GENETIC VARIABILITY AND CHARACTERISATION IN WAX TYPE CHILLI (*Capsicum annuum* L.)

MINI.S

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Dedicated to

Achan and Amma

DECLARATION

I hereby declare that this thesis entitled **"Genetic variability and characterisation in wax type chilli (*Capsicum annuum* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"Genetic variability and characterisation in wax type chilli (*Capsicum annuum* L.)"** is a record of research work done independently by Mrs. Mini.S (2001-11-18) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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EXTERNAL EXAMINER

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MINI.S

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Introduction

1. INTRODUCTION

Chilli (*Capsicum annuum* L.) is one of the most versatile plants, grown as a vegetable as well as a spice crop. Indigenous to Central and South America and the West Indies, it has been cultivated for thousands of years throughout the world. It is grown throughout India, and our country tops the world in area and production. Extract from the pods are used in the manufacture of cosmetics, beverages, pharmaceuticals, dyes, natural colours, Capsaicin, Oleoresin and Vitamin C. Chilli plants have the added attraction of being an ornamental plant which can be kept indoors in pots.

The word Capsicum comes from the Greek word ‘Kapto’ meaning ‘to bite’, referring to the pungency of the fruit, which is due to the alkaloid Capsaicin present in it. Chillies are also known as pepper, Chili, Chile, Agi, Paprika and Capsicum, which are used interchangeably for plants in the Genus Capsicum.

India is one of the largest producers of chilli in the world and shares nearly 47 per cent of the world cultivation. Chilli is grown in an area of 9.56 lakh ha with an annual production of 9.45 lakh tonnes and a productivity of 0.9 t ha^{-1} (Peter, 1999).

Wax type chilli is a distinct horticultural group with light yellow, shining waxy fruits, which are mainly used for salad purposes and in preparations of snacks like Baji. There are short-fruited types (< 7.5 cm) and long-fruited types (> 7.5 cm) in this group. These are suited for cultivation in pots as well. It is the most premium type, fetching maximum price in the market. Many are high yielders and are suitable for cultivation in pots. Mostly, wax type chillies cultivated in India are introductions from different countries. Natural crossing of these types with indigenous types and subsequent selection have resulted in considerable variability. At present a good amount of diversity exists in this group. Hence it is very much desirable to assess the variability present in this group for different characters. Identifying the genotypes with high heritability and genetic advance for desirable characters contributing to yield is a prerequisite for developing high yielding varieties.

Estimation of interrelationship of yield with other traits and correlation studies would facilitate effective selection for simultaneous improvement of one or many yield contributing characters. Assessing the direct and indirect effects of each component towards yield will help in selecting the characters for crop improvement.

Grouping of genotypes based on genetic distance between them with respect to important characters would provide a way to identify the most suitable genotypes that could be taken as parents in future crop improvement programmes. Keeping all these in view, the present investigation was undertaken with the objective of estimating the variability with respect to 14 economic characters and genetic divergence among 25 genotypes of wax type chilli and to group them into clusters based on their genetic distance using Mahalanobis D^2 statistic.

Review of Literature

2. REVIEW OF LITERATURE

With a view to understand the work done so far, an effort has been made to collect and to review the literature on genetic variability in chilli. Literature on heritability, genetic advance, correlation, path coefficient and genetic diversity in chilli is also reviewed.

2.1 YIELD ANALYSIS

2.1.1 Variability

Variability with respect to different characters is an essential pre-requisite for the selection of superior genotypes from a population.

2.1.1.1 Mean performance

The high phenotypic variability and range of variation in different characters indicate the extent of genetic variability in them.

Singh and Singh (1976b) studied 115 genetic stocks and observed high variability for plant height, number of branches, days to flower, days to maturity, fruit length, fruit thickness, number of fruits per plant and yield per plant.

In a preliminary selection programme of 18 chilli varieties, Alam and Khaleque (1983) estimated the genetic variability for 14 quantitative characters.

Number of primary and secondary branches, life span and number of seeds were found to have a wide range of variability in a study involving 30 genotypes (Nair *et al.*, 1984b).

Ado *et al.* (1987) evaluated 16 cultivars and found that fruits per plant, branches per plant and fruit weight were the most variable traits.

Bai *et al.* (1987) studied 12 red pepper varieties and observed significant variation for duration of flowering, plant height and fruit length.

Number of fruits per plant, individual fruit weight and dry fruit yield per plant showed high levels of variation in *Capsicum annuum* and *Capsicum frutescence* cultivars according to Adamu and Ado (1988).

Acharya *et al.* (1992) noted high variability for fruits per plant, yield per plant, fruit length, circumference and seed per fruit.

Pichaimuthu and Pappiah (1992) from their data on fourteen F_6 families, reported that high variability was obtained for number of fruits, dry and fresh weight of fruit and plant height.

While studying yield related traits in 20 chilli genotypes, Singh *et al.* (1994) noted greatest variability for weight of fresh red ripe fruits per plant.

Rahman *et al.* (1995) reported high variability for all the nine characters studied in four *Capsicum annuum* varieties and their F_1s.

Sarma and Roy (1995) obtained high variability for fruit diameter, fruit length and days to 50 per cent flowering.

While evaluating nine yield related characters in 50 *Capsicum annuum* and *C. frutescens* genotypes, Bhatt and Shah (1996) obtained high variability for all the characters studied especially for fruit yield. Similar results were obtained by Ghildiyal *et al.* (1996), Rani (1996 a, b) and Warade *et al.* (1996).

In their study using 54 genotypes, Kataria *et al.* (1997) observed a wide range of phenotypic variability for fresh weight per plant, fruit shape index, number of fruits per plant and plant height.

Jabeen *et al.* (1998) reported high variability for all the characters studied, especially for fruit yield in 71 genotypes of chilli.

Singh and Singh (1998) observed considerable genetic variability for pod yield and other traits in 30 chilli genotypes.

According to Dwivedi and Bhandari (1999), a wide range of variability was seen in all aspects of plant and fruit characteristics among 160 germplasm studied. All characters studied, except fruit girth, showed considerable amount of genetic variability in a study involving 30 germplasm lines of chilli according to Munshi and Behera (2000)

Subashri and Natarajan (2000) noted high genetic variability for yield per plant, number of fruits per plant and number of seeds per fruit.

Rathod *et al.* (2002) studied 8 yield components in 13 chilli cultivars and obtained high variability for number of fruits per plant, fresh red chilli yield per plant and plant height.

2.1.1.2 Variance

The components of variance give a more appropriate idea of the extent of variability in a population.

Arya and Saini (1977) in their study using 30 cultivars of chilli, observed high phenotypic and genotypic variance for fruit yield per plant, number of seeds per fruit, number of fruits per plant, fruit size per plant and plant height.

Ramalingam and Murugarajendran (1977) obtained high variance for plant height, weight of dry fruits, number of fruits and number of branches. High genotypic and phenotypic variances were obtained for plant height, plant spread, number of seeds per fruit and number of fruits per plant by Elangovan *et al.* (1981) in their study of 30 chilli genotypes.

Bai *et al.* (1987) reported maximum genotypic, environmental and phenotypic variances for fresh fruit yield per plant and minimum for branches per plant and percentage of fruit setting.

According to Vijayalakshmi *et al.* (1989) the genotypic and phenotypic variances were high for number of flowers, plant height and spread and low for number of primary branches, average fruit weight, fruit length and fruit girth. Seeds per fruit showed the maximum genotypic variance and 100-seed weight the minimum according to Sahoo *et al.* (1990).

Das and Choudhary (1999b) studied 25 genotypes and reported high phenotypic and genotypic variance for fruit length.

2.1.2 Coefficient of Variation

Coefficient of variation allows the comparison of variability of different characters. It is a unit free measurement.

Arya and Saini (1977) reported that Genotypic Coefficient of Variation ranged from 12.04 (for days to flower) to 223.83 (for rind thickness).

Singh and Brar (1979) observed that phenotypic and genotypic coefficients of variation were high for fruit number and fruit yield, medium for fruit weight and low for all other characters, while conducting variability studies in 31 varieties of sweet pepper.

According to Elangovan *et al.* (1981) genotypic and phenotypic coefficients of variation were higher for plant height, plant spread, number of seeds per fruit and number of fruits per plant.

In a study involving 12 parents and their 66 F_1 and F_2 progenies, Gupta and Yadav (1984) found that the genotypic coefficient of variation ranged from 11.1 for plant height to 62.6 for fruit girth.

Meshram (1987) in a field experiment in chilli involving 13 cultivars, found that length of fruit and days to first flower showed high genotypic correlation with yield.

Barai and Roy (1989) observed that coefficients of variation were greatest for fruit weight and fruits per plant, while evaluating six varieties of chilli.

Gopalakrishnan *et al.* (1987) obtained high GCV for fruit length (42.17), main stem length (44.61), fruit weight (29.70), fruits per plant (35.25) and fruit yield per plant (32.31) in 38 lines of chilli.

Vijayalakshmi *et al.* (1989) found that genotypic and phenotypic coefficients of variation showed greater difference for plant spread, number of flowers, pods and seeds, total pod yield and early yield, where as a close association between GCV and Phenotypic Coefficient of Variation was obtained by Pichaimuthu and Pappiah (1992) for several characters in F_6 generation.

From a study on 8 characters in 9 cultivars, Nandi (1993) reported high genotypic coefficient of variation for length and weight of pod, and yield per plant.

Kataria *et al.* (1997) in their study involving 54 genotypes of *Capsicum annuum* observed that highest GCV was exerted by number of fruits per plant followed by fresh fruit weight per plant and length of fruit. Similar results were obtained by Jabeen *et al.* (1999).

Devi and Arumugam (1999) studied 12 yield related characters in 30 F_2 hybrids and obtained moderate PCV and GCV values for all the characters studied except for days to first flower, dry fruit yield per plant and fruit girth.

In their studies on 25 bell pepper genotypes, Kohli and Chatterjee (2000) observed high GCV for number of lobes per fruit, fruit width at end of flowering and fruit weight at marketable stage.

The number of fruits per plant exhibited high values of genotypic and phenotypic coefficients of variation according to Munshi and Behera (2000). GCV ranged from 5.32 per cent (days to first fruit harvest) to 59.44 per cent (number of fruits per plant).

Subashri and Natarajan (2000) studied four F_2 chilli lines and reported wide variation between phenotypic and genotypic coefficient of variation, revealing the possible role of environment on the characters. But Mishra *et al.* (2001) observed that PCV had slightly higher values than GCV, there by indicating the negligible effect of the environment on fruit characters.

Ibrahim *et al.* (2001) reported that the phenotypic and genotypic coefficients of variation were highest for fruit length (26.64 and 26.21), followed by dry fruit yield (19.93 and 13.28) and number of branches per plant (19.46 and 15.10).

Gogoi and Gautam (2002) obtained high GCV and PCV for fruit drop percentage, fresh fruit yield per plant and dry fruit yield per plant.

High genotypic coefficient of variation was obtained for number of fruits per plant, fresh red chilli yield per plant and plant height, according to Rathod *et al.* (2002).

Sreelathakumary and Rajamony (2002) reported higher phenotypic and genotypic coefficients of variation for fruits per plant, fruit weight, fruit length, fruit girth, yield and leaf area, in both shaded and open areas.

2.1.3 Heritability

Singh and Singh (1977a) reported high estimates of heritability in broad sense for all the characters in a variability study comprising of six genetic populations *viz.*, P_1, P_2, F_1, F_2, B_1 and B_2.

High heritability estimates were obtained by Singh *et al.* (1981) for mean weight of fruit, fruits per plant and fresh fruit weight per plant.

In their study using 18 chilli cultivars, Alam and Khaleque (1983) observed that broad sense heritability estimates varied from 93.05 per cent (fruit volume at harvest) to 51.87 per cent (number of secondary branches at first flower).

In a trial with 10 cultivars of chilli, Gopalakrishnan *et al.* (1985) found that fruit yield showed 62.98 per cent heritability.

Vijayalakshmi *et al.* (1989) found that pods per plant, average pod weight, pod length, pod girth and seeds per pod had high broad sense heritability values.

Variability studies in 30 genotypes by Das *et al.* (1990) revealed that fruit yield and number of fruits per plant recorded high heritability. High heritability estimates were obtained for fruit length, weight of fresh ripe fruits, dry fruit weight and fruit diameter in addition to the above mentioned traits (Singh *et al.*, 1994).

Rahman *et al.* (1995) studied nine yield related characters in four varieties, and estimated high heritability for almost all the characters. Rani and Singh (1996) studied 21 characters and obtained high to moderate heritabilities for all characters except capsanthin content.

Warade *et al*. (1996), Jabeen *et al*. (1998), Devi and Arumugam (1999) and Rathod *et al*. (2002) also obtained similar results for all the characters studied in their experiments.

In variability studies of 25 genotypes, Das and Choudhary (1999b) estimated very high variability (>80 per cent) for fruit length, fruit diameter, fruits per plant, weight of fruits and yield per plant.

Ibrahim *et al*. (2001) observed that the heritability was highest for plant height (98.12 %) followed by fruit length (96.74 %) and number of fruits per plant (96.18 %).

According to Gogoi and Gautam (2002), heritability estimates were moderate to high for all characters except the number of primary branches.

2.1.4 Heritability and Genetic Advance

Heritability estimates along with genetic advance is more useful in selecting superior genotypes than using heritability value alone.

Singh and Singh (1970) studied 19 strains and found low estimates of heritability and expected genetic advance. The heritability estimates ranged from 11.13 per cent for 1000-seed weight to 30.68 per cent for primary forks, while the expected genetic advance ranged from 1.04 per cent for fruit width to 32.07 per cent for fruit number.

Ramalingam and Murugarajendran (1977) reported high heritability associated with high genetic advance for plant height, number of branches, weight of fruits per plant and length of fruit, while low heritability and genetic advance for duration and number of fruits per plant.

Six genetic populations *ie*., P_1, P_2, F_1, F_2, B_1 and B_2 were studied by Singh and Singh (1977a) and they observed high values for heritability and genetic advance for number of fruits per plant, number of branches, plant height, days to maturity and yield per plant.

Elangovan *et al*. (1981) found that high genetic advance was shown by characters like plant spread, number of fruits per plant and weight of a fruit, while it was low for days taken to 50 per cent flowering, plant height and number of seeds per fruit.

High heritability along with low genetic advance was observed for days to flower, plant height, spread, number of primary branches and life span (Nair *et al.*, 1984b).

Choudhary *et al.* (1985) in their study involving 30 genotypes obtained a wide range of heritability from 27.81 (fruit girth) to 99.86 (number of seeds per fruit) and genetic advance from 0.33 (fruit girth) to 98.99 (yield per plant).

Fruit length and days to first flower were found to have high variability and high expected genetic advance (Meshram, 1987).

In a study of seven yield related and morphological traits in a natural population of *Capsicum annuum* cv. Espanol, Depestre *et al.* (1989a) found that mean fruit weight, fruit number per plant and yield showed medium narrow sense heritability and marked genetic advance.

High heritability and genetic advance were noticed for yield per plant, and number of fruits per plant (Sahoo *et al.*, 1989; Bhagyalakshmi *et al.*, 1990 and Das *et al.*, 1989).

Fruits per plant, fruit weight and length and circumference of fruit showed high heritability and genetic advance, according to Ghildiyal *et al.* (1996). Similar results were also obtained by Nandi (1993) and Rani *et al.* (1996).

Jabeen *et al.* (1999) reported high heritability and genetic advance for fruit yield per plant, fruit number per plant and pericarp thickness.

Devi and Arumugam (1999) studied 30F_2 hybrids and observed high heritability coupled with high genetic advance as a percentage of mean for number of fruits per plant and fruit weight.

