

**GENETIC VARIABILITY, GENETIC
DIVERGENCE STUDIES FOR YIELD AND
YIELD RELATED TRAITS IN CHILLI
(*Capsicum annuum* L.) GERMPLASM**

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(VEGETABLE SCIENCE)**



DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF HORTICULTURE, RAJENDRANAGAR, HYDERABAD-500030

**SRI KONDA LAXMAN TELANGANA STATE
HORTICULTURAL UNIVERSITY**

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By

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B. Sc. (Hons.) Horticulture

**THESIS SUBMITTED TO THE
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**DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE, RAJENDRANAGAR, HYDERABAD-500030
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JUNE, 2020

CERTIFICATE

Mr. HOMAYOON SAQIB AZADANI has satisfactorily prosecuted the course of research and that the thesis entitled “**GENETIC VARIABILITY, GENETIC DIVERGENCE STUDIES FOR YIELD AND YIELD RELATED TRAITS IN CHILLI (*Capsicum annuum* L.) GERMPLASM**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

I also certify that the thesis or part there of has not been previously submitted by him for a degree of any University.

Date:

Place: Rajendranagar, Hyderabad.

Dr. P. SAIDAI AH

Major advisor

CERTIFICATE

This is to certify that the thesis entitled “**GENETIC VARIABILITY, GENETIC DIVERGENCE STUDIES FOR YIELD AND YIELD RELATED TRAITS IN CHILLI (*Capsicum annuum* L.) GERMPLASM**” submitted in partial fulfillment of the requirements for the degree of **Master of Science in Horticulture, (Vegetable Science)** of **Sri Konda Laxman Telangana State Horticultural University, Rajendranagar**, is a record of the bonafide research work carried out by **Mr. HOMAYOON SAQIB AZADANI** under our guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part and all the assistance received during the course of the investigation have been duly acknowledged by the author of the thesis.

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I, Mr. HOMAYOON SAQIB AZADANI, hereby declare that the thesis entitled “**GENETIC VARIABILITY, GENETIC DIVERGENCE STUDIES FOR YIELD AND YIELD RELATED TRAITS IN CHILLI (*Capsicum annuum* L.) GERMPLASM**” submitted to Sri Konda Laxman Telangana State Horticultural University, Rajendranagar for the degree of Master of Science in Horticulture in the major field of Vegetable Science is the result of original research work done by me. I further declared that no material contained in the thesis has been published earlier in any manner.

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LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	:	Analysis of Variance
&	:	And
AFs	:	Aflatoxins
<i>et al.</i>	:	And others
ARI	:	Agriculture Research Institute
CD (p=0.05%)	:	Critical Difference at 5% level
CD (p=0.01%)	:	Critical Difference at 1% level
cm	:	Centimeter
CV	:	Coefficient of variation
DAT	:	Days after transplanting
df	:	Degrees of freedom
COH	:	College of Horticulture
Contd,	:	Continued
°C	:	Degree centigrade
Cal	:	Calory
ESS	:	Error Sum of Squares
Fig.	:	Figure
FYM	:	Farm Yard Manure
g	:	Gram
GA	:	Genetic Advance
G	:	Genotypic level
D ²	:	Genetic distance
GV	:	Genetic Variability
GCV	:	Genotypic Coefficient of Variation
σ^2g	:	Genotypic variance
rg	:	Genotypic correlation
h ² b	:	Heritability in broad sense

H	:	High
ha	:	hectare
IARI	:	Indian Institute of Agricultural Research
IIHR	:	Indian Institute of Horticultural Research
ICRISAT	:	International Crop Research Institute for the Semi-Arid Tropics
LOS	:	Level of Significance
L	:	Low
M	:	Medium
mm	:	Millimeter
m	:	Meter
m ²	:	Meter square
ml	:	Milliliter
mg	:	Milligram
MSS	:	Mean Sum of Squares
viz.,	:	Namely/Serially
No.	:	Number
NHB	:	National Horticulture Board
NBPGR	:	National Bureau of Plant Genetic Resources
NARC	:	National Agricultural Research Center
/	:	Per
%	:	Per cent
σ^2_p	:	Phenotypic Variance
PCV	:	Phenotypic Coefficient of Variance
rp	:	Phenotypic correlation
RBD	:	Randomized Block Design
RSS	:	Replication Sum of Squares

Rep	:	Replication
SD	:	Standard Deviation
S. Ed	:	Standard Error of difference
S. Em _±	:	Standard Error of mean
Vs	:	Versus
wt	:	Weight

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ABSTRACT

The present investigation entitled **“Genetic variability, genetic divergence studies for yield and yield related traits in chilli (*Capsicum annuum* L.) germplasm”** was under taken to estimate the genetic variability and genetic divergence in chilli and to carry out yield component analysis through correlation and path analysis. Thirty six genotypes along with 4 checks were evaluated in a Randomized Block Design with three replications during *Kharif*, 2019 at ICAR-NBPGR Regional Station, Rajendranagar, Hyderabad.

The data on analysis of variance (ANOVA) for yield and yield contributing characters under study revealed significant variation among genotypes for all the seventeen characters. The result of mean performance of forty genotypes for seventeen characters revealed that the genotype EC-596940 was superior for yield and yield contributing characters *i.e.*, average fruit weight (13.3g), fruit yield per plant (0.439kg) and fruit yield per hectare (21933.3kg).

The genotype IC-561619 was found to be early for days to first flowering (13.33 days) DAT. The genotype IC-561673 was found to be early for days to 50 per cent flowering (31.00days) DAT, days to first harvest (69. 67days) DAT and days to last harvest (119.66days) DAT. Genotype IC-561670 was found superior for ascorbic acid content (134.01mg/100g). High capsanthin content (358.67 ASTA units) in genotype IC-208534 and high chlorophyll content (2.32%) in genotype EC-628901 were registered. Genotype IC-561673 was found superior for capsaicin content (0.58%).

Mahalanobis D^2 statistical analysis revealed that chlorophyll content contributed maximum (77%) towards diversity followed by ascorbic acid content (62.95%), fresh fruit yield per hectare (51%), capsanthin content (33.08%), fresh

fruit yield per plant (26%), fruit length (13%) and capsaicin content (2.31%) towards total diversity.

The inter cluster D^2 values of the ten clusters revealed that the highest inter cluster generalized distance (11369.49) was between cluster IX and cluster X, while, the lowest (325.48) was between cluster III and cluster VII. This high genetic divergence could be effectively utilized in heterosis breeding programme.

High heritability coupled with high genetic advance as per cent of mean indicated operation of additive gene action as observed in the characters *viz.*, plant height, plant spread, days to first flowering, days to 50 % flowering, fruit length, fruit diameter, fresh fruit weight, number of fruits per plant, fruit yield per plant, fruit yield per hectare, ascorbic acid content, capsanthin content, capsaicin content and chlorophyll content.

High PCV and GCV were recorded for number of primary branches per plant, days to first flowering, days to 50 % flowering, fruit length, fruit diameter, average fruit weight, number of fruits per plant, fresh fruit yield per plant, fresh fruit yield per hectare, ascorbic acid content, capsanthin content, capsaicin content and chlorophyll content indicating the existence of wider genetic variability for these traits in the genotypes under study.

The results on correlation studies indicated positive association of fresh fruit yield per plant with other yield contributing characters though not significant. But fresh fruit yield per hectare showed positive and significant correlation with fruit length, fruit diameter, average fresh fruit weight, number of fruits per plant and ascorbic acid content at phenotypic level indicating that improvement in these characters simultaneously improves fresh fruit yield per hectare.

Path coefficient analysis showed that the number of fruits per plant and fresh fruit yield per hectare recorded positive direct effect at both phenotypic and genotypic levels on fresh fruit yield per plant indicating that direct selection based on these characters would be effective for increasing the yield.

Three genotypes *viz.*, EC-596940, IC-278055 and IC-561614 were found to be promising genotypes based on mean performances for yield, while, genotypes IC-561673 and IC-561688 were early with yield and genotypes IC-561670, IC-561614, EC-628901, IC-528876, IC-208534, EC-402105, IC-561673 and IC-561619 for quality parameters. Hence, these genotypes can be released for commercial cultivation after multi-location trials over seasons.

Chapter – I

INTRODUCTION

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CHAPTER-I

INTRODUCTION

Chilli (*Capsicum annuum* L.) is an important commercial spice-cum-vegetable crop belongs to the Solanaceae family. It is originated from tropical and humid zone of Central and Southern America, having chromosome number of $2n = 2x = 24$. It is probably introduced by Portuguese into Southern parts of India in 16th century and cultivation spread out throughout India by the end of 19th century. It is grown in India under various agro climatic conditions viz., tropical, sub-tropical and temperate climates (Hazra *et al.*, 2011). India is the major producer, consumer and exporter of chilli. In India chilli occupies an area of 366,000ha and production is around 3737 thousand tonnes, with average productivity of 1.93 tonnes per hectare (NHB Data base, 2018-19). It is mainly used for its pungency and pleasant flavor. The genus *Capsicum* consists of a diverse range of plants and fruits, and varies enormously with respect to morphology, yield and nutrition related parameters. Chillies are grown as annual crop, although it can also be grown as perennial shrub in suitable climatic conditions. Among the five cultivated species, *C. annuum* is the most widely cultivated species for its pungent (hot pepper) and non-pungent (sweet pepper) fruits throughout the world.

The presence of capsaicinoids is specific to the genus *Capsicum*, which varies widely among the varieties, seasons and places of origin. (Prasath *et al.*, 2007). Usually the chilli fruits are consumed at different ripening stages such as green, red or partial red-ripe. Telangana State occupies second position in production (279.8 tonnes) and third position in area (78.9 ha) with productivity of 3.54 t/ha (NHB Data base, 2018-19). Dried chillies with a moisture content of 10%, consists of protein (15g), Fat (6.20g), Minerals (6.10g), Carbohydrates (30.20g), Energy (246 k cal), Calcium (160mg), Phosphorus (370mg), Iron (2.30mg), Carotene (345µg), Riboflavin (0.43mg), Niacin (9.50mg), Vitamin C (50.00mg), Sodium (14.00mg), Potassium (530.00mg), Phytin Phosphorus

(71.00), Thiamine (0.93 mg), Mg, Cu, Mn, Zn, Cr, and Oxalic Acid (nill) per every 100 grams.

Red color in chilli is due to capsanthin and capsorubin. The percentage of capsanthin coloring matter is 36%. It is valued for its pungency, which is due to crystalline acid volatile alkaloid capsaicin, present in the placenta of fruits. Capsaicin has significant physiological action which is used in many pharmaceutical preparations and ointments for cold, sore throat, chest congestion *etc.* Capsaicin acts like as anti-bacterial, anti-carcinogenic, analgesic and anti-diabetic. It is also used in cosmetics like prickly heat powders and skin ointments. Amount of capsaicin in green chilli ranges from 160-210mg/g and in ripe fruit is 113-116mg/100g.

Due to long history of cultivation, selection and popularity of crops sufficient genetic variability has been generated. Rich variability in morphological traits in hot pepper occurs throughout India particularly in south peninsular region, North Eastern foot hills of Himalayas and Gangetic plains. The critical assessment of nature and magnitude of variability in the germplasm stock is one of the important pre-requisites for formulating effective breeding methods as the genetic improvement of any crop depends on magnitude of genetic variability and the extent of heritability of economically important characters, though the part played by environment in the expression of such character also needs to be taken into account.

To initiate any breeding work, it is necessary to assess the genetic variability present in the indigenous genotypes for yield and its components. Parameter of genotypic and phenotypic coefficient of variations is useful in detecting the amount of variability present in the germplasm. Heritability and genetic advance helps in determining the influence of environment in expression of the characters and the extent to which improvement is possible after selection. Hence, the genotypes were characterized to assess the variability and identification of promising genotypes which can be used in further breeding programme.

Chilli belongs to the genus *Capsicum* which possesses enormous wealth of genetic diversity. Extent of genetic diversity determines the success level of crop improvement programme. Maximum diversity can be noticed among different cultivars available in India and outside with respect to shape, size, yield, quality and other traits. Collection and maintenance of the genetic diversity in capsicum are important to avoid genetic erosion. Besides the identification of species, the characterization and evaluation of genotypes are of fundamental importance. Among the various methods identified/developed to study the genetic divergence in the genotypes, the Mahalanobis (Mahalanobis, 1936) is reliable and most frequently used.

Since yield is a complex trait, governed by a large number of components traits. It is imperative to know the inter relationship between yield and its component traits to arrive at an optimal selection index for improvement of yield. Wright (1921), was the first to propose the correlation and path analysis to organize the relationship between the predictor and response variables. Correlation simply measures the association between yield and other traits, whereas path coefficient analysis permits the separation of correlation into direct effects (path coefficient) and indirect effects (effects exerted through other variables). This technique, which aims to improve a dependent character like yield when the independent characters have a significant relation in desirable direction and positive direct or indirect effect through other component traits on the dependent characters, became routine in plant breeding programme only after its use by Dewey and Lu (1959).

A number of evolutionary processes can impact the genetic diversity of natural populations. These are: (a) spontaneously arising mutations, (b) gene flow via migration, (c) inbreeding, (d) natural selection, (e) the Wahlund effect, and (f) random genetic drift. Genetic drift introduces random changes in allele frequencies over generations and becomes important for finite population samples and/or a large number of generations. These random allele frequency changes can, over time, lead to allele fixation or extinction. By all means, genetic drift represents a source of differences in genetic diversity among different

populations. On the other hand, gene flow evens out among-population genetic differences, but increases genetic variation within populations, due to the introduction of new alleles. Selection influences within-population diversity, but the effects are dependent on the nature of these selection processes (balancing selection). Furthermore, the effects of natural selection are interwoven with stochastic effects, such as genetic drift. Mutations can counterbalance the loss of allelic diversity.

Keeping the above in mind, the present investigation entitled “**Genetic variability, genetic divergence studies for yield and yield related traits in chilli (*Capsicum annuum* L.) germplasm**” was taken up for research with the following objectives.

Objectives:

1. To study genetic variability, heritability and genetic advance among the germplasm
2. To estimate genetic divergence among the germplasm
3. To study correlation and path coefficient of yield and yield related traits

CHAPTER-II

REVIEW OF LITERATURE

The phenotype of quantitative traits, in principle is the joint product of genotype and environment. Hence, the estimates of variability and its heritable components for the yield contributing characters in the available germplasm are pre-requisite for a breeding programme for high yield.

