on numerical traits. These genotypes exhibited great variations in seed germination, days to 50 per cent flowering, fruit initiation, days to edible maturity, vine length, number of fruit per plant, fruit length and fruit width.

Pushpalatha *et al.* (2017) conducted a study on genetic variability and heritability for growth and yield of cucumber in 24 diverse cucumber genotypes. The results revealed high phenotypic and genotypic coefficients of variation for yield per plant, fruit flesh thickness, number of fruits per plant, number of nodes per plant, number of branches per plant, average fruit weight, internodal length and vine length. High heritability coupled with high genetic advance as per cent mean was recorded for all the characters studied except for days to first female flower anthesis, days to fifty per cent flowering and days to first fruit harvest indicating that there is scope for improvement through the selection.

2.2. Storage studies

Kasim and Kasim (2011) studied the storage quality of cucumber fruits treated with vapour heat treatment at various time intervals and reported that treatment at 48°C for 8 minutes maintained the appearance and peel colour index of fruits at the end of storage period.

The effect of application of gum arabic edible coating on weight loss, firmness and sensory characteristics was investigated for cucumber fruits by Al-Juhaimi *et al.* (2012). Cucumber was coated with gum arabic at different concentrations (5, 10, 15 and 20%) and stored at 10 and 25°C for up to 16 days. Gum coating significantly reduced weight loss of the fruits at both storage temperatures. The firmness of the control fruits significantly decreased with the storage time at both 10 and 25°C. The application of gum edible coating delayed softening of cucumber fruit during 16 days of storage at 10 and 25°C.

Manjunatha and Anurag (2014) revealed that cucumber can be stored under modified atmospheric packaging with two perforations at 4 ± 1 °C and 90 ± 2 % relative humidity (RH) and ambient conditions (23-26 °C and 63-66 % RH) for 12 and 6 days, respectively.

Sudhakar and Shivashankara (2014) reported that packaging materials significantly improved the nutritional quality of cucumber at ambient temperature (24-32 °C and 60-70 % RH) with good surface yellow colour, edible softness, retention of nutritional quality and acceptable organoleptic quality.

Choi *et al.* (2015) studied the changes of post-harvest quality in 'Bagdadagi' cucumber by storage temperature. In their study, it was revealed that storage of at 10°C was selected as an optimal temperature of Bagdadagi cucumber for maintaining storage life up to 20 days.

Miano *et al.* (2016) studied the effect of wrapping materials on physico-chemical and sensory quality of cucumber under ambient and refrigerated

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conditions. The results revealed that packaging materials (newspaper and polyethylene bags) significantly enhanced the weight, length, diameter, TSS, colour, taste and overall acceptability of cucumber fruit under ambient and refrigeration temperature.

Omoba and Onyekwere (2016) studied the effects of chitosan-based edible coatings with lemon grass extract on the physical properties and overall acceptability of cucumber fruits stored at ambient temperature (28 ± 2°C) and 85 to 90 per cent RH for 14 days. After 14 days, weight loss was 1per cent for cucumber fruits treated with 1.0 % C + 1.0 % E, and 4 % for control untreated fruits. No significant difference ($P < 0.05$) was observed in the firmness of all the treated cucumber fruits after 14 days, while the untreated significantly reduced by 4 %. In this study, the combination of chitosan and lemon grass extract, especially 1.0% C +1.0 % E as an edible coating, has proved to have great potential to preserve the physical characteristics of cucumber fruits at ambient temperature 28 ± 2°C peculiar to tropical countries.

2.3. Correlations

Correlation analysis helps to provide an estimate on relationship between characters. The association between characters help the breeder to choose those characters which are directly associated with the yield.

Rajput *et al.* (1991) reported highly significant positive correlation of yield with number of fruits per plant and number of branches per plant, both at phenotypic and genotypic levels in cucumber.

Islam *et al.* (1993) conducted experiment on genetic variability and path analysis in cucumber. They reported significant positive correlation between number of fruits per plant and yield ($r= 0.98$) in cucumber. In their study, most of the genotypic correlation coefficients were higher than their corresponding phenotypic correlation coefficient indicating the masking of the efficiency of the

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environment which modified the expression of a character thereby reducing the phenotypic expression.

Ying *et al.* (2002) observed genetic correlation of six agronomic characters of cucumber. Yield showed positive genetic correlation with single fruit weight, fruit number per plant, leaf area and plant height. No significant correlation was observed between yield and stem number per plant.

Rao *et al.* (2004) conducted a study to evaluate 31 cucumber genotypes of diverse origin. The study on correlation between characters revealed positive association of yield with fruit weight, fruit length and flesh thickness.

Afangideh and Uyoh (2007) assessed the genetic variability and worked out correlation between characters in 11 exotic and six indigenous cultivars of cucumber. Results indicated that mean fruit number per plant and length of vine at 6 weeks correlated positively and significantly with fruit yield while days to flower initiation and days to 50 % flowering showed negative correlation with yield. Length of vine at six weeks also correlated positively and significantly with mean number of fruits. Similarly, there were positive and significant relationships between number of leaves at four weeks and number of leaves at 6 weeks, days to flower initiation and days to 50 % flowering.

Parihar *et al.* (2007) studied the correlation between different characters in cucumber. They reported that highly significant positive association was found between fruit yield per plant and number of fruits per plant, per fruit weight, length of fruit, length of vine and number of nodes per vine, length of vine was significant and positively associated with weight of fruit, length of wine was significant and positively associated with fruit yield per plant. Number of nodes per vine was positively and significantly associated with length of vine.

Hossain *et al.* (2010) studied the character association in 58 long type cucumber accessions. The correlation co-efficient analysis revealed that, yield per plant had highly positive and significant association with fruit length and diameter, average fruit weight and number of fruits per plant.

Golabadi *et al.* (2013) determined the relationships among fruit yield, fruit yield components and morphological traits using 20 different genotypes of cucumber. Result of correlation analysis was indicative of importance of fruit number for predicting of fruit yield in cucumber and there was a significant correlation between total fruit yield and fruit number per plant.

Veena *et al.* (2013) evaluated 38 advanced cucumber lines to study the character association and path analysis. Correlation study revealed that 100-seed weight, number of fruits per plant, average fruit weight, fruit length, flesh thickness and seed cavity length had significant positive correlation with yield per plant.

Khan *et al.* (2015) studied morpho-agronomic characterization of cucumber germplasm for yield and yield associated traits. Twenty four genotypes of cucumber were evaluated to find out their similarities and differences based on numerical traits. They reported that yield was positively correlated with fruit length and fruit width, while fruits per plant showed positive significant correlation with vine length.

Nwofia *et al.* (2015) evaluated response of three cucumber varieties to different rates of fertilizer. Pearson correlation indicated a highly significant and positive correlation between fruit yield and weight of fruit as well as number of fruits per plant.

Alsadon *et al.* (2016) studied the growth response of cucumber under greenhouses covered with plastic films. Correlation coefficients were high or very high among most growth indices. Among the significant and highly significant correlations were leaf area ratio, specific leaf area, leaf weight ratio and stem weight ratio with all growth indices.

2.4. Cluster analysis and principal component analysis

Cluster analysis and principal component analysis (PCA) are important multivariate techniques employed to identify the divergent genotypes and characters contributing to diversity in the population.

Kalloo *et al.* (1982) evaluated 45 Indian and exotic musk melon cultivars for 12 characters and reported that varieties differed significantly for all characters. Grouping of genotypes followed to cluster them into 14 clusters on the basis of D^2 values and found that the clustering pattern of the genotypes did not follow parallelism between genetic and geographic diversity.

Sharma and Sharma (2006) conducted an experiment on genetic divergence for yield and yield contributing traits. The cluster analysis of the genotypes grouped the 31 genotypes into seven clusters. The mean cluster values indicated that different clusters performed superior for different characters. The genotypes Orji Local, Bengal 60, JJL and Derabassi Local were promising for yield per plant and fruit length.

Golabadi *et al.* (2012) undertaken cluster analysis of 20 cucumber genotypes to study the grouping of genotypes based on morphological characters. Cluster analysis with Ward method grouped the genotypes into four distinct groups. Genotypes in cluster II (Gohar, Adrian 451, Green majic, Sina) had the highest total fruit yield per pickling. For other traits, genotypes in cluster I and II (10 genotypes) showed best situation. Selection of superior genotypes with desirable morphologic traits, with high genetic distance has been recommended for hybridization programs.

Kumar *et al.* (2014) evaluated 30 diverse genotypes for different economically important characters by using PCA and regression analyses. PCA characterized the genotypes into four PCs based on their total variation (83.72 %). The first PC accounted for more than 48 % of the total variation and was contributed by number of fruits per plant, fruit length, harvest duration, TSS, seed germination, seed vigour index and yield per plot.

Nwofia *et al.* (2015) evaluated response of three cucumber varieties to different rates of fertilizer application. Principal component analysis showed that PC1, PC2 and PC3 with eigen-vector value loads greater than unity accounted for the cumulative variance of 70 %, which exhibited the degree of influence the plant characters had on fruit yield.

Sixteen cucumber genotypes were evaluated in the early and late planting seasons to estimate the magnitude of their genetic variability and heritability by Ene *et al.* (2016). Genotypes were also classified into groups based on the performance and determination of the highest discriminating trait that accounted for greater variability using cluster analysis and PCA. Principal component analysis involved vine length as the most discriminating trait that accounted for greater variability in cucumber in both the early and late planting seasons.

2.5. Diversity analysis using DIVA-GIS

Geographical Information System (GIS) has been a valuable tool in natural resources management in India. DIVA-GIS, a Geographical Information System designed to assist the plant genetic resources and biodiversity communities to map the range of distribution of species in which they are interested (Hijmans *et al.*, 2000). However, it is less used for plant genetic resources (PGR) management in India. Recently, GIS and remote sensing are widely used for biodiversity assessment and mapping of various phyto-geographic zones of India. GIS is an effective tool used in eco-geographic survey for locating diversity, gap analysis and planning future explorations for collecting PGR. Therefore, in the present study, DIVA-GIS have been used to analyse diversity.

Hijmans and Spooner (2001) utilized the DIVA-GIS tool for the first time to analyse geographic distribution in wild potato germplasm. They analysed 6073 geo-referenced points spread over 16 countries and found that majority of the species are narrowly endemic and the grid cells were used to map species richness. The occurrence of wild species and their richness were predicted using the tool.

Further, Hijmans *et al.* (2003) assessed the predictability of frost tolerance in wild potato species with geographic factors using DIVA-GIS. They observed that there was significant geographic clustering of areas with wild potatoes with similar levels of frost tolerance. There is a greater chance of finding wild potatoes with high levels of frost tolerance in areas with yearly mean minimum temperature below 3^{o}C than in warmer areas.

Jarvis *et al.* (2003) assessed the conservation status of the genus *Arachis* spp. using 2175 geo-referenced points and prioritized the biologically and geographically future conservation actions. The species richness of the genus excluding *Arachis hypogaea,* were assessed by predicting the distribution using 36 climatic variables and synthesizing it with the land data to map potential distribution of each species.

Parthasarathy *et al.* (2006) used DIVA-GIS for mapping the pepper germplasm collection from Kerala state in India to understand the natural distribution, to identify gaps in collection, prioritizing regions for conservation and to identify places suitable for its introduction.

Miller and Knouft (2006) investigated the differences in environmental factors contributing to the geographical distribution of cultivated and wild populations of Mesoamerican fruit tree *Spondias purpurea* using DIVA-GIS. The predicted distribution of the wild *S. purpurea* is nested within cultivated distribution and that the ecological niche of cultivated *S. purpurea* has expanded distribution relative to the wild populations.

Scheldeman *et al.* (2007) used GIS for studying distribution, diversity and environmental adaptation of highland papayas (*Vasconcellea* spp.) in tropical and subtropical America. They used 1553 georeferenced collection sites in 16 countries to arrive at the conclusion that Eucador, Columbia and Peru are areas of high diversity.

Varaprasad *et al.* (2008) mapped the agro-biodiversity belt of Andhra Pradesh using DIVA-GIS by analysing genebank data on explorations conducted in South East Coastal Zone of India during 1986-2007.

Sunil *et al.* (2008) used DIVA-GIS for the analysis of diversity and distribution of *Jatropha curcas* in Peninsular India. Analysis for richness using rarefaction method of DIVA-GIS showed that Ranga Reddy district of Andhra Pradesh is the potential area for germplasm with high oil content. The present study revealed that diverse germplasm accessions of *J. curcas* are distributed all over the south east coastal zone and enabled us to find out gaps in collection and diversity richness from SEC zone of India for conservation.

Abraham *et al.* (2010) used DIVA-GIS for the diversity assessment of pod characteristics in black gram germplasm accessions collected from Andhra Pradesh. High diversity index for pods/cluster was observed in the collections made from parts of northern Telangana and western Telangana regions of Andhra Pradesh followed by southern Telangana, north coastal and Rayalaseema regions

Sivaraj *et al.* (2010) analysed the variability in fatty acid composition of *Canavalia ensiformis* and *Canavalia gladiata* germplasm collections made from South India using DIVA-GIS. Grid maps were generated using DIVA-GIS for the analysis of diversity based on total unsaturated fatty acids and total saturated fatty acids. IC310951, a *C. ensiformis* accession collected from Andhra Pradesh recorded the highest omega-3 fatty acid (linolenic acid, 11.4 %) which forms an essential fatty acid.

Variability in fatty acid composition and seed traits of linseed germplasm collected from Andhra Pradesh and Maharashtra states were also analysed using DIVA-GIS (Sivaraj *et al.*, 2012)

Spandana *et al.* (2012) studied diversity analysis and distribution of sesame germplasm in India using DIVA-GIS. Grid maps were generated for diversity analysis of the eight quantitative traits. The results indicated that diverse accessions for all these traits can be sourced from Maharashtra, Gujarat and Madhya Pradesh (partly covering Chattisgarh) states and these states are diversity rich pockets for sesame germplasm in India.

Dikshit and Sivaraj (2013) analysed agro-morphological diversity and oil content in Indian linseed germplasm using DIVA-GIS. Grid maps were generated for the diversity analysis and they indicated that diverse linseed germplasm accessions for plant height, capsules per plant and oil content were available in the Bihar, Jharkhand, Maharashtra states of India, where the highest Shannon diversity indices (1.99-3.00) were recorded for the traits plant height, capsules per plant and oil content, respectively. The highest coefficient of variation for the trait plant height (15-25 %) recorded for the linseed accessions sourced came from the states of Bihar, Himachal Pradesh and Jharkhand; and with respect to capsules per plant (21-27 %) for the Bihar, Jharkhand and Maharashtra accessions.

Gunjeet *et al.* (2013) studied diversity analysis in eggplant germplasm in India using GIS approach. Morphological diversity and accession's collection site data are integrated using DIVA-GIS software for diversity analysis, and finding gaps relating to germplasm collection and conservation of eggplant germplasm. Grid maps generated for the diversity analysis of several fruit descriptors indicated the occurrence of diverse accessions for plant height from the states of Karnataka, Odisha, Rajasthan and Uttar Pradesh, for fruit colour from Andhra Pradesh, Orissa, Maharashtra, Tamil Nadu, Uttar Pradesh and West Bengal and for fruit shape from Eastern states.

Udaya Sankar *et al.* (2015) studied screening of horse gram germplasm collected from Andhra Pradesh against anthracnose. Grid maps generated using DIVA-GIS indicated the areas with highest Shannon diversity index for PDI (Percent Disease Index) and highest coefficient of variation recorded for horse gram accessions collected from Anantapur district of Andhra Pradesh. The results also indicated that diverse accessions for reaction against *C. dematium* can be sourced from Anantapur district of Andhra Pradesh.

2.6. Organoleptic evaluation

Organoleptic quality of the cucumber is very much important as the tender fruits are eaten as salad. Studies on organoleptic evaluation in cucumber fruits are limited.

Miller *et al.* (1995) studied a non-destructive method utilizing a modified Trebor 101 water core tester to evaluate the internal quality of pickling cucumbers. The method involved the relative amount of visible- infrared light passing through the longitudinal midsection of whole cucumber fruit. The increase in transmission of light is correlated with low internal quality of fruit which might have occurred due to bruises incurred during harvesting. The processed product from fruits exhibiting differential transmission was subjected to sensory evaluation. The spears prepared from fruits exhibiting high transmission were judged to be of lower quality than fruits exhibiting low transmission.

Pardo *et al.* (2000) evaluated nine genotypes of melon, for the external appearance of the fruit. They reported that the cultivars belonging to Piel de Sapo type and Sancho were the most appreciated for the external appearance.

Palma-Harris *et al.* (2002) conducted sensory evaluation of the intensity of fresh cucumber flavour in two lots of cucumber adjusted to different P^H values. The results revealed that significant differences in flavour intensities were perceived when the P^H differences were one unit greater. There was linear relationship of flavour with the amount of (*E,Z*)- 2,6-nonadienal, a compound responsible for flavour.

Twelve beit-alpha cucumber were evaluated in green house condition by Hochmuth *et al.* (2004). In their study, the cultivar Sarig, had the smoothest appearance. They have identified the cultivars with most rough ridges on skin *viz.* Condesa, Alamir, Tenor and Ilas.

Anderson *et al.* (2011) conducted sensory evaluation of cucumbers grown in soilless media and reported that appearance and texture did not differ significantly between cultivars on soilless media treatments and found that highest mean score was observed in Sweet Burpless Hybrid, Sunshine Natural and Organic.

Kasim and Kasim (2011) studied the sensory characteristics of cucumber fruits stored after vapour heat treatment at 48°C for 8 minutes and found that firmness of fruits were maintained at the end of storage period.

The effect of application of gum arabic edible coating on weight loss, firmness and sensory characteristics was investigated for cucumber fruits by Al-Juhaimi *et al.* (2012). Cucumber was coated with gum arabic at different concentration (5, 10, 15 and 20%) and stored at 10 and 25°C for up to 16 days. The application of gum edible coating delayed softening of cucumber fruit during 16 days of storage at 10 and 25°C. Sensory characteristics of cucumber such as colour, taste, tenderness, appearance and overall acceptability of coated (5-20%) cucumbers were much better preserved while storing at 10 and 25°C for 16 days.

Manjunatha and Anurag (2014) evaluated the sensory characteristics of cucumber fruits stored in perforated modified atmospheric packaging under col room and ambient condition. The sensory quality evaluation revealed that samples stored under perforated modified atmospheric packaging maintained good sensory score.

An organoleptic study was conducted with 20 hybrids of cucumber and Garima Super was found to be the best for colour and texture, followed by Joolie and US-249. Minimum score was observed for Manvi Plus and NCH-2 (Patel *et al.*, 2013).

Choi *et al.* (2015) studied the changes of post-harvest quality in 'Bagdadagi' cucumber by storage temperature. The harvested fruits were stored at 0, 5, 10, 13 °C, and room temperature for 25 days. Storage of cucumbers at 0 or 5°C reduced the quality due to chilling injury, while quality at 13°C or room temperature was reduced due to the development of yellowing (small yellow spots) that negatively affected appearance.

Miano *et al.* (2016) studied the effect of wrapping materials on physico-chemical and sensory quality of cucumber under ambient and refrigerated conditions. The results suggested that cucumber fruits wrapped in newspaper under refrigerated conditions (12^0C) scored highest score for fruit colour. Maximum score for taste and appearance was observed for fruits stored in polyethylene bags under refrigerated conditions. Tenderness was maximum in fruits stored under ambient temperature (18 ± 2^0C) and overall acceptability for fruits wrapped with grease free paper.

Velkov and Pevicharova (2016) studied the effects of cucumber grafting on yield and sensory characteristics under glass house conditions. The aim of the study was to compare the yield, elements of productivity and fruit sensory characteristics in order to establish the most appropriate scion/rootstock combinations. The effect of rootstock on fruit quality showed a significant variation in the value of sensory traits like appearance, aroma and taste. The highest yield was recorded in combination cv. 'Kiara F_1' grafted on *Cucurbita maxima* x *C. moschata* F_1.

Omoba and Onyekwere (2016) studied the effects of chitosan-based edible coatings with lemon grass extract on the physical properties and overall acceptability of cucumber fruits stored at ambient temperature (28 ± 2°C) and 85 to 90 per cent relative humidity for 14 days. The results of the study revealed that, the combination of chitosan and lemon grass extract, has proved to have great potential to preserve the physical characteristics of cucumber fruits at ambient temperature 28 ± 2°C peculiar to tropical countries.

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2.7. Selection of promising genotypes

Knapp (1998) suggested marker assisted selection as a strategy for increasing probability of selecting superior genotypes.

Fan *et al.* (2006) suggested population development by phenotypic selection with subsequent marker assisted selection for line extraction in cucumber. In their study, a base population was created by intermating four unique but complementary lines, was subjected to three cycles of phenotypic mass selection for days to flowering, gynoecious nature, multiple lateral branching and long fruited types. Simultaneously marker assisted back crossing for these traits began with selected progeny to produce families and BC_1 for line extraction and for comparative analysis of gain from selection.

Kozak *et al.* (2008) proposed a statistical approach to support selection of promising lines in a breeding programme based on path analysis and cluster analysis. An application of the approach was used to analyse 22 grass pea genotypes, two cultivars (Derek and Krab) and 20 mutants from those cultivars. Among the traits studied, plant height, number of branches/plant, pod length and number of seeds/plant determined seed yield; number of pods/plant influenced seed yield. These results were used for appropriate weighting in cluster analysis, which indicated that cultivar Krab and its two mutants, K3 and K64, had the best level of the traits and were the most stable genotypes.

Bandurska *et al.* (2011) presented a procedure to identify promising chilling insensitive cucumber genotypes from a pool of 55 breeding lines. The approach is based on determining nitrate content, nitrate reductase activity and chlorophyll content in cotyledons of cucumbers grown at 12°C. In the method, genotypes were arranged according to their chilling sensitivity. The set of 55 observations for individual traits was divided into four quartile intervals with a non-decreasing ordering. Each observation was assigned a rank consistent with the number of the quartile interval. For each genotype, the sum of the quartile ranks for all observations was calculated and the higher values of observed traits indicate lower chilling sensitivity.

Afroz *et al.* (2013) suggested multivariate analysis approach to select parents for hybridization in cucumber. In their study, 22 genotypes were evaluated using D^2 and principal component analysis. PCA revealed that the first two axes accounted for 67.39% of the total variation among the fourteen characters studied. As per cluster analysis, the genotypes were grouped into four clusters consisting five, three, eight and six genotypes, which revealed that there exist considerable diversity among the genotypes. Considering all of the characters studied, the Serena, BD-4305, BD-4256, CU937F1 and BD-4309 were selected for future breeding programme.

Mallikarjuna and Susheelamma (2013) evaluated 36 genotypes of mulberry and promising genotypes for moisture stress conditions were selected based on the method suggested by Arunachalam and Bandhyopadhyay (1984). By this joint score analysis, they have identified the genotypes, which were superior over check varieties based on the score and rank obtained by the genotype for leaf yield per plant, total length of shoots per plant and leaf moisture.

Nath *et al.* (2014) conducted an experiment for selection of superior lentil genotypes by assessing character association and genetic diversity. The study revealed that all the genotypes possessed high amount of genetic diversity. Plant height and 100-grain weight showed significant positive correlation with grain yield per plant that was also confirmed by path analysis as indicated by the the highest direct effect on grain yield. The genotypes BM-513 and BM-941 were found to be the best performer in both the seasons and were considered as consistent genotype. The genotypes were grouped into four clusters based on Euclidean distance following Ward's method and RAPD analysis. However, discriminant function analysis revealed a progressive increase in the efficiency of selection and BM-70 ranked as the best followed by the genotypes BM-739, BM-680, BM-185, and BM-513.

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2.8. Molecular characterization

Assessment of genetic diversity based on phenotype has limitations since most of the morphological characters are greatly influenced by environmental factors and developmental stage of the plant. Hence the substantial variation in the morphology of crop needs to be supported by molecular markers as well. Currently, molecular markers are being widely used for genetic diversity analysis in many crops. Besides many other advantages, abundance of polymorphic loci enables the researcher to estimate the similarity between genotypes at the genomic level. Three kinds of molecular markers are generally used for genetic diversity analysis. They include hybridization based markers (*e.g.* Restriction Fragment Length Polymorphism), PCR based (*e.g.* Simple sequence repeats) and Single Nucleotide Polymorphisms (SNPs).

Prior to the wide exploitation of molecular markers, biochemical markers based on the banding profile of isozymes were used. Staub *et al.* (1997) studied the genetic difference between five melon groups using 19 isozyme markers and 47 RAPD (Random Amplified Polymorphic DNA) markers.

Zhang *et al.* (1998) studied the genetic relationship between 34 cultivars of cucumber using 130 RAPD markers, of which 51 markers could distinguish each of the ecotypes. The cluster analysis based on the molecular characterization validated the use of RAPD markers in cultivar classification.

Staub *et al.* (1999) evaluated the genetic relationship in diverse germplasm collection of cucumber using RAPD markers. Cucumber accessions (116 accessions) were analysed using at 71 RAPD markers. Genetic distances between accessions were estimated based on simple matching coefficient and analysed using multi-dimensional scaling. Each accession possessed a unique marker profile indicating the usefulness of RAPD analysis in genotypic differentiation.

Danin-Poleg *et al.* (2000) developed SSR markers for *Cucumis* from melon genomic libraries. Length polymorphism in a sample of 13 melon genotypes and

11 cucumber genotypes were evaluated using 40 markers, and estimated mean gene diversity values for cucumber and melon.

Liu-WanBo *et al.* (2002) studied the genetic diversity of 37 *Cucumis melo* genotypes using RAPD and ISSR (Inter simple sequence repeats) markers. Twenty one polymorphic RAPD markers and 10 polymorphic ISSR primers were identified among the entries. A total of 106 polymorphic bands constituting around 58.62 per cent with mean polymorphism information content (PIC) of 0.47. With respect to ISSR markers, 73 polymorphic bands were produced constituting about 65.51 per cent polymorphic bands.

Lang *et al.* (2007) conducted molecular profiling using RAPD markers to study relationships among 14 cucumber cultivars. Six RAPD primers were used to calculate Jaccard's similarity coefficients for cluster analysis using UPGMA. The genetic relationships identified using RAPD markers were concordant for both RAPD and SSR markers, by exhibiting a genetic distance estimate of r=0.73 through RAPD analysis and accessions were grouped into two clusters.

Aydemir (2009) characterized 92 Turkish cucumber accessions using Sequence Related Amplified Polymorphism. A total of 153 SRAP fragments were obtained of which 138 were polymorphic. Dendrogram drawn using UPGMA (Unweighted Pair Group Method) revealed the presence of four clusters. The genetic distances of the dendrogram varied between 0.16 and 0.99. The neighbour joining dendrogram showed similar clustering of the cucumber accessions. The results showed that Turkish cucumber is genetically quite diverse and has the potential for broadening the genetic base of cucumber.

Choudhary *et al.* (2011) undertaken genetic diversity analysis in cultivated and wild germplasm of cucumber based on RAPD markers. Cluster analysis grouped the genotypes into five different groups on the basis of Jaccard's similarity coefficient values. Four accessions of *Cucumis sativus* var. *hardwickii* were grouped in one cluster.

Manohar *et al.* (2013) conducted genetic diversity in 39 cucumber collections from Karnataka, India using 23 RAPD and 18 ISSR primers. A total of 309 bands were scored, of which 147 (47.57 %) were polymorphic. The average number of bands per primer was 7.82 and an average number of polymorphic bands of 3.58 per primer. The primer UBC855 revealed the highest PIC (polymorphism information content) value of 0.49 followed by the primers UBC846, OPE13, OPC01 and OPR12 (0.48). The Jaccard's similarity coefficients ranged from 0.36 to 0.84 and the first two principal components explained 53.33 % of the total variance. The UPGMA phenogram and the PCA indicated that the populations formed five major clusters.

Zhou *et al.* (2013) conducted a study for genetic analysis of gynoecy and identification of molecular marker associated with gynoecious gene using gynoecious line, monoecious line and SSR marker. The genetic analysis of cucumber gynoecious was evaluated with a gynoecious line 240-1-2-2-3-1, monoecious line 3-5-1-3-2-1-1-1-1-2 and their F_1, F_2, BC_1P_1, BC_1P_2 populations. During analysing the separated rate of F_1 and F_2, the results showed that the gynoecy in 240-1-2-2-3-1 was controlled by oligo gene with some background genes modified. Inheritance of gynoecy was accord with the additive-dominant-epistatic model. From 699 pairs of SSR primer, two pair of stable SSR markers (CSWCT25 and SSR18956), 331 bp and 145 bp in bands size were obtained respectively during PCR. Products of two SSR markers were cloned and sequenced, and linkage analysis indicated that its genetic distance to the gynoecious loci was 7.7 cM and 6.8 cM, respectively. Two SSR markers are tightly linked to gynoecious loci on the chromosome 6.

Innark *et al.* (2013) recorded that total of 17 ISSR markers could amplify in 40 accessions of cucumber with polymorphic information content ranging from 0.12 to 0.45. The average resolving power of markers was averaged at 1.82 ranging from 0.50 to 3.20.

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Yang *et al.* (2015) in their study, undertaken the genetic diversity of 42 cucumber genotypes in China using 51 pairs of SSR primers. These markers identified 129 polymorphic loci. The mean effective number of alleles, mean Nei's gene diversity, and mean Shannon's information index were 0.36, 0.16, and 0.21, respectively. A cluster analysis revealed that the 42 cultivars could be divided into three groups, a result that was largely consistent with those of a PCA. The PCA indicated that the three groups displayed significant variation in fruit traits.

2.9. Combining ability studies

Combining ability is the capacity of an individual to transmit superior performance to its offspring. The inbred/s with good combining ability will produce superior hybrids in combination with other inbred/s. Crosses made in a definite fashion is a pre-requisite for estimating the combining ability. General combining ability (GCA) is an average performance of an individual/inbred in a particular series of crosses. The specific combining ability (SCA) is the performance of an inbred in a specific cross. Thus, SCA deviates a particular cross from general combining ability. The GCA is a measure of additive gene action, whereas SCA of non-additive gene action. The information on the relative importance of GCA and SCA is of value in breeding programmes in species, which are amenable for development of hybrids (Hanchinamani and Patil, 2009).

Combining ability for 36 crosses involving 16 parental lines of cucumber were studied by El-Shawaf and Baker (1978). They observed that hermaphrodite lines of cucumber had greater general combining ability for yield traits. In their further study (El-Shawaf and Baker, 1981) examining 20 hybrids generated by crossing four gynoecious lines with five hermaphrodite lines, the GCA for time to harvest, gynoecious expression and yield of the female parents were higher than that of male parent.

Single and 3-way cross hybrids derived from 13 parental lines of pickling cucumber were used to estimate general and specific combining ability for

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femaleness and yield (Tasdighi and Baker, 1981). Highest general combining ability effects in both single and 3-way crosses for total yield and marketable yield were exhibited by parental lines '551F', '368G', '581H'. and '5802A'. It was reported that the additive effects of genes were found to be relatively more important than non-additive effects for both femaleness and yield.

Combining ability in a diallel cross involving seven diverse cucumber cultivars, from tropical and temperate regions were estimated by Musmade and Kale (1986). They observed that GCA variances were greater than the SCA variances for all the traits except yield per vine. Crosses with highest SCA for yield per vine were Poona Khira x Japanese Long Green and Kalyanpur Ageti x Panvel, which were poor x poor and good x poor general combiners respectively.

Fredrick and Staub (1989) evaluated combining ability of crosses derived from *Cucumis sativus* var. *hardwickii* for all traits related to yield. General and specific combining ability estimates were obtained in a North Carolina Design II experiment for nine near-homozygous cucumber lines, five of which were derived from *hardwickii* germplasm. GCA mean squares were significant at both planting densities for all traits when combined over planting times, except for fruit L:D ratio at the higher density. SCA mean squares were significant for days to anthesis. Of the lines evaluated, WI 2963 and 4H261 produced the greatest *GCA* female and male effects, respectively, for three harvests yield and primary lateral branch number, but the lowest effects for fruit size.

Evaluation of hybrids involving three testers and seven lines in cucumber for yield and yield contributing characters were undertaken by Solanki and Shah (1990). In their study, the lines Balam Kheera and Hinreka were found to be good general combiners. There were significant SCA effects for vine length, inter nodal length, number of female flowers per plant, number of fruits per plant and fruit yield per plant.

In a similar study conducted by Prasad and Singh (1992) involving line x tester analysis of cucumber lines, it was observed that variance due to GCA was

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higher than variance due to SCA for all the characters. They have identified CH-8-2-3-1 and CH-20-3-2-1 as good general combiners for yield, number of fruits, node number and number of branches per vine. The crosses that showed significant SCA effects involved both or at least one good general combiner, suggesting both additive x additive and additive x dominance gene action.

Combining ability of four inbred lines and six F_1 hybrids in cucumber was studied by Li-Jianwer and Zhu-Dewei (1995). They have identified the parent Sel.112 with greatest GCA for fruit weight. Highest SCA for number of fruits, mean fruit weight, vine length, fruit length, length:diameter ratio and leaf area was observed for a cross involving Sel.111 and Sel.112.

Ananthan and Pappiah (1997) evaluated the yield and yield components of five parents and 20 F_1 hybrids of cucumber, for studying the combining ability and correlation between traits. Among the characters studied, days to first male and female flowering, sex ratio, number of fruits per vine, fruit length and girth and tender and ripe fruit weight were significant for both general and specific combining ability.

Verma *et al.* (2000) observed significant differences among the parents and hybrids for both GCA and SCA respectively. They identified the parents K27080, LC-3, C-12 and Gy-2 as good general combiners for yield and its component characters.

Bairagi *et al.* (2001) studied combining ability in an 8 x 8 diallel cross involving parents and direct crosses only (half diallel mating design). The parental lines PCUC-98-25, DC-1 and C-31 were identified as good general combiners for most of the characters studied. Good SCA effects were recorded by hybrid PCUC-98-25 x C-31, for all the characters studied. The GCA variance was higher than SCA indicating predominance of additive gene action.

Line x Tester analysis involving 10 lines and three testers was carried out by Sharma *et al.* (2001). Good general combiners identified were GYNL and Poona

Khira for their earliness in female flowering and days to first picking, Sel. 72-5, Swarapurna and Sheetal for marketable fruit yield (number of fruits and size). The crosses involving Sel. 72-5 x Poinsette and Swarapurna x Poinsette expressed significant SCA effects for most of the characters studied.

Twelve genetically diverse lines and four testers were used to generate 48 F_1s to study the combining ability effects (Gulam-ud-Din and Ahmed, 2002). Observations on 12 characters indicated that variances due to GCA and SCA effects were significant for all the traits studied, except GCA variance for node number at which first female flower appeared and fruit length. Significant GCA effects were revealed by parents SKAU-K-2 and Sweet Deligh for 11 and eight traits respectively. Similarly, significant SCA effects for most of the traits were shown by the crosses Sel.75-2-10 x Poinsette, Green Express x Japanese Long Green, Pioneer Pickling x Japanese Long Green and SKAU-K-2 x EC-381606.

Lopez-Sese and Staub (2002) crossed three U.S.-adapted *Cucumis sativus* var. *sativus* L. lines with one *C. sativus* var. *hardwickii* (R.) Alef. derived line in a half-diallel design to determine their combining ability for several yield-related traits. Six hybrids were evaluated for fruit number and length/diameter ratio (L:D), lateral branch number, number of female flowering nodes, and days to anthesis. Combining ability was significantly influenced ($p < 0.05$) by year for most of the horticultural traits examined. GCA was significant for all traits in each year. SCA was significant in magnitude and direction for only fruit number and days to anthesis.

Fang *et al.* (2004) studied combining ability for early and total yield in six inbred lines of cucumber. Both early and total yield were controlled by additive gene action. The GCA variance for early yield comprised 91.92 % of the genotypic variance. Broad sense heritability for early yield was 86.92 % whereas narrow sense heritability was 80.38 %. The SCA variance for the total yield comprised 82.92 % of the whole genotypic variance.

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Combining ability analysis was undertaken by Kumbhar *et al.* (2005) in 28 cucumber hybrids in 8 x 8 diallel mating design involving eight parents. The best specific combiners were between parents with low or high general combining ability. Subhangi and Sheetal were identified as best combiners for yield among parents. The crosses involving Improved Long Green x Himangi and Poona Khira x Junnar Local were identified as best specific combiners.

Combining ability components were estimated in eight cultivars of cucumber in 8 x 8 half diallel by Sushir *et al.* (2005). The GCA effects were significant for all characters except for number of female flowers, whereas SCA effects were significant for all the characetrs except for number of fruits per plant. Among the parents, Subhangi and Sheetal were identified as best combiners for yield. The crosses namely Improved Long Green x Himangi and Poona Khira x Junnar Local were identified as the best hybrids.

Munshi *et al.* (2006) analyzed the combining ability of a 6 x 6 diallel cross of cucumber excluding reciprocals (half diallel design). The mean square due to GCA and SCA were highly significant for most of the characters indicating the importance of both additive and non-additive genetic components of variation. The variance due to SCA was higher than the variance due to GCA in all characters which indicated the importance of non-additive gene action for the control. The parents DC-1, Poona Khira and CHC I were observed to be good combiners for number of characters including yield per plant. The crosses CHC I x PCUC 28, Poona Khira x PCUC 28 and Sel. 75-1-10 x CHC I were the most promising combinations for different characters including yield per plant.

Yudhvir and Sharma (2006) evaluated fifteen crosses with eight parents for 12 characters following line x tester design. Variance for SCA component was higher than GCA for all traits except fruit length and diameter, indicating the predominance of non-additive gene action. The parents AAUC-2 and Sel-75-1-10 were good general combiners for yield and its component characters. The hybrids

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Sel-75-1-10 x K-Paprola and CHC-2 x Sel-75-1-10, exhibited significant SCA effects for marketable yield per plant.

Forty five cucumber hybrids developed through line x tester technique using 15 lines and three testers were used for studying combining ability (Yadav *et al.*, 2007). The parents 2020 followed by 2017, 2231 and 2336 showed a significant general combining ability effect. Seven superior heterotic crosses namely 2237 x 2226, 2237 x 2238, 2015 x 2014, 2228 x 2238, 2028 x 2238, 2336 x 2014 and 2229 x 2226 were selected for yield and yield contributing traits were identified based on specific combining ability.

Combining ability estimates for yield and its contributing traits were worked out for 35 hybrids involving five lines and seven testers in line x tester design (Hanchinamani and Patil, 2009). The variance due to GCA being higher than the variance due to SCA for all the characters studied indicated the predominance of additive gene action. The parent, BGDL was identified as a good general combiner for yield, fruit number and average fruit weight. Only 13 crosses exhibited significant SCA effects for total fruit yield per vine. The results indicated that most of the crosses that showed significant SCA effects involved both or at least one good general combiner, suggesting additive x additive or additive x dominance type of gene action.

Uddin *et al.* (2009) conducted a study to assess the combining ability effect of different characters in a line x tester method comprising 24 hybrids produced by crossing eight lines with three testers. Significant differences were observed among the parents and hybrids for GCA and SCA respectively. The parents F_1, M_1, F_8 and F_7 were recognized as the good general combiners to improve fruit yield per plant. $F_8 \times M_2$ was the best specific combiner to increase the fruit yield per plant. The magnitude of variance due to SCA was high in all characters compared to variance due to GCA and dominance variance was higher than the additive genetic variance indicating the predominance of non-additive gene action. The ratios of SCA and GCA variance were higher than unity indicating

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predominated non-additive gene action over additive gene action for all characters.

Sarkar and Sirohi (2011) evaluated 45 hybrids and 10 parents in half diallel design to evaluate the combining ability estimates. The results of the investigation revealed over-dominance gene action for all the characters studied except vine length, days to first female flower opening and days to first fruit harvest. Dominance effect was shown by vine length, days to first female flower opening and days to first fruit harvest. Narrow sense heritability was found to be less than 0.5 for all these characters except vine length, days to first female flower opening and days to first fruit harvest indicating predominance of dominance gene action over additive ones.

The F_1 and F_2 progenies of 8 x 8 parent diallel cross (excluding reciprocals) of cucumber were analysed for combining ability in respect of 10 characters (Singh, *et al.*, 2012). Analysis of variance for combining ability revealed highly significant GCA and SCA variances for all the characters studied in F_1 and F_2 generations except fruit length in F_2 generation indicating the importance of both additive and non-additive gene action for inheritance of these attributes. However, the variance due to GCA was lower than the variance due to SCA for all the traits in both F_1 and F_2 generations indicating the predominance of non-additive genetic variance. The parent C 99-12 was best general combiner for yield per vine, days to first male flower, fruit length, fruit weight and vine length in both the generations. The cross combinations EC 43342 x C 99-10, EC 43342 x C 98-6 and PCUC 15-1 x C 98-6 were observed as good general combiners for yield per vine in both F_1 and F_2 progenies.

Reddy *et al.* (2014) developed 36 hybrids from nine diverse parental cucumber lines, through half diallel mating design. The hybrids along with their parents were evaluated for their combining ability for ten important quantitative traits. The parent P3 (CHC-1) was the best general combiner for days to first fruit harvest, whereas, parent P1 (Pusa Uday) was the best general combiner for yield

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per plant and its contributing traits like average fruit weight and diameter and number of fruits per plant. The hybrid P6 × P7 (Poona Khira × Sel. 97-7) exhibited significant SCA effects for earliness with respect to days to first female flower anthesis, node number of first female flower and days to first fruit harvest whereas the highest SCA effect for yield per plant were exhibited by F_1 crosses P2 × P4 (DC-1 × Himangi. The variance due to SCA was higher than variance due to *GCA* for all the characters, which indicated the importance of non-additive gene action for improvement.

Eight genetically divergent parental lines of cucumber were crossed in a diallel pattern to study general and specific combining abilities for yield and its attributing traits (Singh *et al.*, 2016). The combining ability analysis revealed that both GCA and SCA variance were significant for all the characters except equatorial diameter of fruit. On the basis of GCA parent ACC-8 for diameter of fruit and average fruit yield, ACC-2 for days to first fruit harvest and number of fruits per vine, and ACC-4 for average fruit weight were found to be the best general combiners. Cross combinations ACC-2×ACC-6 for days taken to first fruit harvest; ACC-4×ACC-7 for number of fruits per vine; ACC-3×ACC-8 for average fruit weight; ACC-3×ACC-4 for diameter of fruit; ACC-1×ACC-4 for average fruit yield manifested highest *SCA* effects.

Kaur *et al.* (2016) evaluated 28 non-reciprocal F_1 hybrids derived from eight diverse cucumber genotypes to study the combining ability for quality attributing traits. The mean square due to GCA and SCA were highly significant for all the characters indicating the importance of both additive and non-additive genetic components for the characters. The parent 'Gy-14' was the best combiner for flesh to seed cavity ratio and β-carotene and Swarna Sheetal was best combiner for ascorbic acid and dry matter content. The cross combination EC-27075 × Summer Kheera had highest SCA for total soluble solids, whereas Pant Kheera-1 × Japanese Long Green had the highest SCA for ascorbic acid. The study on gene effect of different characters indicated the predominance of non-additive gene effects for most of the characters.

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In another study by Kaur and Dhall (2017), twenty-eight non-reciprocal hybrids derived from eight diverse cucumber genotypes including one gynoecious line were evaluated to study the combining ability for yield and yield attributing traits. The parent 'Summer Kheera' was the best combiner for four characters *viz.* marketable yield, fruit diameter, fruit length and vine length. On basis of SCA effects Gy-14 x Punjab Naveen and Gy-14 x Pant Kheera-1 were observed best with respect to yield and yield attributing traits except earliness.

2.10. Heterosis

Heterosis refers to superiority of F_1 hybrids over both the parents in terms of yield and other economic traits. The heterosis is positive heterosis, when the magnitude of vigour is positive while negative heterosis implies decrease in vigour of F_1 hybrid. Three kinds of heterosis have been described, based on the improvement over mid parent (mid parent or relative heterosis), better parent (better parent heterosis or heterobeltiosis) and standard check (standard heterosis). Heterosis, though occurs in both self and cross pollinated crops, is more pronounced in cross pollinated crops.

Solanki *et al.* (1982) studied the performance of hybrids and parents and observed high better parent heterosis for number fruits per plant, average fruit weight and fruit yield per plant. Negative heterosis in the desirable direction was observed for days to maturity.

Musmade and Kale (1986) conducted diallel analysis of crosses originated from tropical and temperate regions. In the study, they have identified promising crosses like Poona Khira x Japanese Long Green, White Long Cucumber x Poinsette and Kalyanpur Ageti x Panvel, with high SCA effects and recorded better parent heterosis for yield per vine.

Vijayakumari *et al.* (1993) conducted an evaluation experiment with 21 hybrid combinations and identified five hybrids with promising yield.

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Positive heterosis for total yield, early yield, number of fruits, average fruit weight, leaf area, fruit ratio and fruit shape index in cucumber by Li-Jianwer and Zhu-Dewei (1995). Negative heterosis was observed for vine length.

Dogra *et al.* (1997) crossed five indigenous and exotic cucumber lines in a diallel mating design excluding reciprocals. Cross K75 x Gyn 1 recorded the maximum better parent heterosis for yield per plant and 29.60 per cent standard heterosis.

El-Hafez *et al.* (1997) evaluated crosses developed by a 5 x 5 diallel mating scheme and found that heterosis over mid parent and better parent was insignificant for all characters except marketable and total yield on number basis.

Singh *et al.* (1998) conducted experiment for evaluating 98 cucumber hybrids under temperate climate of Himachal Pradesh. Maximum heterosis was reported for yield per plant over standard check Pusa Sanyog, by the cross EC27080 x EC173942. The hybrids namely Gy304 x EC173942, Gy5 x H-15 and Gy319 x Poona Khira exhibited highest heterosis for fruit weight, fruit diameter, fruit length and days to first female flowering respectively.

Bairagi *et al.* (2002) studied effect of heterosis for yield attributes in cucumber and reported that the cross combination PCUC-98-25 x DC-1 exhibited maximum significant better parent heterosis in favorable direction for days to first female flower opening, number of fruits per plant, fruit length, fruit diameter and yield per plant.

Kumbhar *et al.* (2005) evaluated 28 crosses developed by 8 x 8 diallel mating for yield and yield contributing traits. Maximum heterosis to the extent of 80.69 per cent was observed for yield per plant followed by number of fruits per plant (67.12 per cent) and days to first picking (61.70 per cent).

Pandey *et al.* (2005) studied 10 hybrid combinations for presence of heterosis and found that hybrid DC-1 x B-159 and VRC-11-2 x Bihar 10 were found to be the best hybrids for total yield as they recorded the highest positive heterosis over better parent and mid parent. The yield increase was due to increase in number of fruits per plant.

Munshi *et al.* (2005) evaluated 15 cross combinations for assessing heterosis in yield and yield contributing characters. The hybrids were developed by crossing six parents in diallel mating design without reciprocals. Considerable heterosis was observed for all characters except fruit length over better parent and top parent. They have identified best three hybrid combinations for fruit yield per plant.

Kumar *et al.* (2010) evaluated 15 hybrids of cucumber obtained by crossing six parents in diallel fashion without considering reciprocals. The top performing parents identified were Pusa Uday, DC-1 and CH-20 for yield per plant. Considerable heterosis over better parent, top parent and standard check was observed for all the characters studied. The three top performing hybrids in their study were CRC-8 x Pusa Uday, CHC-2 x Pusa Uday and G338 x Pusa Uday, for yield per plant.

Kushwaha *et al.* (2011) studied heterosis for yield and yield contributing characters in 20 hybrid combinations of cucumber. The hybrid combinations namely BC-11 x BC-12 exhibited highest significant better parent heterosis for nodal position of first female flower, BC-16 x Poinsette for length of fruit, BC-14 x BC-16 for diameter of fruit, BC-15 x BC-16 for fruit weight and BC-11 x BC-16 for number of fruits per vine.

Sarkar and Sirohi (2011) evaluated 10 parents and 45 crosses in a half diallel fashion to study heterosis in yield and yield contributing characters. The analysis of variance showed highly significant differences among the varieties and lines studied. The results revealed that the F_1 hybrid, P3 x P7 (DC-2 x PCUC-28) was identified with best performance in yield and has been recommended for commercial cultivation.

Singh *et al.* (2016) conducted analysis of heterosis using eight genetically divergent parental lines of cucumber. They were crossed in a diallel pattern to investigate general, specific combining ability and extent of heterosis for yield and its attributing traits. The combining ability analysis revealed that both GCA and SCA variance were significant for all the characters except equatorial diameter of fruit. Non-additive gene action played a major role in controlling the characters like days taken to first fruit harvest, number of fruits per vine, average fruit weight, diameter of fruit, and average fruit yield. Cross combination of ACC-1 X ACC-4 and ACC-2 x ACC-6 showed 39.25 and 32.23 heterosis for average fruit yield over standard check, respectively.

Kaur *et al.* (2016) evaluated twenty eight non-reciprocal F_1 hybrids derived from eight diverse cucumber genotypes. The results revealed that the cross combination JLG × NCH-1 exhibited maximum heterosis for flesh to seed cavity ratio over better parent (16.67%) and standard check, NS-404 (11.11%), whereas JLG × Summer Kheera exhibited maximum heterosis for total soluble solids over better parent (31.06%) and standard check, NS-404 (34.39 %).

Kaur and Dhall (2017) evaluated twenty-eight non-reciprocal F_1 hybrids derived from eight diverse cucumber genotypes including one gynoecious line. On the basis of mean and heterosis over check, the hybrid combination JLG x Summer Kheera and JLG x NCH-1 were the top ranking genotypes for marketable yield and fruit weight, whereas Swarna Sheetal x EC-27075 and Pant Kheera-1 x EC-27075 were top ranking genotypes for fruit length and diameter. The study of inheritance of different characters indicated the predominance of non-additive gene effects for most of the characters. Therefore, the improvement for these characters can be achieved through hybrid development.

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Materials and Methods

3. Materials and Methods

The present investigation entitled "Genetic diversity and combining ability in cucumber (*Cucumis sativus* L.)" was carried out at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara and the ICAR-National Bureau of Plant Genetic Resources (NBPGR), Regional Station, Thrissur during the period 2014-2017. The study was done as three experiments as detailed below:

Experiment 1: Characterization of cucumber genotypes

- 1.1. Morphological characterization
- 1.2. Molecular characterization

Experiment 2: Evaluation of promising genotypes

Experiment 3: Combining ability studies

- 3.1. Development of hybrids
- 3.2. Evaluation of hybrid combinations

3.1. Experimental location

The field experiments were carried out at ICAR-NBPGR Regional Station, Vellanikkara, Thrissur (Plate 1). Molecular characterization of promising accessions using SSR markers was conducted at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara, Thrissur, Kerala. These institutes are geographically situated at 10.5480° N, 76.2830° E and 10.505480° N, 76.20 ° E, respectively.

3.2. Experimental material

The experimental materials consisting of 50 accessions of cucumber (*Cucumis sativus* L.) were procured from ICAR-National Bureau of Plant Genetic Resources, New Delhi. Three varieties namely, AAUC-2 (Assam Agricultural University Cucumber-2), Swarna Agethi (from ICAR-Research Complex for Eastern Region, Patna) and Poinsette (introduction from USA) were used as

Plate 1. Field view of experiments

check. The accessions for the study comprised primary collections representing various states of India *viz.,*Kerala (1), Karnataka (1), Maharashtra (2), West Bengal (12), Himachal Pradesh (1), Andaman and Nicobar Islands (3), Uttarakhand (2), Odisha (1) and North Eastern states namely Tripura (8), Mizoram (14), Nagaland (1) and Arunachal Pradesh (4).The passport data indicating the state, district, latitude-longitude of the place of collection are mentioned in Appendix I. For molecular characterization, five accessions representing five wild species were also included to study their distinct molecular profiling Table 1.

Table 1. List of wild species used in molecular characterization

S. No.	Collection No.	State	Scientific name
1	JB-11/156	Mizoram	*Cucumis hystrix*
2	N-09/110	Maharashtra	*C. setosus*
3	JP-13/47	Kerala	*C. leosperma*
4	JB-11/36	Mizoram	*C. muriculatus*
5	JBT-51/29	Jharkhand	*C. agrestis*

3.3. Experimental methods

3.3.1. Experiment I

3.3.1.1. Morphological characterization

For morphological characterisation, 50 accessions were raised in augmented block design with eight blocks and three check varieties during June-August, 2015. Each accession was sown in single bed of 4.5 m length at spacing of 1.5m between beds and 0.50 m between plants in a bed. The plants were thinned to single plant per pit to maintain 10 plants per bed. The plants were supported by installing pandals with bamboo and net. Recommended agronomic practices as per package of practices of Kerala Agricultural University (2011) were followed to raise a good crop.

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All the genotypes were selfed simultaneously to produce S_1 seeds. For selfing, well developed male and female flower buds of the same parent were covered using butter paper cover at evening hours on the day before anthesis. In the following day, the pollen grains from the male flower were softly dusted on to the stigma of the opened female flower, during early morning hours before 9.00 am. Pollen was viable up to noon of the day of flower opening. Stigma was receptive for a short period, with maximum receptivity between 6.00 am to 7.00 am and hence pollination was conducted within two hours after anthesis. After pollination, the female flowers were covered again with butter paper cover for two more days to avoid foreign pollen contamination and tagged using jewel tags. The developed primary fruits were further covered with perforated polythene bags to protect from fruit fly damage. Seeds collected from ripened fruits were dried and stored (Plate 2).

Observations on 33 quantitative and 11 qualitative characters were made at various growth stages of the crop from five randomly selected plants from each accession (Plate 3). The descriptor list developed at ICAR-NBPGR, New Delhi (NBPGR, 2001) was used for recording the observations. The descriptor and descriptor states used for morphological characterization are presented in Appendix II.

Scoring for downy mildew disease caused by *Pseudoperonospora cubensis* was undertaken on 60th day after sowing to assess the tolerance level of the accessions. The intensity of downy mildew disease was assessed with the score chart of 0 to 5 scale (0-no infection; 1 - 0 to10 %; 2 - 10.1 to15 %; 3 - 15.1 to 25 %; 4 - 25.1 to 50 % and 5 - more than 50 per cent of leaf area being covered with mildew growth) as described by Jamadar and Desai (1997). The percent disease index of downy mildew was calculated using formula given by Mckinney (1923) as:

$$\text{Percent disease index (PDI)} = \frac{\text{Sum of numerical ratings}}{\text{Total number of leaves}} \times \frac{100}{\text{Maximum disease grade in the score chart}}$$

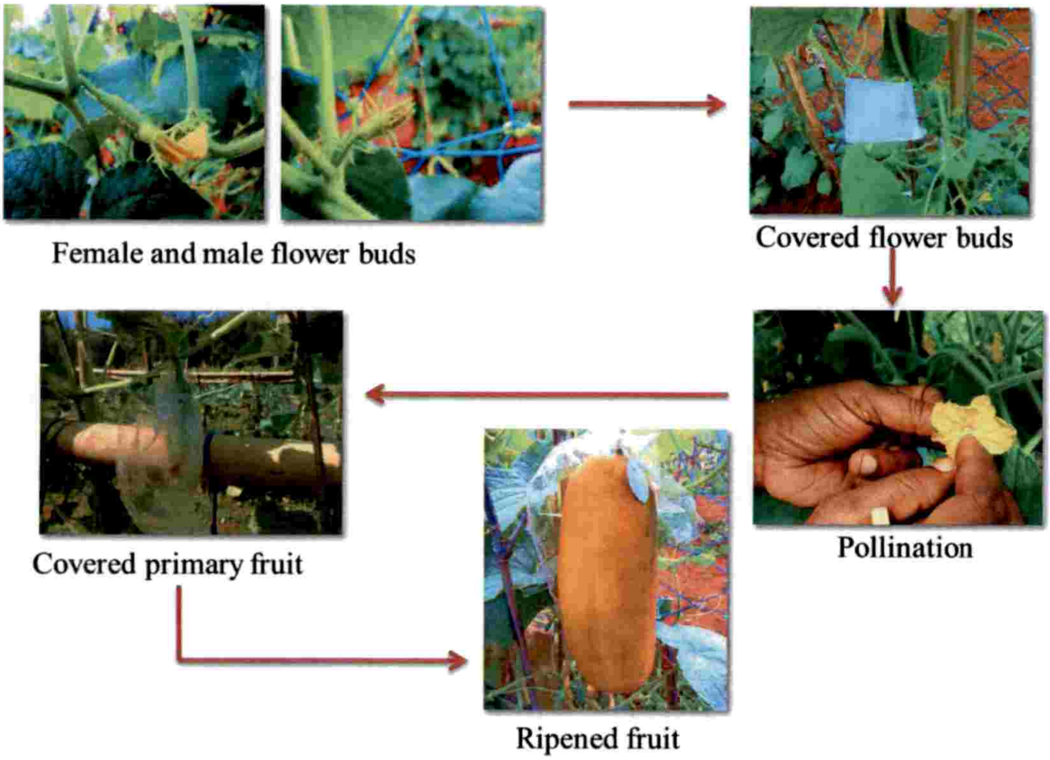

Plate 2. Steps in selfing

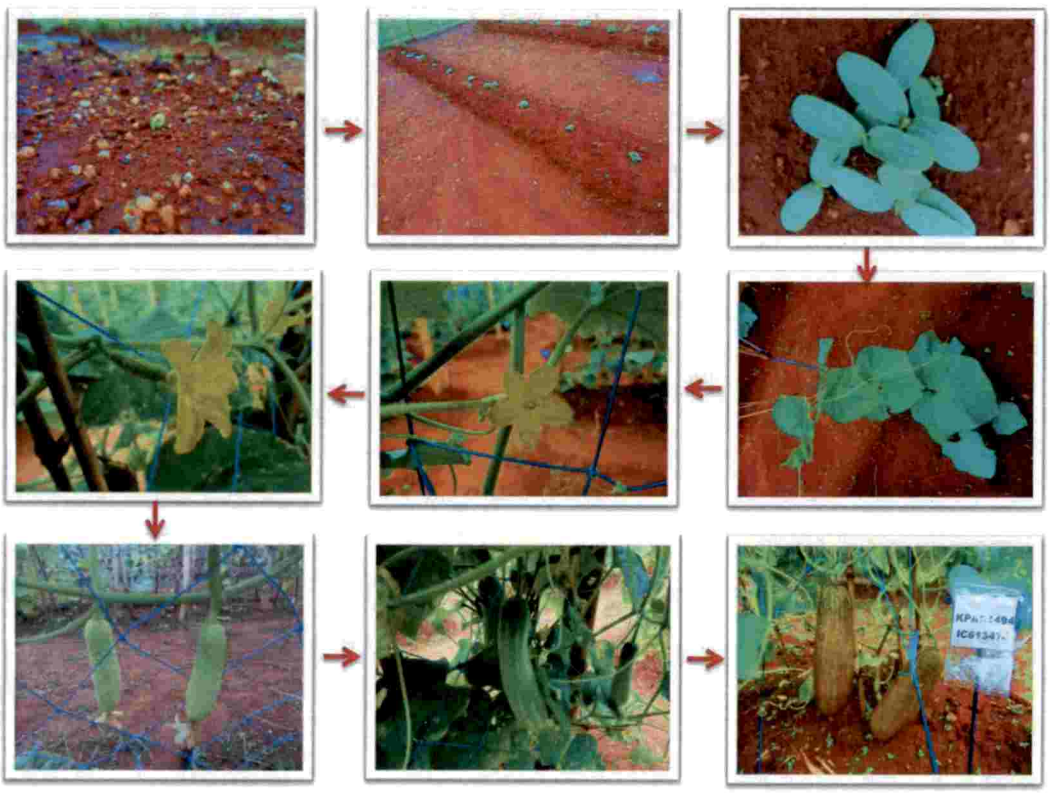

Plate 3. Different growth stages of cucumber

3.3.1.2. Cluster analysis

Cluster analysis is a multivariate approach to reduce the number of cases by classifying them into homogeneous groups, by identifying clusters without previously knowing group membership or the number of possible groups (Almeida *et al.*, 2007). In the present study, clustering was done in the freely downloadable online version of Minitab, following agglomerative hierarchical clustering method. In this method, each treatment was separated into its own individual cluster in the first step so that the initial number of clusters equalled the total number of treatments (Norusis, 2010). In successive steps, similar treatments or clusters were merged together until every treatment is grouped into one single cluster. At each step in the hierarchical procedure, either a new cluster is formed or one case joins a previously grouped cluster (Yim and Ramdeen, 2015). Squared Euclidean distance, the most common distance measure and complete linkage approach, widely used in continuous variables were considered for clustering. A dendrogram depicting grouping of accessions in various clusters at different similarity level was also drawn. Both inter and intra-cluster distances were calculated as the sum of squares of the differences between the mean values of all the 33 characters studied. The cluster mean for a particular trait is the summation of mean values of genotypes included in a cluster divided by number of genotypes in the cluster.

3.3.1.3. Principal component analysis

The objective of Principal component analysis (PCA) is to identify the minimum number of components that can explain maximum variation out of the total variance. PCA was done using the freely downloadable version of Minitab. Principal components (PCs) were computed from the correlation matrix, where number of PCs was equal to the number of variables. The sum of variances of the PCs was equal to the sum of the variances of the original genotypes. The first principal component accounted for the maximum proportion of the total variability in the set of all the variables followed by the second, third and so on accounting for progressively lesser and lesser amounts of variation. In order to investigate the relation between traits and genotypes, biplot analysis was done. Based on this analysis, the angle between different characters was related to correlation coefficient, as an angle less than 90^{o} revealed more correlation, and angle more than 90^{o} showed less correlation between different characters studied.

3.3.1.4. Organoleptic evaluation

Sensory evaluation of the tender fruits from each accession was done immediately after harvest. Score card including quality attributes like bitterness, crispness and flavour was prepared for sensory evaluation. Each quality attribute was scored by using a five point hedonic scale which ranged from zero to five. The score card used is attached as Appendix III.

Freshly harvested fruits were cut into small pieces of uniform size and sensory evaluation was carried out by a panel of 15 individuals consisting teaching and non-teaching staff members, research assistants and students of different age groups. Mean score for each quality attribute over 15 judges for individual genotypes were calculated. To represent the acceptability of the fruit in terms of bitterness, the complement (maximum score - average score) with respect to maximum score was taken. This exercise was done to maintain uniformity in reading the score in ascending order.

Kendall's coefficient of concordance was used to study the significance of perception of taste between the individuals and to rank the plants based on the mean rank of different sensory attributes. The hedonic scales were then converted to rank scores and rank analysis was done by Kendall's coefficient of concordance (Siegel, 1956).

3.3.1.5. Selection of promising genotypes

The majority of experiments in agriculture deal with observations on number of dependent characters based on which the inferences are to be made. In

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the present study, promising genotypes from the base population were identified by following the method suggested by Arunachalam and Bandyopadhyay (1984). As per the method, the accession means for each character were arranged in groups based on least square difference (LSD) following *post-hoc* test (Das and Giri, 1979). The topmost group with highest mean was given a score of one, the next best a score two and so on.

To obtain the standardized score across the characters, the given score for the respective accession was divided by the number of groups for that particular character. When there is overlapping of groups occur, *ie*., the same groups occur in more accessions, the score for that accession was taken to be the average of the score obtained. Similarly, accessions with multiple groups were treated similarly for obtaining the final score. The individual scores for each character were then added to obtain the total score for each accession. The accessions were then ranked in descending order of the numerical values of total score. The accession which obtained the least total score will be given rank I, and the next least value of total score rank II and so on. Further, the ranked accessions were arranged in the decreasing order of their total organoleptic score. Thus 22 promising accessions with high organoleptic score selected by this simultaneous selection procedure (Table 2) were used for further evaluation.