In a study of 25 bell pepper varieties, Kohli and Chatterjee (2000) obtained high heritability and genetic advance for number of lobes/fruit, fruit width at end of flowering and fruit weight at marketable stage.

High estimates of broad sense heritability and genetic advance were observed for fruit length, number of fruits per plant and yield per plant (Munshi and Behera, 2000) and Subashri and Natarajan (2000).

Ibrahim *et al.* (2001) reported that number of fruits per plant, fruit length and plant height showed lower values for genetic advance as a percentage of mean, whereas number of branches per plant, fruit width and dry fruit yield per plant showed higher gentic advance as per cent of mean.

Studying 52 chilli genotypes, Gogoi and Gautam (2002) obtained the highest genetic advance along with high heritability for fruit drop percentage.

High heritability coupled with high expected genetic advance were recorded for the number of fruits per plant, fresh red chilli yield per plant and plant height (Rathod *et al.*, 2002).

Sreelathakumary and Rajamony (2002) studied 70 diverse genotypes of *Capsicum annuum*, *C. frutescens* and *C. chinense* and found that heritability and genetic advance were high for fruits per plant, fruit weight, fruit length, fruit girth, yield and leaf area, in both shaded and open areas.

2.1.5 Correlation

Knowledge of the correlation between yield and its component characters is essential for choosing the characters for selection.

Singh and Singh (1970) found positive correlation of fruit yield with fruit length, fruit width and 100 seed weight. But Arya and Saini (1976) observed a negative correlation of yield with plant height and fruit number per plant.

Total number of fruits harvested per plant was found to be positively associated with flowers produced during 66-86 days (Pandian and Sivasubramanian, 1978).

Sundaram and Ranganathan (1978) observed that yield showed significant positive correlation with days to flowering. Veerappa (1982) and Meshram (1987) also reported similarly. But yield was found to be negatively correlated with days to flowering according to Rao *et al.* (1981).

Studies on correlation conducted by Nair *et al.* (1984a) revealed that five economic characters *viz.*, fruit number, secondary branch number, fruit weight, fruit circumference and duration had positive direct effects on yield.

Gopalakrishnan *et al.* (1985) observed negative correlation of fruit girth with fruit yield per plant, while fruit length showed maximum positive correlation with yield.

Yield was significantly associated both phenotypically and genotypically with fruit length, number of branches, number of fruits and plant spread (Ghai and Thakur, 1987).

Jayasankar *et al.* (1987) reported that fruit length, number of seeds per fruit, fruit girth and number of primary branches had loose association with yield.

Barai and Roy (1989) observed that fruit weight was positively correlated with days to maturity in a variability study involving 30 chilli lines.

Das *et al.* (1990) found that yield per plant was significantly and positively correlated with number of primary and secondary branches per plant and number of seeds per fruit.

Yield was found to have significant negative correlation with days to 50 per cent flowering, and days taken for fruit set was found to have negative correlation with maturity (Bhagyalakshmi *et al.*, 1990).

Ali (1994) observed positive association of fruit yield with number of seeds per fruit and number of fruits per plant.

Rani (1995) observed positive correlation of yield with plant height, plant spread, number of primary branches per plant and number of secondary branches per plant. Rani (1996b) observed positive correlation between fruit seed weight and fruit seed number.

Todorova and Todorov (1998) obtained positive association of yield with fruit length, diameter and weight and weight of fruit with weight of pericarp.

In a study of four F_2 chilli crosses, Subashri and Natarajan (1999) obtained positive association of yield with branches per plant, fruits per plant, fruit weight and fruit length.

Das and Choudhary (1999a) studied 25 genotypes and obtained positive correlation between yield and fruit weight, fruits per plant and primary branches per plant.

Munshi *et al.* (2000) reported that mean fruit weight showed significant negative correlation with number of fruits per plant and positive correlation with fruit length.

Significant positive correlation of fruit yield per plant with plant height, fruit number per plant and canopy width was noted by Legesse *et al.* (1999) and Aliyu *et al.* (2000).

In their study in 17 genotypes of *Capsicum annuum,* Ibrahim *et al.* (2001) observed that number of fruits per plant showed highly significant positive correlation with number of branches and plant height and significant negative correlation with fruit length.

Mishra *et al.* (2001) observed that red chilli yield showed high positive correlation with fruits per plant, but negatively correlated with seeds per fruit

2.1.6 Path coefficient analysis

Gill *et al.* (1977) reported that number of fruits per plant had a positive direct effect on yield while days to flower had a very strong negative direct effect on early yield.

Korla and Rastogi (1977) studied 20 chilli varieties and reported that fruits per plant had the highest direct effect on fruit yield, followed by weight per fruit and plant height.

Rao and Chhonkar (1981) in their study of a 10 x 10 diallel found that number of fruits, fruit weight and dry fruit yield had a direct effect on ripe fruit yield.

Path coefficient analysis of 21 varieties showed that mean fruit weight, fruits per plant and fruit width had the greatest direct effect on yield (Depestre *et al.*, 1989b).

Kaul and Sarma (1989) conducted Path analysis in 14 parents and 24 F_1s and reported that number of fruits per plant, fruit diameter and number of branches per plant had direct effect on yield.

Sarma and Roy (1995) studied eight yield related traits in 20 chilli genotypes and noted the importance of fruit diameter, fruit length and days to 50 per cent flowering as selection criteria for improving chilli genotypes.

According to Das and Choudhary (1999a), fruits per plant and weight of fruits exhibited the highest positive effect on yield.

Legesse *et al.* (1999) reported positive direct effects of canopy width, fruit number per plant and pericarp thickness in 18 hot pepper genotypes.

Path analysis in a 6 x 6 diallel (excluding reciprocals) revealed positive direct effect of total fruit number on total fruit weight. (Tavares *et al.*, 1999)

Aliyu *et al.* (2000) reported that fruit diameter and number of seeds per plant had large positive direct effect on yield, while plant height showed negative direct contribution to final yield.

In a study involving 30 chilli germplasm, Munshi *et al.* (2000) reported direct positive effect of number of fruits per plant, fruit weight and fruit girth on yield per plant.

Ibrahim *et al.* (2001) studied six yield related characters in 17 genotypes of chilli and observed that fruit length and number of fruits per plant had strong positive association with dry fruit yield.

2.1.7 Selection index (Discriminant function)

Use of selection indices will increase the efficiency of selection to improve fruit yield in chilli.

Singh and Singh (1976a) obtained the maximum advance for yield in F_2 when selection indices were based on the seven characters, plant height, number of branches, days to flower, days to maturity, fruit length, fruit thickness and number of fruits per plant. The comparison of different discriminant functions revealed that days to flower, fruit length and number of fruits per plant were major yield components.

Gill *et al.* (1977) reported that multiple regression equation constructed on the basis of fruits per plant and fruit size had an efficiency of 47.74 per cent.

Singh and Singh (1977b) studied 45 strains of chilli and reported that discriminant functions using seven characters at a time, plant height, number of branches, days to maturity, fruit length, fruit size and fruit number per plant was more efficient than straight selection for yield. These characters can be the basis for selection to evolve high yielding lines in chilli.

The study on 50 varieties in chilli by Sundaram *et al.* (1979) revealed that number of fruits per plant and number of branches per plant were the important characters that should be taken care of for selection in hybridization programme.

Ramakumar *et al.* (1981) reported that selection based upon discriminant function involving fruit girth, number of fruits and plant spread may be more efficient than straight selection for yield.

2.1.8 Genetic divergence

Genetic divergence is a basic requirement for effective selection within the existing population or a population arising out of hybridization.

Singh and Singh (1976b) grouped 45 genotypes of chilli into ten clusters based on the similarities of their D^2 values. The clustering pattern of strains did not follow the geographical distribution. Considerable diversity between clusters was noted. The characters contributing maximum towards total divergence were number of branches, fruit thickness, number of fruits per plant and yield per plant.

A study of the diversity in six parents and their 15 F_1 hybrids of sweet pepper showed that the 21 genotypes formed seven clusters. Of the six parents, three were grouped in cluster 1 and the other three formed independent clusters while the remaining clusters were occupied by F_1s. Early yield was mainly responsible for genetic divergence among the genotypes. Cluster II containing all the high yielding crosses should be crossed with cluster V, which contained the derivatives of four parents (Gill *et al.*, 1982).

Varalakshmi and Haribabu (1991) classified the 32 genotypes of chilli into 11 gene constellations. Grouping of genotypes in different clusters was not related to their geographical origin. The intracluster D^2 values ranged form 0.0 (cluster VI to XI) to 36.7 (cluster III). The inter cluster D^2 value was maximum (159.1) between clusters X and XI while the minimum distance was between cluster II and V (36.90) indicating close relationship among the genotypes included. Considerable differences existed between clusters for all the characters. Fruit per plant, leaf area index, fruit weight and total yield were reported to be the chief contributors towards genetic divergence.

Oliviera *et al.* (1999) studied diversity among 133 sweet pepper genotypes through multivariate analysis. The genotypes were clustered into 15 distinct groups. Genotypes P-141-195-F10, P-142-2710-F10, P-141-90-F13, cv. Apolo AG5111 and P-142-222-F13 were the most divergent and showed the highest yields (935 g/plant) and fruit quality. The characteristics that contributed most to the diversity were bifurcation, plant height, length/width ratio of fruits and index of earliness.

Materials and Methods

3. MATERIALS AND METHODS

This study was undertaken to estimate the genetic variability existing in a collection of wax type chilli for different characters and also to do morphological characterization of the genotypes. The result of this study can be utilized for selecting types which can be used for further improvement programmes, especially for selection in segregating generations. The data for the estimation was collected from a field experiment, carried out of the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during summer 2003.

3.1 ESTIMATION OF GENETIC VARIABILITY

3.1.1 Materials

The experimental material consisted of 25 genotypes of wax type chilli collected from different agroclimatic areas of South India. The genotypes are presented in table 1.

3.1.2 Methods

3.1.2.1 Design and Layout

The experiment was conducted in Randomised Block Design (RBD) with three replications. Plot size was 2.25 x 0.90 m^2 with a spacing of 45 x 45 cm. Ten plants were maintained in each plot.

3.1.2.2 Sowing and cultural operations

Seeds were sown on raised nursery beds on 19-1-2003. Transplanting was done when seedlings were one month old, on 20-2-2003.

Cultural operations were carried out according to the Package of Practices recommendations of Kerala Agricultural University (Kerala Agricultural University, 2002).

Table 1. List of genotypes

Sl. No.	Name of Genotypes
T_1	Panathur Local
T_2	Pollachi Local
T_3	Nellimoodu Local
T_4	Erumalam Local
T_5	Nellur Local
T_6	Chettikkunnu Local
T_7	Mulleria Local
T_8	Odayanchal Local
T_9	Marthandam Local
T_{10}	Perambra Local
T_{11}	Kaniyapuram Local
T_{12}	Seethangoli Local
T_{13}	Kozhuvanal Local
T_{14}	Kulasekharam Local
T_{15}	Payyannur Local
T_{16}	Badiyadka Local
T_{17}	Honnavar Local
T_{18}	Hungarian Wax
T_{19}	Malla Local
T_{20}	Pallatheri Local
T_{21}	Vadakarappathi Local
T_{22}	Para Local
T_{23}	Chittoor Local
T_{24}	Kozhinjampara Local
T_{25}	Periya Local

3.1.2.3 Biometric observations

The following biometric observations were recorded from five plants selected at random in each genotype, excluding the border plants. In recording the observations, descriptors for *Capsicum* spp. recommended by IPGRI was followed. The mean values of these observations were worked out and were used for statistical analysis.

3.1.2.3.1 Plant height

Recorded in cm from the base of the plant to the tip of the longest branch, when, in 50 per cent of the plants the first fruit has begun to ripen.

3.1.2.3.2 Number of primary branches

The branches originating from the main stem were counted and recorded at full maturity of the plant.

3.1.2.3.3 Number of secondary branches

The branches borne on the primary branches were counted and recorded as the secondary branches.

3.1.2.3.4 Plant spread

Measured as plant canopy width in cm, taken at the widest point of the plant, immediately after first harvest.

3.1.2.3.5 Number of days to first flowering

Number of days taken from sowing to the appearance of the first flower was recorded.

3.1.2.3.6 Duration of flowering (fruiting span)

Number of days from the appearance of the first flower to the harvest of the last fruit was recorded.

3.1.2.3.7 Number of fruits per plant

The number of fruits at each harvest was recorded for each observational plant to obtain the total number of fruits per plant.

3.1.2.3.8 Length of the fruit

Length of ten ripe fruits of the second harvest taken at random from the observational plants was recorded. The average was worked out and expressed in cm. Length was measured from the base of the pedicle to the tip of the fruit.

3.1.2.3.9 Width of the fruit

The circumference at the widest point of the ten fruits of the second harvest, selected for recording length, was taken, average obtained and expressed in cm.

3.1.2.3.10 Green fruit yield per plant

The fresh weight of fruits at each harvest from the observational plants was recorded, totalled and average was worked out to obtain green fruit yield in grams.

3.1.2.3.11 Average fruit weight

Weight of ten ripe fruits of the second harvest, from each observational plant was recorded and the average was worked out and expressed in grams.

3.1.2.3.12 Number of seeds per fruit

Seeds were extracted from ten fruits taken at random from each observational plant, counted and average was found out.

3.1.2.3.13 100-seed weight

Seeds were extracted from a random sample of ten ripe fruits and dried uniformly. The weight of 100 fully developed seeds taken at random was recorded and expressed in grams.

3.1.2.3.14 Duration of the crop

Number of days from sowing to the last harvest of fruits was considered as the duration of the crop.

3.1.2.4 Statistical Analysis

Analysis of variance (ANOVA) and covariance (ANCOVA) for RBD (Panse and Sukhatme, 1967) in respect of the various characters were done.

The mean values for all the accessions for each of the characters were worked out and compared using critical differences.

3.1.2.4.1 Grouping of genotypes

The genotypes were grouped into poor, average and better categories with respect to each character as follows.

Definition	Category
Less than mean –2SE	: Poor
Between mean ± 2SE	: Average
More than mean + 2SE	: Better

where mean is the overall mean of 25 accessions for each character and SE is the standard error of mean for each character, except for days to first flowering, fruiting span and crop duration wherein genotypes with low values are better and hence the scoring pattern is in the reverse order.

3.1.2.4.2 Variance and covariance

The variance and covariance components were calculated
For i^{th} character from the ANOVA as

$$\text{Environmental variance, } \sigma^2_{ei} = \text{MSE}$$

$$\text{Genotypic variance, } \sigma^2_{gi} = \frac{\text{MST-MSE}}{r}$$

$$\text{Phenotypic variance, } \sigma^2_{pi} = \sigma^2_{gi} + \sigma^2_{ei}$$

where MST and MSE are the mean squares for treatment and error respectively from ANOVA, r is the number of replications. For two characters Xi and Xj, the covariance were worked out from the ANCOVA as

Environmental covariance, σ_{eij} = MSPE

$$\text{Genotypic covariance, } \sigma_{gij} = \frac{\text{MSPT-MSPE}}{r}$$

$$\text{Phenotypic covariance, } \sigma_{pij} = \sigma_{gij} + \sigma_{eij}$$

where MSPT and MSPE are the mean sum of products for treatment and error respectively between i^{th} and j^{th} characters.

3.1.2.4.3 Coefficient of variation

The variability in the genotypes for different characters was expressed using the coefficient of variation which is a unit free measurement.

$$\text{Phenotypic coefficient of variation, PCV} = \frac{\sigma_{pi}}{\overline{Xi}} \times 100$$

$$\text{Genotypic coefficient of variation, GCV} = \frac{\sigma_{gi}}{\overline{Xi}} \times 100$$

$$\text{Environmental coefficient of variation, ECV} = \frac{\sigma_{ei}}{\overline{Xi}} \times 100$$

where $\overline{Xi}$ is the overall mean of the i^{th} trait calculated from all accessions.