Chilli (*Capsicum annuum* L.) being a member of the family Solanaceae, has become a significant commercial crop with respect to area, production, industrial benefits and its tremendous contribution to human nutrition. During the past few decades research and experimental exertions regarding diverse facets of genetics and plant breeding have played a part in to acquire proficiency and comprehending of various related aspects and as such voluminous literature has been generated. In order to commence with any crop improvement schedules, an exhaustive knowledge pertaining to the amount of genetic variability prevailing for assorted characters is indispensable.

In view of the objectives of present investigation on "Genetic variability, genetic divergence studies for yield and yield related traits in chilli (*Capsicum annuum* L.) germplasm", the available literature on genetic parameters, genetic divergence, association between yield and its components has been reviewed and presented under the following headings.

2.1 Genetic Divergence

2.2 Genetic Variability, Heritability and Genetic Advance

2.3 Correlation Coefficient Analysis

2.4 Path Coefficient Analysis

2.1 GENETIC DIVERGENCE

The sum total of genes present in the genotypes is called germplasm. The study of genotype diversity and the information of core subsets are important activities in the conservation, evaluation and utilization of genetic resources (Brown, 1989).

Genetic improvement in any crop mainly depends upon the amount of genetic variability present in the population. The importance of genetic diversity in crop plants was first realized by Darwin (1859). To help the breeder in the process of identifying the better parents, several methods of divergence analysis based on quantitative traits have been proposed to suit various objectives. Mahalanobis D^2 statistics is a powerful tool in quantifying the degree of divergence among biological populations at genetic level and provides a quantitative measure of association between geographic and genetic diversity based on generalized distance (Mahalanobis, 1936). The review of literature pertaining to genetic divergence in *Capsicum annuum* L. is as follows.

Morphological similarity, ecogeographic diversity, phylogenetical relationship, Mahalanobis's D^2 statistics etc, were the few earlier methods used for discriminating divergent populations, which are reinforced by more scientific and advanced biometric techniques viz., multivariate analysis based on principal component analysis, agglomerative cluster analysis.

Singh and Singh (1976) classified 45 strains of chilli including both indigenous and exotic with the help of D^2 statistic into ten distinct groups for fruit yield per plant and component traits. The strains differed significantly for the eight characters considered collectively. Number of branches, fruit thickness, number of fruits per plant and yield per plant were the potent factors in differentiating the germplasm of chilli. The clustering pattern of strains did follow the geographical distribution.

Sundaram *et al.* (1980) evaluated genetic divergence of 35 indigenous and 15 exotic varieties of chilli. The varieties were compared for five yield components and grouped into eight clusters using Mahalanobis's D^2 statistic. Cluster II was the largest containing 20 varieties. The clustering revealed no relationship between genetic diversity and geographic origin. The number of branches and number of fruits per plant were the chief contributors towards genetic divergence.

Mehra and Peter (1980) classified 27 varieties of chilli into nine clusters based on the D^2 values for 15 characters. Cluster II was largest containing 6 genotypes. Fruits per plant contributed maximum (88.03%) diversity in the material studied. The Canonical variate analysis and metroglyphs confirmed the genetic grouping as obtained through Mahalanobis' D^2 statistic.

Gill *et al.* (1982) estimated genetic diversity in 21 sweet pepper genotypes by using D^2 statistics. Twenty one genotypes formed seven clusters. The study material comprised six parents and their 15 F_1 hybrids of sweet pepper. Diversity study indicated that the most divergent was low yielder whereas top yielding parent expressed least diversity within its F_1 's. Hence, the parents with modest level of diversity were crossed to broaden the diverse base and to retain high yield in subsequent populations.

Varalakshmi and Haribabu (1991) subjected 32 genotypes of chilli for measuring the divergence of 10 characters and the genotypes were grouped into 11 gene constellations. Grouping of genotypes in to different clusters were not related to their geographical origin. The intra-cluster D^2 value ranged from 0.0 (cluster VI to XI) to 36.7 (cluster III). The inter-cluster D^2 value was minimum (159.1) between X and XI.

Roy and Sarma (1996) measured the genetic divergence in 20 genotypes of chilli using D^2 statistic for eight characters and grouped them into seven clusters. Cluster I was the largest with 7 genotypes followed by cluster II with 5 genotypes. Cluster IV showed maximum genetic distance from cluster VI, suggesting wide diversity between these groups. Four characters *viz.*, yield per plant, primary branches per plant, fruit diameter and plant heights were the highest contributors to D^2 values.

Usharani (1997) evaluated 73-chilli germplasm through principal component analysis. Data on 20 different characters from the populations were subjected to principal component analysis (PCA). Out of 20 principal components (PCS), 7 PCS accounted 85 per cent of total variability. The PCA produced only 6 significant PCS thus reducing the dimensionality of the data

system to six PCS. The first PC which explained the maximum variability of 25 per cent was significantly correlated with fruit diameter, fruit length, number of secondary branches per plant, number of fruits per plant, number of primary branches per plant. Subjectively, the genotypes were classified into 12 groups of similar characteristics based on first 2 PCS scores for genotypes.

Warade *et al.* (1997) estimated genetic divergence in sixty cultivars of chilli obtained from different eco-geographical regions of India using Mahalanobis' D^2 statistic. Sixty cultivars were grouped into nine clusters. The D^2 statistics showed adequate diversity among the genotypes with D^2 values ranging from 19.24 to 4960.98. Cluster G was the largest one consisting 15 varieties.

Study on forty genotypes, comprising indigenous and exotic chilli, was conducted to estimate the genetic divergence (Karad *et al.*, 2002). Diversity analysis revealed good amount of variation among of the genotypes for 12 characters. Forty genotypes were grouped into eight clusters. The clusters I was the largest containing 23 genotypes. The variance of cluster means revealed maximum contribution of fresh fruit weight and fruits per plant towards divergence. The inter-cluster distance (D^2) ranged between 7.45 (cluster II and V) and 1.15 (cluster III and VII).

Senapati *et al.* (2003) carried out a genetic divergence study with 20 chilli genotypes using Mahalanobis's D^2 statistics for 11 characters. Based on D^2 values, the genotypes were clustered into six groups. Cluster I was largest with 13 genotypes, followed by cluster III and IV with two genotypes each. Cluster II, V and VI had single genotype each. Cluster II showed maximum genetic distance from cluster VI, suggesting wide diversity between these groups. Four characters viz., fresh fruit weight, fruit girth, fruit length and fruit number per plant were the chief contributors towards genetic divergence.

Sreelathakumary and Rajamony (2004b) assessed thirty five chilli genotypes to know the nature and magnitude of genetic divergence using Mahalanobis' D^2 statistics for 9 characters. The population was grouped into six clusters. The clustering pattern indicated that there was no association between

geographical distribution of genotypes and genetic divergence. The characters namely fruits per plant, yield per plant, fruit length, fruit girth and fruit weight were contributing to maximum divergence.

Borgonian *et al.* (2005) studied intra-and inter-specific genetic diversity during the winter season of 2001 and 2002 in 33 chilli (*Capsicum spp.*) accessions of North-Eastern India belonging to 3 species using 40 morphological characteristics and randomly amplified polymorphic DNA (RAPD) markers. Hierarchical cluster analysis on morphological data delineated two major clusters. Cluster I included all but one *Capsicum annuum* accession while cluster II included one *Capsicum annuum* accession, all the *Capsicum frutescens* and *Capsicum chinense* accessions.

Chatterjee (2006) reported that the pattern of distribution of 60 chilli genotypes were grouped into 7 clusters in case of D^2 analysis and 8 clusters in case of principal component analysis at random, which suggested that geographical isolation may not be only factor causing genetic diversity.

Smitha and Basavaraja (2006a) revealed that 40 genotypes were grouped into eight clusters through Mahalanobis D^2 analysis. The cluster A included 10 genotypes and cluster B with 17 genotypes, cluster C with 5 genotypes, clusters D, E, F, G and H with one genotype each. The maximum intra and inter cluster distances were observed for cluster A and between cluster E and H, respectively indicating their suitability for heterosis breeding with respect to few important characters. Maximum relative contribution to the total divergence was made by fruits per plant, fruit yield, number of primary branches, number of secondary branches, seeds per fruit, plant spread, fruit weight and fruit length confirming the existence of ample amount of divergence in genotypes with respect to the traits and hence selection of best genotypes for such traits would be helpful in utilizing the maximum heterosis in future breeding programme.

Gogate *et al.* (2007) studied 55 genetically diverse genotypes of chilli to know the extent of variability through D^2 statistics. These 55 genotypes were grouped into 11 clusters. The distribution of different genotypes revealed that

cluster I represented maximum 24 genotypes followed by cluster IV (11), cluster III (5), cluster II as well as V (3) and cluster VI, VII and VIII (2) whereas, minimum single genotype was with each cluster IX, X and XI. The grouping of genotypes did not show any relationship between genetic divergence and geographic diversity. Maximum intra cluster distance was observed in cluster VI (875.95) and minimum in cluster IX, X and XI (0.00). The inter cluster distance, was maximum between cluster VII and XI (7194.46), suggesting the wider diversity between these two groups, whereas inter cluster distance was minimum between cluster III and IX (1002.58) indicating close relationship among genotypes falling with above two clusters.

Acharya *et al.* (2007) assessed the variation of 26 chilli genotypes for 24 yield components were in Kolkata, India. Total fresh yield was positively and significantly correlated with fresh fruit weight and fruit number per plant at both genotypic and phenotypic levels. Correlation coefficients were positive and significant for capsaicin content and total soluble solids (TSS) content at mature green stage and red ripe stage; and chlorophyll content and TSS at mature green stage, phenotypically and genotypically. Ascorbic acid content was highest in mature green fruit, while carotenoid content was higher in red ripe fruit. The magnitude of heritability was moderate to high suggesting that they were least affected by environmental variation.

Dutonde *et al.* (2008) conducted field studies to determine the genetic diversity in 40 genotypes of chilli for various characters revealed substantial differences for all the characters. The accessions were grouped into 7 clusters. The maximum intercluster distance was observed between Cluster IV and Cluster VII. Intercrossing among the genotypes belonging to Cluster II, IV and VII was suggested to develop high yielding varieties with other desirable characters.

Jyothi *et al.* (2008) evaluated 21 genotypes of chilli (*Capsicum annum* L.) for capsaicin, oleoresin, extractable colour and colour value to identify genotypes with less capsaicin and high colour content. The genotype 'PBC-535' was identified with less pungency and high colour content. Multivariate cluster analysis based on Ward's method showed that the genotypes were mainly

divided at the first node into 2 clusters with 12 and 9 genotypes, which were further sub divided into 2 groups.

Singh and Yadav (2008) studied 36 *Capsicum annuum* genotypes to estimate their genetic variability, heritability and genetic advance. Most of the characters were observed with wide range of variability. High to moderate heritability with high genetic advance were observed for number of seeds per fruit, ascorbic acid content, number of fruits per plant, fresh fruit weight per plant, fresh fruit yield (q/ha), seed weight per plant and seed yield (q/ha) showing dominance of additive gene action suggesting excellent chance of effective selection for improvement of these traits and high heritability coupled with medium genetic advance for stem diameter and total soluble solids and suggesting good chances of effective selection for these traits. While other traits showed non additive type of gene action. Most of the characters were observed with wide range of variability.

Ajjapplavara and Channagoudra (2009) worked on genetic divergence among 36 chilli genotypes using D^2 statistic by. On the basis of genetic distance, these genotypes were grouped in to 11 clusters. Cluster-II was largest, consisting of 16 genotypes, while cluster, IV, V, VI, VII, VIII, IX and XI contained single genotype each. There was no parallelism between genetic diversity and geographical distribution. Among the different characters studied fruits per plant, fruit yield per plant, plant height, green fruit weight, powdery mildew disease incidence, leaf curl complex incidence contribute significantly for the genetic diversity. The maximum inter cluster distance (125.45) was highest between the II and X. The genotypes from these clusters may be used as parental donors for future hybridization programme to develop higher fruit yield with resistance to disease and pests.

Dushyantha *et al.* (2010) studied genetic divergence in 25 chilli genotypes for various characters has revealed substantial differences for all the traits. Based on D^2 values, the genotypes were grouped into eight clusters. Cluster I contained nine genotypes followed by cluster II (four) cluster IV and V (two each). The maximum inter cluster distance ($D^2=12.75$) was observed between cluster VI and

cluster VII. The cluster IV recorded maximum intra cluster distance ($D^2=5.91$). Intercrossing among the genotypes belonging to cluster III, IV and I was suggested to develop high yielding varieties with other desirable characters or may be used as potential donors for future hybridization programme to develop better chilli variety with good fruit yield.

Datta and Das (2013) studied genetic divergence among 53 genotypes. Based on D^2 values, these genotypes were grouped into 17 clusters and results indicated that cluster I and cluster VII are with 29 and 9 genotypes respectively. Rest of clusters consisted of one genotype in each case. Among the different clusters, maximum intra cluster distance (5.90) was recorded in cluster VII. Maximum inter cluster distance (12.89) was observed between cluster XVII and cluster XVI, followed by 12.13 in cluster XVII and cluster V and 11.89 in cluster XVII and cluster IX. So, the genotypes included in these clusters have greater divergence and hence crossing between the genotypes in these clusters were expected to give desirable recombinants.

Genetic divergence studies with 30 chilli (*Capsicum annum* L.) genotypes of Indian origin for twelve quantitative characters were conducted by Tasso *et al.* (2014). The analysis of variance revealed considerable variability among the genotypes for the characters studied. Cluster analysis was used for grouping of 30 chilli genotypes into six clusters. Cluster III had maximum (14) and cluster IV and V had the minimum number (1) of genotypes. The highest (459.81) inter cluster distance was observed between cluster II and IV and the lowest (36.04) between cluster I and IV. Cluster III ($D^2= 67.66$) exhibited highest intra cluster distance and the lowest was observed in cluster II ($D^2=11.19$). The characters capsaicin content and ascorbic acid contributed maximum towards divergence.

Suryakumari *et al.* (2014) evaluated ninety four paprika accessions for 17 different characters for genetic divergence. The findings of multivariable (D^2) analysis showed the random distribution of 94 paprika genotypes into ten clusters and there was no association of genetic diversity with geographical diversity of parents. Principal component analysis identified three principal components

(PCs), which contributed 78.47 per cent of cumulative variance. Dendrogram obtained by cluster analysis showed the sub-grouping of genotypes within the clusters, which was not possible through D^2 analysis. Based on the inter and intra cluster distance among the groups, fourteen parents were selected 3 each from cluster 1X and X and one each from clusters I, II, III, IV, V, VI, VII and VIII, keeping in view the characters contributing for divergence so as to obtain better and desirable segregants.