3.3.2. Experiment II: Evaluation of promising genotypes

The selfed seeds of the 22 selected genotypes from experiment I were raised in Randomly Block Design with two replications at NBPGR farm, Thrissur during November-January, 2016. The spacing, number of plants per bed and number of plants per pit were same as followed for trials for morphological characterization. Observations were made on 30 quantitative characters. Selfing of all the selected genotypes continued to produce S_2 seeds. From the 22 accessions evaluated, six superior accessions (Table 6) were selected based on the method suggested by Arunachalam and Bandyopadhyay (1984) as described in 3.3.1.5 for development of hybrids.

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Table 2. Twenty two promising accessions selected for evaluation

Sl. No.	Collection No.	Accession No.	Sl. No.	Collection No.	Accession No.
1	SKYAC-270	IC613481	12	JB-11/197	IC613470
2	SKYAC-265	IC613480	13	JR-04/13	IC469517
3	JB/12-183A	IC618084A	14	SKYAC-262	IC613479
4	JB/11-217	IC595512	15	JB-11/145	IC613488
5	SKYAC-316	IC613484	16	JB-11/205	IC595510
6	JB/11-28	IC595504	17	KPAC-1494	IC613474
7	JB/12-203	IC613471	18	JJK-10/601	IC595518
8	JS/06-1	IC541367	19	SKYAC-319	IC613485
9	BBD-12/2001	IC331445	20	JB-11/206	IC618083
10	SKYAC-251	IC613477	21	JB-11/91	IC613462
11	SKYAC-247	IC613476	22	JB-11/182A	IC595508A

3.3.3. Molecular characterization of promising accessions using SSR markers

Promising accessions selected (22 nos.) and five accessions representing different wild species (Table 1) were subjected to molecular characterization.

3.3.3.1. Isolation of DNA

Total DNA (Deoxyribo nucleic acid) from the young leaves of the selected promising accessions was extracted following CTAB method (Dellaporta *et al.*, 1983) with minor modifications.

1. 500 mg of tender leaves of cucumber, sterilized by rubbing with cotton dipped in 70 % ethanol, weighed into an autoclaved pre-chilled mortar and pestle.
2. The leaves were ground in1000 μl CTAB buffer in the presence of 5 μl β-mercaptoethanol and a pinch of PVP (Poly vinyl pyrrolidine) in to a smooth paste. This was transferred to a sterile 2 ml centrifuge tube.

3. This mixture was incubated at 65°C for 40 minutes with occasional mixing by gentle inversion.
4. Added equal volume of pre-chilled chloroform: Isoamyl alcohol (24:1) to the incubated sample.
5. Centrifuged at 12000 rpm for 10 minutes at 4°C.
6. The top aqueous layer was pipetted out with a wide bore pipette to a clean tube.
7. Equal volume of pre-chilled chloroform: Isoamyl alcohol (24:1) was again added.
8. The tube was mixed gently by inversion and centrifuged at 12000 rpm for 10 minutes at 4°C.
9. The supernatant was transferred to a clean tube and the previous step was again repeated.
10. 28 µl of 7.5 M Ammonium acetate was added to the supernatant obtained.
11. Equal volume of ice cold isopropanol was gently added through the sides of the tube and mixed well until the DNA precipitated and kept for incubation at 4°C for 2 hours.
12. The tube was centrifuged at 12000 rpm for 10 minutes at 4°C and pour off the supernatant was poured off gently by inverting the tube.
13. The pellet thus obtained was washed with 700 µl of 70% ethanol and centrifuged at 10000 rpm for 10 minutes at 4°C.
14. The liquid was pipetted out and the pellet was again washed with 70% ethanol. Supernatant was removed and pellet dried.
15. The DNA was dissolved in autoclaved sterile distilled water (100 µl), labelled and stored at ˉ20°C.

3.3.3.2. Determination of quality and quantity of DNA

Quantification and quality checking of the isolated genomic DNA was done using Nanodrop-Genway (Genova Nano) spectrophotometrically by estimating the optical density value at 260 nm and 280 nm. A pure double stranded DNA having a concentration of 50 µl/mg will give an OD value of 1 at 260 nm. The

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quality of DNA was checked by estimating the OD260/OD280 value. A pure sample of DNA will give an OD260/OD280 ratio of 1.8. The quality and quantity of DNA isolated from 27 genotypes are presented in Table 3. The DNA samples were diluted to working concentration of 50 ng/µl using the obtained concentration of original sample from Nanodrop.

Table 3. Quality and quantity of DNA used for molecular characterization of 27 *Cucumis* genotypes

Accessions	Quality of DNA (OD_{280}/OD_{260})	Quantity of DNA (ng/µl)
IC613481	1.89	45.18
IC613480	1.98	45.94
IC618084A	1.81	48.09
IC595512	1.98	45.98
IC613484	1.91	43.25
IC595504	1.95	43.46
IC613471	1.96	75.83
IC541367	1.94	51.55
IC331445	1.98	43.89
IC613477	1.94	63.84
IC613476	1.92	67.61
IC613470	1.88	44.09
IC469517	1.92	51.84
IC613479	1.90	50.12
IC613488	1.92	55.48
IC595510	1.97	69.99
IC613474	1.55	45.86
IC595518	1.88	44.46
IC613485	1.97	46.73
IC618083	1.98	45.96
IC613462	1.98	51.94
IC595508A	1.91	74.18
JB-11/156	1.89	62.13
N-09/110	1.93	58.17
JP-13/47	1.98	79.32
JB-11/36	1.81	71.43
JBT-51/29	1.92	65.14

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3.3.3.3. Normalization of DNA concentration for PCR

Normalization of DNA was done by appropriate dilutions so that the DNA of all the samples is brought to relatively equal concentration of 50 ng/μl using the obtained concentration of original sample from Nanodrop.

3.3.3.4. Polymerase Chain Reaction (PCR)

The genomic DNA thus diluted were amplified *in-vitro* by enzymatic process known as PCR. Master reaction mix for PCR was prepared in 0.2 ml flat capped PCR tubes containing the following enlisted components (Table 4). Amplification was carried out in Master Cycler Gradient Eppendorf PCR. The step of PCR is given in Fig. 1.

Table 4. List of components for PCR

S. No.	Components	Quantity (μl)
1	Template DNA	3
2	Primer (5ng/μl) for both forward and reverse primers	4
3	PCR master mix	8
	Total reaction mixture	15

3.3.3.5. Separation of amplified products by agarose gel electrophoresis

Agarose of 1.50 per cent was prepared by weighing 1.50 g agarose in 100 ml of TBE buffer. The components for preparing 200 ml of 10X TBE buffer is given in Table 5. The weighed agarose was heated in micro wave oven for 1 - 2 minutes until it was dissolved and the solution became clear. The solution was allowed to cool by stirring in a magnetic stirrer to a temperature of 45-50°C. Ethidium bromide (5 μl) was added to this solution and mixed well. This warm solution of gel was poured into the gel tray fitted with the comb positioned vertically so that the tip of the teeth were about 1-2 mm above the surface of the tray.

1) Initial denaturation at 94^{o}C temperature for 5 minutes

⇩

2) Denaturation at 94^{o}C for 1 minute

⇩

3) Primer annealing at 54^{o}C for 45 seconds

⇩

4) Primer extension at 72^{o}C for 45 seconds

⇩

Steps 2 - 4 were repeated 35 times

⇩

5) Completed primer extension at 72^{o}C for 10 minutes

⇩

6) Held at 4^{o}C till removal

Fig. 1. Steps of Polymerase Chain Reaction

Table 5. Components for preparing 200 ml of 10X TBE

Chemical	Weight (g)
Tris Base	21.60
Boric acid	11.00
EDTA	0.744
Distilled water	200 ml

The gel was allowed to solidify for about 30-45 minutes at room temperature. The comb and the seal on the sides of the tray were carefully removed. The tray along with the gel was placed in the electrophoresis tank. The electrophoresis tank was filled with 1X TBE buffer till the surface of the gel was just submerged. DNA sample for electrophoresis was added with 1µl gel loading dye (6X) and mixed well and 10 µl of this solution was loaded into the well.

Electrophoresis was carried out at conditions of 70 V and 400 A until the dye has migrated two third the length of the gel. Upon completion of the electrophoresis, the gel was placed in the gel documentation system and viewed under UV light. The image of the banding pattern of DNA was recorded directly in the system. The banding pattern was studied for polymorphism between bands with respect to the marker under study.

3.3.3.6. Primers used in the study

A total of 20 primers reported as polymorphic from earlier studies (Hu *et al.*, 2010; Innark *et al.*, 2013 and Pandey *et al.*, 2013) were used for SSR profiling (Appendix IV). Thermo Scientific Gene Ruler 100 bp DNA ladder was used as molecular size marker.

3.3.4. Experiment III

3.3.4.1. Development of hybrids

Selfed seeds of six accessions, which had performed consistently in the above two experiments (Table 6) were used for hybridization in diallel pattern without reciprocals (half diallel). A non-replicated crossing block was laid out at NBPGR farm during June-August, 2016. Staggered sowing of each genotype was done at weekly intervals to ensure ample male and female flowers availability. Recommended agronomic practices as followed in the above experiments were adopted.

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Selfing of all the genotypes continued to produce S_3 seeds. For crossing, well developed male and female flower buds of the male and female parents were covered using butter paper cover at evening hours on the day before anthesis. In the following day, the pollen grains from the male flower were softly dusted on to the stigma of the opened female flower during early morning hours before 9.00 am.

After pollination, the female flowers were covered again with butter paper cover for two more days, till the primary fruits developed to avoid foreign pollen contamination and tagged using jewel tags. The developed fruits were further covered with perforated polythene bags to protect from fruit fly damage. Seeds were collected from ripened fruits of the crossed female flower, dried and stored.

Table 6. Parents selected for hybridization

S. No.	Collection No.	Accession No.
1	SKYAC/265	IC613480
2	SKYAC/319	IC613485
3	JB-12/203	IC613471
4	SKYAC/247	IC613476
5	JB-11/145	IC613488
6	JB-11/182A	IC595508A

3.3.4.2. Evaluation of hybrid combinations

Fifteen direct crosses and six parents were raised in Randomized Block Design during Oct 2016- Jan-2017 with 3 replications to study the combining ability and heterosis of hybrids. Sowing and cultural practices followed were same as adopted in the previous experiments. The observations on all characters taken during previous experiments were recorded in the current experiment also. Selfing of the parents continued to produce S_4 seeds. The hybrids and parents used in the experiment are depicted in Table 7.

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Table.7. Hybrids and parents used in combining ability studies

S. No.	Hybrids	S. No.	Parents
1	IC613480 x IC613488	1	IC613480
2	IC613480 x IC613476	2	IC613488
3	IC613480 x IC613471	3	IC613476
4	IC613480 x IC613485	4	IC613471
5	IC613480 x IC595508A	5	IC613485
6	IC613488 x IC613476	6	IC595508A
7	IC613488 x IC613471		
8	IC613488 x IC613485		
9	IC613488 x IC595508A		
10	IC613476 x IC613471		
11	IC613476 x IC613485		
12	IC613476 x IC595508A		
13	IC613471 x IC613485		
14	IC613471 x IC595508A		
15	IC613485 x IC595508A		

3.4. Statistical analysis

3.4.1. Experiment 1: Morphological characterization

Analysis of variance, path analysis, estimation of genetic parameters and correlation studies were done using software Windostat Version 9.2 from Indostat Services, Hyderabad, India. Principal component analysis and clustering of genotypes based on complete linkage squared Euclidean distance were done using freely available online version of Minitab statistical software. Promising accessions based on yield contributing traits, storage study and organoleptic evaluation were selected following method suggested by Arunachalam and Bandyopadhyay (1984) after grouping the accessions based on LSD values following *post-hoc* tests (Das and Giri, 1979).

3.4.1.1. Analysis of Variance

The format of Analysis of variance is given below:

Source of variation	Degrees of freedom	Sum of squares	F ratio
Block (ignoring Treatments)	(b-1)	SS(b)	SS(b)/SS(e)
Treatment (eliminating Blocks)	(t-1)	SS(t)	SS(t)/SS(e)
Varieties	(v-1)	SS(v)	SS(v)/SS(e)
Checks	(c-1)	SS(c)	SS(c)/SS(e)
Checks Vs variety	1	SS(vc)	SS(vc)/SS(e)
ERROR	(b-1) (c-1)	SS(e)	

t = number of treatments

v = number of varieties/genotypes

b = number of blocks

3.4.1.2. Coefficient of variation

$$\text{Phenotypic coefficient of variation (PCV \%)} = \frac{\text{Phenotypic variance}}{\text{Mean}} \times 100$$

$$\text{Genotypic coefficient of variation (GCV \%)} = \frac{\text{Genotypic variance}}{\text{Mean}} \times 100$$

PCV and GCV were classified as low (0 - 10%); moderate (10 - 20%) and high (> 20%) as per Sivasubramanian and Menon (1973).

3.4.1.3. Heritability in broad sense (h^2)

The broad sense heritability was calculated as the ratio of genotypic variance to the total or phenotypic variance as suggested by Lush (1949) and Hanson *et al.* (1956).

$$h^2 = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}}$$

The heritability estimates were categorized as low (0 - 30%); Medium (31 - 60%) and high (> 60%) as suggested by Johnson *et al.* (1955).

3.4.1.4. Genetic Advance (GA)

Genetic advance was estimated by following the formula given by Johnson *et al.* (1955).

$$GA = h^2 \times \sigma p \times K$$

where, h^2 = heritability estimate in broad sense

σ_p = Phenotypic standard deviation of the trait

K = Standard selection differential which is 2.06 at 5 per cent selection intensity

Genetic advance was classified as low (< 10%); moderate (10 - 20%) and high (>20%) as suggested by Johnson *et al.* (1955).

Further genetic advance as per cent of mean (Genetic gain) was computed by using the formula:

$$\text{GA as per cent of mean, Genetic gain} = \frac{GA}{\text{Grand mean}} \times 100$$

Genetic advance as per cent of mean was categorised as low (< 10%); moderate (10 - 20%) and high (>20%) as suggested by Johnson *et al.* (1955).

3.4.1.5. Correlation studies

The correlation coefficients were calculated to determine the degree of association of characters with yield and also among the yield components. Both genotypic and phenotypic coefficients of correlation between character pairs were determined by using the variance and covariance components as suggested by Al-Jobouri *et al.* (1958).

$$r_g(x, y) = \frac{Cov_g(xy)}{\sqrt{\sigma_g^2(x)}.\sqrt{\sigma_g^2(y)}} \qquad r_p(x, y) = \frac{Cov_p(xy)}{\sqrt{\sigma_p^2(x).\sigma_p^2(y)}}$$

where, r_g (x, y) and r_p (x, y)are the genotypic and phenotypic correlation coefficients respectively. Cov_g and Cov_p are the genotypic and phenotypic covariance and σ^2 g and σ^2p are the genotypic and phenotypic variance of x and y respectively. The calculated value of 'r' was compared with table 'r' values with n-2 degrees of freedom at 5% and 1% level of significance, where 'n' refers to number of character combinations.

3.4.1.6. Analysis of diversity using DIVA-GIS

A study on the distribution of diversity in a species at the ecosystem level (geographical distribution) is an important aspect as it gives an insight into the environmental conditions conducive for propagating the diversity (Abraham, 2012). The regions where diverse accessions occur could be found by analysing the geographical diversity distribution. The importance of an eco-geographic database in providing information on conservation priorities of germplasm has already been established (Maxted *et al.*, 1995)

To study the diversity and distribution of the study material using DIVA-GIS, geo-referenced points of the collection sites of the genotypes and observations recorded on agro-morphological plant traits were exploited. The morphological data recorded were supplemented to shape files and map geo-referenced points using DIVA-GIS software version 7.1.6. The mapped points were analysed with the software in order to know the spatial distribution and assessment of variability for each of the plant trait recorded. Point-to-grid option using circular neighbourhood method on the "Analysis Menu" was used to get grids over the points of collection. The output variables *diversity* and *statistics* were selected for getting output files.

Under *Diversity* Shannon Diversity Index was picked. Under *Statistics*, coefficient of variation was selected. From these output maps, the distribution pattern, diversity and coefficient of variation were generated. Thus, grid maps were generated for diversity analysis of six traits in 50 accessions. Based on the genetic variability, the colour of the grid varied from green, light green, yellow,

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orange and red, in the order of their magnitude of variability. Green coloured grids indicated the less diverse regions whereas red coloured grid, the most diverse region.

Shannon Diversity Index (SDI) accounts for both abundance and evenness of the trait in the states (Negassa, 1985). The proportion of descriptors states *i* relative to the total number of states (*pi*) is calculated, and then multiplied by the natural logarithm of this proportion (ln *pi*). The resulting product is summed across the states and multiplied by -1:

$$H = - \sum pi \ln pi$$

where, '*pi*' is the proportion of individuals found in species 'i'.

3.4.1.7. Selection of promising genotypes

The majority of experiments in agriculture deal with number of dependent characters based on which the inferences are to be made. As it is evident that all the morphological characters will not have significant direct effect on the yield, the focus was limited to major yield contributing characters namely, fruit weight (g), fruit length (cm), fruit diameter (cm), days to first harvest, number of fruits per plant and sex ratio for selecting promising genotypes. In addition, storability behaviour assessed in terms of loss of weight during storage and number of days of storage, tolerance to downy mildew disease estimated as per cent disease index and the organoleptic qualities were also considered for selecting promising genotypes.

If the analysis of variance for these selected characters revealed significant difference between the treatments, a stepwise multiple comparisons following the *post-hoc* test, Duncan's Multiple Range Test (DMRT) grouped the genotypes by identifying the sample means which are significantly different. Further, the grouped accessions were scored for selecting promising genotypes based on the method suggested by Arunachalam and Bandyopadhyay (1984).

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3.4.2. Experiment II: Evaluation of promising genotypes

Those superior accessions which performed better in both experiment I and II were selected based on yield contributing traits, storage study and organoleptic evaluation, by method suggested by Arunachalam and Bandyopadhyay (1984).

3.4.3. Molecular characterization

The banding pattern generated based on the distance travelled by the DNA fragments were scored based on the molecular weight of the fragments generated. The molecular weight of each band was estimated by using the software Uvitech by selecting molecular weight analysis option.

3.4.3.1. Scoring of bands and data analysis

Clear and unambiguous bands of various molecular weights were scored for the presence (1) and absence of the bands (0) respectively. Manually scored bands were prepared in the form of a binary matrix and the data matrix was further subjected to analysis using NTSYS (Numerical Taxonomy and Multivariate Analysis System) version 2.1 (Rohlf, 2000). SIMQUAL programme was used to calculate pair wise Jaccard's similarity coefficient (Jaccard, 1908) and generated a similarity matrix. This similarity matrix was used in cluster analysis following Unweighted Pair Group Method (UPGMA) (Sneath and Sokal, 1973) using SAHN clustering algorithm (Sequential agglomerative Hierarchical and Nested) based on the similarity indices and genetic related among the 27 genotypes to construct dendrogram.

Polymorphic information content (PIC) of each SSR marker was calculated (Anderson *et al.,* 1993) and Marker index (MI) (Powell *et al.*, 1996) were the parameters used for measuring the performance of markers. Both PIC and MI confirm the suitability of the primer, PIC represents the ability of a marker to detect the polymorphism within a population and MI helps to understand the

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capacity of primer to detect polymorphic loci among varieties. Markers were classified as informative when PIC was ≥ 0.5

$$\text{PIC} = 1 - \sum_{j=1}^{n} (Pij)^2$$

Where, n is the number of marker alleles for marker i and P*ij* is the frequency of the j^{th} allele for marker '*i*',

$$\text{MI} = \text{PIC} \times \text{No. of polymorphic bands}$$

3.4.4. Experiment III. Evaluation of hybrids

3.4.4.1. Combining ability studies

Combining ability analysis of the traits with significant genotypic difference was done according to the model I (fixed genotypic effects) and method II (half diallel) of Griffing (1956).

The mean data of biometrical characters recorded on all genotypes are subjected to appropriate analysis of variance (ANOVA). The significance of F value for genotypes indicated the significant difference among the genotypes studied and continued for combining ability analysis.

In this approach, the mean measurement is partitioned into two major components, apart from a general mean (μ) and an environmental component (i) the contribution of parents, the general combining ability (GCA) and specific combining ability (SCA) effect. The experimental materials comprised 6 parents (inbreds) and 15 direct crosses (F_1s).

Griffing's analysis indicates the performance of the parents and their relative contribution to the F_1s expressed as general and specific combining ability. The degrees of freedom and formulae to work out sum of squares due to various sources of variation for combining ability with regard to method II is furnished below:

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Source	df	Sum of squares
GCA	$(p\text{-}1)$	$\frac{1}{(p+2)}[\sum(Yi. + Yii)^2 - \frac{4}{p} Y^2..]$
SCA	$\frac{p(p-1)}{2}$	$\sum\sum Yij^2 - \frac{1}{(p+2)}[\sum(Yi. + Yii)^2] + \frac{2}{(p+1)(p+2)} Y^2..$
Error		
Total	$\frac{p(p+1)}{2} - 1$	

where, p = number of parents

In Griffing's approach GCA represents additive variance whereas SCA represents non-additive effects. The significant differences within each of the component effects were tested by F-test.

Source	df	MS	Expectations of Mean Squares
GCA	$(p\text{-}1)$	Mg	$\sigma_e^2 + p + [\frac{1}{p-1}] \sum g_i^2$
SCA	$\frac{p(p-1)}{2}$	Ms	$\sigma_e^2 + p + 2[\frac{1}{p(p-1)}] \sum\sum s_{ij}^2$
Error		Me'	σ_e^2

where,

Mg = Mean sum of squares due to GCA

Ms = Mean sum of squares due to SCA

Me' = Mean sum of square due to error

Diallel tables were prepared by computing the averages over the three replications of all the parents and F_1s in the appropriate cells. The row sums, columns sums, the sum of square of GCA, SCA were computed from these tables.

The GCA of the parents was estimated as the difference between its array mean and the overall mean. The analysis of variance for method II and model I giving expectations of mean square is depicted above.

3.4.4.1.1. Genetic components

$$\text{Variance due to GCA} = \frac{1}{p-1} \sum g_i^2$$

$$= \frac{\text{Mg-Me'}}{2(p-2)}$$

$$\text{Variance due to SCA} = \frac{2}{p(p-3)} \sum\sum s_{ij}^2$$

$$= \frac{\text{Ms-Me'}}{2}$$

When mean square due GCA and SCA were significant, the estimates of GCA and SCA effects were calculated using the formula:

$$\text{GCA effect of parents } (gi) = \frac{1}{(p+2)} [(Yi. + Yii)^2 - \frac{2}{p} Y^2..]$$

$$\text{SCA effect of hybrids } (Sij) = Yij - \frac{1}{(p+2)} [(Yi. + Yii)^2] + \frac{2}{(p+1)(p+2)} Y..$$

Where, Yii – Mean value of i^{th} parent

Yij- Mean value of j^{th} parent

Test of significance of effects by '*t*' test

$$\text{SE for GCA effect of parents} = \sqrt{\frac{(p-1)}{p(p+2)} Me'}$$

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$$\text{SE for SCA effect of hybrids} = \sqrt{\frac{(p+1)(p+2)}{p(p-1)} Me'}$$

$$\text{Predictability Ratio (Baker, 1978)} = \frac{2\sigma^2 g}{(2\sigma^2 g + \sigma^2 s)}$$

where, $\sigma^2 g$ - variance due to GCA

$\sigma^2 s$ - variance due to SCA

3.4.4.2. Estimation of heterosis

The hybrids were evaluated for selected characters by three kinds of heterosis namely relative (Mid-parent) heterosis, heterobeltiosis (better parent heterosis) and standard heterosis by using method suggested by Briggle (1963) and Hayes (1965). The mean values over replications were used for analysis.

$$\text{Relative heterosis} = \frac{\overline{F1} - \overline{MP}}{\overline{MP}}$$

$$\text{Heterobeltiosis} = \frac{\overline{F1} - \overline{BP}}{\overline{MP}}$$

$$\text{Standard heterosis} = \frac{\overline{F1} - \overline{SV}}{\overline{SV}}$$

where, MP - value of mid parent; BP - value of better parent; SV - value of standard variety.

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Results

4. Results

The results of the present study entitled "Genetic diversity and combining ability in cucumber (*Cucumis sativus* L.)" are detailed in this chapter.

4.1. Characterization of cucumber genotypes

4.1.1. Morphological characterization

Observations were taken on 11 qualitative and 33 quantitative characters.

4.1.1.1. Qualitative characters

Qualitative characters included leaf shape, leaf pubescent density, leaf margin, fruit skin colour, fruit shape, flesh colour, stem end fruit shape, blossom end fruit shape, fruit skin texture, presence of seed cavity and primary fruit colour (Plate 4). No variability among accessions was found in leaf shape, leaf pubescence density, leaf margin, stem end fruit shape and blossom end fruit shape. Table 8 depicts the scores for different qualitative characters studied.

4.1.1.1.1. Fruit skin colour

Among the 53 accessions studied, seven accessions namely IC613457, IC277048, IC277030, IC202058A, IC612081 and IC595518 possessed cream coloured fruit skin. Light green colour was exhibited by 27 accessions whereas green and dark green colour for fruit skin was observed in 16 and three accessions respectively. IC595505, IC613459 and Poinsette exhibited dark green colour for fruit skin. Among check varieties, light green colour was observed for both AAUC-2 and Swarna Agethi (Plate 5).

4.1.1.1.2. Fruit shape

Fruits of elliptical elongate, oblong ellipsoid and globular shapes were observed among the accessions studied. Fifty five per cent (29 accessions)

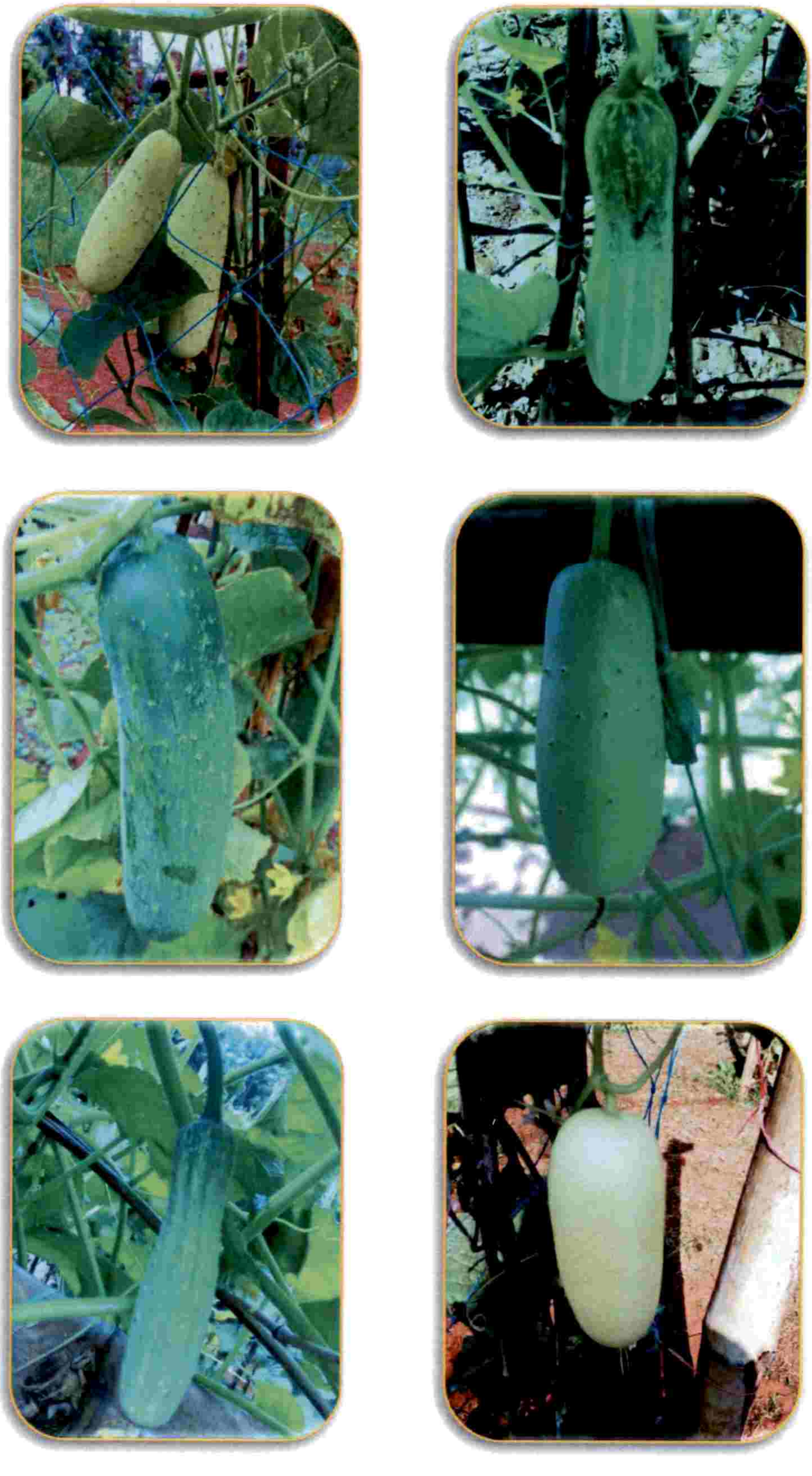
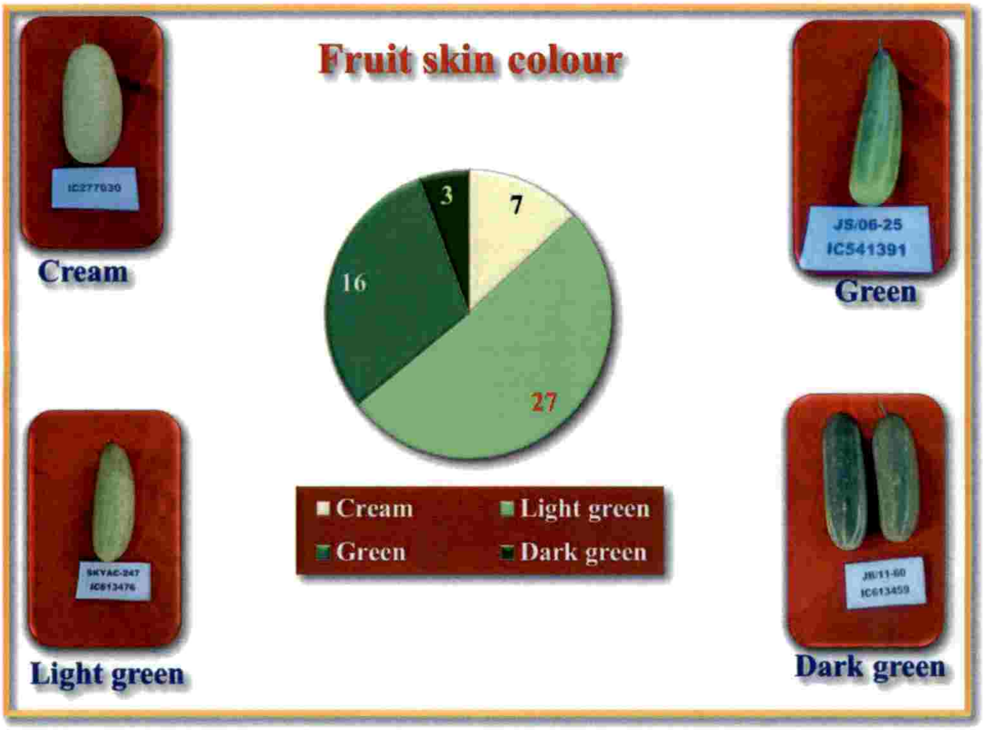


Plate 4. Variability in cucumber fruits



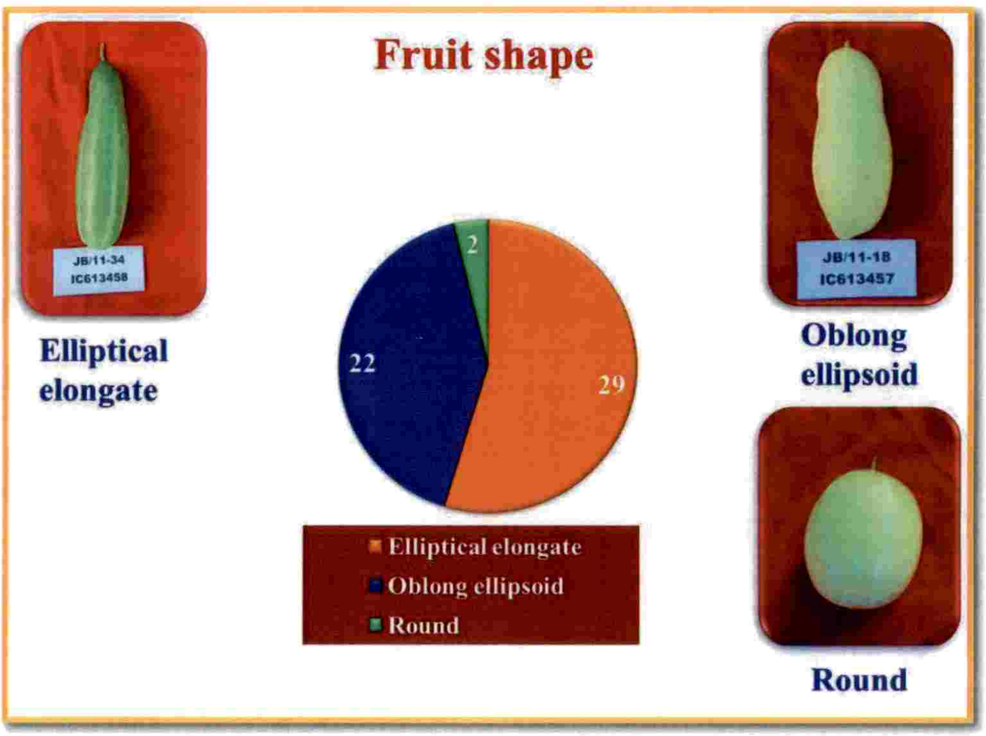


Plate 5. Variability and frequency distribution of qualitative characters

Table 8. Qualitative characters in 53 cucumber accessions

S. No.	Accessions	LS	LPD	LM	FSC	FS	FC	SEFS	BEFS	FST	PSC	PFC
1	IC613457	1	7	99	1	2	1	3	3	2	0	1
2	IC595504	1	7	99	3	1	1	3	3	3	0	4
3	IC613458	1	7	99	4	1	99	3	3	3	0	5
4	IC595505	1	7	99	5	1	99	3	3	3	1	3
5	IC613459	1	7	99	5	2	2	3	3	3	0	5
6	IC612081	1	7	99	4	2	1	3	3	3	0	4
7	IC613461	1	7	99	3	2	99	3	3	3	0	3
8	IC613462	1	7	99	1	2	1	3	3	2	0	3
9	IC612082	1	7	99	3	2	1	3	3	2	0	3
10	IC613465	1	7	99	3	2	99	3	3	2	1	3
11	IC613466	1	7	99	3	1	1	3	3	3	1	3
12	IC613467	1	7	99	3	2	1	3	3	2	0	3
13	IC613488	1	7	99	3	2	1	3	3	2	0	3
14	IC595508A	1	7	99	4	2	1	3	3	3	0	3
15	IC613460	1	7	99	3	2	1	3	3	2	0	3
16	IC595510	1	7	99	4	1	99	3	3	3	0	4
17	IC618083	1	7	99	4	2	99	3	3	3	1	3
18	IC595512	1	7	99	4	2	1	3	3	3	0	3
19	IC595514	1	7	99	3	1	1	3	3	3	0	3
20	IC595515	1	7	99	4	2	1	3	3	3	0	3
21	IC595517	1	7	99	3	1	1	3	3	3	1	3
22	IC613471	1	7	99	3	2	1	3	5	2	0	4
23	IC613472	1	7	99	3	1	1	3	3	2	0	3
24	IC613473	1	7	99	3	1	1	3	3	3	0	3
25	SKYAC/239	1	7	99	4	1	1	3	3	3	0	3

LS-Leaf shape; LPD-Leaf pubescence density; LM-Leaf margin; FSC-Fruit skin colour; FS-Fruit shape; FC-Fruit flesh colour; SEFS- Stem end fruit shape; BEFS-Blossom end fruit shape; FST-Fruit skin texture; PSC-Presence of seed cavity; PFC-Primary fruit colour

Contd..

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Table 8. Qualitative characters in 53 cucumber accessions

S. No.	Accessions	LS	LPD	LM	FSC	FS	FC	SEFS	BEFS	FST	PSC	PFC
26	IC613475	1	7	99	1	1	1	3	3	3	0	4
27	IC613476	1	7	99	3	2	1	3	3	3	0	3
28	IC613477	1	7	99	4	1	1	3	3	3	0	3
29	IC613478	1	7	99	3	1	1	3	3	3	0	3
30	IC613479	1	7	99	4	1	1	3	3	3	0	3
31	IC613480	1	7	99	3	1	1	3	3	3	0	3
32	IC613481	1	7	99	3	1	1	3	3	3	0	3
33	IC613482	1	7	99	3	1	1	3	3	3	0	3
34	IC613483	1	7	99	4	1	1	3	3	3	1	3
35	IC613484	1	7	99	3	1	1	3	3	2	0	3
36	IC613485	1	7	99	3	1	1	3	3	3	0	3
37	IC613474	1	7	99	4	1	1	3	3	3	0	3
38	IC595518	1	7	99	1	2	1	3	3	3	0	1
39	IC618084A	1	7	99	4	1	1	3	3	3	0	3
40	IC331445	1	7	99	3	1	1	3	7	3	1	3
41	IC331627	1	7	99	4	3	2	3	3	1	0	3
42	IC277048	1	7	99	1	3	1	3	3	1	0	3
43	IC331619	1	7	99	3	2	99	3	3	1	0	3
44	IC541367	1	7	99	3	2	99	3	3	3	1	3
45	IC541391	1	7	99	4	1	2	3	3	3	0	3
46	IC469517	1	7	99	3	2	1	3	3	2	0	3
47	IC539818	1	7	99	4	1	1	3	3	2	1	3
48	IC277030	1	7	99	1	2	1	3	3	1	0	3
49	IC613470	1	7	99	3	1	1	3	3	3	0	3
50	IC202058-A	1	7	99	1	2	1	3	3	2	0	3
51	AAUC-2	1	7	99	3	1	1	3	3	3	0	3
52	Poinsette	1	7	99	5	1	1	3	3	2	0	4
53	Swarna Agethi	1	7	99	3	1	1	3	3	3	0	3

LS-Leaf shape; LPD-Leaf pubescence density; LM-Leaf margin; FSC-Fruit skin colour; FS-Fruit shape; FC-Fruit flesh colour; SEFS - Stem end fruit shape; BEFS-Blossom end fruit shape; FST-Fruit skin texture; PSC-Presence of seed cavity; PFC-Primary fruit colour

possessed elliptical elongate fruits. Oblong ellipsoid shape was exhibited by 22 genotypes (41.05 per cent), whereas two accessions (IC331627 and IC277048) possessed globular/round shape. All the check varieties uniformly had the elliptical elongated shaped fruits.

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4.1.1.1.3. Flesh colour

Forty two accessions (79 per cent) had white colour for fruit flesh whereas green and light green colour for fruit flesh were exhibited by five per cent (three accessions) and 15 per cent (eight accessions) respectively. Two genotypes, which possessed light green flesh were IC331627, IC613459 and IC541391. White colour for flesh was exhibited by all the control varieties. Ten accessions IC595515, IC613467, IC613464, IC613471, IC613472, IC613461, IC595514, IC618084A, IC595508A and IC613463 exhibited orange coloured flesh in the ripened fruit, indicating carotenoid content in the flesh (Plate 6 - 8).

4.1.1.1.4. Fruit skin texture

The fruit skin texture was exhibited as plain in four genotypes (IC331627, IC277048, IC331619 and IC277030), netted in 14 genotypes and rough in 35 accessions. Among the control varieties, Poinsette possessed netted texture, whereas AAUC-2 and Swarna Agethi had rough textured fruit surface.

4.1.1.1.5. Presence of seed cavity

Forty one out of the 53 accessions (82 per cent) did not possess seed cavity in tender fruits and the remaining 18 per cent (nine genotypes) possessed seed cavity. No seed cavity was observed for the control varieties.

4.1.1.1.6. Primary fruit colour

Primary fruit colour was cream for two accessions *viz.*, IC613457 and IC595518, light green for 43 accessions, green for six accessions *viz.*, IC595504, IC612081, IC595510, IC613471 and IC613475, Poinsette and dark green for two accessions *viz.*, IC613458 and IC613459.

4.1.1.2. Quantitative characters

Quantitative characters include shoot, floral and fruit characters (Plate 9-10).

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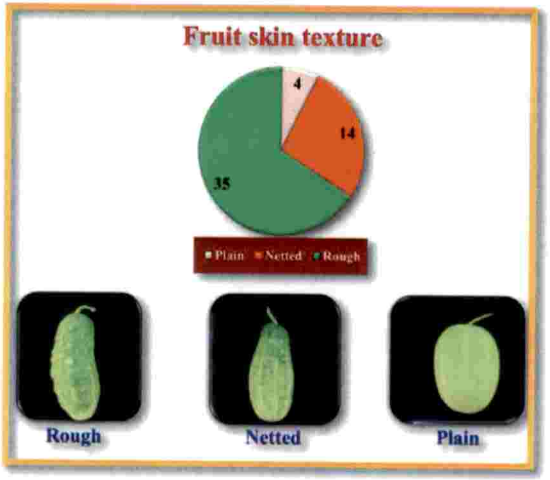


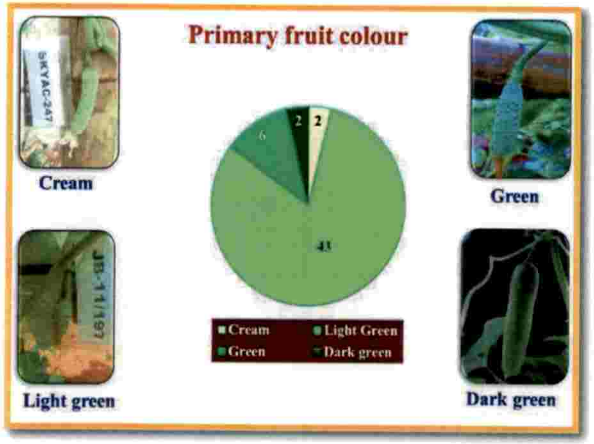
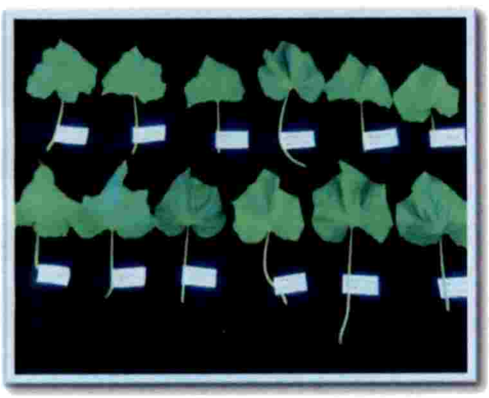


Plate 6. Variability and frequency distribution of qualitative characters among cucumber accessions

Plate 7. Variability in flesh colour of ripened fruits of cucumber accessions

Plate 8. Cucumber accessions with orange flesh at the ripened stage



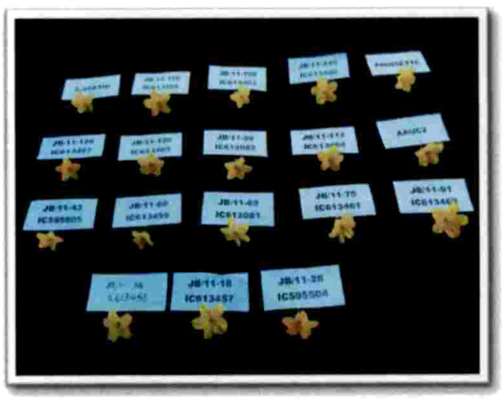


Plate 9. Leaf and flower variability in cucumber accessions

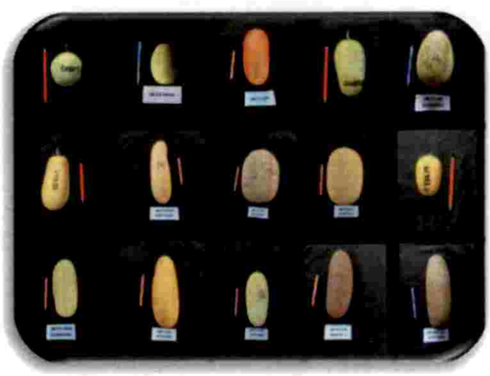


Plate 10. Variability in tender and ripened fruits in cucumber accessions

4.1.1.2.1. Shoot characters

Shoot characters considered for the study included vine length, number of primary branches per plant, length of mature leaf at 1^{st} flowering node, width of mature leaf at 1^{st} flowering node and petiole length. The statistically corrected mean values for shoot characters have been illustrated in Table 9.

4.1.1.2.1.1. Vine length

Vine length ranged from 178.48 (IC202058A) to 480.75 cm (IC541367) with an overall mean value of 323.22 cm. The value recorded for the check varieties AAUC-2, Poinsette and Swarna Agethi were 280.55, 287.00 and 291.10 cm, respectively (Table 9).

4.1.1.2.1.2. Number of primary branches

Maximum value for number of primary branches was recorded for IC613485 (13.29) and minimum value for IC613466 (6.49) with overall mean of 10.88.

4.1.1.2.1.3. Length of mature leaf at 1^{st} flowering node

Leaf length ranged from 12.85 cm in IC331627 to 18.94 cm in IC613483 with an overall mean of 16.15 cm. Among the check varieties, Swarna Agethi recorded highest mean leaf length (16.56 cm) followed by AAUC-2 (15.60 cm).

4.1.1.2.1.4. Width of mature leaf at 1^{st} flowering node

Leaf width ranged from 14.94 cm in IC613473 to 23.96 cm in IC613479 with an overall mean of 19.92 cm. Among the check varieties, AAUC-2 recorded highest mean leaf width (20.59 cm) followed by Swarna Agethi (20.29 cm).

4.1.1.2.1.5. Petiole length

Highest value for petiole length was recorded for IC613483 (28.65 cm) and lowest value for IC331627 (9.23 cm) with overall mean of 19.42.

Table 9. Shoot characters and Per cent Disease Index of downy mildew disease in 53 cucumber accessions

S. No	Accessions	VL (cm)	NPB	LMLFFN (cm)	WMLFFN (cm)	PL (cm)	PDI (%)
1	IC613457	219.42	12.03	18.54	22.80	16.50	74.50
2	IC595504	432.02	13.23	17.70	22.34	16.32	70.50
3	IC613458	355.02	10.03	15.40	17.62	18.12	48.50
4	IC595505	388.02	13.03	15.00	19.36	18.80	66.50
5	IC613459	286.62	9.83	14.52	18.42	19.84	80.50
6	IC612081	271.42	8.83	15.06	19.54	15.50	88.50
7	IC613461	284.62	9.23	15.28	17.80	14.94	78.50
8	IC613462	241.88	9.49	14.74	17.86	18.99	83.17
9	IC612082	250.88	9.09	15.32	18.84	13.31	89.17
10	IC613465	269.68	10.49	17.06	20.66	17.37	77.17
11	IC613466	240.08	6.49	15.42	18.68	17.13	79.17
12	IC613467	377.08	7.49	15.18	17.66	13.73	83.17
13	IC613488	326.48	11.29	16.98	20.28	23.33	63.17
14	IC595508A	261.35	10.16	16.79	19.39	17.83	59.17
15	IC613460	217.55	8.96	14.99	19.39	16.23	47.17
16	IC595510	354.15	11.96	17.79	21.79	22.43	69.17
17	IC618083	301.15	12.96	16.49	21.59	17.83	53.17
18	IC595512	315.95	11.56	17.19	22.37	23.63	65.17
19	IC595514	300.55	8.96	17.39	21.59	24.47	53.17
20	IC595515	290.95	12.16	16.69	21.69	18.23	55.17
21	IC595517	394.15	12.29	18.52	19.04	20.08	59.17
22	IC613471	360.15	10.09	17.08	18.94	20.42	69.17
23	IC613472	358.95	10.09	15.64	17.34	21.12	59.17
24	IC613473	414.75	11.69	14.58	14.94	14.42	41.17
25	SKYAC-239	461.75	12.49	15.58	16.54	18.02	63.17
26	IC613475	379.15	12.69	14.28	20.94	14.82	55.17
27	IC613476	312.68	10.16	16.02	21.94	21.15	54.50
28	IC613477	288.08	11.96	16.90	23.44	17.67	22.50

VL-Vine length; NPB-Number of primary branches; LMLFFN-Length of mature leaf at first flowering node; WMLFFN-Width of mature leaf at first flowering node; PL-Petiole length; PDI-Per cent Disease Index

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Table 9. Shoot characters and Per cent Disease Index of downy mildew disease in 53 cucumber accessions

S. No	Accessions	VL (cm)	NPB	LMLFFN (cm)	WMLFFN (cm)	PL (cm)	PDI (%)
29	IC613478	390.88	12.16	17.66	22.70	21.87	52.50
30	IC613479	324.48	11.16	17.82	23.96	23.07	34.50
31	IC613480	207.48	10.96	16.00	22.44	18.13	36.50
32	IC613481	390.48	12.96	15.86	21.70	18.43	48.50
33	IC613482	253.88	11.56	18.64	23.82	20.79	42.50
34	IC613483	414.48	12.49	18.94	22.04	28.65	30.50
35	IC613484	330.48	12.09	17.54	21.18	28.33	52.50
36	IC613485	439.28	13.29	16.92	21.16	28.33	62.50
37	IC613474	324.48	10.89	17.24	20.04	24.01	66.50
38	IC595518	441.48	11.29	17.20	22.46	23.87	18.50
39	IC618084A	423.88	11.69	14.80	18.12	21.11	62.50
40	IC331445	418.08	12.29	17.02	21.86	27.93	56.50
41	IC331627	229.35	9.76	12.85	15.60	9.23	61.17
42	IC277048	224.15	11.16	13.49	16.20	11.95	59.17
43	IC331619	223.75	10.76	14.37	17.66	12.83	45.17
44	IC541367	480.75	11.16	17.17	21.48	25.13	79.17
45	IC541391	276.15	10.76	14.03	16.42	21.93	71.17
46	IC469517	339.48	11.43	15.81	19.32	21.44	79.83
47	IC539818	361.68	9.43	15.51	18.92	19.42	43.83
48	IC277030	276.48	9.63	17.49	20.20	19.44	45.83
49	IC613470	367.88	10.63	15.05	17.10	22.74	75.83
50	IC202058A	178.48	6.83	14.89	19.06	11.56	85.83
51	AAUC-2	280.55	11.67	15.60	20.59	19.42	69.50
52	Poinsette	287.00	10.35	15.31	18.49	17.06	72.75
53	Swarna Agethi	291.10	11.45	16.56	20.29	20.24	79.25
	Mean	**323.22**	**10.88**	**16.15**	**19.92**	**19.42**	**61.15**
	Minimum	**178.48**	**6.49**	**12.85**	**14.94**	**9.23**	**18.50**
	Maximum	**480.75**	**13.29**	**18.94**	**23.96**	**28.65**	**89.17**
	CD (Ci - Vi)	81.749	2.239	2.156	3.621	6.339	25.74

VL-Vine length; NPB-Number of primary branches; LMLFFN-Length of mature leaf at first flowering node; WMLFFN-Width of mature leaf at first flowering node; PL-Petiole length; PDI-Per cent disease index

4.1.1.2.2. Floral characters

4.1.1.2.2.1. Days to first male flower opening

Male flowering initiated from 20.89 days (IC613477) to 50.56 days (IC202058A) with an overall mean value of 35.95 days (Table 10). 93

Table 10. Floral characters in 53 cucumber accessions

Accessions	DMFO	DFFO	DFMF	DFFF	NMFP	NFFP	MFD (cm)	FFD (cm)	NFFA	SR
IC613457	39.76	43.92	44.58	52.79	214.36	8.62	4.21	4.17	4.31	0.06
IC595504	34.76	41.92	35.58	47.79	388.36	18.02	4.03	4.25	2.31	0.07
IC613458	31.16	41.13	41.58	55.79	361.16	14.42	3.83	4.25	4.11	0.06
IC595505	29.76	34.13	36.58	41.79	364.76	16.42	3.37	3.75	2.51	0.07
IC613459	34.76	35.13	40.58	50.79	213.96	14.22	2.75	2.97	1.91	0.08
IC612081	45.16	54.52	46.58	64.79	125.16	4.02	3.19	3.19	2.91	0.05
IC613461	46.16	51.52	48.58	60.79	154.56	8.02	3.97	4.57	2.91	0.07
IC613462	39.09	47.19	42.58	51.13	278.56	12.28	4.33	4.13	1.98	0.07
IC612082	41.69	46.79	48.58	54.13	169.56	8.68	3.67	3.73	1.78	0.08
IC613465	43.49	45.79	48.58	54.13	95.16	2.88	3.93	3.55	1.58	0.06
IC613466	38.69	51.19	46.58	56.13	229.76	5.08	4.39	4.83	2.17	0.06
IC613467	34.09	44.19	41.58	53.13	304.16	7.08	4.07	4.11	1.38	0.06
IC613488	42.09	52.19	44.58	59.13	284.36	8.08	4.31	4.11	3.38	0.06
IC595508A	39.29	43.13	46.92	56.79	252.96	13.62	3.51	3.34	2.58	0.08
IC613460	41.49	49.32	46.92	54.79	176.36	7.22	3.57	3.34	2.17	0.06
IC595510	39.49	41.92	44.92	46.79	299.16	13.02	4.09	4.22	2.78	0.07
IC618083	26.89	31.32	35.92	39.79	388.76	17.22	3.97	3.02	0.78	0.07
IC595512	31.29	40.92	37.92	47.79	313.96	13.02	3.81	3.72	2.58	0.07
IC595514	35.29	40.52	44.92	46.79	382.56	15.22	4.21	4.18	2.17	0.07
IC595515	43.69	45.52	47.92	52.79	281.96	17.02	3.49	4.00	1.78	0.09
IC595517	37.22	55.13	40.58	60.79	383.29	6.55	4.12	4.29	3.24	0.02
IC613471	28.82	45.72	33.58	54.79	295.29	4.40	3.28	3.39	4.04	0.03
IC613472	32.62	43.13	40.58	62.79	419.29	9.35	4.00	3.43	4.04	0.04
IC613473	39.62	51.93	43.58	59.79	299.09	5.70	4.24	3.27	1.64	0.03
SKYAC-239	30.23	48.53	35.58	51.79	425.89	8.55	4.48	4.09	3.24	0.03
IC613475	25.63	43.93	27.58	47.79	503.69	13.35	4.08	3.67	3.04	0.04
IC613476	31.09	41.19	38.25	51.46	520.56	20.88	4.40	4.69	1.78	0.06
IC613477	20.89	32.59	28.25	41.46	522.76	17.88	4.34	3.43	4.77	0.05

DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

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Table 10. Floral characters in 53 cucumber accessions

Accessions	DMFO	DFFO	DFMF	DFFF	NMFP	NFFP	MFD (cm)	FFD (cm)	NFFA	SR
IC613478	29.29	36.79	35.25	42.46	480.56	19.28	4.40	4.21	2.38	0.06
IC613479	24.09	31.19	33.25	39.46	486.16	16.08	3.82	4.21	1.97	0.05
IC613480	28.69	35.99	37.25	49.46	526.56	19.28	3.80	4.23	1.78	0.06
IC613481	28.49	36.79	35.25	43.46	606.56	21.48	4.08	4.27	2.17	0.05
IC613482	30.89	36.39	40.25	46.46	226.96	13.28	4.40	4.33	4.38	0.09
IC613483	40.89	44.26	41.25	44.79	405.16	14.42	3.66	3.84	2.37	0.06
IC613484	32.09	34.86	35.25	44.79	450.96	21.62	4.18	4.18	1.98	0.07
IC613485	39.29	41.46	40.25	44.79	388.96	13.42	4.00	4.00	1.38	0.06
IC613474	31.49	33.66	33.25	37.79	224.76	21.22	3.64	3.86	1.38	0.12
IC595518	48.89	54.46	49.25	65.79	202.96	9.02	3.62	4.00	2.57	0.07
IC618084A	40.19	46.46	40.25	47.79	300.16	13.02	3.44	3.68	1.77	0.07
IC331445	44.49	54.06	48.25	60.79	311.96	7.22	3.76	3.86	2.57	0.05
IC331627	35.89	36.53	43.58	49.46	236.76	5.55	3.46	3.00	2.04	0.05
IC277048	27.69	32.73	31.58	34.46	231.63	27.35	3.72	3.74	2.24	0.15
IC331619	35.09	36.13	37.58	38.46	183.63	14.55	3.40	2.80	1.64	0.11
IC541367	43.69	49.33	49.58	59.46	339.02	6.75	4.02	4.24	3.84	0.05
IC541391	33.09	40.93	37.58	46.46	262.42	5.75	3.62	3.74	1.64	0.05
IC469517	45.16	55.46	52.25	55.79	375.69	9.68	4.01	4.06	2.31	0.05
IC539818	36.16	48.06	50.25	62.79	424.89	19.28	3.93	4.06	2.11	0.07
IC277030	37.56	47.26	55.25	59.79	331.29	20.68	4.61	4.34	2.31	0.09
IC613470	35.76	34.06	40.25	41.79	460.89	19.28	4.55	4.80	5.71	0.07
IC202058A	50.56	53.06	53.25	56.79	132.89	9.28	3.71	3.58	2.11	0.09
AAUC-2	35.95	38.10	39.75	45.63	277.67	18.10	4.04	4.26	2.00	0.13
Poinsette	33.20	38.58	39.88	45.63	298.80	13.90	4.02	4.29	1.80	0.05
Swarna Agethi	32.72	40.30	39.13	45.13	355.80	13.05	4.26	4.04	2.33	0.04
Mean	**35.95**	**43.04**	**41.49**	**50.72**	**324.01**	**12.89**	**3.92**	**3.91**	**2.50**	**0.06**
Lowest	**20.89**	**31.19**	**27.58**	**34.46**	**95.16**	**2.88**	**2.75**	**2.80**	**0.78**	**0.02**
Highest	**50.56**	**55.46**	**55.25**	**65.79**	**606.56**	**27.35**	**4.61**	**4.83**	**5.71**	**0.15**
CD (Ci - Vi)	15.30	16.09	19.30	20.81	251.60	7.00	0.62	1.13	1.36	0.04

DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

Swarna Agethi, the check variety recorded lowest value for days to first male flowering (32.72 days).while AAUC-2 took 35.95 days for its first male flower to develop.

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4.1.1.2.2.2. Days to first female flower opening

Female flower opening started at 31.19 days after sowing in IC613479 and 55.46 days in IC613473. The overall mean for the character across accessions was 43.29 days after sowing. Among check varieties, AAUC-2 produced female flowers on 38.10 days after sowing, followed by Poinsette (38.58 days).

4.1.1.2.2.3. Days to 50 per cent male flowering

IC613475 recorded the least value (27.58 days) for days to 50 per cent flowering. Highest value of 55.25 days after sowing was recorded for IC277030. The overall mean for the character was 41.49 days after sowing. Least value for the character among check varieties was exhibited by Swarna Agethi (39.13 days).

4.1.1.2.2.4. Days to 50 per cent female flowering

IC277048 took only 34.46 days to attaining 50 per cent female flowering whereas the highest value for this character was observed for IC595518 (65.79 days). The accessions exhibited a mean value of 50.72 days. Swarna Agethi (45.13 days) exhibited least value for the character among check varieties.

4.1.1.2.2.5. Number of male flowers per plant

The values for the number of male flowers per plant ranged between 95.16 (IC613465) to 606.56 (IC613481) with an overall mean of 324.01.

4.1.1.2.2.6. Number of female flowers per plant

Lowest value for number of female flowers was recorded for IC613465 (2.88) whereas highest number of female flowers (27.35) recorded for IC277048. The mean value across accessions was 12.89. Among the check varieties, AAUC-2 produced 18.10 female flowers followed by 13.90 in Poinsette.

4.1.1.2.2.7. Male flower diameter

Diameter of male flower ranged from 2.75 cm in IC613459 to 4.61 cm in IC277030 with an overall mean of 3.92 cm. Among the check varieties, Swarna Agethi recorded highest mean leaf width (4.26 cm) followed by AAUC-2 (4.04 cm).

4.1.1.2.2.8. Female flower diameter

Maximum female flower diameter was recorded for IC613466 (4.83 cm) and minimum for IC331619 (2.80 cm) with overall mean of 3.91 cm.

4.1.1.2.2.9. Node number at which first female flower appeared

IC618083 recorded lowest value for node number at which first female flower appeared (0.78). The overall mean across the accessions were 2.50, while IC613470 has recorded highest value of 5.71 for the character. Among the check varieties, Poinsette performed better with a mean value of 1.80 than both AAUC-2 (2.00) and Swarna Agethi (2.33). Eleven accessions recorded lower value than the check variety Poinsette.

4.1.1.2.2.10. Sex ratio

Sex ratio ranged from 0.02 (IC595517) to 0.15 (IC277048) with a mean value of 0.06. Highest value for sex ratio was exhibited by AAUC-2 (0.13) among check variety followed by Poinsette (0.05).

4.1.1.2.3. Fruit characters

The statistically corrected mean values for fruit characters have been illustrated in Table 11.

4.1.1.2.3.1. Days to first harvest

The mean value for days to first harvest was 50.34 days among the accessions studied.