3.1.2.4.4 Heritability (H^2)

Heritability in broad sense was calculated as a percentage based on the formula given by Jain (1982).

$$\text{Heritability, } H^2 = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

where σ^2g and σ^2p are the genotypic and phenotypic variance of the trait.

Heritability per cent was categorized as suggested by Robinson *et al.* (1949) *viz.*, low (0-30), moderate (30-60) and high (above 60).

3.1.2.4.5 Genetic advance under selection

Genetic advance as a percentage of mean was estimated as per the method suggested by Lush (1940) and Johnson *et al.* (1955) for each trait as

$$\text{Genetic advance, GA} = \frac{KH^2\sigma_p}{\bar{X}} \times 100$$

Where K is the standardized selection differential (K = 2.06) at five per cent selection intensity (Miller *et al.*,1958) and $\bar{X}$ is the mean of the character over all accessions.

Genetic advance was categorized into low (less than 10 %), moderate (10-20 %) and high (more than 20 %) as suggested by Johnson *et al.* (1955).

3.1.2.4.6 Correlation analysis

The correlation coefficients (phenotypic, genotypic and environmental) were worked out for two characters X_i and X_j as

$$\text{Genotypic correlation } (r_{gij}) = \frac{\sigma_{gij}}{\sigma_{gi} \times \sigma_{gj}}$$

$$\text{Phenotypic correlation } (r_{pij}) = \frac{\sigma_{pij}}{\sigma_{pi} \times \sigma_{pj}}$$

$$\text{Environmental correlation } (r_{eij}) = \frac{\sigma_{eij}}{\sigma_{ei} \times \sigma_{ej}}$$

3.1.2.4.7 Path coefficient analysis

The direct and indirect effects of component characters on yield were estimated through path analysis technique (Wright, 1954).

3.1.2.4.8 Selection index

The selection index developed by Smith (1937) using discriminant function of Fisher (1936), was used to discriminate the genotypes based on 14 characters under study.

The selection index is described by the function $I= b_1x_1 + b_2x_2 +\ldots + b_kx_k$ and the merit of a plant is described by the function $H= a_1G_1 + a_2G_2 +\ldots + a_kG_k$ where $x_1, x_2,\ldots x_k$ are the phenotypic values and $G_1, G_2,\ldots G_k$ are the genotypic values of the plants with respect to the characters $x_1, x_2,\ldots, x_k$ and H is the genetic worth of the plant. It is assumed that the economic weight assigned to each characters in equal to unity *ie*., $a_1, a_2,\ldots,a_k = 1$.

The b (regression) coefficients are determined such that the correlation between H and I is maximum. The procedure will reduce to an equation of the form $b = P^{-1}Ga$ where P is the phenotypic variance-covariance matrix and G is the genotypic variance-covariance matrix.

3.1.2.4.9 Mahalanobis D^2 analysis

Genetic divergence was estimated using Mahalanobis D^2 statistic as described by Rao (1952).

For ith and jth accessions, D^2 value is computed as

$$D^2 = \sum_{l=1}^{k} (X_{il} - X_{jl})^2$$

Where k is the number of characters, X_{il} and X_{jl} are the uncorrelated means for the characters X_i and X_j in the l^{th} genotype. The significance of D^2 values was tested by Chi square test with k degrees of freedom.

The genotypes were grouped into several clusters based on these D^2 values following Tocher's method of clustering.

3.2 MORPHOLOGICAL CHARACTERISATION

Morphological characterization of the genotypes was done, with reference to the Descriptors for Capsicum by IPGRI. Six morphological traits *viz*. plant growth habit, branching, leaf density, fruit shape, fruit surface and fruit cross sectional corrugation were taken for this study.

Results

4. RESULTS

The 25 genotypes of chilli were evaluated for morphological characters and yield and the results are presented here:

4.1 ANALYSIS FOR YIELD AND MORPHOLOGICAL CHARACTERS

4.1.1 Variability

The genotypes showed significant difference for all the traits under study at five per cent level of significance.

4.1.1.1 Mean performance

Table 2 gives the mean values of the genotypes for yield and other traits.

Plant height showed significance at five per cent level. It was highest for T_{25} (48.40 cm). This was on par with T_3, T_8, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}, T_{17}, T_{19}, T_{20} and T_{22}. It was lowest for T_1 (36.27 cm) and was found to be on par with T_2, T_4, T_5, T_6, T_7, T_9, T_{18}, T_{21} and T_{24}.

Number of primary branches varied from 7.13 (T_8) to 4.60 (T_{24}). T_8 was on par with T_{11}, T_{13}, T_{14}, T_{15}, T_{16} and T_{17} where as T_{24} was on par with nine other genotypes.

The genotype T_{15} had the highest number of secondary branches per plant (20.53) and was on par with T_8, T_{11}, T_{16} and T_{17}. T_{21} had the lowest number (11.67) and was on par with T_1, T_2, T_5, T_6, T_{10}, T_{12}, T_{23} and T_{24}.

Plant spread ranged from 35.80 cm (T_{25}) to 28.07 cm (T_2). T_{25} was on par with 12 other genotypes and T_2 on par with T_9 and T_{24}.

The genotypes T_{17} took only 60.80 days to produce the first flower whereas T_{23} took 71.87 days. T_5 and T_{22} were on par with T_{17}.

Fruit length was highest for T_{17} (9.93 cm) and was on par with T_{22} (Plate 2). It was lowest for T_{12} (4.40 cm) and was on par with T_1, T_6, T_9, T_{10}, T_{20} and T_{24}.

Table 2. Varietal difference with respect to various characters

Genotype	Plant height, cm	No. of primary branches	No. of secondary branches	Plant spread, cm	No. of days to first flowering	Fruit length, cm	Fruit width, cm	No. of fruits per plant	Green fruit yield / plant, g	Average fruit weight, g	No. of seeds/ fruit	100-seed weight, g	Fruiting span	Duration of crop
T_{1}	36.27	5.53	14.13	32.27	70.60	4.53	5.60	20.13	85.53	5.40	44.07	0.1958	51.87	123.47
T_{2}	37.47	5.20	13.67	28.07	71.47	5.40	5.60	17.73	78.27	5.40	56.73	0.2224	71.93	143.27
T_{3}	44.53	5.80	16.47	34.40	68.40	5.67	4.93	10.93	41.20	4.53	36.33	0.1831	62.40	130.13
T_{4}	39.93	5.67	15.53	33.60	66.73	6.00	6.20	18.60	85.27	6.07	38.07	0.2380	76.67	145.00
T_{5}	37.67	5.13	14.20	31.93	61.20	6.33	6.20	24.40	148.93	6.87	46.40	0.3231	57.40	119.40
T_{6}	39.13	5.47	13.47	32.00	69.33	4.93	5.73	16.33	63.27	5.33	35.20	0.2463	52.20	121.60
T_{7}	41.00	6.07	16.87	33.67	67.73	6.27	6.53	26.73	140.80	6.60	33.13	0.3981	63.13	129.40
T_{8}	45.93	7.13	19.53	35.40	68.40	7.67	6.07	34.80	237.80	8.87	41.07	0.3745	62.00	130.53
T_{9}	39.40	5.67	14.67	29.73	68.33	4.80	5.80	28.47	122.53	5.53	43.00	0.1800	70.27	139.07
T_{10}	43.00	5.40	12.80	31.80	70.33	4.67	6.47	28.13	161.73	6.93	34.20	0.2957	66.53	136.93
T_{11}	45.13	6.53	19.27	35.20	69.66	6.07	6.27	41.47	230.53	7.20	44.87	0.2234	56.47	125.67
T_{12}	42.73	5.47	13.67	30.93	68.87	4.40	7.07	43.20	228.67	7.13	40.60	0.3145	55.53	124.67
T_{13}	44.13	6.13	17.73	34.13	67.40	5.87	6.00	26.87	152.13	7.13	40.67	0.2009	55.20	122.13
T_{14}	42.60	6.27	17.60	33.40	65.27	6.33	5.80	28.93	169.87	7.27	35.40	0.2254	64.73	130.07
T_{15}	42.87	7.00	20.53	34.80	68.87	5.60	6.40	40.00	261.53	8.60	38.07	0.3976	55.53	124.60
T_{16}	45.20	6.40	18.93	33.47	68.40	6.00	5.67	28.00	154.33	6.87	43.47	0.2334	72.27	141.07
T_{17}	44.27	6.47	20.13	34.67	60.80	9.93	6.80	24.20	247.73	13.33	35.40	0.3912	74.00	135.40
T_{18}	41.87	5.40	15.60	31.27	65.60	8.73	6.80	27.80	255.47	12.13	37.20	0.3993	64.87	131.20
T_{19}	43.40	5.53	16.40	34.27	69.53	7.93	6.33	20.73	180.53	11.73	24.47	0.3509	60.33	129.80
T_{20}	43.73	6.00	17.07	33.73	68.87	4.47	6.40	46.53	217.53	5.80	37.80	0.2051	61.80	131.13
T_{21}	39.73	4.73	11.67	30.93	63.40	7.27	5.00	26.13	155.00	7.27	21.73	0.2183	61.80	124.67
T_{22}	44.80	5.87	16.20	34.60	61.80	9.80	6.67	23.00	233.40	13.13	44.87	0.2713	81.20	143.47
T_{23}	41.27	5.20	13.60	32.13	71.87	6.40	5.00	33.60	172.93	7.07	26.27	0.1975	56.33	127.60
T_{24}	39.80	4.60	13.33	28.33	70.87	4.53	6.27	24.40	133.60	6.33	35.13	0.2232	74.80	146.60
T_{25}	48.40	5.73	14.73	35.80	71.73	5.73	6.80	36.67	233.07	8.73	38.20	0.2197	71.47	142.87
Mean	42.17	5.78	15.91	32.82	67.82	6.21	6.10	27.91	167.67	7.65	38.09	0.2691	64.03	131.99
SE	2.11	0.37	0.94	0.86	0.67	0.34	0.22	2.80	20.74	0.58	5.36	0.0161	1.28	1.56
CD*	6.00	1.04	2.68	2.46	1.91	0.96	0.61	7.95	58.96	1.64	15.22	0.0459	3.65	4.44

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

Plate 1. High yielding genotypes

Plate 2. Variability in fruit characters

Fruit width was maximum for T_{12} (7.07 cm) followed by T_{17}, T_{18} and T_{25}. The minimum fruit width was for T_3 (4.93 cm). Both T_{21} and T_{23} was on par with T_3 (Plate 2).

The largest number of fruits were produced by T_{20} (46.53) and T_{12} (43.20) while T_3 produced the lowest number (10.93). T_{11} (41.47) and T_{15} (40) were on par with T_{20}.

Green fruit yield per plant varied from 261.53 g (T_{15}) to 41.20 (T_3). However T_{18}, T_{17}, T_8, T_{22}, T_{25}, T_{11}, T_{12} and T_{20} were statistically as high yielding as T_{15} (Plate 1).

The genotypes T_{17} showed the highest value for average fruit weight (13.33 g) on par with T_{22}, T_{18} and T_{19}. It was lowest for T_3 (4.53 g).

Number of seeds per fruit was highest for T_2 (56.73), T_5, T_{22}, T_{11}, T_{16} and T_9. It was lowest for T_{21} (21.73).

The maximum hundred seed weight was for T_{18} (0.3993 g), T_7 (0.3981 g), T_{15} (0.3976 g) and T_{17} (0.3912 g) and was on par with each other, while it was least for T_9 (0.1800 g).

The highest fruiting span was for T_4 (76.67 days), followed by T_{24} (74.80 days) and T_{17} (74.00 days). It was lowest for T_1 (51.87 days), on par with T_6, T_{13}, T_{12} and T_{15}.

Crop duration ranged from 119.40 (T_5) to 146.60 (T_{24}). T_6, T_{13} and T_1 were on par with T_5 while T_2, T_5 and T_{22} were on par with T_{24}.

4.1.1.2 Classification of genotypes

The genotypes were classified into poor, medium and better with respect to each character, considering the deviation from the mean value (Table 3).

Plant height was less than 37.95 for three genotypes (poor) while it was more than 46.39 for only one genotype (better).

Table 3. Classification of genotypes

Character	Poor	Medium	Better
	< Mean – 2 SE	Mean ± 2 SE	Mean + 2 SE
Plant height, cm	< 37.95	37.95 – 46.39	> 46.39
	T_1, T_2, T_5	T_3, T_4, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T16, T_{17}, T_{18}, T_{19}, T_{20}, T_{21}, T_{22}, T_{23}, T_{24}	T_{25}
Number of primary branches	< 5.04	5.04 – 6.52	> 6.52
	T_{21}, T_{24}	T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_9, T_{10}, T_{12}, T_{13}, T_{14}, T_{16}, T_{17}, T_{18}, T_{19}, T_{20}, T_{22}, T_{23}, T_{25}	T_8, T_{11}, T_{15}
Number of secondary branches	< 14.03	14.03 – 17.79	> 17.79
	T_2, T_6, T_{10}, T_{12}, T_{23}, T_{24}	T_1, T_3, T_4, T_5, T_7, T_9, T_{13}, T_{14}, T_{18}, T_{19}, T_{20}, T_{21}, T_{22}, T_{25}	T_8, T_{11}, T_{15}, T_{16}, T_{17}
Plant spread, cm	< 31.10	31.10 – 34.54	> 34.54
	T_2, T_9, T_{12}, T_{21}, T_{24}	T_1, T_3, T_4, T_5, T_6, T_7, T_{10}, T_{13}, T_{14}, T_{16}, T_{18}, T_{19}, T_{20}, T_{23}	T_8, T_{11}, T_{15}, T_{17}, T_{22}, T_{25}
Number of days to first flowering	> 69.16	69.16 – 66.48	< 66.48
	T_1, T_2, T_{10}, T_{11}, T_{19}, T_{23}, T_{24}, T_{25}	T_3, T_4, T_5, T_7, T_8, T_9, T_{12}, T_{13}, T_{15}, T_{16}, T_{20}	T_5, T_{14}, T_{17}, T_{18}, T_{21}, T_{22}
Fruit length, cm	< 5.53	5.53 – 6.89	> 6.89
	T_1, T_2, T_6, T_9, T_{10}, T_{12}, T_{20}, T_{24}	T_3, T_4, T_5, T_7, T_{11}, T_{13}, T_{14}, T_{15}, T_{16}, T_{23}, T_{25}	T_8, T_{17}, T_{18}, T_{19}, T_{21}, T_{22}
Fruit width, cm	< 5.66	5.66 – 6.54	> 6.54
	T_1, T_2, T_3, T_{21}, T_{23}	T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{13}, T_{14}, T_{15}, T_{16}, T_{19}, T_{20}, T_{24}	T_{12}, T_{17}, T_{18}, T_{22}, T_{25}
Number of fruits per plant	< 22.31	22.31 – 33.51	> 33.51
	T_1, T_2, T_3, T_4, T_6, T_{19}	T_5, T_7, T_9, T_{10}, T_{13}, T_{14}, T_{16}, T_{17}, T_{18}, T_{21}, T_{22}, T_{24}	T_8, T_{11}, T_{12}, T_{15}, T_{20}, T_{23}, T_{25}

Table 3. continued

Green fruit yield per plant, g	< 126.19	126.19 – 209.15	> 209.15
	T_1, T_2, T_3, T_4, T_6, T_9	T_5, T_7, T_{10}, T_{13}, T_{14}, T_{16}, T_{19}, T_{21}, T_{23}, T_{24}	T_8, T_{11}, T_{12}, T_{15}, T_{17}, T_{18}, T_{20}, T_{22}, T_{25}
Average fruit weight, g	< 6.49	6.49 – 8.81	> 8.81
	T_1, T_2, T_3, T_4, T_6, T_9, T_{20}	T_5, T_7, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}, T_{21}, T_{23}, T_{24}, T_{25}	T_8, T_{17}, T_{18}, T_{19}, T_{22}
Number of seeds per plant	< 27.37	27.37 – 48.81	> 48.81
	T_{19}, T_{21}, T_{23}	T_1, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}, T_{17}, T_{18}, T_{20}, T_{22}, T_{24}, T_{25}	T_2
100 seed weight, g	< 0.2369	0.2369 – 0.3013	> 0.3013
	T_1, T_2, T_3, T_9, T_{11}, T_{13}, T_{14}, T_{16}, T_{20}, T_{21}, T_{23}, T_{24}, T_{25}	T_4, T_6, T_{10},T_{22}	T_5, T_7, T_8, T_{12}, T_{15}, T_{17}, T_{18}, T_{19}
Fruiting span	>66.59	61.47 – 66.59	<61.47
	T_2, T_4, T_9, T_{10}, T_{16}, T_{17}, T_{22}, T_{24}, T_{25}	T_3, T_7, T_8, T_{14}, T_{18}	T_1, T_5, T_6, T_{11}, T_{13}, T_{15}, T_{19}, T_{20}, T_{21}, T_{23}
Duration of the crop	> 135.11	128.87 - 135.11	< 128.87
	T_2, T_4, T_9, T_{10}, T_{16}, T_{17}, T_{22}, T_{24}, T_{25}	T_3, T_7, T_8, T_{14}, T_{18}, T_{19}, T_{20}	T_1, T_5, T_6, T_{11}, T_{12}, T_{13}, T_{15}, T_{21}, T_{23}

For number of primary branches, two genotypes were grouped under poor (< 5.04), 20 under medium (5.04 – 6.52) and three under the better category (> 6.52).