Yatung *et al.* (2014) studied genetic diversity of 30 chilli (*Capsicum annum* L.) genotypes. Cluster analysis was used for grouping the 30 chilli genotypes under study into six clusters. Cluster III had maximum (14) and cluster IV and V minimum number (1) of genotypes. The highest (459.81) inter cluster distance was observed between cluster II and IV and the lowest (36.04) between cluster I and IV. Cluster III ($D^2 = 67.66$) have exhibited highest intra cluster distance and the lowest was observed in cluster II ($D^2 = 11.19$). Considering diversity pattern and other horticultural performances the genotype CHFC-7 from cluster VI, genotype CHFC-27 from cluster II and CHFC-15 from cluster III may be taken into consideration as better parents for an efficient hybridization programme of chilli.

Rokib *et al.* (2015) investigated thirteen genotypes of chilli (*Capsicum annum* L.) to understand the extent of genetic diversity through 6 yield attributing characters. Genetic diversity in chilli genotypes based on six characters was estimated using Mahalanobis's D^2 statistics. The results indicated that fruits/plant (35.8%) contributed maximum to the total divergence followed by fruit length (21.6%) and yield/plant (21.1%).

Hasan *et al.* (2015) grouped thirteen genotypes of chilli (*Capsicum annum* L.) into five different clusters. Cluster I had the maximum number (5) of genotypes while cluster IV and V were with only one genotype. The highest inter-cluster distance was observed between cluster I and IV (24.483) and the lowest inter-cluster distance was observed between the clusters II and V (11.633). The results indicated that fruits/plant (35.8%) contributed maximum to the total divergence followed by fruit length (21.6%) and yield/plant (21.1%).

Cluster IV produced highest mean for fruit weight (4.48), fruits/plant (149.90) and yield/plant (676.03). Cluster V produced highest mean for fruit length (10.23), pedicel length (4.94) and fruit diameter (10.36). Therefore, genotypes belonging to the cluster IV and V may be used as potential parents for future hybridization programme to develop superior Chilli varieties with desired traits.

Janaki *et al.* (2015) grouped 63 genotypes into 8 clusters. Among the clusters, cluster II was the largest containing 18 genotypes followed by cluster III with 15 genotypes and cluster VIII had only one genotype. The highest inter cluster distance was observed between cluster IV and VIII (7941.635) whereas the lowest was observed between cluster VI and VIII (2836.497). The Cluster VII exhibited highest intra cluster distance (614.548) and the lowest was observed in cluster VIII (0.00). The maximum contribution towards genetic divergence was shown by fruit diameter (44.14%) followed by yellow carotenoids (16.90%). Considering diversity pattern and horticultural performance, the genotypes Warangal chapatta, LCA-702, LCA-724, LCA756, LCA-353 and LCA-716 were identified as promising parents and could be utilized for efficient hybridization in chilli.

Sharma and Sridevi (2016) studied genetic diversity among eight genotypes of chilli and were grouped into three clusters (Tocher's method). Cluster I and cluster II had maximum intra-cluster distance indicating maximum divergence than other clusters. Clusters III had zero intra-cluster distance. Highest inter-cluster distance was observed between II and III clusters. Therefore, hybrids falling in these two clusters may have wider variability. In the present study clusters III and I included high yielding hybrids, whereas cluster II included poor yielding hybrids. The characteristics that played the greatest role in differentiation were plant height, fruit weight, and seed weight, which can be utilized as morphological markers for the improvement of chilli yield and for obtaining good segregants in chilli breeding programmes.

Vanitha and Jansi Rani (2016) conducted genetic divergence studies in 74 genotypes of chilli (*Capsicum annum* L.) which were grouped into 7 clusters with maximum number of genotypes (33) in cluster V and minimum number of

genotypes (2) in clusters I, II, and VI each. Maximum intra cluster distance (228.90) was observed in cluster VII followed by cluster IV (205.6) which suggested appreciable genetic diversity within particular cluster. Maximum inter cluster distance was observed between cluster II and IV (292.86) followed by cluster IV and V (266.67). Inter crossing among the genotypes belonging to cluster I, II, IV and V was suggested to develop high yielding genotypes with desirable characters.

Kalyani *et al.* (2017) conducted a study on genetic diversity in 12 chilli genotypes for various characters which revealed substantial differences for all the traits. Relative contribution of fruit yield per plant to genetic divergence of genotypes in chilli was the maximum, followed by days to 50% flowering and plant height.

Akhilesh *et al.* (2017) conducted an experiment to determine the degree of divergence in 64 genotypes of chilli which were evaluated in a Randomized Complete Block Design with three replications during summer–rainy season. A considerable amount of genetic diversity was observed among the genotypes. Leaf length contributed maximum towards total genetic divergence followed by fruit length, number of primary branches per plant, plant height, capsaicin content, fresh fruit yield per plant, pedicel length, oleoresin content and fruit girth.

Jogdhande *et al.* (2017) studied thirty genotypes of Chilli (*Capsicum annum* L.) for nineteen traits and found significant differences among the genotypes, except number of flowers per axil. Among the genotypes evaluated in Southern Telangana conditions, four genotypes, viz., Warangal Chapata, LCA-625, AVPP0514 and IC-255916 of chilli were found to be promising based on yield and yield attributes of fruit quality.

Udachappa *et al.* (2017) studied 63 chilli genotypes for the assessment of genetic diversity. Using Mahalanobis D^2 statistics method, 63 genotypes were grouped into 5 divergent clusters. Maximum intra cluster distance was observed in cluster II followed by cluster I which suggested appreciable genetic diversity

within particular cluster. Maximum inter cluster distance was observed between cluster I and II indicating presence of sufficient amount of diversity with genotypes of respective clusters. Considering diversity pattern and horticultural performance, the genotypes. Inter crossing among the genotypes belonging to cluster I, II, III and V was suggested to develop high yielding genotypes with desirable characters.

Nahak *et al.* (2018) investigated on 11 genotypes of chilli to understand the extent of genetic diversity through 16 growth and yield attributing characters. Genetic diversity in chilli genotypes based on sixteen characters was estimated using Mahalanobis's D^2 statistics. The genotypes were grouped into four different clusters by non-hierarchical clustering. The cluster I had the maximum number (7) of genotypes while cluster III and IV each contained only one genotype. Cluster II and III had highest intercluster distance (249.759) followed by cluster III and IV (239.433). It was also observed that the contribution of fruit yield per plant to genetic divergence of genotypes in chilli was the maximum followed by leaf curl/plot and fruit weight. So, selection of parents differing in these quantitative traits may be proved useful for heterosis breeding programme in chilli.

Priyanka *et al.* (2018) conducted study on genetic diversity was with 16 chilli (*Capsicum annuum* L.) genotypes. Genetic diversity among 16 chilli genotypes were worked out using D^2 statistic. On the basis of genetic distance, these genotypes were grouped into 5 clusters. Cluster I was largest, consisting of nine genotypes followed by cluster II with four genotypes while cluster III, IV and V contained single genotype each. The maximum inter cluster distance was found between cluster III and cluster V and minimum was found between cluster III and cluster IV. The character ascorbic acid content contributed maximum towards divergence. Considering diversity pattern and other performance of the genotypes UHF-C-13-2, UHF-C-12-4, Kashmiri Long and UHF-C-13-4 from cluster II, genotype UHF-C-12-1 from cluster V, UHF-C-13 6 from cluster IV may be taken into consideration as better parents for an efficient hybridization programme of chilli.

Majjiga *et al.* (2019) characterized and evaluated 12 qualitative characters and 15 quantitative characters of indigenous and exotic genotypes for identification of spice chilli lines from 45 genotypes and found that the genotypes varied considerably in plant growth habit, branching habit, leaf size, leaf shape, leaf colour through RHS colour chart, pigment at node, fruit surface, number of flowers per axil, anther colour, ripe fruit colour through RHS colour chart, fruit position and fruit shape. But significant divergence was lacking in case of seed colour, leaf margin and blossom end fruit shape. Three genotypes Srinagar, BCCH Sel-4 and Beldanga were found most promising as spice chilli in respect of dry fruit yield per plant and could be recommended for large scale cultivation in the Gangetic plains of West Bengal after critical testing.

Paramjeet and Akhilesh (2019) genetic diversity studies grouped 33 chilli genotypes into six clusters. Maximum genotypes were placed in cluster I (16 genotypes) followed by cluster II (7 genotypes). Highest intra-cluster distance was observed for cluster IV followed by cluster II while maximum inter-cluster distance was observed between cluster V and VI followed by IV and V. Cluster V was observed to be the most important with maximum cluster means for most of the valuable traits. Total red ripe fruits per plant contributed maximum towards total genetic divergence followed by oleoresin content and marketable red ripe fruits per plant. Based on genetic divergence studies, best performing genotypes from cluster V, I, II, VI and III offer promise for their direct use as varieties and as potential parents in future breeding programmes to isolate transgressive segregants.

2.2 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

Heritability as described by Smith (1936) is “the ratio expressed as percentage of variance component due to additive (fixable) gene effects ($\sigma^2 A$) to the sum of additive ($\sigma^2 A$), dominance ($\sigma^2 D$) and epistatic ($\sigma^2 E$) gene effects”. Heritability in broad sense may be defined as the ratio of genetic variance to phenotypic variance (Lush, 1949). If heritability of a character is very high, a selection for the character is fairly easy as it will enable the plant breeder to formulate criteria based on phenotypic performance because of close

correspondence between genotype and phenotype due to a relatively smaller contribution of environment to the phenotype. But for characters with low heritability, a selection may be considerably difficult due to masking effect of environment on the genotype effects.

Genetic variability for yield and yield component is essential in the base population for successful crop improvement (Allard., 1960). Yield and yield components are quantitative characters and are polygenically inherited which are greatly influenced by the environment. The phenotype of a character is the resultant of interaction between phenotype and environment. Partitioning of observed variability into heritable and non-heritable component is essential to get a through indication of the genetic variation of the traits. Genetic parameters such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2) and genetic advance (GA) are commonly used in describing the variability and genetic of a character.

Genetic variability is a gift of nature. Variability differs from diversity in the sense that the former is observable phenotypic differences, whereas the latter may or may not have such expression. The more diverse the parents greater are the chance of increased spectrum of variability. However, this cannot be measured directly. We can only measure it phenotypically and attempt to partition this variability. In plants, it is not freely manifested and is not exhibited in the form of difference in itself. Much of the variability is hidden in the genotypes. Furthermore, partitioning of these variabilities into heritable and non-heritable components will enable to know the effectiveness of selection. It is quite important for a success of crop improvement programme to have wide range of genetic variability for yield and yield components in the base population. The success of phenotypic selection depends upon variability.

Genetic advance is the expected genetic gain or improvement in the next generation by selecting the superior individuals under selection pressure. Chhonkar *et al.* (1979) reported that heritability estimates and genetic advance were more valid for selection than heritability estimates alone. It was observed that a greater amount of genetic advance may be expected if the heritability is

chiefly due to additive gene action. It was further stated that high heritability did not necessarily increase genetic advance. If heritability is coupled with high genetic advance, it indicates that the character is chiefly governed by additive genes and will be most effective for selection and further utilization in breeding programmes.

Thirty exotic paprika accessions were evaluated by Deshpande and Anand (1988) at IIHR, Bangalore. Besides yield, part of the germplasm has been evaluated for quality and economic characteristics. The germplasm exhibited a wide variability for various traits like dry pod yield per plant (7.8-48.0 g), number of fruits per plant (5.8-126.6), per cent seed weight (19.0-58.6), per cent capsaicin (0.03-1.81), per cent capsanthin (0.08-0.41) and ascorbic acid (58.7-192.1 mg/100 g).

Evaluation of selected 21 genotypes of chilli for 9 traits was done by Amarchandra *et al.* (1990). Variability was greatest for weight of fresh red ripe fruits per plant. High heritability estimates were obtained for fruit length, weight of fresh ripe fruits, dry fruit weight, and number of fruits per plant and fruit diameter.

Acharya *et al.* (1992) conducted studies on genetic variability in chilli. Analysis of data collected for 12 quantitative characters indicated that improvement should be based on selection for fruits per plant, yield per plant, fruit length and circumference, seeds per fruit and leaves per plant.

Joshi *et al.* (1995) recommended three promising paprika genotypes from IARI, Katrain viz., Kt-P1-8, Kt-P1-18 and Kt-P1-19. Among them Kt-P1-19 was identified for large scale multiplication. It is a high oleoresin and coloring unit line.

A field experiment was conducted with 79 genotypes of chilli (*Capsicum annuum* L.) by Rani *et al.* (1996) at TNAU, Coimbatore. The genotypic and phenotypic coefficients of variation were high for number of fruits per plant, mean fruit weight, capsaicin content, yield per plant, fruit length, weight of seeds per fruit, 100 seed weight and dry matter production. High heritability estimates

coupled with high genetic advance as per cent of mean were observed for yield per plant, number of fruits per plant, mean fruit weight, dry matter production and ascorbic acid. The results revealed that these traits could be exploited for improvement through selection.

Evaluation of 73 genotypes of chilli (*Capsicum annuum* L.) for yield and pod characters was done by Usharani (1997). The genotypes namely DH-7-6-5, Belgium Local, Shankeshwar and Bydagi recorded highest fruit length. Highest fruit diameter was recorded by JCA-154 and PM-217 whereas Red local Bangalore and CA-960 measured highest 1000 seed weight. Maximum dry fruit yield was noticed in 32 genotypes. JCA154, Arun local, P-217 of France, JCA 232 and Ducale recorded maximum 50 fruit peel weight.

Choudhary and Das (1998) studied variability and scope of improvement in summer chilli. Among the 25 genotypes studied, the results indicated considerable amount of genetic variability for fruit yield, number of fruits per plant, fruit length, fruit diameter and fruit weight. High heritability recorded in the above traits revealed considerable scope for the improvement of these characters by selection.

Usharani (2001) evaluated a total of 73 genotypes for fruit surface area and observed significant differences among the genotypes.

Shirshat *et al.* (2006) conducted studies on genetic variability in 72 germplasm lines and three commercial cultivars. The phenotypic coefficient of variation was higher than genotypic coefficient of variation for all characters indicating the influence of environment on these characters. Moderate genetic advance was observed for the characters like number of fruits per plant, number of seeds per fruit and sugar content of the fruit. Heritability was high in these characters except for number of fruits per plant. In case of attributes like fruit length, fruit surface area, weight of dry fruit, pericarp weight of fruit, number of seeds per fruit and weight of seeds per fruit, the genetic advance was low to moderate coupled with high heritability. Yield per plant, the complex trait, which

is dependent on several component characters showed moderate heritability with low genetic advance.