Table 11. Fruit characters in 53 cucumber accessions

Accessions	DFH	DLH	FL (cm)	FD (cm)	NFPP	FW (g)	SCL (cm)	SCB (cm)	PC (cm)	EC (cm)	FT (cm)	YPP (g)	HD	TSS (°Brix)	LWDS (g)	NDS	PedL (cm)
IC613457	48.21	80.88	15.55	5.24	3.00	268.04	12.55	3.10	15.52	16.67	1.37	841.96	32.67	2.99	19.04	6.39	2.49
IC595504	50.21	84.88	16.15	4.65	5.20	236.04	12.97	3.20	14.88	16.15	1.13	1218.36	34.67	2.72	19.04	6.19	3.91
IC613458	47.21	82.88	19.59	5.09	5.00	303.04	16.45	3.54	13.04	17.89	1.21	1612.96	45.67	2.72	16.04	5.99	5.07
IC595505	37.21	84.88	15.51	5.36	5.60	259.04	12.45	3.36	15.62	17.49	1.23	1479.16	47.67	3.29	12.04	5.79	2.25
IC613459	37.21	73.88	10.65	5.12	3.60	180.04	8.31	3.60	15.58	17.39	0.99	546.36	36.67	2.95	12.04	6.19	2.12
IC612081	59.21	80.88	13.31	4.96	1.60	210.04	10.37	3.82	14.98	16.59	1.17	278.36	21.67	2.37	20.04	5.99	4.23
IC613461	59.21	79.88	14.55	4.94	3.00	256.04	11.87	3.30	14.54	17.13	1.01	786.76	30.67	2.72	9.04	4.19	4.09
IC613462	56.21	71.21	15.25	5.71	4.33	281.38	12.87	3.39	14.49	18.62	1.25	1284.16	15.00	2.43	19.71	6.06	3.03
IC612082	53.21	69.21	12.65	5.85	2.13	234.38	10.29	3.89	15.45	18.48	1.15	603.76	16.00	2.73	11.71	4.26	2.57
IC613465	56.21	69.21	15.45	5.59	2.33	274.38	12.94	3.79	15.48	17.06	1.21	1000.96	13.00	2.60	18.71	5.86	3.07
IC613466	60.21	81.21	18.25	5.09	2.13	273.38	15.87	3.29	15.33	16.00	1.09	697.36	21.00	2.16	20.71	5.46	2.83
IC613467	45.21	73.21	14.81	5.87	2.13	283.38	12.39	4.17	16.45	18.96	1.11	721.36	28.00	2.30	16.71	6.06	1.83
IC613488	61.21	76.21	15.05	5.81	3.93	292.38	12.23	4.11	16.51	18.22	1.01	1227.16	15.00	3.10	13.71	6.21	2.41
IC595508A	52.88	76.54	11.25	5.11	6.00	176.38	9.91	3.69	13.10	16.38	0.83	1130.96	33.67	3.42	11.71	4.39	2.57
IC613460	60.88	81.54	13.75	4.73	4.40	234.38	12.07	3.39	13.78	16.90	1.07	1030.56	30.67	4.25	9.71	4.79	3.43
IC595510	39.88	76.54	18.99	4.51	6.40	282.38	17.15	3.07	12.78	15.56	0.81	1777.76	36.67	4.28	16.71	5.59	3.59
IC618083	38.88	66.54	15.37	5.73	6.40	265.38	13.01	3.35	16.60	19.18	1.39	1685.96	37.67	4.18	14.71	5.19	2.89
IC595512	48.88	74.54	11.66	4.79	5.60	168.38	9.17	3.25	13.64	16.08	1.17	1019.76	35.67	3.92	20.71	5.79	3.83
IC595514	45.88	81.54	15.23	4.35	5.60	163.38	12.07	2.67	11.58	13.50	1.19	996.76	45.67	3.68	17.71	4.79	3.34
IC595515	55.88	84.54	11.65	6.31	6.80	273.38	9.57	4.37	13.28	19.14	1.29	1842.36	28.67	3.92	13.71	5.99	3.53

DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm); EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP- Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (° Brix); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

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Table 11. Fruit characters in 53 cucumber accessions

Accessions	DFH	DLH	FL (cm)	FD (cm)	NFPP	FW (g)	SCL (cm)	SCB (cm)	PC (cm)	EC (cm)	FT (cm)	YPP (g)	HD	TSS (°Brix)	LWDS (g)	NDS	PedL (cm)
IC595517	63.21	94.21	16.67	3.85	5.13	176.04	13.57	2.48	14.02	14.06	0.94	907.49	41.00	3.89	16.38	5.66	3.14
IC613471	52.21	84.21	17.01	6.15	3.53	304.04	13.87	3.42	15.94	17.36	1.22	1417.09	32.00	4.56	15.38	6.06	1.98
IC613472	53.21	89.21	20.85	5.95	4.33	343.04	18.17	3.76	17.60	17.88	1.02	1536.69	36.00	3.06	15.38	4.86	2.84
IC613473	59.21	86.21	18.47	4.75	5.33	282.04	17.09	3.26	15.24	14.92	1.04	1506.29	27.00	3.53	20.38	5.46	2.96
SKYAC-239	55.21	86.21	19.79	5.09	6.73	316.04	17.27	3.44	15.18	18.30	0.98	2070.69	31.00	3.59	19.38	6.66	2.94
IC613475	49.21	85.21	16.97	4.25	8.73	223.04	14.47	2.88	13.62	14.06	0.96	1796.29	36.00	2.99	12.38	4.66	1.34
IC613476	49.88	79.21	15.37	4.39	7.93	191.71	13.70	2.72	13.24	13.39	1.34	1574.89	39.33	2.48	12.71	4.99	2.15
IC613477	41.88	72.21	15.25	4.83	9.93	219.71	13.04	2.84	13.38	15.41	1.06	2205.29	40.33	3.44	9.71	5.39	2.69
IC613478	39.88	79.21	14.45	4.07	7.93	191.71	13.10	3.08	11.78	14.15	0.82	1574.89	39.33	2.41	9.71	4.99	1.21
IC613479	39.88	72.21	18.27	4.75	7.93	269.71	15.68	2.82	13.38	15.01	1.00	2105.29	42.33	3.18	4.71	3.99	2.67
IC613480	41.88	78.21	15.29	4.47	9.53	159.71	12.76	3.04	12.14	13.53	0.76	1613.29	36.33	2.18	13.71	4.59	2.07
IC613481	39.88	78.21	17.27	5.05	8.33	238.71	14.54	3.12	14.08	14.91	1.12	1990.09	38.33	2.81	8.71	4.79	1.77
IC613482	39.88	76.21	16.19	4.73	6.33	216.71	13.86	3.14	12.76	14.95	0.90	1397.69	36.33	3.01	13.71	5.19	3.11
IC613483	51.54	80.88	16.47	4.51	6.33	205.38	13.96	2.89	13.06	13.56	1.17	1278.03	29.33	2.02	16.04	4.66	4.32
IC613484	45.54	70.88	15.27	4.39	7.33	194.38	12.70	2.85	13.12	14.18	0.99	1419.63	35.33	2.42	12.04	4.46	4.54
IC613485	47.54	77.88	15.03	4.89	6.73	225.38	12.52	3.19	14.34	15.72	1.01	1503.23	34.33	2.26	10.04	4.66	3.74
IC613474	37.54	76.88	14.59	4.69	7.53	183.38	12.16	3.07	12.64	14.84	0.93	1378.43	39.33	1.72	14.04	4.26	1.82
IC595518	57.54	86.88	15.57	5.71	3.53	321.38	12.84	3.07	16.56	17.82	1.59	1071.23	29.33	2.99	17.04	4.46	4.30
IC618084A	54.54	90.88	16.63	4.97	4.13	238.38	14.08	3.23	13.30	15.70	1.11	926.02	36.33	2.62	12.04	3.66	3.38

DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm); EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP- Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (° Brix); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

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Table 11. Fruit characters in 53 cucumber accessions

Accessions	DFH	DLH	FL (cm)	FD (cm)	NFPP	FW (g)	SCL (cm)	SCB (cm)	PC (cm)	EC (cm)	FT (cm)	YPP (g)	HD	TSS (°Brix)	LWDS (g)	NDS	PedL (cm)
IC331445	64.54	87.88	17.19	4.81	2.33	218.38	13.40	2.49	13.66	14.60	1.19	417.23	23.33	2.29	14.04	4.06	3.94
IC331627	47.88	61.88	5.14	4.27	2.87	32.97	4.07	3.12	12.76	13.34	0.52	94.53	14.00	2.99	8.38	6.06	2.49
IC277048	40.88	61.88	5.86	5.33	11.47	73.38	4.67	4.48	15.68	15.82	0.48	1024.43	11.00	3.79	10.38	6.26	2.59
IC331619	51.88	61.88	7.28	4.59	7.47	81.38	5.81	3.56	15.18	15.64	0.72	642.83	10.00	4.12	9.38	6.26	2.27
IC541367	56.88	77.88	14.72	5.27	2.67	208.38	12.77	4.12	15.68	17.72	1.02	452.63	21.00	3.59	18.38	5.86	5.07
IC541391	55.88	74.88	16.46	4.11	1.87	174.38	14.09	2.62	12.88	12.96	1.02	181.02	19.00	2.99	19.38	5.26	3.57
IC469517	64.21	90.21	17.47	5.30	3.40	312.21	14.12	3.06	14.35	16.11	1.25	1045.89	26.00	3.60	19.04	4.79	4.06
IC539818	54.21	90.21	17.77	5.07	5.00	261.71	14.62	3.51	11.91	16.03	1.14	1303.49	36.00	2.70	15.04	4.19	3.72
IC277030	54.21	76.21	12.59	5.13	6.60	235.71	9.56	3.73	14.51	16.65	1.16	1556.29	22.00	3.36	14.04	6.59	2.68
IC613470	56.21	89.21	12.67	4.71	6.40	198.71	9.72	3.19	14.31	15.41	1.08	1279.69	33.00	3.13	11.04	4.19	3.90
IC202058A	59.21	73.21	8.77	5.11	3.00	147.71	6.50	3.65	12.55	15.41	0.84	460.29	14.00	2.90	9.04	5.39	3.28
AAUC-2	38.38	75.75	17.15	4.80	6.35	241.25	14.24	2.93	13.77	15.48	1.08	1520.80	37.38	2.68	15.38	5.45	3.08
Poinsette	43.00	75.63	15.92	5.02	4.78	241.63	13.14	3.04	14.32	16.17	1.12	1152.22	32.63	2.58	14.88	5.13	2.38
Swarna Agethi	45.25	75.25	16.60	4.63	4.67	211.25	14.04	2.92	13.32	14.71	1.04	985.85	30.00	3.56	14.88	5.00	3.12
Mean	**50.34**	**78.62**	**15.01**	**4.99**	**5.35**	**227.45**	**12.54**	**3.30**	**14.21**	**15.94**	**1.06**	**1189.03**	**30.47**	**3.06**	**14.34**	**5.27**	**3.06**
Lowest	**37.21**	**61.88**	**5.14**	**3.85**	**1.60**	**32.97**	**4.07**	**2.48**	**11.58**	**11.56**	**0.48**	**94.53**	**10.00**	**1.72**	**4.71**	**3.66**	**1.21**
Highest	**64.54**	**94.21**	**20.85**	**6.31**	**11.47**	**343.04**	**18.17**	**4.48**	**17.60**	**19.18**	**1.59**	**2205.29**	**47.67**	**4.56**	**20.71**	**6.66**	**5.07**
CD (Ci - Vi)	23.26	9.36	4.02	0.87	2.74	90.70	3.22	0.51	2.14	2.23	0.35	773.98	21.44	1.78	9.31	1.55	1.88

DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm); EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP- Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (° Brix); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

However, first harvest started by 37.21 days after sowing in IC595505 and was delayed up to 64.54 days in IC331445. AAUC-2 was the best performer among the controls with a value of 38.38 days (Table 11).

4.1.1.2.3.2. Days to last harvest

The last harvest was prolonged until 94.21 days in IC595517 and 61.88 days in IC331627, IC277048 and IC331619. The mean value for days to last harvest across the accessions was 78.62 days after sowing. Last harvest was extended up to 75 days in all the check varieties with an insignificant difference among the checks.

4.1.1.2.3.3. Fruit length

The mean value for fruit length across accessions was 15.01 cm, ranging from 5.14 cm in IC331627 to 20.85 cm in IC613472, respectively (Plate 11). AAUC-2 (17.15 cm) recorded the highest value for fruit length among check varieties.

4.1.1.2.3.4. Fruit diameter

Fruit diameter among the accessions ranged from 3.85 cm (IC595517) to 6.31 cm (IC595515) (Plate 12). The overall mean was 4.99 cm. The highest value for fruit diameter was recorded for Poinsette (5.02 cm) among check varieties while Swarna Agethi recorded least value of 4.63 cm.

4.1.1.2.3.5. Number of fruits per plant

IC277048 and IC612081 recorded highest and lowest values for number of fruits per plant (11.47 and 1.60 respectively).

The mean value across accessions was 5.35 fruits per plant. AAUC-2 recorded the maximum number of fruits with a value of 6.35 followed by Poinsette (4.78).

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IC331627 **IC613472**

Plate 11. Accessions with minimum and maximum values for fruit length and weight

IC595515 **IC595517**

Plate 12. Accessions with maximum and minimum values for fruit diameter

4.1.1.2.3.6. Fruit weight

Fruit weight recorded for single fruit ranged from 32.97 g (IC331627) to 343.04 g (IC613472) with an overall mean of 227.45 g. Poinsette (241.63 g) recorded the highest value for the single fruit weight among checks.

4.1.1.2.3.7. Seed cavity length

The highest value for seed cavity length was recorded for IC613472 (18.17 cm) whereas minimum value for IC331627 (4.07 cm). The overall mean among accessions was 12.54 cm.

4.1.1.2.3.8. Seed cavity breadth

IC277048 and IC595517 recorded the highest and lowest values for seed cavity breadth (4.48 cm and 2.48 cm respectively) with a mean value across accessions being 3.30 cm. The best check variety for this character was Poinsette (3.04 cm)

4.1.1.2.3.9. Polar circumference

The range of polar circumference of the tender fruits recorded was 11.58 cm to 17.60 cm in IC595514 and IC613472 respectively, with an overall mean of 14.21 cm.

4.1.1.2.3.10. Equatorial circumference

The equatorial circumference ranged from 11.56 cm (IC613483) to 19.18 cm (IC618083) with an overall mean of 15.94 cm.

4.1.1.2.3.11. Flesh thickness

The value for flesh thickness ranged from 0.48 cm (IC277048) to 1.56 cm (IC595518) with a mean value of 1.06 cm. AAUC-2 recorded the maximum value of 1.12 cm among check varieties for the character.

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4.1.1.2.3.12. Yield per plant

Highest yield per plant was observed in IC613477 (2205.29 g) and lowest in IC331627 (94.53 g) with an overall mean of 1189.03 g. Among the control varieties, AAUC-2 exhibited the highest yield per plant (1520.80 g).

4.1.1.2.3.13. Harvest duration

The period of harvest ranged from 10.00 days (IC331619) to 47.67 (IC595505) days with a mean value of 30.47 days for accessions studied. The best performing check variety was AAUC-2 with a period of 37.38 days.

4.1.1.2.3.14. Total Soluble Solids (TSS)

Total soluble solids (TSS) was maximum in IC613471 (4.56 ^{o}Brix) and minimum in IC613474 (1.72 ^{o} Brix). The overall mean across the accessions was 3.06 ^{o} Brix.

4.1.1.2.3.15. Loss in weight during storage

Weight loss during storage was recorded maximum in IC613466 (20.71 g) whereas minimum in IC613479 (4.71 g) with a mean value of 14.34 g across accessions. Both Poinsette and Swarna Agethi recorded a weight loss of 14.88 g compared to AAUC-2 (15.38 g).

4.1.1.2.3.16. Number of days of storage

The appearance of the fruit was not mutilated until 6.66 days of storage in SKYAC-239 whereas IC618084 recorded the least value for the days of storage (3.66 days).

4.1.1.2.3.17. Peduncle length

Highest value for peduncle length (5.07 cm) was recorded for IC541367 and IC613458, whereas lowest value (1.21 cm) for IC613478. The mean value across accessions was 3.06.

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4.1.1.2.4. General incidence of pests and diseases

The diseases and pests observed were downy mildew (*Pseudoperonospora cubensis*), cucumber mosaic virus, aphids (*Aphis gossipii*), Red melon beetle (*Aulacophora africana)*, leaf miner (*Liriomyza trifoli*) and powdery mildew (*Sphaerotheca fuliginea*) (Plate 13).

4.1.1.2.4.1. Per cent Disease Index (PDI) of downy mildew

The incidence of downy mildew was maximum observed in IC612082 (89.17%) and minimum in IC595518 (18.50 %).The mean value observed for accessions was 61.16 per cent. Among control varieties, the lowest value for downy mildew incidence was recorded for AAUC-2 (69.50 per cent) (Table 9).

4.1.1.3. Analysis of variance

4.1.1.3.1. Shoot characters

The results of analysis of variance for shoot characters indicated that the mean sum of squares due to genotypes were significant at 5 per cent level for vine length, number of primary branches and PDI scored for downy mildew incidence (Table 12).

4.1.1.3.2. Floral characters

Among the floral characters studied, number of female flowers per plant and node number at which first female flower appeared showed significance at 1 per cent level whereas diameter of male flower and sex ratio showed significant difference at 5 per cent level (Table 13).

4.1.1.3.3. Fruit characters

The results on analysis of variance of fruit characters indicated that the mean sum of squares due to genotypes were significant at 5 per cent level for six characters (Table 14).

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Ahids (*Aphis gossipii*)

Leaf miner (*Liriomyza trifoli*)

Red melon beetle
(*Aulacophora africana*)

Powdery mildew disease
(*Sphaerotheca fuliginea*)

Downy mildew disease
(*Pseudoperonospora cubensis*)

Cucumber mosaic virus

Plate 13. General incidence of pests and diseases observed

Table 12. Analysis of variance for shoot characters in 53 cucumber accessions

Source	Df	VL (cm)	NPB	LMLFN (cm)	WMLFN (cm)	PL (cm)	PDI (%)
Block (ignoring Treatments)	7.00	11294.84**	1.25	2.43	2.60	21.97	356.13*
Treatment (eliminating Blocks)	52.00	4590.29	2.03*	1.67	3.41	13.94	238.71*
Genotypes	49.00	**5861.77***	**1.98***	1.80	2.87	15.18	**226.94***
Checks	2.00	226.26	4.02*	3.40	10.30	21.76	197.17
Checks vs. Genotypes	1.00	23965.78**	1.86	1.54	0.00	2.20	2754.61**
Error	14.00	2398.42	0.73	1.54	4.67	13.44	96.02

*- significant at 5% level; **- significant at 1% level; Df-Degrees of freedom; VL-Vine length (cm); NPB-Number of primary branches; LMLFN-Length of mature leaf at 1st flowering node (cm); WMLFN-Width of mature leaf at 1st flowering node (cm); PL-Petiole length (cm); PDI-Percent disease index (%)

Table 13. Analysis of variance for floral characters in 53 cucumber accessions

Source	Df	DMFO	DFFO	DFMF	DFFF	NMFP	NFFP	MFD (cm)	FFD (cm)	NFFA	SR
Block (ignoring Treatments)	7.00	54.35	125.99*	58.96	172.11	9473.57	36.45**	0.17*	0.22	0.51	0.01
Treatment (eliminating Blocks)	52.00	37.78	48.64	35.79	63.30	9882.32	28.48**	0.13*	0.21	0.90**	0.00
Genotypes	49.00	41.35	48.33	39.59	66.74	9904.63	**24.58****	**0.13***	0.21	**0.88****	0.00*
Checks	2.00	24.25	10.72	1.29	0.67	13065.04	58.49**	0.14	0.15	0.56	0.02
Checks vs. Genotypes	1.00	80.04	436.52**	65.95	418.76*	3447.31	90.75**	0.61**	1.44*	3.90**	0.02
ERROR	14.00	33.92	37.50	54.01	62.76	9174.26	7.11	0.06	0.18	0.27	0.02

*- significant at 5% level; **- significant at 1% level; Df-Degrees of freedom; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFFA-Node number at which 1st female flower appeared; SR-Sex ratio

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Table 14. Analysis of variance for fruit characters in 53 cucumber accessions

Source	Df	DFH	DLH	FL (cm)	FD (cm)	NFPP	FW (g)	SCL (cm)	SCB (cm)	PC (cm)
Block (ignoring Treatments)	7.00	84.52	56.07**	6.27	0.18	4.94**	2436.03	5.26*	0.08	2.61*
Treatment (eliminating Blocks)	52.00	71.86	39.87*	8.48**	0.26*	3.79**	2785.85*	7.10**	0.20**	1.56*
Genotypes	49.00	60.35	**35.55***	**8.39****	**0.27***	**4.12****	**2935.19***	**7.12****	**0.17****	**1.74***
Checks	2.00	98.29	0.54	3.03	0.30	7.06*	2430.38	2.72	0.03	2.02
Checks vs. Genotypes	1.00	708.88**	153.67**	43.44**	0.57*	0.09	304.46	29.92**	2.21**	2.87
Error	14.00	78.43	12.68	2.34	0.11	1.08	1192.28	1.50	0.04	0.66

*- significant at 5% level; **- significant at 1% level; Df-Degrees of freedom; DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm)

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Table 14. Analysis of variance for fruit characters in 53 cucumber accessions

Source	Df	EC (cm)	FT (cm)	YPP (g)	HD	TSS (° Brix)	LWDS (g)	NDS	PedL (cm)
Block (ignoring Treatments)	7.00	4.31**	0.09**	283898.94*	58.59	0.19	19.55	0.38	0.83
Treatment (eliminating Blocks)	52.00	2.50**	0.03	191220.00	58.64	0.32	12.34	0.44	0.67
Genotypes	49.00	**2.83****	**0.04***	191829.55*	46.16	0.20	14.42*	0.46**	0.65
Checks	2.00	4.24*	0.01	599600.44**	111.79	2.31*	0.67	0.43	1.39
Checks vs. Genotypes	1.00	4.25*	0.01	20600.99	202.45	0.34	5.12	0.11	0.77
Error	14.00	0.72	0.02	86817.84	66.60	0.46	12.57	0.35	0.51

*- significant at 5% level; **- significant at 1% level; Df-Degrees of freedom; EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP-Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (° Brix); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

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They include days to last harvest, fruit diameter, fruit weight, polar circumference, flesh thickness yield per plant and loss of weight during storage. The characters namely, fruit length, number of fruits per plant, seed cavity length, seed cavity breadth, equatorial circumference and number of days of storage showed significant difference at 1 per cent level (Table 14).

4.1.1.4. Genetic parameters

4.1.1.4.1. Shoot characters

Among the shoot characters studied, PCV was greater than GCV for all the characters. High PCV was recorded for vine length (20.89 %) whereas moderate value of PCV was exhibited by number of primary branches (11.89 %), petiole length (18.54 %) and PDI (16.58 %). None of the shoot characters exhibited high GCV whereas moderate value was exhibited by vine length (18.57 %), petiole length (13.68 %) and PDI (10.57 %). Low PCV and GCV were recorded for length and breadth of mature leaf at first flowering node (Table 15). Broad sense heritability was high in vine length (78.95 %). Medium value of broad sense heritability was exhibited by number of primary branches (56.11 %), length (55.48 %) and width (27.44 %) of mature leaf at first flowering node, petiole length (54.40 %) and PDI (40.65 %). Width of mature leaf exhibited low value for broad sense heritability. Genetic gain, the genetic advance expressed as percentage of mean was high in vine length (43.55 %) and petiole length (26.63 %), whereas number of primary branches (17.62 %), length of mature leaf and PDI showed medium values. Width of the leaf (5.92 %) showed low value for genetic gain.

4.1.1.4.2. Floral characters

PCV was higher than GCV for all the floral characters studied. The values for PCV and GCV were high in number of male flowers per plant (27.86 % and 21.44 % respectively), number of female flowers per plant (34.30 % and 32.18 % respectively).

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Similarly the values for PCV and GCV were high in node number at which first female flower appeared (32.64 % and 29.48 % respectively) and sex ratio (40.93 % and 31.59 % respectively) (Table 15). Moderate values of PCV were exhibited by days to first male flower opening (15.93 %), days to first female flower opening (13.98 %), days to 50 per cent male flowering (14.29 %), days to 50 per cent female flowering (16.04 %) and diameter of female flower (10.63 %). Low value for PCV was recorded for diameter of male flower only. Days to first male flower opening and days to first female flower opening showed moderate values of GCV. However, days to 50 per cent male and female flowering showed low GCV as against moderate PCV exhibited by them. In addition, diameter of male and female flowers showed low GCV (7.14 % and 7.95 % respectively).

Broad sense heritability was high in days to first male and female flower opening (70.79 % and 76.77 %), number of female flowers per plant (87.98 %), diameter of male flower (74.22 %) and node number at which first female flower appeared (81.60 %). Days to 50% female flowering exhibited low broad sense heritability. Days to first male and female flower opening, number of male flowers per plant, number of female flowers per plant and node number at which first female flower appeared and sex ratio exhibited high genetic advance as per cent of mean *ie* genetic gain. Low genetic gain was expressed by days to 50 per cent female flowering (1.91 %). Medium values for genetic gain was exhibited by days to 50% male flowering (13.18 %) and male and female flower diameter (16.23 % and 15.67 % respectively) (Table 15).

4.1.1.4.3. Fruit characters

Among the fruit characters studied, number of fruits per plant (34.23 %), fruit weight (21.25 %), yield per plant (34.29 %), harvest duration (24.07 %), loss of weight during storage (22.95 %) and peduncle length (24.12 %) exhibited high PCV whereas days to last harvest (6.68 %), fruit diameter (9.23 %), polar and equatorial circumference (8.24 % and 9.47 % respectively) exhibited low values for PCV.

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Table 15. Genetic parameters of shoot and floral characters in 53 cucumber accessions

Characters	PCV (%)	GCV (%)	h^2 (Broad sense heritability) (%)	GA	GG (%)
Shoot characters					
VL (cm)	20.89	18.57	78.95	141.39	43.55
NPB	11.89	8.91	56.11	1.91	17.62
LMLFN (cm)	7.63	5.68	55.48	1.80	11.17
WMLFN (cm)	8.17	4.28	27.44	1.17	5.92
PL (cm)	18.54	13.68	54.40	5.13	26.63
PDI % (ASIN)	16.58	10.57	40.65	9.17	17.79
Floral characters					
DMFO	15.93	13.40	70.79	10.77	29.76
DFFO	13.98	12.25	76.77	12.52	28.34
DFMF	14.29	8.44	34.94	5.48	13.18
DFFF	16.04	3.40	4.50	0.96	1.91
NMFP	27.86	21.44	59.22	141.73	43.56
NFFP	34.30	32.18	87.98	10.08	79.68
MFD (cm)	8.28	7.14	74.22	0.64	16.23
FFD (cm)	10.63	7.95	55.82	0.61	15.67
NFFA	32.64	29.48	81.60	1.78	70.30
SR	40.93	31.59	59.57	0.03	64.37

PCV-Phenotypic coefficient of variation; GCV-Genotypic coefficient of variation; GA-Genetic advance; GG-Genetic gain
VL-Vine length (cm); NPB-Number of primary branches; LMLFN-Length of mature leaf at 1st flowering node (cm); WMLFN-Width of mature leaf at 1st flowering node (cm); PL-Petiole length (cm); PDI-Percent disease index (%)

DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFFA-Node number at which 1st female flower appeared; SR-Sex ratio

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Table 15. Genetic parameters of fruit characters in 53 cucumber accessions

Characters	PCV (%)	GCV (%)	h^2 (Broad sense heritability) (%)	Genetic advance	Genetic gain (%)
DFH	14.73	10.24	48.33	9.17	18.79
DLH	6.68	6.11	83.75	11.60	14.76
FL (cm)	16.97	16.06	89.57	5.98	40.12
FD (cm)	9.23	8.20	78.94	0.96	19.24
NFPP	34.23	28.13	67.54	3.26	61.04
FW (g)	21.25	18.42	75.19	95.76	42.17
SCL (cm)	18.68	17.84	91.23	5.60	44.98
SCB (cm)	10.77	10.12	88.42	0.84	25.13
PC (cm)	8.24	7.25	77.34	2.39	16.83
EC (cm)	9.47	7.83	68.43	2.73	17.10
FT (cm)	17.51	15.66	79.98	0.39	36.98
YPP (g)	34.29	23.58	47.31	395.64	33.41
HD	24.07	-13.07	-29.50	-5.59	-18.75
TSS (%)	16.76	14.19	-71.69	-0.98	-31.72
LWDS (g)	22.95	21.53	88.00	7.72	53.32
NDS	11.60	9.56	67.88	1.10	20.79
PedL (cm)	24.12	17.53	52.81	1.03	33.63

DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD-Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm); EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP- Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (%); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

Remaining all characters showed moderate PCV. High GCV was observed for number of fruits per plant (28.13 %), yield per plant (23.58 %) and loss of weight during storage (21.53 %). Among the remaining characters except days to last harvest (6.11 %), fruit diameter (8.20 %), polar and equatorial circumference

(7.25 % and 7.83 % respectively) and number of days of storage (11.60 %) showed moderate values for GCV. Broad sense heritability was high for all the characters except days to first harvest (48.33 %), yield per plant (47.31 %), Peduncle length (52.80 %), harvest duration (-29.50 %) and TSS (-71.69 %). However, genetic gain was high in fruit length (40.12 %) and number of fruits per plant (61.04 %), fruit weight (42.17 %), seed cavity length and breadth (44.98 % and 25.13 % respectively), flesh thickness (36.98 %), yield per plant (33.41 %), loss of weight during storage (53.32 %), number of days of storage (20.79 %) and peduncle length (33.63 %). All the remaining characters exhibited medium values for genetic gain (Table 15).

4.1.1.5. Correlation studies

Phenotypic as well as genotypic correlation coefficients were worked out for the characters namely, yield per plant, fruit weight, fruit length, fruit diameter, days to first harvest, number of fruits per plant and sex ratio (Table 16).

4.1.1.5.1. Genotypic correlation

Fruit length, days to first harvest and number of fruits per plant showed positive and significant correlation at one per cent (0.452, 0.810 and 0.764 respectively), whereas fruit weight (0.338) at 5 per cent level with yield per plant. Negative correlations were observed for fruit diameter (-0.182) and sex ratio (-0.052) with yield per plant. Fruit length (0.759) exhibited positive and significant correlations at 1 per cent level with fruit weight.

However, days to first harvest (-0.820), number of fruits per plant (-0.292) and sex ratio (-0.023) had negative correlation with fruit weight. Positive but non-significant correlation was showed for fruit diameter with sex ratio (0.003). Number of fruits per plant and sex ratio exhibited positive and significant correlation at one per cent level with days to first harvest (0.997 and 0.614 respectively).

Table 16. Phenotypic correlation coefficients (upper diagonal values) and genotypic correlation coefficients (lower diagonal values) for selected quantitative characters

Characters	YPP (g)	FW (g)	FL (cm)	FD (cm)	DFH	NFPP	SR
YPP (g)	1.000	0.420**	0.396**	0.127^{NS}	-0.387	0.725**	0.022^{NS}
FW (g)	**0.338***	1.000	0.742**	0.556**	0.07^{NS}	-0.258	-0.122
FL (cm)	**0.452****	0.759**	1.000	-0.011	-0.041	-0.137	-0.259
FD (cm)	**-0.182**	0.283*	-0.337	1.000	0.162^{NS}	-0.205	0.033^{NS}
DFH	**0.810****	-0.820	0.116^{NS}	-0.540	1.000	-0.409	-0.192
NFPP	**0.764****	-0.292	-0.100	-0.192	0.997**	1.000	0.162^{NS}
SR	**-0.052**	-0.023	-0.240	0.003^{NS}	0.614**	-0.004	1.000

Table value at 1 % significance (**) = .3613; 5% significance (*) = .27892; YPP- Yield per plant (g); FW-Fruit weight (g); FL-Fruit length (cm); FD-Fruit diameter (cm); DFH-Days to first harvest; NFPP-Number of fruits per plant; SR-Sex Ratio

Positive and significant correlation at 1% level

Positive but non-significant correlation

Positive and significant correlation at 5 percent level

Negative correlation

4.1.1.5.2. Phenotypic correlation

Positive and significant correlations were observed for fruit weight (0.420), fruit length (0.396) and number of fruits per plant (0.725) with yield per plant. The characters like fruit diameter (0.127) and sex ratio (0.022) exhibited positive but non-significant correlation with yield per plant. Negative correlation was exhibited by days to first harvest (-0.387). Fruit weight showed positive and significant correlation with fruit length (0.742) and fruit diameter (0.556).The characters namely, number of fruits per plant (-0.258) and sex ratio (-0.122) showed negative correlation whereas days to first harvest (0.07) showed positive but non-significant correlation with fruit weight.

Fruit length was negatively correlated with characters namely, fruit diameter (-0.011), days to first harvest (-0.041), number of fruits per plant (-0.137) and sex ratio (-0.259). Fruit diameter exhibited non-significant positive correlation with days to first harvest (0.162), and sex ratio (0.033) whereas negative correlation with number of fruits per plant (-0.205). Negative correlation of days to first harvest with number of fruits per plant (-0.409) and sex ratio (-0.192) was observed.

4.1.1.6. Cluster analysis

The accessions were subjected to multivariate analysis of clustering using the free online software Minitab accommodating all 33 quantitative characters were considered for cluster analysis. Accordingly, seven distinct clusters were formed based on complete linkage, squared Euclidean distance method with 80 per cent similarity among accessions.

4.1.1.6.1. Group constellation

The distribution pattern of 50 genotypes and 3 control varieties in different clusters are given in the Table 17. Cluster II and cluster III were the largest clusters consisting of 14 accessions each.

Table 17. Distribution of 53 cucumber accessions in various clusters

Cluster	Number of accessions in each cluster	Similarity (%)	Accessions and their respective state (parenthesis)
Cluster I	8	90.02	IC613457 (Mi), IC613462 (Mi), IC613459 (Mizo), IC595512 (T), IC595514 (T), IC595510 (T), IC613471 (ArP), IC469517 (Ka)
Cluster II	14	86.12	IC595504 (Mi), IC595505 (Mi), IC613475 (WB), IC613481 (WB), IC613458 (Mi), IC613472 (ArP), IC613488 (Mi), IC539818 (A&N), IC618083 (T), IC613479 (WB), IC613476 (WB), IC613484 (WB), IC613477 (WB), Swarna Agethi
Cluster III	14	87.92	IC612081 (Mi), IC612082 (Mi), IC595508A (T), IC613474 (N), IC541391 (A&N), IC613461 (Mi), IC595515 (T), IC613466 (Mi), IC277030 (Ma), AAUC-2, Poinsette, IC613465 (Mi), IC613460 (Mi), IC613482 (WB)
Cluster IV	11	84.69	IC613467 (WB), IC613483 (WB), SKYAC-239 (WB), IC613485 (WB), IC613473 (ArP), IC618084A (ArP), IC331445 (O), IC541367 (A&N), IC595517 (T), IC613478 (WB), IC613470 (T)
Cluster V	1	77.37	IC613480 (WB)
Cluster VI	1	67.7	IC595518 (Ke)
Cluster VII	4	85.32	IC331627 (U), IC277048 (Ma), IC331619 (HP), IC202058A (U)

A&N- Andaman &Nicobar Islands; ArP- Arunachal Pradesh; HP-Himachal Pradesh; Ka-Karnataka; Ke- Kerala; Ma-Maharashtra; Mi-Mizoram; N-Nagaland; O-Odisha; T-Tripura; U-Uttarakhand; WB-West Bengal

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Cluster II included IC595504, IC595505, IC613475, IC613481, IC613458, IC613472, IC613488, IC539818, IC618083, IC613479, IC613476, 613484, IC613477and Swarna Agethi (control variety). The genotypes in cluster III were IC612081, IC612082, IC595508A, IC613474, IC541391, IC613461, IC595515, IC613466, IC277030, AAUC-2, Poinsette, IC613465, IC613460 and IC613482. This was followed by cluster IV with 11 genotypes *viz.*, IC613467, IC613483, SKYAC/239, IC613485, IC613473, IC618084, IC331445, IC541367, IC595517, IC613478 and IC613470. Further cluster I with eight genotypes (IC613457, IC613462, IC613459, IC595512, IC595514, IC595510, IC613471and IC469517), cluster VII with four accessions (IC331627, IC277048, IC331619, IC202058A) and two mono-genotypic clusters *ie.*, cluster V (IC613480) and cluster VI (IC595518) were also observed. The accessions in cluster I shared a similarity of 90.02 % among the accessions whereas cluster II, III, IV and VII shared a similarity of 86.12, 87.92, 84.69 and 85.32 per cent respectively. IC613480 and IC 595518 were the outliers with minimum similarity of 77.37 and 67.70 per cent, respectively.

4.1.1.6.2. Mean inter and intra-cluster distances

The mean inter and intra-cluster values are presented in Table 18. Inter cluster distance was found to be greater than the intra cluster distance, which indicated wider genetic diversity among the genotypes. The intra cluster distance ranged from zero (cluster V and VI) to 77.48 (cluster I). The intra cluster values of cluster V and VI were zero, since these clusters were represented by single genotype. However, the inter cluster distances ranged from 79.61 to 388.84, the least distance recorded between cluster I and III and maximum was recorded between cluster V and VI. It was observed that cluster 1 had least distance with cluster III (79.61) and maximum distance with cluster VI (217.29). Cluster II exhibited wide diversity with cluster VII whereas least distance with cluster IV. Close proximity of cluster III was observed with cluster VII (138.52), but wider distance with cluster V.

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Table 18. Mean inter cluster (off-diagonal values) and intra cluster (diagonal values) distances estimated using 33 quantitative characters

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
Cluster I	**77.48**	128.08	79.61	137.26	182.87	217.29	194.74
Cluster II		**70.85**	206.52	108.10	164.21	271.17	302.60
Cluster III			**62.83**	195.96	231.25	213.88	138.52
Cluster IV				**73.03**	244.63	200.42	286.56
Cluster V					**0.00**	388.84	269.46
Cluster VI						**0.00**	317.01
Cluster VII							**70.22**

Cluster IV had maximum distance to cluster VII (286.56) and minimum distance with cluster VI. The nearest and farthest clusters for cluster V was cluster VII (269.46) and cluster VI (388.84) respectively.

4.1.1.6.3. Mean cluster values

The character wise mean values of clusters with respect to shoot, floral and fruit characters were estimated.

4.1.1.6.3.1. Shoot characters

Cluster VI and clusterV recorded maximum and minimum mean values with respect to vine length with values of 446.40 cm and 200.20 cm, respectively (Table 19). Mean value for number of primary branches was highest in cluster II (11.54) and lowest in cluster VII (9.70). Length of mature leaf ranged from 14.60cm in cluster VII to 16.75 cm in cluster I. Cluster VII and VI exhibited minimum and maximum mean values with respect to width of mature leaf. Petiole length recorded highest in cluster I (70.50 cm) and lowest in cluster VI (28.00 cm).

4.1.1.6.3.2. Floral characters

Highest values for mean days to both male and female flower opening were recorded in cluster VI (47.40 and 55.00 days), whereas lowest values were

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observed in cluster II (30.37 and 38.55 days) (Table 19). Days to 50 per cent male and female flowering was maximum in cluster VI (51 and 67 days) and minimum in cluster II (36.30 and 46.43 days). Cluster VI and cluster VII recorded maximum and minimum values for number of male flowers per plant (444.40 and 182.68 respectively). Highest mean value for number of female flowers per plant was observed in cluster II (16.26) whereas lowest value in cluster VI (7.60).

Table 19. Character wise mean values of clusters for shoot and floral characters in 53 cucumber accessions

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
shoot characters							
VL (cm)	293.90	339.22	270.38	420.06	200.20	446.40	231.55
NPB	10.83	11.54	10.09	11.44	10.20	10.60	9.70
LMLFN (cm)	16.75	16.12	15.97	16.30	15.68	16.40	14.60
WMLFN (cm)	20.42	20.21	19.42	19.36	20.40	21.56	18.65
PL (cm)	20.57	19.72	17.58	21.39	18.60	20.56	14.04
PDI (%)	70.50	54.09	67.59	61.82	42.00	28.00	61.00
Floral characters							
DMFO	36.15	30.37	38.28	37.71	32.20	47.40	40.40
DFFO	43.90	38.55	45.71	46.04	41.60	55.00	46.50
DFMF	41.88	36.30	44.26	42.64	39.00	51.00	43.00
DFFF	48.88	46.43	53.23	50.64	49.00	67.00	49.50
NMFP	313.05	430.86	238.05	363.96	444.40	205.40	182.68
NFFP	11.10	16.26	10.91	12.25	15.60	7.60	13.00
MFD (cm)	3.77	4.02	3.82	4.16	3.76	3.90	3.64
FFD (cm)	3.92	3.95	3.92	4.12	4.00	4.12	3.19
NFFA	2.90	2.49	2.37	2.67	1.20	2.80	1.95
SR	0.04	0.04	0.05	0.03	0.04	0.04	0.07

VL-Vine length (cm); NPB-Number of primary branches; LMLFN-Length of mature leaf at 1st flowering node (cm); WMLFN-Width of mature leaf at 1st flowering node (cm); PL-Petiole length (cm); PDI-Percent disease index (%); DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

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Table 19. Character wise mean values of clusters for fruit characters in 53 cucumber accessions

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
Fruit characters							
DFH	47.75	42.94	50.88	51.00	48.00	58.00	50.25
DLH	77.75	77.03	77.88	83.27	78.00	88.00	71.00
FL (cm)	15.34	16.52	14.75	15.71	14.78	16.04	7.80
FD (cm)	5.14	4.97	5.06	4.78	4.54	5.76	4.97
NFPP	4.60	6.44	4.50	5.06	8.40	3.60	6.40
FW (g)	240.69	244.89	231.71	227.00	160.00	339.00	112.15
SCL (cm)	12.55	13.92	12.27	13.29	12.30	13.32	6.15
SCB (cm)	3.15	3.23	3.41	3.28	3.22	3.28	3.67
PC (cm)	14.45	14.16	14.19	14.03	12.00	16.50	14.30
EC (cm)	16.28	15.90	16.29	15.35	13.98	18.14	15.66
FT (cm)	1.18	1.13	1.09	1.02	0.72	1.50	0.65
YPP (g)	1116.22	1581.51	1039.82	1148.87	1613.29	1071.23	555.52
HD	30.00	33.86	27.00	32.27	30.00	30.00	20.75
TSS (° Brix)	3.46	3.09	2.93	2.98	2.17	3.50	3.10
LWDS (g)	17.50	13.91	14.88	14.82	17.00	18.00	7.25
NDS	5.55	5.13	5.10	5.26	4.80	5.00	6.00
PedL (cm)	3.08	3.09	2.98	3.33	2.46	3.66	2.34

DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm); EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP- Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (%); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

Cluster IV exhibited maximum mean male and female flower diameter whereas cluster VII exhibited minimum value. Node number at which first female flower appeared was highest in cluster I (2.90) as against the lowest in cluster V. Highest sex ratio was observed for cluster VII (0.07) and lowest in cluster IV (0.03).

4.1.1.6.3.3. Fruit characters

Cluster VI exhibited highest mean values with respect to days to first and last harvest (58.00 and 88.00 respectively). Lowest values for days to first and last harvest were expressed by cluster II and cluster VII, respectively. The mean fruit length and diameter were highest in cluster II (16.52 cm) and cluster VI (5.76 cm) respectively. Highest and lowest mean values for number of fruits per plant were observed in cluster V (8.40) and cluster VI (3.60). The mean values for fruit weight ranged from 112.15 g (cluster VII) to 339.00 g (cluster VI). Seed cavity length and breadth were highest in cluster II and cluster I, respectively. Cluster VI exhibited maximum value with respect to both polar and equatorial circumference (16.50 cm and 18.14 cm respectively) whereas minimum values were exhibited by cluster V (12.00 cm and 13.98 cm). Mean value for flesh thickness was highest in cluster VI (1.50 cm) and lowest in cluster VII. The range of values with regard to yield per plant was 555.52 g in cluster VII to 1613.29 g in cluster V.

The mean values of harvest duration ranged from 20.75 days to 33.86 days in cluster VII and II, respectively. Cluster VI exhibited highest value for mean TSS whereas cluster V lowest value. Loss of weight during storage was maximum exhibited by cluster VI followed by cluster I. Cluster VII recorded highest value for number of days of storage as against cluster V, which recorded lowest value for the character. Maximum peduncle length was exhibited by cluster VI, and minimum by cluster VII.

4.1.1.7. Principal Component Analysis (PCA)

Principal component analysis was carried out using eight yield contributing characters to transform the interdependent variables into a set of independent variables (Hottling, 1933; Mardia, 1971). The values of the Eigen vectors and their contribution to variation are presented in Table 20.

The five principal components accounted for 98.70 per cent of the total variance with the first three components having Eigen values more than 1.00 accounting for 85.80 per cent of variability. The first principal component (PC1) with an Eigen value of 2.52 corroborated for 36.00 per cent of total variance, and had high contributing factor loadings from days to first harvest (0.35), fruit diameter (0.28), fruit weight (0.54) and fruit length (0.45), thus revealing the correlation of PC1 with these characters.

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Table 20. Eigen value and eigen vectors of the first five principal components

Variables	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
Eigenvalue	2.52	2.23	1.26	0.52	0.38
Per cent variance	36.00	31.80	17.90	7.50	5.50
Cumulative variance (%)	36.00	67.80	85.80	93.30	98.70
FW (g)	0.54	-0.27	0.24	0.08	-0.17
FL (cm)	0.45	-0.36	-0.25	0.33	-0.38
FD (cm)	0.28	0.01	0.76	-0.14	0.38
DFH	0.35	0.39	-0.10	-0.73	-0.42
NFPP	-0.38	-0.48	-0.07	-0.45	0.00
SR	-0.41	-0.01	0.54	0.14	-0.72
YPP (g)	0.02	-0.64	0.03	-0.33	0.05

FW-Fruit weight; FL-Fruit length; FD-Fruit diameter; DFH- Days to first harvest; NFPP-Number of fruits per plant; YPP-Yield per plant

Second principal component (PC2) with Eigen value of 2.23 was correlated with days to first harvest (0.39) and contributed to 31.80 per cent of the total variation. The third principal component (PC3) accounted for 17.90 per cent of the total variation, with high contributions from fruit diameter (0.76), sex ratio (0.54), fruit weight (0.24) and yield per plant (0.03). The fourth principal component was a measure of fruit length with a loading factor of 0.33 and sex ratio (0.14) and contributed for 7.50 per cent of total variation. Similarly, the fifth component contributed 5.50 per cent of the total variation contributed by fruit diameter and yield per plant.

The loading plot depicting the relation among various characters based on first two PCs is presented in Fig. 21. The association between two characters in terms of correlation is estimated by the cosine of angle between their vectors (Sameer, 2016). The loading plot revealed positive correlation between fruit length and fruit weight; fruit weight and fruit diameter; fruits per plant and yield per plant and sex ratio and number of fruits per plant which is revealed by the acute angle between them. A negative correlation between yield per plant and days to first harvest; number of fruits per plant and days to first harvest; fruits per plant and fruit weight was also revealed as the angle between these characters are obtuse.

4.1.1.8. Diversity analysis using DIVA-GIS

Cucumber germplasm collected from 12 states of India representing different agro-ecological zones were used for studying the diversity analysis. The geographical coordinates of the collection sites and accession identity used for DIVA-GIS analysis are provided in Appendix I detailed in section 3.2. The mean values obtained for eight quantitative characters were subjected to DIVA-GIS analysis and grid maps were generated. Colours of grids are indicative of the extent of diversity in the germplasm lines.

All quantitative characters exhibited variability as obvious by the high coefficient of variation (CV) observed in most of the traits studied. The high CV observed among morphological characters is an indication of the level of diversity within the populations of cucumber found growing in these habitats. Rich diversity was observed for days to first harvest in states namely West Bengal and Mizoram as depicted by red grids (Fig. 2 and 3). The value of Shannon Diversity Index (SDI) ranged from 0 - 0.035 for accessions from Kerala, Karnataka, Maharashtra, Orissa, Tripura and Uttarakhand. High SDI (1.39 - 2.00) was observed in accessions collected from West Bengal and Mizoram, as indicated by red coloured grids. Similarly, the accessions from Mizoram, Arunachal Pradesh, Tripura and Nagaland registered moderate coefficient of variation (CV) of 12-20 per cent for the character.

Accessions from Kerala, Karnataka, Orissa, Tripura, Nagaland and Himachal Pradesh recorded the lowest SDI (0.00 - 0.46) for fruit length. High SDI ranging from 1.84 - 3.0 was recorded for accessions collected from West Bengal and Mizoram. CV ranged from 0.00 - 5.00 per cent for fruit length in collections from Kerala, Karnataka, Maharashtra, Orissa, West Bengal, Tripura, Nagaland and Himachal Pradesh. The accessions from Uttaranchal and Tripura had recorded CV as high as 19 - 24 per cent (Fig. 4 and 5).