The medium category had the largest number (14) of genotypes lying in the range 14.03 to 17.79 for the trait number of secondary branches. Five genotypes were classified as better (> 17.79) and six as poor (< 14.03).

As for plant spread, five genotypes were classified as poor (< 31.1), 14 genotypes as medium (31.1 – 34.54) and six genotypes as better (> 34.54).

Six genotypes took less than 66.48 days to produce the first flower and were grouped under the better class while eight genotypes took more than 69.16 days (poor). The remaining eleven genotypes were grouped in the medium category (66.48 – 69.16 days).

Fruit length of eleven genotypes varied from 5.53 – 6.89 cm (medium) where as eight genotypes had fruits shorter than 5.53 cm (poor) and six genotypes had fruits longer than 6.89 cm.

Five genotypes each were included in the poor (< 5.66 cm) and better (> 6.54 cm) categories for the trait fruit width whereas the remaining 15 genotypes were included in the medium class (5.66 – 6.54 cm).

The number of fruits per plant was less than 22.31 for 6 genotypes (poor) while it was more than 33.51 for seven genotypes (better). Twelve genotypes had medium number of fruits ranging from 22.31 to 33.51.

Six genotypes were low yielders (poor) producing less than 126.19 g green fruit per plant while nine genotypes producing more than 209.15 g per plant were included under the better class. The medium group comprised of ten genotypes (126.19 – 209.15 g).

The average fruit weight was less than 6.49 g for seven genotypes (poor) whereas it was more than 8.81 g for five genotypes (better). The remaining 13 genotypes fell in the medium class (6.49 – 8.81 g).

As for the number of seeds per fruit, three genotypes were classified as poor (< 27.37), 21 genotypes as medium (27.37 – 48.81), and as only one genotype, T_2 fell in the better class (> 48.81).

Thirteen genotypes had less than 0.2369 g for the weight of 100 seeds (poor) while eight genotypes had more than 0.3013 g (better). The medium class was made up of only four genotypes (0.2369 – 0.3013 g).

The fruiting span was less than 61.47 days for eleven genotypes (better) whereas it was more than 66.59 days for nine genotypes (poor). Only five genotypes (61.47 – 66.59) fell in the medium class.

The crop duration was less than 128.87 days for nine genotypes (better). Seven genotypes having the range of 128.87 – 135.11 days were classified as medium and nine genotypes with more than 135.11 days were grouped in the poor class.

4.1.1.3 Components of variance

The details of the components of variance *viz.*, phenotypic, genotypic and environmental variances and the coefficients of variation are given in Table 4.

4.1.2 Coefficient of variation

The phenotypic, genotypic and environmental coefficients of variation were worked out and are furnished in Table 4.

4.1.2.1 Phenotypic coefficient of variation

The phenotypic coefficient of variation (PCV) was highest for green fruit yield per plant (42.31) while it was lowest for number of days to first flowering (4.90). Other traits showing high PCV were number of fruits per plant (34.58) average fruit weight (33.77) and 100-seed weight (29.53) (Fig. 1).

4.1.2.2 Genotypic coefficient of variation

Genotypic coefficient of variation (GCV) ranged from 4.59 for number of days to first flowering to 36.48 for green fruit yield per plant.

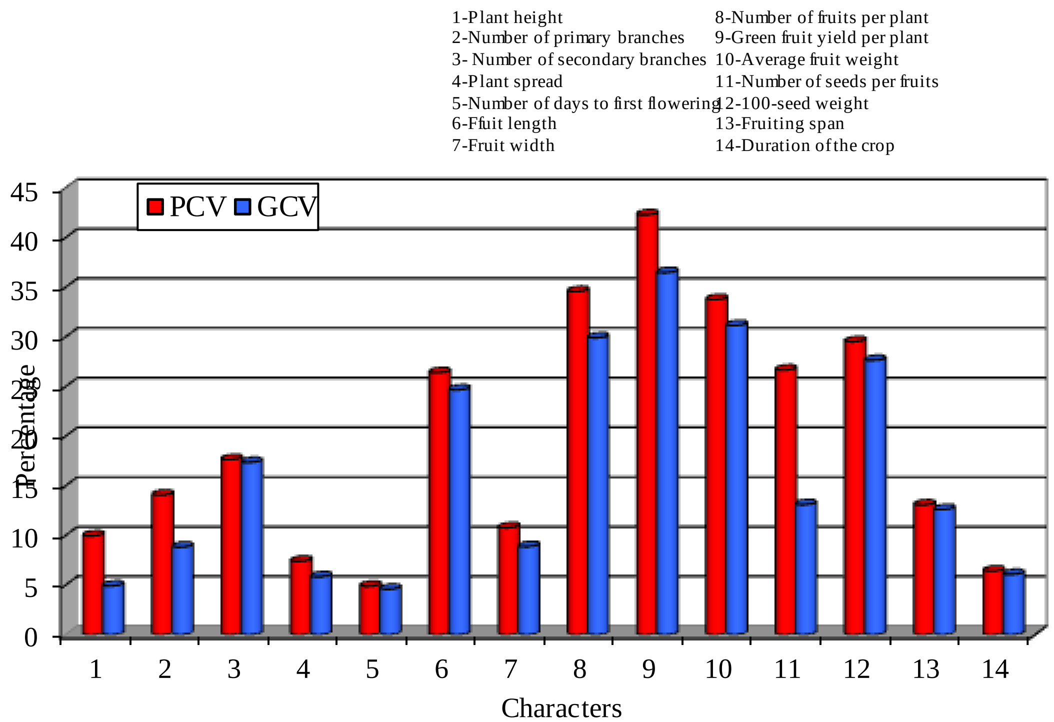

Fig. 1. Phenotypic and genotypic coefficients of variation for 14 characters

Other traits showing high GCV values were average fruit weight (31.15) and number of fruits per plant (29.92) (Fig. 1).

4.1.2.3 Environmental coefficient of variation

This value was low for most of the traits except number of seeds per fruit (13.57), green fruit yield per plant (5.83), number of primary branches (5.25) and plant height (5.05) indicating greater influence of environment on these characters.

4.1.3 Heritability (in broad sense)

Low, moderate and high heritability estimates were recorded for the different traits under study (Table 4). Heritability was highest for fruiting span (92.94 %) followed by crop duration (89.80 %), number of days to first flowering (87.76 %), 100-seed weight (87.64 %), and fruit length (87.22 %). Average fruit weight (85.10 %), number of fruits per plant (74.82 %), green fruit yield per plant (74.35 %), fruit width (67.75 %), number of secondary branches (66.28 %) and plant spread (62.08 %) also showed high heritability. Medium heritability was recorded for number of primary branches (39.33 %). The lowest value of heritability was recorded for number of seeds per fruit (22.40 %) followed by plant height (24.34 %) (Fig.2).

4.1.4 Genetic Advance (as percentage of mean)

Green fruit yield per plant recorded the highest genetic advance (64.80 %) (Table 4). Other characters showing high genetic advance were average fruit weight (59.22 %), number of fruits per plant (53.31 %), 100 seed weight (52.03 %), fruit length (47.50 %), fruiting span (25.04 %) and number of secondary branches (24.07 %). The lowest value was obtained for plant height (5.00 %) followed by number of days to first flowering (8.85 %) (Fig.2).

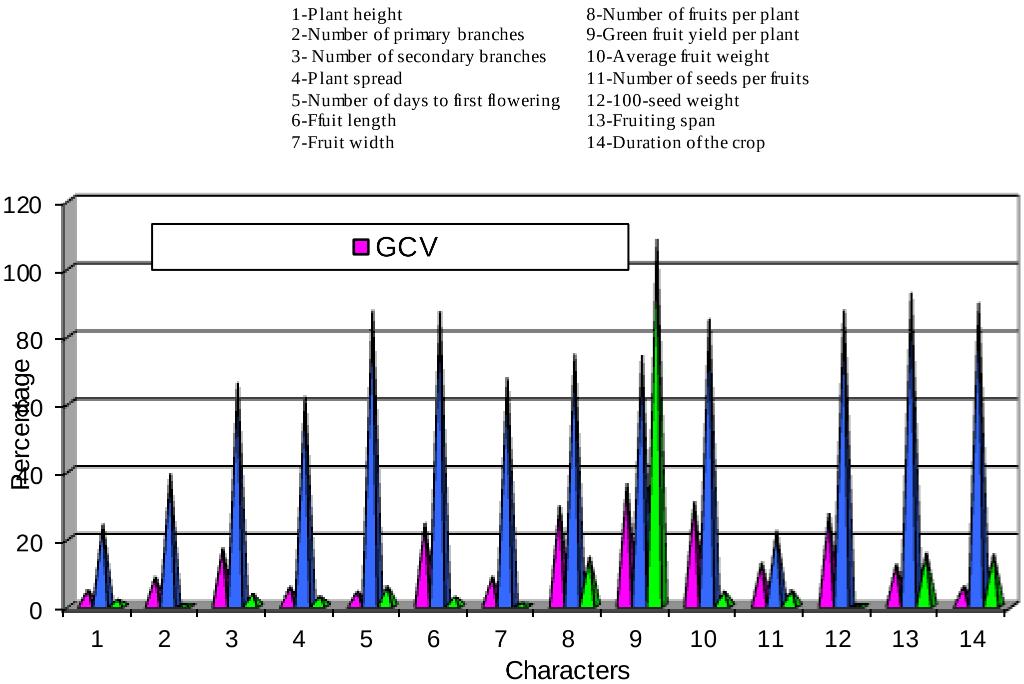

Fig. 2. Genotypic coefficient of variation, heritability and genetic advance for fourteen characters

Table 4. Genetic parameters

Sl. No.	Characters	Variance			Coefficient of variation			Heritability, %	Genetic advance (as % of mean)
		σ^2p	σ^2g	σ^2e	PCV	GCV	ECV		
1.	Plant height	17.681	4.304	13.377	9.97	4.92	5.05	24.34	5.00
2.	Number pf primary branches	0.662	0.260	0.402	14.08	8.83	5.25	39.33	11.24
3.	Number of secondary branches	7.888	5.228	2.660	17.65	14.37	3.28	66.28	24.07
4.	Plant spread	5.910	3.669	2.241	7.41	5.84	1.57	62.08	9.48
5.	Number of days to first flowering	11.033	9.683	1.350	4.90	4.59	0.31	87.76	8.85
6.	Fruit length	2.692	2.348	0.344	26.41	24.67	1.74	87.22	47.5
7.	Fruit width	0.433	0.293	0.140	10.79	8.88	1.91	67.75	15.08
8.	Number of fruits per plant	93.187	69.726	23.461	34.58	29.92	4.66	74.82	53.31
9.	Green fruit yield / plant	5031.653	3741.137	1290.516	42.31	36.48	5.83	74.35	64.8
10.	Average fruit weight	6.674	5.679	0.995	33.77	31.15	2.62	85.10	59.22
11.	Number of seeds per fruit	111.003	24.947	86.056	26.68	13.11	13.57	22.40	12.81
12.	100 seed weight	0.006	0.006	0	29.53	27.65	1.88	87.64	52.03
13.	Fruiting span	70.122	65.170	4.952	13.08	12.61	0.47	92.94	25.04
14.	Duration of the crop	71.889	64.556	7.333	6.42	6.09	0.33	89.80	11.88

4.1.5 Correlation Analysis

The correlation between different traits was computed as phenotypic, genotypic and environmental correlation coefficients.

4.1.5.1 Phenotypic correlation coefficient

The phenotypic correlation coefficients among characters are presented in Table 5.

Plant height showed high positive phenotypic correlation with plant spread (0.6814), number of secondary branches (0.5194), number of primary branches (0.4877) and green fruit yield per plant (0.3963).

Number of primary branches recorded a strong positive correlation with number of secondary branches (0.7914), plant spread (0.6506) and plant height (0.4877) where as its association with number of days to first flowering was negative (-0.1251) but non significant.

The association of number of secondary branches with number of primary branches (0.7914), plant spread (0.6611), plant height (0.6814) and green fruit yield per plant (0.4014) was strong and positive, while it was negative and non significant with number of days to first flowering (-0.2035). High positive correlation was recorded for plant spread with plant height (0.6814), number of secondary branches (0.6611) and number of primary branches (0.6506).

Days to first flower had a strong negative association with fruit length (-0.6388) and average fruit weight (-0.4771). Its association with most of the other traits was also negative.

There was strong positive association of fruit length with average fruit weight (0.8541), green fruit yield per plant (0.4631) and 100-seed weight (0.4600) while the correlation was highly negative with number of days to first flowering (-0.6388).

Fruit width had positive correlation with green fruit yield per plant (0.5560), average fruit weight (0.5404) and 100-seed weight (0.5078).