Sood and Sharma (2006) studied genetic variability, heritability and genetic advance for fourteen characters in twenty-two genotypes of capsicum (*Capsicum annuum* L.) in Palampur (India). A wide range of phenotypic variability was observed for all the fourteen characters like fruits yield per plant, fruits per plant, marketable fruits per plant, fruit length, plant height etc. High estimates of heritability were also shown by these characters. This indicated that selection could be better option for improvement in these traits. Genetic advance was high for most of the characters like fruits per plant, marketable fruits per plant and fruits per plant. Also, PCV and GCV values were high for marketable fruits per plant, fruits per plant, fruit yield per plant and fruit weight.

Krishna *et al.* (2007a) assessed genetic variability, heritability, genetic advance and genetic advance as a percent over mean for twelve characters by field evaluation of eighty chilli accessions and high degree of variation was observed for all characters. The difference between phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were found to be narrow for most of the traits studied except primary and secondary branches, tertiary branches, fifty per cent flowering, early and late fruit yield per plant. Most of these characters also had moderate to high estimates of genetic advances as a percent over mean except days to first flowering.

Fekadu *et al.* (2008) investigated genetic components and heritability of yield and yield related traits in hot pepper. Broad sense heritability ranged from 0.85 to 0.96 and signified the observed variation to be genotypic in origin. Heterosis and pedigree methods with recurrent selection would facilitate simultaneous exploitation of the genetic components for improvement of hot pepper.

Arati and Salimath (2008) evaluated seven F₂ populations of chilli (*Capsicum annuum* L.) derived from six parents, for genetic variability, genotypic and phenotypic coefficients of variation, heritability in broad sense

and genetic advance for 15 quantitative traits. The variability and heritability coupled with genetic advance were high in segregating progenies of the cross S-32 x LCA-312 and S-32 x SK for most of the characters.

Tembhurne *et al.* (2008) studied the performance of chilli cultivars including paprika types and evaluate the variability and association among the traits of chilli. Eleven elite advanced lines were evaluated along with KDC 1, Byadgi Dabbi and Byadgi Kaddi as controls. HCS G1 recorded the highest yield (18.52 quintal/ha) due to the highest number of fruits per plant (144.2), fruit width (1.36 cm) and yield per plant (100.2 g). The superior performance of 9626-6-1 was due to its fruit weight and fruit width. The differences between phenotypic and genotypic coefficients of variation were low for number of days to 50% flowering, plant height, fruit diameter and number of fruits per plant. High genetic advance over the mean, coupled with high heritability, was observed for number of fruits per plant. The yield was positively associated with most of the traits, but the magnitudes of correlation were high for number of fruits per plant and fruit diameter.

Sarkar *et al.* (2009) evaluated forty nine genotypes of chilli to study the genetic variability as well as association for 12 growth and fruit characters. There was significant variation among the genotypes. Fruit yield per plant, number of fruits per plant, fruit length (cm), placenta length (cm), fruit weight (g), number of seeds per fruit and plant height (cm) showed high values of GCV and PCV. High heritability in broad sense coupled with high GA in % grand mean was recorded for fruit yield per plant, number of fruits per plant, fruit length, days to 50% flowering and plant height indicating such characters were controlled by additive gene action. The phenotypic path coefficient analysis revealed that number of fruits per plant, fruit weight and 1000 seed weight had positive and direct effect on fruit yield indicating reliability as selection criteria to improve yield of chilli.

Gupta *et al.* (2009) a total of 40 hybrids of chilli were evaluated on a field experiment at PAU, Ludhiana to estimate variability, heritability, genetic advance and correlation among fruit yield and component traits. Genotypic and

phenotypic coefficients of variation were high for number of fruits and fruit yield per plant and fruit weight and length. High heritability estimates coupled with high-expected genetic advances per cent of mean were observed for number of fruits per plant, fruit yield per plant, fruit length, fruit weight and capsaicin content. Fruit yield per plant was positively correlated with number of fruits per plant and fruit length.

Ullah *et al.* (2011) evaluated chili genotypes for genetic variability, association of correlation and cause effect analysis for morphological traits. The higher genotypic coefficient of variations was found in case of fruit yield per plant followed by fruits per plant, average fruit weight and fruit length. Fruits per plant, fruit length and fruit diameter were the major characters contributing to yield as these traits were significantly and positively associated with yield per plant.

Samuel *et al.* (2012) conducted studies on genetic relationships between thirteen genotypes of chilli and paprika collected from different places of India which were analyzed using twelve RAPD and nine SSR primers. Both RAPD and SSR markers showed genetic variability in the studied pepper genotypes and they are powerful tools for estimating genetic similarities and diversity.

Khan *et al.* (2013) conducted investigation on the competence and magnitude of manual hand-picked sorting of red chillies on the reduction of total aflatoxins (AFs). AFs contents were determined by thin layer chromatography (TLC) technique. The nondestructive physical hand-picked sorting of red chillies can be applied as a rapid, safe and cost effective method for the reduction of AFs content in red chillies with preserved nutritional values.

Mahantesh *et al.* (2015) conducted studies on genetic variability, heritability, and genetic advance as a per cent over mean for eleven characters of fifty chilli genotypes. The difference between phenotypic coefficient of variation and genotypic coefficient of variation were found to be narrow for most of the traits. The high estimates of heritability was found for number of fruits per plant at first picking (98.20%), total number of fruits per plant (94.67%), early yield

(94.67%), late yield (95.62%) and total yield (91.37%), fruit length (96.22%), fruit width (96.22%), stalk length (81.04%) and ten fruit weight (96.44%), ascorbic acid (98.30%), chlorophyll-a (95.45%), chlorophyll-b (97.52%) and their total chlorophyll (97.87%).

Pandiyaraj *et al.* (2017) investigated on thirty three chilli germplasm in a randomized block design with two replications to estimate genetic variability, heritability and genetic advance of twelve quantitative and four qualitative traits. The overall values of GCV lower than the PCV for all the traits.

Udachappa *et al.* (2017) conducted experiment to study the genetic variability, heritability, correlation and path analysis of 63 chilli genotypes with two replications. Environmental influence was very less on expression of characters as it was evident by narrow gap between genotypic and phenotypic coefficients of variation. High heritability was observed for all characters, except 1000-seed weight and high genetic advance as per cent mean indicating that simple selection would be sufficient for these traits to bring genetic improvement. Path coefficient analysis revealed that fruit set percentage and fruit weight had the highest positive direct effect on fruit yield both at genotypic and phenotypic levels and most of the fruit related traits contributed to fruit yield mainly through fruit girth and fruit weight.

Faiza *et al.* (2018) studied twenty three chili accessions originating from nine countries including Pakistan for genetic variability for morphological attributes and total seed protein during the cropping seasons of 2011 and 2012 at National Agricultural Research Centre (NARC), Islamabad, Pakistan. Traits diversity was analyzed by employing statistical tools that revealed not only considerable variation but also grouping on similarities and associations that can accelerate their utilization in research. Considerable differences noted for different morpho-agronomic traits revealed substantial variation for leaf length, plant height, number of locules, fruit width, seed diameter and fruit bearing period. However, pedicel length, fruit wall thickness and number of seeds/fruit displayed low variation in both years. Association among various quantitative parameters based on correlation coefficients was significant. Fruit weight and

fruit wall thickness showed significant association with number of fruits, fruit yield per plant, total yield and number of locules. Clustering pattern observed was regardless of their origin. Contrary to variability observed in field evaluation, seed-protein profiling through SDS-PAGE depicted low variation in chili accessions. The genetic variability among chili accessions observed in this study would be a good base line to devise a better crop improvement program in chilli.

Laura *et al.* (2019) studied variability and genetic parameters of seven agronomic characteristics of 11 genotypes, and high values of the phenotypic coefficient of variation (PCV) of capsaicin content (CC) were obtained. Heritability (h^2) was high for yield per plant (YP; 0.98) and CC (0.93). The principal components analysis (PCA) revealed that the first three components explained 94.02% of the total variation. Therefore, genotypes with higher YP values and fruit weight (FW) (AKN-08, ASBC- 09) were placed in quadrant I. Those with greater CC and lowest YP and FW (MBI-11, RES-05) were placed in quadrant II. The greatest fruit length (RNJ-04) was placed in quadrant III. Those with the greatest number of fruits per plant (NBA-06, RKI-01, RHC-02, RHN-03, NKA-07, and MSB-12) were placed in quadrant IV. The results showed that the genotypes studied comprise an excellent source of genetic material for Habanero pepper improvement programs.

Ephilo *et al.* (2019) the present work was carried out with 16 genotypes of *Bhut jolokia*' (*Capsicum chinense* Jacq.) to estimate variability, heritability and genetic advance over mean for fruit yield and yield component characters. A wide range of variability along with high estimates of PCV and GCV was observed for characters. It is concluded that selection on the basis of the characters will be more useful for the improvement of this crop towards attaining higher fruit yield per plant.

The available literature on genetic parameters in *Capsicum annuum* L. is summarized and presented in Table 2.2.

Table 2.2: Summary of review of literature on genetic parameters of various traits in chilli

PCV (%)	GCV (%)	Heritability (%)	GA as % of mean	Reference
1. Plant height (cm)				
21.51 (H)	19.25 (M)	80.10 (H)	35.50 (H)	Usharani and Singh (1996)
18.60 (M)	16.50 (M)	78.40 (H)	30.09 (H)	Warade <i>et al.</i> (1996b)
17.94 (M)	16.37 (M)	83.28 (H)	30.76 (H)	Basavaraja (1997)
16.09 (M)	15.13 (M)	88.68 (H)	29.39 (H)	Venkatareddy (1997)
23.11 (H)	21.80 (H)	88.90 (H)	42.80 (H)	Devi and Arumugam (1998)
22.37 (H)	22.94 (H)	96.40 (H)	46.38 (H)	Nayeema <i>et al.</i> (1998)
8.45 (L)	5.76 (L)	40.00 (M)	7.48 (L)	Singh and Singh (1998)
24.21 (H)	23.44 (H)	93.70 (H)	26.58 (H)	Nandadevi (1999)
22.5 (H)	8.08 (L)	12.90 (L)	5.98 (L)	Subashri and Natarajan (2000)
15.36 (M)	15.21 (M)	98.12 (H)	69.05 (H)	Ibrahim <i>et al.</i> (2001)
18.66 (M)	16.51 (M)	78.33 (H)	30.11 (H)	Gogoi and Gautam (2002)
20.09 (H)	18.82 (M)	87.77 (H)	36.32 (H)	Manju and Sreelathakumary (2002a)
20.48 (M)	19.84 (M)	93.84 (H)	39.59 (H)	Rathod <i>et al.</i> (2002)
16.69 (M)	18.22 (M)	95.09 (H)	36.61 (H)	Sreelathakumary and Rajamony(2002)
5.68 (L)	5.57 (L)	96.40 (H)	11.27 (L)	Acharya and Rajput (2003)
12.77 (M)	11.51(M)	81.20 (H)	21.36 (M)	Khurana <i>et al.</i> (2003)
16.57 (M)	15.82 (M)	82.81 (H)	28.27 (H)	Mallikarjun <i>et al.</i> (2003a)
23.22 (H)	23.10 (H)	99.00 (H)	47.35 (H)	Choudhary and Samadia (2004)
22.78 (H)	22.44 (H)	96.98 (H)	10.60 (M)	Sreelathakumary and Rajamony (2004a)
14.94 (M)	13.86 (M)	86.10 (H)	26.50 (H)	Wasule <i>et al.</i> (2004)
27.93 (H)	25.20 (H)	81.00 (H)	42.04 (H)	Singh <i>et al.</i> (2005)
26.77 (H)	24.61 (H)	84.51 (H)	46.61 (H)	Karad <i>et al.</i> (2006)
24.26 (H)	23.01(H)	89.92 (H)	-	Johri and Kumar (2007)
20.57 (H)	19.89 (M)	93.5 (H)	39.62 (H)	Krishna <i>et al.</i> (2007a)
13.98 (M)	10.52 (M)	56.6 (M)	16.30 (M)	Tembhurne <i>et al.</i> (2008)
11.98 (M)	10.44 (M)	75.88 (H)	18.72 (M)	Sharma <i>et al.</i> (2010)
15.23 (M)	14.8 (M)	95 (H)	29.79 (H)	Suryakumari <i>et al.</i> (2010)
27.21 (H)	29.22 (H)	92.81(H)	39.43 (H)	Singh and Singh (2011)
16.44 (M)	15.44 (M)	86.10 (H)	37.81 (H)	Datta and Das (2013)
23.75 (H)	18.56 (M)	61.04 (H)	29.87 (H)	Krishnamurthy <i>et al.</i> (2013)
23.68 (H)	23.29 (H)	896.72 (H)	47.18 (H)	Amit <i>et al.</i> (2014)
17.27 (M)	17.14 (M)	98 (H)	35 (H)	Pandiyaraj <i>et al.</i> (2017)
13 (M)	12 (M)	92 (H)	31 (H)	Udachappa <i>et al.</i> (2017)
2. Number of primary branches per plant				
29.78 (H)	29.56 (H)	98.50 (H)	60.16 (H)	Devi and Arumugam (1998)
23.37 (H)	23.45 (H)	92.60 (H)	46.52 (H)	Nayeema <i>et al.</i> (1998)
44.94 (H)	43.04 (H)	91.70 (H)	84.99 (H)	Nandadevi (1999)

Table 2.2: Summary of review of literature on genetic parameters of various traits in chilli (contd...)