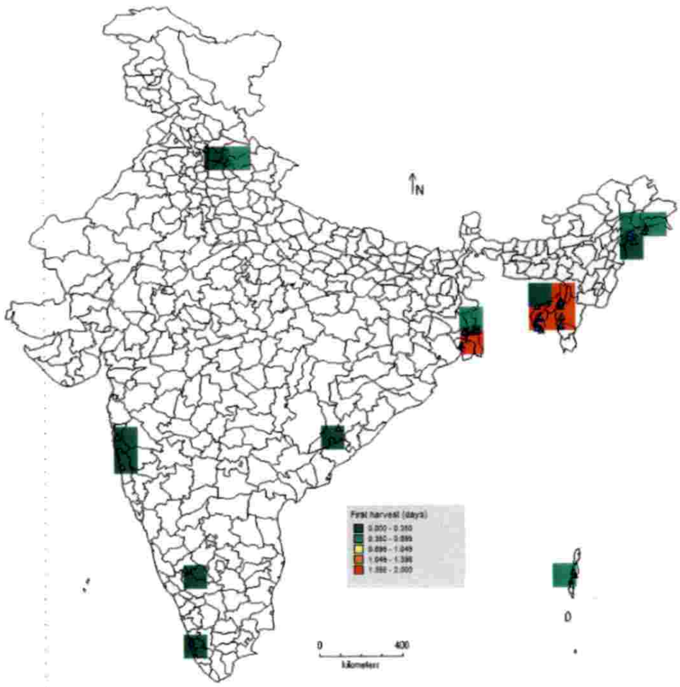

Fig. 2. DIVA-GIS analysis of diversity in days to first harvest

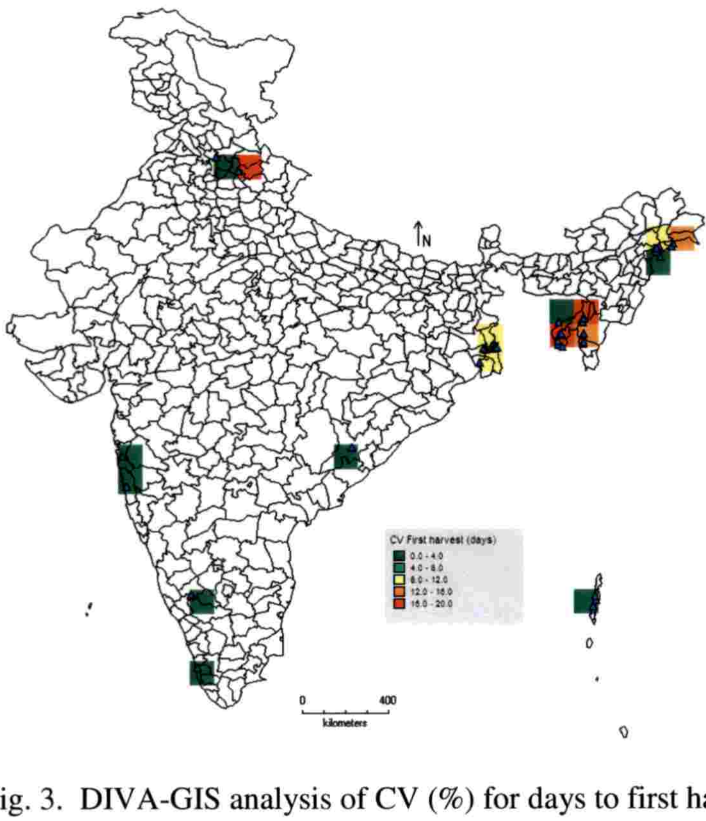

Fig. 3. DIVA-GIS analysis of CV (%) for days to first harvest

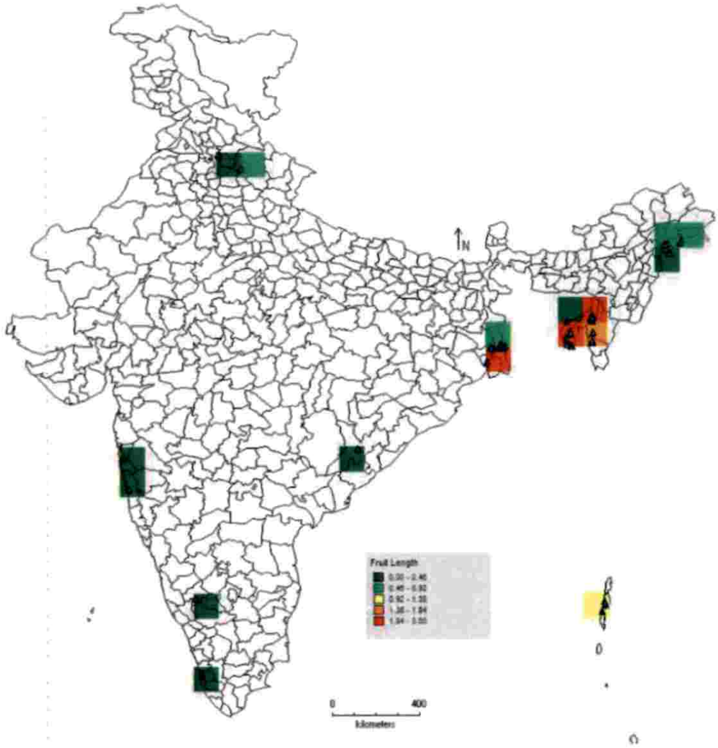

Fig. 4. DIVA-GIS analysis of diversity in fruit length

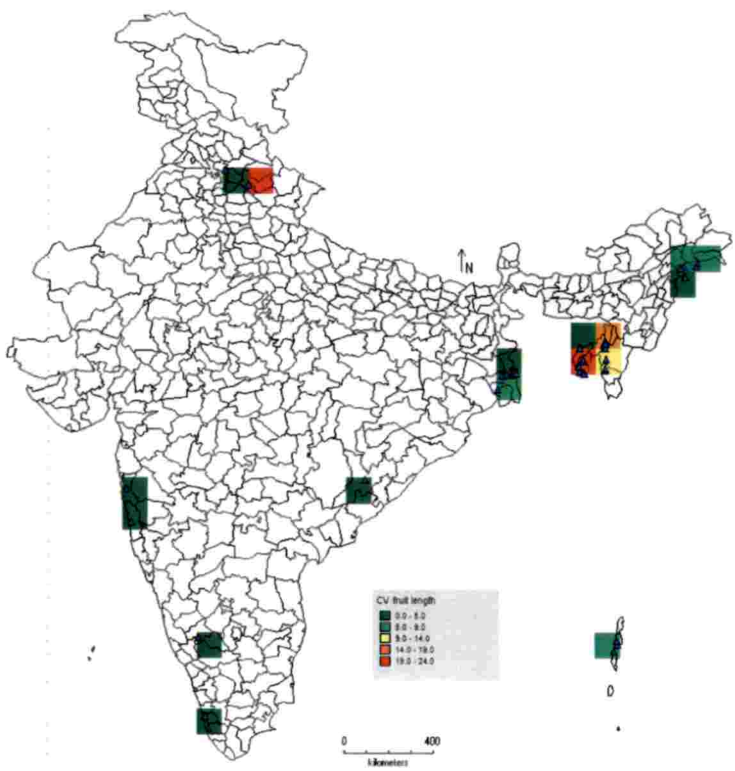

Fig. 5. DIVA-GIS analysis of CV (%) for fruit length

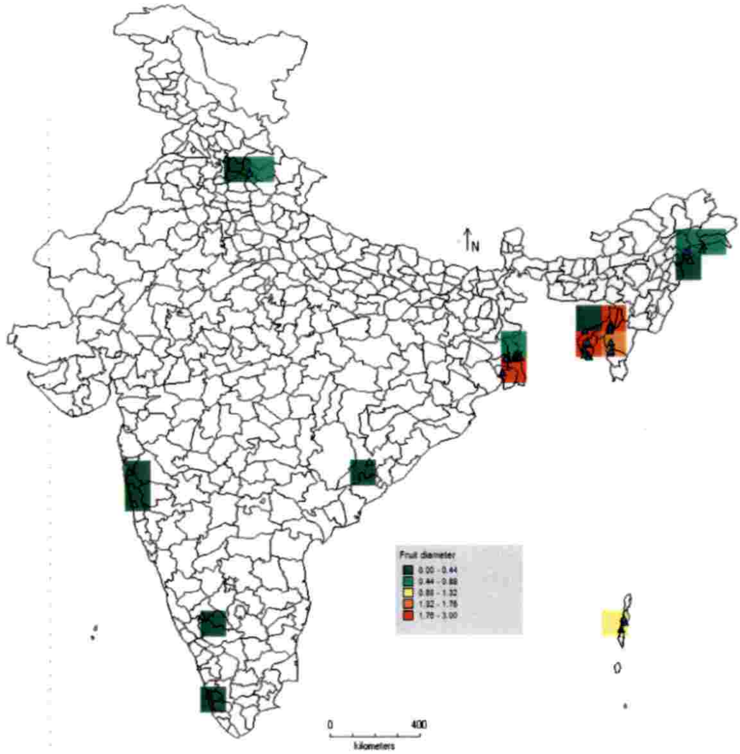

Fig. 6. DIVA-GIS analysis of diversity for fruit diameter

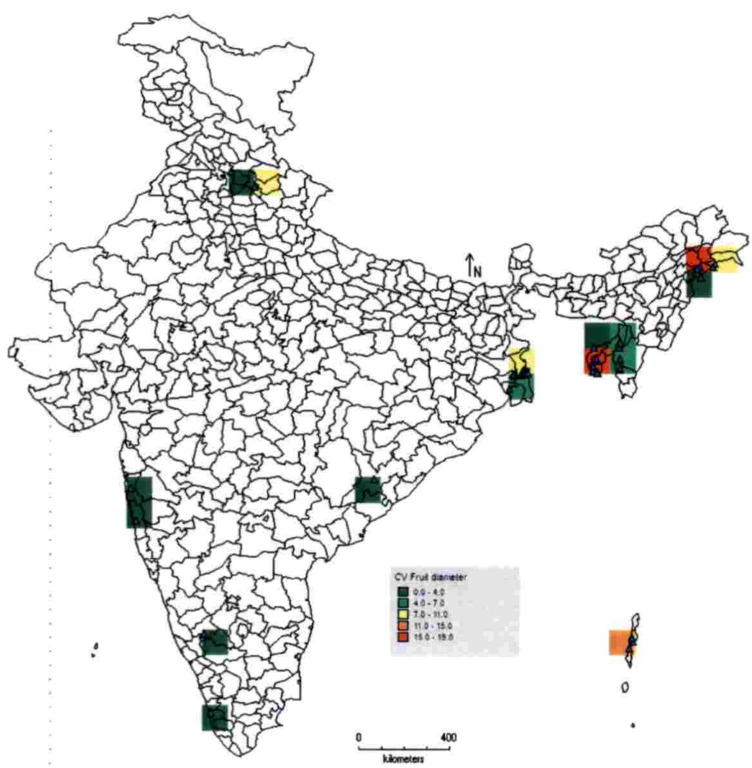

Fig. 7. DIVA-GIS analysis of CV (%) for fruit diameter

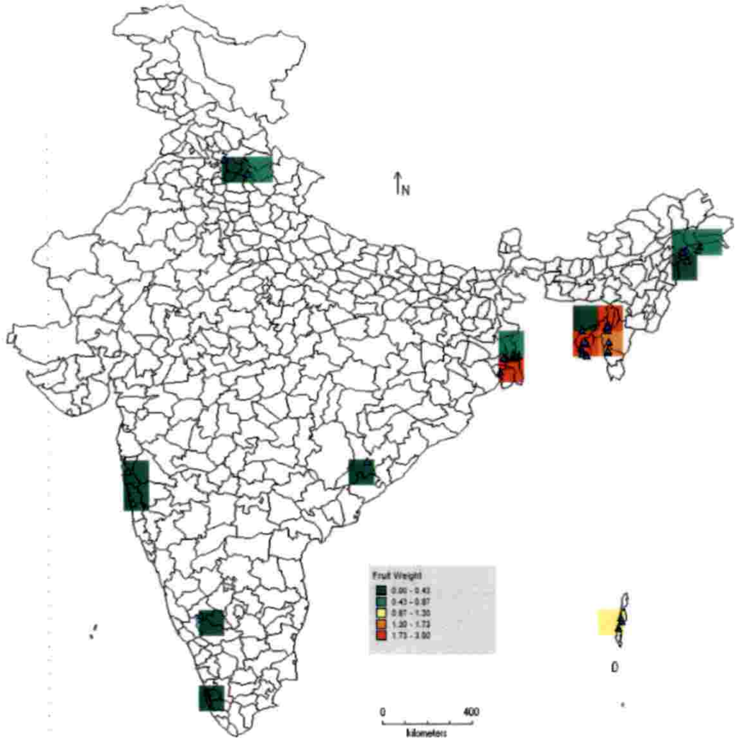

Fig. 8. DIVA-GIS analysis of diversity in fruit weight

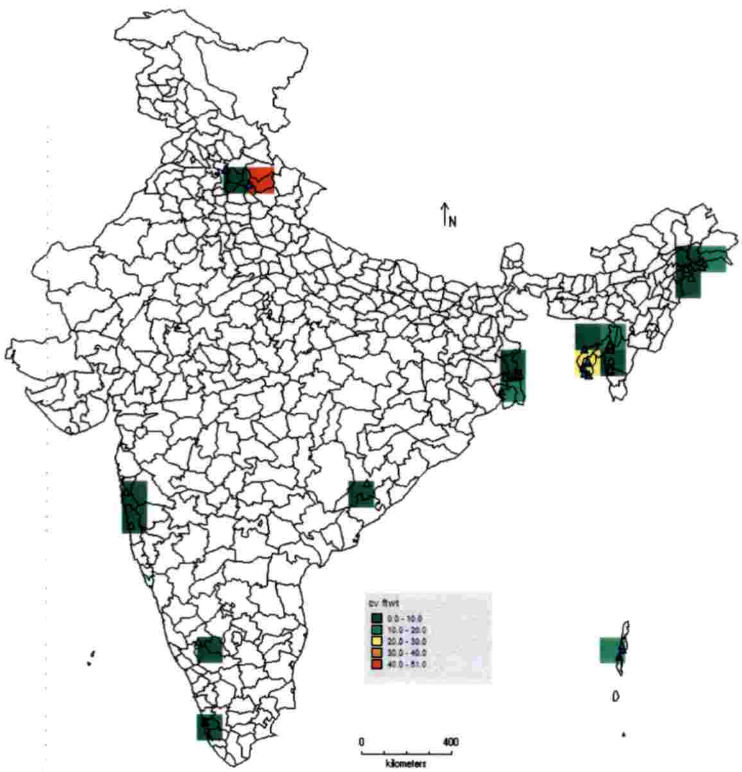

Fig. 9. DIVA-GIS analysis of CV (%) for fruit weight

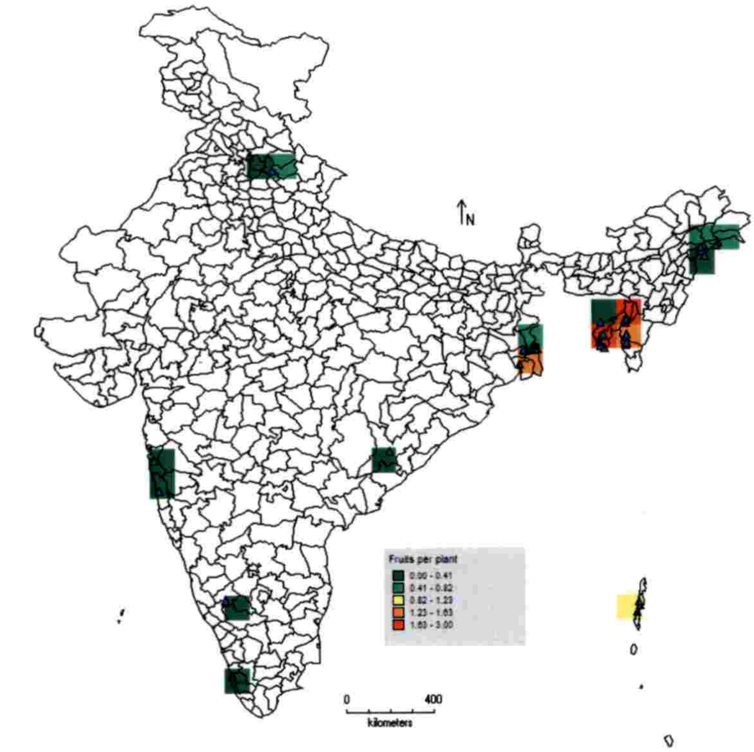

Fig. 10. DIVA-GIS analysis of diversity in number of fruits per plant

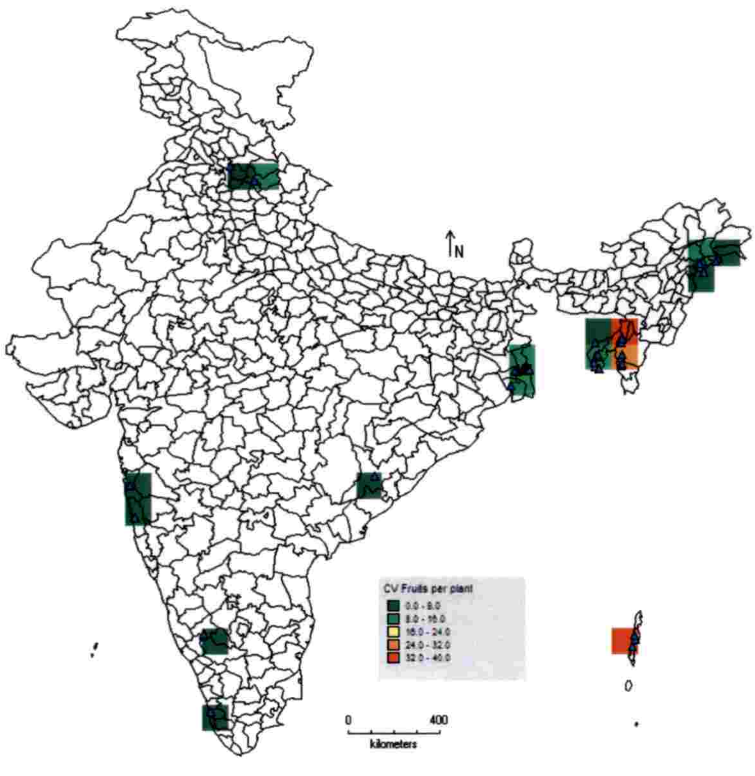

Fig. 11. DIVA-GIS analysis of CV (%) for number of fruits per plant

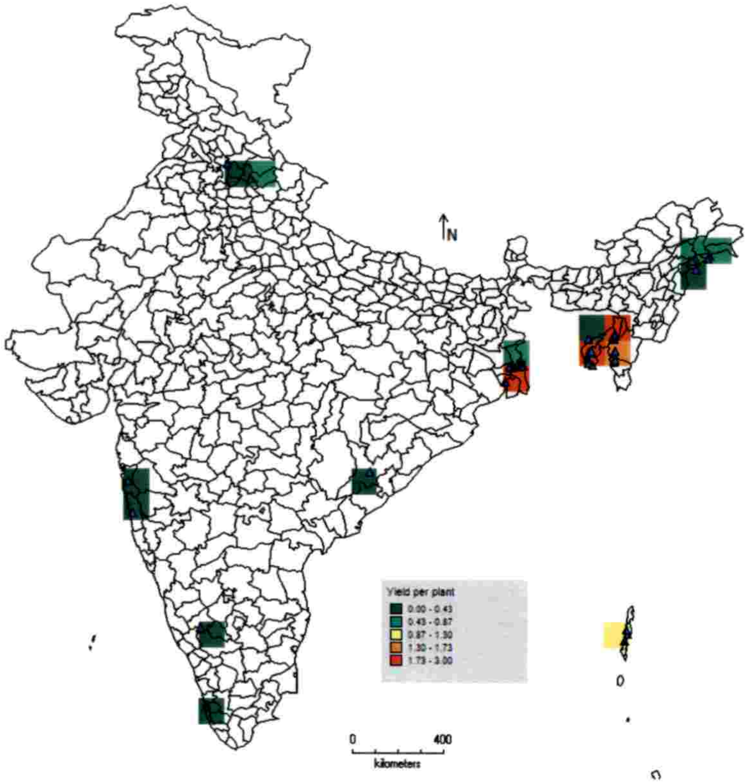

Fig. 12. DIVA-GIS analysis of diversity in yield per plant

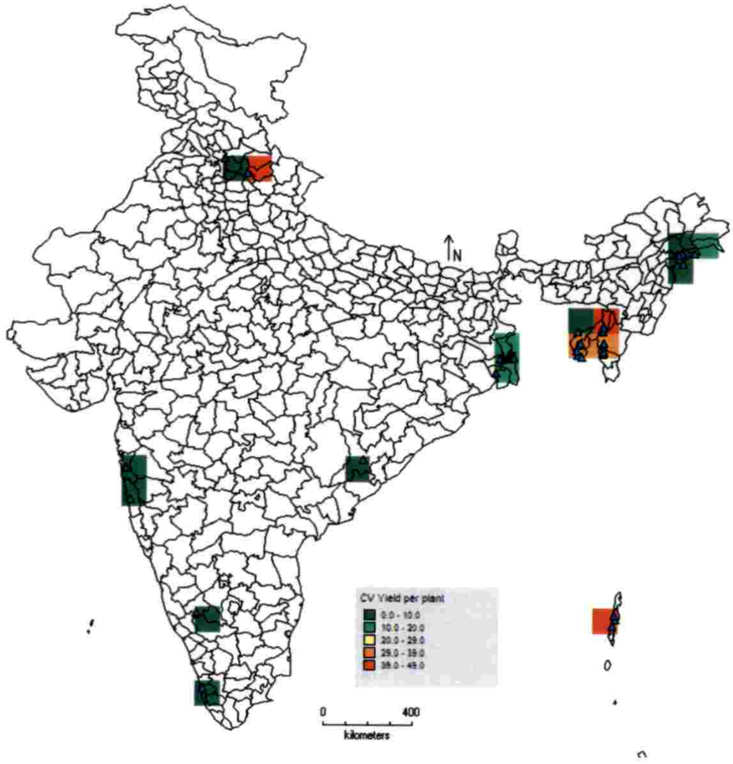

Fig. 13. DIVA-GIS analysis of CV (%) for yield per plant

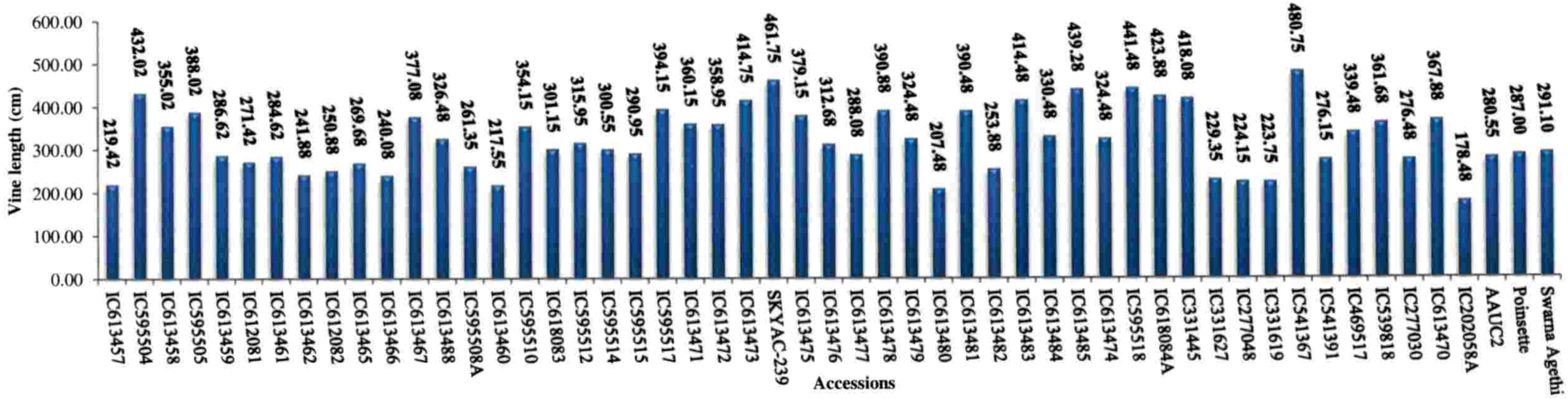

Fig. 14. Distribution of vine length in 53 cucumber accessions

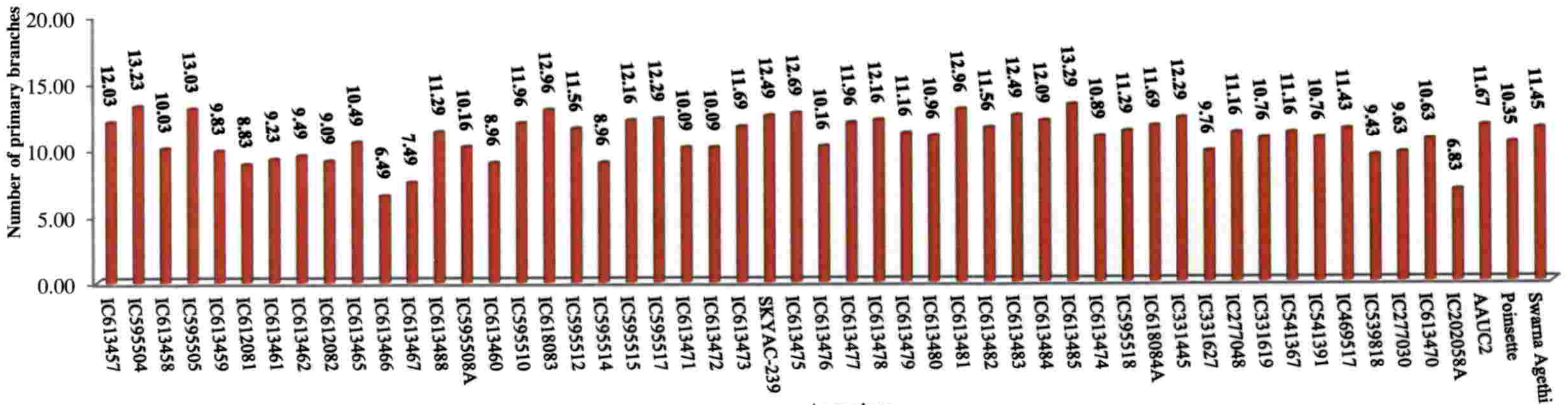

Fig. 15. Distribution of number of primary branches in 53 cucumber accessions

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Fruit diameter recorded SDI of 0.00 to 0.44 in collections from Kerala, Karnataka, Maharashtra, Orissa, Tripura and Arunachal Pradesh. Accessions collected from West Bengal, Tripura and Mizoram recorded SDI of 1.76 - 3.00 (Fig. 6). CV of 15 - 19 per cent for fruit diameter was observed in accessions collected from Tripura and Arunachal Pradesh. However, low CV of 0.0 to 4 per cent was recorded in collections representing Kerala, Karnataka, Maharashtra, Orissa, Tripura and Arunachal Pradesh (Fig. 7).

Accessions from Kerala, Karnataka, Maharashtra, Orissa, Tripura, Himachal Pradesh and Nagaland recorded low SDI of 0.00 to 0.43 whereas accessions from West Bengal, Tripura and Mizoram recorded SDI of 1.73 to 3.00 for fruit weight (Fig. 8). CV of more than 200 per cent was recorded for accessions collected from Tripura and Uttarakhand. CV of 10 - 20 per cent was recorded from accessions representing Andaman and Nicobar Islands, West Bengal, Tripura and Arunachal Pradesh. All the remaining accessions recorded very low CV (0.00 to 10 %) (Fig. 9).

SDI ranging from 0.00 to 0.41 was exhibited by accessions from Kerala, Karnataka, Maharashtra, Orissa, Himachal Pradesh, Tripura, Arunachal Pradesh and Nagaland for number of fruits per plant. Accessions from Tripura and Mizoram recorded high SDI of 1.63 to 3.00 (Fig. 10). Similarly, high CV of 32 - 40 per cent was observed for collections from Andaman and Nicobar Islands and Mizoram (Fig. 11).

Collections from Kerala, Karnataka, Maharashtra, Orissa, Himachal Pradesh, Tripura, Arunachal Pradesh and Nagaland had low CV (0.00 to 8.00 per cent). High SDI of 1.73 to 3.00 was recorded for accessions collected from Andaman and Nicobar Islands, Tripura and Uttarakhand for yield per plant (Fig. 12). SDI as low as 0.00 to 0.43 was observed in accessions from Kerala, Karnataka, Maharashtra, Orissa, Tripura and Arunachal Pradesh. Accessions from Andaman and Nicobar Islands, Tripura and Uttarakhand recorded highest CV of 39 to 49 per cent. High CV of 29 to 39 was also recorded from accessions from Mizoram and Tripura (Fig. 13).

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4.1.1.9. Organoleptic evaluation

Organoleptic evaluation was done by estimating Kendall's coefficient of concordance to study the significance of perception of taste between the individuals and to rank the plants based on the mean rank of different sensory attributes. The mean rank obtained for bitterness, crispness and flavour in 53 accessions is given in Table 21.

The maximum and minimum score for bitterness was observed for IC541391 (35.13) and IC277048 (2.73), thus IC541391being the least bitter and IC277048 the most bitter accession. Crispness was maximum observed in IC618084A with a score of 42.18 and minimum in IC613465 with a value of 8.32. IC469517 exhibited highest score for flavour and lowest score was for IC331627. A cumulative score was obtained by adding the scores obtained of bitterness, crispness and flavour. The cumulative total score was highest in IC613480 with a score of 101.65 and lowest in IC613459 having a score of 40.97. Therefore, when ranking of accessions based on organoleptic scoring was done; first rank was recorded for IC613480 followed by IC613481 and least rank was recorded for IC613459 (Plate 14-15).

4.1.1.10. Selection of promising genotypes

All the morphological characters will not have significant direct effect on the yield, hence the focus was limited to major yield contributing characters namely, fruit weight (g), fruit length (cm), fruit diameter (cm), days to first harvest, number of fruits per plant and sex ratio for selecting promising genotypes. In addition, storability behaviour assessed in terms of loss of weight during storage and number of days of storage and tolerance to downy mildew disease estimated as per cent disease index and the organoleptic qualities were also considered for selecting promising genotypes. The analysis of variance for these selected characters revealed significant difference between the treatments.

IC613481 IC613480 IC618084A

Plate 14. Organoleptically superior cucumber accessions

Plate 15. Bitter cucumber accessions

Table 21. Mean ranks recorded for organoleptic qualities in 53 cucumber accessions

Accession No.	Bitter ness	Crisp ness	Flavour	COS	Accession No.	Bitter ness	Crisp ness	Flavour	COS
IC613457	26.03	27.54	23.68	77.25	IC613477	32.20	37.11	24.71	94.02
IC595504	30.07	39.21	25.43	94.71	IC613478	31.77	16.96	32.64	81.37
IC613458	30.93	19.50	25.04	75.47	IC613479	32.33	31.43	26.71	90.47
IC595505	29.67	25.00	24.43	79.10	IC613480	32.87	36.14	31.02	100.03
IC613459	3.97	18.07	18.93	40.97	IC613481	33.53	36.32	31.80	101.65
IC612081	25.10	14.86	27.50	67.46	IC613482	25.13	22.61	29.57	77.31
IC613461	25.00	13.32	31.79	70.11	IC613483	30.43	24.36	25.54	80.33
IC613462	30.27	25.68	26.43	82.38	IC613484	34.10	32.18	30.75	97.03
IC612082	28.50	18.61	25.93	73.04	IC613485	31.50	30.89	27.64	90.03
IC613465	26.97	8.32	30.29	65.58	IC613474	29.70	36.57	24.50	90.77
IC613466	27.97	12.61	32.32	72.90	IC595518	32.53	27.61	26.07	86.21
IC613467	30.57	26.07	25.00	81.64	IC618084A	28.17	42.18	28.93	99.28
IC613488	28.83	30.07	30.00	88.90	IC331445	33.07	34.46	26.29	93.82
IC595508A	28.20	29.04	26.89	84.13	IC331627	2.90	23.61	18.43	44.94
IC613460	29.87	15.14	25.57	70.58	IC277048	2.73	24.07	20.43	47.23
IC595510	32.70	32.96	24.07	89.73	IC331619	9.43	34.71	25.29	69.43
IC618083	29.47	23.14	28.86	81.47	IC541367	35.13	27.61	30.71	93.45
IC595512	33.53	27.50	33.96	94.99	IC541391	27.37	16.50	28.79	72.66
IC595514	15.40	8.57	34.64	58.61	IC469517	31.83	27.43	34.68	93.94
IC595515	29.90	26.07	25.75	81.72	IC539818	28.20	23.25	26.50	77.95
IC595517	30.60	33.68	22.11	86.39	IC277030	29.97	21.32	28.11	79.40
IC613471	29.90	41.21	23.64	94.75	IC613470	31.40	36.75	26.21	94.36
IC613472	27.47	22.93	24.18	74.58	IC202058A	3.53	16.79	21.79	42.11
IC613473	22.77	26.86	30.18	79.81	AAUC-2	27.43	38.14	30.46	96.03
SKYAC-239	29.70	24.71	23.86	78.27	Poinsette	29.13	30.89	29.71	89.73
IC613475	27.23	31.04	21.96	80.23	Swarna Agethi	15.07	39.57	25.32	79.96
IC613476	28.93	39.82	25.96	94.71	Minimum	2.73	8.32	18.43	40.97
					Maximum	35.13	42.18	34.68	101.65
COS: Cumulative organoleptic score					Kendall's coefficient	**0.41**	**0.33**	**0.07**	

A stepwise multiple comparisons following the *post-hoc* test, Duncan's Multiple Range Test (DMRT) grouped the genotypes by identifying the sample means which are significantly different. Further, the grouped accessions were scored based on the method suggested by Arunachalam and Bandyopadhyay (1984). The accession which secured the lowest rank will be the most promising one, followed by the accession which scored the second lowest total score and so on.

4.1.1.10.1. Total and cumulative organoleptic scores of 53 cucumber accessions

The genotypes were grouped based on the LSD values and scores were given based on grouping of genotypes. The lesser total score indicated better performance of accessions with respect to the characters considered. Table 22 depicts the individual score for each character considered, total score and cumulative organoleptic score observed for 53 accessions. The total score ranged from 3.93 in IC613458 to 6.63 in IC202058A. IC613479 and IC469517 scored the lowest and highest score with respect to days to first harvest. The maximum and minimum score for fruit length were recorded for IC331627 (1.00), IC277048 and IC595510 (0.08) respectively.

Among the control varieties, AAUC-2 and Poinsette scored lowest score for days to first harvest and fruit length, respectively. Total score for fruit diameter ranged from 0.06 (IC595515) to 1.70 (IC613475). Poinsette scored the lowest score among control varieties for fruit diameter. IC277048 and IC595518 recorded the minimum total scores with respect to number fruits per plant and fruit weight, respectively. For storage parameters, IC613479 and IC277030 scored the lowest values for loss of weight during storage and number of days of storage. Very high total score for these storage parameters was expressed by IC595512 and IC618084A, respectively. The total score for loss of weight during storage was uniform among the control varieties *ie*, 0.58. Sex ratio was best expressed in IC277048 by scoring the lowest score among the accessions. Total score for PDI was lowest in IC613477 and highest in IC612081 and IC612082, respectively. AAUC-2 scored the lowest total score (4.72) and highest organoleptic score (96.03) among the control varieties.

The cumulative organoleptic score was highest in IC613481 whereas least in IC613459.

Table 22. Scores and mean ranks recorded in 53 cucumber accessions

S. No.	Accession No.	DFH	FL (cm)	FD (cm)	NFPP	FW (g)	LWDS (g)	NDS	SR	PDI (%)	TS	COS
1	IC613457	0.58	0.42	0.32	0.75	0.32	0.83	0.19	0.75	0.77	4.94	77.25
2	IC595504	0.58	0.27	0.68	0.63	0.36	0.83	0.25	0.75	0.68	5.03	94.71
3	IC613458	0.42	0.12	0.41	0.63	0.14	0.67	0.31	0.75	0.50	3.93	75.47
4	IC595505	0.42	0.42	0.29	0.63	0.32	0.58	0.38	0.75	0.64	4.42	79.10
5	IC613459	0.42	0.88	0.38	0.69	0.68	0.58	0.25	0.75	0.86	5.50	40.97
6	IC612081	0.75	0.65	0.47	0.94	0.45	0.92	0.31	0.75	1.00	6.25	67.46
7	IC613461	0.58	0.54	0.47	0.75	0.32	0.42	0.88	0.75	0.82	5.52	70.11
8	IC613462	0.58	0.62	0.26	0.75	0.32	0.75	0.38	0.75	0.91	5.32	82.38
9	IC612082	0.58	0.81	0.18	1.00	0.45	0.50	0.94	0.75	1.00	6.21	73.04
10	IC613465	0.58	0.58	0.29	0.88	0.32	0.67	0.44	0.75	0.77	5.27	65.58
11	IC613466	0.75	0.27	0.53	1.00	0.32	0.83	0.56	0.75	0.82	5.83	72.90
12	IC613467	0.58	0.62	0.18	1.00	0.32	0.58	0.38	0.75	0.91	5.31	81.64
13	IC613488	0.83	0.62	0.21	0.81	0.32	0.58	0.31	0.75	0.64	5.07	88.90
14	IC595508A	0.58	0.73	0.38	0.63	0.59	0.58	0.88	0.75	0.64	5.76	84.13
15	IC613460	0.67	0.54	0.65	0.75	0.32	0.50	0.75	1.00	0.55	5.72	70.58
16	IC595510	0.58	0.08	0.71	0.63	0.18	0.67	0.50	1.00	0.77	5.11	89.73
17	IC618083	0.33	0.27	0.22	0.63	0.27	0.58	0.63	1.00	0.59	4.52	81.47
18	IC595512	0.58	0.69	0.59	0.63	0.68	1.00	0.44	1.00	0.68	6.29	94.99
19	IC595514	0.58	0.35	0.79	0.63	0.68	0.75	0.75	1.00	0.59	6.12	58.61
20	IC595515	0.92	0.69	0.06	0.63	0.23	0.58	0.38	0.75	0.59	4.82	81.72
21	IC595517	0.58	0.54	1.00	0.63	0.82	0.58	0.44	1.00	0.55	6.13	86.39
22	IC613471	0.58	0.54	0.09	0.63	0.32	0.58	0.31	1.00	0.64	4.69	94.75
23	IC613472	0.58	0.15	0.15	0.63	0.14	0.58	0.69	1.00	0.55	4.46	74.58
24	IC613473	0.58	0.27	0.74	0.63	0.32	0.83	0.50	0.75	0.27	4.89	79.81
25	SKYAC-239	0.58	0.19	0.59	0.44	0.27	0.75	0.13	1.00	0.59	4.54	78.27
26	IC613475	0.58	0.54	1.07	0.19	0.64	0.58	0.75	1.00	0.50	5.85	80.23
27	IC613476	0.58	0.58	0.85	0.44	0.73	0.58	0.69	0.75	0.55	5.74	94.71

FW-Fruit weight; FL-Fruit length; FD-Fruit diameter; DFH- Days to first harvest; LWS-Loss in weight during storage; NDS-Number of days of storage; NFP-Number of fruits per plant; PDI-Per cent disease index of downey mildew; SR-Sex ratio; TS-Total score; COS-Cumulative organoleptic score

Contd..

Crispness score was maximum in IC618084 (42.18) and minimum in IC613465 (8.32). IC469517 recorded maximum score for flavour where as IC331627 recorded the minimum flavour score (18.43). AAUC-2 scored the maximum values for crispness as well as flavour among the control varieties.

Table 22. Scores and mean ranks recorded in 53 cucumber accessions

S. No.	Accession No.	DFH	FL (cm)	FD (cm)	NFPP	FW (g)	LWDS (g)	NDS	SR	PDI (%)	TS	COS
28	IC613477	0.25	0.58	0.68	0.19	0.50	0.50	0.56	0.75	0.09	4.09	94.02
29	IC613478	0.58	0.65	0.97	0.44	0.73	0.50	0.69	0.75	0.50	5.81	81.37
30	IC613479	0.17	0.23	0.68	0.44	0.32	0.17	1.00	0.75	0.27	4.02	90.47
31	IC613480	0.58	0.58	0.82	0.25	0.82	0.58	0.81	0.75	0.23	5.43	101.65
32	IC613481	0.58	0.27	0.47	0.38	0.32	0.42	0.75	0.75	0.45	4.39	100.03
33	IC613482	0.58	0.50	0.71	0.63	0.50	0.58	0.63	0.75	0.32	5.19	77.31
34	IC613483	0.58	0.27	0.79	0.50	0.45	0.58	0.69	0.75	0.27	4.89	80.33
35	IC613484	0.58	0.27	0.82	0.44	0.55	0.58	0.81	0.75	0.14	4.94	97.03
36	IC613485	0.50	0.54	0.65	0.44	0.36	0.33	0.69	0.75	0.64	4.89	90.03
37	IC613474	0.25	0.54	0.71	0.31	0.68	0.58	0.81	0.75	0.64	5.27	90.77
38	IC595518	0.58	0.42	0.21	0.69	0.09	0.58	0.75	0.75	0.09	4.16	86.21
39	IC618084A	0.58	0.27	0.53	0.63	0.36	0.50	1.00	0.75	0.64	5.26	99.28
40	IC331445	0.83	0.23	0.68	0.81	0.32	0.58	0.88	1.00	0.59	5.92	93.82
41	IC331627	0.58	1.00	0.88	0.81	1.00	0.25	0.38	0.75	0.64	6.29	44.94
42	IC277048	0.58	1.00	0.32	0.13	0.95	0.42	0.31	0.50	0.59	4.81	47.23
43	IC331619	0.58	0.96	0.71	0.38	0.91	0.33	0.31	0.75	0.45	5.39	69.43
44	IC541367	0.58	0.54	0.35	0.81	0.32	0.67	0.44	0.75	0.86	5.32	93.45
45	IC541391	0.58	0.27	0.91	0.94	0.68	0.75	0.63	0.75	0.73	6.24	72.66
46	IC469517	1.00	0.27	0.41	0.81	0.27	0.83	0.69	0.75	0.82	5.86	93.94
47	IC539818	0.58	0.27	0.53	0.63	0.36	0.58	0.88	0.75	0.36	4.94	77.95
48	IC277030	0.58	0.77	0.47	0.56	0.45	0.58	0.13	0.75	0.41	4.71	79.40
49	IC613470	0.67	0.77	0.71	0.63	0.73	0.58	0.88	0.75	0.77	6.48	94.36
50	IC202058A	0.83	0.96	0.47	0.88	0.86	0.42	0.50	0.75	0.95	6.63	42.11
51	AAUC-2	0.33	0.23	0.68	0.50	0.32	0.58	0.56	0.75	0.77	4.72	96.03
52	Poinsette	0.58	0.21	0.47	0.63	0.32	0.58	0.63	0.75	0.73	4.90	89.73
53	Swarna Agethi	0.58	0.53	0.68	0.63	0.45	0.58	0.69	1.00	0.83	5.97	79.96
	Minimum	**0.17**	**0.08**	**0.06**	**0.13**	**0.09**	**0.17**	**0.13**	**0.50**	**0.09**	**3.93**	**40.97**
	Maximum	**1.00**	**1.00**	**1.07**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**6.63**	**101.65**

FW-Fruit weight; FL-Fruit length; FD-Fruit diameter; DFH- Days to first harvest; LWS-Loss in weight during storage; NDS-Number of days of storage; NFP-Number of fruits per plant; PDI-Per cent disease index of downey mildew; SR-Sex ratio; TS-Total score; COS-Cumulative organoleptic score

4.1.1.10.2. Total and cumulative organoleptic scores of 22 promising genotypes

The individual scores for each character, total score over the characters and total organoleptic score for 22 promising genotypes and control varieties are given in Table 23. Total scores ranged from 4.02 and 6.48 in IC613479 and in IC613470 respectively.

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Table 23. Scores and ranks recorded for the 22 promising cucumber genotypes identified

Accession No.	DFH	FL (cm)	FD (cm)	NFFP	FW (g)	LWDS (g)	NDS	SR	PDI (%)	TS	COS	Rank
IC613481	0.58	0.27	0.47	0.38	0.32	0.42	0.75	0.75	0.45	**4.39**	**101.65**	**1**
IC613480	0.58	0.58	0.82	0.25	0.82	0.58	0.81	0.75	0.23	**5.43**	**100.03**	**2**
IC618084A	0.58	0.27	0.53	0.63	0.36	0.50	1.00	0.75	0.64	**5.26**	**99.28**	**3**
IC595512	0.58	0.69	0.59	0.63	0.68	1.00	0.44	1.00	0.68	**6.29**	**94.99**	**4**
IC613484	0.58	0.27	0.82	0.44	0.55	0.58	0.81	0.75	0.14	**4.94**	**97.03**	**5**
IC595504	0.58	0.27	0.68	0.63	0.36	0.83	0.25	0.75	0.68	**5.03**	**94.71**	**6**
IC613471	0.58	0.54	0.09	0.63	0.32	0.58	0.31	1.00	0.64	**4.69**	**94.75**	**7**
IC541367	0.58	0.54	0.35	0.81	0.32	0.67	0.44	0.75	0.86	**5.32**	**93.45**	**8**
IC331445	0.83	0.23	0.68	0.81	0.32	0.58	0.88	1.00	0.59	**5.92**	**93.82**	**9**
IC613477	0.25	0.58	0.68	0.19	0.50	0.50	0.56	0.75	0.09	**4.09**	**94.02**	**10**
IC613476	0.58	0.58	0.85	0.44	0.73	0.58	0.69	0.75	0.55	**5.74**	**94.71**	**11**
IC613470	0.67	0.77	0.71	0.63	0.73	0.58	0.88	0.75	0.77	**6.48**	**94.36**	**12**
IC469517	1.00	0.27	0.41	0.81	0.27	0.83	0.69	0.75	0.82	**5.86**	**93.94**	**13**
IC613479	0.17	0.23	0.68	0.44	0.32	0.17	1.00	0.75	0.27	**4.02**	**90.47**	**14**
IC613488	0.83	0.62	0.21	0.81	0.32	0.58	0.31	0.75	0.64	**5.07**	**88.90**	**15**
IC595510	0.58	0.08	0.71	0.63	0.18	0.67	0.50	1.00	0.77	**5.11**	**89.73**	**16**
IC613474	0.25	0.54	0.71	0.31	0.68	0.58	0.81	0.75	0.64	**5.27**	**90.77**	**17**
IC595518	0.58	0.42	0.21	0.69	0.09	0.58	0.75	0.75	0.09	**4.16**	**86.21**	**18**
IC613485	0.50	0.54	0.65	0.44	0.36	0.33	0.69	0.75	0.64	**4.89**	**90.03**	**19**
IC618083	0.33	0.27	0.22	0.63	0.27	0.58	0.63	1.00	0.59	**4.52**	**81.47**	**20**
IC613462	0.58	0.62	0.26	0.75	0.32	0.75	0.38	0.75	0.91	**5.32**	**82.38**	**21**
IC595508A	0.58	0.73	0.38	0.63	0.59	0.58	0.88	0.75	0.64	**5.76**	**84.13**	**22**
AAUC-2	0.33	0.23	0.68	0.50	0.32	0.58	0.56	0.75	0.77	**4.72**	**96.03**	
Poinsette	0.58	0.21	0.47	0.63	0.32	0.58	0.63	0.75	0.73	**4.90**	**89.73**	
Swarna Agethi	0.58	0.53	0.68	0.63	0.45	0.58	0.69	1.00	0.83	**5.97**	**69.96**	
Minimum	**0.17**	**0.08**	**0.09**	**0.19**	**0.09**	**0.17**	**0.25**	**0.75**	**0.09**	**4.02**	**81.47**	
Maximum	**1.00**	**0.77**	**0.85**	**0.81**	**0.82**	**1.00**	**1.00**	**1.00**	**0.91**	**6.48**	**101.65**	

FW-Fruit weight; FL-Fruit length; FD-Fruit diameter; DFH- Days to first harvest; LWS-Loss in weight during storage; NDS-Number of days of storage; NFP-Number of fruits per plant; PDI-Per cent disease index of downey mildew; SR-Sex ratio; TS-Total score; COS-Cumulative organoleptic score

The selected genotypes in general possessed low total scores, which indicate the superiority in yield performance of these genotypes. The genotypes possessed high organoleptic scores ranging from 84.13 in IC595508A and 101.65 in IC613480. Rank 1 was obtained for IC613481 which has got a total score of 4.39 and cumulative organoleptic score of 101.65, followed by IC613480 with total score and total organoleptic score of 5.43 and 100.03, respectively. IC595508A obtained a total score of 5.76 with cumulative organoleptic score of 84.13, was ranked 22. Among control AAUC-2 was the best with lowest total score (4.72) with respect to yield contributing traits and storage behaviour and highest cumulative organoleptic score (96.03). The minimum and maximum total score for days to first harvest were recorded by IC613479 and ICC469517, whereas IC595510 and IC613470 recorded lowest and highest scores for fruit length. IC613471 and IC613476 recorded the lowest and highest total score for fruit diameter respectively. The total score for number of fruits was maximum in IC469517 (0.81) and minimum in IC613477 (0.19). The range of values for total score in fruit weight was 0.09 in IC595518 and 0.82 in IC613480. Among the storage parameters, IC613479 and IC595512 recorded minimum and maximum scores, respectively, whereas number of days was minimum in IC595504 and maximum in IC613479, respectively. The minimum total score for PDI was observed in IC613477. Total score for sex ratio (1.00) was highest in four accessions and in all the remaining accessions, the score was 0.75.

4.1.1.10.3. Mean values for selected characters in 22 promising genotypes

Table 24 depicts the mean values observed for the selected characters in the 22 promising genotypes. IC613474 recorded early harvesting among the selected promising genotypes (37.54 days) whereas IC331445 recorded the maximum value by recording first harvesting date on 64.54 days after sowing. Among control varieties, AAUC-2 recorded first harvesting by 38.38 days after sowing whereas Swarna Agethi showed delayed harvesting. The overall mean observed was 49.00 days. Fruit length was maximum in IC595510 (18.99 cm) whereas minimum in IC595508A. The overall mean among the genotypes was 15.64 cm. AAUC-2 exhibited highest value for fruit length (17.15 cm) among the check varieties. Maximum and minimum fruit diameter was observed in IC613471 (6.15 cm) and IC613476 (4.39 cm) respectively. Poinsette recorded the maximum fruit diameter among the control varieties. Number of fruits per plants was highest in IC613477.

Table 24. Characteristics of 22 promising cucumber genotypes identified

Accession	DFH	FL (cm)	FD (cm)	NFPP	FW (g)	YPP (g)	LWDS (g)	NDS	SR	PDI (%)
IC613481	39.88	17.27	5.05	8.33	238.71	1990.09	8.71	4.79	0.05	48.50
IC613480	41.88	15.29	4.47	9.53	159.71	1613.29	13.71	4.59	0.06	36.50
IC618084A	54.54	16.63	4.97	4.13	238.38	926.02	12.04	3.66	0.07	62.50
IC595512	48.88	11.66	4.79	5.60	168.38	1019.76	20.71	5.79	0.07	65.17
IC613484	45.54	15.27	4.39	7.33	194.38	1419.63	12.04	4.46	0.07	52.50
IC595504	50.21	16.15	4.65	5.20	236.04	1218.36	19.04	6.19	0.07	70.50
IC613471	52.21	17.01	6.15	3.53	304.04	1417.09	15.38	6.06	0.03	69.17
IC541367	56.88	14.72	5.27	2.67	208.38	452.63	18.38	5.86	0.05	79.17
IC331445	64.54	17.19	4.81	2.33	218.38	417.23	14.04	4.06	0.05	56.50
IC613477	41.88	15.25	4.83	9.93	219.71	2205.29	9.71	5.39	0.05	22.50
IC613476	49.88	15.37	4.39	7.93	191.71	1574.89	12.71	4.99	0.06	54.50
IC613470	56.21	12.67	4.71	6.40	198.71	1279.69	11.04	4.19	0.07	75.83
IC469517	64.21	17.47	5.30	3.40	312.21	1045.89	19.04	4.79	0.05	79.83
IC613479	39.88	18.27	4.75	7.93	269.71	2105.29	4.71	3.99	0.05	34.50
IC613488	61.21	15.05	5.81	3.93	292.38	1227.16	13.71	6.21	0.06	63.17
IC595510	39.88	18.99	4.51	6.40	282.38	1777.76	16.71	5.59	0.07	69.17
IC613474	37.54	14.59	4.69	7.53	183.38	1378.43	14.04	4.26	0.12	66.50
IC595518	57.54	15.57	5.71	3.53	321.38	1071.23	17.04	4.46	0.07	18.50
IC613485	47.54	15.03	4.89	6.73	225.38	1503.23	10.04	4.66	0.06	62.50
IC618083	38.88	15.37	5.73	6.40	265.38	1685.96	14.71	5.19	0.07	53.17
IC613462	56.21	15.25	5.71	4.33	281.38	1284.16	19.71	6.06	0.07	83.17
IC595508A	52.88	11.25	5.11	6.00	176.38	1130.96	11.71	4.39	0.08	59.17
AAUC-2	38.38	17.15	4.80	6.35	241.25	1520.80	15.38	5.45	0.13	69.50
Poinsette	43.00	15.92	5.02	4.78	241.63	1152.22	14.88	5.13	0.05	72.75
Swarna Agethi	45.25	16.60	4.63	4.67	211.25	985.85	14.88	5.00	0.04	79.25
Minimum	**37.54**	**11.25**	**4.39**	**2.33**	**159.71**	**417.23**	**4.71**	**3.66**	**0.03**	**18.50**
Maximum	**64.54**	**18.99**	**6.15**	**9.93**	**321.38**	**2205.29**	**20.71**	**6.21**	**0.13**	**83.17**
Mean	**49.38**	**15.57**	**5.00**	**5.69**	**235.08**	**1308.87**	**14.39**	**5.02**	**0.06**	**60.67**

DFH- Days to first harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); YPP- Yield per plant (g); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; SR- Sex ratio; PDI-Percent disease index (%)

The lowest value was recorded in IC331445 (2.33). Among the control varieties, AAUC-2 produced the highest fruits per plant. The overall mean was 5.80 fruits per plant. The range of fruit weight was 159.71 g to 321.38 g in IC613480 and IC595518 respectively. The selected genotypes produced fruits with an average weight of 235.22 g. The fruit weight was highest in Poinsette among the control varieties. IC613477 recorded the highest yield per plant among

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the promising genotypes by yielding 2205.29 g of fruits per plant. The lowest value was recorded by IC331445 (417.23 g). The performance of control varieties was in the range of 985.85 g in Swarna Agethi to 1520.80 g in AAUC-2. Number of days of storage was minimum in IC618084 (3.66 days) and maximum in IC613488 (6.21 days). The overall mean was recorded as 5.01 days. AAUC-2 could be stored up to 5.45 days among the control varieties.

Maximum and minimum sex ratio was observed for IC613471 (0.03) and IC613474 (0.12) with an average of 0.06 recorded for the entire genotypes. Among control varieties, AAUC-2 recorded a sex ratio of 0.13, which was the highest. Highest PDI was recorded in IC613462 (83.17 %) whereas lowest in IC596618 (18.50 %). The overall mean was 60.18 per cent among the genotypes. Maximum infection of downy mildew was observed in Swarna Agethi (79.25 per cent) among control varieties.

4.1.1.10.4. Geographical diversity of 22 promising genotypes

The promising accessions and the respective states from which they were collected are depicted in Table 25.

Table 25. Geographic location of 22 promising cucumber genotypes

S. No.	Accession	State	S. No.	Accession	State
1	IC613481	West Bengal	12	IC613470	Tripura
2	IC613480	West Bengal	13	IC469517	Karnataka
3	IC618084A	Arunachal Pradesh	14	IC613479	West Bengal
4	IC595512	Tripura	15	IC613488	Mizoram
5	IC613484	West Bengal	16	IC595510	Tripura
6	IC595504	Mizoram	17	IC613474	Nagaland
7	IC613471	Arunachal Pradesh	18	IC595518	Kerala
8	IC541367	A&N Islands	19	IC613485	West Bengal
9	IC331445	Odisha	20	IC618083	Tripura
10	IC613477	West Bengal	21	IC613462	Mizoram
11	IC613476	West Bengal	22	IC595508A	Tripura

They represented nine states with seven accessions from West Bengal (IC613481, IC613480, IC613484, IC613477, IC613476, IC613479 and IC613485,

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five from Tripura (IC595512, IC613470, IC595510, IC618083 and IC595508), three from Mizoram (IC595504, IC613488 and IC613462), two from Arunachal Pradesh (IC618084 and IC613471) and one each from A&N Islands (IC541367), Karnataka (IC469517), Kerala (IC595518), Nagaland (IC613474) and Odisha (IC331445).

4.1.2. Molecular characterization

Twenty polymorphic primers which produced polymorphic patterns in at least two accessions were used to study the molecular divergence among the genotypes selected. In addition to the 22 promising genotypes selected, five accessions representing five different wild species were also included in the study.

A total of 82 amplicon products were obtained. The mean number of alleles per locus was 4.10 and the size of the amplicons ranged from 121.13 bp (SSR12810) to 362.84 bp (SSR11742). Number of amplicons ranged from 2.00 (SSR19493) to 6.00 (SSR11742 and AF202378). The PIC (Polymorphism Information Content) ranged from 0.20 in SSR06660 to 0.81 in AF20237. Marker index ranged from 0.35 in SSR19493 to 4.05 in AF202378 (Table 26). The Jaccard's similarity coefficient values obtained are depicted in Table 27. Maximum similarity coefficient was exhibited between IC618084A and IC613480 and between IC613484 and IC595512, both with a similarity coefficient of 0.83. No similarity was observed between N-09/110 and IC613474. Alleles of primer UW053690 and SSR11742 were in heterozygous condition. However, minimum similarity of 0.02 was exhibited between N-09/110 with IC613488, IC595518and IC613485 and between JBT-51/29 and IC595508A.

4.1.2.1. Cluster analysis

Cluster analysis based on UPGMA categorized 27 *Cucumis* genotypes into four distinct clusters (Table 28).

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Table 26. Characteristics of 20 SSR markers used for molecular characterization of 27 *Cucumis* genotypes

Primer ID	PIC	No. of amplicons	Marker Index	Amplicon size	
				Min	Max
UW053690	0.65	5	2.61	190.66	300.00
UW029476	0.73	5	2.93	161.55	251.72
SSR12810	0.63	3	1.26	121.13	170.18
SSR12227	0.46	3	0.92	147.74	213.74
SSR05830	0.52	3	1.05	145.97	200.00
SSR22071	0.43	4	1.28	187.83	300.00
SSR05737	0.44	3	0.87	135.79	188.61
SSR19493	0.35	2	0.35	169.01	234.05
SSR06660	0.20	3	0.41	174.18	221.68
SSR33278	0.32	3	0.64	159.34	257.09
SSR11742	0.75	6	3.77	128.36	362.84
DN910157	0.64	4	1.93	142.89	217.41
DN910437	0.68	4	2.03	193.69	325.57
DN909941	0.66	5	2.66	200.00	292.66
AF202378	0.81	6	4.05	182.99	300.00
BI740103	0.62	5	2.49	174.16	292.78
AY942801	0.52	3	1.05	174.15	250.85
CK758649	0.62	4	1.87	200.00	314.48
yfSSR108	0.73	5	2.92	121.34	276.17
SSR17292	0.70	4	2.09	185.99	259.81
Max	**0.81**	**6**	**4.05**	**200.00**	**362.84**
Min	**0.20**	**2**	**0.35**	**121.13**	**170.18**

PIC-Polymorphism information content

Cluster I with five genotypes, cluster II with four genotypes, III with four genotypes and IV with 14 genotypes (largest cluster). All the genotypes of wild species except JB-11/156 were included in cluster II. All the remaining genotypes were included in cluster IV. IC613485, IC595518, IC613474, IC595510 and 613488 were the genotypes in cluster I, whereas cluster III contained JB-11/36, IC595508A, IC613462 and IC618083.

4.2. Evaluation of promising genotypes

4.2.1. Qualitative characters

No variability was found for stem end fruit shape, blossom end fruit shape and presence of seed cavity. All the genotypes exhibited flattened shape at stem

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Table 27. Jaccard's similarity coefficient between 27 *Cucumis* genotypes

IC613481	1.00																										
IC613480	0.62	1.00																									
IC618084A	0.75	0.83	1.00																								
IC595512	0.68	0.56	0.62	1.00																							
IC613484	0.68	0.50	0.62	0.83	1.00																						
IC595504	0.50	0.50	0.56	0.50	0.50	1.00																					
IC613471	0.43	0.39	0.43	0.54	0.54	0.59	1.00																				
IC541367	0.62	0.62	0.68	0.56	0.56	0.68	0.48	1.00																			
IC331445	0.50	0.31	0.40	0.40	0.45	0.40	0.39	0.45	1.00																		
IC613477	0.56	0.45	0.50	0.50	0.50	0.45	0.48	0.68	0.62	1.00																	
IC613476	0.56	0.40	0.50	0.45	0.50	0.40	0.43	0.56	0.68	0.75	1.00																
IC613470	0.45	0.40	0.40	0.35	0.40	0.31	0.34	0.45	0.68	0.56	0.68	1.00															
IC469517	0.40	0.35	0.35	0.31	0.35	0.35	0.34	0.40	0.56	0.45	0.56	0.83	1.00														
IC613479	0.31	0.40	0.35	0.31	0.27	0.56	0.34	0.45	0.40	0.45	0.45	0.40	0.45	1.00													
IC613488	0.20	0.20	0.20	0.17	0.24	0.31	0.23	0.20	0.35	0.27	0.31	0.45	0.50	0.45	1.00												
IC595510	0.14	0.14	0.14	0.17	0.17	0.27	0.19	0.17	0.24	0.20	0.20	0.27	0.27	0.31	0.62	1.00											
IC613474	0.13	0.13	0.13	0.16	0.16	0.26	0.22	0.16	0.23	0.19	0.23	0.19	0.23	0.30	0.34	0.43	1.00										
IC595518	0.11	0.11	0.11	0.14	0.14	0.24	0.19	0.14	0.20	0.17	0.17	0.17	0.17	0.24	0.24	0.27	0.48	1.00									
IC613485	0.05	0.08	0.05	0.05	0.08	0.11	0.16	0.08	0.11	0.11	0.11	0.11	0.11	0.11	0.14	0.14	0.26	0.45	1.00								
IC618083	0.35	0.31	0.40	0.31	0.31	0.27	0.23	0.31	0.31	0.35	0.35	0.24	0.20	0.20	0.24	0.17	0.19	0.14	0.08	1.00							
IC613462	0.24	0.27	0.27	0.27	0.27	0.24	0.19	0.20	0.20	0.24	0.27	0.20	0.17	0.17	0.24	0.24	0.23	0.17	0.08	0.62	1.00						
IC595508A	0.24	0.20	0.20	0.27	0.27	0.17	0.19	0.14	0.24	0.20	0.24	0.24	0.20	0.14	0.24	0.24	0.23	0.20	0.11	0.45	0.75	1.00					
JB-11/156	0.20	0.17	0.20	0.27	0.27	0.24	0.19	0.35	0.24	0.27	0.27	0.24	0.20	0.14	0.08	0.11	0.05	0.08	0.05	0.24	0.20	0.24	1.00				
N-09/110	0.11	0.14	0.14	0.17	0.17	0.11	0.16	0.17	0.14	0.17	0.17	0.14	0.14	0.08	0.02	0.05	0.00	0.02	0.02	0.17	0.24	0.27	0.56	1.00			
JP-13/47	0.24	0.17	0.21	0.21	0.21	0.21	0.20	0.32	0.28	0.32	0.24	0.24	0.21	0.21	0.14	0.17	0.11	0.17	0.14	0.24	0.14	0.21	0.37	0.24	1.00		
JB-11/36	0.17	0.11	0.11	0.08	0.11	0.17	0.10	0.17	0.20	0.17	0.20	0.24	0.27	0.20	0.24	0.11	0.13	0.11	0.05	0.35	0.27	0.24	0.27	0.20	0.28	1.00	
JBT-51/29	0.17	0.17	0.20	0.20	0.20	0.24	0.23	0.27	0.24	0.27	0.31	0.24	0.27	0.27	0.17	0.17	0.16	0.17	0.08	0.17	0.14	0.20	0.56	0.40	0.37	0.24	1.00

end and blossom end shape of the fruit and without the seed cavity. Variability was observed for fruit skin colour, fruit shape, flesh colour, fruit skin texture and primary fruit colour (Table 29).

Table 28. Distribution of 27 *Cucumis* genotypes in different clusters

Cluster No.	Number of genotypes	Genotypes
I	5	IC613485 (WB), IC595518 (Ke), IC613474 (N), IC595510 (T) and IC613488 (Mi)
II	4	JP-13-47(Ke), JBT-51/29 (Jh), N-09-110 (Ma), JB-11/156 (Mi)
III	4	JB-11/36 (Mi), IC595508A (T), IC613462 (Mi) and IC618083 (T)
IV	14	IC613479 (WB), IC469517 (Ka), IC613470 (T), IC613476 (WB), IC613477 (WB), IC331445 (O), IC613471 (ArP), IC541367 (A&N), IC595504 (Mi), IC613484 (WB), IC595512 (T), IC618084A (ArP), IC613480 (WB) and IC613481 (WB)

A&N- Andaman &Nicobar Islands; ArP- Arunachal Pradesh; Ka-Karnataka; Ke- Kerala; Ma-Maharashtra; Mi-Mizoram; N-Nagaland; O-Odisha; T-Tripura; WB-West Bengal

4.2.1.1. Fruit skin colour

Among the 25 genotypes studied, two accessions namely IC613462 and IC595518 possessed cream colour for fruit skin. Light green colour was exhibited by 13 genotypes whereas green and dark green colour for fruit skin was observed in nine and one genotypes respectively. Poinsette exhibited green colour for fruit skin in contrast to light green colour for both AAUC-2 and Swarna Agethi.

4.2.1.2. Fruit shape

Fruit shapes of elliptical elongate and oblong ellipsoid were observed among the genotypes studied. Seventeen genotypes possessed elliptical elongate fruits. Oblong ellipsoid shape was exhibited by eight genotypes.

Table 29. The variability in qualitative characters in 25 genotypes of cucumber

S. No.	Accession	**FSC**	**FS**	**FC**	**FST**	**PFC**	S. No.	Accession	**FSC**	**FS**	**FC**	**FST**	**PFC**
1	IC613481	3	1	1	3	3	13	IC469517	3	2	1	3	3
2	IC613480	3	1	1	3	3	14	IC613479	4	1	1	3	3
3	IC618084A	3	1	1	3	3	15	IC613488	3	2	1	3	3
4	IC595512	3	2	1	3	3	16	IC595510	4	1	99	3	4
5	IC613484	4	1	1	2	3	17	IC613474	4	1	1	3	3
6	IC595504	4	1	1	3	4	18	IC595518	1	2	1	3	1
7	IC613471	4	1	1	3	4	19	IC613485	3	1	1	3	3
8	IC541367	3	1	99	3	3	20	IC618083	4	2	99	3	3
9	IC331445	3	1	1	3	3	21	IC613462	1	2	1	2	1
10	IC613477	4	1	1	3	3	22	IC595508A	4	2	1	3	3
11	IC613476	3	2	1	3	3	23	AAUC-2	3	1	1	3	3
12	IC613470	3	1	1	3	3	24	Poinsette	5	1	1	3	4
							25	Swarna Agethi	3	1	1	3	3

FSC-Fruit skin colour; FS-Fruit shape; FC-Fruit flesh colour; FST-Fruit skin texture; PFC-Primary fruit colour

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4.2.1.3. Flesh colour

All genotypes except three (IC541367, IC595510 and IC618083) had white fleshed fruits.

4.2.1.4. Fruit skin texture

The fruit skin texture was exhibited as rough in 23 genotypes and netted in two genotypes (IC613484 and IC613462).

4.2.1.5. Primary fruit colour

Primary fruit colour was cream in IC595518 and IC613462. Light green colour was exhibited by 19 genotypes whereas four exhibited green colour.

4.2.2. Quantitative characters

The mean and range showing the lowest and highest values for the respective traits have been presented.

4.2.2.1. Shoot characters

4.2.2.1.1. Vine length

Vine length was observed maximum in IC613481, with a value of 295.00 cm and minimum in IC613470 and IC613488 (195.00 cm). Among control varieties, AAUC-2 recorded highest value for vine length (277.50 cm). The mean value over all genotypes was recorded as 238.00 cm (Table 30).

4.2.2.1.2. Number of primary branches

The range of values for number of branches was 5.50 and 10.00 in IC618084A and IC613471 respectively, with an overall mean of 6.87. The maximum and minimum values in the character among control varieties were 8.65 in AAUC-2 and 6.45 in Swarna Agethi respectively.

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4.2.2.2. Floral characters

4.2.2.2.1. Days to first male flower opening

Maximum value for days to first male flower opening was exhibited by IC595504 (37.00 days). IC595518 exhibited early male flower opening at 26.00 days after sowing, among the 22 genotypes. The overall mean for the character was observed as 30.80 days. Among the control varieties, Poinsette exhibited lowest value of 25.50 days, which was earlier than all the genotypes studied (Table 30).

4.2.2.2.2. Days to first female flower opening

Maximum value for days to female flower opening was observed for IC613471 (47 days) with an overall mean of 36.04 days among the genotypes. Similar to days to male flower opening,

4.2.2.2.3. Days to 50 per cent male flowering

IC613474 took only 32.00 days to attain 50 per cent male flowering whereas IC613471 attained 50 per cent male flowering by 40.50 days after sowing. Overall mean among the genotypes for the character was observed as 35.26 days. Swarna Agethi was the control variety which attained 50 per cent male flowering earlier than the other control varieties.

4.2.2.2.4. Days to 50 per cent female flowering

The range of values for days to 50 per cent female flowering was recorded as 34 days (IC613474) and 52 days (IC613471) respectively with a mean among genotypes recorded as 42.68 days after sowing. Among the checks, Poinsette attained 50 per cent female flowering by 38 days after sowing.

Table 30. Shoot and floral characters in 25 cucumber genotypes

S. No.	Accession	Shoot characters		Floral characters										
		VL (cm)	NPB	DFMO	DFFO	DFMF	DFFF	NMFP	NFFP	MFD (cm)	FFD (cm)	NFMA	NFFA	SR
1	IC613481	295.00	9.60	32.50	37.50	35.00	46.50	264.60	8.80	3.88	4.30	3.60	10.20	0.03
2	IC613480	237.50	6.30	30.50	36.00	34.00	39.50	124.80	7.40	4.21	4.04	3.60	4.40	0.06
3	IC618084A	207.50	5.50	29.00	34.00	35.00	43.00	119.70	8.40	4.08	4.23	4.00	8.10	0.07
4	IC595512	222.50	5.95	29.50	31.50	36.50	42.00	181.90	7.30	3.57	3.81	4.20	8.70	0.04
5	IC613484	230.00	5.80	33.50	35.50	37.00	46.50	170.60	7.40	4.12	4.56	3.90	8.00	0.04
6	IC595504	257.50	6.80	37.00	38.50	39.50	47.50	187.70	8.10	3.75	4.28	5.00	8.10	0.05
7	IC613471	290.00	10.00	35.50	47.00	40.50	52.00	236.60	5.70	3.79	4.14	8.50	8.30	0.03
8	IC541367	212.50	5.95	30.00	33.50	38.50	44.00	156.50	7.10	4.33	4.90	6.20	8.00	0.05
9	IC331445	270.00	8.33	36.50	41.50	40.00	47.50	213.50	8.40	4.70	4.92	7.70	9.80	0.04
10	IC613477	265.00	8.15	30.00	37.00	33.00	40.50	275.50	8.80	4.32	5.13	4.40	6.90	0.04
11	IC613476	267.50	6.80	33.00	36.50	34.00	40.50	147.20	7.60	4.25	4.85	3.40	5.80	0.05
12	IC613470	195.00	8.00	28.00	36.00	32.50	44.00	284.40	10.70	4.29	4.62	3.10	4.80	0.04
13	IC469517	232.50	6.65	29.00	33.50	34.00	40.00	218.50	8.10	3.98	4.35	4.20	8.80	0.04
14	IC613479	280.00	7.30	30.50	37.50	33.00	42.00	169.90	8.50	4.34	4.53	4.10	8.90	0.05

VL-Vine length (cm); NPB-Number of primary branches; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50 % male flowering; DFFF-Days to 50 % female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFMA-Node number at which 1st male flower appeared; NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

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Table 30. Shoot and floral characters in 25 cucumber genotypes

		Shoot characters		Floral characters										
S. No.	**Accessions**	**VL (cm)**	**NPB**	**DFMO**	**DFFO**	**DFMF**	**DFFF**	**NMFP**	**NFFP**	**MFD (cm)**	**FFD (cm)**	**NFMA**	**NFFA**	**SR**
15	IC613488	195.00	6.10	32.00	38.50	37.00	48.00	311.00	8.30	3.60	4.19	4.70	8.80	0.03
16	IC595510	222.50	6.47	32.00	34.00	35.50	42.00	91.30	6.80	4.41	4.89	4.30	9.00	0.08
17	IC613474	200.00	5.80	28.00	31.50	32.00	34.00	74.50	8.90	4.09	4.79	3.90	4.60	0.12
18	IC595518	200.00	5.95	26.00	31.00	35.00	38.50	54.70	5.70	3.68	4.63	3.70	8.20	0.11
19	IC613485	270.00	6.60	27.50	38.50	37.50	44.50	168.10	7.50	3.86	4.54	5.10	10.00	0.05
20	IC618083	232.50	7.15	31.50	34.50	34.50	39.50	141.50	8.00	3.85	4.39	3.40	5.80	0.06
21	IC613462	225.00	6.10	31.50	38.50	33.00	41.50	298.30	9.10	4.26	4.55	3.80	8.00	0.03
22	IC595508A	222.50	5.65	32.00	37.50	37.00	41.50	148.30	9.00	3.61	4.32	4.60	6.80	0.06
23	AAUC-2	277.50	8.65	33.00	39.50	35.50	45.50	316.40	9.00	3.98	4.72	4.20	8.00	0.03
24	Poinsette	222.50	5.80	25.50	28.00	32.00	38.00	158.50	9.50	3.63	3.83	3.10	3.80	0.06
25	Swarna Agethi	220.00	6.45	26.50	34.00	30.00	38.50	176.20	8.80	4.24	4.34	3.10	5.80	0.05
	Mean	**238.00**	**6.87**	**30.80**	**36.04**	**35.26**	**42.68**	**187.61**	**8.12**	**4.03**	**4.47**	**4.39**	**7.50**	**0.05**
	Maximum	**295.00**	**10.00**	**37.00**	**47.00**	**40.50**	**52.00**	**316.40**	**10.70**	**4.70**	**5.13**	**8.50**	**10.20**	**0.12**
	Minimum	**195.00**	**5.50**	**25.50**	**28.00**	**30.00**	**34.00**	**54.70**	**5.70**	**3.57**	**3.81**	**3.10**	**3.80**	**0.03**

VL-Vine length (cm); NPB-Number of primary branches; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50 % male flowering; DFFF-Days to 50 % female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFMA-Node number at which 1st male flower appeared; NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

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4.2.2.2.5. Number of male flowers per plant

IC595518 produced only 54.70 male flowers per plant, whereas the highest value of male flowers was exhibited by the control variety AAUC-2 (316.40), which was higher than the genotypes studied. The minimum value among control varieties was observed for Poinsette (158.50).

4.2.2.2.6. Number of female flowers per plant

Number of female flowers per plant was highest in IC613470 (10.70) and lowest in IC595518 (5.70) with a mean of 8.12 among the genotypes. Poinsette produced highest number of female flowers per plant (9.50) among control varieties.

4.2.2.2.7. Male flower diameter

Diameter of male flower was highest in IC331445 (4.70 cm) and lowest in IC595512 (3.57 cm) with an overall mean of 4.03 cm among the genotypes.

4.2.2.2.8. Female flower diameter

IC613477 and IC595512 recorded maximum and minimum values for female flower diameter with values 5.13 cm and 3.81 cm respectively. AAUC-2 recorded highest value for female flower diameter among the control varieties.

4.2.2.2.9. Node number at which first male flower appeared

The mean value for node number at which first male flower appeared was recorded as 4.39 with maximum and minimum values ranging from 3.10 in IC613470 and 8.50 in IC613471 respectively. Poinsette and Swarna Agethi also recorded the lowest value (3.10) for the character among the control varieties.

4.2.2.2.10. Node number at which first female flower appeared

Highest value for node number at which first female flower appeared was observed in IC6134891 (10.20). Poinsette was the control variety, which exhibited lowest value of 3.80 among the control as well as genotypes.

4.2.2.2.11. Sex ratio

Sex ratio was highest in IC613474 (0.12) and lowest in IC613462, IC613481 and the control variety AAUC-2. Highest among control varieties was Poinsette (0.06). The overall mean among genotypes was 0.05.

4.2.2.3. Fruit characters

4.2.2.3.1. Days to first harvest

The mean value for days to first harvest among the genotypes was observed as 50 days with maximum (60 days) recorded in IC613471 and minimum in IC469517 and IC595518 (45 days) respectively. Poinsette, the control variety also performed better by exhibiting low value (45 days) for days to first harvest. AAUC-2 took maximum days (54 days) to initiate harvest (Table 31).

4.2.2.3.2. Days to last harvest

Harvesting prolonged for 89.50 days after sowing in five genotypes namely IC613481, IC595512, IC595504, IC613488 and IC505510. The mean value among the genotypes for the character was 86.00 days. Among controls, Poinsette recorded the highest value of 89.50 days.

4.2.2.3.3. Fruit length

The observations on fruit length ranged from 10.43 cm (IC613470) to 19.57 cm (IC595510) with an overall mean value of 16.34 cm among the genotypes. Swarna Agethi recorded the highest value (18.66 cm) among the check varieties.