Table 5. Phenotypic correlation coefficients

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_1	1.0000													
X_2	0.4877*	1.0000												
X_3	0.5194**	0.7914**	1.0000											
X_4	0.6814**	0.6506**	0.6611**	1.0000										
X_5	-0.0025	-0.1251	-0.2035	-0.1492	1.0000									
X_6	0.2228	0.1638	0.3373	0.3188	-0.6388**	1.0000								
X_7	0.1964	0.1499	0.1857	0.1904	-0.1535	0.2321	1.0000							
X_8	0.2997	0.2895	0.2589	0.2105	0.1327	-0.1244	0.3381	1.0000						
X_9	0.3963*	0.3373	0.4014*	0.3368	-0.2432	0.4631*	0.5560**	0.7512**	1.0000					
X_{10}	0.2903	0.1814	0.3338	0.3184	-0.4771*	0.8541**	0.5404**	0.0811	0.6765**	1.0000				
X_{11}	-0.0474	0.1869	0.0967	-0.0953	0.0036	-0.1604	0.0799	0.1366	0.0577	-0.1585	1.0000			
X_{12}	0.0840	0.2021	0.3176	0.1693	-0.2980	0.4600*	0.5078**	0.1196	0.4802*	0.5691**	-0.0585	1.0000		
X_{13}	0.1372	-0.0291	0.0086	-0.0912	-0.2190	0.3060	0.1667	-0.2177	0.0278	0.2690	0.1502	-0.0256	1.0000	
X_{14}	0.1242	-0.0824	-0.0678	-0.1591	0.1483	0.0523	0.1174	-0.1689	-0.0711	0.0844	0.1632	-0.1428	0.9239**	1.0000

X_1- Plant height
X_2 – Number of primary branches
X_3 – Number of secondary branches
X_4 – Plant spread
X_5 – Number of days to first flowering
X_6- Fruit length
X_7 – Fruit width
X_8 – Number of fruits /plant
X_9 – Green fruit yield / plant
X_{10} – Average fruit weight
X_{11} – Number of seeds/fruit
X_{12} – 100-seed weight
X_{13} – Fruiting span
X_{14} – Duration of the crop

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

Number of fruits per plant had a high and positive correlation only with green fruit yield per plant (0.7512)

Green fruit yield per plant showed high positive association with number of fruits per plant (0.7512), average fruit weight (0.6765), fruit width (0.5560), 100-seed weight (0.4802), fruit length (0.4631), number of secondary branches (0.4014) and plant height (0.3963).

The inter relationship of average fruit weight with fruit length (0.8541), green fruit yield per plant (0.6765), 100-seed weight (0.5691) and fruit width (0.5404) was positive whereas it was negative with number of days to first flowering (-0.4771).

Number of seeds per fruit did not show any substantial association with any other trait.

A strong positive correlation was observed for 100-seed weight with average fruit weight (0.5691), fruit width (0.5078), green fruit yield per plant (0.4802) and fruit length (0.4600).

The association of fruiting span with duration of the crop was high and positive (0.9239).

Crop duration recorded high and positive correlation with fruiting span (0.9239). Its association with most of the other characters was negative and insignificant

4.1.5.2 Genotypic correlation coefficient

The genotypic correlation coefficients among characters are furnished in Table 6.

Plant height showed positive genotypic correlation with all the characters except number of seeds per fruit. However its associations with fruit yield per plant (0.8868), plant spread (0.8431), number of primary branches (0.7590) number of secondary branches (0.6763), average fruit weight (0.6369), number of fruits (0.6193), fruit width (0.5575) and fruit length (0.4515) were substantial.

Table 6. Genotypic correlation coefficients

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_1	1.0000													
X_2	0.7590**	1.0000												
X_3	0.6763**	0.0700	1.0000											
X_4	0.8431**	0.8429**	0.7381**	1.0000										
X_5	0.0336	-0.0508	-0.1964	-0.1853	1.0000									
X_6	0.4515*	0.2887	0.3819	0.4222*	-0.6888**	1.0000								
X_7	0.5575**	0.3012	0.2993	0.2455	-0.1907	0.1958	1.0000							
X_8	0.6193**	0.4500*	0.3031	0.2565	0.2098	-0.1991	0.4682*	1.0000						
X_9	0.8868**	0.5512**	0.5126*	0.4805*	-0.2254	0.4705*	0.7107**	0.7341**	1.0000					
X_{10}	0.6369**	0.2903	0.3789	0.4112*	-0.5064*	0.8837**	0.5556**	0.0832	0.7386**	1.0000				
X_{11}	-0.2630	0.2695	0.2741	-0.1971	0.0580	-0.2246	0.2882	-0.1761	-0.2690	-0.2252	1.0000			
X_{12}	0.2288	0.4713*	0.4261*	0.2861	-0.3642	0.5280**	0.6636**	0.1480	0.5814**	0.6465**	-0.2155	1.0000		
X_{13}	0.2748	-0.1066	0.0360	-0.0887	-0.2610	0.3699	0.2733	-0.2384	0.0577	0.3397	0.2373	-0.0361	1.0000	
X_{14}	0.2493	-0.1407	-0.0487	-0.1825	0.1121	0.1052	0.2270	-0.1677	-0.0259	0.1574	0.2985	-0.1749	0.9305**	1.0000

X_1 - Plant height
X_2 – Number of primary branches
X_3 – Number of secondary branches
X_4 – Plant spread
X_5 – Number of days to first flowering
X_6 - Fruit length
X_7 – Fruit width
X_8 – Number of fruits /plant
X_9 – Green fruit yield / plant
X_{10} – Average fruit weight
X_{11} – Number of seeds/fruit
X_{12} – 100-seed weight
X_{13} – Fruiting span
X_{14} – Duration of the crop

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

A positive correlation of number of primary branches with all the traits except number of days to first flowering, fruiting span and duration of the crop was noticed. Its correlation with plant spread (0.8429), number of primary branches (0.7590), green fruit yield per plant (0.5512), 100-seed weight (0.4713) and number of fruits per plant (0.4500) was high.

Number of secondary branches recorded a positive association with ten traits where as negative correlation was observed with number of days to first flowering and duration of the crop. It had significant positive correlation with plant spread (0.7381), plant height (0.6763), green fruit yield per plant (0.5126) and 100-seed weight (0.4261).

There was positive association of plant spread with nine traits of which correlation with plant height (0.8431), number of primary branches (0.8429), number of secondary branches (0.7381), green fruit yield per plant (0.4805), fruit length (0.4222) and average fruit weight (0.4112) was significant.

All the traits except plant height, number of fruits per plant, number of seeds per fruit and crop duration showed negative correlation with days to first flowering. However, only fruit length (-0.6888) had significant correlation with the trait.

The correlation of fruit length with number of days to first flowering, number of fruits per plant and number of seeds per fruit was negative while it was positive for the remaining traits. The correlation with average fruit weight (0.8837), 100-seed weight (0.5280), green fruit yield per plant (0.4705), plant height (0.4515) and plant spread (0.4222) was high and positive while that with number of days to first flowering was high and negative (-0.6888).

Fruit width was positively associated with all traits except number of days to first flowering. High value of correlation was noticed with green fruit yield per plant (0.7107), 100-seed weight (0.6636), average fruit weight (0.5556), plant height (0.5575), and number of fruits per plant (0.4682).

Number of fruits per plant showed negative but insignificant association with fruit length, number of seeds per fruit, fruiting span and duration of the crop. It was positive with the remaining nine traits, the correlation with green fruit yield per plant (0.7341), plant height (0.6193), fruit width (0.4682) and number of primary branches (0.4500) being high.

All traits except number of days to first flowering, number of seeds per fruit and crop duration showed positive association with green fruit yield per plant (Fig. 3). The correlation was significant with plant height (0.8868), average fruit weight (0.7386), number of fruits per plant (0.7341), fruit width (0.7107), number of secondary branches (0.5126), plant spread (0.4805) and fruit length (0.4705).

The correlation of average fruit weight was high and positive with fruit length (0.8837), green fruit yield per plant (0.7360), 100-seed weight (0.6465), plant height (0.6369), fruit width (0.5556) and plant spread (0.4112). Its correlation with days to first flowering was high and negative (-0.5064).

Number of seeds per fruit showed positive but low correlation with number of primary branches, number of secondary branches, number of days to first flowering, fruit width, fruiting span and crop duration. It showed negative but insignificant correlation with the remaining traits.

Hundred seed weight showed high positive association with average fruit weight (0.6465), fruit width (0.6636), fruit yield per plant (0.5814), fruit length (0.5280), number of primary branches (0.4713) and number of secondary branches (0.4261).

The correlation of fruiting span was high and positive with duration of the crop (0.9305).

Crop duration showed negative, but insignificant correlation with six traits. Its association was high and positive only with fruiting span (0.9305).

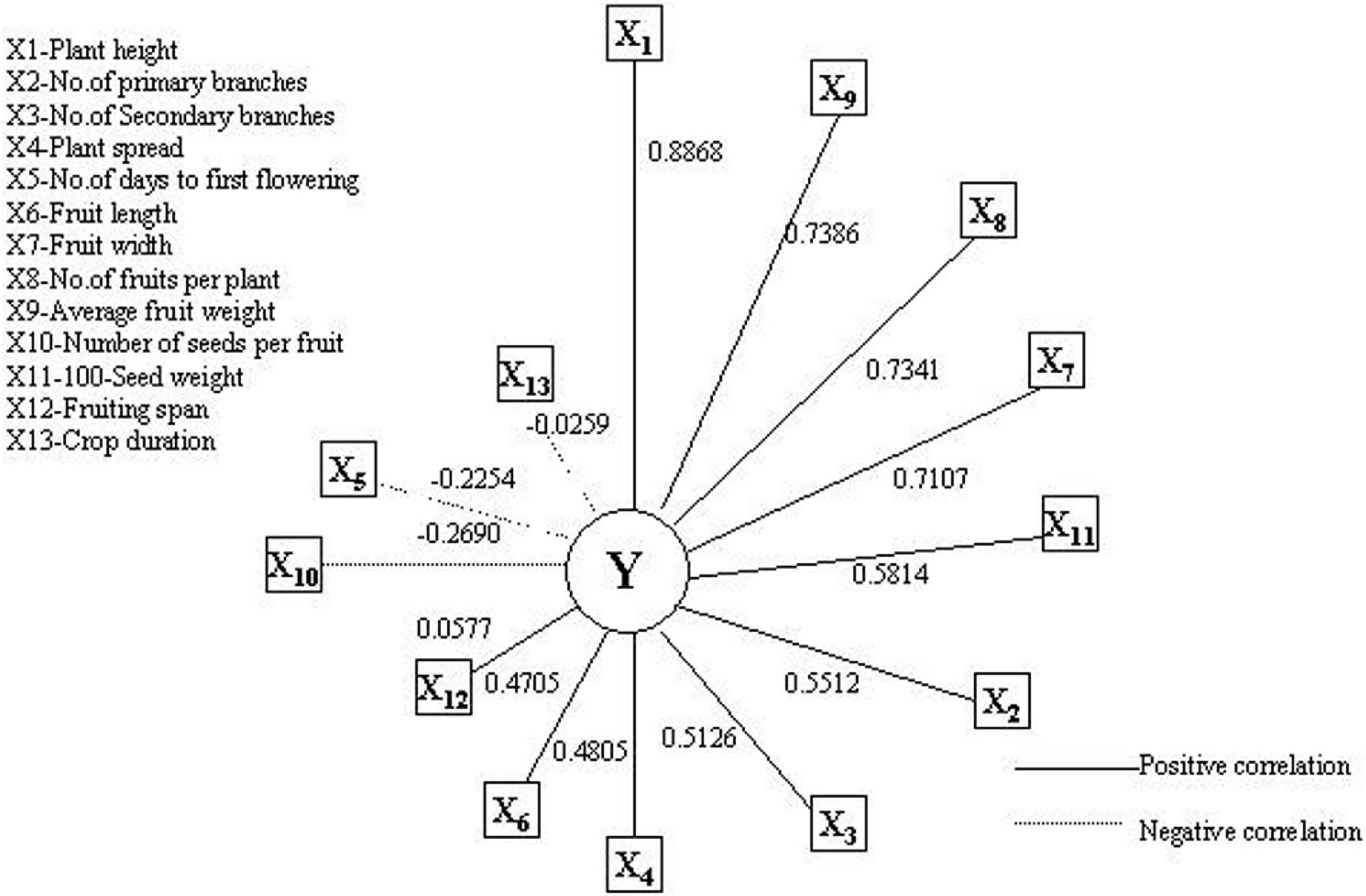

Fig. 3. Genotypic correlation of yield with other characters

4.1.5.3 Environmental correlation coefficient

The environmental correlation coefficients are presented in Table 7.

Most of the characters showed a low value for environmental correlation. However, high positive correlation was obtained for green fruit yield per plant with number of fruits per plant (0.8017), average fruit weight (0.4552) and fruit length (0.4651).

Average fruit weight showed high positive correlation with fruit length (0.6724), fruit width (0.5409) and green fruit yield per plant (0.4552).

Plant spread was associated with plant height (0.6603), number of secondary branches (0.5246) and number of primary branches (0.4882).

Fruiting span exhibited a strong and positive association with duration of the crop (0.8706).

4.1.6 Path coefficient analysis

The direct and indirect effects of the component characters on yield were estimated using path coefficient analysis (Table 8). The characters with high genotypic correlation with yield were selected and they included plant height, number of primary branches, number of secondary branches, plant spread, fruit length, fruit width, number of fruits per plants, average fruit weight and 100 seed weight (Fig. 4).

All traits except plant height, number of primary branches, fruit length and 100-seed weight had a positive direct effect on yield. The direct effect of number of fruits per plant and average fruit weight on yield was high and positive, while the direct effect of plant height was negative.

The direct effect of plant height on yield was negative (-0.2481). Its indirect effect via number of fruits per plant (0.4607) and average fruit weight (0.4862) were high and positive. Its genotypic correlation with yield was high and positive (0.8868).

Table 7. Environmental correlation coefficients

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_1	1.0000													
X_2	0.3732	1.0000												
X_3	0.4905	0.5419	1.0000											
X_4	0.6603	0.4882	0.5246	1.0000										
X_5	-0.0593	-0.3495	-0.2646	-0.0578	1.0000									
X_6	0.0473	-0.0190	0.2261	0.0367	-0.2898	1.0000								
X_7	-0.0549	-0.0126	-0.0449	0.0891	-0.0323	0.4016	1.0000							
X_8	0.0810	0.1161	0.1562	0.1153	-0.2127	0.2034	0.0166	1.0000						
X_9	0.0431	0.0994	0.1412	0.0331	-0.3451	0.4651	0.1796	0.8017	1.0000					
X_{10}	0.0012	0.0447	0.2193	0.0822	-0.2921	0.6724	0.5409	0.0760	0.4552	1.0000				
X_{11}	0.0185	0.1557	-0.0178	-0.0400	-0.0718	-0.1938	-0.0650	0.4725	0.3761	-0.1764	1.0000			
X_{12}	-0.0707	-0.2726	-0.0353	-0.1930	0.1743	-0.0129	-0.0180	-0.0015	0.0612	0.0790	0.1199	1.0000		
X_{13}	0.0280	0.1708	-0.1275	-0.1455	0.1800	-0.2846	-0.3327	-0.1423	-0.1499	-0.3221	0.1785	0.0747	1.0000	
X_{14}	0.0275	0.0048	-0.1640	-0.1163	0.4369	-0.3572	-0.3289	-0.1962	-0.1962	-0.4310	0.1035	0.1102	0.8706	1.0000

X_1 - Plant height
X_2 – Number of primary branches
X_3 – Number of secondary branches
X_4 – Plant spread
X_5 – Number of days to first flowering
X_6 - Fruit length
X_7 – Fruit width
X_8 – Number of fruits /plant
X_9 – Green fruit yield / plant
X_{10} – Average fruit weight
X_{11} – Number of seeds/fruit
X_{12} – 100-seed weight
X_{13} – Fruiting span
X_{14} – Duration of the crop

Table 8. Path coefficient analysis

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Genotypic Correlation Coefficient
Plant height (X_1)	**-0.2481**	-0.0092	0.0665	0.1093	-0.0003	0.0422	0.4607	0.4862	-0.0204	0.8868
Number of primary branches (X_2)	-0.1883	**-0.0121**	0.1052	0.1092	-0.0002	0.0231	0.3347	0.2216	-0.0420	0.5512
Number of secondary branches (X_3)	-0.1678	-0.0129	**0.0983**	0.0957	-0.0003	0.0229	0.2255	0.2893	-0.0380	0.5126
Plant spread (X_4)	-0.2092	-0.0102	0.0726	**0.1296**	-0.0003	0.0188	0.1908	0.3139	-0.0255	0.4805
Fruit length (X_5)	-0.1120	-0.0035	0.0375	0.0547	**-0.0007**	0.0150	-0.1481	0.6746	-0.0471	0.4705
Fruit width (X_6)	-0.1366	-0.0036	0.0294	0.0318	-0.0001	**0.0766**	0.3483	0.4242	-0.0592	0.7107
Number of fruits per plant (X_7)	-0.1537	-0.0054	0.0298	0.0332	-0.0001	0.0359	**0.7438**	0.0635	-0.0132	0.7341
Average fruit weight (X_8)	-0.1580	-0.0035	0.0372	0.0533	-0.0006	0.0426	0.0619	**0.7634**	-0.0577	0.7386
100-seed weight (X_9)	-0.0568	-0.0057	0.0419	0.0371	-0.0004	0.0508	0.1101	0.4935	**-0.0892**	0.5814

Residual, R = 0.0435

The figures in bold are the direct effects.