PCV (%)	GCV (%)	Heritability (%)	GA as % of mean	Reference
19.46 (M)	15.10 (M)	60.05 (H)	166.11(H)	Ibrahim <i>et al.</i> (2001)
15.93 (M)	8.64 (L)	29.39 (L)	9.65 (L)	Gogoi and Gautam (2002)
30.56 (H)	19.17 (M)	39.35 (M)	24.77 (H)	Manju and Sreelathakumary (2002a)
7.74 (L)	7.70 (L)	99.10 (H)	15.80 (M)	Rathod <i>et al.</i> (2002)
21.24 (M)	21.09 (H)	98.60 (H)	43.15 (H)	Acharya and Rajput (2003)
29.90 (H)	28.03 (H)	87.87 (H)	54.30 (H)	Mallikarjun <i>et al.</i> (2003a)
25.32 (H)	24.28 (H)	91.9 (H)	47.98 (H)	Choudhary and Samadia (2004)
21.15 (H)	16.79 (M)	63 (H)	27.49 (H)	Wasule <i>et al.</i> (2004)
21.74 (H)	13.90 (M)	421.00 (M)	1.28 (L)	Singh <i>et al.</i> (2005)
15.42 (M)	14.57 (M)	89.35 (H)	28.37 (H)	Mishra <i>et al.</i> (2005)
50.92 (H)	48.66 (H)	91.36 (H)	95.82 (H)	Karad <i>et al.</i> (2006)
23.07 (H)	3.86 (L)	2.63 (L)	9.43 (L)	Johri and Kumar (2007)
19.67 (M)	10.08 (M)	26.20 (L)	10.60 (M)	Shirshat <i>et al.</i> (2007)
12.46 (M)	5.55 (L)	19.80 (L)	5.09 (L)	Tembhurne <i>et al.</i> (2008)
9.66 (L)	12.38 (M)	60.88 (H)	15.29 (L)	Sharma <i>et al.</i> (2010)
17.57 (M)	15.30 (M)	75.80 (H)	20.67 (H)	Singh and Singh (2011)
12.47 (M)	11.98 (M)	92.30 (H)	30.39 (H)	Datta and Das (2013)
23.67 (H)	23.63 (H)	99.70 (H)	48.61 (H)	Amit <i>et al.</i> (2014)
19.49 (M)	19.28 (M)	97.58 (H)	2.90 (L)	Priyanka and Naidu (2015)
28 (H)	25 (H)	96 (H)	32 (H)	Sunnia <i>et al.</i> (2016)
15 (M)	14.9 (M)	89.2 (H)	29 (H)	Pandiyaraj <i>et al.</i> (2017)
11 (M)	8 (L)	46 (M)	13 (M)	Udachappa <i>et al.</i> (2017)
3. Days to first flowering				
18.63 (M)	15.47 (M)	68.99 (H)	26.47 (H)	Gogoi and Gautam (2002)
12.80 (M)	12.53 (M)	95.91 (H)	25.27 (H)	Sreelathakumary and Rajamony (2004a)
21.04 (H)	18.93 (M)	81.00 (H)	25.81 (H)	Singh <i>et al.</i> (2005)
17.04 (M)	15.57 (M)	83.50 (H)	29.31 (H)	Krishna <i>et al.</i> (2007)
12.48 (M)	12.35 (M)	97.96 (H)	25.18 (H)	Amit <i>et al.</i> (2014
32 (H)	31 (H)	94 (H)	29 (H)	Sunnia <i>et al.</i> (2016)
7 (L)	5 (L)	57 (M)	8 (L)	Pandiyaraj <i>et al.</i> (2017
8 (L)	5 (L)	36 (M)	7 (L)	Udachappa <i>et al.</i> (2017)
4. Days to 50% flowering				
8.18 (L)	4.59 (L)	31.50 (M)	5.30 (L)	Sharma <i>et al.</i> (2010)
27.97 (H)	27.47 (H)	96.50 (H)	25.33 (H)	Chattopadhyay <i>et al.</i> (2011)
16.18 (M)	16.15 (M)	99.59 (H)	27.11 (H)	Priyanka and Naidu (2015)
7 (L)	4 (L)	38 (M)	6.6 (L)	Udachappa <i>et al.</i> (2017)
5. Days to first harvest				
Low	Low	> 90 (H)	-	Hasanuzzaman <i>et al.</i> (2012)
3.87 (L)	3.83 (L)	97.61 (H)	8.63 (L)	Priyanka and Naidu (2015)

Table 2.2: Summary of review of literature on genetic parameters of various traits in chilli (contd...)

PCV (%)	GCV (%)	Heritability (%)	GA as % of mean	Reference
6. Average fruit weight (g)				
67.18 (H)	66.99 (H)	99.41 (H)	137.57(H)	Sreelathakumary and Rajamony (2002)
4.09 (L)	3.85 (L)	88.40 (H)	7.46 (L)	Acharya and Rajput (2003)
20.96 (H)	19.40 (M)	85.69 (H)	37.00 (H)	Mallikarjun <i>et al.</i> (2003a)
41.79 (H)	40.39 (H)	93.40 (H)	88.55 (H)	Choudhary and Samadia (2004)
51.04 (H)	50.89 (H)	98.86 (H)	104.48(H)	Sreelathakumary and Rajamony (2004a)
17.32 (M)	18.44 (M)	88.19 (H)	33.50 (H)	Mishra <i>et al.</i> (2005)
9.84 (L)	9.46 (L)	92.36 (H)	48 (H)	Johri and Kumar (2007)
24.49 (H)	23.52 (H)	91.29 (H)	46.55 (H)	Sharma <i>et al.</i> (2010)
35.47 (H)	35.37 (H)	99.42 (H)	72.66 (H)	Amit <i>et al.</i> (2014)
61.37 (H)	61.04 (H)	99.02 (H)	4.12 (L)	Priyanka and Naidu (2015)
42 (H)	41 (H)	97.4 (H)	53 (H)	Sunnia <i>et al.</i> (2016)
35 (H)	34 (H)	73 (H)	48 (H)	Syed <i>et al.</i> (2017)
6 (L)	5 (L)	99 (H)	11.9 (M)	Udachappa <i>et al.</i> (2017)
7. Fruit length (cm)				
28.31 (H)	28.28 (H)	99.82 (H)	58.21 (H)	Mishra <i>et al.</i> (2001)
35.53 (H)	34.29 (H)	93.18 (H)	68.19 (H)	Gogoi and Gautam (2002)
18.07 (M)	17.51 (M)	93.95 (H)	34.97 (H)	Manju and Sreelathakumary (2002a)
19.22 (M)	18.89 (M)	94.27 (H)	39.58 (H)	Acharya and Rajput (2003)
27.73 (H)	22.33 (H)	88.57 (H)	43.29 (H)	Khurana <i>et al.</i> (2003)
16.33 (M)	14.88 (M)	83.04 (H)	27.94 (H)	Mallikarjun <i>et al.</i> (2003a)
23.58 (H)	22.23 (H)	88.90 (H)	40.82 (H)	Choudhary and Samadia (2004)
38.56 (H)	38.50 (H)	99.68 (H)	79.19 (H)	Sreelathakumary and Rajamony (2004a)
14.48 (M)	11.73 (M)	65.60 (H)	19.55 (M)	Wasule <i>et al.</i> (2004)
29.46 (H)	28.39 (H)	92.86 (H)	56.35 (H)	Mishra <i>et al.</i> (2005)
35.21 (H)	34.35 (H)	95.00 (H)	30.58 (H)	Singh <i>et al.</i> (2005)
33.77 (H)	32.77 (H)	94.15 (H)	65.52 (H)	Karad <i>et al.</i> (2006)
15.09 (M)	13.92 (M)	85.91 (H)	43 (H)	Johri and Kumar (2007)
27.74 (H)	26.66 (H)	92.4 (H)	52.80 (H)	Krishna <i>et al.</i> (2007a)
23.88 (H)	21.28 (H)	79.50 (H)	39.08 (H)	Shirshat <i>et al.</i> (2007)
14.19 (M)	9.81 (L)	47.80 (M)	13.96 (M)	Tembhurne <i>et al.</i> (2008)
9.31 (L)	7.88 (L)	71.70 (H)	11.85 (M)	Sharma <i>et al.</i> (2010)
24.37 (H)	22.69 (H)	86.68 (H)	43.50 (H)	Suryakumari <i>et al.</i> (2010)
23.91 (H)	22.54 (H)	88.85 (H)	24.83 (H)	Singh and Singh (2011)
27.41 (H)	21.01 (H)	33.17 (M)	58.75 (M)	Krishnamurthy <i>et al.</i> (2013)
16.29 (M)	16.26 (M)	99.50 (H)	2.93 (L)	Priyanka and Naidu (2015)
26.51 (H)	23.61 (H)	79.30 (H)	42.93 (H)	Nandadevi (1999)
35.06 (H)	35.04 (H)	99.86 (H)	72.12 (H)	Amit <i>et al.</i> (2014)

Table 2.2: Summary of review of literature on genetic parameters of various traits in chilli (contd...)

PCV (%)	GCV (%)	Heritability (%)	GA as % of mean	Reference
19 (H)	18 (M)	95 (H)	46 (H)	Udachappa <i>et al.</i> (2017)
8. Fruit diameter (cm)				
20.27 (M)	13.98 (M)	47.57 (M)	19.89 (M)	Sundaram and Irulappan (1998)
26.51 (H)	23.61 (H)	79.30 (H)	42.93 (H)	Nandadevi (1999)
21.08 (H)	17.22 (M)	66.70 (H)	29.19 (H)	Munshi and Behera (2000a)
28.00 (H)	13.90 (M)	24.80 (L)	14.30 (M)	Subashri and Natarajan (2000)
32.96 (H)	28.68 (H)	75.69 (H)	51.39 (H)	Gogoi and Gautam (2002)
17.79 (M)	17.67 (M)	98.68 (H)	36.17 (H)	Manju and Sreelathakumary (2002a)
12.28 (M)	12.22 (M)	99.12 (H)	25.07 (H)	Rathod <i>et al.</i> (2002)
49.21 (H)	49.12 (H)	99.65 (H)	101.02 (H)	Sreelathakumary and Rajamony (2002)
10.54 (M)	9.71 (L)	97.00 (H)	19.40 (M)	Acharya and Rajput (2003)
38.83 (H)	33.13 (H)	72.81 (H)	58.24 (H)	Khurana <i>et al.</i> (2003)
15.19 (M)	13.81 (M)	82.57 (H)	25.84 (H)	Mallikarjun <i>et al.</i> (2003a)
21.16 (H)	19.33 (M)	83.50 (H)	36.36 (H)	Choudhary and Samadia (2004)
28.27 (H)	26.12 (H)	85.40 (H)	50.00 (H)	Wasule <i>et al.</i> (2004)
33.81 (H)	31.76 (H)	88.00 (H)	8.86 (L)	Singh <i>et al.</i> (2005)
25.03 (H)	24.21 (H)	92.29 (H)	47.91 (H)	Karad <i>et al.</i> (2006)
19.07 (M)	13.91 (M)	53.24 (M)	36 (H)	Johri and Kumar (2007)
31.52 (H)	28.51 (H)	81.9 (H)	53.68 (H)	Krishna <i>et al.</i> (2007a)
17.64 (M)	15.08 (M)	73.10 (H)	26.55 (H)	Tembhurne <i>et al.</i> (2008)
9.95 (L)	9.14 (L)	84.29 (H)	9.86 (L)	Sharma <i>et al.</i> (2010)
30.61 (H)	28.63 (H)	87.509 (H)	51.16 (H)	Suryakumari <i>et al.</i> (2010)
14.60 (M)	10.83 (M)	54.99 (M)	51.74 (H)	Singh and Singh (2011)
19.89 (M)	12.62 (M)	40.26 (M)	16.50 (M)	Krishnamurthy <i>et al.</i> (2013)
30.54 (H)	30.09 (H)	97.04 (H)	61.05 (H)	Amit <i>et al.</i> (2014)
21.12 (H)	20.80 (H)	96.77 (H)	0.60 (L)	Priyanka and Naidu (2015)
27 (H)	25 (H)	83 (H)	39 (H)	Sunnia <i>et al.</i> (2016)
22 (H)	21 (H)	75 (H)	33 (H)	Pandiyaraj <i>et al.</i> (2017)
19 (M)	18 (M)	92 (H)	46 (H)	Udachappa <i>et al.</i> (2017)
9. Fruit yield per plant (kg/plant)				
40.80 (H)	40.16 (H)	96.90 (H)	81.43 (H)	Mallikarjun <i>et al.</i> (2003a)
44.20 (H)	42.91 (H)	94.30 (H)	56.86 (H)	Choudhary and Samadia (2004)
39.21 (H)	38.99 (H)	94.45 (H)	79.87 (H)	Sreelathakumary and Rajamony (2004)
28.70 (H)	26.89 (H)	87.10 (H)	51.88 (H)	Wasule <i>et al.</i> (2004)
35.35 (H)	31.68 (H)	80.00 (H)	42.04 (H)	Singh <i>et al.</i> (2005)
38.33 (H)	37.85 (H)	97.53 (H)	77.01 (H)	Mishra <i>et al.</i> (2005)
67.74 (H)	64.13 (H)	89.62 (H)	125.07(H)	Karad <i>et al.</i> (2006)
24.11 (H)	23.61 (H)	95.89 (H)	59 (H)	Johri and Kumar (2007)
32.28 (H)	35.05 (H)	88.4 (H)	67.87 (H)	Krishna <i>et al.</i> (2007a)

Table 2.2: Summary of review of literature on genetic parameters of various traits in chilli (contd...)