Table 31. Fruit characters in 25 cucumber genotypes

Accessions	DFH	DLH	FL (cm)	FD (cm)	NFPP	FW (g)	SCL (cm)	SCW (cm)	PC (cm)
IC613481	50.50	89.50	17.35	4.89	5.00	260.50	14.63	2.97	14.15
IC613480	47.00	80.00	16.72	4.92	6.60	251.50	13.57	3.24	15.08
IC618084A	50.00	87.50	16.45	5.13	3.90	288.00	13.79	3.04	15.03
IC595512	55.00	89.50	13.71	4.92	5.20	199.50	10.58	3.16	15.00
IC613484	46.00	85.00	16.36	4.93	4.30	252.50	13.72	3.21	14.37
IC595504	49.00	89.50	17.47	4.59	4.50	235.50	15.24	2.61	13.70
IC613471	60.00	85.00	17.71	4.65	4.60	226.50	14.26	2.92	14.37
IC541367	56.50	89.50	12.82	5.13	3.80	206.00	10.20	3.26	14.56
IC331445	49.00	87.00	18.98	4.84	3.50	284.00	15.67	2.49	14.79
IC613477	54.00	87.50	18.29	4.88	7.20	281.00	15.61	3.13	14.59
IC613476	47.00	87.50	16.41	5.05	5.50	265.50	13.17	3.20	15.07
IC613470	50.00	80.50	10.43	5.12	5.90	171.00	7.83	3.34	13.19
IC469517	45.00	80.50	15.84	5.32	4.40	237.00	13.01	3.30	15.22
IC613479	52.00	88.00	15.12	5.03	7.10	232.50	12.45	3.24	14.58
IC613488	49.00	85.50	16.41	5.16	5.00	206.50	13.38	3.09	15.05
IC595510	47.50	89.50	19.57	4.87	5.70	282.00	16.88	3.01	15.13
IC613474	46.00	84.00	15.72	4.64	5.90	198.00	13.27	3.19	14.48
IC595518	45.00	74.00	15.56	5.47	3.00	277.00	13.07	3.45	16.21
IC613485	53.50	88.00	18.44	4.83	5.90	270.00	15.72	2.99	14.70
IC618083	51.50	88.00	16.17	5.38	3.80	275.00	12.94	3.37	15.95
IC613462	50.00	87.50	16.37	5.17	4.40	283.00	14.12	2.88	14.55
IC595508A	47.50	84.50	13.38	5.35	6.40	242.00	10.84	3.39	15.37
AAUC-2	54.00	84.00	17.61	4.79	5.20	265.00	15.45	2.93	14.70
Poinsette	45.00	89.50	17.02	4.79	5.10	249.00	14.23	2.83	14.24
Swarna Agethi	50.00	89.00	18.66	4.93	4.90	273.00	15.69	2.90	14.29
Mean	**50.00**	**86.00**	**16.34**	**4.99**	**5.07**	**248.46**	**13.57**	**3.09**	**14.73**
Maximum	**60.00**	**89.50**	**19.57**	**5.47**	**7.20**	**288.00**	**16.88**	**3.45**	**16.21**
Minimum	**45.00**	**74.00**	**10.43**	**4.59**	**3.00**	**171.00**	**7.83**	**2.49**	**13.19**

DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm)

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Table 31. Fruit characters in 25 cucumber genotypes

Accessions	EC (cm)	FT (cm)	YPP (g)	HD	TSS (°Brix)	LWDS (g)	NDS	PedL (cm)
IC613481	15.78	1.09	1302.50	39.00	2.73	18.50	3.30	2.42
IC613480	15.79	0.99	1659.90	33.00	3.42	15.50	2.80	2.13
IC618084A	16.75	1.17	1123.20	37.50	3.30	31.50	9.20	1.57
IC595512	15.93	1.27	1037.40	34.50	3.37	22.00	7.50	1.77
IC613484	15.89	1.14	1085.75	39.00	2.22	23.50	3.20	2.32
IC595504	14.88	1.13	1059.75	40.50	3.69	32.00	7.00	1.79
IC613471	15.30	1.17	1041.90	25.00	2.62	24.50	4.40	2.85
IC541367	16.38	1.19	782.80	36.50	3.12	29.00	5.60	2.51
IC331445	15.17	1.34	994.00	38.00	2.90	29.50	8.10	2.52
IC613477	16.10	1.17	2023.20	33.50	3.40	22.00	2.90	2.07
IC613476	16.34	1.10	1460.25	40.50	2.62	22.00	2.70	2.76
IC613470	15.85	1.08	1008.90	30.50	2.84	21.00	3.50	1.94
IC469517	17.08	1.26	1042.80	35.50	3.25	19.00	3.10	2.02
IC613479	15.92	0.99	1650.75	36.00	2.57	19.00	2.30	2.26
IC613488	16.68	1.10	1032.50	33.00	3.52	20.50	10.30	1.14
IC595510	16.06	1.11	1607.40	42.00	3.22	31.50	8.40	2.17
IC613474	14.72	0.97	1168.20	38.00	2.69	32.50	4.00	2.20
IC595518	17.51	1.22	831.00	29.00	3.29	21.50	4.00	1.75
IC613485	15.63	1.17	1593.00	34.50	2.75	25.00	3.60	2.33
IC618083	16.46	1.32	1045.00	36.50	3.47	36.50	5.80	2.06
IC613462	16.61	1.35	1245.20	37.50	2.70	34.30	14.50	2.20
IC595508A	16.80	1.40	1548.80	37.00	3.62	18.00	10.40	2.05
AAUC-2	15.82	1.20	1378.00	30.00	3.65	32.00	3.70	2.34
Poinsette	15.29	1.24	1269.90	44.50	2.85	32.00	8.40	1.84
Swarna Agethi	15.92	1.10	1337.70	39.00	2.84	31.50	8.70	1.87
Mean	**16.03**	**1.17**	**1253.19**	**36.00**	**3.06**	**25.77**	**5.90**	**2.12**
Maximum	**17.51**	**1.40**	**2023.20**	**44.50**	**3.69**	**36.50**	**14.50**	**2.85**
Minimum	**14.72**	**0.97**	**782.80**	**25.00**	**2.22**	**15.50**	**2.30**	**1.14**

EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP-Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (°Brix); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL-Peduncle length (cm)

4.2.2.3.4. Fruit diameter

Fruit diameter was maximum observed in IC595518 (5.47 cm) and minimum by IC595504 (4.59 cm). The mean value for the character was 4.99 cm. Similar to fruit length, the highest value of fruit diameter was also recorded for Swarna Agethi (4.93 cm).

4.2.2.3.5. Number of fruits per plant

The highest and lowest values for number of fruits per plant were exhibited by IC595518 (3.00) and IC613477 (7.20) respectively. On overall basis, the genotypes produced 5.07 fruits per plant. AAUC-2, the control variety also performed on par with the best genotype by producing 5.20 fruits per plant.

4.2.2.3.6. Fruit weight

The mean fruit weight exhibited by the genotypes was 248.46 g with maximum value observed for IC618084A (288.00 g) and minimum value by IC613470 (171.00 g). Swarna Agethi produced fruits with highest weight (273.00 g) among the check varieties.

4.2.2.3.7. Seed cavity length

Seed cavity length was highest in IC595510 (16.88 cm) as against the lowest value of 7.83 cm observed for IC613470. Swarna Agethi recorded the highest value among the control varieties (15.69 cm).

4.2.2.3.8. Seed cavity breadth

The values observed for seed cavity breadth was 2.49 cm (lowest) for IC331445 and 3.45 cm (IC595518) with a mean value of 3.09 cm among the genotypes.

4.2.2.3.9. Polar circumference

Polar circumference was highest observed in IC595518 (16.21 cm) and lowest in IC613470 (13.19 cm). Maximum and minimum values among the control varieties were 14.70 cm in AAUC-2 and 14.29 cm in Swarna Agethi.

4.2.2.3.10. Equatorial circumference

The fruits of IC595518 expressed highest value for equatorial circumference (17.51 cm). The lowest value of 14.72 cm was exhibited by IC613474. The genotypes had shown a value of 16.03 cm as overall mean for the character. Swarna Agethi recorded the maximum value of 15.92 cm among the control varieties.

4.2.2.3.11. Flesh thickness

The mean value for flesh thickness was observed as 1.17 cm with values ranging from 0.97 cm in 613474 and 1.40 cm in IC595508A. Both Poinsette and AAUC-2 recorded a flesh thickness above 1.00 cm.

4.2.2.3.12. Yield per plant

Highest and lowest yield per plant was exhibited by IC613477 (2023.20 g) and IC541367 (782.80 g) respectively with an overall mean value of 1253.19 g among the genotypes. Among control varieties AAUC-2 recorded the highest yield of 1378.00 g.

4.2.2.3.13. Harvest duration

The range of value observed for harvest duration in genotypes was 25.00 days to 42.00 days in IC613471 and IC595510 respectively with an overall mean of 36.00 days. Maximum harvest duration was exhibited by Poinsette by recording 44.50 days for harvest duration.

4.2.2.3.14. Total soluble solids

TSS was maximum recorded in IC595504 (3.69 ^{o} Brix) and minimum in IC613484 (2.22 ^{o} Brix). The mean value was recorded as 3.06 ^{o} Brix. AAUC-2 had the highest TSS content among control varieties.

4.2.2.3.15. Loss of weight during storage

Maximum weight loss was observed in IC618083 (36.50 g) with mean value of 25.77 g among the genotypes. Loss of weight was minimum in IC613480

(15.50 g). Among check varieties, Poinsette recorded weight loss of 32.00 g, highest value for the character.

4.2.2.3.15. Number of days of storage

The range of values with respect to number of days of storage was 2.30 days (IC613479) to 14.50 days (IC613462) with an overall mean of 5.90 days. Swarna Agethi performed well by exhibiting the storability up to 8.70 days.

4.2.2.3.16. Peduncle length

Peduncle length was maximum in IC613471 and minimum in IC613488. AAUC-2 recorded highest value of 2.34 cm among the control varieties.

4.2.3. Analysis of variance

4.2.3.1. Shoot characters

The results of analysis of variance for shoot characters indicated that the mean sum of squares due to genotypes was significant at one per cent level for vine length and number of primary branches (Table 32).

4.2.3.2. Floral characters

Among the floral characters studied, all the characters except days to first male flower opening and number of female flowers per plant were significantly different at one percent level, with node number at which first female flower appeared significantly different at five per cent level (Table 33).

4.2.3.3. Fruit characters

Analysis of variance for fruit characters revealed that the characters namely days to last harvest and harvest duration were not significantly different between the genotypes. The remaining characters except days to first harvest, number of

Table 32. Analysis of variance for shoot and floral characters in 25 cucumber genotypes

		Mean sum of squares												
		Shoot characters		Floral characters										
Source	**Df**	**VL (cm)**	**NPB**	**DMFO**	**DFFO**	**DFMF**	**DFFF**	**NMFP**	**NFFP**	**MFD**	**FFD**	**NFMA**	**NFFA**	**SR**
Replication	1	722.00	3.86	0.08	42.32	1.62	50.00	1339.55	4.74	0.00	0.07	0.00	3.92	0.00
Treatment	24	1920.83**	3.09**	18.67	29.41**	14.30**	31.58**	10638.88**	2.52	0.18**	0.23**	3.50**	6.60*	0.001**
Error	24	705.33	1.10	13.16	9.99	4.29	10.71	934.52	1.28	0.11	0.09	0.36	2.85	0.00

*- significant at 5 % level; **- significant at 1 % level; Df-Degrees of freedom; VL-Vine length (cm); NPB-Number of primary branches; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFMA-Node number at which 1st male flower appeared; NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

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Table 33. Analysis of variance for the fruit characters in 25 cucumber genotypes

Source	Df	Mean sum of squares								
		DFH	DLH	FL (cm)	FD (cm)	NFPP	FW (g)	SCL (cm)	SCB (cm)	PC (cm)
Replication	1	35.28	0.72	0.73	0.01	0.42	79.38	0.43	0.01	1.09
Treatment	24	29.88*	29.79	8.60**	0.11**	1.55*	1942.66**	8.38**	0.11**	0.80**
Error	24	11.66	24.60	0.50	0.03	0.65	715.05	0.50	0.03	0.29

*- significant at 5 % level; **- significant at 1 % level; Df-Degrees of freedom; DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm)

Source	Df	Mean sum of squares							
		EC (cm)	FT (cm)	YPP (g)	HD	TSS (°Brix)	LWDS (g)	NDS	PedL
Replication	1	0.07	0.02	28084.50	46.08	2.32	99.12	0.01	0.25
Treatment	24	0.90**	0.03**	136996.50*	37.92	0.33**	129.29*	20.21**	0.28**
Error	24	0.32	0.01	60235.57	26.91	0.10	52.62	3.32	0.10

*- significant at 5 % level; **- significant at 1 % level; Df-Degrees of freedom; EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP- Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (°Brix); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

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fruits per plant, yield per plant and loss of weight during storage were significantly different at one per cent level (Table 33).

4.2.4. Organoleptic evaluation

Mean rank scores in 25 promising genotypes are given in Table 34. The maximum Kendall's score for bitterness was observed for IC613471, IC541367 and IC613484, with a score of 14.6, indicating their acceptability for least bitterness and minimum score for IC618084A (10.3). IC595508A with a rank score of 18.07 in crispness secured the highest position whereas IC595510 with a score of 7.93 was the poor performer with respect to crispness. The score for flavour attribute was highest in IC613471 (17.37) and lowest in IC613477 (8.17). However, the cumulative score of 45.63 was observed for IC613480 followed by IC595508A with a cumulative organoleptic score of 45.07. The least cumulative organoleptic score was attained by IC613477 (30.34).

4.2.5. Selection of promising genotypes

In the current experiment also, the focus was limited to major yield contributing characters namely, fruit weight (g), fruit length (cm), fruit diameter (cm), days to first harvest, number of fruits per plant and sex ratio for selecting promising genotypes in addition to storability behaviour and organoleptic qualities.

Table 35 depicts the individual scores observed for different characters, the total score and the cumulative organoleptic score for 25 genotypes evaluated in the present experiment. The minimum score represents the superior performance in terms of the characters considered. Minimum score for days to first harvest was observed for IC613484, IC469517, IC613474 and IC595518, all of them obtained a score of 0.20, with the days to first harvest observed after 45 and 46 days of sowing. IC613471, which exhibited a score of 1.00 (maximum), had recorded its first fruit harvesting by 60 days after sowing.

Table 34. Mean ranks recorded for organoleptic qualities in 25 cucumber genotypes

S. No.	Acc. No.	Bitterness	Crispness	Flavour	Cumulative organoleptic score
1	IC613481	12.57	10.13	9.73	32.43
2	IC613480	13.93	16.97	14.73	45.63
3	IC618084A	10.30	16.00	13.10	39.40
4	IC595512	11.33	16.80	14.03	42.16
5	IC613484	14.60	9.77	12.10	36.47
6	IC595504	12.23	12.53	13.67	38.43
7	IC613471	14.60	12.60	17.37	44.57
8	IC541367	14.60	16.20	12.23	43.03
9	IC331445	13.10	13.57	14.37	41.04
10	IC613477	13.77	8.40	8.17	30.34
11	IC613476	11.77	16.90	14.43	43.10
12	IC613470	13.93	9.47	11.47	34.87
13	IC469517	12.07	9.77	14.03	35.87
14	IC613479	12.83	12.83	10.83	36.49
15	IC613488	13.93	16.57	13.27	43.77
16	IC595510	12.93	7.93	13.07	33.93
17	IC613474	11.97	14.00	14.03	40.00
18	IC595518	13.10	11.77	14.07	38.94
19	IC613485	13.80	15.13	14.33	43.26
20	IC618083	13.40	8.50	9.27	31.17
21	IC613462	13.77	8.60	14.57	36.94
22	IC595508A	13.23	18.07	13.77	45.07
23	AAUC-2	12.70	13.40	14.00	40.10
24	Poinsette	12.67	13.23	12.60	38.50
25	Swarna Agethi	11.87	16.97	10.77	39.61
	Maximum	**14.60**	**18.07**	**17.37**	**45.63**
	Minimum	**10.30**	**7.93**	**8.17**	**30.34**
Kendall's coefficient		**0.08**	**0.23**	**0.10**	

IC505510 and IC595518 recorded the lowest score for fruit length and fruit diameter respectively with scores of 0.08 and 0.11 and length and diameter of 19.57 cm and 5.47 cm respectively. Highest score for fruit weight observed for IC613470 (1.00), has recorded the least value for fruit weight of 171.00 g. IC618084A recorded a score of 0.17 (minimum), for fruit weight had a mean fruit weight of 288 g. Minimum score for number of fruits per plant attained for

IC613477, which yielded 7.20 fruits per plant. IC595518 produced only 3.00 fruits per plant had recorded the highest score for the character.

Table 35. Total and cumulative organoleptic score for 25 cucumber genotypes

S. No.	Accessions	DFH	FL (cm)	FD (cm)	FW (g)	NFPP	LWDS (g)	NDS	SR	TS	COS
1	IC613481	0.50	0.38	0.72	0.42	0.80	0.36	0.14	0.94	4.25	32.43
2	IC613480	0.30	0.54	0.67	0.50	0.50	0.14	0.14	0.50	3.29	45.63
3	IC618084A	0.50	0.58	0.44	0.17	0.50	0.50	0.79	0.44	3.92	39.40
4	IC595512	0.80	0.88	0.67	0.92	0.80	0.36	0.64	0.81	5.87	42.16
5	IC613484	0.20	0.58	0.67	0.50	0.40	0.36	0.21	0.81	3.73	36.47
6	IC595504	0.40	0.38	1.00	0.50	0.40	0.71	0.57	0.81	4.77	38.43
7	IC613471	1.00	0.29	0.94	0.67	0.80	0.36	0.36	1.00	5.62	44.57
8	IC541367	0.90	0.92	0.44	0.83	0.70	0.36	0.86	1.00	6.01	43.03
9	IC331445	0.40	0.13	0.78	0.25	0.60	1.00	0.71	0.81	4.68	41.04
10	IC613477	0.70	0.21	0.72	0.33	0.20	0.36	0.14	0.88	3.54	30.34
11	IC613476	0.30	0.58	0.56	0.33	0.80	0.36	0.14	0.69	3.76	43.10
12	IC613470	0.50	1.00	0.44	1.00	0.80	0.36	0.21	0.88	5.19	34.87
13	IC469517	0.20	0.67	0.22	0.50	0.90	0.29	0.14	0.88	3.79	35.87
14	IC613479	0.50	0.79	0.56	0.58	0.30	0.29	0.14	0.81	3.97	36.49
15	IC613488	0.40	0.58	0.33	0.42	0.80	0.43	0.43	0.81	4.20	43.77
16	IC595510	0.30	0.08	0.72	0.25	0.50	0.57	0.79	0.38	3.59	33.93
17	IC613474	0.20	0.67	0.94	0.92	0.50	0.93	0.29	0.25	4.69	40.00
18	IC595518	0.20	0.71	0.11	0.33	1.00	0.36	0.29	0.13	2.92	38.94
19	IC613485	0.70	0.21	0.83	0.33	0.70	0.36	0.14	0.81	4.09	43.26
20	IC618083	0.50	0.63	0.17	0.33	0.50	0.64	0.43	0.56	3.76	31.17
21	IC613462	0.50	0.58	0.28	0.25	0.40	0.57	1.00	0.81	4.40	36.94
22	IC595508A	0.30	0.92	0.22	0.50	0.40	0.21	0.86	0.50	3.91	45.07
23	AAUC-2	0.70	0.33	0.89	0.33	0.20	0.50	0.29	0.94	4.18	40.10
24	Poinsette	0.20	0.46	0.89	0.50	0.80	0.50	0.79	0.50	4.63	38.50
25	Swarna Agethi	0.50	0.17	0.67	0.33	0.80	0.86	0.79	0.81	4.92	39.61
	Maximum	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**6.01**	**45.63**
	Minimum	**0.20**	**0.08**	**0.11**	**0.17**	**0.20**	**0.14**	**0.14**	**0.13**	**2.92**	**30.34**

DFH- Days to first harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); YPP- Yield per plant (g); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; SR- Sex ratio; TS- Total score; COS-Cumulative organoleptic score

Storage qualities were best expressed in IC613480 with respect to loss of weight during storage, by securing a score of 0.14 and losing a weight of 15.50 g in 2.80 days. IC331445 had recorded the maximum weight loss during storage by losing 29.50 g during storage. Minimum score for number of days of storage was exhibited by IC613481, IC613480, IC613477, IC613476, IC469517, IC613479 and IC613485 with a score of 0.14. These genotypes exhibited the storability of fruits for 3.30, 2.80, 2.90, 2.70, 3.10, 2.30 and 3.60 days. IC613471 and IC541367 scored highest score for sex ratio, and lowest by IC595518. However, the lowest total score was exhibited by IC595518 (2.92), followed by IC613480 (3.29), indicating their superiority in performance for the characters considered.

Six genotypes were selected based on the score and cumulative organoleptic score of selected characters. The scores and ranks obtained for the six genotypes are depicted in Table 36. It was found that Rank I was secured by IC613480, which had recorded a total score of 3.29 and cumulative organoleptic score of 45.63. The sixth rank was secured by IC613476, with a total score of 3.76 and cumulative organoleptic score of 43.10.

The mean values of selected characters for the six genotypes are illustrated in Table 37. It was found that days to first harvest ranged from 47.00 days to 60.00 days among the selected genotypes with a mean of 51.92 days. Minimum days for first harvest were exhibited by IC613476 and maximum by IC613471. Mean fruit length for the selected genotypes was 15.91 cm with maximum and minimum exhibited by IC613485 (18.44 cm) and IC613488 (12.82 cm). Fruit diameter ranged from 4.65 cm (IC613471) to 5.35 cm (IC595508A). Maximum number of fruits of 6.60 was produced by IC613480, whereas minimum by IC613471. IC613488 produced fruits with least mean weight of 206.50 g. Fruits with maximum average weight of 270.00 g was produced by IC613485. Yield per plant was maximum in IC613480 (1659.90 g) and minimum in IC613488 (1032.50 g). IC613480 had recorded the minimum weight loss during storage (15.50 g) whereas weight loss was as high as 25.00 g in IC613485. The fruits of IC613476 could store up to 2.70 days which recorded a weight loss of 22.00 g. Sex ratio ranged from 0.03 (IC613471 and IC613488) to 0.06 (IC613480 and IC595508A). AAUC-2 ranked 10^{th} position in the ranking procedure with a mean yield of 1378.00 g per plant. The accessions selected for hybridization experiment *viz*., IC613476, IC613480 and IC613485 belonged to West Bengal, IC613471 from Arunachal Pradesh, and IC613488 from Mizoram and IC595508A from Tripura.

4.3.1. Development of hybrids

Six parents were crossed in diallel mating fashion without reciprocals to develop 15 hybrid combinations. The list of 15 hybrid combinations and six parents are given in Table 7.

4.3.2. Evaluation of hybrid combinations

4.3.2.1. Qualitative characters

Qualitative characters included fruit blossom end shape, tem end shape, fruit skin texture, fruit shape, fruit skin colour, fruit flesh colour and primary fruit colour. Parents did not differ with respect to fruit blossom end shape, fruit stem end shape, fruit skin texture and fruit flesh colour. The fruits of IC613488, IC613476 and IC595508A possessed oblong ellipsoid shape whereas IC613480, IC613471 and IC613485 possessed elliptical elongate shape. Fruit skin colour was light green in all parents except IC613471 and IC595508A (Table 38).

There was no variability for fruit blossom and stem end shape, as fruits of all hybrid combinations exhibited flattened surface at blossom end and stem end. Fruit skin texture was rough in fruits of all hybrids due to the presence of tubercles or the cell mass remaining at the tubercle position on fruit surface. However, there was variability with respect to fruit shape, fruit skin colour, fruit flesh colour and primary fruit colour.

With respect to fruit shape, five crosses namely IC613488 x IC613471, IC613488 x IC613485, IC613488 x IC595508A, IC613476 x IC595508A and IC613485 x IC595508A possessed oblong ellipsoid shape and remaining all hybrids with elliptical elongate shape. Fruit skin colour varied considerably among hybrids. Seven out of 15 crosses exhibited green colour whereas remaining crosses had light green coloured fruit skin. Flesh colour was white in all hybrids.

Table 36. Scores and ranks for the six genotypes selected as parents

S. No.	Genotypes	DFH	FL (cm)	FD (cm)	FW (g)	NFPP	LWDS (g)	NDS	SR	TS	COS	Rank
1	IC613480	0.30	0.50	0.50	0.54	0.67	0.14	0.14	0.50	3.29	45.63	**I**
2	IC595508A	0.30	0.40	0.50	0.92	0.22	0.21	0.86	0.50	3.91	45.07	**II**
3	IC613471	1.00	1.00	0.67	0.29	0.94	0.36	0.36	1.00	5.62	44.57	**III**
4	IC613488	0.90	0.70	0.83	0.92	0.44	0.36	0.86	1.00	6.01	43.77	**IV**
5	IC613485	0.70	0.70	0.33	0.21	0.83	0.36	0.14	0.81	4.09	43.26	**V**
6	IC613476	0.30	0.80	0.33	0.58	0.56	0.36	0.14	0.69	3.76	43.10	**VI**

DFH-Days to first harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); FW- Fruit weight (g); NFPP- Number of fruits per plant; LWDS- Loss of weight during storage; NDS-Number of days of storage; SR- Sex ratio; TS-Total score; COS-Cumulative organoleptic score

Table 37. Characteristics of six genotypes selected as parents

S. No.	**DFH**	**FL (cm)**	**FD (cm)**	**NFPP**	**FW (g)**	**YPP (g)**	**LWDS (g)**	**NDS**	**SR**
IC613480	47.00	16.72	4.92	6.60	251.50	1659.90	15.50	2.80	0.06
IC595508A	47.50	13.38	5.35	6.40	242.00	1548.80	18.00	10.40	0.06
IC613471	60.00	17.71	4.65	4.60	226.50	1041.90	24.50	4.40	0.03
IC613488	56.50	12.82	5.13	5.00	206.50	1032.50	20.50	10.30	0.03
IC613485	53.50	18.44	4.83	5.90	270.00	1593.00	25.00	3.60	0.05
IC613476	47.00	16.41	5.05	5.50	265.50	1460.25	22.00	2.70	0.05
Mean	**51.92**	**15.91**	**4.99**	**5.67**	**243.67**	**1389.39**	**20.92**	**5.70**	**0.04**
Minimum	**47.00**	**12.82**	**4.65**	**4.60**	**206.50**	**1032.50**	**15.50**	**2.70**	**0.03**
Maximum	**60.00**	**18.44**	**5.35**	**6.60**	**270.00**	**1659.90**	**25.00**	**10.40**	**0.06**

DFH-Days to first harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); FW- Fruit weight (g); NFPP- Number of fruits per plant; LWDS- Loss of weight during storage; NDS-Number of days of storage; SR- Sex ratio

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Four crosses (IC613480 x IC613476, IC613488 x IC613476, IC613488 x IC613471 and IC613471 x IC595508A) possessed green colour for primary fruits whereas the remaining hybrids had light green colour.

Table 38. Qualitative characters in hybrids and parents

S. No	Cross	FBES	FSES	FST	FS	FSC	FFC	PFC
1	IC613480×IC613488	3	3	3	1	3	1	3
2	IC613480×IC613476	3	3	3	1	3	1	4
3	IC613480×IC613471	3	3	3	1	4	1	3
4	IC613480×IC613485	3	3	3	1	3	1	3
5	IC613480×IC595508A	3	3	3	1	4	1	3
6	IC613488×IC613476	3	3	3	1	3	1	4
7	IC613488×IC613471	3	3	3	2	4	1	4
8	IC613488×IC613485	3	3	3	2	3	1	3
9	IC613488×IC595508A	3	3	3	2	4	1	3
10	IC613476×IC613471	3	3	3	1	3	1	3
11	IC613476×IC613485	3	3	3	1	3	1	3
12	IC613476×IC595508A	3	3	3	2	3	1	3
13	IC613471×IC613485	3	3	3	1	4	1	3
14	IC613471×IC595508A	3	3	3	1	4	1	4
15	IC613485×IC595508A	3	3	3	2	4	1	3
S. No.	**Parents**							
1	IC613480	3	3	3	1	3	1	3
2	IC613488	3	3	3	2	3	1	3
3	IC613476	3	3	3	2	3	1	3
4	IC613471	3	3	3	1	4	1	4
5	IC613485	3	3	3	1	3	1	3
6	IC595508A	3	3	3	2	4	1	3

FBES-Fruit blossom end shape; FSES- Fruit stem end shape; FST-Fruit skin texture; FS-Fruit shape; FSC-Fruit skin colour; FFC-Fruit flesh colour; PFC-Primary fruit colour

4.3.2.2. Quantitative characters

4.3.2.2.1. Shoot characters

4.3.2.1.1. Vine length

IC613480 x IC613485 and IC613488 x IC595508A exhibited maximum (357.20 cm) and minimum (227.67 cm) values for vine length among hybrids. The mean vine length among hybrids was 301.39 cm (Table 39). Among the parents, maximum and minimum vine lengths were exhibited by IC613471 (342.87 cm) and IC595508A (233.07 cm) respectively with a mean value among parents with a value of 284.56 cm (Table 40). A mean vine length of 236.67 cm was observed for the control variety AAUC-2.

4.3.2.2.1.2. Number of primary branches

Maximum number of primary branches was produced by IC613476 x IC613485 (12.33) and minimum branches by IC613488 x IC595508A (7.27). The mean value among hybrids was 10.62. Number of primary branches was maximum in C613471 (11.33) and minimum in IC595580A with a mean of 9.93 among the parents.

4.3.2.2.2. Floral characters

4.3.2.2.2.1. Days to first male flower opening

The hybrid IC613471 x IC595508A and IC613488 x IC613476 took 29.40 days and 34.93 days for first male flower opening (Table 39). Among the parents, IC613488 took 34.93 days after sowing to develop the first male flower whereas IC613485 took only 28.93 days for the first opening of male flowers. The mean value for the character was 32.21 days and 31.40 days after sowing for parents and hybrids respectively (Table 40). However, the standard check AAUC-2 took only 29.27 days for its first male flower opening.

4.3.2.2.2.2. Days to first female flower opening

IC613485 x IC595508A recorded the minimum value (37.87 days) for days to first female flower opening whereas IC613471 x IC613485 recorded the maximum value (43.93 days). The mean value for the character among hybrids was 40.80 days. AAUC-2 took 39.07 days for the character. Days to first female flower opening were delayed (47.93 days) in IC613471 with mean days of 41.40 among the parents. IC613480 took only 38.87 days for the first female flower to open.

Table. 39. Shoot and floral characters in hybrids

		Shoot characters		Floral characters										
S. No	Hybrids	NPB	VL (cm)	DFMO	DFFO	DFMF	DFFF	NMFP	NFFP	MFD (cm)	FFD (cm)	NFMA	NFFA	SR
1	IC613480 x IC613488	10.20	294.73	30.00	38.00	39.00	43.00	206.20	13.13	3.88	3.81	3.93	5.93	0.06
2	IC613480 x IC613476	10.47	285.20	32.80	41.00	38.33	46.33	157.73	11.93	4.31	4.25	3.40	6.80	0.08
3	IC613480 x IC613471	11.47	331.40	31.33	42.60	40.33	46.00	127.00	14.40	3.89	4.19	5.07	8.13	0.11
4	IC613480 x IC613485	11.07	357.20	31.13	40.73	42.00	44.67	213.87	11.33	4.05	4.13	4.07	5.20	0.06
5	IC613480 x IC595508A	10.33	308.53	32.00	39.93	39.33	42.67	90.53	13.53	4.05	3.77	4.93	6.40	0.15
6	IC613488 x IC613476	10.27	260.47	34.93	43.27	40.00	46.00	162.60	11.07	4.17	3.88	3.27	6.53	0.07
7	IC613488 x IC613471	11.13	315.33	30.53	43.27	40.33	47.00	145.00	11.60	4.00	4.10	4.80	5.80	0.08
8	IC613488 x IC613485	11.07	328.73	32.33	41.80	40.33	47.00	199.47	10.60	3.90	3.93	4.93	6.07	0.05
9	IC613488 x IC595508A	7.27	227.67	31.93	39.00	37.67	45.67	60.87	10.60	3.63	4.20	3.67	6.13	0.18
10	IC613476 x IC613471	11.53	301.67	31.80	42.87	41.33	46.67	144.47	11.73	4.25	4.47	5.33	6.87	0.08
11	IC613476 x IC613485	12.33	342.53	29.73	39.87	39.67	46.33	154.60	12.40	4.21	4.23	4.80	7.00	0.08
12	IC613476 x IC595508A	9.87	279.87	29.60	38.00	36.67	47.33	84.07	12.67	4.16	4.05	3.80	7.73	0.16
13	IC613471 x IC613485	11.73	350.67	32.27	43.93	40.67	47.33	191.53	8.00	4.07	3.89	6.40	6.73	0.04
14	IC61371 x IC595508A	10.20	267.87	29.40	39.80	41.00	46.33	101.73	12.00	3.99	4.00	5.00	6.80	0.12
15	IC613485 x IC595508A	10.40	268.93	31.27	37.87	37.33	46.00	76.93	12.53	3.61	3.75	4.67	5.40	0.17
	Mean	**10.62**	**301.39**	**31.40**	**40.80**	**39.60**	**45.89**	**141.11**	**11.84**	**4.01**	**4.04**	**4.54**	**6.50**	**0.10**
	Maximum	**12.33**	**357.20**	**34.93**	**43.93**	**42.00**	**47.33**	**213.87**	**14.40**	**4.31**	**4.47**	**6.40**	**8.13**	**0.18**
	Minimum	**7.27**	**227.67**	**29.40**	**37.87**	**36.67**	**42.67**	**60.87**	**8.00**	**3.61**	**3.75**	**3.27**	**5.20**	**0.04**
	C.D. 5%	2.39	54.80	2.27	4.82	3.10	3.11	35.70	2.51	0.29	0.44	1.03	1.34	0.02

VL-Vine length (cm); NPB-Number of primary branches; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFMA-Node number at which 1st male flower appeared; NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

4.3.2.2.2.3. Days to 50 per cent male flowering

The hybrids showed a mean value of 39.60 days for the character. IC613476 x IC595508A exhibited the minimum value for days to 50 per cent male flowering with a value of 36.67 days whereas IC613480 x IC613485 exhibited maximum number of days (42.00 days). AAUC-2 exhibited a value of 40.67 days. Fifty per cent male flowering was achieved by 36.67 days in IC613476 (minimum) and 43.00 days in IC613471 (maximum) among parents. The mean over parents was 40.44 days after sowing.

4.3.2.2.2.4. Days to 50 per cent female flowering

IC613480 x IC595508A had recorded days for attaining 50 per cent female flowering whereas, two hybrid combinations namely IC613471 X IC613485 and IC613476 x IC595508A took the maximum days (47.33 days) among hybrids, with a mean of 45.89 days. AAUC-2, the check variety took 40.67 days for achieving 50 % female flowering. Among parents, maximum and minimum days for attaining 50 per cent female flowering were exhibited by IC613471 (53.33 days) and IC613480 (42.33 days) respectively. The overall mean among parents is 47.22 days for the character.

4.3.2.2.2.5. Number of male flowers per plant

As low as 60.87 male flowers were produced by the hybrid IC613488 x IC595508A, whereas IC613480 x IC613485 produced 213.87 male flowers. The mean values for number of male flowers among parents and hybrids were 156.02 and 141.11 respectively. The parents produced on an average 156.02 male flowers per plant with minimum number of flowers produced by IC595508A (70).

4.3.2.2.2.6. Number of female flowers per plant

Hybrid IC613480 x IC613471 produced the maximum number (14.40) of female flowers with a mean of 11.84 female flowers among hybrids. AAUC-2 produced 7.80 female flowers.

Table 40. Shoot and floral characters in parents

	Parents										
Characters	**IC613480**	**IC613488**	**IC613476**	**IC613471**	**IC613485**	**IC595508A**	**Mean**	**Maximum**	**Minimum**	**AAUC-2**	**C.D. (5%)**
NPB	10.53	9.60	10.33	11.33	10.33	7.47	**9.93**	**11.33**	**7.47**	9.20	2.39
VL (cm)	303.53	268.80	244.87	342.87	314.20	233.07	**284.56**	**342.87**	**233.07**	236.67	54.80
DFMO	29.87	34.93	32.47	34.73	28.93	32.33	**32.21**	**34.93**	**28.93**	29.27	2.27
DFFO	38.87	42.40	39.80	47.93	40.00	41.20	**41.70**	**47.93**	**38.87**	39.07	4.82
DFMF	40.67	40.67	36.67	43.00	41.00	40.67	**40.44**	**43.00**	**36.67**	40.67	3.10
DFFF	42.33	47.33	47.67	53.33	46.33	46.33	**47.22**	**53.33**	**42.33**	44.33	3.11
NMFP	175.00	210.20	182.53	192.47	105.93	70.00	**156.02**	**210.20**	**70.00**	150.73	35.70
NFFP	9.93	11.13	11.67	8.13	12.27	8.87	**10.33**	**12.27**	**8.13**	7.80	2.51
MFD (cm)	4.22	4.11	3.93	3.82	4.03	3.75	**3.97**	**4.22**	**3.75**	3.97	0.29
FFD (cm)	4.03	3.87	3.63	3.90	4.12	3.91	**3.91**	**4.12**	**3.63**	4.03	0.44
NFMA	4.20	3.47	3.80	6.67	4.27	3.60	**4.33**	**6.67**	**3.47**	3.53	1.03
NFFA	6.60	6.13	6.33	8.60	6.20	3.47	**6.22**	**8.60**	**3.47**	4.67	1.34
SR	0.06	0.06	0.07	0.04	0.12	0.13	**0.08**	**0.13**	**0.04**	0.05	0.02

VL-Vine length (cm); NPB-Number of primary branches; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFMA-Node number at which 1st male flower appeared; NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

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IC613485 produced the maximum number of female flowers (12.27) with mean female flowers of 10.33 among parents. Minimum number of female flowers was produced by IC613471.

4.3.2.2.2.7. Male flower diameter

Male flower diameter was maximum in IC613480 (4.22 m) and IC613480 x IC613476 (4.31 cm) among parents and hybrids respectively with a mean value of 3.97 cm and 4.31 cm respectively.

4.3.2.2.2.8. Female flower diameter

IC613485 x IC595508A and IC613476 x IC613471 recorded minimum and maximum values for the character among hybrids. IC613476 and IC613485 recorded minimum (3.63 cm) and maximum (4.01 cm) values respectively for female flower diameter among parents.

4.3.2.2.2.9. Node number at which first male flower appeared

Hybrids develop male flowers at a mean nodal position of 4.54 with maximum and minimum nodes reported in IC613471 x IC613485 and IC613488 x IC613476 with values 6.40 and 3.27 respectively. AAUC-2 developed male flowers at a nodal position of 3.53. The minimum and maximum values with respect to the character were 3.47 and 6.67 in IC613488 and IC613471 respectively among parents. On average, the parents produce male flowers at a nodal position of 4.33.

4.3.2.2.2.10. Node number at which first female flower appeared

Maximum value for node number at which first female flower appeared was exhibited by the hybrid combination IC613480 x IC613471 (8.13), whereas IC613480 x IC613485produced female flowers at a nodal position of 5.20 from the base. IC595508A produced female flowers at a nodal position of 3.47 from the base where as the highest value for node number was exhibited by IC613471

(8.60). The mean value for the character among parents was 6.22 among the parents.

4.3.2.2.2.11. Sex ratio

Sex ratio among parents and hybrids was 0.13 and 0.18 in IC505508A and IC613488 x IC613485 respectively. Sex ratio as low as 0.04, was exhibited by IC613471 and IC613471x IC613485 among parents and hybrids respectively. Mean among parents and hybrids was 0.08 and 0.10 respectively.

4.3.2.2.3. Fruit characters

4.3.2.2.3.1. Days to first harvest

First fruit harvest was done on 43.00 days after sowing in IC613480 xIC613488 whereas IC613471 x IC613485 was delayed in first fruit harvest by recording a value of 50.67 days. The mean days for first fruit harvest among hybrids were 46.60 days after sowing. Fruit harvest was started on 44.67 days after sowing in AAUC-2 (Table 41).

Parents exhibited a mean value of 47.39 days for the character, with minimum and maximum days by IC613485 (44.00 days) and IC613471 (55.33 days) respectively.

4.3.2.2.3.2. Days to last harvest

IC613476 x IC613485 and IC613476 x IC595508A recorded minimum value (76.67 days) for days to last harvest whereas IC613471 x IC613485 recorded the maximum value of 86.33 days with a mean value of 81.11 days among the hybrids. Harvesting was extended up to 89.93 days after sowing in IC613471 (maximum) whereas IC613480 gave fruits up to 76.67 days (minimum) only. The mean value among parents for the character was 80.06 days.

Table 41. Fruit characters of hybrids and parents

Hybrids	DFH	DLH	FL (cm)	FD (cm)	NFPP	FW (g)	SCL (cm)	SCB (cm)	PC (cm)
IC613480 x IC613488	43.00	83.67	14.97	4.50	9.67	194.00	12.47	3.03	12.60
IC613480 x IC613476	45.67	86.00	16.23	4.39	8.85	188.00	13.27	2.92	11.73
IC613480 x IC613471	47.33	86.00	17.07	4.14	11.43	189.33	14.31	2.64	11.18
IC613480 x IC613485	47.33	82.00	17.01	4.17	9.81	193.33	14.63	2.65	10.55
IC613480 x IC595508A	46.00	85.67	16.15	4.65	10.47	220.33	13.89	3.17	13.52
IC613488 x IC613476	48.33	80.00	12.09	4.60	9.00	173.33	9.70	3.25	13.93
IC613488 x IC613471	48.33	78.33	13.57	4.45	8.90	180.67	11.15	2.97	11.85
IC613488 x IC613485	47.67	78.67	15.06	4.63	7.86	202.33	12.65	3.67	11.80
IC613488 x IC595508A	46.00	80.33	12.23	4.83	6.81	186.33	9.99	3.50	12.66
IC613476 x IC613471	49.00	77.67	17.84	4.55	8.41	224.00	14.53	2.71	12.19
IC613476 x IC613485	45.33	76.67	16.26	4.23	8.85	207.33	13.55	2.70	12.41
IC613476 x IC595508A	44.67	76.67	15.31	4.61	8.76	205.33	12.83	3.09	11.49
IC613471 x IC613485	50.67	86.33	16.95	4.09	6.19	170.00	13.97	2.51	10.54
IC613471 x IC595508A	44.33	81.67	15.97	4.36	9.55	177.33	12.13	3.41	11.31
IC613485 x IC595508A	45.33	77.00	15.10	4.75	9.57	195.33	12.58	4.77	10.61
Mean	**46.60**	**81.11**	**15.45**	**4.46**	**8.94**	**193.80**	**12.78**	**3.13**	**11.89**
Maximum	**50.67**	**86.33**	**17.84**	**4.83**	**11.43**	**224.00**	**14.63**	**4.77**	**13.93**
Minimum	**43.00**	**76.67**	**12.09**	**4.09**	**6.19**	**170.00**	**9.70**	**2.51**	**10.54**
Parents									
IC613480	44.00	76.67	16.35	4.36	7.47	193.00	14.19	2.65	11.77
IC613488	48.33	80.67	12.06	4.69	8.95	166.67	10.11	3.13	12.40
IC613476	45.67	78.33	12.35	4.79	7.75	191.15	9.56	3.21	14.29
IC613471	55.33	89.33	17.01	3.74	6.57	192.67	13.65	2.53	12.74
IC613485	44.00	77.00	16.76	4.19	8.86	187.33	14.30	2.71	10.85
IC595508A	47.00	78.33	12.40	4.84	7.05	171.33	10.85	3.06	12.46
Mean	**47.39**	**80.06**	**14.49**	**4.43**	**7.78**	**183.69**	**12.11**	**2.88**	**12.42**
Maximum	**55.33**	**89.33**	**17.01**	**4.84**	**8.95**	**193.00**	**14.30**	**3.21**	**14.29**
Minimum	**44.00**	**76.67**	**12.06**	**3.74**	**6.57**	**166.67**	**9.56**	**2.53**	**10.85**
AAUC-2	44.67	73.33	16.49	4.11	7.42	186.67	13.87	2.65	11.66
C.D. 5%	4.32	4.87	1.34	0.49	1.72	23.05	1.22	0.56	1.38

DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP-Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm)

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4.3.2.2.3.3. Fruit length

High variability was observed in fruit length. Among hybrids, highest fruit length was exhibited by IC613476 x IC613471 (17.84 cm) whereas lowest value by IC613488 x IC613476 (12.09 cm). The mean fruit length among hybrids was 15.45 cm. The fruits of AAUC-2, the standard check exhibited a fruit length of 16.49 cm. Fruit length of 17.01 cm was exhibited by the parent IC613471 (maximum) and 12.06 cm by IC613488 (minimum).The average fruit length among parents was 14.49 cm.

Table 41. Fruit characters in hybrids and parents

Hybrids	EC (cm)	FT (cm)	YPP (g)	HD	TSS (°Brix)	LWDS (g)	NDS	PedL (cm)
IC613480 x IC613488	13.64	0.55	1875.33	40.67	3.67	11.67	3.27	2.71
IC613480 x IC613476	14.27	0.63	1664.43	40.33	3.37	11.67	2.93	3.46
IC613480 x IC613471	13.25	0.65	2163.45	38.67	3.00	15.00	3.73	3.41
IC613480 x IC613485	13.37	0.70	1896.60	34.67	3.13	7.67	2.73	3.50
IC613480 x IC595508A	14.89	0.81	2307.63	39.67	3.47	11.33	4.07	2.63
IC613488 x IC613476	14.64	0.65	1559.42	31.67	3.43	13.67	3.07	3.57
IC613488 x IC613471	14.96	0.63	1608.54	30.00	3.33	12.67	4.27	3.09
IC613488 x IC613485	14.84	0.65	1589.67	31.00	2.50	10.33	3.73	2.72
IC613488 x IC595508A	15.83	0.83	1268.93	34.33	4.37	11.33	6.67	2.08
IC613476 x IC613471	13.88	0.70	1884.59	28.67	3.07	14.80	3.00	3.39
IC613476 x IC613485	13.93	0.61	1835.59	31.33	2.77	10.73	3.87	3.63
IC613476 x IC595508A	14.57	0.66	1798.04	32.00	3.30	11.00	4.40	3.28
IC613471 x IC613485	13.02	0.56	1051.73	35.67	2.93	12.87	3.27	3.72
IC613471 x IC595508A	14.54	0.62	1694.12	37.33	3.77	15.00	6.47	2.81
IC613485 x IC595508A	14.96	0.71	1869.99	31.67	2.63	10.00	3.33	2.52
Mean	**14.31**	**0.66**	**1737.87**	**34.51**	**3.25**	**11.98**	**3.92**	**3.10**
Maximum	**15.83**	**0.83**	**2307.63**	**40.67**	**4.37**	**15.00**	**6.67**	**3.72**
Minimum	**13.02**	**0.55**	**1051.73**	**28.67**	**2.50**	**7.67**	**2.73**	**2.08**
Parents								
IC613480	13.47	0.57	1442.35	32.67	3.00	12.00	3.00	3.53
IC613488	14.81	0.54	1492.22	32.33	3.67	17.00	4.20	2.64
IC613476	15.49	0.74	1481.39	32.67	3.97	10.00	3.47	4.21
IC613471	13.26	0.68	1265.82	34.00	3.33	29.00	4.87	3.52
IC613485	13.70	0.49	1659.15	33.00	3.13	12.67	2.13	3.47
IC595508A	15.52	0.73	1207.90	31.33	3.57	15.33	6.47	2.28
Mean	**14.37**	**0.62**	**1424.81**	**32.67**	**3.44**	**16.00**	**4.02**	**3.27**
Maximum	**15.52**	**0.74**	**1659.15**	**34.00**	**3.97**	**29.00**	**6.47**	**4.21**
Minimum	**13.26**	**0.49**	**1207.90**	**31.33**	**3.00**	**10.00**	**2.13**	**2.28**
AAUC-2	13.09	0.58	1385.69	28.67	3.53	9.67	3.60	2.64
C.D. 5%	1.21	0.16	445.60	4.51	0.45	4.12	1.10	0.69
C.D. 1%	1.62	0.22	595.74	6.03	0.60	5.51	1.47	0.92

EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP- Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (°Brix); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

4.3.2.2.3.4. Fruit diameter

IC613488 x IC595508A and IC613471 x IC613485 exhibited maximum and minimum values for fruit diameter with values of 4.83 cm and 4.09 cm respectively. The mean value for fruit diameter among the hybrids was 4.46 cm. Maximum and minimum values for fruit diameter were exhibited by the parents namely IC595508A (4.84 cm) and IC613471 (3.74 cm) ,respectively, with a mean value of 4.43 cm .

4.3.2.2.3.5. Number of fruits per plant

IC613480 x IC613471, the highest scorer for number of fruits per plant produced 11.43 fruits with a mean number of 8.94 fruits among hybrids. Minimum number of fruits of 6.19 was produced by IC613471 x IC613485. AAUC-2, the standard check produced 7.42 fruits per plant. IC613488 produced the maximum value for number of fruits per plant (8.95) whereas IC613471 produced only 6.57 fruits. The mean number of fruits produced by the parents was 7.78.

4.3.2.2.3.6. Fruit weight

The range of fruit weight in hybrids was 170.00 g in IC613471 x IC613485 (minimum) and 224.00 g in IC613476 x IC613471 (maximum), with a mean fruit weight of 193.80 g among hybrids. The mean weight of fruits of AAUC-2 was 186.67 g. Among parents, fruit weight ranged from 166.67 g (IC613488) to 193.00 g in IC613480. The mean fruit was recorded as 183.69 g among parents.

4.3.2.2.3.7. Seed cavity length

The crosses IC613480 x IC613485 and IC613488 x IC613476 recorded maximum (14.63 cm) and minimum (9.70 cm) values respectively, for seed cavity length among the hybrids. Maximum seed cavity length was expressed by IC613485 (14.30 cm) whereas minimum by IC613476 (9.56 cm), among parents.

4.3.2.2.3.8. Seed cavity breadth

Among hybrids, maximum seed cavity breadth observed for IC613485 x IC595508A (4.77 cm) and minimum by IC613471 x IC613485 (2.51 cm), with a mean value of 3.13 cm. Seed cavity breadth ranged from 2.53 cm in IC613471 and 3.21 cm in IC613476. The mean value among parents was 2.88 cm.

4.3.2.2.3.9. Polar circumference

IC613488 x IC613476 and IC613471 x IC613485 recorded maximum and minimum values for polar circumference among hybrids with values 13.93 cm and 10.54 cm, respectively. Polar circumference ranged from 10.85 cm (613485) to 14.29 cm (IC613476) with a mean value of 12.42 cm among parents.

4.3.2.2.3.10. Equatorial circumference

The range of values for the character among hybrids was 13.02 cm and 15.83 cm in IC613471 x IC613485 and IC613488 x IC595508A, respectively. AAUC-2 recorded a mean equatorial circumference of 13.09 cm. Maximum and minimum values for equatorial circumference were exhibited by IC595508A (15.52 cm) and IC613471 (13.26 cm), respectively with a mean value of 14.37 cm among the parents.

4.3.2.2.3.11. Flesh thickness

The mean flesh thickness exhibited by the hybrids was 0.66 cm with maximum and minimum values exhibited by IC613488 x IC595508A (0.83 cm) and IC613480 x IC613488 (0.55 cm). Among the parents, flesh thickness was maximum in IC613476 with a value of 0.74 cm and minimum in IC613485 (0.49 cm). Mean flesh thickness was 0.62 cm.

4.3.2.2.3.12. Yield per plant

Among hybrids, the highest yielder was IC613480 x IC595508A with a mean yield of 2307.63 g per plant whereas lowest yield was exhibited by

IC613471 x IC613485 (1051.73 g per plant). The mean yield of the control variety, AAUC-2 was 1385.69 g per plant. Maximum yielder among the parents was IC613485 (1659.15 g per plant) whereas minimum yield was IC595508A (1207.90 g per plant). Mean yield among parents was 1424.81 g per plant.

4.3.2.2.3.13. Harvest duration

Maximum harvest duration among hybrids was observed for IC613480 x IC613488 (40.67 days) and minimum by IC613476 x IC613471 (28.67 days). The mean value for harvest duration was 34.51 days among hybrids. Harvest duration was maximum in IC613471 (34.00 days) and minimum in IC595508A (31.33 days) with an average of 32.67 days among parents.

4.3.2.2.3.14. TSS

Maximum TSS was recorded in IC613476 (3.97° Brix) among parents and IC613488 x IC595508A (4.37° Brix) among hybrids. The mean values among parents and hybrids were 3.44° Brix and 3.25°Brix respectively.

4.3.2.2.3.15. Loss in weight during storage

Loss of weight during storage ranged from 7.67 g in IC613480 x IC613485 to 15.00 g in IC613480 x IC613471 and IC613471 x IC595508A. Hybrids exhibited a mean loss of weight of 11.98 g on storage whereas mean weight loss in parents was 9.67 g. During storage, loss of weight was maximum in IC613471 (29.00 g) and minimum in IC613476 (10.00 g) with a mean of 16.00 g among parents.

4.3.2.2.3.16. Number of days of storage

Hybrids exhibited a mean storage days of 3.92 days with maximum storage days observed in IC613488 x IC595508A (6.67 days) and minimum in IC613480 x IC613485 (2.73 days). Parental genotypes could store for 4.02 days on an average with maximum and minimum days of storage exhibited by IC595508A and IC613485 with values 6.47 days and 2.13 days respectively.

4.3.2.2.3.17. Peduncle length

IC613471 x IC613485 and IC613488 x IC595508A exhibited maximum (3.72 cm) and minimum (2.08 cm) values of peduncle length in fruits respectively. Among parents the range of values with respect to peduncle length was 2.28 cm and 4.21 cm in IC595508A and IC613476 respectively.

4.3.2.3. Analysis of variance

The analysis of variance for shoot characters, floral characters and fruit characters was undertaken.

4.3.2.3.1. Shoot characters

The results of analysis of variance for shoot characters indicated that the mean sum of squares due to genotypes were significant at one per cent level for vine length among parents as well as among the hybrids. Number of primary branches differed between treatments, though did not differ significantly between parents and between hybrids (Table 42).

4.3.2.3.2. Floral characters

Among floral characters, all the characters except female flower diameter differed significantly between treatments at one per cent level of significance, with days to first female flower opening at five per cent level. Significant differences among hybrids were observed for characters namely days to first male flower opening, days to 50 per cent male flowering, number of male and female flowers per plant, diameter of male flower, node number at which first male and female flower appeared and sex ratio (Table 42).

Table 42. Analysis of variance for shoot and floral characters in parents and hybrids

Source	Df	Mean sum of squares					
		VL (cm)	NPB	DMFO	DFFO	DFMF	DFFF
Replicates	2.00	100.95	1.75	2.80	4.36	10.21	1.78
Treatments	20.00	4427.11**	4.46**	9.39**	17.75*	8.62**	14.82**
Parents	5.00	5468.21**	5.30	18.06**	32.47**	12.76**	37.82**
Hybrids	14.00	4111.35**	4.04	6.36**	13.00	7.10*	6.03
Parent *Vs*.Hybrids	1.00	3642.25	6.10	8.37*	10.52	9.17	22.86*
Error	40.00	1118.83	2.21	1.90	8.14	3.59	3.71

Source	Df	Mean sum of squares						
		NMFP	NFFP	MFD	FFD	NFMA	NFFA	SR
Replicates	2.00	175.44	7.34	0.04	0.01	0.90	0.52	0.00
Treatments	20.00	7609.89**	8.15**	0.11**	0.12	2.56**	3.39**	0.005**
Parents	5.00	9141.09**	7.98*	0.10**	0.08	4.22**	8.05**	0.003**
Hybrids	14.00	7402.28**	6.712**	0.13**	0.13	2.11**	1.90**	0.006**
Parent *Vs*.Hybrids	1.00	2860.38*	29.01**	0.02	0.22	0.54	1.01	0.006**
Error	40.00	489.71	2.36	0.03	0.07	0.39	0.67	0.00

Df-Degrees of freedom; *- significant at 5 % level; **- significant at 1 % level; VL-Vine length (cm); NPB-Number of primary branches; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFMA-Node number at which 1st male flower appeared; NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

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Table 43. Analysis of variance for fruit characters among parents and hybrids

Source	Df	DFH	DLH	FL (cm)	FD (cm)	NFPP	FW (g)	SCL (cm)	SCB (cm)	PC (cm)
Replicates	2.00	5.73	12.00	0.27	0.01	0.12	354.80	0.20	0.23	0.74
Treatments	20.00	22.49**	45.79**	11.19**	0.25**	5.20**	699.38	8.75**	0.78**	3.34**
Parents	5.00	54.06**	67.92**	17.92**	0.54**	2.78*	407.17	14.16**	0.24	3.89**
Hybrids	14.00	12.25	40.13**	8.73**	0.16	5.19**	759.85	7.03**	0.97**	3.12**
Parent *Vs*. Hybrids	1.00	8.00	14.33	11.97**	0.01	17.50**	1313.87*	5.70**	0.82*	3.58*
Error	40.00	7.10	9.10	0.65	0.08	1.12	192.47	0.53	0.12	0.71

Df- Degrees of freedom; *- significant at 5 % level; **- significant at 1 % level; DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm)

Contd...

Table 43. Analysis of variance for fruit characters among parents and hybrids

Source	Df	EC (cm)	FT (cm)	YPP (g)	HD	TSS (°Brix)	LWDS (g)	NDS	PedL (cm)
Replicates	2.00	1.33	0.00	13093.59	4.11	0.03	16.38	0.24	0.04
Treatments	20.00	2.06**	0.02*	260626.11**	36.42**	0.60**	54.27**	4.70**	0.89**
Parents	5.00	3.15**	0.03*	88478.83	2.27	0.39**	140.13**	6.98**	1.45**
Hybrids	14.00	1.82**	0.02	267202.06**	48.09**	0.68**	12.66*	4.21**	0.72**
Parent *Vs*. Hybrids	1.00	0.06	0.02	1029298.94**	43.74*	0.49*	207.55**	0.13	0.38
Error	40.00	0.53	0.01	75511.30	7.71	0.07	5.96	0.46	0.18

Df-Degrees of freedom;*- significant at 5 % level; **- significant at 1 % level; EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP- Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (%); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

4.3.2.3.3. Fruit characters

All the characters except fruit weight were significantly different at one per cent level except flesh thickness which was significantly different at five per cent level among the treatments. Days to first harvest, fruit diameter, fruit weight and flesh thickness are the characters which did not differ significantly among the hybrids (Table 43).

4.3.2.4. Combining ability

4.3.2.4.1. Analysis of variance for combining ability

4.3.2.4.1.1. Shoot characters

The results of analysis of variance for general and specific combining ability indicated that mean sum of squares for GCA were significantly different for vine length and number of primary branches at one per cent level. However, the mean sum of squares for SCA was not significant for these characters (Table 44).

4.3.2.4.1.2. Floral characters

Among floral characters, all the characters except number of female flowers per plant and female flower diameter were not significantly different with respect to GCA. However, Days to first female flower opening, days to 50 per cent male and female flowering and node number at which first male flower appeared did not differ significantly for SCA. The remaining characters were significantly different at one per cent level (Table 44).

4.3.2.4.1.3. Fruit characters

All the fruit characters except number of fruits per plant significantly differed at one per cent for GCA, whereas days to first harvest, fruit diameter, equatorial circumference and flesh thickness did not differ for SCA. Remaining characters, differed significantly at one per cent level with respect to SCA (Table 44).

Table 44. Analysis of variance for combining ability in shoot, floral and fruit characters

Mean sum of squares				Mean sum of squares			
Source	**GCA**	**SCA**	**Error**	**Source**	**GCA**	**SCA**	**Error**
Df	**5.00**	**15.00**	**40.00**	**Df**	**5.00**	**15.00**	**40.00**
Shoot characters				**Fruit characters**			
VL (cm)	4378.62**	508.06	372.94	DFH	17.55**	4.14	2.37
NPB	4.33**	0.54	0.74	DLH	24.62**	12.14**	3.03
Floral characters				FL (cm)	11.65**	1.09**	0.22
DMFO	3.91**	2.87**	0.63	FD (cm)	0.27**	0.02	0.03
DFFO	15.67**	2.67	2.71	NFPP	0.82	2.04**	0.37
DFMF	6.25**	1.75	1.20	FW (g)	193.83*	246.22**	64.16
DFFF	14.03**	1.91	1.24	SCL (cm)	9.04**	0.87**	0.18
NMFP	6797.41**	1116.37**	163.24	SCB (cm)	0.40**	0.21**	0.04
NFFP	1.63	3.08**	0.79	PC (cm)	2.42**	0.68**	0.24
MFD	0.06**	0.03**	0.01	EC (cm)	2.13**	0.21	0.18
FFD	0.01	0.05**	0.02	FT (cm)	0.01**	0.01	0.00
NFMA	2.73**	0.23	0.13	YPP (g)	66887.61*	93537.95**	25170.43
NFFA	2.28**	0.75**	0.22	HD	15.53**	11.01**	2.57
SR	0.004**	0.001**	0.000	TSS (^{o}Brix)	0.35**	0.15**	0.02
				LWDS (g)	44.34**	9.34**	1.99
				NDS	4.83**	0.48**	0.15
				PedL (cm)	1.03**	0.05	0.06

**- significant at 1% level; Df-Degrees of freedom; VL-Vine length (cm); NPB-Number of primary branches; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFMA-Node number at which 1st male flower appeared; NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP-Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm); EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP-Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (%); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL-Peduncle length (cm)

4.3.2.4.2. Combining ability effects

4.3.2.4.2.1. General combining ability effects

4.3.2.4.2.1.1. Shoot characters

The estimates of GCA effects of parents revealed that positive GCA effects for vine length was exhibited by IC613471 (22.08) and IC613480 (13.51).

However, negative GCA effects was shown by IC595508A (-32.12), IC613476 (-14.57), and IC613488 (-13.94) (Table 45). IC613485 (0.54), IC613471 (0.72), IC613476 (0.27) and IC613480 (0.20) exhibited positive GCA effects for number of primary branches (Table 45).

Ratio of variance due to GCA to SCA was -2.27 and 3.71 for number of primary branches per plant and vine length respectively. The predictability ratio for number of primary branches was 1.28 and that of vine length was 0.88 (Table 46).

4.3.2.4.2.1.2. Floral characters

IC595508A, IC613485 and IC613480 exhibited negative GCA effects in desirable direction for days to first male flower opening with values -0.32, -0.86, -0.56. Similarly negative GCA effects in desirable direction was shown by IC595508A (-1.30), IC613485 (-0.40), IC613476 (-0.35) and IC613480 (-0.92) for days to first female flower opening. For days to 50 per cent male and female flowering, IC595508A and IC613488 had recorded negative GCA effects (-0.69, -0.40 and -0.03, -0.07 respectively). IC613485 and IC613471 had recorded positive GCA effects for both these characters. Negative GCA effect for days to 50 per cent male flowering was exhibited by IC613476 (-1.19) and IC613488 (-0.03).

Significant positive GCA effect for number of male flowers was observed inIC613471, IC613488 and IC613480 with values 9.64, 22.12 and 15.97 respectively. However, negative GCA effects for the character were exhibited by IC595508A (-57.93). Positive though non-significant GCA effects for number of male flowers were shown by IC613485 (3.84) and IC613476 (6.37). IC613476 (0.41) and IC613480 (0.54) had recorded positive GCA effects for number of female flowers per plant.