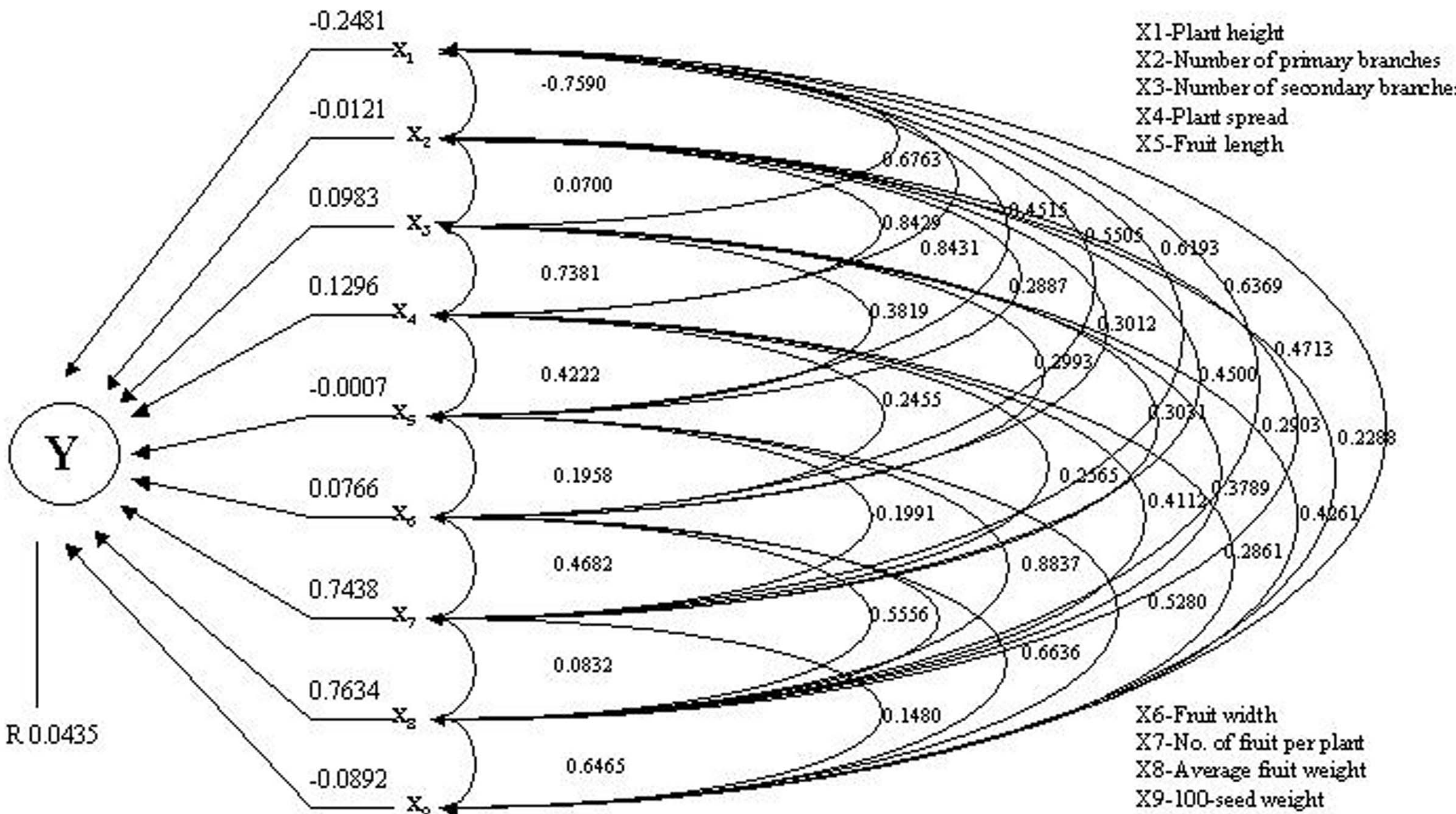

Fig. 4. Path diagram of direct effects and inter correlations

Number of primary branches had negative direct effect (-0.0121) on yield. It had positive indirect effects through number of fruits per plant (0.3347), average fruit weight (0.2216), plant spread (0.1092) and number of secondary branches (0.1052). Its genotypic correlation coefficient was positive (0.5512).

The direct effect of number of secondary branches was positive (0.0983), but it exerted greater influence on yield indirectly via number of fruits per plant (0.2255) and average fruit weight (0.2893). The trait had a negative indirect effect through plant height (-0.1678). Its correlation with yield was positive and high (0.5126).

Plant spread had a positive direct effect on yield (0.1296). The indirect effect of the trait via average fruit weight (0.3139), number of fruits per plant (0.1908) and number of secondary branches (0.0726) was positive where as it was negative through plant height (-0.2092). It had a genotypic correlation coefficient of 0.4805 with yield.

Fruit length had negative but negligible direct effect (-0.0007) and indirect effect through plant height (-0.1120), number of fruits per plant (-0.1481) and 100-seed weight (-0.0471). But it had high and positive indirect effect through average fruit weight (0.6746). It was genetically correlated with yield with a correlation coefficient of 0.4705.

The direct effect of fruit width was positive but low (0.0766) though its genotypic correlation with yield was high (0.7107). Its indirect effect via number of fruits per plant (0.3483) and average fruit weight (0.4242) was high and positive but low and negative for the remaining traits.

Number of fruits per plant showed a high and positive direct effect on yield (0.7438). Its indirect effect through average fruit weight (0.0635), fruit width (0.0359) and plant spread (0.0332) was positive but not significant. It exerted negative indirect effect through plant height (-0.1537), 100-seed weight (-0.0132) and number of primary branches

(-0.0054). The genotypic correlation coefficient (0.7341) was close to the direct effect.

The direct effect of average fruit weight on yield (0.7634) as well as correlation with yield (0.7386) was high and positive. Its indirect effect through plant height (-0.1580), 100-seed weight (-0.0577) and number of primary branches (-0.0035) was negative and low whereas it exerted positive indirect effect through the remaining traits.

Hundred seed weight showed a negative direct effect (-0.0892) on yield though it had a positive correlation with yield (0.5814). Its indirect effect through average fruit weight (0.4935) was high and positive, and contributed to its positive correlation with yield (0.5814). It exerted negative indirect effect through three traits.

The nine traits taken for path analysis explained 95.65 per cent of the variation in yield as is evidenced by the residual value of 0.0435.

4.1.7 Selection Index

Selection index was computed based on all the 14 traits and is given in Table 9. The index values were closer for genotypes with traits of similar nature.

The selection index was highest for the genotype T_{17} (2151.64) followed by T_{15} (2098.66), T_{25} (2093.47), T_{22} (2080.38) and T_{18} (2057.05). It was lowest for the genotypes T_3 (1454.95) and T_6 (1506.26).

4.1.8 Genetic Divergence Analysis

The 25 genotypes were subjected to Mahalanobis D^2 analysis based on nine characters *viz.*, plant height, number of primary branches, number of secondary branches, plant spread, fruit length, fruit width, number of fruits per plant, average fruit weight and 100-seed weight.

The genotypes were grouped into nine clusters based on Tocher's method (Table 10 and Fig. 5).

Table 9. Selection index

Genotype	Selection index	Rank
T_{17}	2151.64	1
T_{15}	2098.66	2
T_{25}	2093.47	3
T_{22}	2080.38	4
T_{18}	2057.05	5
T_8	2033.51	6
T_{20}	2024.06	7
T_{12}	2001.73	8
T_{19}	1967.46	9
T_{11}	1963.69	10
T_{16}	1889.52	11
T_{10}	1879.92	12
T_7	1850.98	13
T_{14}	1844.20	14
T_{24}	1833.47	15
T_{23}	1800.03	16
T_9	1772.14	17
T_4	1754.72	18
T_{13}	1741.01	19
T_{21}	1696.59	20
T_5	1656.77	21
T_2	1597.20	22
T_1	1526.48	23
T_6	1506.26	24
T_3	1454.95	25

Table 10. Clustering pattern of genotypes.

Cluster	Number of genotypes	Genotypes
I	5	T_8, T_{11}, T_{12}, T_{20}, T_{25}
II	7	T_5, T_7, T_{10}, T_{13}, T_{14}, T_{16}, T_{21}
III	3	T_{15}, T_{17}, T_{18}
IV	2	T_9, T_{24}
V	2	T_{19}, T_{23}
VI	2	T_2, T_4
VII	2	T_1, T_6
VIII	1	T_{22}
IX	1	T_3

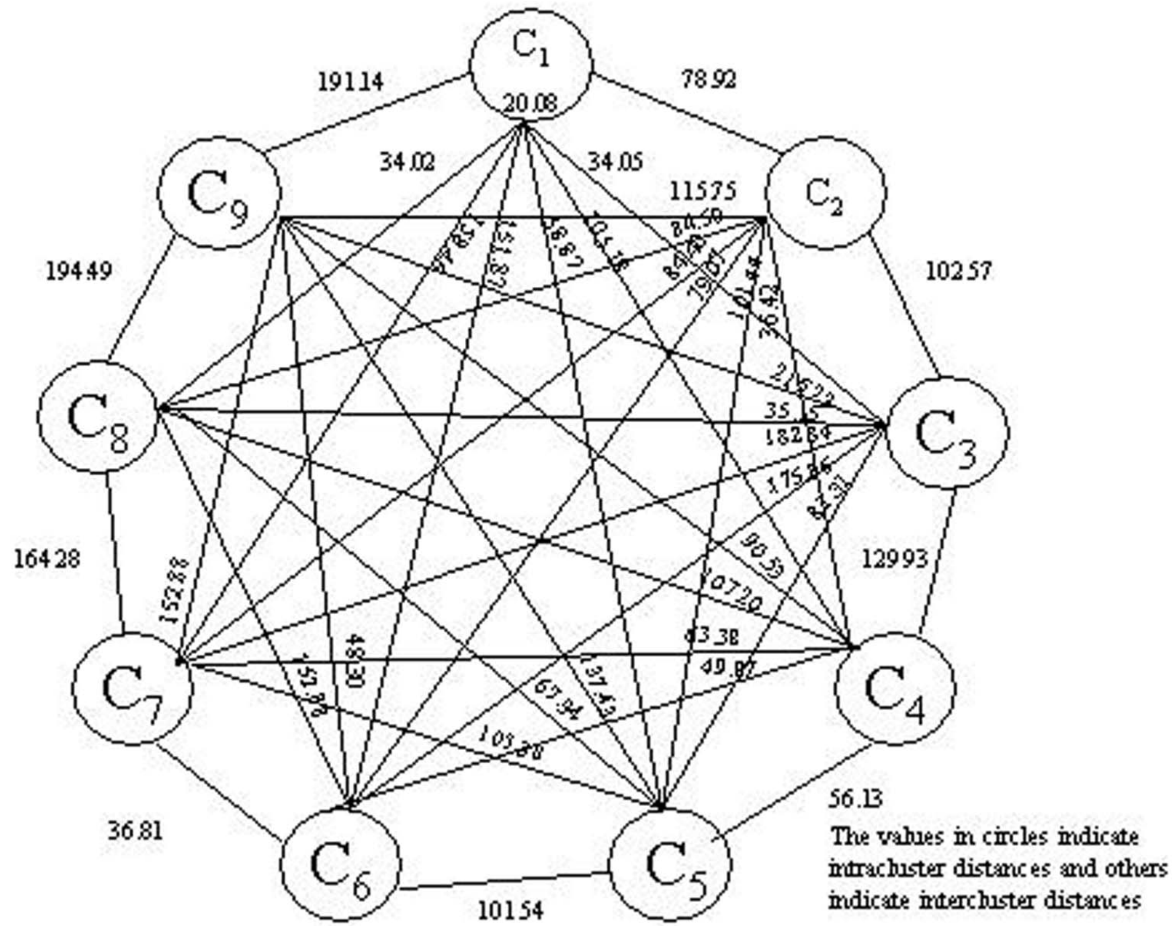

Fig. 5. Cluster diagram showing intra and intercluster distance

Cluster II was the largest with seven genotypes followed by cluster I with five genotypes and cluster III with three genotypes. Clusters IV, V, VI and VII contained two genotypes each where as clusters VIII and IX contained only one genotype each.

The cluster means for nine characters are furnished in Table 11.

Cluster I had the maximum cluster means for plant height (45.18 cm) and number of fruits per plant (40.53). Cluster III showed the maximum mean values for number of primary branches (6.29), number of secondary branches (18.75), fruit width (6.67), green fruit yield per plant (254.91 g) and 100-seed weight (0.3960 g). With respect to average fruit weight (13.13 g) and plant spread (34.60 cm), cluster VIII excelled the other clusters.

The minimum values for plant height (37.7 cm) and number of secondary branches (13.80 cm) was shown by cluster VII. The lowest cluster means for number of primary branches (5.14), plant spread (29.03 cm) and fruit length (4.67 cm) was shown by cluster IV whereas cluster IX had the minimum cluster means for the rest of the characters *ie*., fruit width (4.93 cm), number of fruits per plant (41.20 g), average fruit weight (4.53 g) and 100-seed weight (0.1831 g).

Average inter and intra clusters D^2 values and D values were calculated based on the total D^2 values and are presented in Table 12. The intracluster distances (D values) ranged from 17.05 (cluster IV) to 24.56 (cluster VII). Clusters VIII and IX had only one genotype each. The distance between cluster III and IX was the highest (215.23) while it was least between I and VIII (34.02). In general the inter cluster distances were much higher (often more than twice) than the intra cluster distances.

4.2 MORPHOLOGICAL CHARACTERISATION

The morphological characterisation of the 25 genotypes are given in Table 13.