PCV (%)	GCV (%)	Heritability (%)	GA as % of mean	Reference
38.10 (H)	20.31 (H)	28.40 (L)	22.30 (H)	Shirshat <i>et al.</i> (2007)
34.88 (H)	26.17 (H)	56.30 (M)	40.44 (H)	Tembhurne <i>et al.</i> (2008)
40.27 (H)	38.00 (H)	89.03 (H)	73.87 (H)	Sharma <i>et al.</i> (2010)
35.56 (H)	35.53 (H)	99.80 (H)	73.10 (H)	Suryakumari <i>et al.</i> (2010)
33.80 (H)	31.32 (H)	85.88 (H)	93.26 (H)	Singh and Singh (2011)
23.42 (H)	22.34 (H)	91.00 (H)	56.29 (H)	Datta and Das (2013)
50.33 (H)	32.73 (H)	42.28 (M)	43.84 (H)	Krishnamurthy <i>et al.</i> (2013)
45.98 (H)	45.41 (H)	97.53 (H)	92.38 (H)	Amit <i>et al.</i> (2014)
52 (H)	49 (H)	98 (H)	53 (H)	Sunnia <i>et al.</i> (2016)
38 (H)	37 (H)	94 (H)	48 (H)	Syed <i>et al.</i> (2017)
35 (H)	34 (H)	99 (H)	90 (H)	Udachappa <i>et al.</i> (2017)
10. Fruit yield per hectare (Kg/ha)				
35 (H)	34 (H)	99 (H)	90 (H)	Udachappa <i>et al.</i> (2017)
11. Ascorbic acid content (mg/ 100 g of fruit)				
36.43 (H)	35.36 (H)	94.20 (H)	70.70 (H)	Shirshat <i>et al.</i> (2007)
27.98 (H)	26.68 (H)	90.89 (H)	52.39 (H)	Sharma <i>et al.</i> (2010)
8.47 (L)	6.32 (L)	55.60 (M)	12.44 (M)	Datta and Das (2013)
19.1 (M)	18.3 (M)	92 (H)	36 (H)	Pandiyaraj <i>et al.</i> (2017)
23 (H)	21 (H)	99 (H)	80 (H)	Udachappa <i>et al.</i> (2017)
12. Capsaicin content (%)				
27.57 (H)	27.52 (H)	99.62 (H)	56.58(H)	Manju and Sreelathakumary (2002a)
6.36 (L)	6.12 (L)	92.80 (H)	12.36 (H)	Acharya and Rajput (2003)
40.31 (H)	39.83 (H)	97.62 (H)	81.05 (H)	Suryakumari <i>et al.</i> (2010)
45.29 (H)	45.17 (H)	99.48 (H)	95.52 (H)	Datta and Das (2013)
38 (H)	36 (H)	95 (H)	53 (H)	Sunnia <i>et al.</i> (2016)
51 (H)	50 (H)	97 (H)	103 (H)	Pandiyaraj <i>et al.</i> (2017)
23 (H)	19 (M)	70 (H)	42 (H)	Udachappa <i>et al.</i> (2017)
13. Capsanthin content (ASTA units)				
21.40 (H)	21.34 (H)	99.44 (H)	43.83 (H)	Khurana <i>et al.</i> (2003)
24.53 (H)	23.99 (H)	95.64 (H)	48.33 (H)	Mallikarjun <i>et al.</i> (2003a)
58.89 (H)	58.61 (H)	99.10 (H)	120.20(H)	Suryakumari <i>et al.</i> (2010)
38.5 (H)	37 (H)	99 (H)	79 (H)	Pandiyaraj <i>et al.</i> (2017)
14. Chlorophyll content of green chilli (%)				
31.32 (H)	32.48 (H)	92.99 (H)	65.45 (H)	Smitha <i>et al.</i> (2006b)
35.87 (H)	35.43 (H)	98.67 (H)	72.89 (H)	Dixita <i>et al.</i> (2015)
15. Number of fruits per plant				
28.72 (H)	25.07 (H)	76.35 (H)	33 (H)	Johri and Kumar (2007)
37.96 (H)	33.70 (H)	80.00 (H)	62.08 (H)	Tembhurne <i>et al.</i> (2008)
29.47 (H)	24.82 (H)	70.95 (H)	43.07 (H)	Sharma <i>et al.</i> (2010)
47.1 (H)	45.83 (H)	94.38 (H)	11.09 (M)	Singh and Singh (2011)
26.56 (H)	25.62 (H)	93.00 (H)	66.21 (H)	Datta and Das (2013)

Table 2.2: Summary of review of literature on genetic parameters of various traits in chilli (contd...)

PCV (%)	GCV (%)	Heritability (%)	GA as % of mean	Reference
8.22 (L)	6.45 (L)	78.46 (H)	10.43 (M)	Acharya and Rajput (2003)
55.94 (H)	55.46 (H)	98.26 (H)	113.26 (H)	Mallikarajun <i>et al.</i> (2003)
37.69 (H)	37.46 (H)	98.80 (H)	76.69 (H)	Choudhary and Samadia (2004)
6.88 (H)	63.70 (H)	99.42 (H)	130.84 (H)	Sreelathakumary and Rajamony (2004)
37.06 (H)	37.57 (H)	92.10 (H)	70.32 (H)	Wasule <i>et al.</i> (2004)
33.88 (H)	30.90 (H)	83.00 (H)	52.51 (H)	Singh <i>et al.</i> (2005)
40.14 (H)	39.39 (H)	96.30 (H)	79.63 (H)	Mishra <i>et al.</i> (2005)
68.37 (H)	64.87 (H)	90.00 (H)	126.78 (H)	Karad <i>et al.</i> (2006)
28.72 (H)	25.07 (H)	76.35 (H)	33 (H)	Johri and Kumar (2007)
48.72 (H)	32.36 (H)	44.10 (M)	44.29 (H)	Shirshat <i>et al.</i> (2007)
37.68 (H)	33.70 (H)	80.00 (H)	62.08 (H)	Tembhurne <i>et al.</i> (2008)
29.47 (H)	24.82 (H)	70.95 (H)	43.07 (H)	Sharma <i>et al.</i> (2010)
47.1 (H)	45.83 (H)	94.38 (H)	11.09 (M)	Singh and Singh (2011)
26.56 (H)	25.62 (H)	93.00 (H)	66.21 (H)	Datta and Das (2013)
17.66 (H)	16.42 (H)	70.32 (M)	48.23 (H)	Krishnamurthy <i>et al.</i> (2013)
35.57 (H)	34.14 (H)	92.13 (H)	67.51 (H)	Amit <i>et al.</i> (2014)
90 (H)	83 (H)	98 (H)	161 (H)	Sunnia <i>et al.</i> (2016)
38 (H)	36 (H)	93 (H)	42 (H)	Syed <i>et al.</i> (2017)
32 (H)	31 (H)	99 (H)	65 (H)	Pandiyaraj <i>et al.</i> (2017)
34 (H)	33 (H)	99 (H)	88 (H)	Udachappa <i>et al.</i> (2017)

2.3 CORRELATION COEFFICIENT ANALYSIS

The idea of correlation was presented by Galton (1889) and later elaborated by Fisher (1918) and Wright (1921). It measures the relationship between two or more variables and gives a clear indication for the breeder to base his selection on characters to improve economic yield and also for planning more efficient breeding programmes.

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. Simple correlations are of three types viz., phenotypic, genotypic and environmental. Phenotypic correlation is the observable correlation between two variables, measures the environmental deviation together with non-additive gene action. Genotypic correlation on the other hand is the inherent association between two variables. They can be estimated from replicated data only. Unfavorable associations between the desired attributes under selection may limit genetic advance.

A knowledge of genetic correlation among the characters contributing to the yield leads to the most effective method of selection. By this way combination of favourable characters could be brought out by minimizing the effect of antagonistic relations. The magnitude and direction of association is measured by correlation coefficients. Correlation coefficient studies provide information such that selection for one character results in progress for all positively correlated characters.

Yield component characters exhibit association among themselves and with yield. Unfavourable association between the desired attributes under selection may limit genetic advance. Hence, study of association of component characters with yield would aid in planning of an effective selection programme. Hence brief review of literature on associations in *Capsicum annuum* L. are presented in Tables 2.3.1 and 2.3.2

Table 2.3.1: Review of literature on the association of yield component characters with fruit yield per plant in chilli

Character	Association	S/NS	Reference
Plant height (cm)	Positive	S	Ibrahim <i>et al.</i> (2001) Sreelathakumary and Rajamony (2002) Gogoi and Gautam (2003) Gouda and Mulge (2003) Khurana <i>et al.</i> (2003) Chatterjee (2006) Karad <i>et al.</i> (2006) Krishna <i>et al.</i> (2007b) Abrham <i>et al.</i> (2017) Sujatha <i>et al.</i> (2017)
	Positive	NS	Nazir <i>et al.</i> (2005) Sharma <i>et al.</i> (2007) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008) Amit <i>et al.</i> (2014)
	Negative	S	Krishnamurthy <i>et al.</i> (2013)
	Negative	NS	Ahmed <i>et al.</i> (2006) Kaur and Singh (2009) Sharma <i>et al.</i> (2010) Singh and Singh (2011) Shiva <i>et al.</i> (2015)
Number of primary branches per plant	Positive	S	Chatterjee (2006) Hosamani and Shivkumar (2008) Kaur and Singh (2009) Maneet <i>et al.</i> (2015) Hasan <i>et al.</i> (2016) Vidya <i>et al.</i> (2018)
	Positive	NS	Nehru <i>et al.</i> (2003) Farhad <i>et al.</i> (2008) Sharma <i>et al.</i> (2010) Amit <i>et al.</i> (2014)
	Negative	S	Gouda and Mulge (2003)
	Negative	NS	Ahmed <i>et al.</i> (2006) Singh and Singh (2011) Priyanka and Mishra (2014)

S-Significant, NS-Non Significant

Table 2.3.1: Review of literature on the association of yield component characters with fruit yield per plant in chilli (contd...)

Character	Association	S/NS	Reference
Days to first flowering	positive	S	Hasan <i>et al.</i> (2016) Sujatha <i>et al.</i> (2017)
	Negative	S	Gouda and Mulge (2003) Khurana <i>et al.</i> (2003) Amit <i>et al.</i> (2014)
	Negative	NS	Ahmad <i>et al.</i> (2006) Singh and Singh (2011)
Days to 50 percent flowering	Positive	S	Rajya and Vijaya (2011) Mahantesh <i>et al.</i> (2013) Hasan <i>et al.</i> (2016) Sujatha <i>et al.</i> (2017) Srividya <i>et al.</i> (2017)
	Negative	S	Gouda and Mulge (2003) Khurana <i>et al.</i> (2003) Amit <i>et al.</i> (2014) Shiva <i>et al.</i> (2015)
	Negative	S	Tasso <i>et al.</i> (2014)
Days to first harvest	Positive	S	Mahantesh <i>et al.</i> (2013) Sujatha <i>et al.</i> (2017)
	Negative	S	Gouda and Mulge (2003) Khurana <i>et al.</i> (2003) Amit <i>et al.</i> (2014) Shiva <i>et al.</i> (2015)
	Negative	NS	Choudhary and Samadia (2004) Hari <i>et al.</i> (2005) Krishna <i>et al.</i> (2007b)
Fruit length (cm)	Positive	S	Sharma <i>et al.</i> (2010) Singh and Singh (2011) Amit <i>et al.</i> (2014) Sujatha <i>et al.</i> (2017) Vidya <i>et al.</i> (2018)
	Positive	NS	Nazir <i>et al.</i> (2005) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008) Krishnamurthy <i>et al.</i> (2013) Shiva <i>et al.</i> (2015)
	Negative	S	Kaur and Singh (2009) Hasan <i>et al.</i> (2016)
Fruit diameter (cm)	Positive	S	Krishna <i>et al.</i> (2007b) Sharma <i>et al.</i> (2007)

S-Significant, NS-Non Significant

Table 2.3.1: Review of literature on the association of yield component characters with fruit yield per plant in chilli (contd...)

Character	Association	S/NS	Reference
			Sharma <i>et al.</i> (2010) Amit <i>et al.</i> (2014) Hasan <i>et al.</i> (2016) Vidya <i>et al.</i> (2018)
	Positive	NS	Hosamani and Shivkumar (2008) Singh and Singh (2011) Shiva <i>et al.</i> (2015)
	Negative	NS	Krishnamurthy <i>et al.</i> (2013)
Fruit weight (g)	Positive	S	Sharma <i>et al.</i> (2010) Amit <i>et al.</i> (2014) Sujatha <i>et al.</i> (2017)
	Positive	NS	Hosamani and Shivkumar (2008) Mahantesh <i>et al.</i> (2013) Hasan <i>et al.</i> (2016)
Number of fruits per plant	Positive	S	Karad <i>et al.</i> (2006) Krishna <i>et al.</i> (2007b) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008) Sharma <i>et al.</i> (2010) Singh and Singh (2011) Krishnamurthy <i>et al.</i> (2013) Amit <i>et al.</i> (2014) Tasso <i>et al.</i> (2014)
	Positive	NS	Ahmed <i>et al.</i> (2006) Sharma <i>et al.</i> (2007) Kaur and Singh (2009) Priyanka and Mishra (2014)
	Negative	NS	Nazir <i>et al.</i> (2005)
Ascorbic acid content (mg/100g)	Positive	NS	Sharma <i>et al.</i> (2010) Shiva <i>et al.</i> (2015) Sujatha <i>et al.</i> (2017)
	Positive	S	Diwakar <i>et al.</i> (2012)
Capsanthin content (ASTA units)	Positive	S	Khurana <i>et al.</i> (2003) Magaji <i>et al.</i> (2016)
	Positive	NS	Kaur and Singh (2009) Diwakar <i>et al.</i> (2012)
Capsaicin content (%)	Positive	S	Khurana <i>et al.</i> (2003) Sujatha <i>et al.</i> (2017)

S-Significant, NS-Non Significant

Table 2.3.2: Review of literature on the association among the yield component characters in chilli

Character	Association	S/NS	Reference
Association of plant height (cm) with			
Number of primary branches per plant	Positive	S	Gogoi and Gautam (2003) Mallikarjun <i>et al.</i> (2003b) Ahmed <i>et al.</i> (2006) Singh and Singh (2011) Amit <i>et al.</i> (2014) Hasan <i>et al.</i> (2016) Sujatha Kumari <i>et al.</i> (2017)
	Positive	NS	Nazir <i>et al.</i> (2005) Hosamani and Shivkumar (2008) Kaur and Singh (2009) Shiva <i>et al.</i> (2015)
	Negative	NS	Hari <i>et al.</i> (2005) Farhad <i>et al.</i> (2008) Sharma <i>et al.</i> (2010)
Days to first flowering	Positive	S	Acharya and Rajput (2003) Hosamani and Shivkumar (2008) Sunnia <i>et al.</i> (2016)
	Positive	NS	Hari <i>et al.</i> (2005) Krishna <i>et al.</i> (2007) Farhad <i>et al.</i> (2008) Magaji <i>et al.</i> (2016)
	Negative	S	Amit <i>et al.</i> (2014)
	Negative	NS	Khurana <i>et al.</i> (2003) Choudhary and Samadia (2004) Tasso <i>et al.</i> (2014)
Fruit length (cm)	Positive	S	Aliyu <i>et al.</i> (2000) Acharya and Rajput (2003) Singh and Singh (2011) Mahantesh <i>et al.</i> (2013)
	Positive	NS	Ibrahim <i>et al.</i> (2001) Khurana <i>et al.</i> (2003) Hari <i>et al.</i> (2005) Krishna <i>et al.</i> (2007b) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008) Sharma <i>et al.</i> (2010) Krishnamurthy <i>et al.</i> (2013) Amit <i>et al.</i> (2014) Shiva <i>et al.</i> (2015)
	Negative	NS	Gogoi and Gautam (2003) Gouda and Mulge (2003) Mallikarjun <i>et al.</i> (2003b)