Table 45. General combining effects of parents for different characters

Characters	IC613480	IC613488	IC613476	IC613471	IC613485	IC595508A	CD (gi) 5%
VL (cm)	13.51*	-13.94	-14.57	22.08**	25.05**	-32.13	16.02
NPB	0.20	-0.48	0.27	0.72*	0.54	-1.25	0.71
DMFO	-0.56	1.02**	0.29	0.42	-0.86	-0.32	0.66
DFFO	-0.92	0.34	-0.35	2.62**	-0.40	-1.30	1.37
DFMF	0.18	-0.03	-1.19	1.35**	0.39	-0.69	0.91
DFFF	-2.07	-0.07	0.51	2.01**	0.01	-0.40	0.92
NMFP	15.97**	22.12**	6.37	9.64*	3.84	-57.93	10.60
NFFP	0.54	-0.07	0.41	-0.73	-0.06	-0.10	0.74
MFD	0.08*	-0.03	0.12**	-0.02	-0.01	-0.13	0.08
FFD	0.02	-0.05	0.01	0.05	0.02	-0.05	0.13
NFMA	-0.19	-0.48	-0.39	1.07**	0.26*	-0.26	0.30
NFFA	0.09	-0.28	0.33*	0.82**	-0.27	-0.69	0.39
SR	-0.01	-0.01	-0.01	-0.02	0.00	0.05**	0.00
DFH	-1.31	0.28	-0.43	2.82**	-0.43	-0.93	1.28
DLH	1.37*	-0.42	-1.50	2.87**	-1.38	-0.96	1.44
FL (cm)	0.99**	-1.78	-0.48	1.15**	0.96**	-0.84	0.39
FD (cm)	-0.08	0.15**	0.10	-0.26	-0.12	0.21**	0.14
NFPP	0.61**	-0.02	-0.11	-0.33	-0.03	-0.12	0.51
FW (g)	4.33	-8.30**	5.49*	-1.21	0.83	-1.13	6.65
SCL (cm)	1.11**	-1.49	-0.64	0.66**	0.99**	-0.62	0.35
SCB (cm)	-0.21	0.16*	-0.04	-0.26	0.04	0.33**	0.17
PC (cm)	-0.15	0.42*	0.76**	-0.22	-0.83**	0.03	0.40
EC (cm)	-0.49**	0.41**	0.25	-0.51**	-0.35*	0.69**	0.35
FT (cm)	-0.01	-0.02	0.02	-0.01	-0.04	0.06**	0.05
YPP (g)	165.88**	-77.61	20.43	-81.33	7.03	-34.40	131.63
HD	2.68**	-0.69	-1.07	0.06	-0.94	-0.03	1.33
TSS (°Brix)	-0.06	0.19**	0.09	-0.05	-0.36	0.19**	0.13
LWDS	-1.32	0.22	-1.26	4.55**	-1.87	-0.32	1.17
NDS	-0.61	0.22	-0.43	0.35**	-0.81	1.28**	0.33
PedL (cm)	0.09	-0.33**	0.46**	0.18*	0.12	-0.52**	0.20

VL-Vine length (cm); NPB-Number of primary branches; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFMA-Node number at which 1st male flower appeared; NFFA-Node number at which 1st female flower appeared; SR- Sex ratio; DFH-Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP-Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm); EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP- Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (°Brix); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

Table 46. Ratio of GCA to SCA variance and predictability ratio for shoot, floral and fruit characters

Parameters	**NPB**	**VL (cm)**	**DMFO**	**DFFO**	**DFMF**	**DFFF**	**NMFP**	**NFFP**	**MFD (cm)**	**FFD (cm)**	**NMFA**	**NFFA**	**SR**
$\sigma^2 g/\sigma^2 s$ Ratio	-2.27	3.71	0.18	-33.73	1.15	2.38	0.87	0.05	0.33	-0.05	3.27	0.49	0.55
Predictability Ratio	1.28	0.88	0.27	1.02	0.70	0.83	0.64	0.08	0.40	-0.12	0.87	0.50	0.53

Parameters	**DFH**	**DLH**	**FL (cm)**	**FD (cm)**	**NFFP**	**FW (g)**	**SCL (cm)**	**SCB (cm)**	**PC (cm)**
$\sigma^2 g/\sigma^2 s$ Ratio	1.07	0.30	1.64	-4.00	0.03	0.09	1.58	0.26	0.62
Predictability Ratio	0.68	0.37	0.77	1.14	0.06	0.15	0.76	0.34	0.55

Parameters	**EC (cm)**	**FT (cm)**	**YPP (g)**	**HD**	**TSS (°Brix)**	**LWDS (g)**	**NDS**	**PedL (cm)**
$\sigma^2 g/\sigma^2 s$ ratio	8.36	0.38	0.08	0.19	0.32	0.72	1.80	-16.24
Predictability ratio	0.94	0.43	0.13	0.28	0.39	0.59	0.78	1.03

VL-Vine length (cm); NPB-Number of primary branches; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NMFA-Node number at which 1st male flower appeared; NFFA-Node number at which 1st female flower appeared; SR- Sex ratio

DFH- Days to first harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL (cm)-Seed cavity length; SCB (cm)-Seed cavity breadth; PC (cm)-Polar circumference

EC-Equatorial circumference; FT- Flesh thickness (cm); TSS-Total soluble solids (°Brix); YPP- Yield per plant (g); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL (cm)-Peduncle length

Negative GCA effects for male and female flower diameter were exhibited by IC595508A (-0.13 and -0.05 respectively) and IC613488 (-0.03 and -0.05 respectively), whereas positive GCA effects for both characters by IC613476 (0.12 and 0.01 respectively) and IC613480 (0.08 and 0.02 respectively). IC595508A and IC613488 exhibited negative GCA effects in the desirable direction for node number at which both male and female flower appeared with values -0.26 and -0.69 and -0.48 and -0.28 respectively. However, IC613471 had positive GCA effects for both the characters. Positive significant GCA effect was exhibited by IC595508A (0.05), whereas IC613471 (-0.02), IC613476 (-0.01), IC613488 (-0.01) and IC613480 (-0.01) had negative GCA effects for sex ratio (Table 45).

Among floral characters, ratio of GCA variance to SCA variance of above unity was observed in days to 50 per cent male flowering, days to 50 per cent female flowering and node number at which first male flower appeared. Days to first female flower opening had recorded predictability ratio of more than unity ie., 1.02. A predictability ratio more than 0.80 was expressed by the characters days to 50 per cent female flowering (0.83) and node number at which first male flower appeared (0.87) (Table 46).

4.3.2.4.2.1.3. Fruit characters

High negative GCA effects in the desirable direction were exhibited by IC595508A (-0.93), IC613485 (-0.43), IC613476 (-0.43) and IC613480 (-1.31). However, positive GCA effects were shown by IC613471 (2.82) and IC613488 (0.28). The parents namely IC613471 and IC613480 exhibited positive GCA effects for days to last harvest with values 2.87 and 1.37 respectively. GCA effects for fruit length was positive and significant in IC613485 (0.96), IC613471 (1.15) and IC613480 (0.99). Similarly, IC595508A, IC613476 and IC613488 recorded positive GCA effect for fruit diameter. Only IC613480 recorded positive and significant GCA effect for number of fruits per plant. Positive GCA effect for fruit weight was exhibited by IC613485 (0.83), IC613476 (5.49) and IC613480

(4.33). IC595508A, IC613476 and IC613488 recorded negative GCA effects for seed cavity length with values -0.62, -0.64 and -1.49 respectively. In contrast to this, IC613485, IC613471 and IC613480 had positive GCA effects. Similarly, positive GCA effects was shown by IC595508A (0.33), IC613485 (0.04), IC613488 for seed cavity breadth.

IC595508A, IC613476 and IC613488 recorded positive GCA effects for polar (0.03, 0.76 and 0.42 respectively) and equatorial circumference (0.69, 0.25 and 0.41 respectively). However, negative GCA effects for both the characters were exhibited by IC613485, IC613471 and IC613480. Positive GCA effect for flesh thickness was observed in IC595508A (0.06) and IC613476 (0.02). A positive and significant GCA effect for harvest duration was exhibited by IC613480 (2.68).

Maximum GCA effect for yield per plant was exhibited by IC613480 (165.88) followed by IC613476 (20.43). Negative GCA effect for yield per plant was shown by IC595508A (-34.40), IC613471 (-81.33) and IC613488 (-77.61). A positive but nonsignificant GCA effect was exhibited by IC613485 (7.03). TSS exhibited positive GCA effect in IC595508A (0.19) and IC613471 (0.09).

Storage parameters like loss of weight during storage and number of days of storage had positive GCA effect in IC613471 (4.55 and 0.35 respectively) and IC613488 (0.22 for both characters). Negative GCA effect desirable for loss of weight during storage was expressed by IC595508A (-0.32), IC613485 (-1.87), IC613476 (-1.26) and IC613480 (-1.32). IC595508A and IC613488 exhibited negative GCA effects for peduncle length.

Among the fruit characters, ratio of GCA variance to SCA variance of more than one was exhibited by days to first harvest (1.07), fruit length (1.64), seed cavity length (1.58), equatorial circumference (8.36), number of days of storage (1.80). Fruit diameter (1.14) and peduncle length (1.03) showed a predictability ratio of more than one. Predictability ratio of more than 0.80 ie nearing unity was shown by equatorial circumference (0.94) only (Table 46).

Table 47. Specific combining ability of hybrids for shoot and floral characters in hybrids

	VL (cm)	NPB	DMFO	DFFO	DFMF	DFFF	NMFP	NFFP	MFD	FFD	NFMA	NFFA	SR
IC613480 x IC613488	-1.42	0.05	-2.10**	-2.48	-0.99	-1.13	22.74	1.25	-0.17	-0.17	0.13	-0.30	-0.01
IC613480 x IC613476	-10.32	-0.43	1.43	1.22	-0.49	1.62	-9.97	-0.43	0.11	0.21	-0.49	-0.04	0.00
IC613480 x IC613471	-0.77	0.12	-0.17	-0.15	-1.04	-0.21	-43.97**	3.18**	-0.17	0.11	-0.29	0.80	0.04**
IC613480 x IC613485	22.06	-0.10	0.91	1.00	1.59	0.45	48.69**	-0.56	-0.02	0.08	-0.47	-1.04*	-0.03**
IC613480 x IC595508A	30.57	0.95	1.24	1.10	0.01	-1.13	-12.87	1.68*	0.11	-0.20	0.91*	0.58	0.02**
IC613488 x IC613476	-7.6	0.05	1.98*	2.22	1.38	-0.71	-11.26	-0.68	0.08	-0.09	-0.34	0.06	-0.01
IC613488 x IC613471	10.62	0.47	-2.54**	-0.75	-0.83	-1.21	-32.12*	1.00	0.05	0.09	-0.27	-1.17*	0.02**
IC613488 x IC613485	21.04	0.59	0.53	0.8	0.13	0.79	28.14*	-0.68	-0.06	-0.05	0.68	0.19	-0.03**
IC613488 x IC595508A	-22.84	-1.43	-0.40	-1.10	-1.45	-0.13	-48.69**	-0.64	-0.21*	0.30*	-0.07	0.68	0.05**
IC613476 x IC613471	-2.42	0.12	-0.55	-0.46	1.34	-2.13*	-16.91	0.65	0.15	0.40*	0.18	-0.71	0.01*
IC613476 x IC613485	35.48	1.10	-1.34	-0.44	0.63	-0.46	-0.97	0.64	0.10	0.20	0.46	0.52	0.00
IC613476 x IC595508A	29.99	0.42	-2.01*	-1.41	-1.29	0.95	-9.74	0.95	0.17	0.09	-0.02	1.68**	0.02**
IC613471 x IC613485	6.96	0.05	1.07	0.66	-0.91	-0.96	32.69*	-2.62**	0.11	-0.19	0.59	-0.24	-0.03**
IC61371 x IC595508A	-18.66	0.30	-2.33**	-2.58	0.51	-1.55	4.66	1.42	0.15	0.00	-0.29	0.25	0.00
IC613485 x IC595508A	-20.57	0.69	0.81	-1.49	-2.20*	0.12	-14.34	1.28	-0.24*	-0.22	0.19	-0.06	0.03**
Sij <> 0 at 95%	36.71	1.63	1.51	3.13	2.08	2.11	24.29	1.69	0.19	0.30	0.69	0.90	0.01

*- significant at 5% level; **- significant at 1% level; Df-Degrees of freedom; VL-Vine length (cm); NPB-Number of primary branches; DMFO-Days to 1st male flower opening; DFFO-Days to 1st female flower opening; DFMF-Days to 50% male flowering; DFFF-Days to 50% female flowering; NMFP-Number of male flowers per plant; NFFP-Number of female flowers per plant; MFD-Male flower diameter (cm); FFD-Female flower diameter (cm); NFMA-Node number at which 1st male flower appeared; NFFA-Node number at which 1st female flower appeared; SR-Sex ratio

4.3.2.4.2.2. Specific combining ability effects

4.3.2.4.2.2.1. Shoot characters

Positive SCA effects for vine length were exhibited by the crosses IC613480 x IC613485 (22.06), IC613480 x IC595508A (300.57), IC613488 x IC613471 (10.62), IC613488 x IC613485 (21.04), IC613476 x IC613485 (35.48), IC613476 x IC595508A (29.99) and IC613471 x IC613485 (6.96). Maximum SCA effect for number of primary branches was exhibited by IC613476 x IC613485 (1.10) (Table 47).

4.3.2.4.2.2.2. Floral characters

Among floral characters, negative SCA effects in desirable direction for days to first male and female flower opening, days to 50 per cent male and female flowering were shown by IC613480 x IC613488 (-2.10, -2.48, -0.99 and -1.13 respectively), IC613480 x IC613471 (-0.17, -0.15, -1.04 and -0.21 respectively), IC613488 x IC613471 (-2.54, -0.75, -0.83 and -1.21 respectively) and IC613488 x IC595508A (-0.40, -1.10, -1.45 and -0.13 respectively). In addition, IC613476 x IC613471, IC613476 x IC613485 and IC613471 x IC595508A exhibited negative SCA effects for days to first male and female flower opening and days to 50 per cent female flowering.

IC613480 x IC613488, IC613480 x IC613485, IC613488 x IC613485, IC613471 x IC613485 and IC613471 x IC595508A showed positive SCA effects for number of male flowers per plant with values 22.74, 48.69, 28.14, 32.69 and 4.66 respectively. Likewise, positive SCA effects for number of female flowers per plant was exhibited by IC613480 x IC613488 (1.25), IC613480 x IC613471 (3.18), IC613480 x IC595508A (1.68), IC613488 x IC613471 (1.00), IC613476 x IC613471 (0.65), IC613476 x IC613485 (0.64), IC613476 x IC595508A (0.95), IC61371 x IC595508A (1.42) and IC613485 x IC595508A (1.28). However, negative SCA effects for both the characters were shown by IC613480 x IC613476, IC613488 x IC613476 and IC613488 x IC595508A.

Positive SCA effects for both male and female flower diameter were shown by IC613480 x IC613476, IC613488 x IC613471, IC613476 x IC613471, IC613476 x IC613485 and IC613476 x IC595508A. Negative SCA effects in desirable direction for node number at which first male and female flower appeared were exhibited by IC613480 x IC613476 (-0.49 and -0.04 respectively), IC613480 x IC613485 (-0.47 and -1.04 respectively) andIC613488 x IC613471 (-0.27 and -1.17 respectively). For sex ratio, positive significant SCA effect was exhibited by IC613480 x IC613471 (0.04), IC613480 x IC595508A (0.02), IC613488 x IC613471 (0.02), IC613488 x IC595508A (0.05), IC613476 x IC613471 (0.01), IC613476 x IC595508A (0.02) and IC613485 x IC595508A (0.03) (Table 47).

4.3.2.4.2.2.3. Fruit characters

IC613480 x IC613488, IC613480 x IC613471, IC613488 x IC613471, IC613488 x IC595508A, IC613476 x IC613471, IC613476 x IC613485, IC613476 x IC595508A, IC613471 x IC595508A and IC613485 x IC595508A recorded negative SCA effect in the desirable direction for days to first harvest with values -2.80, -1.01, -1.59, -0.17, -0.21, -0.63, -0.80, -4.38 and -0.13 respectively. Maximum negative and significant SCA effect was exhibited by the cross IC613471 x IC595508A. For the character days to last harvest, positive significant SCA effect was exhibited by IC613480 x IC613476 (5.32), IC613480 x IC595508A (4.44) and IC613471 x IC613485 (4.02). Highest positive and significant SCA effect for fruit length was exhibited by the cross IC613476 x IC613471 (1.99) followed by IC613476 x IC595508A (1.45). Positive significant SCA effect for fruit diameter was not exhibited by any of the crosses studied (Table 48). Maximum value for SCA effect in the positive direction for number of fruits per plant was exhibited by IC613480 x IC613471 (2.53) followed by IC613471 x IC595508A (1.4). However, four crosses exhibited negative SCA effects for the character.

Table 48. Specific combining ability effects of fruit characters in hybrids

Hybrids	DFH	DLH	FL (cm)	FD (cm)	NFPP	FW (g)	SCL (cm)	SCB (cm)	PC (cm)
IC613480 x IC613488	-2.80	1.90	0.58	-0.03	0.46	7.06	0.27	0.03	0.29
IC613480 x IC613476	0.58	5.32**	0.55	-0.08	-0.26	-12.73	0.22	0.11	-0.92*
IC613480 x IC613471	-1.01	0.94	-0.24	0.03	2.53**	-4.69	-0.04	0.06	-0.50
IC613480 x IC613485	2.24	1.19	-0.11	-0.09	0.62	-2.73	-0.05	-0.23	-0.51
IC613480 x IC595508A	1.41	4.44*	0.82	0.06	1.37	26.23**	0.82*	-0.01	1.60**
IC613488 x IC613476	1.66	1.11	-0.84	-0.10	0.51	-14.77	-0.76	0.08	0.72
IC613488 x IC613471	-1.59	-4.93**	-0.98*	0.11	0.64	-0.73	-0.61	0.01	-0.39
IC613488 x IC613485	0.99	-0.35	0.70	0.14	-0.70	18.89*	0.57	0.41*	0.17
IC613488 x IC595508A	-0.17	0.90	-0.33	0.01	-1.66**	4.85	-0.48	-0.05	0.17
IC613476 x IC613471	-0.21	-4.52*	1.99**	0.26	0.25	28.81**	1.92**	-0.04	-0.39
IC613476 x IC613485	-0.63	-1.27	0.60	-0.20	0.39	10.11	0.62	-0.35	0.45
IC613476 x IC595508A	-0.80	-1.68	1.45**	-0.15	0.38	10.06	1.50**	-0.26	-1.34**
IC613471 x IC613485	1.45	4.02*	-0.33	0.02	-2.06**	-20.52*	-0.26	-0.33	-0.45
IC61371 x IC595508A	-4.38**	-1.06	0.48	-0.04	1.40*	-11.23	-0.50	0.29	-0.54
IC613485 x IC595508A	-0.13	-1.48	-0.20	0.20	1.12	4.73	-0.37	1.35**	-0.62
Sij <> 0 at 95%	2.92	3.31	0.89	0.32	1.16	15.23	0.80	0.38	0.93

*- significant at 5% level; **- significant at 1% level; DFH- Days to first harvest; DLH-Days to last harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); SCL-Seed cavity length (cm); SCB-Seed cavity breadth (cm); PC-Polar circumference (cm)

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Table 48. Specific combining ability of fruit characters in hybrids

	EC (cm)	FT (cm)	YPP (g)	HD	TSS (°Brix)	LWDS (g)	NDS	PedL (cm)
IC613480 x IC613488	-0.60	-0.07	125.83	4.70**	0.24	-0.36	-0.29	-0.20
IC613480 x IC613476	0.19	-0.03	-151.66	4.74**	0.03	1.11	0.03	-0.24
IC613480 x IC613471	-0.07	0.01	388.22*	1.95	-0.20	-1.36	0.05	0.00
IC613480 x IC613485	-0.12	0.10	68.44	-1.05	0.25	-2.27	0.20	0.14
IC613480 x IC595508A	0.36	0.10	493.91**	3.03*	0.03	-0.15	-0.55	-0.09
IC613488 x IC613476	-0.34	0.00	-35.88	-0.55	-0.15	1.57	-0.67	0.29
IC613488 x IC613471	0.74	0.00	116.19	-3.35*	-0.11	-5.24**	-0.25	0.09
IC613488 x IC613485	0.45	0.06	16.39	-1.35	-0.63**	-1.14	0.37	-0.23
IC613488 x IC595508A	0.41	0.14*	-249.84	1.07	0.68**	-1.69	1.22**	-0.22
IC613476 x IC613471	-0.18	0.03	297.00	-4.3**	-0.28	-1.63	-0.87*	-0.40
IC613476 x IC613485	-0.30	-0.02	159.08	-0.64	-0.27	0.73	1.15**	-0.10
IC613476 x IC595508A	-0.70	-0.08	115.53	-0.89	-0.29	-0.55	-0.40	0.19
IC613471 x IC613485	-0.45	-0.04	-503.68**	2.57	0.04	-2.94*	-0.23	0.27
IC61371 x IC595508A	0.03	-0.09	132.41	3.32*	0.32*	-2.36	0.89*	0.01
IC613485 x IC595508A	0.29	0.03	240.67	-1.35	-0.50**	-0.94	-1.09**	-0.23
Sij <> 0 at 95%	0.80	0.11	301.62	3.05	0.29	2.68	0.75	0.46
Sij <> 0 at 99%	1.11	0.15	418.63	4.23	0.41	3.72	1.04	0.64

*- significant at 5 % level; **- significant at 1 % level; Df-Degrees of freedom; EC-Equatorial circumference (cm); FT-Flesh thickness (cm); YPP- Yield per plant (g); HD-Harvest duration (days); TSS-Total Soluble Solids (° Brix); LWDS-Loss in weight during storage (g); NDS-Number of days of storage; PedL- Peduncle length (cm)

Two crosses IC613480 x IC595508A and IC613488 x IC613485 exhibited high positive SCA effect for fruit weight. IC613471 x IC613485 exhibited significant SCA effect in the negative direction for fruit weight with values 26.23 and 18.89 respectively.

Positive significant effect for seed cavity length was exhibited by IC613480 x IC595508A, IC613476 x IC613471and IC613476 x IC595508A with values 0.82, 1.92 and 1.50 respectively whereas positive SCA effect for seed cavity breadth was observed for IC613488 x IC613485 (0.41) and IC613485 x IC595508A (1.35). IC613480 x IC595508A is the only one cross which showed positive significant SCA effect for polar circumference whereas none of the crosses had significant positive SCA effect for equatorial circumference.

Positive significant SCA effect was exhibited by IC613488 x IC595508A (0.14) for flesh thickness. Two crosses namely IC613480 x IC613471 and IC613480 x IC595508A exhibited high positive significant SCA effects of 388.22 and 493.91 respectively for yield per plant. The crosses IC613480 x IC613476, IC613488 x IC613476, IC613488 x IC595508A and IC613471 x IC613485 exhibited negative SCA effects of -151.66, -35.88, -249.84 and -503.68 respectively. The remaining crosses exhibited positive SCA effect but not significant for the character. Harvest duration was high and positive for SCA effect in IC613480 x IC613488 (4.70), IC613480 x IC613476 (4.74), IC613480 x IC595508A (3.03) and IC613471 x IC595508A (3.32).

Only two crosses namely IC613488 x IC595508A and IC613471 x IC595508A exhibited positive and significant SCA effect for TSS with values 0.68 and 0.32 respectively. Negative significant SCA effect in the desirable direction was shown by IC613488 x IC613471 (-5.24) and IC613471 x IC613485 (-2.94). IC613488 x IC595508A (1.22), IC613476 x IC613485 (1.15) and IC613471 x IC595508A (0.89) showed positive SCA effect for number of days of storage. None of the crosses exhibited positive SCA effect for peduncle length.

4.3.2.5. Heterosis

Magnitude of heterosis *viz.*, mid parent or relative heterosis, better parent heterosis or heterobeltiosis and standard heterosis over standard variety (AAUC-2) was worked out for yield and yield contributing characters (Table 49).

4.3.2.5.1. Days to first harvest

Negative relative heterosis, heterobeltiosis and standard heterosis which is considered desirable for the character was exhibited by IC613480 x IC613488 (-6.86 %, -11.03 %and –3.73 % respectively) and IC613471 x IC595508A (-13.36 %, -19.88 %and -0.75 % respectively).

Further, heterosis in negative direction over better parent and mid parent was exhibited by IC613480 x IC613471 (-4.70 % and -14.46 % respectively), IC613488 x IC613471 (-6.75 % and -12.65 %), IC613488 x IC595508A (-3.50 % and -4.83 % respectively), IC613476 x IC595508A (-3.60 % and -4.90 % respectively) and IC613485 x IC595508A (-0.37 % and -3.55 % respectively).

4.3.2.5.2. Fruit length

Five crosses namely IC613480 x IC613476, IC613480 x IC595508A, IC613476 x IC613471, IC613476 x IC613485 and IC613476 x IC595508A exhibited relative heterosis with values 13.12 per cent, 12.31 per cent, 21.53 per cent, 11.73 per cent and 23.76 per cent respectively. Heterobeltiosis was exhibited by the cross IC613476 x IC595508A (23.49 %) only. None of the cross exhibited heterosis over the standard check. However, IC613488 x IC613476 and IC613488 x IC613471 exhibited negative heterosis over mid parent, better parent as well as standard check.

4.3.2.5.3. Fruit diameter

None of the cross combinations showed positive significant heterosis over mid parent and better parent. The cross combinations IC613480 x IC595508A, IC613488 x IC613485 showed heterosis at 5 per cent and IC613488 x IC595508A and IC613471 x IC613485 at one per cent respectively over the standard check. Twelve crosses exhibited positive standard heterosis, but were not significant.

4.3.2.5.4. Fruit weight

Positive relative heterosis, heterobeltiosis and standard heterosis for fruit weight was exhibited by the cross IC613480 x IC595508A and IC613476 x IC613471, with heterosis estimates of 22.17 per cent, 14.94 per cent and 19.06 per cent for IC613480 x IC595508A and 17.64 per cent, 17.15 per cent and 21.13 per cent for IC613476 x IC613471 respectively. Though all the heterosis estimates for IC613480 x IC613485 and IC613476 x IC613485 were positive, they were found to be nonsignificant. However, three crosses IC613488 x IC613476, IC613471 x IC613485 and IC613471 x IC595508A had recorded negative estimates for all the three heterosis.

4.3.2.5.5. Number of fruits per plant

High level of positive significant heterosis over mid parent, better parent as well as standard check variety were observed for crosses namely IC613480 x IC613471 (62.73 %, 52.90 % and 53.93 % respectively), IC613480 x IC595508A (44.23 %, 40.41 % and 41.09 % respectively) and IC613471 x IC595508A (40.28 %, 35.51 % and 28.69 % respectively).

However, all the estimates of heterosis *ie.*, over mid parent, better parent and check variety were negative for IC613488 x IC595508A (-14.89 %, -23.94 % and -8.26 % respectively) and IC613471 x IC613485 (-19.79 %, -30.15 % and -16.66 % respectively).

4.3.2.5.6. Yield per plant

High positive and significant heterosis over the mid parent (55.24 %), better parent (41.91 %) and check variety (54.76 %) was exhibited by IC613480 x IC613471 and IC613480 x IC595508A with 70.55 per cent (mid parent), 52.51

Table 49. Estimates of relative heterosis, heterobeltiosis and standard heterosis for different characters

	Days to first harvest			Fruit length (cm)			Fruit diameter			Fruit weight (g)		
Crosses	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)
IC613480 x IC613488	-6.86	-11.03*	-3.73	5.40	-8.44	-9.18*	-0.52	-3.98	9.40	7.88	0.52	3.93
IC613480 x IC613476	1.86	0.00	2.24	13.12**	-0.73	-1.54	-4.01	-8.34	6.81	-2.12	-2.59	0.71
IC613480 x IC613471	-4.70	-14.46**	5.97	2.34	0.35	3.56	2.22	-5.05	0.65	-1.82	-1.90	1.43
IC613480 x IC613485	7.58	7.58	5.97	2.72	1.47	3.15	-2.50	-4.43	1.30	1.67	0.17	3.57
IC613480 x IC595508A	1.10	-2.13	2.99	12.31**	-1.26	-2.06	1.01	-3.99	12.97*	20.95*	14.16	18.04*
IC613488 x IC613476	2.84	0.00	8.21	-0.96	-2.11	-26.69**	-2.95	-4.03	11.83	-3.12	-9.32	-7.14
IC613488 x IC613471	-6.75	-12.65**	8.21	-6.67	-20.26**	-17.71**	5.70	-4.98	8.27	0.56	-6.23	-3.21
IC613488 x IC613485	3.25	-1.38	6.72	4.51	-10.14*	-8.65*	4.43	-1.14	12.64*	14.31	8.01	8.39
IC613488 x IC595508A	-3.50	-4.83	2.99	0.03	-1.34	-25.80**	1.33	-0.28	17.34**	10.26	8.75	-0.18
IC613476 x IC613471	-2.97	-11.45**	9.70	21.53**	4.86	8.21	6.56	-5.15	10.53	16.72*	16.26*	20.00*
IC613476 x IC613485	1.12	-0.73	1.49	11.73**	-2.98	-1.37	-5.72	-11.68*	2.92	9.56	8.47	11.07
IC613476 x IC595508A	-3.60	-4.96	0.00	23.76**	23.49**	-7.12	-4.22	-4.68	12.16	13.29	7.42	10.00
IC613471 x IC613485	2.01	-8.43*	13.43**	0.36	-0.39	2.79	3.28	-2.23	-0.49	-10.53	-11.76	-8.93
IC613471 x IC595508A	-13.36**	-19.88**	-0.75	8.57*	-6.15	-3.15	1.63	-9.92	6.00	-2.56	-7.96	-5.00
IC613485 x IC595508A	-0.37	-3.55	1.49	3.57	-9.90*	-8.41*	5.32	-1.79	15.56**	8.92	4.27	4.64
CD at 5.00 %	4.040	4.665	4.665	1.225	1.415	1.415	0.438	0.506	0.506	21.040	24.295	24.295
CD at 1.00 %	5.094	5.883	5.883	1.545	1.784	1.784	0.552	0.638	0.638	26.531	30.635	30.635

RH- Relative heterosis, HB- Heterobeltiosis, SH-Standard heterosis

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Table 49. Estimates of relative heterosis, heterobeltiosis and standard heterosis for different characters

Crosses	Number of fruits per plant			Yield per plant (g)			Sex ratio		
	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)
IC613480 x IC613488	17.69	7.97	30.22*	27.81	25.67	35.34	8.57	5.56	18.75
IC613480 x IC613476	16.31	14.24	19.26	13.86	12.36	20.12	21.05	15.00	43.75**
IC613480 x IC613471	62.73**	52.90**	53.93**	59.77**	49.99*	56.12*	119.35**	88.89**	112.50**
IC613480 x IC613485	20.15*	10.76	32.15**	22.30	14.31	36.87*	-37.04**	-52.78**	6.25
IC613480 x IC595508A	44.23**	40.14**	41.09**	74.14**	59.99**	66.53**	60.71**	18.42**	181.25**
IC613488 x IC613476	7.72	0.48	21.19	4.88	4.50	12.54	13.51	5.00	31.25
IC613488 x IC613471	14.71	-0.56	19.94	16.64	7.79	16.08	66.67**	47.06**	56.25**
IC613488 x IC613485	-11.77	-12.25	5.84	0.89	-4.19	14.72	-39.62**	-55.56**	0.00
IC613488 x IC595508A	-14.89	-23.94*	-8.26	-6.01	-14.96	-8.43	96.36**	42.10**	237.50**
IC613476 x IC613471	17.50	8.56	13.34	37.20*	27.22	36.00	51.52**	25.00	56.25**
IC613476 x IC613485	6.62	-0.04	19.26	16.90	10.63	32.47	-14.29	¯33.33	50.00**
IC613476 x IC595508A	18.33	12.99	17.96	33.72*	21.38	29.76	62.07**	23.68**	193.75**
IC613471 x IC613485	-19.79	-30.15**	-16.66	-28.09	-36.61	-24.10	-46.94**	-63.89**	-18.75
IC613471 x IC595508A	40.28**	35.51**	28.69*	36.97**	33.84	22.26	41.18**	-5.26	125.00**
IC613485 x IC595508A	20.37*	8.09	28.96*	30.45	12.71	34.95	35.14**	31.58**	212.50**
C.D.95 %	1.607	1.855	1.855	416.748	481.219	481.219	0.016	0.018	0.018
C.D.99 %	2.026	2.339	2.339	525.498	606.793	606.793	0.020	0.023	0.023

RH- Relative heterosis, HB- Heterobeltiosis, SH-Standard heterosis per cent (better parent) and 66.32 per cent (standard check). Heterosis over mid parent and standard variety were significant and positive for IC613476 x IC613471 (38.33 % and 36.83 % respectively).

IC613471 x IC595508A and IC613485 x IC595508A showed positive and significant heterosis at five per cent level over mid parent whereas IC613480 x IC613485 over standard check. IC613488 x IC595508A and IC613471 x IC613485 exhibited negative heterosis over mid parent, better parent and standard check variety.

4.3.2.5.7. Sex ratio

IC613480 x IC613471, IC613480 x IC595508A, IC613488 x IC613471, IC613488 x IC595508A, IC613476 x IC595508A and IC613485 x IC595508A showed positive and significant heterosis over mid parent, better parent and also standard check at one per cent level. However, IC613480 x IC613476 and IC613476 x IC613485 exhibited standard heterosis only with values 43.75 per cent and 50.00 per cent respectively. Similarly, IC613476 x IC613471 and IC613471 x IC595508A showed heterosis over mid parent as well as standard check at one per cent level.

4.3.2.6. Organoleptic evaluation

Maximum score for bitterness was observed for IC613480 x IC613476 (13.00) among hybrids and IC613471 (13.20) among parents. Minimum score was exhibited by IC61371 x IC595508A (10.33) and IC595508A (7.3) among hybrids and parents respectively. IC613480 x IC613476 and IC613471 recorded highest score for crispness with scores 14.4 and 15.37 among crosses and parents respectively. Least score for crispness was observed for IC613488 x IC595508A (8.37) and IC595508A (7.53), respectively. Highest score for flavour among hybrids was observed in IC613476 x IC613485 (14.43) and lowest in IC61371 x IC595508A (7.53). Among parents, IC613471 scored the highest score of 14.07, as against the lowest score of 8.97 for IC595508A (Table 50).

The crosses with maximum and minimum cumulative scores were IC613480 x IC613476 (42.64) and IC61371 x IC595508A (25.96). IC613471 was the best parent with respect to cumulative organoleptic score (42.64) as against the least scored parent IC595508A (23.8).

Table 50. Organoleptic scores for hybrids and parents

Crosses	Bitterness	Crispness	Flavour	Cumulative organoleptic score
IC613480 x IC613488	12.13	14.30	9.87	36.30
IC613480 x IC613476	13.00	14.40	13.73	41.13
IC613480 x IC613471	11.83	13.53	12.33	37.69
IC613480 x IC613485	11.83	11.63	9.97	33.43
IC613480 x IC595508A	11.20	8.87	8.43	28.50
IC613488 x IC613476	11.33	14.00	10.77	36.10
IC613488 x IC613471	11.17	9.13	13.23	33.53
IC613488 x IC613485	10.37	9.80	10.07	30.24
IC613488 x IC595508A	12.50	8.37	11.37	32.24
IC613476 x IC613471	12.00	12.30	12.23	36.53
IC613476 x IC613485	11.70	11.50	14.43	37.63
IC613476 x IC595508A	12.50	10.27	10.43	33.20
IC613471 x IC613485	12.50	12.53	13.77	38.80
IC613471 x IC595508A	10.33	8.60	7.03	25.96
IC613485 x IC595508A	12.50	13.50	12.43	38.43
Minimum	**10.33**	**8.37**	**7.03**	**25.96**
Maximum	**13.00**	**14.40**	**14.43**	**41.13**
Parents				
IC613480	11.73	12.30	11.90	35.93
IC613488	11.10	8.87	13.83	33.80
IC613476	7.87	11.37	11.80	31.04
IC613471	13.20	15.37	14.07	42.64
IC613485	11.77	12.30	11.17	35.24
IC595508A	7.30	7.53	8.97	23.80
Minimum	**7.30**	**7.53**	**7.03**	**23.80**
Maximum	**13.20**	**15.37**	**14.43**	**42.64**
AAUC-2	13.13	12.53	11.17	36.83
Kendall's coefficient	0.19	0.15	0.11	

4.3.2.7. Selection of promising genotypes

Superior hybrids were identified by following the method suggested by Arunachalam and Bandyopadhyay (1984). The significantly different characters were subjected to post-hoc analysis and groupings were done based on the least square difference values. Scoring was done based on the above method and total score (TS) was estimated. Simultaneous selection for hybrids with low TS and high cumulative organoleptic score (COS) was selected (Table 51).

Table 51. Ranks and scores for hybrids and parents

Crosses	Total score	Cumulative organoleptic score	Rank
IC613480 x IC613476	**4.40**	**41.13**	**I**
IC613485 x IC595508A	**3.24**	**38.43**	**II**
IC613480 x IC613471	**4.37**	**37.69**	**III**
IC613476 x IC613485	4.40	37.63	
IC613471 x IC613485	6.08	38.80	
IC613476 x IC613471	4.93	36.53	
IC613480 x IC613488	4.60	36.30	
IC613488 x IC613476	5.46	36.10	
IC613480	**4.83**	**35.93**	**I**
IC613485	**4.42**	**35.24**	**II**
IC613488	**4.80**	**33.80**	**III**
AAUC-2	5.36	36.83	
IC613488 x IC613471	5.09	33.53	
IC613480 x IC613485	4.04	33.43	
IC613476 x IC595508A	3.69	33.20	
IC613488 x IC595508A	3.94	32.24	
IC613471	6.18	42.64	
IC613476	5.07	31.04	
IC613488 x IC613485	4.95	30.24	
IC613480 x IC595508A	3.25	28.50	
IC613471 x IC595508A	3.65	25.96	
IC595508A	4.82	23.80	

Minimum TS was observed for IC613485 (4.42) and IC613485 x IC595508A (3.24) among parents and hybrids respectively. IC613471 and IC613471 x IC613485 recorded maximum total score of 6.18 and 6.08 respectively. Results on simultaneous selection to identify crosses with good yielding ability and organoleptic qualities revealed that three crosses IC613480 x IC613476, IC613485 x IC595508A and IC613480 x IC613471 secured first, second and third position respectively. Three parents with good yield characters and organoleptic qualities are IC613480, IC613485 and IC613488 respectively. The TS and COS for parents were 4.83 and 35.93, 4.42 and 35.24 and 4.80 and 33.80 respectively.

Discussion

5. Discussion

Characterization and evaluation of the available germplasm are the two primary steps in any plant breeding programme. Cucumber is indigenous to India (Sebastian *et al.*, 2010) and originated likely from the foothills of the Himalayan Mountain, where its only two botanical varieties were discovered, namely the domesticated cucumber *Cucumis sativus* var. *sativus* and the wild cucumber *C. s.* var. *hardwickii* (Royle) Alef. (Lv *et al.*, 2012). A diverse source of germplasm will definitely provide the base material for selecting promising lines, which can be evaluated for their yield contributing traits and other quality attributes. The magnitude of heritable variability will provide an understanding of the intensity of selection to be practised for breeding. Improvement in yield is the ultimate aim of the breeder, incorporating quality and organoleptic attributes.

5.1. Characterization of cucumber genotypes

5.1.1. Morphological characterization

5.1.1.1. Qualitative characters

Quality traits like fruit colour, shape and size of fruits and nutritional quality are of prime importance in cucumber breeding (Kumar *et al.,* 2017). These morphological characters, which can be monitored visually are the preferred choice for diversity studies, since these are among the easiest morphological markers used in germplasm management (Stanton, *et al.,* 1994). Genetic diversity analysis using the qualitative traits and their correlation with SSR makers were studied by Yang *et al.* (2015). Esteras *et al.,* (2008) observed variability in characteristics like fruit predominant shape at stem and blossom ends, fruit shape, brightness, stripes colour and intensity of skin texture among the genotypes studied.

Among 11 qualitative characters studied absence of variability was observed for leaf margin, leaf shape and leaf pubescence density. Significant and distinct variation were observed for fruit skin colour, fruit shape, primary fruit colour and fruit flesh colour (Plate. 4-8). Fruit stem end shape also did not vary among the accessions studied. In contrast to this Esteras *et al.* (2008) observed high variation among stem end and blossom end shape of cucumber fruits. Variation in skin colour, flesh colour and fruit shape was also reported by Dissanayaka *et al.* (2011) and Pragathi (2014) in hybrid varieties of cucumber.

Fruit shape was elliptical elongate in majority of the accessions. Elliptical elongate shape is highly preferred by consumers, since for salad purpose this shape gives maximum slices per fruit. Effect of time of pollination on fruit has been detailed in the work conducted by Tiedjens (1928), and shown that conditions of environment have a profound effect on the shape and size of mature fruits. Much variability was found with respect to fruit skin colour, where majority (27 accessions) exhibited light green colour, 16 accessions had green colour and three accessions *viz.*, IC5955058, IC613459 and Poinsette exhibited dark green colour. Similar results have also been reported by Verma (2003) and Kumar *et al.* (2013) for this character.

Seed cavity was absent in 44 out of 53 accessions studied. It was noticed that the presence and absence of seed cavity was influenced by the maturity of fruit at the time of harvest. The over maturity of fruit by 2-3 days will lead to development of seed cavity. Fruit skin texture is a key trait from the point of view of consumer acceptance. Smooth or plain skin is preferred over netted and rough skin. Among the accessions studied, only four (IC331627, IC277048, IC277030, IC331619) had plain skin surface. The texture difference is due to the persistence of tubercles or the mass of tissues at the site of tubercles on the fruit surface. Effort should be directed for selecting fruits with smooth or plain with glossy skin texture. The rough textured skin was possessed by 35 accessions. Rough and spiny fruit skin texture in cucumber genotypes were earlier reported by Zhang *et al.* (2012).

The flesh colour of tender fruits was white (42 accessions) predominantly and green (3 accessions) in IC613459, IC331627 and IC541391 (Plate 6-8). Ten accessions exhibited orange flesh at the ripened stage, indicating the carotenoid content in the flesh. The carotenoid pigments in the flesh are an important source of vitamin A. Cucumbers generally lacks the pigmentation of mesocarp (flesh) in contrast to other cucurbits fruits. It was reported that a distinct group of cultivars namely Xishuangbanna gourd, is a source for high carotenoid content (Qi and Yuan, 1983) for introgression of β-carotene (orange flesh) genes to cucumber Kumar *et al.*, 2017). Lv *et al.*, (2012) reported that Xishuangbanna gourd is closely related to cucumber germplasm of Indian origin.

Another important observation was the presence of varied colours in primary fruits (Plate 6). The colour of primary fruits ranged from cream, light green, green to dark green colour. The colour was light green in 43 accessions, green in 6 accessions, dark green in two accessions and cream in two accessions (IC613457). These traits were also influenced by environmental conditions prevailing during the growth period. A detailed study on inheritance of qualitative characters may help the breeders to identify unique morphological markers specific to various accessions.

5.1.1.2. Quantitative characters

Genetic variability for agro-morphological traits is the key component of crop improvement programmes for broadening the gene pool of crops (Govindaraj *et al.*, 2015). Hence, an insight into the magnitude of genetic variability present in a population is of paramount importance to utilize the germplasm in a judicious manner in crop improvement programmes (Abraham, 2012). Heritability in broad sense is not true indicator of inheritance of traits, since only additive component of genetic variance is efficiently transferred from generation to generation. Therefore, considering heritability in broad sense along with genetic advance may reveal the prevalence of specific components (additive or non-additive) of genetic variance for the trait more accurately (Basavarajeshwari *et al.*, 2014).

5.1.1.2.1. Shoot characters

Presence of significant difference among the accessions for vine length and number of primary branches indicated that there was sufficient variability for selection of these traits. High variability in vine length among different genotypes were earlier reported by Abusaleha and Dutta (1990), Hossain *et al* (2010), Golabadi *et al*. (2012), Khan *et al.* (2015) and Ranjan *et al*. (2015). The accession (IC541367) which exhibited maximum vine length was collected from Andaman and Nicobar Islands whereas IC202058A, with lowest vine length was from Uttarakhand (Fig. 14). Similarly, IC613485, a collection from West Bengal and IC613466, from Mizoram recorded the highest and the lowest number of primary branches respectively. The variability in these characters can be attributed to the varied genetic architecture due to the diverse source of collection. All the accessions in general showed a good vegetative growth during the crop season. This is because the study was conducted during the monsoon season (June-August, 2015), which had direct impact on the vegetative characters like vine length and primary branches. Thirty out of the 50 accessions recorded higher vine length than the check varieties.

Number of primary branches more than the highest performing check variety AAUC-2 (11.68) was observed in 11 accessions (Fig. 15). Earlier reports indicated that the vine length and number of primary branches, being traits associated with inter nodal length and number of nodes on the stem has much bearing on fruit yield. Pandey *et al.* (2013) reported in their study that the genotype having maximum vine length had recorded the highest yield. In contrary to this, in the present study, IC541367, the accession which exhibited highest value for vine length, yielded 452.63 g per plant only, whereas the maximum yield recorded was 2205.29 g in IC613477. This was attributed to the less number of fruits per plant produced by the accession. Length and width of mature leaf and petiole length were uniform among the accessions studied, though they represent collections from varied agro-climatic conditions. Similar result was reported by Zhang *et al*. (2012).

In contrast to this, Pragathi (2014) reported significant difference in leaf width and petiole length among nine cucumber hybrids grown in net house. This was ascribed both to their genetic difference as well as the micro climate prevailing in the net house. Hossain *et al.* (2010) in their study comprising 58 accessions of cucumber and Golabadi *et al.* (2012) with 20 genotypes, reported significant variation in leaf length and breadth between accessions.

The improvement of any crop through selection is basically a function of available genetic variability. The estimate of phenotypic and genotypic coefficients of variation provides a direct measure of available genetic variation in the germplasm. In the present study, the genetic parameter PCV was greater than GCV for all the shoot characters, but to a very lesser magnitude, indicating only marginal influence of environment on the expression of these characters. This finding was in consonance with the result reported by Pati (2008). Presence of high PCV in vine length and number of primary branches were earlier reported by Hossain *et al.* (2010) and Kumar *et al.* (2013). Further, none of the shoot characters exhibited high GCV. Ranjan *et al.* (2015) observed low GCV for vine length as well as number of primary branches. High broad sense heritability and genetic advance expressed as per cent of mean along with high PCV in vine length is a good indication of positive effect of selection, which can be adopted for this character. High heritability along with high genetic gain in vine length and low genetic gain in number of primary branches were reported by Dutta (2013).

5.1.1.2.2. Floral characters

The distribution of days to first male and female flower opening and days to 50 per cent male and female flowering in accessions studied are depicted in Fig. 16 and 17. It was revealed from the graph that, in all the accessions, male flower opened earlier than female flowers. Similarly, 50 per cent flowering was attained earlier in male flowering than female flowering. Days to first male and female flowering was early in accessions namely IC613477 and IC613479, respectively, both collected from Hoogly, West Bengal.

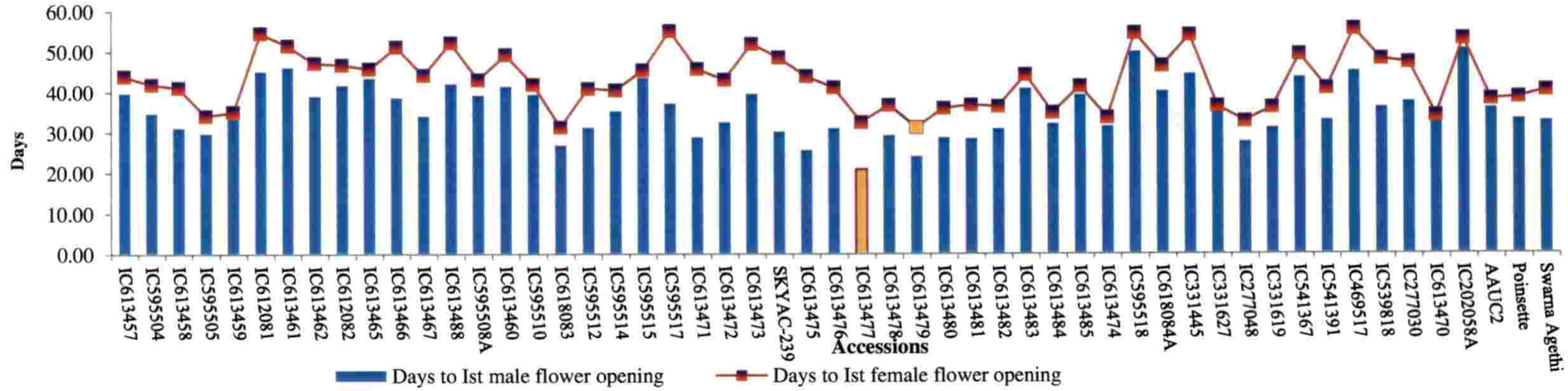

Fig. 16. Distribution of days to first male and female flower opening in 53 cucumber

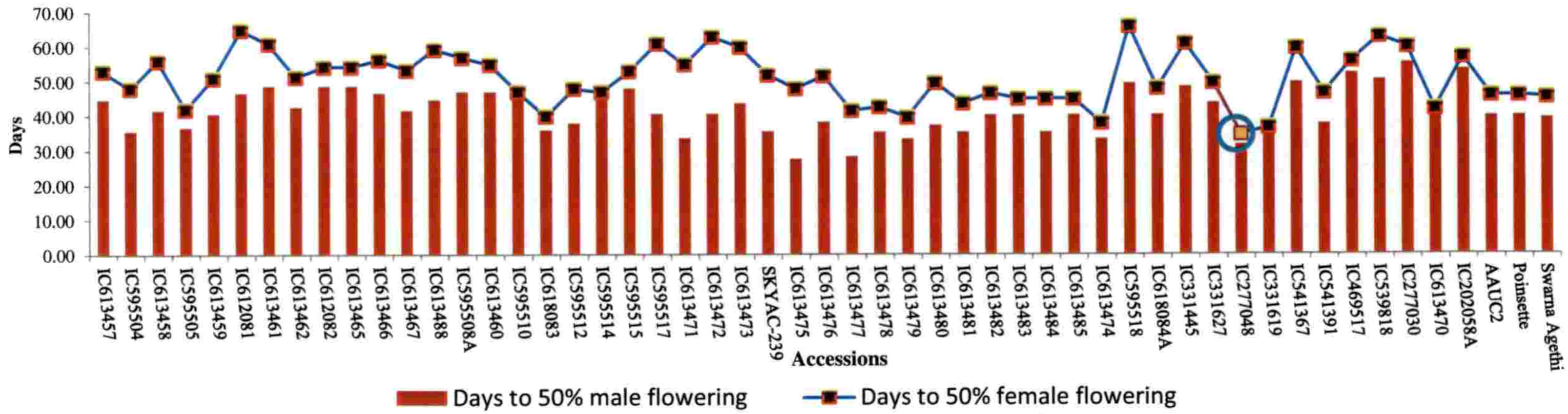

Fig. 17. Distribution of days to 50 % male and female flowering in 53 cucumber accessions

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Though IC613479 showed early female flowering, 50 per cent female flowering was first achieved by IC277048 (Fig. 17). This accession took only two days to achieve 50 per cent female flowering. IC277048 exhibited the superior performance in number of female flowers produced, sex ratio and number of fruits produced. However, being a bitter type, it could only be used with specific objectives and exhaustive screening, as a source material in cucumber improvement programme. The floral characters studied were not significantly different among the accessions except for number of female flowers per plant, male flower diameter, sex ratio and node number at which first female flower appeared. Significant difference in node number was reported earlier by Kumar *et al.* (2013) and Kumar *et al.* (2014). This observation was in contrast to result reported by Kanwar *et al.* (2003) and Afangideh and Uyoh (2007). Significant difference in days to first flowering and days to 50 per cent flowering was reported earlier by Dutta (2013).

Eighteen accessions initiated male flowering earlier than Swarna Agethi, whereas 15 accessions initiated female flowering earlier than AAUC-2, the check varieties which had exhibited early male and female flower opening respectively. Similarly, 18 accessions and 13 accessions attained 50 per cent male and female flowering earlier than the best check, Swarna Agethi (39 and 45 days respectively) for this character. However, these early flowering accessions did not exhibit any geographic similarity as they represented different states. Since early flowering is a desirable character for early fruit set, the accessions which flowered early are to be considered in selection programmes for early bearing varieties.

Cucumber, being a monoecious plant produces predominantly staminate flowers than pistillate flowers, an exception being gynoecious plants with higher sex ratio. Greater number of pistillate flowers is expected to produce greater number of fruits, thus resulting in higher yield (Ahmed *et al.* 2004). IC277048, the accession which exhibited highest sex ratio was the one which produced highest number of fruits per plant. During the study season, the number of male flowers was also as high as 606 in IC613481 with a mean value of 324.80 across accessions. Greater number of male flowers negatively influences the sex ratio. Sex ratio was lowest in IC595517, which produced 383.29 male flowers and 6.65 female flowers per plant. Sex expression of cucumber is genetically controlled (Kater *et al*., 2001; Yamasaki *et al*., 2001), nevertheless several environmental factors like nutrients, day length and temperature influence the flower sex (Matsubara, 1977; Chailakhyan, 1979; Freeman *et al*., 1980; Malepszy and Niemirowicz-Szczytt, 1991 and Yamasaki *et al*., 2005).

The node number at which first female flower appeared and total number of female flowers are both reliable indices of sex expression *ex vitro* (Yamasaki *et al.* 2001). Node number at which first female flower appeared has also a direct relation with the earliness in flowering and fruiting. IC618083, which exhibited female flowering at first node itself, took only 31 days for its female flower opening. The accession which exhibited lesser days for female flower opening has economic importance. Identification of such genotypes would be useful in extending the availability of female flowers, thus increased fruit set during crop season. Early fruiting varieties can optimally utilize the natural resources than late types, where vegetative phase of the crop exploits the available resources than the reproductive phase.

High PCV and GCV observed in number of male flowers per plant, number of female flowers per plant, node number at which first female flower appeared and sex ratio are desirable as they are directly contributing to the yield component. Further, number of female flowers per plant and node number at which first female flower appeared are associated with high broad sense heritability and genetic gain. Thus these characters may be improved by direct selection methods. High PCV and GCV in node number were observed earlier by Hossain *et al.* (2010) and Gaikwad *et al.* (2011). High PCV and GCV were observed in days to male and female flowering by Hossain *et al*. (2010). High genetic gain observed in male and female flower opening was also reported earlier by Pushpalatha *et al*. (2017). A significant difference between PCV and GCV in days to 50 per cent male and female flowering indicated a considerable amount of environmental influence on these characters. Hence, phenotypic selection cannot be followed for these characters.

5.1.1.2.3. Fruit characters

All the fruit characters except days to first harvest, harvest duration and TSS revealed significant difference among the accessions studied. However, significant differences among genotypes were reported earlier by Gaikwad *et al.*, (2011) in days to first harvest and Ahmed *et al.* (2004), Pragathi (2014), Kumar *et al.* (2014) and Khan *et al.* (2015) in harvest duration. Earliness in yielding is a preferred character for commercial cultivation. IC595505, a collection from Kolazib, Mizoram took only 37.21 days for its first harvest, which also recorded the highest harvest duration. Three accessions namely IC595505, IC613459 and IC613474 outperformed the best check AAUC-2 for this character by initiating harvest on 37 days after sowing. IC613474, a collection from Nagaland, was the only accession among the above three, selected as promising one for the second experiment, other two with low organoleptic qualities. In addition, all the early maturing varieties did not give high yield as revealed by IC613459 which recorded its first harvest on 37 days after sowing but had only an yield of 546.36 g per plant. Days to last harvest extended up to 94.21 days in IC595517, a collection from Tripura. Harvest duration was recorded the lowest in IC331619 consequently, it exhibited a low yield of 642.83 g per plant only. Eleven accessions performed better than AAUC-2, the control variety, which extended the harvest for 37.38 days from first harvest.

The estimates on polar and equatorial circumference of fruits give an idea about the shape of the fruit. Consumers prefer mostly elliptical elongate fruits with more or less same circumference at polar as well as equatorial region. Three accessions namely IC613472, IC613473 and IC613466 where fruit length was greater than 18 cm and difference between polar and equatorial circumference very meagre were having good fruit shape *viz.*, elliptical elongated shape and hence could be considered as having better market value. The above three accessions possessed fruit length of 20.85 cm, 18.47 cm and 18.26 cm respectively.

Usually pickling cucumbers are canned as a whole fruit, but slicing cucumbers are canned after making slices (Ranjan *et al.* 2015). Fruit length differed significantly in the accessions studied, as reported earlier by Basavarajeshwari *et al.* (2014) and Khan *et al.* (2015). Fruit length, diameter and fruit weight are generally considered as the most important yield contributing characters. Long thin fruits are preferred in slicing cucumbers. Maximum fruit length was recorded in IC613472, which possessed fruits with a mean length of 20.85 cm. On the other hand, IC331627, with smallest fruits of 5.14 cm were of globular (round) shape with bitter taste. Fruit diameter was maximum in IC595515 (6.31 cm), which possessed oblong ellipsoid shape (Plate 12).

Seed cavity length and breadth give an idea about the placental coverage in the fruit. Flesh thickness is also an important character, since more flesh thickness gives more crispness, when consumed for salad purpose. Seed cavity length was highest in IC613472, which exhibited the highest value for fruit length of 20.85 cm. Thus, seed cavity length was directly proportional to fruit length. More seed cavity may not be considered as a positive character, as it loses the crispiness of the fruit.

Number of fruits harvested from a single plant directly gives an estimate of its yielding potential. In the present study, the number of fruits per plant ranged from 1.60 (IC612081) to 11.47 (IC277048). The more will be the number of fruits; greater will be the fruit yield as suggested by Resende (1999). All the female flowers produced on a plant, need not be resulting in fruits. The number of flowers, which had ultimately converted to fruits is more important in the yield potential of an accession. This conversion was less in accessions like IC612082, IC613459, IC539818 and IC595504, with only less than 30 per cent of the female flowers converting to fruits (Fig. 18). This gives an indication that number of female flowers did not give an ultimate idea of fruit yield.

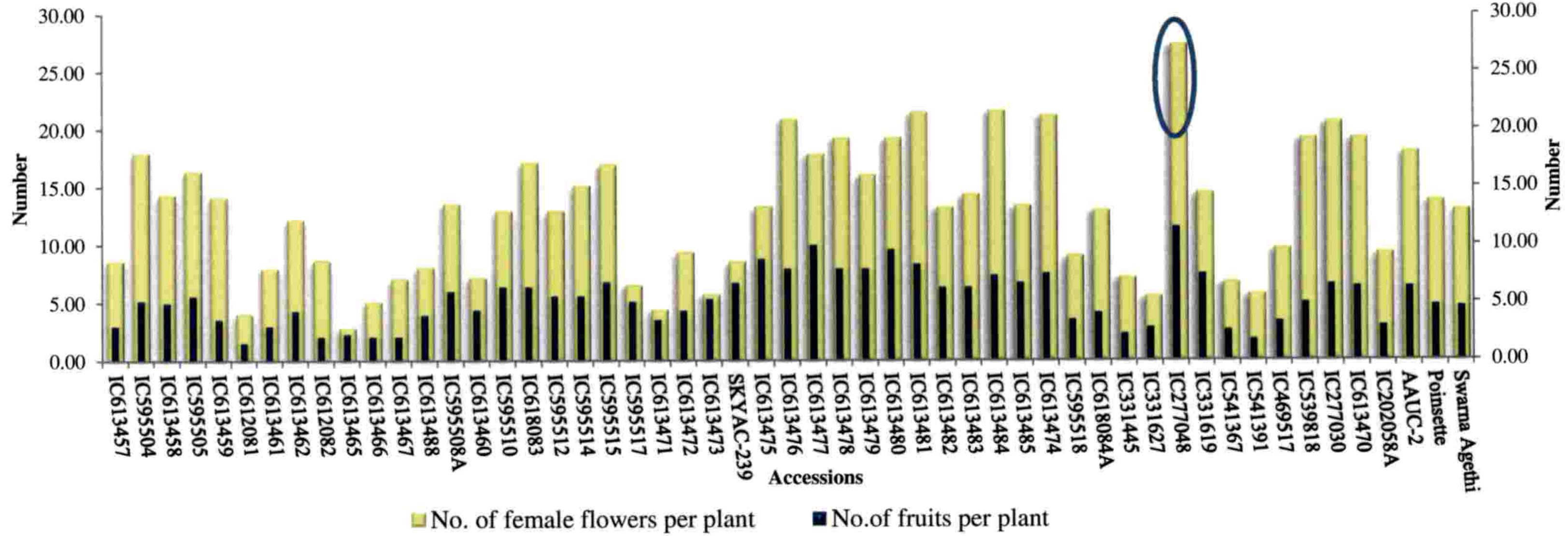

Fig. 18. Distribution of accessions for number of female flowers and number of fruits in 53 cucumber accessions

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This reduction in conversion may be attributed to high flower abscission, attack of pests on flowers as well as on primary fruits and also premature fruit shedding. Sensitivity of cucumber to rain was reported by Uwah and Afangideh (2000), consequently leading to flower abscission during rains (Afangideh and Uyoh, (2007). A detailed study need to be conducted for understanding the genetic and physiological reasons for less fruit setting.

Yield is the reflection of number of fruits per plant and the average weight of the fruit. Yield per plant ranged from 2205.29 g in IC613477 to 94.53 in IC331627. The average fruit weight of 219.71 g with 9.93 fruits per plant resulted as the best yielder among the accessions studied. SKYAC-239, a West Bengal collection yielded as high as 2070.69 g per plant, but was not selected as promising genotype in the further evaluation, because of its low Kendall's score (organoleptic score) of 78.27, revealing its poor organoleptic qualities. IC331627, the lowest yielder among the accessions had produced only 2.87 fruits per plant weighing an average of 32.97 g per fruit. IC613472, having an average fruit weight of 343.04 g yielded 1536.69 g per plant, though it produced 4.33 fruits only. Thus, selecting accessions with high fruit bearing ability and comparable fruit weight is important. Thus, high yielders who were rejected for further evaluation comprised genotypes with low organoleptic qualities. Yield being the primary objective of the breeder as well as farmers, the characters which are positively correlated with yield are to be promoted.

Total Soluble Solids (TSS) did not differ among the accessions. TSS, a quality attribute of cucumber fruit, improves the flavour and increases the palatability. Thus salad cucumber with high TSS is highly preferred. Enhanced deposition of solids may be the probable reason for higher TSS values. Significant difference in TSS between 52 genotypes was observed by Basavarajeshwari *et al.* (2014) and Ranjan *et al.* (2015).

Storage studies are very important, since maintenance of fresh and wholesome appearance of the fruits is of great value. After picking, cucumber lose their quality gradually owing to the cell destruction and colour variations due to enzymatic reactions (Miano *et al.* 2016). The main deteriorative changes in cucumber during storage and distribution are mostly due to yellowing, loss of moisture leading to shrivelling and physiological injury caused by low temperature (Adamicki, 1985). The shelf life of cucumber is generally limited to 2-4 days, depending on the climate. Storage studies indicated that accessions were significantly differing for their storage potential in terms of loss of weight during storage and number of days of storage.

Majority of the accessions developed shrivelled symptoms and discolouration at the stem end during storage. Similar results were reported by Villata *et al.* (2003) in cucumber. The weight loss during storage ranged from 4.71 g (IC613479) to 20.71 g (613466). IC618084 recorded the least days of storage, with a weight loss of 12.04g on storage. On an average, the accessions could store up to 5.27 days with a mean weight loss of 14.34 g. It was observed that weight loss was not directly related to the number of days of storage. The accessions possessing less weight loss and more number of storage days are preferred. In the accessions studied, IC331627, IC613481, IC613461, IC202058A, IC331619, IC613460, IC613477 and IC613478 were possessing good storability with weight loss of less than 10 g and storage days of 4-6 days.

Choi *et al.* (2015) opined that the storage of fruits at 10°C was selected as an optimal temperature of 'Bagdadagi', a cultivar of cucumber in Korea for maintaining storage life up to 20 days. The effect of application of gum arabic edible coating on weight loss, firmness and sensory characteristics was investigated for cucumber fruits by Al-Juhaimi *et al.* (2012). It was found that the coating has improved the storability of fruits at 10 and 25°C for 16 days. Shelf life of cucumber can be improved by storing them whole and unpeeled in plastic bags in the vegetables drawer in the refrigerator (Miano *et al.* 2016).

Fruit length and breadth exhibited moderate and low PCV and GCV respectively, indicating that more variability for these characters needs to be incorporated into the genepool through more collection missions from the rich diversity areas. Though loss of weight during storage recorded high PCV, GCV, heritability and genetic gain, the character was observed to be influenced by the climatic condition. It was also observed that the storage behaviour was highly influenced by the maturity of fruit during harvest. It was interesting to note that the fruits harvested at most optimum marketable stage showed better storability as compared to fruits, which just passed that stage. The fruits, which passed the optimum harvesting stage showed discolouration at the stem end of the fruit.

Number of fruits per plant is a very reliable character for selection for yield improvement, since it is associated with high estimate of PCV, GCV, broad sense heritability and genetic gain. Yield per plant had high PCV, GCV and genetic gain but with moderate heritability. Similar results were earlier reported by Gaikwad *et al.* (2011); Pati (2008) and Dutta (2013). Fruit weight recorded high PCV but moderate GCV, implicates some amount of environmental influence on this character. This was in agreement with Kumar *et al.* (2014) where moderate GCV reported for fruit weight. High PCV and GCV for the trait yield per plant indicated that the accessions under study possessed considerable variability. However, moderate heritability revealed influence of environment on yield. High genetic gain showed that there is scope for selection in yield, more focussed to the yield contributing characters which can easily be improved by selection.

Downy mildew is a major disease of cucumber in the open field as well as greenhouse conditions. There are currently very less cultivars tolerant to this disease. The incidence ranged from 18.50 per cent in IC595518 to 89.17 per cent in IC612082. Thirteen accessions recorded less than 50 per cent incidence of downey mildew disease. Moderate PCV, GCV, heritability and genetic gain revealed that the incidence of downy mildew is influenced by environment. It is known that the multiplication and spread of fungus *Pseudoperonospora cubensis* causing downy mildew is highly dependent on the temperature and relative humidity prevailing in the area.