Table 11. Cluster means

Character	Clusters									
	I	II	III	IV	V	VI	VII	VIII	IX	Mean
Plant height	45.18	41.90	43.00	39.60	42.34	38.70	37.70	44.80	44.53	41.97
Number of primary branches	6.17	5.73	6.29	5.14	5.37	5.44	5.50	5.87	5.80	5.70
Number of secondary branches	16.85	15.69	18.75	14.00	15.00	14.60	13.80	16.20	16.47	15.71
Plant spread	34.21	32.76	33.58	29.03	33.20	30.84	32.14	37.60	34.40	32.75
Fruit length	5.67	6.11	8.09	4.67	7.17	5.70	4.73	9.80	5.67	6.40
Fruit width	6.52	5.95	6.67	6.04	5.67	5.90	5.67	6.67	4.93	6.00
Number of fruits per plant	40.53	27.03	30.67	26.44	27.17	18.17	18.23	23.00	10.93	24.69
Green fruit yield per plant	229.52	154.68	254.91	128.07	176.73	81.77	74.40	233.40	41.20	152.74
Average fruit weight	7.55	7.01	11.35	5.93	9.40	5.94	5.37	13.13	4.53	7.78
100-seed weight	0.2674	0.2707	0.3960	0.2016	0.2742	0.2302	0.2211	0.2713	0.1831	0.2573

Table 12. Average inter and intra cluster D^2 value

	I	II	III	IV	V	VI	VII	VIII	IX
I	403.18 (20.08)	6228.37 (78.92)	1159.61 (34.05)	11062.13 (105.18)	3465.54 (58.87)	23063.19 (151.87)	25108.97 (158.46)	1157.30 (34.02)	36534.45(191.14)
II		550.88 (23.47)	10518.95 (102.57)	1340.92 (36.62)	10290.03 (101.44)	6252.84 (79.07)	71.23.91 (84.40)	7140.62 (85.40)	13397.73((115.75)
III			548.75 (23.43)	16700.20 (129.23)	6611.08 (81.31)	30927.44 (175.86)	33432.23 (182.84)	1235.68 (35.15)	46325.83 (215.23)
IV				290.58 (17.05)	3150.17 (56.13)	2486.70 (49.87)	4017.40 (63.38)	11491.54 (107.20)	8195.44 (90.53)
V					295.82 (17.20)	10311.28 (101.54)	11104.66 (105.38)	4534.44 (67.34)	18886.01 (137.43)
VI						487.58 (22.08)	1354.81 (36.81)	23371.99(152.88)	2333.19 (48.30)
VII							602.98 (24.56)	26986.84 (164.28)	1545.99 (39.32)
VIII								0(0)	37828.29 (194.49)
IX									0(0)

D values given in parenthesis

All the genotypes showed considerable variation for the different morphological characters.

Four genotypes showed erect and two showed prostrate growth habit, while the majority (19 genotypes) showed intermediate growth habit.

Five genotypes each were dense and sparse in branching and the remaining 15 were intermediate.

Leaf density was sparse and dense for 5 genotypes each and intermediate for 15 genotypes.

Twelve genotypes produced triangular shaped fruits, 11 produced elongated fruits and fruits were companulate in 2 genotypes.

Nine genotypes had smooth surface for their fruits, 11 had semiwrinkled surface and 5 had wrinkled fruit surface.

Fruit cross section was corrugated and intermediate for 8 genotypes each, while the remaining 9 genotypes showed slightly corrugated nature.

Table 13. Morphological characterization of the 25 genotypes

Geno-types	Plant Growth Habit	Branching	Leaf Density	Fruit Shape	Fruit Surface	Fruit Cross sectional Corrugation
T1	Intermediate	Sparse	Sparse	Triangular	Semiwrinkled	Corrugated
T2	Intermediate	Sparse	Sparse	Triangular	Smooth	Slightly corrugated
T3	Intermediate	Sparse	Sparse	Elongate	Smooth	
T4	Intermediate	Intermediate	Sparse	Triangular	Semiwrinkled	Slightly corrugated
T5	Intermediate	Intermediate	Intermediate	Companulate	Wrinkled	Corrugated
T6	Intermediate	Sparse	Sparse	Triangular	Smooth	Intermediate
T7	Erect	Intermediate	Intermediate	Elongate	Semiwrinkled	Corrugated
T8	Intermediate	Intermediate	Intermediate	Companulate	Wrinkled	Corrugated
T9	Intermediate	Intermediate	Intermediate	Triangular	Wrinkled	Corrugated
T10	Intermediate	Intermediate	Intermediate	Triangular	Smooth	Intermediate
T11	Intermediate	Intermediate	Intermediate	Triangular	Semiwrinkled	Slightly corrugated
T12	Intermediate	Intermediate	Intermediate	Triangular	Smooth	Intermediate
T13	Intermediate	Intermediate	Intermediate	Elongate	Smooth	Intermediate
T14	Intermediate	Intermediate	Dense	Elongate	Semiwrinkled	Slightly corrugated
T15	Intermediate	Dense	Dense	Triangular	Semiwrinkled	Slightly corrugated
T16	Erect	Intermediate	Dense	Elongate	Semiwrinkled	Slightly corrugated
T17	Erect	Dense	Dense	Elongate	Semiwrinkled	Slightly corrugated
T18	Intermediate	Dense	Dense	Elongate	Smooth	Slightly corrugated
T19	Intermediate	Intermediate	Intermediate	Elongate	Semiwrinkled	Intermediate
T20	Intermediate	Intermediate	Intermediate	Triangular	Smooth	Intermediate
T21	Prostrate	Intermediate	Intermediate	Elongate	Wrinkled	Corrugated
T22	Erect	Intermediate	Intermediate	Elongate	Semiwrinkled	Corrugated
T23	Intermediate	Dense	Intermediate	Elongate	Wrinkled	Corrugated
T24	Prostrate	Sparse	Intermediate	Triangular	Smooth	Intermediate
T25	Intermediate	Dense	Intermediate	Triangular	Semiwrinkled	Slightly corrugated

Discussion

5. DISCUSSION

The results of the study conducted to assess the genetic variability in wax type chilli with respect to various characters are discussed below.

5.1 ASSESSMENT OF VARIABILITY

The study of the phenotypic variation present in a population with respect to the various characters gives the basic idea of the extent of variability.

All the characters studied showed a wide range of variation, except plant height and number of seeds per fruit (Table 2). This was further confirmed by analysis of variance in which significant difference was observed for all the traits.

Green fruit yield per plant showed the greatest range of variation. The genotype T_{15} (Payyannur local) was the highest yielder (Plate 1) followed by T_{18} (Hungarian Wax), T_{17} (Honnavar local) and T_8 (Odayanchal local). The lowest yielders were T_3 (Nellimoodu local), T_6 (Chettikkunu local) and T_2 (Pollachi local). In addition to yield, high phenotypic variability was observed for fruit length, number of fruits per plant, average fruit weight and number of seeds per fruit. This was in accordance with the findings of Singh and Singh (1976b), Ado *et al.* (1987), Adamu and Ado (1988), Pichaimuthu and Pappiah (1992), Bai *et al.* (1987) and Bhatt and Shah (1996). Variability in number of primary and secondary branches was noticed and this was supported by the findings of Nair *et al.* (1984b).

Variation in fruit length and fruit girth was observed (Plate 2) and similar view was expressed by Acharya *et al.* (1992), Sarma and Roy (1995) and Rani (1996a,b). Number of seeds per fruit also showed high phenotypic variability. Nair *et al.* (1984) also expressed a similar view.

5.2 CLASSIFICATION OF GENOTYPES

The genotypes were grouped into different classes in order to identify phenotypically superior genotypes for each character. Deviation from the mean to the tune of twice the standard error magnitude was used as the basis for this classification.

With regard to fruit yield, nine genotypes were included in the better class. Number of fruits per plant and average fruit weight were higher than mean for seven and five genotypes respectively. Six cultivars each were better performing for fruit length and plant spread. Only a single genotype each was found to be better for the characters plant height and number of seeds per fruit. Six genotypes with values less than mean were included in the better class for days to first flowering.

Fruiting span and duration of the crop were lower than mean (better) for eleven and nine genotypes each. The better class consisted of five genotypes each for number of secondary branches and fruit width. Eight and three genotypes with values greater than mean were included in the better class for 100- seed weight and number of primary branches respectively.

The genotypes T_8 (Odayanchal local), T_{11} (Kaniyapuram local), T_{15} (Payyannur local), T_{17} (Honnavar local) and T_{25} (Periya local) fell in the better class while T_1 (Panathur local), T_2 (Pollachi local), T_3 (Nellimoodu local) T_6 (Chettikkunnu local) and T_9 (Marthandam local) were included to the poor class for most of the traits.

5.3 ANALYSIS OF VARIANCE

The estimates of phenotypic, genotypic and environmental variance will give a better idea of the extent of variation in genotypes. High genotypic and phenotypic variance indicates the scope for phenotypic selection of these traits. High estimates of phenotypic and genotypic variances were observed for green fruit yield per plant followed by number of seeds per fruit, number of fruits per plant and duration of the crop. Similar results were observed by Arya and Saini (1977), Ramalingam and Murugarajendran (1977), Bai *et al.* (1987), Elangovan *et al.* (1981) and Das and Choudhary (1999b). The difference between phenotypic and genotypic variances was less in most of the traits suggesting the predominance of genetic component over environmental effect on its phenotype. However environmental variance was higher than genotypic variance for plant height, number of primary branches and number of seeds per fruit suggesting the influence of environment over this trait. This was in accordance with the report of Bai *et al.* (1987) who obtained similar results for branches per plant.

5.4 COEFFICIENT OF VARIATION

Coefficient of variation, being a unit free measurement, provides an excellent basis for the comparison of variation among the different characters studied.

The phenotypic coefficient of variation ranged from 4.90 for days to first flowering to 42.31 for fruit yield per plant. Other traits showing high PCV were number of fruits per plant, average fruit weight and 100-seed weight. This was in accordance with the reports by Singh and Brar (1979), Elangovan *et al.* (1981), Barai and Roy (1989), Kataria *et al.* (1997), Jabeen *et al.* (1999), Munshi and Behera (2000) and Sreelathakumary and Rajamony (2002). Other characters showed moderate to low values for PCV. Similar results were reported by Devi and Arumugam (1999).

The genotypic coefficient of variation describes the inherent genetic variation. In the present study GCV also showed a similar trend as PCV. Highest estimate of GCV was observed for green fruit yield per plant (36.48) followed by average fruit weight and number of fruits per plant. These findings are in accordance with Arya and Saini (1977), Gopalakrishnan *et al.* (1987), Vijayalakshmi *et al.* (1989), Nandi (1993), Munshi and Behera (2000), Gogoi and Gautam (2002) and Rathod *et al.* (2002).

The value of environmental coefficient of variation was low for most of the traits implying that the observed variation was mainly due to genetic factors. Similar reports were obtained form Pichaimuthu and Pappiah (1992) and Mishra *et al.* (2001). But comparatively higher values for ECV were obtained for plant height, number of primary branches and number of seeds per fruit, suggesting the role of environment in the expression of these characters. Vijayalakshmi *et al.* (1989), Subashri and Natarajan (2000) also have similar observations.

5.5 HERITABILITY AND GENETIC ADVANCE

Heritability coefficient defines the heritable portion of total variance and it indicates the effectiveness with which selection of genotypes could be based on phenotypic performance.

Low, moderate and high heritability estimates were recorded for the different traits in the present study. Heritability was highest for fruiting span, followed by crop duration, number of days to first flowering, 100-seed weight, fruit length, average fruit weight, number of fruits per plant, fruit yield per plant, fruit width, number of secondary branches and plant spread while medium heritability was shown by number of primary branches. This was in accordance with the reports of Singh and Singh (1977a), Singh *et al.* (1981), Gopalakrishnan *et al.* (1985), Das *et al.* (1990) Das and Choudhary (1999b) and Gogoi and Gautam (2002).

Lowest value of heritability was obtained for number of seeds per fruit and plant height. Singh and Singh (1970) and Elangovan *et al.* (1981) also reported similar results. However, Ibrahim *et al.* (2001) observed that heritability was the highest for plant height.

Number of primary branches recorded medium heritability. Mean while Singh and Singh (1970) observed low heritability for number of branches per plant.

Heritability estimates along with genetic advance are more useful than using heritability alone in predicting the resultant effect of selecting the best individuals (Johnson *et al*., 1955). A high genetic advance result if the heritability is due to additive gene effects and the expected genetic advance would be low if the heritability is mainly due to non-additive gene effect (Panse, 1957).

High heritability along with high genetic advance was observed only for 100-seed weight, fruit length, average fruit weight, number of fruits per plant, green fruit yield per plant, fruiting span and number of secondary branches, indicating the additive gene effects in these characters. Singh and Singh (1977a), Meshram (1987), Sahoo *et al*. (1989) Bhagyalakshmi *et al*. (1990), Das *et al*. (1989), Jabeen *et al*. (1999), Munshi and Bahera (2000), Ibrahim *et al*. (2001), Sreelathakumary and Rajamony (2002) also reported that fruit yield showed high heritability coupled with genetic advance, along with many other characters.

Crop duration showed high heritability along with moderate genetic advance whereas Nair *et al*. (1984) observed high heritability but low genetic advance for life span.

Number of secondary branches showed moderate values of heritability and genetic advance. However, Singh and Singh (1977 a) and Ibrahim *et al*. (2001) obtained high values for heritability and genetic advance for number of branches.

Number of seeds per fruit showed low heritability and medium genetic advance indicating that the character had little scope for selection. Elangovan *et al*. (1981) also reported similarly whereas Choudhary *et al*. (1985) obtained a high value for the same, contrary to the above result.

A study of the genetic parameters is essential to obtain a clear picture of the extent of variability in a population. It provides an essential tool for selection based on phenotype. Characters with high genotypic coefficient of variation, heritability and genetic advance offer a better scope for improvement through selection. Fruit yield per plant, number of fruits per plant, average fruit weight and 100-seed weight possessed high values for the above genetic parameters emphasizing the scope for improvement through selection in these characters.

5.6 CORRELATION ANALYSIS

Yield is influenced by a number of other component characters. The extent of relationship between yield and its component traits as well as among the component traits is revealed through correlation analysis. Significant increase in yield can be obtained by improvement of characters with high correlation with yield.

The genotypic correlations were higher than the phenotypic correlations (Tables 5 and 6) for most of the characters indicating that phenotypic expression is reduced by the influence of environment despite inherent association between various characters. Similar observations were made by Sundaram and Ranganathan (1978) and Choudhary *et al.* (1985).

The genotypic correlations of green fruit yield per plant was significant and positive with plant height, average fruit weight, number of fruits per plant, fruit width, 100-seed weight, number of primary branches, number of secondary branches, plant spread and fruit length while it was negative but insignificant with number of days to first flowering, number of seeds per fruit and duration of the crop (Table 6 and Fig. 3).

Plant height was positively associated with yield suggesting its importance in improving yield. Rani (1995), Legesse *et al.* (1999) and Ibrahim *et al.* (2001) reported similarly, whereas Arya and Saini (1976) observed a negative correlation of yield with plant height. The association of fruit yield with number of primary branches was high and positive. Similar results were reported by Ghai and Thakur (1987), Das *et al.* (1990), Rani (1995), Subashri and Natarajan (1999), Das and Choudhary (1999a) and Ibrahim *et al.* (2001), while Jayasankar *et al.* (1987) reported that number of primary branches had poor association with yield.

Number of secondary branches showed positive and high association with yield, as reported by Nair *et al.* (1984) and Rani (1995). Similarly, plant spread also had positive and high association with yield. Ghai and Thakur (1987), Legesse *et al.* (1999) and Aliyu *et al.* (2001) also reported likewise.

The genotypic correlation of fruit length with yield was significant and positive as reported earlier by Singh and Singh (1970), Todorova and Todorov (1998) and Munshi *et al.* (2000). But Jayasankar *et al.* (1987) reported that fruit length had low association with yield.

High positive genotypic correlation was observed between fruit width and fruit yield per plant. Similar observation was made by Nair *et al.* (1984) and Todorova and Todorov (1998).

Another important economic trait showing high positive genotypic correlation with yield was average fruit weight. Similar view was expressed by Nair *et al.* (1984), Todorova and Todorov (1998), Subashri and Natarajan (1999), and Das and Choudhary (1999a). Munshi *et al.* (2000) reported that mean fruit weight showed positive correlation with fruit length.

Hundred seed weight showed high positive correlation with yield as reported earlier by Singh and Singh (1970) with respect to 1000 seed weight.

Yield showed slight positive association with fruiting span. Barai and Roy (1989) observed that fruit weight was positively correlated with days to maturity.