S-Significant, NS-Non Significant

Table 2.3.2 continued.,

			Nehru <i>et al.</i> (2003) Nazir <i>et al.</i> (2005) Ahmed <i>et al.</i> (2006) Kaur and Singh (2009)
Fruit diameter (cm)	Positive	S	Aliyu <i>et al.</i> (2000) Ibrahim <i>et al.</i> (2001) Gogoi and Gautam (2003)
	Positive	NS	Khurana <i>et al.</i> (2003) Choudhary and Samadia (2004) Farhad <i>et al.</i> (2008) Singh and Singh (2011) Krishnamurthy <i>et al.</i> (2013) Amit <i>et al.</i> (2014) Maurya <i>et al.</i> (2017b)
	Negative	S	Chaim and Paran (2000) Gouda and Mulge (2003) Sharma <i>et al.</i> (2010)
	Negative	NS	Sreelathakumary and Rajmony (2002) Acharya and Rajput (2003) Mallikarjun <i>et al.</i> (2003b) Hari <i>et al.</i> (2005) Nazir <i>et al.</i> (2005) Ahmed <i>et al.</i> (2006) Krishna <i>et al.</i> (2007b) Hosamani and Shivkumar (2008) Diwakar <i>et al.</i> (2012) Shiva <i>et al.</i> (2015)
Fruit weight (g)	Positive	S	Gogoi and Gautam (2003) Amit <i>et al.</i> (2014) Sujatha <i>et al.</i> (2017)
	Positive	NS	Krishna <i>et al.</i> (2007b) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008) Kaur and Singh (2009) Hasan <i>et al.</i> (2016)
	Negative	S	Sharma <i>et al.</i> (2010)
	Positive	NS	Acharya and Rajput (2003) Choudhary and Samadia (2004) Hari <i>et al.</i> (2005) Nazir <i>et al.</i> (2005) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008)
	Negative	NS	Gouda and Mulge (2003) Mallikarjun <i>et al.</i> (2003b) Tasso <i>et al.</i> (2014)
Number of fruits per plant	Positive	S	Aliyu <i>et al.</i> (2000) Ibrahim <i>et al.</i> (2001)

S-Significant, NS-Non Significant

Table 2.3.2 continued.,

			Gouda and Mulge (2003) Hari <i>et al.</i> (2005) Ahmed <i>et al.</i> (2006) Karad <i>et al.</i> (2006) Amit <i>et al.</i> (2014) Sujatha <i>et al.</i> (2017)
	Positive	NS	Gogoi and Gautam (2003) Khurana <i>et al.</i> (2003) Mallikarjun <i>et al.</i> (2003) Nehru <i>et al.</i> (2003) Nazir <i>et al.</i> (2005) krishna <i>et al.</i> (2007) Hosamani and Shivkumar (2008) Sharma <i>et al.</i> (2010) Diwakar <i>et al.</i> (2012)
	Negative	NS	Acharya and Rajput (2003) Choudhary and Samadia (2004) Farhad <i>et al.</i> (2008) Kaur and Singh (2009) Singh and Singh (2011) Krishnamurthy <i>et al.</i> (2013)
Ascorbic acid content (mg/100g)	Positive	NS	Ahmed <i>et al.</i> (2006) Hasan <i>et al.</i> (2016)
	Negative	S	Sharma <i>et al.</i> (2010)
	Negative	NS	Farhad <i>et al.</i> (2008) Shiva <i>et al.</i> (2015)
Capsanthin content (ASTA units)	Positive	S	Khurana <i>et al.</i> (2003) Magaji <i>et al.</i> (2016)
	Positive	NS	Khurana <i>et al.</i> (2003) Mallikarjun <i>et al.</i> (2003b) Hari <i>et al.</i> (2005) Shiva <i>et al.</i> (2015)
	Negative	NS	Ahmed <i>et al.</i> (2006)
Capsaicin content (%)	Positive	S	Khurana <i>et al.</i> (2003) Sujatha <i>et al.</i> (2017)
	Positive	NS	Khurana <i>et al.</i> (2003) Ahmed <i>et al.</i> (2006)
	Negative	NS	Hari <i>et al.</i> (2005) Shiva <i>et al.</i> (2015)
Association of number of primary branches per plant with			
Days to first flowering	Positive	S	Acharya and Rajput (2003) Hosamani and Shivkumar (2008) Shiva <i>et al.</i> (2015) Maurya <i>et al.</i> (2017b)
	Positive	NS	Tasso <i>et al.</i> (2014) Sunnia <i>et al.</i> (2016)

S-Significant, NS-Non Significant

Table 2.3.2 continued.,

	Negative	NS	Farhad <i>et al.</i> (2008) Amit <i>et al.</i> (2014)
Days to first harvest	Positive	NS	Mallikarjun <i>et al.</i> (2003b) Kaur and Singh (2009)
	Negative	NS	Acharya and Rajput (2003) Gogoi and Gautam (2003) Sharma <i>et al.</i> (2010) Amit <i>et al.</i> (2014)
Fruit length (cm)	Positive	S	Acharya and Rajput (2003) Singh and Singh (2011) Tasso <i>et al.</i> (2014) Leeladhar <i>et al.</i> (2016)
	Positive	NS	Gogoi and Gautam (2003) Hari <i>et al.</i> (2005) Nazir <i>et al.</i> (2005) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008) Amit <i>et al.</i> (2014)
	Negative	NS	Mallikarjun <i>et al.</i> (2003b) Nehru <i>et al.</i> (2003) Kaur and Singh (2009) Sharma <i>et al.</i> (2010) Priyanka and Mishra (2014)
Fruit diameter (cm)	Positive	S	Gouda and Mulge (2003) Hari <i>et al.</i> (2005) Nazir <i>et al.</i> (2005) Singh and Singh (2011)
	Positive	NS	Aliyu <i>et al.</i> (2000) Acharya and Rajput (2003) Hari <i>et al.</i> (2005) Sharma <i>et al.</i> (2010) Amit <i>et al.</i> (2014)
	Negative	S	Gogoi and Gautam (2003) Mallikarjun <i>et al.</i> (2003b) Hasan <i>et al.</i> (2016)
	Negative	NS	Gogoi and Gautam (2003) Mallikarjun <i>et al.</i> (2003b) Ahmed <i>et al.</i> (2006) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008)
Number of fruits per plant	Positive	S	Ahmed <i>et al.</i> (2006) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008) Amit <i>et al.</i> (2014) Vidya <i>et al.</i> (2018)
	Positive	NS	Gogoi and Gautam (2003) Nehru <i>et al.</i> (2003) Hari <i>et al.</i> (2005)

S-Significant, NS-Non Significant

Table 2.3.2 continued.,

			Kaur and Singh (2009) Sharma <i>et al.</i> (2010) Singh and Singh (2011)
	Negative	S	Goude and Mulge (2003) Nazir <i>et al.</i> (2005)
Fruit weight (g)	Positive	S	Nazir <i>et al.</i> (2005) Amit <i>et al.</i> (2014)
	Positive	NS	Gogoi and Gautam (2003) Hosamani and Shivkumar (2008) Sharma <i>et al.</i> (2010)
	Negative	S	Hari <i>et al.</i> (2005)
	Negative	NS	Farhad <i>et al.</i> (2008) Kaur and Singh (2009) Priyanka and Mishra (2014)
Ascorbic acid content (mg/100g)	Positive	NS	Hari <i>et al.</i> (2005) Sharma <i>et al.</i> (2010) Deepak <i>et al.</i> (2017)
	Negative	NS	Farhad <i>et al.</i> (2008)
Capsanthin content (ASTA units)	Positive	S	Mahentesh <i>et al.</i> (2013) Priyanka and Mishra (2014)
	Positive	NS	Mallikarjun <i>et al.</i> (2003b) Ahmed <i>et al.</i> (2006)
	Negative	NS	Hari <i>et al.</i> (2005)
Capsaicin content (%)	Positive	S	Manju and Sreelathakumary (2002b) Sujatha <i>et al.</i> (2017)
	Positive	NS	Ahmed <i>et al.</i> (2006)
	Negative	NS	Hari <i>et al.</i> (2005)
Association of days to first flowering with			
Number of fruits per plant	Positive	S	Khurana <i>et al.</i> (2003) Diwakar <i>et al.</i> (2012)
	Positive	NS	Khurana <i>et al.</i> (2003) Hari <i>et al.</i> (2005) Tasso <i>et al.</i> (2014)
	Negative	NS	Acharya and Rajput (2003) Choudhary and Samadia (2004) Krishna <i>et al.</i> (2007) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008) Amit <i>et al.</i> (2014) Abraham <i>et al.</i> (2017)
Fruit length (cm)	Positive	NS	Acharya and Rajput (2003) Krishna <i>et al.</i> (2007) Hosamani and Shivkumar (2008) Rajya and vijaya (2012)
	Negative	S	Farhad <i>et al.</i> (2008) Hasan <i>et al.</i> (2016)

S-Significant, NS-Non Significant

Table 2.3.2 continued.,

	Negative	NS	Khurana <i>et al.</i> (2003) Choudhary and Samadia (2004) Hari <i>et al.</i> (2005) Amit <i>et al.</i> (2014)
Fruit diameter (cm)	Positive	S	Priyanka and Mishra (2014) Shiva <i>et al.</i> (2015)
	Positive	NS	Farhad <i>et al.</i> (2008) Leeladhar <i>et al.</i> (2016)
	Negative	NS	Acharya and Rajput (2003) Khurana <i>et al.</i> (2003) Choudhary and Samadia (2004) Hari <i>et al.</i> (2005) Krishna <i>et al.</i> (2007b) Hosamani and Shivkumar (2008) Amit <i>et al.</i> (2014)
Fruit weight (g)	Positive	S	Krishna <i>et al.</i> (2007b)
	Negative	NS	Farhad <i>et al.</i> (2008) Amit <i>et al.</i> (2014)
Seed content (%)	Positive	S	Acharya and Rajput (2003) Hari <i>et al.</i> (2005) Sunnia <i>et al.</i> (2016)
	Positive	NS	Hosamani and Shivkumar (2008)
	Negative	NS	Choudhary and Samadia (2004) Farhad <i>et al.</i> (2008)
Ascorbic acid content (mg/100g)	Positive	NS	Diwakar <i>et al.</i> (2012)
Capsanthin content (ASTA units)	Positive	NS	Priyanka and Mishra (2014) Leeladhar <i>et al.</i> (2016)
	Negative	S	Rajya and Vijaya (2011)
Capsaicin content (%)	Positive	NS	Khurana <i>et al.</i> (2003)
	Negative	NS	Hari <i>et al.</i> (2005)
Association of fruit length (cm) with			
Fruit diameter (cm)	Positive	S	Singh and Singh (2011) Amit <i>et al.</i> (2014) Abraham <i>et al.</i> (2017) Sujatha Kumari <i>et al.</i> (2017)
	Positive	NS	Farhad <i>et al.</i> (2008) Krishnamurthy <i>et al.</i> (2013) Priyanka and Mishra (2014) Shiva <i>et al.</i> (2015)
	Negative	S	Gogoi and Gautam (2003) Khurana <i>et al.</i> (2003) Hari <i>et al.</i> (2005) Farhad <i>et al.</i> (2008) Sharma <i>et al.</i> (2010)
	Negative	NS	Mallikarjun <i>et al.</i> (2003b) Nazir <i>et al.</i> (2005)

S-Significant, NS-Non Significant

Table 2.3.2 continued.,

			Farhad <i>et al.</i> (2008) Amit <i>et al.</i> (2014) Deepak <i>et al.</i> (2017)
Fruit weight (g)	Positive	S	Krishna <i>et al.</i> (2007b) Farhad <i>et al.</i> (2008) Diwakar <i>et al.</i> (2013) Amit <i>et al.</i> (2014)
	Positive	NS	Kaur and Singh (2009) Sharma <i>et al.</i> (2010) Shiva <i>et al.</i> (2015) Hasan <i>et al.</i> (2016)
Ascorbic acid content (mg/100g)	Positive	NS	Farhad <i>et al.</i> (2008) Deepak <i>et al.</i> (2017)
	Negative	NS	Sharma <i>et al.</i> (2010)
Capsanthin content (ASTA units)	Positive	S	Hasan <i>et al.</i> (2016) Abrham <i>et al.</i> (2017)
	Positive	NS	Krishnamurthy <i>et al.</i> (2013) Tasso <i>et al.</i> (2014)
	Negative	NS	Diwakar <i>et al.</i> (2012) Shiva <i>et al.</i> (2015)
Capsaicin content (%)	Positive	S	Sujatha Kumari <i>et al.</i> (2017)
	Positive	NS	Hari <i>et al.</i> (2005) Ahmed <i>et al.</i> (2006)
	Negative	NS	Khurana <i>et al.</i> (2003) Krishnamurthy <i>et al.</i> (2013) Shiva <i>et al.</i> (2015)
Association of fruit diameter (cm) with			
Fruit weight (g)	Positive	S	Krishna <i>et al.</i> (2007b) Farhad <i>et al.</i> (2008) Hosamani and Shivkumar (2008) Sharma <i>et al.</i> (2010) Amit <i>et al.</i> (2014)
	Positive	NS	Rajya and Vijaya (2011) Diwakar <i>et al.</i> (2012) Abrham <i>et al.</i> (2017)
	Negative	NS	Acharya and Rajput (2003) Nazir <i>et al.</i> (2005) Priyanka and Mishra (2014)
Ascorbic acid content (mg/100g)	Positive	NS	Ahmed <i>et al.</i> (2006) Sharma <i>et al.</i> (2010) Hasan <i>et al.</i> (2016) Leeladhar <i>et al.</i> (2016)
	Negative	NS	Farhad <i>et al.</i> (2008) Mahantesh <i>et al.</i> (2013)
Capsanthin content (ASTA units)	Positive	NS	Khurana <i>et al.</i> (2003) Hari <i>et al.</i> (2005) Ahmed <i>et al.</i> (2006)

S-Significant, NS-Non Significant

Table 2.3.2 continued.,

	Negative	NS	Shiva <i>et al.</i> (2015)
Capsaicin content (%)	Positive	S	Ahmed <i>et al.</i> (2006)
	Positive	NS	Khurana <i>et al.</i> (2003) Hari <i>et al.</i> (2005)
	Negative	NS	Mallikarjun <i>et al.</i> (2003) Shiva <i>et al.</i> (2015) Hasan <i>et al.</i> (2016)
Association of fruit weight (g) with			
Ascorbic acid content (mg/100g)	Positive	S	Sharma <i>et al.</i> (2010) Sunnia <i>et al.</i> (2016)
	Positive	NS	Rajya and Vijaya (2011) Pandit and Ahikary (2014)
	Negative	NS	Farhad <i>et al.</i> (2008)
Capsanthin content (ASTA units)	Positive	NS	Amit <i>et al.</i> (2014) Hasan <i>et al.</i> (2016)
Association of ascorbic acid content (mg/100g) with			
Capsanthin content (ASTA units)	Negative	NS	Kaur and Singh (2009) Diwakar <i>et al.</i> (2012) Hasan <i>et al.</i> (2016)
Capsaicin content (%)	Positive	NS	Ahmed <i>et al.</i> (2006) Sujatha <i>et al.</i> (2017) Chakrabarty and Islam (2017)
	Negative	NS	Kaur and Singh (2009) Diwakar <i>et al.</i> (2012) Priyanka and Mishra (2014)
Association of capsanthin content (ASTA units) with			
Capsaicin content (%)	Positive	S	Krishnamurthy <i>et al.</i> (2013)
	Positive	NS	Kaur and Singh (2009) Shiva <i>et al.</i> (2015) Deepak <i>et al.</i> (2017) Sujatha <i>et al.</i> (2017)

S-Significant, NS-Non Significant

2.4 PATH COEFFICIENT ANALYSIS

Yield being a complex polygenic character, direct selection may not be a reliable approach on account of being highly influenced by environmental factors. Therefore, it becomes essential to identify the component characters through which yield improvement could be obtained. Though correlations give information about the components of a complex character like yield, but it could not provide an exact picture of relative importance of the direct and indirect contributions of the component characters to yield. In this context, path coefficient analysis is an important method in partitioning the correlation coefficients into direct and indirect effects of an independent variable on dependent variable. Thus, correlation in conjunction with path analysis would give a better insight into cause and effect relationship between different pairs of characters (Wright, 1921).