5.1.1.3. Correlation studies

Correlation was worked out for major yield contributing traits ,namely, yield per plant, fruit weight, fruit length, fruit diameter, days to first harvest, number of fruits per plant and sex ratio. Correlation analysis gives an association between characters. Positive and significant association between fruit weight, fruit length and number of fruits per plant with yield per plant indicated that a direct selection of these characters can improve the yield. Similar results were earlier reported by Afangideh and Uyoh (2007). A positive direct correlation of vine length and yield was reported by Hanchinamani and Patil (2009) and Golabadi *et al.* (2013). However, Xin *et al.* (2012) have identified a dwarf mutant of cucumber characterised by short internodes and under developed tendrils, but with more female flowers and fruits and short growing period than the vine types. Non-significant association of fruit diameter and sex ratio with yield implies that a direct selection adopted in these characters will not always result in increased yield. This is evident from the fact that the high sex ratio as a result of high female flowers will not give as much number of fruits as discussed under floral characters. Non-significant positive correlation of fruit width with yield was in agreement with results of Hossain *et al.*, (2010) and non-agreement with the results reported by Abusaleha and Dutta (1989) and Khan *et al.* (2015). Similarly days to first harvest had a positive but non-significant correlation with fruit weight and negative correlation with number of fruits per plant and sex ratio. The observation of negative correlation of fruit length with fruit diameter was in contrast to the report by Khan *et al.* (2015).

5.1.1.4. Cluster analysis

Clustering pattern of accessions could be utilised in choosing the most divergent lines to be used as parents for hybridization programme, which will likely to generate the highest possible variability for various economic characters. Cluster analysis grouped 53 accessions into seven distinct clusters based on their level of similarity (Fig. 19).

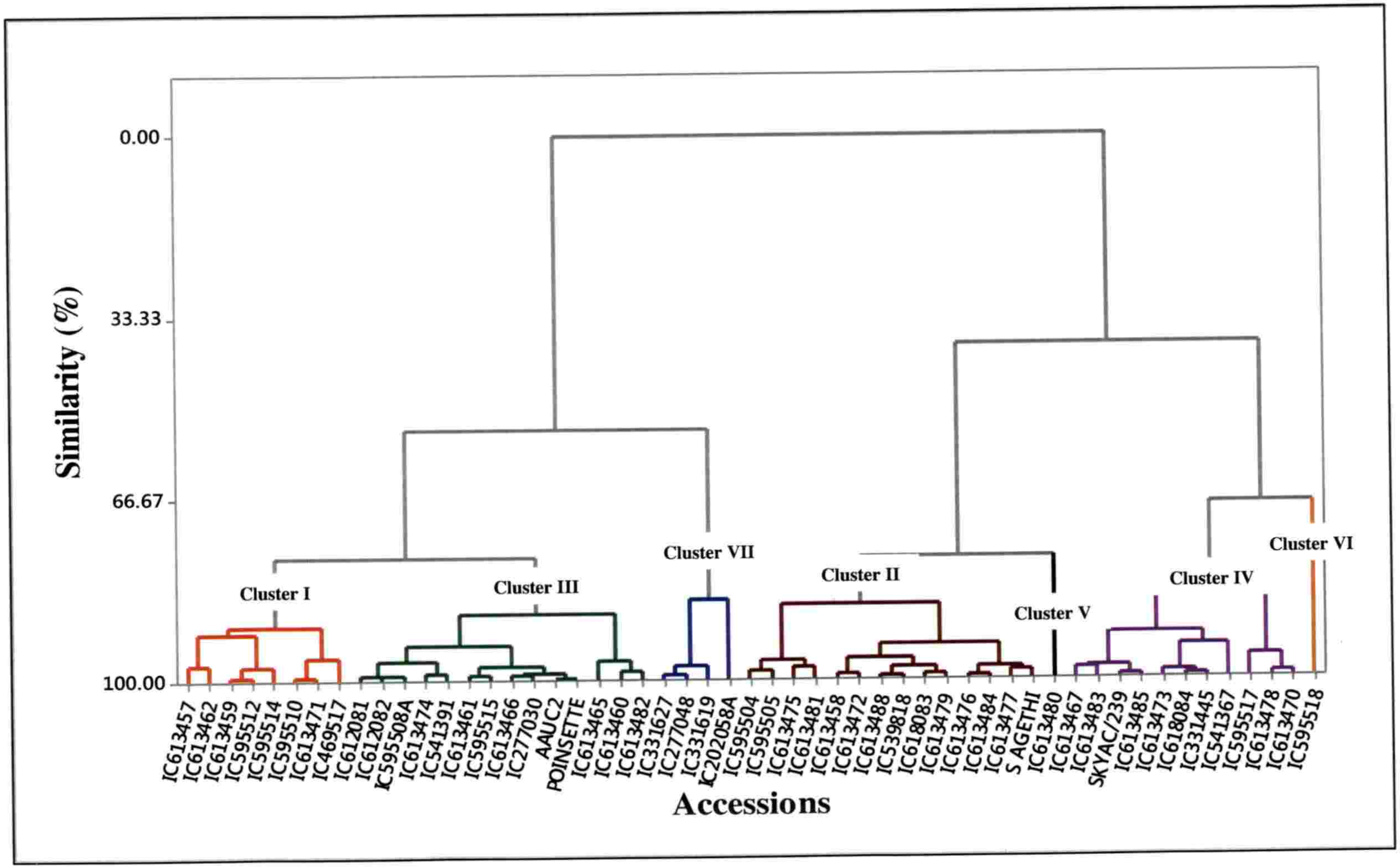

Fig. 19. Dendrogram depicting grouping of cucumber accessions into distinct clusters

Cluster II and III were the largest clusters with 14 accessions each, followed by cluster IV with 11 accessions, cluster I with 8 accessions, cluster VII with four accessions and cluster V and VI with one accession each. The divergence among clusters was proved by the high inter cluster distance than the intra cluster distance. This indicated the existence of high degree of genetic diversity in the germplasm evaluated.

The genetic distance, revealed by clustering was scrutinised against their geographic distribution using the passport data information related to the place of collection of the genotypes, and it was revealed that genotypes from different states were included in same cluster. Out of the 50 accessions, 14 accessions were from Mizoram falling in four clusters, 12 accessions from West Bengal falling in four clusters; eight accessions from Tripura in four clusters; four accessions from Arunachal Pradesh falling in three clusters; three from Andaman and Nicobar Islands in three clusters and two accessions from Maharashtra falling in two different clusters. It was interesting to note that accessions from Uttarakhand were falling to the same cluster indicating that a high similarity between them. The random pattern of distribution of accessions representing various states in different clusters revealed that there was no parallelism between genetic diversity and geographic diversity. This non-parallelism between genetic and geographic diversity had already been reported by Prasad *et al.* (1993) and Pati (2008). One of the possible reasons that free and frequent exchange of genetic material might have led to mixing of genotypes at farmer or breeder level, thus difficult to establish the real place of origin and identity of genotypes. Thus, it could be stated that forces like exchange of germplasm, genetic drift, natural and artificial selection were also responsible for genetic diversity. In addition, clustering pattern of the given genotypes might also be influenced by environment and genotype x environment interaction resulting in varying gene expression. Therefore, confirmation may be possible by conducting further trials.

Cluster I had eight accessions with 90.02 per cent similarity among the accessions. They represented collections from Mizoram (3 accessions), Tripura

(3) and one each from Arunachal Pradesh and Karnataka. Thus, all the accessions except one were from North Eastern Himalayan region. Cluster II and III exhibited 86.12 and 87.92 per cent similarity among the accessions respectively. Cluster II included six accessions from West Bengal, four accessions from Mizoram and one each from Arunachal Pradesh, Andaman and Nicobar Islands and Tripura, and Swarna Agethi, the check variety. Cluster III contained 6 accessions from Mizoram, two from Tripura, one each from Nagaland, West Bengal, Maharashtra and Andaman and Nicobar islands. Cluster IV contained one accession from Mizoram, four from west Bengal, two from Arunachal Pradesh and Tripura, one from Orissa and Andaman and Nicobar Islands, respectively. Cluster V and VI were monogenotypic cluster with single accession from West Bengal and Kerala, respectively. Cluster VII represented collections from Uttarakhand (2), Maharashtra (1) and Himachal Pradesh (1).

Accession from Kerala (IC595518) was distinct from others; the reason may be attributed to its specific characters, which gave the accession a distinct cluster status. IC595518 (Kerala accession) possessed good vine length (446.40 cm) with more than 10 primary branches and very low incidence of downy mildew (28.00 %). This accession showed comparatively delayed male and female flowering with 47.50 days and 55.00 days, respectively. It produced on an average 205.40 male flowers and 7.60 female flowers per plant giving 3.60 fruits per plant with an average fruit weight of 339.00 g. The yield was 1071.23 g per plant. It possessed good organoleptic qualities and thus selected as one of the 22 promising accessions selected for further evaluation. This accession was distinct in terms of its longest vine length, delayed flowering, delayed fruiting and highest fruit weight.

Similarly IC613480, which remained as a single cluster (cluster V), was having a vine length of 200.20 cm and 10 primary branches. Male and female flower opening started by 32.20 days and 41.60 days after sowing indicating its earliness in flowering. First harvest started by 48 days after sowing and extended up to 30 more days. However, both these accessions were selected and advanced as promising genotypes. Monogenotypic clusters comprising specific valuable traits and other genotypes falling in most divergent groups will help in broadening the existing genetic base and may produce new genotypes with hitherto unknown combinations (Pati, 2008).

Five accessions (IC613462, IC595512, IC595510, IC613471 and IC469517) from cluster I, eight accessions from cluster II (IC595504, IC613481, IC613488, IC618083, IC613479, IC613476, 613484 and IC613477), two from cluster III (IC595508A), IC613474, five from cluster IV (IC613485, IC618084A, IC331445, IC541367 and IC613470) and two monogenotypes representing cluster V and VI were selected among promising lines. Hence, during selection, the accessions scattered in different clusters, belonging to different geographical locations were selected.

The intra cluster distances were maximum in cluster I revealing that the accessions with in this cluster were diverse. The maximum inter cluster distance (388.84) was observed between cluster V and cluster VI (388.84), from Kerala and West Bengal respectively. This indicated that the monogenotypic clusters were the most diverse ones. This was followed by cluster VI and VII, holding a distance of 317 between them. The genotypes from these diverse clusters can be used as parents for hybridization programme to get higher heterotic hybrids from the segregating population. The closest clusters were cluster I and cluster III, as revealed by their lowest inter cluster distance (79.61).

Table 19 depicts the mean values of cluster, for various characters. Depending upon the aim of the breeding programme, the potential genotypes can be selected from different clusters for using in hybridization programmes. Similarly Edang *et al.* (1971) stated that the clustering pattern could be utilized in choosing parents for cross combinations which are likely to generate the highest possible variability among economic characters. It could be seen that cluster II had the least days to first harvest indicating earliness of genotypes. Hence, these genotypes in this cluster can be exploited for specific objective *viz*, earliness.

Similarly, the genotype in the cluster V had the maximum yield and number of fruits per plant. Hence, it is a promising genotype, which requires detailed evaluation. Minimum days of storage were exhibited by genotype in cluster V and maximum storability by genotypes in cluster VII.

Weight loss during storage was lowest in genotypes representing cluster VII, and highest in cluster VI. Hence, it could be noted that genotypes in cluster VII possessed good storability behaviour. However, it was worthy to note that in calculating cluster means, the superiority of particular genotype, with respect to a given character gets diluted by other genotypes that are related and grouped in the same cluster, which are inferior or intermediary for that character in question. This is because, clustering is a multivariate analysis which takes into consideration multiple variables for grouping. Hence, apart from selecting genotypes for hybridization from the clusters which give maximum inter-cluster distance, one can think of selecting parents based on extent of genetic divergence with respect to a particular character of interest.

5.1.1.5. Principal component analysis

During any plant breeding experiment, observations are taken for multiple characters. If number of variables is measured for each observation, then separate univariate statistical analyses are required. These analyses apply only to the individual components of the factor, not to the factor itself. Furthermore, the variables are usually highly inter-correlated since biological systems, being complex and highly integrated; contain a great number of interacting components which are interrelated (Kumar *et al.* 2014). Consequently these variables should not be treated as independent components of the factor in question in statistical analyses. Principal component analysis (Hotelling, 1933) restructures the data, so that a general factor can be measured by 'p' correlated variables and could be expressed in terms of $n<p$ uncorrelated variables which would be highly desirable. The first few components usually account for most of the variation of the original variables, with Eigen value more than unity as illustrated in Fig. 20.

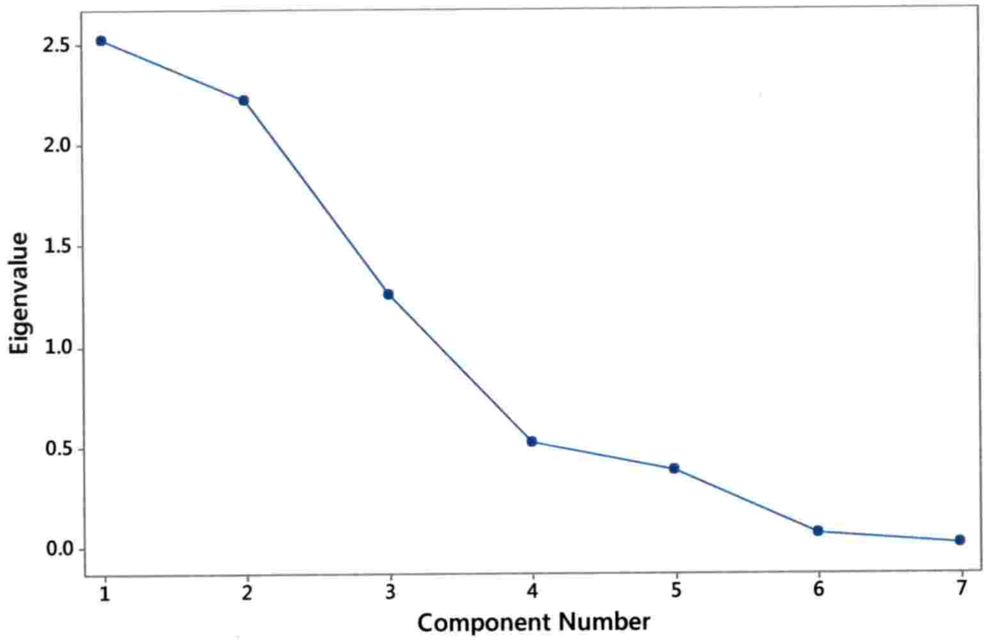

Fig. 20. Screeplot in response to two principal components

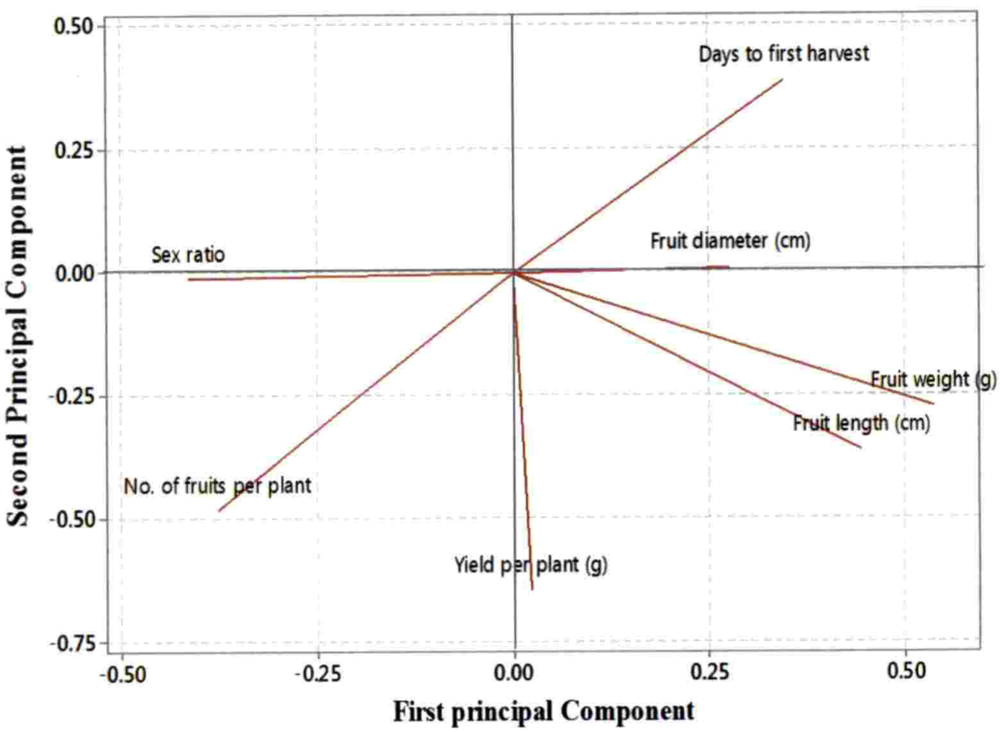

Fig. 21. Loading plot of selected quantitative characters based on two principal components

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Contribution of different characters towards the divergence was estimated with the help of principle component analysis in accordance with Lawley and Maxwell (1963).

The results of PCA revealed that only the first three principal component axes (PC1, PC2 and PC3) had eigen-vector values, whose loads were more than unity, which indicated that the identified characters within these components exhibited great influence on the accessions, hence, could effectively be utilized for selection in cucumber breeding (Table 20). The findings corroborate results reported by Cui *et al.* (1995) in their investigation on traits selection in cucumber breeding, expressing the efficacy of PCA in enhancing cucumber improvement strategies. The efficiency of PCA was also strengthened by the report of Staub *et al.* (1997) in their studies on problems associated with the selection of determinant cucumber plant types in a multiple lateral background and Shetty and Wehner (2002) in their studies on fruit yield of cucumber. The loading plot revealed positive correlation between fruit length and fruit weight; fruit weight and fruit diameter; fruits per plant and yield per plant and sex ratio and number of fruits per plant which was revealed by the acute angle between them (Fig. 21). The first five components explained 98.70 per cent of total variation. The first component contributed 36.00 per cent variation and was a measure of fruit weight and fruit length as the coefficients associated with these traits having the maximum magnitude. Second principal component was determined by days to first harvest. Fruit diameter and sex ratio were represented by third component, whereas fourth component was a measure of fruit length. According to Mardia *et al.* (1979), total variance accumulated by principal component close to 80 per cent explains satisfactorily the variability manifested between individuals.

5.1.1.6. Diversity analysis using DIVA-GIS

The DIVA-GIS is a Geographic Information System designed to assist in plant genetic resources and biodiversity research communities to map the range of distribution of species of interest (Dikshit and Sivaraj, 2015). It is useful in explaining the genetic, ecological and geographic patterns of the distribution of crops and wild species using locality (points) data available with gene banks, herbarium and natural history museum databases (Hijmans *et al.*, 2001). The mapping could be extended to agronomic-traits for assessing the genetic diversity of collected germplasm. For a successful breeding programme, the identification of potential donor(s) for yield combined with desirable agronomic and quality traits is a prerequisite.

Grid maps were generated for diversity analysis of six characters (Fig. 2 - 13). Based on the genetic variability, the colour of the grid varied from green, light green, yellow, orange and red, in the order of their magnitude of variability. Green coloured grids indicated the less diverse regions, whereas red coloured grid, the most diverse region. A wide range of variability was observed for the quantitative traits studied, among the 53 accessions as evidenced by the wide range of SDI for days to first harvest (0 - 0.035 to 1.39 - 2.00) to fruit length (0 - 0.46 to 1.84 - 2.00). The Shannon index increases as both the richness and the evenness of the population increase. Collections from West Bengal, Tripura and Mizoram possessed diversity for days to first harvest, fruit weight, fruit diameter and yield per plant, as indicated by the appearance of red grids in these states for these characters. However, high SDI for number of fruits per plant was observed in Mizoram and Tripura. Hence, maximum variability for the characters considered was observed in Mizoram and Tripura, as indicated by the high SDI and CV values.

The results of the study indicated that diverse accessions for all these traits can be sourced from Mizoram and Tripura. Accessions from West Bengal also exhibited variability in majority of characters. In addition, other North Eastern states like Arunachal Pradesh and Nagaland also harbours diversity for various characters, as indicated by the light green coloured grids revealing that these regions are also rich in cucumber diversity. It is known that cucumber is indigenous to India (Sebastian *et al.*, 2010) and the study confirmed that the crop rich diversity of *Cucumis sativus* can be explored from the foothills of the

Himalayan Mountain. Singh (2010) reported that the wild progenitor *C. hardwickii,* likely progenitor of cucumber is found growing in natural habitats in the foothills of Himalayan Mountain also occurs in Meghalaya.

Among the *Cucumis* germplasm sourced from twelve Indian states, and based on DIVA-GIS analysis it could be concluded that Mizoram, Tripura, and West Bengal were diversity rich pockets for *Cucumis sativus* germplasm for various characters. Future germplasm collections can be targeted from these diversity rich states. DIVA-GIS have been successfully used for *in-situ* assessment of *Jatropha* (Sunil *et al.*, 2008) and assessing diversity and identifying diversity rich pockets in *Phaseolus* bean (Jones *et al.*, 1997), wild potatoes (Hijmans and Spooner., 2001), Sesame (Spandana *et al.*, 2012), eggplant (Kumar *et al.*, 2013) and Dikshit *et al.* (2015). GIS mapping may also be effectively used for documentation, diversity analysis and gap analysis.

5.1.1.7. Organoleptic evaluation

Tender cucumbers are highly considered for their unique flavour as well as for the crispness of the flesh. Crispness is described as one of the most versatile single texture parameter universally liked by the consumers. Thus, organoleptic qualities are important factors to be analysed in crop breeding programmes. Consumer preference of the fruit depends on many factors including non-bitterness, crispness and flavour of the fruit. In the present study, twenty nine accessions recorded less bitterness than Poinsette, (Table 21), the control variety which exhibited least bitterness among checks.

Crispness was highest in Swarna Agethi, among the control varieties and only three accessions performed better than Swarna Agethi. Flavour was best expressed in fruits of AAUC-2 among control varieties and nine accessions recorded better values for flavour than AAUC-2. Based on the cumulative organoleptic score, IC613481 recorded the first rank followed by IC613480, both being collections from West Bengal. AAUC-2 recorded a total score of 96.03, thus AAUC-2 being the most organoleptically superior control variety. Only four accessions namely IC613480, IC613481, IC618084A and IC613484 have exhibited organoleptic quality better than AAUC-2.

Similar studies on sensory evaluation of nine cucumber hybrids was done by Pragathi (2014), where, a hybrid cucumber (Multi-Star) scored the best score for overall acceptability. Palma-Harris *et al.* (2002) conducted an experiment to determine changes in cucumber flavour during storage of non-acidified, refrigerated pickles and found a linear correlation between sensory scores and the amount of (E,Z)-2-6-nonadienal, flavour impact compound in cucumber. Miano *et al.* (2016) evaluated the effect of wrapping materials on sensory quality of cucumber. They have observed that packing materials had effect on taste, appearance and overall acceptability of cucumber fruit under ambient and refrigeration temperature. Similar studies on sensory evaluation of cucumber were done by Vora *et al.* (2014).

5.1.1.8. Selection of promising genotypes

Plant breeding involves manipulation of genetic architecture of plants for use by human beings. One of the basic methods of breeding is selection. Breeding and variety development is not a single step process. Breeder needs to identify promising or superior accessions from a diverse population and through sequential selection, identify a stable and consistent genotype. Generally phenotypic characterization is the primary step for identifying promising types. In contrast to this, Knapp (1998) suggested marker assisted selection (MAS) as a strategy for increasing the probability of selecting superior genotypes and proposed that MAS produce greater selection gains than phenotypic selection for normally distributed quantitative characters. The promising genotypes were selected based on major yield contributing characters, storage parameters and organoleptic qualities. The yield contributing characters include days to first harvest, fruit length, fruit diameter, fruit weight, yield per plant, number of fruits per plant and sex ratio. Golabadi *et al.* (2012) also suggested that the superior genotypes for fruit yield and its components could be used as superior genotypes in cucumber cultivation, and also can be recommended for fruit yield improvement, as a high yield parent in hybridization programs of cucumber.

The storage parameters included loss of weight during storage and number of days of storage. Since cucumber is consumed as salads at tender stage, the organoleptic qualities of the fruit need to be investigated. Thus the scores recorded for bitterness, crispness and flavour were also considered for selecting promising genotypes. The disease scoring was done for downy mildew incidence and per cent disease index (PDI) was calculated.

The promising accessions belonged to different states, thus ascertaining their geographical diversity. Maximum number of promising genotypes selected was from West Bengal followed by Tripura (Table 25). The parents used for hybridization from geographically diverse locations, are expected to give better hybrids than parents from same area.

Table 22 depicts the total score for yield contributing traits and storage parameters and organoleptic score obtained for each accession used in the study. The accession with lowest total score is to be considered as the ideal one. Accordingly, the lowest total score among the 53 accessions was recorded for IC613458, a collection from West Bengal. But contrary to this lowest score, total organoleptic score was only 75.47, with bitterness score of 30.93 (13^{th}position among 53 accessions), crispness score of 19.5 (39^{th} position) and flavour score of 25.04 (20^{th} position). It was clear that low crispness of the fruit, made it to secure only 40^{th} rank among the 53 accessions and hence was not selected as promising genotype for further studies. IC202058A, one of the poor performers among the accessions with a mean yield of only 460.29 g per plant, had the highest total score (6.63) and very low cumulative organoleptic score (42.11), hence do not have commercial potential.

Among the promising genotypes selected, rank I was secured by IC613481, from West Bengal, with a total score of 4.39 and total organoleptic score of 101.65. The accession had earliness in harvesting (39.88 days), with a yield of

1990.09 per plant. The average fruit weight was 238.71 g with fruit length and diameter of 17.27 cm and 5.05 cm, respectively. It showed the capacity to produce 8.33 fruits per plant. The storage qualities were also better in terms of loss of weight of only 8.71 g after 4.79 days of storage. The downy mildew incidence was 48.50 per cent. With all these characters, IC613481 could be considered as a promising genotype.

IC613480, from West Bengal was ranked second with a total score of 5.43 and total organoleptic score of 100.03. Harvesting was started by 41.88 days after sowing. The length and diameter was 15.29 cm and 4.47 cm, respectively. The accession yielded 9.53 fruits per plant weighing on an average 159.71 g per fruit. The yield per plant was 1613.29 g per plant. Incidence of downy mildew was comparatively lower (36.50 %).

The lowest total score (4.02) among the 22 selected genotypes was IC613479, which had registered a yield of 2105.29 g per plant but with lesser organoleptic score. IC613477, the 10th ranked accession had recorded the highest yield of 2205.29 g per plant, also with a lower PDI of 22.50 per cent had organoleptic score of 94.02. Similarly, IC595508A secured 22nd rank among the selected genotypes, with a yield of 1130.96 g per plant. The control variety, AAUC-2 secured 12th rank among the 53 accessions for total score with respect to yield contributing characters and storage parameters. For organoleptic qualities, AAUC-2 secured 5th rank, indicating its superiority.

Therefore, among the 53 accessions characterized, the best five accessions with respect to yield contributing characters and storage behaviour were IC613458, IC613479, IC613477, IC595518 and IC613481. The best organoleptic qualities were expressed by IC613481, IC613480, IC618084A, IC613484 and IC595512. Thus IC613481, with both good yield contributing and organoleptic qualities could be assessed as the best in preliminary trial.

A multivariate analysis approach to select parents for hybridization aiming for yield improvement in cucumber was undertaken by Afroz *et al.* (2013). They evaluated twenty two genotypes of cucumber using D^2 and principal component analysis and identified genotypes from distant clusters for hybridization. Similarly, Nath *et al.* (2014) conducted studies to select superior lentil genotypes based on genetic diversity and character association.

5.1.2. Molecular characterization

Use of SSR markers is one of the common and best choices for molecular characterization, as they are highly polymorphic, multi-allelic, co-dominant, easily reproducible and widely distributed along the genome and PCR based marker (Powell *et al.*, 1996). SSR markers are increasingly being used in number of crop species for the purpose of gene mapping, marker assisted selection, germplasm analysis and varietal identification.

SSR profiling of 22 accessions of *Cucucmis sativus* and five of wild *Cucumis* genotypes revealed high level of genetic distinctness among the genotypes studied. The analysis revealed varied size of amplicons ranging from 121.13 bp to 362.84 bp (Fig. 22). Maximum number of alleles (6) was obtained with primer SSR11742 and AF202378, indicating the informative nature of these markers (Fig. 23 and 24). All primers considered for study revealed polymorphism in wild species also. However, a total of 83 amplicons with an average of 4.1 alleles per locus was detected in the study. Similar reports of divergence at genome level was earlier reported by Pandey *et al.* (2013), on studies on molecular characterization of 44 cucumber genotypes using 53 polymorphic SSR primers. They have identified 163 amplification products with an average of 3.05 alleles per locus. In contrary, Singh *et al.* (2016) obtained 9.3 alleles per locus by characterization using eight ISSR (Inter Simple Sequence Repeats) markers. Two markers namely UW053690 and SSR11742 showed heterozygous condition in the banding pattern. UW053690 exhibited heterozygous condition in the genotype IC613476 (West Bengal).

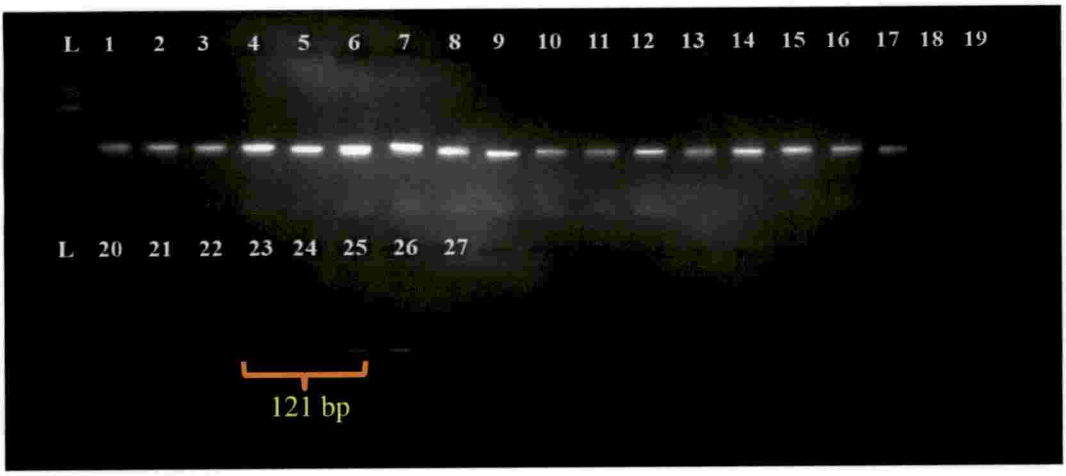

Fig. 22. SSR profiling of SSR12810 in *Cucumis* genotypes

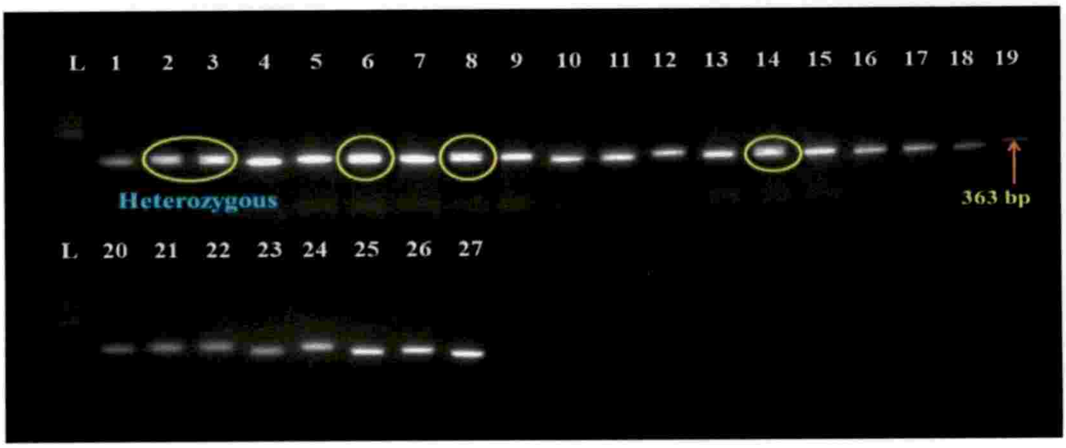

Fig. 23. SSR profiling of SSR11742 in *Cucumis* genotypes

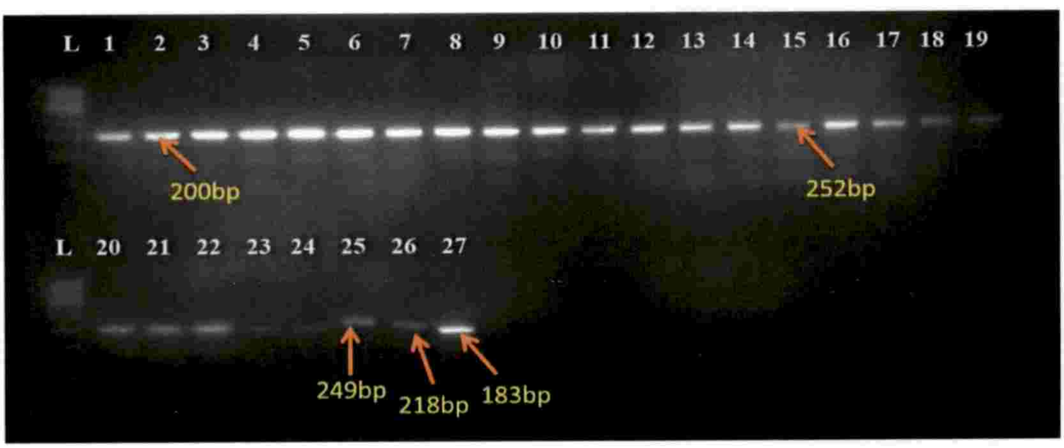

Fig. 24. SSR profiling of AF202378 in *Cucumis* genotypes

L-Ladder; 1-IC613481; 2-IC613480; 3-IC618084A; 4-IC595512, 5-IC613484; 6-IC595504; 7-IC613471; 8-IC541367; 9-IC331445; 10-IC613477; 11-IC613476; 12-IC613470; 13-IC469517; 14-IC613479; 15-IC613488; 16-IC595510; 17-IC613474; 18-IC595518; 19-IC613485; 20-IC618083; 21-IC613462; 22-IC595508A; 23-*C.hystrix*; 24-*C.setosus*; 25-*C.leosperma*; 26-*C.muriculatus*; *27-C.agrestis*

SSR11742 in IC613480 (West Bengal), IC618084A (Arunachal Pradesh), IC541367 (A&N islands) and IC613479 (West Bengal). It was revealed through nucleotide BLAST (blastn) that the sequence of SSR11742 had sequence homology with *Cucumis melo* ras-related protein Rab7-like (LOC103489588) mRNA. The distinctness of this region in the genome of 27 *Cucumis* genotypes was revealed by this marker. Pair wise similarity matrix based on Jaccard's coefficient for 27 genotypes is presented in Table 27. The similarity coefficient was maximum (0.83) between IC618084A and IC613480, IC613484 and IC595512 and IC613470 and 469517, which was in consonance with the clustering pattern followed in the dendrogram. Both IC618084A and IC613480 were collected from West Bengal. However, IC595512, a collection from Tripura, showed similarity with IC613484, from West Bengal, a state lying near the North Eastern belt of India. In contrary, IC613470 from Tripura exhibited high similarity with IC469517 from Karnataka. Similar studies were earlier conducted by Staub *et al.* (1997); Pandey *et al.* (2013) and Mliki *et al.* (2003).

A random grouping of genotypes was observed in the dendrogram as genotypes from same state grouped in different clusters and from different states falling in same cluster (Fig. 25). The clustering pattern did not reveal any parallelism with dendrogram generated using morphological data. The reason may be attributed to the influence of environmental conditions on the expression of character.

This is in agreement with the earlier reports that similarity in morphological data and Jaccard's similarity based on molecular markers usually showed non-correspondence with each other as reported by Ortiz (1997), Riday *et al.* (2003), Pandey *et al.* (2008) and Pandey *et al.* (2013). This mismatch may be due to the long term differential selection and local seed flow between farmers. Inclusion of considerable number of genotypes into cluster IV indicated the narrow genetic base of cucumber germplasm used by farmers. Hence, a diverse collection is still needed to be augmented from rich diversity areas.

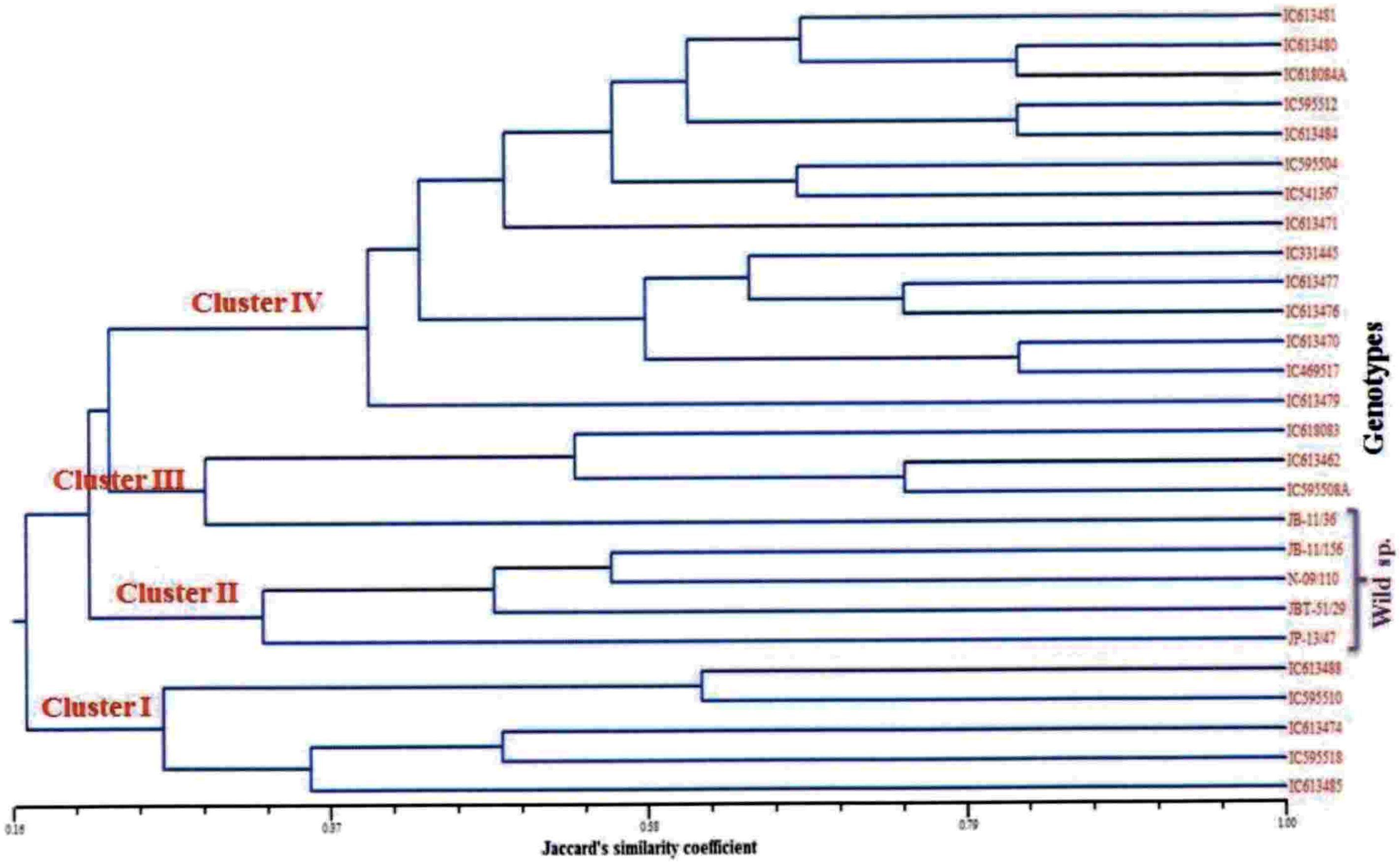

Fig. 25. Dendrogram generated based on molecular characterization of *Cucumis* genotypes

All the accessions of wild species grouped in cluster II, whereas, JB-11/36, an accession of *C. muriculatus* fallen in cluster III. Highest PIC and marker index values in AF202378 (0.81 and 4.05 respectively) followed by SSR11742 (0.75 and 3.77 respectively) are in agreement with their maximum number of amplicons produced, indicating that these markers are very informative and can be used in future genetic diversity analysis studies in cucumber (Table 24). Unique bands produced by SSR11742 in the genotype IC613485 and JBT-51/29 (*C. agrestis*) may be characterised in detail in future studies.

5.2. Evaluation of promising genotypes

The performance of a genotype depends on the genetic makeup as well as the environmental conditions affecting the expression of genes. The consistency in the performance of a genotype is exercised by evaluating them under varied environmental conditions. In-depth evaluation will reveal potentially of useful variability for further use in crop improvement programmes and commercial uses. Evaluation goes deeper than characterization. It usually includes evaluation of agronomic characters including yield.

In the present study 22 promising genotypes identified from the preliminary characterization were evaluated for determining their consistency in performance. Observations on shoot, floral and fruit characters were taken for study.

5.2.1. Quantitative characters

5.2.1.1. Shoot characters

Shoot characters studied included vine length and number of primary branches. There was a considerable decrease in vine length and number of primary branches in all the accessions studied. Vine length and number of primary branches were significantly different among the genotypes studied. IC613481 possessed maximum vine length, the accession which ranked first among the 53 accessions characterised in the preliminary characterization. The vine length for this accession in experiment I was 32.36 per cent higher than that in the current experiment. The minimum vine length (195.00) cm was observed in IC613470, which exhibited a decrease of 47 per cent than experiment I. The mean vine length of the genotypes in experiment II was 238.00 cm whereas mean vine length of genotypes was 323.22 cm in experiment I. This indicated that there was a mean reduction of 26.36 per cent in vine length in experiment II.

As in the case of vine length, number of primary branches also, a clear reduction was noticed in the current experiment. Number of primary branches was highest in IC613471 and lowest in IC618084A. IC613485, which produced the maximum number of primary branches of 13.29 in experiment I, had produced only 6.60 branches in the current experiment. The reduction in shoot characters can be mainly attributed to environmental factors, since the present study was conducted during *rabi* season (Nov 2015 – Jan 2016), with high atmospheric temperature during day time.

5.2.1.2. Floral characters

Days to male flower opening and number of female flowers per plant did not differ significantly among the genotypes evaluated. Early male and female flowering was expressed by IC595518 (25.50 days) and Poinsette (28.00 days) respectively. Hence, a drastic reduction in days to male flower opening was exhibited by IC595518 compared to experiment I. However, Poinsette did not exhibit obvious difference in days to female flower opening in two experiments. The mean days to male and female flowering was 36.01days and 43.29 days in experiment I, whereas those observed in experiment II were 30.80 days and 36.04 days respectively. Likewise, days to male flower and female flower opening, days to 50 per cent male and female flowering was less in this experiment compared to experiment I. This earliness may be due to the fact that the plants may shift to reproductive phase early due to the stress caused by unfavourable environmental factors. Similarly, a considerable decrease in mean number of male flowers and female flowers produced by the genotypes was noticed in the current experiment compared to experiment I. Fig. 26 depicts the comparison of female flowers produced by the 22 accessions in experiment I and experiment II. This reduction in number of female flowers was also reflected in number of fruits developed. The mean node number at which first male and female flowers appeared was recorded as 4.39 and 7.50 respectively. Sex ratio ranged from 0.03 to 0.12, with highest value observed in IC613474, a collection from Nagaland, which produced 74.50 and 8.90 male and female flowers respectively. The sex ratio did not differ between experiment I and II, as there was parallel decrease in both male and female flowers in majority of genotypes. To support this, IC613474, showed same sex ratio (0.12) in both the experiments.

5.2.1.3. Fruit characters

Significant difference among the genotypes was observed for all fruit characters except days to last harvest and harvest duration. IC468517 took a minimum 45 days for first harvest in this experiment whereas it took more days (64.21 days) for first harvest in experiment I, due to excessive vegetative growth. On the other hand, AAUC-2 took only 38.38 days for first harvest in experiment I, whereas in the current experiment harvesting was delayed up to 54 days. First harvest was recorded after 45 days of sowing in two genotypes namely IC469517 and IC595518, in which female flowering was also comparatively early (33.50 and 31.00 days respectively). On analysing the performance of genotypes for earliness in harvest, minimum days to first harvest (37.21 days) was less in experiment I. Thus, it was clear that, even though, the genotypes exhibited earliness in flowering in the current experiment, harvest date was delayed. This may be because the female flowers developed during the initial reproductive phase might have shed off due to unfavourable conditions.

Fruit length ranged from 10.43 cm to 19.57 cm in IC613470 and IC595510 respectively. IC595510, a long fruited genotype, could be an important source for improving the length of the fruit, since the genotype produced fruits with a mean length of 18.99 cm in experiment I also. Fruit length is a key character during

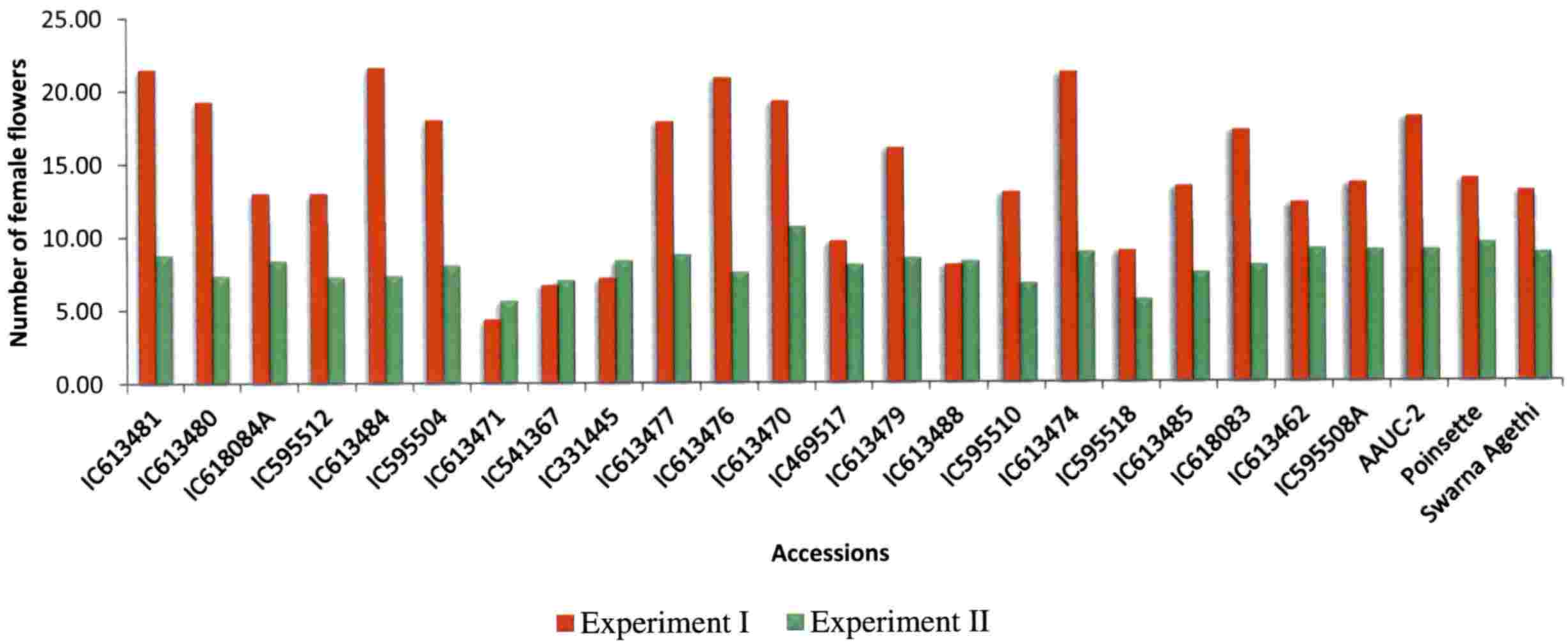

Fig. 26. Comparison of number of female flowers produced by 22 genotypes in experiment I and II

selection, since it has direct effect on yield and moreover, long fruits are more preferred by customers. Fruit diameter, though increases the yield, will contribute to bulginess of the fruits. Fruit diameter was observed maximum in IC595518, which produced oblong ellipsoid shaped fruits. Fruit diameter was minimum in IC595504, which produced elongate ellipsoid fruits.

Fruit weight was minimum (171.00 g) in IC613470 and maximum in IC618084A. Number of fruits per plant, a character directly related to yield, was maximum in IC613477 (7.20) which produced 9.93 fruits in experiment I, thus showing a consistent performance in yielding. The higher number of fruits led to high yield (2023.20 g per plant) in this genotype. The yield per plant was lowest in IC541367 (782.80 g). The general fruit setting in all the genotypes were also low, a factor which could be related to the environmental influence. This was clear from the less mean number of fruits per plant (5.75) in experiment II. Though these genotypes had good genetic potential, the climatic conditions limited the expression of the character in these genotypes. A comparison of performance in yield per plant in two experiments is plotted (Fig. 27).

It revealed that majority of the genotypes had less yield in experiment II. However, IC618084A recorded more yield (1123.20 g per plant) than the yield recorded in experiment I (926.02). IC618084A had a mean fruit weight of 288.00 g, which has contributed to this yield rather than number of fruits. Similar trend of increased yield in the current experiment was observed in IC595508A and IC613485 also. These genotypes may have the ability to tolerate the stress conditions. A detailed study in this direction to examine the stability of performance over different locations and environments may confirm these results. Moreover, there was drastic decrease in yield in IC613481, the most promising genotype identified from experiment I. Though it produced 8.80 female flowers per plant, the high flower abscission might be the reason for low fruit set. This should be confirmed by further studies. Severe and wider incidence of pest and disease attack was not observed during experiment II, though the incidence of powdery mildew occurred towards the end of the crop season. Swarna Agethi,

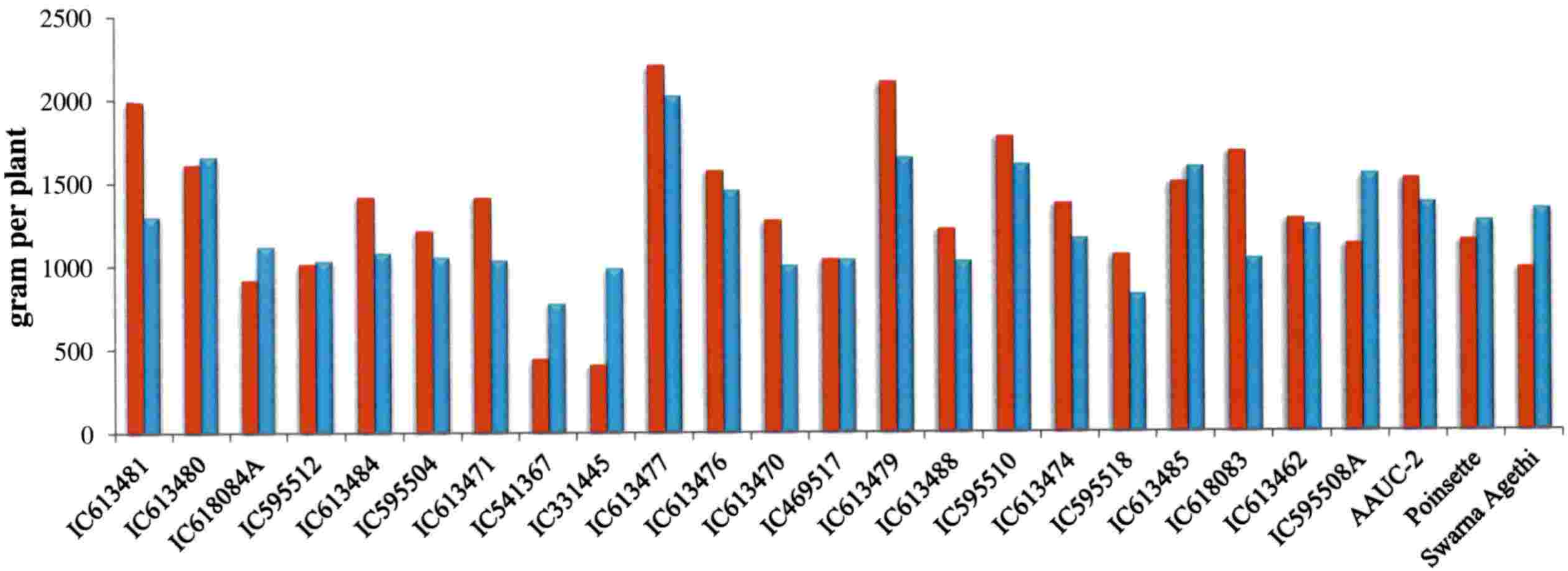

Fig. 27. Comparison yield per plant produced by 22 genotypes in experiment I and II

one of the check varieties that recorded higher yield (1337.70 g) in experiment II than experiment I (985.85 g). The decrease in yield in experiment I might be due to high level of downy mildew incidence (79.25 per cent) during the season. This variety, from Bihar state could not tolerate the incidence of downy mildew which aggravated during high humidity conditions.

On examining the storage parameters, it was evident that the genotypes did not exhibit a linear decrease or increase in the days of storage in the genotypes studied (Fig. 28). In addition, the genotypes expressed differently in experiment I and II. IC618084A, IC595512, IC595504, IC331445, IC613488, IC595510, IC618083, IC613462, IC595508A, Poinsette and Swarna Agethi, performed better in terms of the days of storage, than in experiment I, where as in all other genotypes except IC613474, the number of days of storage decreased. Number of days of storage was on par with that of experiment I in IC613474. The better performance of some of these genotypes may be attributed to the climate during the harvesting and storage season, since the time of harvest and storage coincided with the winter season.

Loss of weight during storage was greater in all the accessions except IC469517, when compared with their weight loss in experiment I. In IC469517, the weight loss in the current experiment was on par with that of the previous experiment (19.04 and 19.00 respectively). The mean weight loss during storage was also higher (25.77 g) than in previous experiment (14.34 g). This was due to the high temperature prevailed in the atmosphere during day time. Maximum weight loss was observed in IC618083 (36.56 g) and minimum in IC613480 (15.50 g). A drastic difference in weight loss between experiment I and II was observed in IC618083.

Control varieties also did not exhibit good storage behaviour in this study. An interesting observation was that the maturity of fruits and the appearance of fruit during harvest greatly influenced the storability. If harvesting is delayed by one or two days, development of a brownish discolouration at the stem end of the

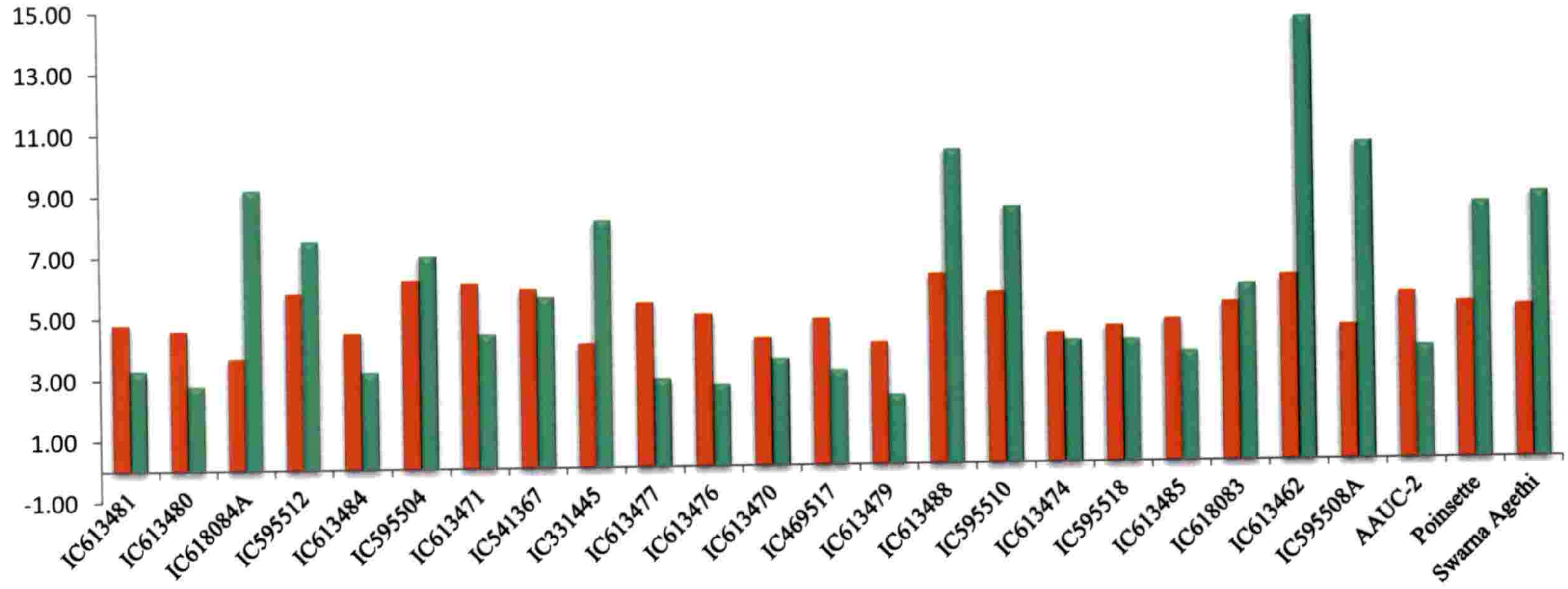

Fig. 28. Comparison of days of storage of 22 genotypes in experiment I and II

fruit was noticed. This discolouration spread very fast on the fruit surface thus causing a deterioration of the morphological appearance of the fruit. This mutilated appearance of the fruit will detract consumers.

5.2.1.4. Organoleptic evaluation

Organoleptic scoring aided in selecting the most superior genotypes with least bitterness and maximum crispness and flavour. Least bitter genotype was IC613471 with a score of 14.60. Superior genotypes with respect to crispness and flavour were 595508A and IC613471. Better organoleptic qualities exhibited by IC613471 led to selection of this genotype for experiment III, even though it has registered average yield parameters. All other genotypes had also recorded good cumulative organoleptic scores.

5.2.1.5. Selection of promising genotypes

Six genotypes were selected based on the method adopted in the first experiment. The mean values for the different characters considered for the selected genotypes are depicted in Table 37. IC613480 secured rank I with a total score of 3.29 and cumulative organoleptic score of 45.63. IC613480 was found superior in terms of minimum days for harvest, number of fruits per plant, yield per plant and minimum weight loss during storage among the six genotypes. All these selected genotypes performed better than the three checks in terms of these characters. IC595508A, which performed better than in experiment I with respect to yield, has proved its consistency in performance. These selected genotypes had the best organoleptic qualities with cumulative scores above 43.10.

However, two genotypes namely, IC613477 and IC613479 which recorded comparatively good yield in both experiment I and also in II, were not carried forward to the third experiment owing to their low organoleptic qualities. The cumulative organoleptic score for these genotypes were 30.34 and 36.49 respectively. These genotypes can be used as source material for incorporating genes for stable yield characters.

Similar studies for selection of superior genotypes as donor parent for hybridization were attempted by many researchers in various crops. Twenty two genotypes of cucumber were evaluated using D^2 and principal component analysis to select suitable donor parents for improved breeding of cucumber (Afroz *et al.*, 2013). Considering diversity pattern and other field performances, five genotypes from different clusters were identified as best choice as suitable parents for efficient hybridization program. Efficiency of early generation testing in pickling cucumber during recurrent selection was investigated by Rubino and Wehner (1986). In their study, inbreds were developed from families selected from improved population through recurrent selection by selecting for yield and other traits of interest.

5.3. Development of hybrids and evaluation of hybrid combinations

Exploitation of hybrid vigour is a model approach to boost the cucumber production in different parts of the world. Hayes and Jones (1916) first reported hybrid vigour in cucumber. In India, though a number of studies have been undertaken to utilize the prospects of hybrid vigour in cucumber, only few reports are available on the hybrids released as varieties. From Kerala Agricultural University, Thrissur, two hybrids (Heera and Subhra) have been released as suitable for open field cultivation. However, a number of hybrids have been developed and released by the private companies. Hence development and evaluation of hybrids need to be given much emphasis for crops like cucumber. In the present investigation, 15 hybrid combinations were developed and evaluated.

5.3.1. Qualitative characters

Quality attributes like fruit colour, shape, size and nutritional quality are to be given prime importance by the breeders to improve cucumber. Visual appearance of the fruit is a consumer preference determining factor. Attractive fruit skin colour like light green or green, uniformly long cylindrical fruits with smooth surface without prominent spines, prickles, crook neck and crispy with tender flesh are the primary objectives of breeding for the quality characters in

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cucumber (Kumar *et al.* 2017). Hence, the final goal of breeder is to develop high yielding cucumber varieties with combinations of acceptable quality traits, organoleptic qualities and good storability behaviour. The genotypes possessing good qualitative traits can be included in the breeding programme for specifically transferring the favourable characters. In the present study, variability among hybrids was observed for qualitative traits namely fruit shape, fruit skin colour and primary fruit colour.

All the hybrids except IC613488 x IC613471, IC613488 x IC613485, IC613488 x IC595508A, IC613476 x IC595508A and IC613485 x IC595508A possessed elliptical elongated shape, a consumer preferred character. Among the parents, IC613480, IC613471 and IC613485 also possessed the elliptical elongated shape. Both the parents of the hybrids IC613488 x IC595508A and IC613476 x IC595508A possessed oblong ellipsoid shape, and thus the hybrids too possessed the same. But in contrary, in hybrids IC613488 x IC613471and IC613488 x IC613485, the oblong ellipsoid shape was inherited from the female parent whereas in IC613485 x IC595508A, the character was from male parent. Similarly, the hybrids IC613480 x IC613471, IC613480 x IC613485 and IC613471 x IC613485 exhibited elliptical elongate shape of the fruit, as both the parents involved in the crosses had elliptical elongate shaped fruits. Thus a detailed study on inheritance of these characters will provide a clear cut result and explanation for the same.

Seven out of 15 hybrids exhibited green colour whereas remaining hybrids had light green colour for fruit skin. Random transfer of genes from both male and female parent was noticed for the character fruit skin colour also. Paternal inheritance was observed for fruit skin colour in IC613480 x IC613471, IC613488 x IC595508A, IC613488 x IC613471, IC613488 x IC595508A and IC613485 x IC595508A. All these hybrids possessed fruits with green colour while their female parent had light green fruits. In contrary, character from female parent was transferred in IC613476 x IC613471, IC613476 x IC595508A and IC613471 x IC613485. The colour of primary fruits was light green in all the parents except

IC613471. However, the IC613480 x IC613476, IC613488 x IC613476, IC613488 x IC613471 and IC613471 x IC595508A had green coloured primary fruits in non-consonance with the parental character.

From the study, it can be concluded that fruit shape, fruit skin colour and colour of primary fruits are not fully maternal characters as there was random flow of genes from both male and female parents. Moreover, the characters are highly controlled by the environmental factors like temperature and light intensity.

5.3.2. Quantitative characters

Observations on shoot, floral and fruit characters were considered for hybrid evaluation. Shoot characters included vine length and number of primary branches. Maximum vine length was exhibited by IC613480 x IC613485 (357.20 cm). The mean vine length among parents was 284.56 and that of hybrids was 301.39 cm (Table 46). Thus, a marginal increase in mean vine length was observed in hybrids over the parents, which indicated the improvement in vigour for vine length in hybrids. Expression of hybrid vigour for vine length in cucumber had been reported earlier by Kaur and Dhall (2017).