Yield per plant was negatively correlated with days to first flowering indicating that selection for earliness can lead to an increase in yield. Similar view was expressed by Rao *et al.* (1981) and Bhagyalakshmi *et al.* (1990). But Sundaram and Ranganathan (1978), Veerappa (1982) and Meshram (1987) observed positive correlation between yield and days to flowering.

Number of seeds per fruit also showed negative association with yield. Arya and Saini (1976) also held similar views whereas a positive association was observed by Pandian and Sivasubramanian (1978), Ghai and Thakur (1987), Ali (1994) and Mishra *et al*. (2001).

The correlation of yield per plant with crop duration was negative, suggesting that increased life span will lead to a decrease in yield. Bhagyalakshmi *et al*. (1990) also has reported that days taken for fruit set was negatively correlated with yield.

A negative correlation was observed between number of seeds per fruit and 100-seed weight. However, a positive correlation between fruit seed weight and number of seeds per fruit was observed by Rani (1996 b).

Average fruit weight showed high positive correlation with fruit length. Munshi *et al*. (2000) also obtained a similar result.

Number of fruits per plant showed a positive and significant association with plant height and number of primary branches, and a negative association with fruit length, as reported by Ibrahim *et al*. (2001).

5.7 PATH COEFFICIENT ANALYSIS

The genotypic correlation may not indicate the actual effect of one character upon another and at times can be misleading. Path analysis provides information on the real nature of association of several yield related characters contributing to yield by partitioning the genotypic correlation into direct and indirect effects.

The direct effects of number of fruits per plant and average fruit weight was high and positive, while that of plant height was high and negative (Table 8 and Fig. 4).

The direct effect of number of fruits was positive and very close to its genotypic correlation with yield, indicating that the correlation represents a true relationship between the two traits. Its indirect effect through number of secondary branches, plant spread and average fruit weight was positive while its contribution through plant height, number of primary branches and 100-seed weight was negative. The positive direct effect of number of fruits was observed by Gill *et al.* (1977), Korla and Rastogi (1977), Kaul and Sarma (1989), Das and Choudhary (1999), Munshi *et al.* (2000) and Ibrahim *et al.* (2001).

Average fruit weight had high and positive direct effect, very close to its genotypic correlation with yield, indicative of the true relationship between the two traits. Its indirect effect through plant spread, number of fruits per plant, fruit width and number of secondary branches was positive, while that through plant height, fruit length and 100- seed weight was negative. The direct effect of fruit weight was supported by Depestre *et al.* (1989b), Das and Choudhary (1999) and Munshi *et al.* (2000).

Plant height showed a high negative effect on yield, though its correlation with yield was high and positive. But it exerted high and positive indirect effect through number of fruits per plant and average fruit weight, thus contributing to the positive correlation with yield. The negative direct effect of plant height was also supported by Aliyu *et al.* (2000) whereas Korla and Rastogi (1977) reported that plant height had a direct positive effect on yield.

Plant spread had a positive but low direct effect on yield. Its genotypic correlation was also positive. Its indirect effect through number of secondary branches, fruit width, number of fruits per plant and average fruit weight was positive, while that through plant height, number of primary branches, fruit length and 100-seed weight was negative. Legesse *et al.* (1999) also reported the positive direct effect of canopy width.

Fruit width had a positive, but low direct effect on yield. However, its genotypic correlation with yield was high and positive. This could be due to the indirect effect of fruit width through number of fruits and average fruit weight which was high and positive. Depestre *et al.* (1989), Kaul and Sarma (1989), Sarma and Roy (1995) and Aliyu *et al.* (2000) also reported the positive direct effect of fruit width on yield. Fruit length also had a very low and negative direct effect with yield though its correlation was positive. The negative direct effect was nullified by the strong positive indirect effect through average fruit weight. Its indirect effect through number of secondary branches, plant spread and fruit width was positive, but was negative through number of fruits and fruit length. Sarma and Roy (1995) and Ibrahim *et al.* (2001) had reported strong positive association between fruit length and yield, contrary to the results in this study. The residual value was low indicating that most of the important component characters contributing to yield were included in the study and also very well explains the effect. Rao and Chhonkar (1981) and Munshi *et al.* (2000) also observed low residual value in their study. Based on correlation and path analysis studies, it could be concluded that selection for average fruit weight and number of fruits per plant might lead to increase in yield.

5.8 SELECTION INDEX

Selection index involving several yield related characters would be more efficient in identifying a superior genotype. Use of selection index also provides scope for greater efficiency in increasing yield through selection rather than straight selection for yield alone. In the present study, selection index was constructed based on all the 14 traits studied (Table 9). Many of the high yielding and superior genotypes such as T_{17}, (Honnavar Local) T_{15} (Payyannur Local), T_{25} (Periya Local), T_{22} (Para Local) and T_{18} (Hungarian Wax) were found to have high selection indices while low yielding types like T_3 (Nellimoodu Local), T_6, (Chettikkunnu Local), T_1 (Panathur Local), T_2 (Pollachi Local) and T_5 (Nellur Local) were having low selection indices, indicating its efficiency in identifying the superior genotypes. This may be due to the inclusion of several important yield related characters in computing the selection index. Gill *et al.* (1977), Singh and Singh (1977b), Sundaram *et al.* (1979) and Ramakumar *et al.* (1981)

also reported that efficiency of selection was higher when important yield related characters were included in the selection index.

It was also noted that many of the genotypes with high selection index fell under the ‘better’ class and the genotypes with low index under ‘poor’ class with respect to the mean values for yield per plant, plant spread, fruit width, average fruit weight and 100-seed weight.

5.9 GENETIC DIVERGENCE ANALYSIS

Genetic divergence between genotypes is estimated to identify suitable parents from a population. Mahalanobis D^2 statistic was found to be a powerful tool to assess the degree of relationship among the genotypes and to group them into different clusters. This would help in identifying genetically divergent parents to be used in breeding programmes.

Twenty-five accessions were grouped into nine clusters with varying number of genotypes in each (Table 10). The genotypes with minimum divergence got clustered together. Cluster II with seven genotypes was the largest and clusters VIII and IX containing one genotype each were the smallest.

Cluster I had five genotypes, all of which performed in an average manner, expect T_{25} (Periya local), which was a high yielder. It had the maximum cluster means for plant height and number of fruits per plant.

Cluster II, the largest, had seven genotypes and contained most of the genotypes grouped under medium class with respect to the various characters. It also included the genotype T_5 (Nellur local) that was a low yielder.

Cluster III contained three genotypes, all of them belonging to the high yielding class. It had the highest cluster means for five characters *viz.*, number of primary branches, number of secondary branches, fruit width, green fruit yield per plant and 100-seed weight indicating the superiority of the genotypes included in this cluster for these traits. Selection index was the highest for these genotypes.

Cluster IV contained only two genotypes which were grouped into the average class for number of fruits per plant, number of seeds per fruit and fruit width. This cluster showed the lowest cluster means for number of primary branches, plant spread and fruit length.

Cluster V also contained two genotypes, which belonged to the average class with respect to fruit yield, plant height and plant spread. They also had medium ranks when ranked using selection index.

Cluster VI, contained two genotypes, which were low yielders. It showed intermediate cluster means for all the traits taken for clustering.

Seventh cluster also consisted of two genotypes, which were grouped into the 'poor' category for most of the traits. But this cluster showed the highest cluster means for plant spread and average fruit weight, and minimum values for plant height and number of secondary branches.

Cluster VIII had only one genotype, T_{22} (Para local) which was found to be a high yielding one. It showed high cluster means for most of the characters.

The last cluster IX also had a single genotype, T_3 (Nellimoodu local) which was a low yielder. It had the lowest cluster means for fruit width, number of fruits per plant, green fruit yield per plant, average fruit weight and 100-seed weight, indicating its inferiority. This genotype also ranked the lowest when ranked on the basis of selection index.

The clustering pattern was found to be in agreement with the phenotypic classification based on mean values of genotypes for yield per plant.

Similarly, selection index was also high for most of the genotypes grouped in clusters I, III and VIII, which contained superior genotypes and it was low for genotypes clustered in VI, VII, and IX.

The intercluster distance (D) was maximum between III and IX suggesting that these were the most divergent clusters (Table 12 and Fig. 5)). The low value of intercluster distance between clusters I and VIII indicate that these two clusters were genetically close.

High intracluster distance indicated high degree of variability within that cluster offering scope for improvement by various selection methods. In this study cluster VII had the highest intracluster distance, followed by clusters II and III respectively.

In general, intercluster distances were much higher than the intracluster values, suggesting that there was homogeneity among the genotypes included in a cluster while heterogeneity existed between clusters.

Hence based on the present variability studies, it was concluded that the superior genotypes with high desirable characters *viz.*, Payyannur local, Honnavar local, Hungarian Wax, Para local and Periya local (belonging to clusters III, VIII and I), can be used as parents in a hybridisation programme to evolve high yielding varieties and with respect to characters selection in average fruit weight and number of fruits per plant can lead to increase in yield.

5.10 MORPHOLOGICAL CHARACTERISATION

Morphological characters of the high yielding types are as follows.

Honnavar local showed erect growth habit, dense branching and high leaf density. It had elongated fruits with semiwrinkled surface and slightly corrugated cross section.

Payyannur local had intermediate growth habit, dense branching and high leaf density. Elongated fruits with semiwrinkled surface and slightly corrugated cross section were its speciality.

For the genotype Periya local, growth habit and leaf density were intermediate, whereas the branching was dense. The fruits were triangular with semiwrinkled surface and cross section slightly corrugated.

Erect growth habit, and intermediate branching and leaf density were shown by the Para local. It produced elongated fruits with semiwrinkled surface and corrugated cross section.

The variety Hungarian Wax was intermediate in growth habit, and dense in branching and leaf density. Fruits were elongated, smooth and slightly corrugated.

Summary

6. SUMMARY

The present study entitled "Genetic variability and characterization in wax type chilli" was conducted at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2002-2003 with the objective of estimating the extent of genetic diversity in a germplasm collection of wax type chilli.

The data for investigations were collected from a field experiment in which 25 chilli cultivars collected from various agroclimatic zones of South India were evaluated for yield and its component characters. The design used was RBD with three replications. Fourteen characters were selected for recording observations *viz.*, plant height, number of primary branches, number of secondary branches, plant spread, days to first flowering, fruit length, fruit width, number of fruits per plant, green fruit yield per plant, average fruit weight, number of seeds per fruit, 100-seed weight, fruiting span and crop duration. Morphological characterisation of the twenty five genotypes was done based on the traits, plant growth habit, branching, leaf density, fruit shape, fruit surface and fruit cross sectional corrugation.

Significant differences were observed among the varieties for all the fourteen traits studied when analysis of variance was conduced. Payyannur local and Hungarian was the highest yielders and the low yielders were Nellimoodu local and Chettikkunnu local. Pallatheri local produced the largest number of fruits while Nellimoodu local produced the least number.

The difference between phenotypic and genotypic variances was less in most of the traits suggesting the predominance of genetic component over environmental effect on its phenotype, except for plant height, number of primary branches and number of seeds per fruit. A similar trend was noticed in the case of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV). High values of PCV

and GCV were obtained for fruit yield per plant, number of fruits per plant and average fruit weight. Green fruit yield per plant recorded the maximum values for PCV and GCV while number of days to first flowering recorded the minimum.

Heritability values ranged from 22.4 (number of seeds per fruit) to fruiting span (92.94). Low, medium and high heritability values were obtained for the various traits. High heritability along with genetic advance was noticed for fruit yield per plant, suggesting additive gene action.

On analyzing the correlation between yield and its component characters at the genotypic and phenotypic level, genotypic correlation was found to be greater than phenotypic correlation for most of the traits. Green fruit yield per plant showed high positive genotypic correlation with most of the traits, except number of days to first flowering, number of seeds per fruit and duration of the crop.

Path coefficient analysis revealed that the direct effect of number of fruits per plant and average fruit weight with yield was high and positive while plant height showed high negative direct effect on yield. The residual value (0.0435) obtained was low indicating that the major component character contributing to yield were included in the study and well explains the effect.

Selection index was constructed based on all the fourteen characters studied and the genotypes were ranked based on this. High yielding and superior genotypes like Payyannur local, Honnavar local, Hungarian wax, Para local and Periya local had high selection indices, while low yielding genotypes like Nellimoodu local, Chettikkunnu local and Panathur local had low values for selection index.

A study of genetic diversity using Mahalanobis D^2 statistic indicated considerable diversity among the 25 genotypes. The genotypes were clustered into IX clusters. Cluster II contained seven genotypes and was the largest one and clusters VIII and IX containing a single genotype each was the smallest. Intercluster distance was maximum between III and IX while intracluster distance was maximum in cluster VII, which was found to be the superior cluster for most of the desirable traits based on cluster mean values.

Based on this study, it was concluded that high yielding genotypes like Honnavar Local, Payyannur Local, Periya Local, Para Local and Hungarian Wax could be used as parents in a crop improvement programme to evolve high yielding varieties.

Honnavar Local showed erect growth habit, dense branching and high leaf density. It had elongated fruits with semiwrinkled surface and slightly corrugated cross section.

Payyannur Local had intermediate growth habit, dense branching and high leaf density. Elongated fruits with semiwrinkled surface and slightly corrugated cross section were its specialty.

For the genotype Periya Local, growth habit and leaf density were intermediate, whereas the branching was dense. The fruits were triangular with semiwrinkled surface and cross section slightly corrugated.

Erect growth habit, and intermediate branching and leaf density were shown by the Para Local. It produced elongated fruits with semiwrinkled surface and corrugated cross section.

The variety Hungarian Wax was intermediate in growth habit, and dense in branching and leaf density. Fruits were elongated, smooth and slightly corrugated.

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*Originals not seen

GENETIC VARIABILITY AND CHARACTERISATION IN WAX TYPE CHILLI (*Capsicum annuum* L.)

MINI.S

Abstract of the
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Department of Plant Breeding and Genetics
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VELLAYANI, THIRUVANANTHAPURAM

ABSTRACT

The present study entitled "Genetic variability and characterisation in wax type chilli (*Capsicum annuum* L.). was conducted at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Thiruvananthapuram, during 2002-2003. The data for investigation was collected from a field experiment laid out in Randomised Block Design (RBD) with three replications.

The 25 genotypes included in the study showed significant difference for the 14 traits. The maximum values for phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were recorded for green fruit yield per plant and the minimum values for number of days to first flowering. PCV and GCV were high for fruit yield, number of fruits per plant, average fruit weight, 100-seed weight and fruit length. Fruiting span, 100-seed weight, fruit length, average fruit weight, number of fruits per plant, fruit yield per plant and number of secondary branches showed high heritability coupled with high genetic advance.

Yield per plant was positively correlated with plant height, average fruit weight, number of fruits per plant, fruit width, 100-seed weight, number of primary branches, number of secondary branches, plant spread and fruit length. Path analysis revealed high positive direct effects of number of fruits per plant and average fruit weight with yield. Hence selection for these characters can improve yield.

The 25 genotypes were grouped into nine clusters based on Mahalanobis D^2 statistic. Cluster II was the largest with seven genotypes while cluster VIII and IX with one genotype each were the smallest. Intercluster distance was maximum between III and IX while intracluster distance was maximum in VII. Cluster III containing three genotypes and cluster VIII containing a single genotype was found to be superior to the other clusters in respect of desirable characters. The genotypes also

obtained high ranks when ranked on the basis of selection index. Morphological characterisation of the genotypes with respect to six morphological traits *viz.*, Plant growth habit, branching, leaf density, fruit shape, fruit surface and fruit cross sectional corrugation was also done.

The high yielding types *viz.*, Honnavar Local, Payyannur local, Periya local, Para local and Hungarian Wax identified from the study could be used as parents in crop improvement to evolve high yielding varieties.