Number of primary branches among hybrids was highest in IC613476 x IC613485 (12.33) and lowest in IC613488 x IC595508A (7.27). The maximum vine length and number of primary branches in IC613480 x IC613485 and IC613476 x IC613485 was not directly reflected in the yield of these hybrids. However, Pandey *et al.* (2013) reported that the genotype having maximum vine length has recorded the highest yield. IC613488 x IC595508A was proved to be poor in vegetative growth characters, as evident from its lowest vine length (227.67 cm) and number of primary branches (7.27) among hybrids. It was reported by Sharma (2010), that an increased vine length and number of primary branches are desirable traits to realize higher marketable yield, only when the environmental conditions are otherwise suitable for growth and fruiting over a longer period.

Not much difference was observed between parents and hybrids for days to first male and female flower opening. Even though IC613485 was early in male flower opening, this character was not reflected in the hybrids with IC613485 as one of the parent. Days to first female flower opening was very much delayed in IC613471 x IC613485, which recorded a value of 43.93 days as against the parental value of 47.93 days in IC613471 (Table 43 & 44). Early flowering is desired for getting yield with early maturity. Earliness in production of female flowers may be a genetic character as suggested by Prasad and Singh (1992); Verma (2003); and Kumar *et al.* (2008) in cucumber or may be due to the effect of growing environment as reported by Yogesh *et al.* (2009). However, days to 50 percent male and female flowering of hybrids were on par with the parents.

The mean number of male flowers was more in parents than that of hybrids, but showed non-significant difference. In contrast to this, number of female flowers per plant was higher in hybrids than parents, thus contributing to higher yield in hybrids. Number of female flowers per plant plays an important role in yield production in cucumber hybrid. The increase in number of female flowers in hybrids was earlier reported by Ahmed *et al.* (2004) and Patel *et al.* (2013). This increase in female flowers in hybrids directly led to significant increase in sex ratio for hybrids over the parents. The high sex ratio would have been responsible for higher yield in hybrids as reported by Ahmed *et al.* (2004).

The nodal position at which first male and female flowers produced was lower in parents compared to hybrids. This was in contrary to the results reported by Jat *et al.* (2014). The mean value for days taken for first female flower opening was less in hybrids than the parents, which was in consonance with fewer days to first harvest in hybrids. Earliness plays important role on fetching higher price and more income. Therefore, early varieties are generally preferred for cultivation on commercial scale (Pragathi, 2014). Days to last harvest was delayed in parents than hybrids, which was a desirable feature with respect to yield.

The mean fruit length (15.45 cm) of hybrids was higher than the mean fruit length of parents (Table 45). The highest fruit length was observed in IC613476 x IC613471 (17.84 cm). IC613471, the male parent of this cross recorded the maximum fruit length among parents. Similarly, hybrid with lowest fruit length (IC613488 x IC613476), was having a parent (IC613488) recorded with lowest fruit length. In the character fruit diameter also, similar trend was observed. IC613488 x IC595508A, the highest performing hybrid with respect to fruit diameter (4.83 cm), had IC595508A as male parent which recorded maximum fruit diameter (4.84 cm) among parents. The lowest fruit dimeter was exhibited by the cross IC613471 x IC613485 (4.09 cm), in which IC613471, the female parent, which had lowest fruit diameter among parents. However, there was not much vigour expressed in hybrids with respect to this character. Fruit diameter appears to be more controlled by environmental factors while fruit length appeared to be varietal character of some fruit-vegetables (Chandima *et al.*, 2006).

There was significant increase in number of fruits produced in hybrids than the parents. IC613480 x IC613471 and parent IC613488 produced maximum number of fruits among hybrids and parents with values 11.43 and 8.95 respectively. Hence, IC613488 can be used as a parental source during selection with specific objective of improving the number of fruits per plant. Though IC613471 recorded lowest number of fruits among parents, the fruit number was more in hybrids, with IC613471 as one of the parents, except in cross IC613471 x IC613485 (6.19). All the crosses involving IC613488 produced more than eight fruits per plant except in IC613488 x IC613485 (7.86).

Though fruit weight, improved in hybrids than the parents in general, the increase was not significant. Maximum fruit weight was observed in IC613476 x IC613471 (224.00 g) among hybrids and IC613480 (193.00 g) among parents. Total fruit yield per plant is influenced mainly by mean fruit weight and number of fruits per plant.

Fruit yield is usually the most important index for selecting hybrids with high yield potential per plant or per unit area basis which determines commercial value (Pragathi, 2014). Yield of cucumber is positively correlated with the fruit length, fruit diameter and fruit weight (Ahmed *et al.* 2004), whereas fruit weight is more of a time function (Kaur and Dhall, 2017). There was significant yield improvement in hybrids than that of parents. IC613480 x IC595508A exhibited highest yield of 2307.63 g per plant as against the parental highest of 1659.15 g in IC613485. Six hybrids out of 15, showed greater yield than the standard check AAUC-2 (1385.69 g). The increased yield may be due to improvement in yield contributing characters like fruit length, fruit diameter, fruit weight, number of fruits per plant and harvest duration in hybrids. Similar reports of increase in horticultural traits in hybrids than that of parents were reported earlier by Munshi *et al.* (2005), Kumbhar *et al.* (2005), Pandey *et al.* (2005), Pati (2008), Kumar *et al.* (2010); Airina, (2013) and Kaur and Dhall (2017).

Results of storage behaviour in hybrids and parents are given in Table 45. The mean weight loss during storage was more in parents than the hybrids. Hence the performance of hybrids was better than the parents for the character. However, number of days of storage did not differ significantly between parents and hybrids.

5.3.3. Combining ability studies

Analysis of combining ability has been used in practical crop improvement programmes to determine the relative importance of general combining ability (GCA) of the parents and specific combining ability (SCA) of the crosses. Each inbred used as parent for hybridization programme, differ in their ability to combine with other inbred. Similarly, each cross combination differs with respect to their specific combining ability to express the performance when compared to other crosses. Estimation of general and specific combining ability variances and their effects, aid the researchers to find the inbreds as suitable parents to be used in hybridization programmes, to develop superior hybrids. GCA is the manifestation of additive gene action whereas SCA, the non-additive component (Singh *et al.* 2011). Evaluation of hybrids was done as per method suggested by Griffing (1956), following method II and model I. As per method II, only direct crosses were evaluated using selected parents (fixed effect model). Reciprocal crosses were not evaluated, because earlier studies indicated that reciprocal differences in such crosses were not significant for the traits evaluated and assumed no significant epistasis (Staub and Kupper, 1985). Limited number of parents were considered, because they were specifically selected based on their performance.

The results of the analysis of variance for combining ability revealed that mean squares for general combining ability calculated from six parental lines were highly significant for shoot characters, all floral characters except number of female flowers per plant and female flower diameter; and all fruit characters except number of fruits per plant, indicating the variability with respect to their general combining ability. The mean squares for SCA were significant for most of the floral characters and fruit characters suggesting the presence of significant variation among crosses. Similar results for significance in GCA and SCA in various horticultural traits have been reported by various researchers (Lopez-Sese and Staub, 2002; Reddy *et al.*, 2014; Vidhya and Kumar, 2014; Kaur *et al.* 2016; Kaur and Dhall, 2017). The hybridization between the selected inbreds could be done either for exploiting heterosis or for selecting transgressive segregants or for effecting recurrent selection (Vidhya and Kumar, 2014). Significance of mean squares due to GCA and SCA indicate the importance of both additive and non-additive genetic components for the characters studied (Pati, 2011).

It was observed that IC613485 having highest positive GCA effect (25.05) is the best combiner for vine length (Table 51). IC613471, which exhibited positive significant GCA for both vine length and number of primary branches, indicated its considerable vegetative growth. IC613480 is the only parent which showed positive significant GCA effect (0.61) for number of fruits per plant. Negative GCA effects in the desirable direction for days to 50 per cent female

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flowering (-2.07) and days to first harvest (-1.31) were also expressed by IC613480. The genotype IC595508A was the best combiner for node number at which first female flower appeared (high negative GCA effect of -0.69). All the parents except IC613485 and IC595508A exhibited negative GCA effects for sex ratio.

Positive and significant GCA effect was also exhibited by IC613471 and IC613485, in addition to IC613480 for fruit length. IC613488 was best combiner for fruit diameter, equatorial circumference and TSS content. IC613476 showed positive and significant GCA effect (5.49) for fruit weight. Best combiner for storage attributes *viz.*, loss of weight during storage was IC613485 and for number of days of storage was IC595508A. None of the parents exhibited significant negative GCA effects in the favourable direction for days to first harvest, though IC613480, IC613476, IC613485 and IC595508A exhibited negative GCA effect. IC613480 was proved to be a promising parent by exhibiting favourable GCA effects for number of male flowers per plant, days to last harvest, fruit length, number of fruits per plant, seed cavity length, yield per plant and harvest duration, followed by IC613485, which exhibited GCA effects in six characters. These superior genotypes identified from this study for different characters could be used in recombination breeding programs to accumulate suitable genes that are responsible for improving yield as reported by (Golabadi *et al.*, 2015). High GCA estimates indicated about the gene flow from parents to offspring at high frequency and gives information about the concentration of predominantly additive genes. Franco *et al.* (2001) proposed that when genotypes with greater estimates of GCA are used in hybridization, the resulting crosses will be superior for selection of lines in the advanced generation.

Positive and significant SCA effect for vine length and number of primary branches were not observed in any of the crosses (Table 52). In contrary, Solanki and Shah (1990), reported significant SCA effects for vine length. Among floral characters, the cross IC613480 x IC613471, which exhibited highest SCA for number of female flowers per plant (3.18), showed the highest SCA effect for sex ratio (0.04) also. Similarly, the cross IC613480 x IC613485 with highest SCA effect for number of male flowers had exhibited high negative SCA effect for sex ratio. Solanki and Shah (1990), reported significant SCA effects for number of female flowers per plant, number of fruits per plant and yield per plant in most of the cucumber crosses. The hybrid IC613488 x IC613471 exhibited highest negative SCA effect, for characters like days to first male flower opening and node number at which first female flower appeared, which favour SCA effect in negative direction. IC613480 x IC613488, IC613488 x IC613471, IC613476 x IC595508A and IC613471 x IC595508A exhibited negative heterosis in desirable direction for days to first male flower opening. Significant negative SCA effect for days to 50 per cent female flowering was exhibited by IC613476 x IC613471 (-2.13).

Among fruit characters, highest SCA effect in the favourable negative direction for days to first harvest was recorded for IC613471 x IC595508A, in which the parent IC505508A had recorded comparatively low *per se* value for this character (47 days) (Table 45 & 53). The highest SCA effect for fruit length was exhibited by the cross combination IC613476 x IC613471 (1.99), which also showed highest SCA effect for fruit weight (28.81) and seed cavity length (1.92). IC613471, one of the parents in the cross recorded the highest *per se* performance for fruit length. It was noted that high GCA effects of parents were reflected in high SCA effect of the crosses involving those parents, *i.e.*, if either of the parental lines involved in a cross have high GCA for a character, the resulting cross also show superiority for that character as earlier reported by Reddy (2008) and Pati (2011). This was evident from the fact that cross IC613480 x IC595508A with highest SCA effect of 493.91 for yield per plant was developed from the parent IC613480 with highest GCA effect (165.88) for the character. Similarly, crosses developed using IC595508A as one of the parents have exhibited significant SCA effect for sex ratio, as IC595508A had the highest GCA effect for the character. The present results are in conformity with the earlier studies conducted by Singh *et al.* (1998) and Munshi *et al.* (2006) in cucumber. However, IC613488 x IC613471, which exhibited highest negative SCA effect (-5.24) in the favourable direction for loss of weight during storage, showed positive GCA effect by both the parents. This may be attributed to the high influence of environment on the shelf life of cucumber rather than its genetic makeup. A slight change in the harvesting maturity of the fruits affected the storage life of the fruit. Storability of the raw fruits without affecting the quality and appearance, is determining factor in the market, as low storage behaviour of the fruits lead to brownish discolouration on fruit surface and decline in firmness and crispness of the flesh.

It was observed that, among the 15 crosses considered for the present study, significant SCA effects in desirable direction for days to first harvest was exhibited by one cross (IC613471 x IC595508A), two crosses for fruit length (IC613476 x IC613471 and IC613476 x IC595508A), one cross for number of fruits per plant (IC613480 x IC613471), three crosses for fruit weight (IC613480 x IC595508A, IC613488 x IC613485 and IC613476 x IC613471), two for yield per plant (IC613480 x IC613471 and IC613480 x IC595508A) and seven for sex ratio (IC613480 x IC613471, IC613480 x IC595508A, IC613488 x IC613471, IC613488 x IC595508A, IC613476 x IC613471, IC613476 x IC595508A and IC613485 x IC595508A).

It was also interesting to observe that there was a linear relationship between the *per se* performance of the parents and hybrids with their respective GCA effects and SCA effect respectively in characters namely sex ratio and fruit length. The parents with high *per se* performance along with high GCA effect had maximum concentration of favourable genes for these traits (Dogra and Kanwar, 2011). No linear relation for *per se* performance and the GCA and SCA effects was observed for days to first harvest. Dogra and Kanwar, (2011) suggested such effects might be due to a higher degree of gene action involved. However, direct association between *per se* performance of the cross and their respective SCA effects for fruit weight, number of fruits per plant and yield per plant were also

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observed. Similarly, effects were also observed between *per se* performance of parents and their GCA effect for fruit diameter.

Ratio of variance due to GCA to variance due to SCA and predictability ratio of more than unity in vine length, days to 50 per cent male flowering, days to 50 per cent female flowering and node number at which first male flower appeared, days to first harvest, fruit length, seed cavity length, equatorial circumference and number of days of storage indicated that these characters are controlled by additive gene effects (Table 52). These characters can be improved by selection methods or by adopting recombination method followed by selection in early segregating generation. Frederick and Staub (1989) also observed a significant role for GCA effects on the genetic control of fruit length. These results agree with those reported by Dogra and Kanwar (2011) and Sarkar and Sirohi (2011), but are inconsistent with those reported by Hormuzdi and More (1989).

Yield contributing characters namely number of fruits per plant, fruit weight, yield per plant and harvest duration exhibited low GCA variance to SCA variance ratio and predictability ratio indicated that these characters are controlled by non-additive gene effects. Hence heterosis breeding based on these characters will be a promising breeding method for yield improvement. Non-additive gene action for fruit weight was also obtained by Ghaderi and Lower (1979) in consonance with the present findings. Importance of non-additive gene action for number of fruits per plant was also reported (Ghaderi and Lower, 1979). However, the present results with regard to fruit weight and number of fruits are in disagreement with El-Hafez *et al.* (1997). This may be due to differences in the parental material used for making diallel crosses.

In the present study, the results revealed the importance of heterosis breeding for effective utilization of non-additive genetic variance which had a prominent role for improvement in yield and yield contributing characters (Reddy, 2008). The crosses which showed high SCA effects may be utilized for heterosis breeding. The parents with high GCA effects may be utilized for selection as well as parents in recombination breeding.

5.3.4. Heterosis

Exploitation of heterosis in cultivated plants is one of the most important accomplishments of science of genetics in agriculture (Samant, 2014). Production of hybrids may be the best way to exploit the heterosis in F_1s. Hybrid vigour in vegetable crops was first reported in tomato in early 1900s. The first commercial hybrid variety of cucumber was developed in Japan in 1935 (Pati, 2011). Cucumber, being a highly cross pollinated crop, an improvement in the crop can be brought about by assessing the genetic variability and exploitation of heterosis. Hence in addition to have understanding of the combining ability and genetic components of variation, it is imperative for a researcher to work out the magnitude of heterosis, based on which inferences are to be made.

In the present study, the estimates of heterosis were worked out for the major yield contributing characters. The study revealed that range of mean values in hybrids were higher than that of parents for all the characters considered except for fruit diameter, indicated by the presence of mid parent heterosis in these characters. Considerable amount of heterosis were observed in most of the characters (Table 49).

Number of heterotic hybrids over their corresponding mid parent (relative heterosis), better parent (heterobeltiosis) and standard check (standard heterosis) were two (IC613480 x IC595508A and IC613476 x IC613471) for fruit weight, six for sex ratio (IC613480 x IC613471, IC613480 x IC595508A, IC613488 x IC613471, IC613488 x IC595508A, IC613476 x IC595508A and IC613485 x IC595508A), three for number of fruits per plant (IC613480 x IC613471, IC613480 x IC595508A and IC613471 x IC595508A) and two for yield per plant (IC613480 x IC613471 and IC613480 x IC595508A) (Plate 16). The results indicated that these crosses are promising hybrids for the respective characters. The results also revealed that IC613480 x IC613471 exhibited relative heterosis,

Fruit length

Fruit weight

Number of fruits per plant and yield per plant

Plate 16. Heterotic hybrids for different characters

heterobeltiosis and standard heterosis for sex ratio, number of fruits per plant and yield per plant, thus revealing the superiority in performance.

Heterosis in negative direction is desirable for days to first harvest. Relative heterosis, heterobeltiosis and standard heterosis in the negative direction which is considered desirable for the character days to first harvest was exhibited by IC613471 x IC595508A (-13.36 %, -19.88 % and -0.75 % respectively). This hybrid combination came to harvest on 44.33 days after sowing and the harvest duration extended up to 37.33 days after first harvest. Minimum days for first harvest was exhibited by IC613480 x IC613488, which showed heterobeltiosis of -11.03 per cent. Further, significant heterosis in negative direction was exhibited by IC613480 x IC613471 (-14.46 %), IC613488 x IC613471 (-12.65 %) and IC613476 x IC613471 (-11.45 %) over better parent. IC613471 x IC613485 exhibited significant negative heterosis over both better parent and standard check, but showed delay in initiation of harvest (50.67 days after sowing). IC613471 x IC595508A exhibited negative heterosis over mid and better parent for the character. Musmade and Kale (1986) reported high heterosis for earliness and yield per vine in cucumber in most of the hybrids studied.

Considerable heterosis was not observed in fruit weight except two hybrids (IC613480 x IC595508A and IC613476 x IC613471), which exhibited significant heterosis over mid parent, better parent and standard check. Five hybrids namely IC613480 x IC613476, IC613480 x IC595508A, IC613476 x IC613471, IC613476 x IC613485 and IC613471 x IC595508A exhibited relative heterosis for fruit length. The above hybrids had IC613480, IC613471 or IC613485, having fruit length of more than 16 cm as one of the parents. In contrary, IC613476 x IC595508A showed significant positive values for both relative as well as heterobeltiosis for fruit length. In this hybrid both the parents had fruit length of 12.35 cm and 12.40 cm respectively. Significant standard heterosis in positive direction was observed in IC613480 x IC595508A (12.97 %), IC613488 x IC613485 (12.64 %), IC613488 x IC595508A (17.34 %) and IC613485 x IC595508A (15.56 %) for fruit diameter. Thus IC613480 x IC595508A is a

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promising hybrid for fruit length as well as fruit diameter. Fruit length and diameter are two important yield contributing character, as evident from the highest yield reported by this hybrid. It was important to note that in two of the above three hybrids IC595508A which has recorded highest fruit diameter for *per se* performance, is the male parent. Presence of only standard heterosis for fruit diameter revealed that relative heterosis and heterobeltiosis for fruit diameter were either on par or lower in the hybrids, as indicated by negative heterosis in several hybrids. This indicated the lesser possibility of increasing fruit diameter through heterosis breeding using the above genetic material. Solanki *et al.* (1982), observed pronounced heterosis over better parent in F_1 cucumber hybrids for number of fruits per plant, fruit weight, yield per plant and negative significant heterosis for days to maturity.

Significant and high positive heterosis for mid parent, better parent and standard check in the character sex ratio implied that there was much increase in female flowers in hybrids than the parents. The hybrids IC613480 x IC613476 and IC613476 x IC613485 exhibited positive and significant standard heterosis for sex ratio (43.75 % and 50.00 % respectively). In addition, IC613476 x IC613471 and IC613471 x IC595508A exhibited positive and significant mid parent as well as standard heterosis for the character. Though, IC613471 was poor in most of the characters studied, the hybrid combination involving this parent had shown positive heterosis for some of the characters. This may be attributed to the contribution of genes from the second parent involved in the development of hybrid.

Standard heterosis of 30.22 per cent in IC613480 x IC613488; mid parent and standard heterosis for IC613485 x IC595508A with values 20.37 per cent and 28.96 per cent respectively, were observed for number of fruits per plant. Some of the hybrids which showed heterosis for sex ratio did not exhibited heterosis for number of fruits per plant. The reason may be attributed to the flower abscission and flower damage leading to lesser fruit set. Singh and Amarchandra (1970) suggested that number of fruits per plant is the most important character in cucurbits which may be considered as the best measure of increased vigour.

With regard to yield per plant, in addition to the two hybrids (IC613480 x IC613471 and IC613480 x IC595508A), which exhibited relative heterosis, heterobeltiosis and standard heterosis, IC613480 x IC613485 showed standard heterosis, IC613476 x IC613471 and IC613471 x IC595508A showed relative heterosis for yield per plant. Mid parent, better parent and standard heterosis in IC613480 x IC595508A, is in consonance with the highest yield (2307.63 g) recorded by it among hybrids.

The highest average fruit weight recorded in IC613480 and highest fruit diameter in IC595508A might have contributed to the highest yield. Hence, it is important to note that promising lines with respect to most important yield contributing characters should be considered to achieve maximum yield gain in F_1 hybrids. Hayes and Jones (1916) reported that the first generation crosses in cucumber frequently exhibited high heterosis due to increased fruit size and fruit number per plant.

In the present study also, positive heterosis was observed in both fruit weight and number of fruits per plant. Li and Zhu (1995) reported positive heterosis for total yield, early yield, number of fruits and fruit weight and negative heterosis for vine length. Bairagi *et al*. (2002) reported significant heterosis over better parent for fruit length, fruit diameter and yield per plant as contrary to Munshi *et al*. (2005) where no heterosis was observed for fruit length. Similar reports for heterosis were reported Dogra *et al*. (1997), Singh *et al.* (1999), Kumbhar *et al*. (2005), Pandey *et al.* (2005), Kumar *et al.* (2010) and Pati (2011) in different characters studied in cucumber.

5.3.5. Organoleptic evaluation

Among the 15 hybrids evaluated, IC613480 x IC613476 recorded the maximum cumulative score followed by IC613471 x IC613485 indicating their

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superiority over others in organoleptic characters. Among the parents, IC613471 was the best for organoleptic score. Minimum score for bitterness and crispness was observed in IC595508A, thus proving to be an organoleptically poor genotype among the genotypes studied, even though it had recorded highest sex ratio and fruit diameter among the parents (Table 48).

5.3.6. Selection of superior genotypes

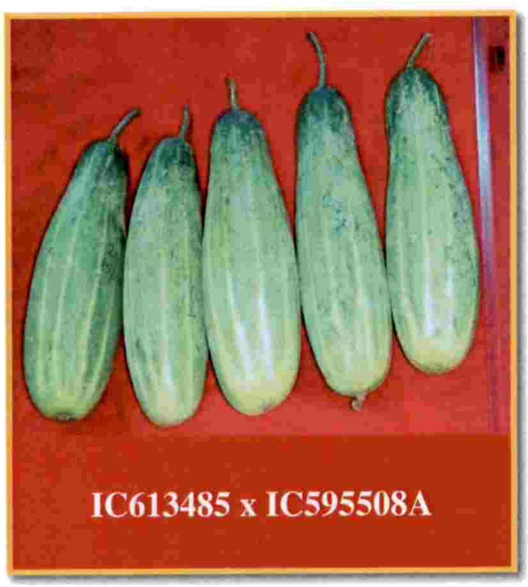
Superior hybrids were selected considering the major yield contributing traits namely sex ratio, fruit weight, fruit length, fruit diameter, days to first harvest, yield per plant and storage parameters. Since fruit weight did not differed significantly among the crosses and parents, grouping of genotypes based on the CD (critical difference) values was not possible. Hence scoring based on grouping for single fruit weight was not included for selection of superior hybrids. After simultaneous selection for yield contributing traits as well as organoleptic evaluation, three hybrids namely IC613480 x IC613476, IC613485 x IC595508A and IC613480 x IC613471 were identified as most promising (Plate 17-18). Similarly, the best parents identified were IC613480, IC613485 and IC613488 (Table 56). These parents can be exploited in selection as well as recombination breeding during future cucumber improvement programmes.

Among the most promising three hybrids identified, IC613480 x IC613471 secured top rank for number of fruits per plant, second position for yield (2163.45 g) and fruit length (17.01 cm) and comparatively earlier harvest date (47.33 days). In addition, IC613480 x IC613471 also exhibited positive significant heterosis for sex ratio, number of fruits per plant and yield per plant, and negative heterosis desirable for days to first harvest. The superiority of IC613480 x IC613471 over other crosses is further strengthened by the high positive and significant SCA effects of the cross for characters namely number of female flowers per plant, number of fruits per plant, sex ratio, yield per plant and negative SCA for loss of weight during storage.

IC613480 x IC613476

IC613485 x IC595508A

IC613480 x IC613476



IC613485 x IC595508A

Plate 17. Plants and fruits of promising hybrids

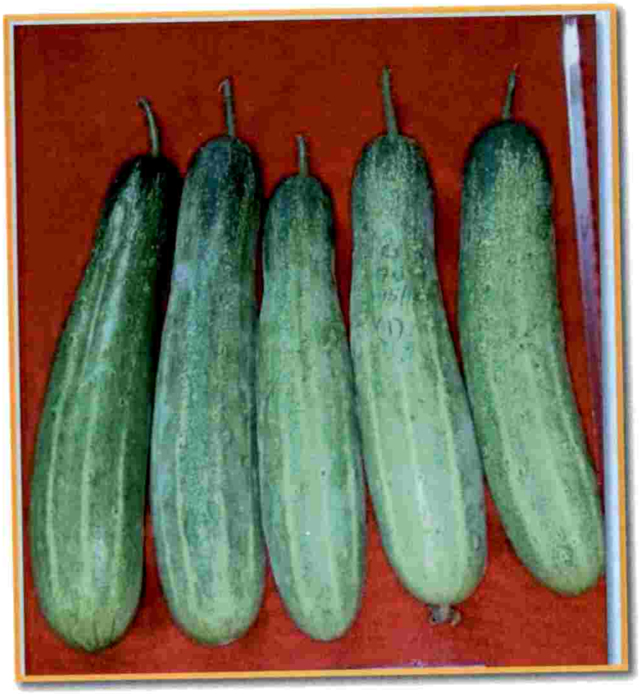


Plate 18. Plants and fruits of promising hybrid-
IC613480 x IC613471

IC613480 x IC613476, recorded less days for harvest (45.67 days), fruit length of 16.23 cm and comparatively less weight loss during storage (11.67 g). In addition, IC613480 x IC613476 recorded positive heterosis for fruit length and sex ratio and showed positive SCA effects for days to last harvest and harvest duration.

IC613485 x IC595508A recorded favourable characters like earliness (45.33 days for first harvest), second position in fruit diameter (4.75 cm), fruit length of 15.10 cm and with less weight loss during storage (10.00 g). The hybrid also exhibited positive heterosis for sex ratio and number of fruits per plant over mid parent and standard check. Positive significant SCA effects for sex ratio, negative SCA effects for days to first harvest and loss of weight during storage was shown by IC613485 x IC595508A.

IC613480 and IC613485 were identified as most promising genotypes in terms of yield and yield contributing characters and the storage parameters (Plate 19). IC613480 had recorded a yield of 1442.35 g per plant, fruit length of 16.35 cm with mean fruit weight of 193.00 g. Harvest was comparatively early (44 days) in this genotype with favourable storage attributes. The fruits were light green coloured with elliptical elongated shape. It has exhibited positive and significant GCA effect for number of fruits per plant, harvest duration, fruit length, vine length and yield per plant and possessed good organoleptic qualities. IC613485 had recorded yield of 1659.15 g per plant with a fruit length of 16.76 cm. It exhibited comparatively earliness for fruit harvest (44 days) with lesser weight loss of 12.67 g on storage. The organoleptic qualities were also promising in this genotype. IC613485 also exhibited positive GCA effects for vine length, fruit length, seed cavity length and number of days of storage. IC613485 also produced light green coloured elliptical elongated fruits.

Conclusion

Wide variability was observed for majority of qualitative and quantitative characters studied. Cluster analysis produced seven distinct clusters based on

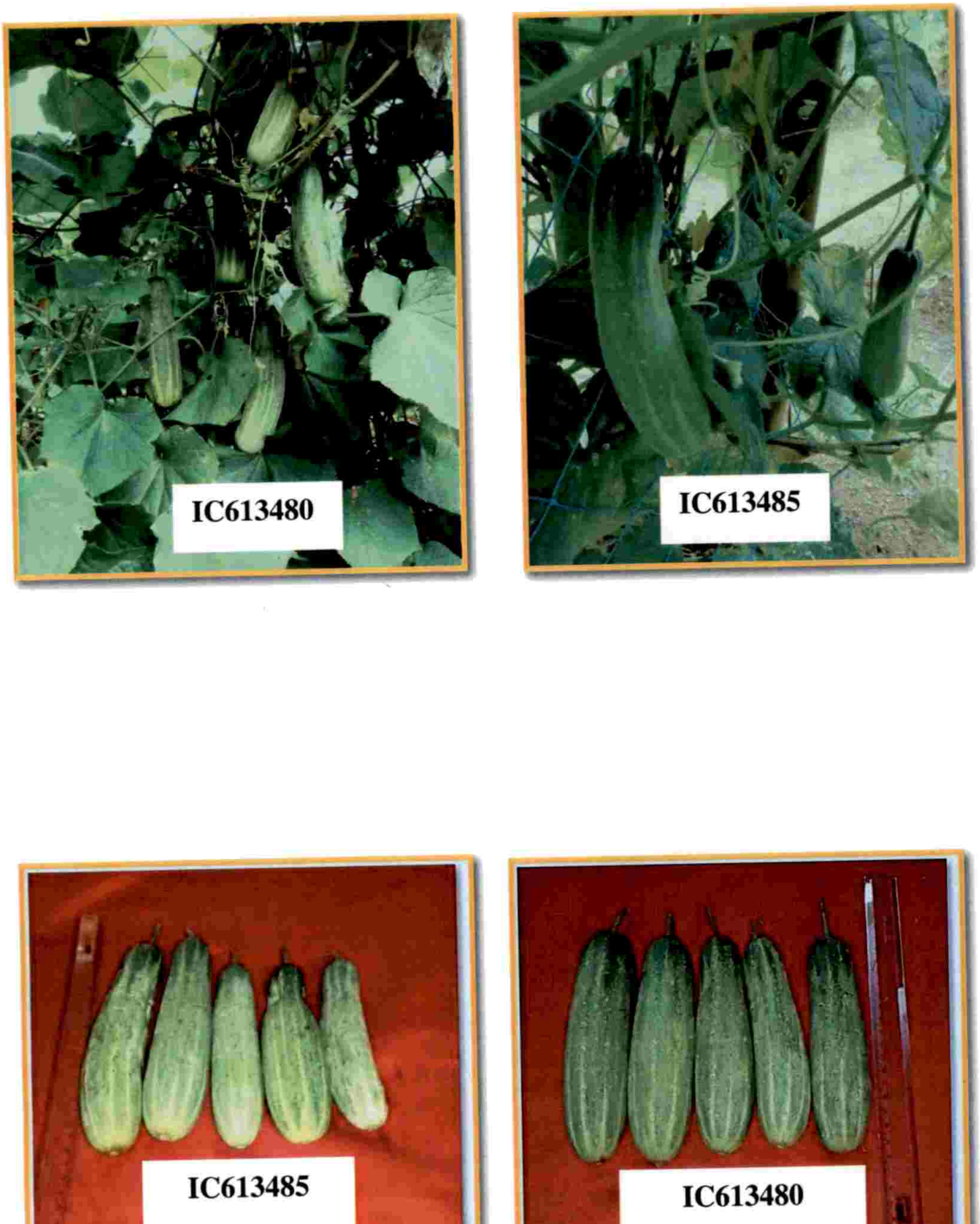


Plate 19. Plants and fruits of promising genotypes

quantitative characters. Fruit weight, fruit length, fruit diameter and days to first harvest were contributing maximum divergence among the accessions. Mizoram, Tripura and West Bengal were the diversity rich regions for cucumber germplasm. Twenty two genotypes identified were promising in terms of yield, yield contributing characters, storage attributes and organoleptic qualities. The results of molecular characterization revealed high distinctness among the accessions and identified two informative and polymorphic markers (SSR11742 and AF202378). Six consistently performing genotypes identified as parents for hybridization. Three promising hybrids *viz.*, IC613480 x IC613471, IC613480 x IC613476 and IC613485 x IC595508A, were identified from combining ability and heterosis studies. Two genotypes identified as promising were IC613480 and IC613485.

Future line of work

Further evaluation of the promising hybrids and genotypes is to be undertaken for their commercial utilization. Parents with desirable *per se* performance and significant GCA effects for different characters could be used in multiple crossing scheme to recombine multiple gene effects. Future collection missions should be targeted from the diversity rich areas identified. As wild species harbour many valuable genes, incorporating genes from wild genepool could also be considered during crop improvement programmes.

Summary

6. Summary

The present investigation entitled "Genetic diversity and combining ability in cucumber (*Cucumis sativus* L.)" was carried out at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara and the ICAR-National Bureau of Plant Genetic Resources (NBPGR), Regional Station, Thrissur during the period 2014-2017. The experimental material consisted of 50 accessions of cucumber genotypes augmented from ICAR-NBPGR, New Delhi, and three check varieties. The study aimed to explore genetic diversity in cucumber genotypes using morphological and molecular markers and to study combining ability and heterosis in selected genotypes.

Morphological characterization revealed presence of significant difference for majority of shoot, floral and fruit characters among the accessions. Vine length and number of primary branches varied significantly among the accessions. In all the accessions, male flower opening and 50 per cent male flowering were earlier than female flower opening and 50 per cent female flowering. Fifteen accessions initiated female flowering earlier than AAUC-2, the national check variety. Similarly, 18 accessions and 13 accessions attained 50 per cent male and female flowering respectively, earlier than AAUC-2. These accessions with early flowering nature are to be considered in crop improvement programmes aiming for early bearing varieties in cucumber.

First harvesting initiated after 37 days of sowing and extended up to 60 more days. Sixteen accessions exhibited significantly higher fruit length than AAUC-2, the maximum being 20.85 cm in IC613472. The mean fruit diameter of the accessions was 4.99 cm. Number of fruits per plant ranged from 1.60 (IC612081) to 11.47 (IC277048). Eighteen accessions recorded more number of fruits than AAUC-2. Fruit weight ranged from 32.97 g with an overall mean of 227.45 g. Fourteen accessions exhibited significantly higher yield than AAUC-2.

Storage studies indicated that accessions were significantly differing for their storage potential in terms of loss of weight during storage and number of days of storage. Nine accessions namely, IC331627, IC202058A, IC331619, IC613477, IC277048, IC595505, IC613488, IC595515 and IC613482 were possessing good storability.

The genetic parameter PCV was greater than GCV for all the shoot characters, but to a very lesser magnitude. Further, number of female flowers per plant and node number at which first female flower appeared were associated with high broad sense heritability and genetic gain. Fruit length and breadth exhibited moderate and low PCV and GCV respectively. Number of fruits per plant is a very reliable character for selection for yield improvement since it was associated with high estimate of PCV, GCV, broad sense heritability and genetic gain.

Positive and significant correlation between fruit weight, fruit length and number of fruits per plant with yield per plant indicated that a direct selection of these characters can improve the yield.

Cluster analysis grouped 53 accessions into seven distinct clusters based on their level of similarity. Cluster II and III were the largest clusters with 14 accessions each followed by cluster IV with 11 accessions. The divergence among clusters was proved by the high inter cluster distance than the intra cluster distance. The random pattern of distribution of accessions from various states in different clusters revealed that there was no parallelism between genetic diversity and geographic diversity. Grid maps generated through DIVA-GIS (Geographical Information System) revealed wide range of genetic variability at West Bengal, Tripura and Mizoram.

The result of PCA revealed that only the first three principal component axes had eigen-vector values, whose loads were more than unity, which indicated that the identified characters namely fruit weight, fruit length, fruit diameter and days to first harvest, within these components exhibited great influence on the accessions.

Among 11 qualitative characters studied significant variation was observed for fruit characters like skin colour, shape, primary fruit colour and flesh colour. Fruit shape was elliptical elongate and fruit skin colour was light green in majority of the accessions. The flesh colour of tender fruits was white predominantly. Ten accessions exhibited orange flesh at the ripening stage.

Cumulative organoleptic scores revealed superiority of four accessions namely IC613480, IC613481, IC618084A and IC613484 than AAUC-2 based on bitterness, crispness and flavour.

Based on the preliminary evaluation, 22 genotypes were identified as promising. IC613481 with rank I had earliness in harvesting (39.88 days), promising yield (1990.09 g per plant), average fruit weight of 238.71 g, fruit length of 17.27 cm, and produced 8.33 elliptical elongated fruits per plant with better storage and best organoleptic qualities. IC6134801 was ranked second in the preliminary evaluation.

In-depth evaluation of selected 22 genotypes revealed that vine length and number of primary branches were significantly different among the genotypes studied. Significant difference among the genotypes was observed for all fruit characters except days to last harvest and harvest duration. IC595510, recorded consistently good performance for fruit length and hence could be an important source for improving the length of the fruit.

In-depth evaluation further revealed the superiority of IC613480 in terms of minimum days for harvest, number of fruits per plant, yield per plant and minimum weight loss during storage. IC595508A, IC613485, IC613476 and IC613488 were the other promising genotypes identified.

SSR profiling analysis using 20 primers on 22 promising genotypes and five wild genotypes revealed the high level of genetic distinctness among the genotypes studied. A total of 83 amplicons with an average of 4.1 alleles per locus was detected in the study. Two markers namely UW053690 and SSR11742 showed heterozygous condition in the banding pattern. The Jaccard's similarity coefficient was maximum (0.83) between IC618084A and IC613480, IC613484 and IC595512 and IC613470 and 469517, which was in consonance with the clustering pattern followed in the dendrogram. Highest PIC and marker index values in AF202378 (0.81 and 4.05 respectively) followed by SSR11742 (0.75 and 3.77 respectively) are in agreement with their maximum number of amplicons (6) produced, indicating their usefulness in future genetic diversity analysis studies in cucumber.

Evaluation of 15 hybrid combinations revealed that, variability among hybrids was observed for qualitative traits like fruit shape, fruit skin colour and primary fruit colour. Majority of the hybrids possessed elliptical elongated shape. Seven out of 15 crosses exhibited green colour for fruit skin, whereas remaining crosses had light green colour.

The parents and hybrids were significantly different for majority of characters studied. Hybrids recorded earliness in 50 percent female flowering. Maximum fruit length of 17.84 cm was observed in IC613476 x IC613471. Among the hybrids, IC613480 x IC613471 produced maximum number of fruits. Six hybrids out of 15, showed significantly greater yield than the standard check AAUC-2. The mean weight loss during storage was more in parents than the hybrids. However, number of days of storage did not differ significantly between parents and hybrids. Among parents, IC613488 and IC613485 produced significantly higher number of fruits.

The results of the analysis of variance for combining ability revealed that mean squares for general combining ability calculated from six parental lines were highly significant for majority of shoot, floral and fruit characters, indicating the variability with respect to their general combining ability. IC613480, a promising genotype identified with favourable yield attributing characters and organoleptic qualities in in-depth evaluation studies was proved to be a promising parent by exhibiting favourable GCA effects for number of male flowers per

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plant, days to last harvest, fruit length, number of fruits per plant, seed cavity length, yield per plant and harvest duration. IC613485, another promising genotype identified exhibited GCA effects for six characters. Best combiner for loss of weight during storage was IC613485 and for number of days of storage was IC595508A.

Among the 15 hybrids considered for the present study, two hybrids *viz.* IC613476 x IC613471 and IC613476 x IC595508A exhibited significant SCA effects for fruit length. Similarly significant SCA effects were exhibited by three hybrids (IC613480 x IC595508A, IC613488 x IC613485 and IC613476 x IC613471) for fruit weight and two (IC613480 x IC613471 and IC613480 x IC595508A) for yield per plant. It was noted that high GCA effects of parents were reflected in high SCA effects of the hybrids developed from those parents.

Ratio of GCA variance to SCA variance and predictability ratio of more than unity in vine length, days to 50 per cent male flowering, days to 50 per cent female flowering and node number at which first male flower appeared, days to first harvest, fruit length, seed cavity length, equatorial circumference and number of days of storage indicated that these characters are controlled by additive gene effects. Yield contributing fruit characters namely number of fruits per plant, fruit weight, yield per plant and harvest duration exhibited low GCA variance to SCA variance ratio and predictability ratio indicating that these characters are controlled by non-additive gene effects.

The hybrid IC613480 x IC613471 exhibited relative heterosis, heterobeltiosis and standard heterosis for sex ratio, number of fruits per plant and yield per plant, thus revealing its superiority in performance. Two hybrids (IC613480 x IC595508A and IC613476 x IC613471) exhibited relative heterosis, heterobeltiosis and standard heterosis for fruit weight. Significant heterosis over mid parent, better parent and standard check was exhibited by three hybrids (IC613480 x IC613471, IC613480 x IC595508A and IC613471 x IC595508A) for number of fruits per plant and two (IC613480 x IC613471 and IC613480 x IC595508A) for yield per plant.

With regard to yield per plant two hybrids (IC613480 x IC613471 and IC613480 x IC595508A) exhibited relative heterosis, heterobeltiosis and standard heterosis. Five hybrids (IC613480 x IC613476, IC613480 x IC595508A, IC613476 x IC613471, IC613476 x IC613485 and IC613471 x IC595508A) exhibited relative heterosis for fruit length.

In organoleptic evaluation, IC613480 x IC613476 recorded the maximum cumulative score followed by IC613471 x IC613485 indicating their superiority over others. Among the parents, IC613471 was the best with respect to organoleptic score.

Based on yield and yield contributing traits, storage attributes and organoleptic qualities, IC613480 x IC613471, IC613480 x IC613476 and IC613485 x IC595508A were identified as promising hybrids. Among them, IC613480 x IC613471 produced 11.43 fruits per plant, yield of 2163.45 g, fruit length of 17.01 cm, better organoleptic qualities and comparatively earlier harvest date (47.33 days). In addition, this hybrid also exhibited positive significant heterosis for sex ratio, number of fruits per plant and yield per plant, and negative heterosis desirable for days to first harvest. The superiority of IC613480 x IC613471 over other hybrids is further strengthened by the high positive and significant SCA effects for number of female flowers per plant, number of fruits per plant, sex ratio, yield per plant and negative SCA for loss of weight during storage.

IC613480 x IC613476 recorded earliness in harvest (45.67 days), 16.23 cm fruit length and comparatively less weight loss (11.67 g) during storage. In addition, this hybrid recorded positive heterosis for fruit length and sex ratio and showed positive SCA effects for days to last harvest and harvest duration. This hybrid recorded superior organoleptic qualities also.

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IC613485 x IC595508A recorded favourable characters like earliness (45.33 days for first harvest), acceptable fruit diameter (4.75 cm), fruit length (15.10 cm), less weight loss (10.00 g) during storage and better organoleptic qualities. This hybrid also exhibited positive relative and standard heterosis for sex ratio and number of fruits per plant with positive significant SCA effects for sex ratio, negative SCA effects for days to first harvest and loss of weight during storage.

IC613480 and IC613485 were identified as most promising genotypes in terms of yield and yield contributing characters and the storage parameters. IC613480 had recorded a yield of 1442.35 - 1660.00 g per plant, fruit length of 15.29 - 16.72 cm with mean fruit weight of 159.71 - 251.50 g. This genotype produced 6.60 - 9.53 fruits per plant. Harvest was comparatively early in this genotype with favourable storage attributes. The fruits were light green in colour with elliptical elongated shape and good organoleptic qualities. It had exhibited positive and significant GCA effect for number of fruits per plant, harvest duration, fruit length, vine length and yield per plant and possessed good organoleptic qualities.

IC613485 had recorded an yield of 1503.23 - 1659.15 g per plant with a fruit length of 15.03 – 18.44 cm and 5.90 – 8.86 fruits per plant. It exhibited comparatively earliness for harvest (44 days) with lesser weight loss on storage. This genotype produced elliptical elongated fruits with light green colour. The organoleptic qualities were also promising in this genotype. IC613485 also exhibited positive GCA effects for vine length, fruit length, seed cavity length and number of days of storage.

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Appendices

Appendix I: Passport data of cucumber accessions used in the study

S. No	Collection No.	Accession No.	Genus	Species	State	Latitude	Longitude
1	JS/06-01	IC541367	*Cucumis*	*sativus*	A&N Islands	12.229	92.809
2	JS/06-25	IC541391	*Cucumis*	*sativus*	A&N Islands	12.508	92.932
3	MS/05-12	IC539818	*Cucumis*	*sativus*	A&N Islands	12.654	92.899
4	JB/12-203	IC613471	*Cucumis*	*sativus*	Arunachal Pradesh	27.158	95.569
5	JB/12-217	IC613472	*Cucumis*	*sativus*	Arunachal Pradesh	27.299	96.148
6	JB/12-236	IC613473	*Cucumis*	*sativus*	Arunachal Pradesh	27.086	95.442
7	JB-12-183A	IC618084A	*Cucumis*	*sativus*	Arunachal Pradesh	27.176	96.078
8	BB-11/2001A	IC331619	*Cucumis*	*sativus var. hardwickii*	Himachal Pradesh	30.905	77.097
9	JR-04-13	IC469517	*Cucumis*	*sativus*	Karnataka	12.763	76.060
10	JJK/10-601	IC595518	*Cucumis*	*sativus*	Kerala	9.684	76.337
11	BBL-67/2000	IC277048	*Cucumis*	*sativus var. hardwickii*	Maharashtra	17.248	73.371
12	BBL-49/2000	IC277030	*Cucumis*	*sativus var. hardwickii*	Maharashtra	18.516	73.182
13	JB-11/18	IC613457	*Cucumis*	*sativus*	Mizoram	23.545	92.442
14	JB-11/28	IC595504	*Cucumis*	*sativus*	Mizoram	24.150	92.384
15	JB-11/34	IC613458	*Cucumis*	*sativus*	Mizoram	24.150	92.384
16	JB-11/43	IC595505	*Cucumis*	*sativus*	Mizoram	24.102	92.342
17	JB-11/60	IC613459	*Cucumis*	*sativus*	Mizoram	24.145	92.405
18	JB-11/69	IC612081	*Cucumis*	*sativus*	Mizoram	24.185	92.422
19	JB-11/75	IC613461	*Cucumis*	*sativus*	Mizoram	24.236	92.431
20	JB-11/91	IC613462	*Cucumis*	*sativus*	Mizoram	24.224	92.431
21	JB-11/99	IC612082	*Cucumis*	*sativus*	Mizoram	24.011	92.403
22	JB-11/120	IC613465	*Cucumis*	*sativus*	Mizoram	23.145	92.405
23	JB-11/126	IC613466	*Cucumis*	*sativus*	Mizoram	23.154	92.384
24	JB-11/128	IC613467	*Cucumis*	*sativus*	Mizoram	23.154	92.384
25	JB-11/145	IC613488	*Cucumis*	*sativus*	Mizoram	23.224	92.431

Contd..

Appendix I. Passport data of cucumber accessions used in the study

S. No	Collection No.	Accession No.	Genus	Species	State	Latitude	Longitude
26	JB/11-71	IC613460	*Cucumis*	*sativus*	Mizoram	24.185	92.422
27	KPAC-1494	IC613474	*Cucumis*	*sativus*	Nagaland	26.760	95.610
28	BBD-12/2001	IC331445	*Cucumis*	*sativus*	Odisha	18.856	82.735
29	JB/11-182-A	IC595508A	*Cucumis*	*sativus*	Tripura	23.084	91.364
30	JB/11-205	IC595510	*Cucumis*	*sativus*	Tripura	23.025	91.541
31	JB/11-206	IC618083	*Cucumis*	*sativus*	Tripura	23.025	91.541
32	JB/11-217	IC595512	*Cucumis*	*sativus*	Tripura	23.262	91.346
33	JB/11-229	IC595514	*Cucumis*	*sativus*	Tripura	24.012	91.381
34	JB/11-242	IC595515	*Cucumis*	*sativus*	Tripura	23.482	91.535
35	JB/11-262	IC595517	*Cucumis*	*sativus*	Tripura	23.545	91.502
36	JB/11-197	IC613470	*Cucumis*	*sativus*	Tripura	23.005	91.546
37	BB-19/2001A	IC331627	*Cucumis*	*sativus var. hardwickii*	Uttarakhand	30.317	78.032
38	U38/IS/AD/36	IC202058A	*Cucumis*	*sativus var. hardwickii*	Uttarakhand	30.317	78.032
39	SKYAC/239	IC613470	*Cucumis*	*sativus*	West Bengal	22.370	88.090
40	SKYAC/244	IC613475	*Cucumis*	*sativus*	West Bengal	22.900	88.300
41	SKYAC/247	IC613476	*Cucumis*	*sativus*	West Bengal	22.900	88.300
42	SKYAC/251	IC613477	*Cucumis*	*sativus*	West Bengal	22.900	88.300
43	SKYAC/253	IC613478	*Cucumis*	*sativus*	West Bengal	22.900	88.300
44	SKYAC/262	IC613479	*Cucumis*	*sativus*	West Bengal	22.940	88.230
45	SKYAC/265	IC613480	*Cucumis*	*sativus*	West Bengal	22.940	88.230
46	SKYAC/270	IC613481	*Cucumis*	*sativus*	West Bengal	23.070	88.590
47	SKYAC/295	IC613482	*Cucumis*	*sativus*	West Bengal	22.950	88.610
48	SKYAC/314	IC613483	*Cucumis*	*sativus*	West Bengal	23.050	88.700
49	SKYAC/316	IC613484	*Cucumis*	*sativus*	West Bengal	22.960	88.720
50	SKYAC/319	IC613485	*Cucumis*	*sativus*	West Bengal	22.990	88.820

Appendix II. Minimal descriptor list used for morphological characterization

I Quantitative characters

1 Leaf length

To be recorded as average of 5-10 leaves at full vegetative stage

2 Leaf breadth

To be recorded as average of 5-10 leaves at full vegetative stage

3 Petiole length

To be recorded as average of 5-10 leaves at full vegetative stage

4 Node number at which first female flower appears

To be recorded at opening of first female flower

5 Days to first male flower opening

To be recorded at opening of first of male flower

6 Days to first female flower opening

To be recorded at first appearance of male flower

7 Days to 50% male flowering

To be recorded when opening of male flowers occurs in 50 per cent of plants

8 Days to 50% female flowering

To be recorded when opening of female flowers occurs in 50 per cent of plants

9 Number of male flowers per plant

To be recorded during the entire flowering period

10 Number of female flowers per plant

To be recorded during the entire flowering period

11 Sex Ratio

To be recorded as ratio of female (including hermaphrodite) to male flowers at flowering stage

12 Male flower diameter

To be recorded as average of 5-10 flowers at flowering stage

13 Female flower diameter

To be recorded as average of 5-10 flowers at flowering stage

14 Peduncle length (cm)

To be recorded as average of 5-10 random fruits at marketable stage

15 Vine length (cm)

To be recorded as average length of main stem of 5 random plants at the end of flowering

16 Number of primary branches

To be recorded as average of 10 plants at the end of flowering stage. The branch that arises from the main vine/stem is known as primary branch.

17 Days to first fruit harvest

To be recorded as number of days from date of sowing/transplanting to the date of first marketable fruit harvest

18 Days to last fruit harvest

To be recorded as number of days from date of sowing/transplanting to the date of last marketable fruit harvest

19 Harvest duration

To be recorded as difference in initial and final date of picking/harvesting

20 Fruit length (cm)

To be recorded as average of 5-10 random fruits at marketable stage

21 Fruit breadth (cm)

To be recorded as average of 5-10 fruits at marketable stage

22 Polar circumference

To be recorded as average of 5-10 fruits at marketable stage

23 Equatorial circumference

To be recorded as average of 5-10 fruits at marketable stage

24 Flesh thickness

To be recorded as average of 5-10 fruits at marketable stage

25 Number of fruits per plant

To be recorded as average of 5-10 plants

26 Yield of marketable fruits per plant (g)

To be recorded as average of cumulative yield of all pickings in 5-10 plants

27 Fruit weight (g)

To be recorded as average of 5-10 fruits at marketable stage

28 Seed cavity length (cm)

To be recorded as the length of placenta, as average of 5-10 fruits

29 Seed cavity breadth (cm)

To be recorded as the breadth of placenta as average of 5-10 fruits

30 Biotic stress susceptibility

II Qualitative characters

1 Leaf margin

To be recorded at full foliage stage as given below

S. No.	Character	Score
1	Unifid	1
2	Bifid	2
3	Multifid	3
4	Others (Specify in the 'Remarks' descriptor)	99

2 Leaf shape

To be recorded at full foliage stage as given below

Sl No	Character	Score
1	Cordate	1
2	Oblong	2
3	Ovate	3
4	Ovovate	4
5	Reniform	5
6	Others (Specify in the 'Remarks' descriptor)	99

3 Leaf pubescence density

To be recorded at full foliage stage

Sl No	Character	Score
1	No hairs	0
2	Sparse	3
3	Intermediate	5

4	Dense	7
5	Others (Specify in the 'Remarks' descriptor)	99

4 Stem-end fruit shape

To be recorded at marketable stage

Sl No	Character	Score
1	Depressed	1
2	Flattened	3
3	Rounded	5
4	Pointed	7
5	Others (Specify in the 'Remarks' descriptor)	99

1 Depressed 3 Flattened 5 Rounded 7 Pointed

Stem-end fruit shape

5 Blossom-end fruit shape

To be recorded at marketable stage

Sl No	Character	Score
1	Depressed	1
2	Flattened	3
3	Rounded	5
4	Pointed	7
5	Others (Specify in the 'Remarks' descriptor)	99

1 Depressed 3 Flattened 5 Rounded 7 Pointed

Blossom-end fruit shape

6 Fruit skin texture

To be recorded at marketable stage

Sl No	Character	Score
1	Plain	1
2	Netted	2
3	Rough	3
4	Others (Specify in the 'Remarks' descriptor)	99

7 Fruit skin colour

To be recorded at marketable stage

S. No	Character	Score
1	Cream	1
2	Yellow	2
3	Light green	3
4	Green	4
5	Dark green	5
6	Orange	6
7	Pink	7
8	Brown	8
9	Others (Specify in the 'Remarks' descriptor)	99

8 Primary fruit colour

To be recorded 3 days after pollination

S. No.	Character	Score
1	Cream	1
2	Yellow	2
3	Light green	3
4	Green	4
5	Dark green	5
6	Orange	6
7	Pink	7
8	Brown	8
9	Others (Specify in the 'Remarks' descriptor)	99

9 Presence of seed cavity

To be recorded at marketable stage

S. No	Character	Score
1	Absent	0
2	Present	1

10 Flesh colour

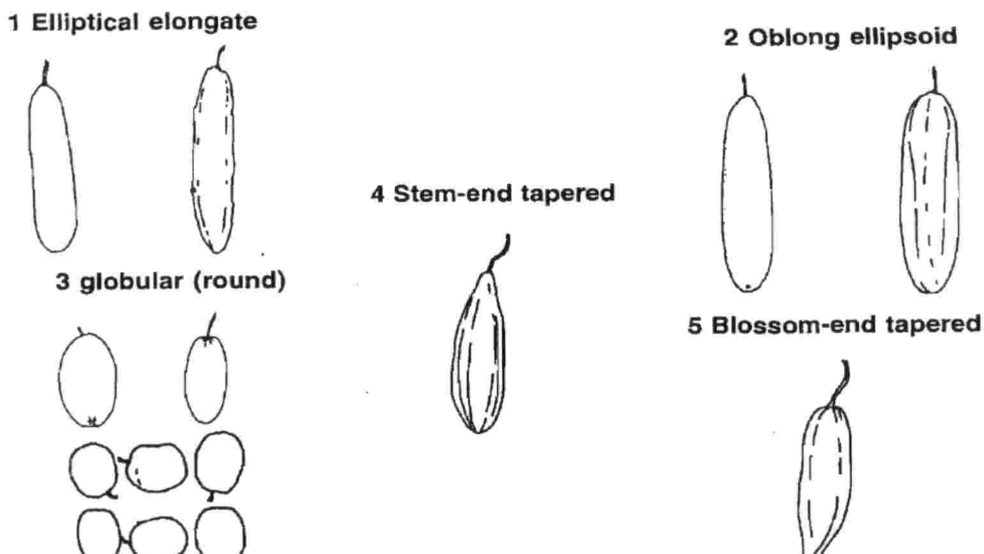
To be recorded at marketable stage

S. No	Character	Score
1	White	1
2	Green	2
3	Yellow	3
4	Orange	4
5	Others (Specify in the 'Remarks' descriptor)	99

11 Fruit shape

To be recorded at marketable stage

S. No	Character	Score
1	Elliptical elongate	1
2	Oblong ellipsoid	2
3	Globular (round)	3
4	Stem-end tapered	4
5	Blossom-end tapered	5
6	Others (Specify in the 'Remarks' descriptor)	99



Fruit shape

III Storage parameters

1 Days of storage

To be recorded as the days of storage till the fruit loses its glossy appearance

2 Loss in weight during storage

To be recorded as difference in weight between initial and final date of storage

IV Total Soluble Solids (TSS)

To be recorded in the freshly harvested fruits

Appendix III. Score card used for organoleptic evaluation of cucumber genotypes

Name of the assessor:

Category: Student/Teacher/Others

Acc.No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Bitterness															
Crispiness															
Flavour															

0	Nil
1	Very low
2	Low
3	Medium
4	High
5	Very high

Signature

Date:

Appendix IV. List of primers used for molecular characterization

S.No.	Primer ID	Forward primer	Reverse primer
1	UW053690	TCTAATTCGCTCCGGATGAT	TTGCAGCGAACAATCCTGTA
2	UW029476	ATTTCGATTGGGAAAAAGGG	GCTGGCTCCTTCACATTGTT
3	SSR12810	TTCCCACAAAACAAATCTTGG	TTTTGGAGAGAAAAGGTTGGA
4	SSR12227	GGCATCGGTGAGTACCAACT	TTTCTCCTCCTTGGCCATAA
5	SSR05830	TTTCGTTGTGCTCAGTGGAG	ACACCTTTCTTTCAC CCCCT
6	SSR22071	GCTGCTTGAATCGGTTCTGT	GAGGAGGTAAATCATGCTCCA
7	SSR05737	TTGCCTTCGTAAGCAAAAA	GAAGTAAATGGGTTGGACGC
8	SSR 19493	AAGAGGCCAGAGATGGATGA	GCCAAAAATAGGCCCAAAGT
9	SSR06660	GATCGTTGCAAAACTCACGA	CGATTGACAGTTCGCTGAAA
10	SSR33278	GCAAACGCAATTAAAACACG	GTTGGAATGAGGGAGTGAGC
11	SSR11742	GCTATCCCCAAGGATGATGA	AGCTTGGCTTCGTCTTTTGA
12	DN910157	TCTTCGCAGTCACCATTTC	CCTTCCTCTGTTTCTGTTCC
13	DN910437	ACAACACAACCGCTTCTCGT	TGAGCCCAAGCACATAACAG
14	DN909941	GTTGGAAGGCACACAAAGTC	CGAGATGATTGGAGGATGATG
15	AF202378	GATCCCCATCATAATCACCC	CAAAGGGCTACAATAACAAAC
16	BI740103	CCAAGTTTAAGTTATTTAGGAG	GAAGAGGACGATAAAGATGA
17	AY942801	CGATCTTTGTCATCCGACCT	AGAACGAGCACGTTTTGAGC
18	CK758649	CGTGTTTTCTCAGATTTCCCA	CACTTCCCTTATCAACCCCA
19	yfSSR108	TTTGAGGGCACTCACAAGC	CATTCGATCGATGGTGGATT
20	SSR17292	CCCTCTTCTTTCCCACATCA	TGGAAGTGCCAGATGAAATG

GENETIC DIVERSITY AND COMBINING ABILITY IN CUCUMBER (*Cucumis sativus* L.)

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ABSTRACT OF THE THESIS

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Abstract

Assessment of genetic diversity is the key tool in any crop improvement and germplasm management programme. Evaluation of genetic variation will help to provide valuable information about new sources of genes. The studies on combining ability and heterosis can support utilization of promising lines in further crop improvement programmes.

Cucumber (*Cucumis sativus* L. 2n= 2x= 14) is an indigenous vegetable crop of India. Even though rich diversity for cucumber is available in India, studies on genetic diversity of this crop are scanty. Therefore, the present project was proposed to explore genetic diversity in cucumber using morphological and molecular markers and to study combining ability and heterosis in selected genotypes.

Morphological characterization of 50 accessions of cucumber revealed presence of significant difference among accessions for majority of vegetative, floral and fruit characters. Mean days to first male and female flower opening was 36 and 43 days respectively. Majority of the accessions possessed elliptical elongated fruits with light green skin colour and white flesh colour. Sixteen accessions exhibited significantly higher fruit length than AAUC-2, the standard check, the maximum being exhibited by IC613472 (20.85 cm). Accessions with oblong ellipsoid fruits possessed higher fruit diameter. Mean fruit weight showed high variability among accessions with a range of 33 g to 343 g. Fourteen accessions exhibited significantly high yield than AAUC-2. Number of fruits per plant, yield per plant, loss of weight during storage and sex ratio showed high values for all the genetic parameters studied. IC613481 was the promising genotype identified in morphological characterization, followed by IC613480.

Cluster analysis grouped accessions into seven distinct clusters based on the level of similarity in quantitative characters. Random grouping of accessions into various clusters indicated absence of parallelism between genetic diversity and

geographical diversity. Cluster II and III were the largest clusters, with 14 accessions each and Cluster V and VI, the smallest ones with single accession each. Results of Principal component analysis revealed that first three principal components, with Eigen values more than unity accounted for 85.80 per cent of cumulative variance, contributed by fruit weight, fruit length, fruit diameter and days to first harvest.

The diversity analysis of the accessions was done using DIVA-GIS by generating grid maps. The results of the study indicated that highly diverse accessions with respect to the selected characters were sourced from Mizoram, Tripura and West Bengal.

Molecular characterization revealed high level of genetic distinctness between genotypes. SSR11742 and AF202378 were found to be highly polymorphic markers, with high polymorphism information content and number of polymorphic bands.

In-depth evaluation of selected 22 genotypes revealed significant difference for all fruit characters except days to last harvest and harvest duration and further revealed the superiority of IC613480.

Evaluation of 15 hybrid combinations developed through half diallel mating design and their parents indicated presence of significant difference among parents and hybrids for various characters studied. Among the parental genotypes, IC613480, exhibited significantly high GCA effects for fruit length, number of fruits per plant and yield per plant whereas IC595508A, for fruit weight and loss of weight during storage, and IC613485 for fruit diameter, thus proving to be promising parents for accumulating genes for these characters.

The hybrids, IC613480 x IC595508A and IC613480 x IC613471 showed significant SCA effects for yield per plant and sex ratio. IC613480 x IC613471, IC613480 x IC595508A and IC613471 x IC595508A were exhibiting significantly high relative heterosis, heterobeltiosis and standard heterosis for number of fruits per plant and yield per plant.

IC613480 and IC613485 were the most promising genotypes identified from the study whereas IC613480 x IC613471 was the most promising hybrid based on SCA effects, heterosis, *per se* performance on yield contributing characters and organoleptic qualities. This hybrid showed high fruit length (17.01 cm), yield per plant (2163.45 g), number of fruits per plant (11.43) and sex ratio (0.11). IC613480 x IC613476 and IC613485 x IC595508A were the other promising hybrids.