Path coefficient is simply a standardized partial regression coefficient and as such, measures the direct influence of one variable upon another and permits the separation of correlation coefficient into components of direct and indirect effects (Dewey and Lu, 1959).

The review of literature on direct effects of yield contributing characters on fruit yield per plant in *Capsicum annuum* L. is summarized and presented in Table 2.4.1

Table 2.4.1: Review of literature on direct effects of yield contributing characters on fruit yield in chilli

S. No.	Character	Positive direct effect	Negative direct effect
1	Plant height	Khurana <i>et al.</i> (2003) Choudhary and Samadia (2004) Karad <i>et al.</i> (2006) Patel <i>et al.</i> (2009) Mahantesh <i>et al.</i> (2013) Priyanka and Mishra (2014) Manoj <i>et al.</i> (2018)	Devi and Arumugam (1999) Farhad <i>et al.</i> (2008) Sharma <i>et al.</i> (2010) Rajya and Vijaya (2011) Tasso <i>et al.</i> (2014) Maurya <i>et al.</i> (2017b)
2	Number of primary branches per plant	Bhalekar <i>et al.</i> (2004) Nazir <i>et al.</i> (2005) Farhad <i>et al.</i> (2008) Kaur and Singh (2009) Sharma <i>et al.</i> (2010) Krishnamurthy <i>et al.</i> (2013) Pandit and Ahikary (2014) Hasan <i>et al.</i> (2016) Manoj <i>et al.</i> (2018)	Sunnia <i>et al.</i> (2016) Udachappa <i>et al.</i> (2017) Vidya <i>et al.</i> (2018)
3	Days to first flowering	Hasan <i>et al.</i> (2016) Priyanka and Mishra (2014) Hasan <i>et al.</i> (2016)	Mahantesh <i>et al.</i> (2013) Pandit and Ahikary (2014) Vidya <i>et al.</i> (2018)
4	Days to 50 % flowering	Gogoi and Gautam (2003) Ahmed <i>et al.</i> (2006) Farhad <i>et al.</i> (2008) Sunnia <i>et al.</i> (2016) Sujatha <i>et al.</i> (2017)	Karad <i>et al.</i> (2006) Udachappa <i>et al.</i> (2017) Manoj <i>et al.</i> (2018)
5	Days to first harvest	Krishna <i>et al.</i> (2007b) Sharma <i>et al.</i> (2007)	Sharma <i>et al.</i> (2010)
6	Days to last harvest	Srividhya <i>et al.</i> (2017)	
7	Fruit length	Khurana <i>et al.</i> (2003) Gogoi and Gautam (2003) Smitha and Basavaraja (2006b) Kaur and Singh (2009) Mahantesh <i>et al.</i> (2013) Priyanka and Mishra (2014) Hasan <i>et al.</i> (2016) Deepak <i>et al.</i> (2017) Manoj <i>et al.</i> (2018)	Choudhary and Samadia (2004) Sunnia <i>et al.</i> (2016) Udachappa <i>et al.</i> (2017) Sreelathakumary and Rajamony (2002) Sharma <i>et al.</i> (2010)
8	Fruit diameter	Gogoi and Gautam (2003) Sreelathakumary and Rajamony(2002) Nazir <i>et al.</i> (2005)	Choudhary and Samadia (2004) Priyanka and Mishra (2014) Shiva <i>et al.</i> (2015)

Table 2.4.1: Review of literature on direct effects of yield contributing characters on fruit yield in chilli (contd...)

S. No.	Character	Positive direct effect	Negative direct effect
	Fruit diameter	Sharma <i>et al.</i> (2007) Farhad <i>et al.</i> (2008) Krishnamurthy <i>et al.</i> (2013) Udachappa <i>et al.</i> (2017) Vidya <i>et al.</i> (2018) Manoj <i>et al.</i> (2018)	
9	Average fruit weight	Sreelathakumary and Rajamony (2002) Nazir <i>et al.</i> (2005) Ahmed <i>et al.</i> (2006) Sharma <i>et al.</i> (2007) Hosamani and Shivkumar (2008) Farhad <i>et al.</i> (2008) Kaur and Singh (2009) Sharma <i>et al.</i> (2010) Mahantesh <i>et al.</i> (2013) Priyanka and Mishra (2014) Dixita <i>et al.</i> (2015) Hasan <i>et al.</i> (2016) Sunnia <i>et al.</i> (2016) Maurya <i>et al.</i> (2017) Udachappa <i>et al.</i> (2017) Manoj <i>et al.</i> (2018)	Choudhary and Samadia (2004) Pandit and Ahikary (2014) Tasso <i>et al.</i> (2014)
10	Ascorbic acid content	Farhad <i>et al.</i> (2008) Sharma <i>et al.</i> (2010) Diwaker <i>et al.</i> (2012) Shiva <i>et al.</i> (2015) Mahantesh <i>et al.</i> (2013)	Rajya and Vijaya (2011) Sunnia <i>et al.</i> (2016) Manoj <i>et al.</i> (2018)
11	Capsaicin content	Khurana <i>et al.</i> (2003) Pandit and Ahikary (2014)	Kaur and Singh (2009) Diwaker <i>et al.</i> (2012)
12	Capsanthin content	Kaur and Singh (2009) Krishnamurthy <i>et al.</i> (2013)	Diwaker <i>et al.</i> (2012)
13	Chlorophyll content	Mahantesh <i>et al.</i> (2013)	

2.4.2: The review of literature pertaining to direct and indirect effects on fruit yield per plant in *Capsicum annuum* L. is presented as follows:

Munshi *et al.* (2000b) used a total of thirty germplasm of chilli to study the association between yield and yield attributes. Path analysis of yield and its components revealed that number of fruits/plant, fruit weight and fruit girth had direct positive effect on yield plant. When correlation and path analysis were viewed together, it revealed that yield improvement in chilli can be achieved by selection for number of fruits per plant, days to first fruit harvest and fruit weight.

Sreelathakumary and Rajamony (2002) studied and recorded the data of nine plant characters for fifteen accessions of hot chilli. Path analysis revealed that number of fruits per plant, fruit weight and fruit girth had positive direct effects on yield. Fruit length had a negative direct effect on yield, but its indirect effect through number of fruits per plant, fruit girth and fruit weight was high and positive. These results suggested that selection for number of fruits per plant, fruit weight, fruit length and fruit girth might lead to an increase in the yield of hot chilli.

Bhalekar *et al.* (2004) conducted study on path coefficient analysis of yield and its components in 40 genotypes of chilli. The study has revealed that the number of primary branches was the important yield determiner possessing maximum direct influence on yield.

Nazir *et al.* (2005) studied path coefficient analysis in a set of twenty one diverse genotypes for twelve horticultural traits. The study revealed that the characters like number of fruits, number of branches per plant, weight per fruit, fruit diameter and seed yield exercised maximum direct effect on fruit yield at genotypic level, indicating these traits are of great importance for yield improvement. High positive direct effect of number of branches, fruit diameter and fruit weight was the main cause of their positive association with fruit yield.

Karad *et al.* (2006) performed experimental studies on variability and path coefficient analysis for various yield and yield contributing characters in chillies

collected from NBPGR, New Delhi. The path coefficient analysis revealed fresh fruit weight as the most important component in determining the yield and has a direct effect on yield. Hence, direct selection based on fresh weight weight of fruits and fruits per plant can be done.

Ahmed *et al.* (2006) evaluated twenty five diverse germplasm lines of *Capsicum annuum* L. for thirteen characters, *i.e.* days to 50% flowering, plant height, number of branches, fruit length, fruit girth, flesh thickness, flesh-to-seed ratio, fruit weight, number of fruits per plant, seed weight per fruit, vitamin C content, pungency (OD value) and color (ASTA units). Path analysis revealed that fruit weight, seed weight per fruit, flesh-to-seed ratio, number of fruits per plant and days to 50% flowering had appreciable direct effects on fruit yield.

Path analysis in eighty genotypically diverse indigenous and exotic genotypes of chilli for thirteen important characters were studied by Krishna *et al.* (2007b) The phenotypic and genotypic path coefficient studies explained that early fruit yield per plant had the low positive direct effect on yield followed by late fruit yield per plant had the high positive direct effect which was counter balanced by its negative indirect effect through days to first flowering. Its positive indirect effect through plant height, fruit length, fruit breadth, number of fruits per plant, ten fruit weight, late fruit yield were responsible for its strong positive correlation with yield. Its positive indirect effect through ten fruit weight, plant height, fruit length, fruit girth, number of fruits per plant were mainly brought about its positive significant association with yield.

Sharma *et al.* (2007) carried out an investigation with fourteen diverse genotypes of bell pepper for fourteen characters. In path analysis, the highest direct positive effect was shown by average fruit weight followed by number of fruits per plant and fruit width. Besides days to first picking, harvest duration and seeds per fruit also had positive direct effect on total yield. However, net correlation of number of fruits per plant with fruit yield per plant was non-significant due to cancellation of high direct positive effects through indirect negative effects through average fruit weight and plant height. On the other hand, fruit width at stem end and blossom end showed negative direct effects but their

net correlation with fruit yield was significantly positive due to high positive indirect effects through average fruit weight and fruit width of the fruit.

Farhad *et al.* (2008) studied variability, association and direct and indirect effects among forty five chilli (*Capsicum annuum* L.) genotypes. Path analysis revealed that number of fruits per plant and fruit weight had highest positive direct effect at genotypic and phenotypic levels.

Hosamani and Shivkumar (2008) studied correlation and path coefficient analyses for yield and yield components in 69 chilli genotypes. Path analysis revealed that fruit yield per plant was directly affected by the number of fruits per plant, fruit weight and number of seeds per fruit. The results indicated that selection based on these characters may enhance the yield of pepper.

Ganesh *et al.* (2008) conducted correlation studies with 14 genotypes of chilli and revealed that the indirect effect of days to 50 per cent flowering through seed weight per fruit, plant height through number of fruits per plant and seed weight per fruit, number of primary branches via plant height, number of fruits per plant and seed weight per fruit, number of secondary branches through plant height, number of primary branches, number of fruits per plant and seed weight per fruit, number of fruits per plant via plant height, number of primary branches, number of seeds per fruit and seed weight per fruit, fruit width through average fruit weight, average fruit weight through fruit width, pedicel length, number of secondary branches, pericarp thickness and number of primary branches, number of fruits per plant, number of seed per fruit and seed weight per fruit and seed weight through number of secondary branches and fruit width were positive and high, which indicated that selection for any of these characters would indirectly improve the yield through the association characters.

Direct and indirect effects of twelve characters on yield per plant in thirty three genotypes of chilli assessed by Kaur and Singh (2009). Path analysis at phenotypic level revealed that number of fruits per plant had highest positive direct effect on yield per plant followed by fruit weight, fruit length and number of branches per plant, while plant height had highest direct effects in negative direction followed by days to first fruit harvest. Plant height had highest indirect

effect on yield per plant through number of fruits per plant and fruit weight. The indirect effect of fruit weight on fruit yield was highest in negative direction through number of fruit per plant. Number of branches per plant had positive indirect effect through plant height. Capsaicin content had highest positive direct effect on yield per plant. Ascorbic acid content had the highest direct effect in negative direction on yield per plant.

Sharma *et al.* (2010) studied path analysis in twenty three genotypes of bell pepper and reported that at genotypic level, number of fruits per plant had the highest positive direct effect on yield per plant followed by average fruit weight, number of branches, pedicel length and harvest duration, while negative direct effect was observed for days to first harvest, plant height and fruit length. Average fruit weight had high positive direct effect along with indirect effect via days to first harvest, number of fruits per plant and pedicel length. The highly significant positive association of fruit diameter was the result of positive indirect effect through average fruit weight, number of fruits per plant and days to first harvest and also some individual direct effect of average fruit weight. Number of fruits per plant had positive indirect effects *via* days to first harvest, average fruit weight and harvest duration.

Priyanka and Mishra (2016) conducted investigation on the correlation and path coefficient analysis in sixteen genotypes in chilli for 15 different qualitative and quantitative characters. Correlation coefficients at genotypic and phenotypic levels indicated that fruit yield per plant was positively and significantly correlated with fruit weight at edible maturity, number of fruits per plant, fruit length, number of branches per plant and ascorbic acid content but negative and significant association was found with days to 50% flowering. Path coefficient analysis revealed that the highest positive direct effect on fruit yield per plant was exerted by fruit weight at edible maturity followed by number of fruits per plant and fruit length, while as highest negative direct effect on fruit yield per plant was exerted by number of branches per plant and pedicel length.

Pandiyaraj *et al.* (2016) investigated genetic correlation and path coefficient analysis in thirty three germplasm in chilli for twelve quantitative and

four qualitative characters. The genotypic correlation coefficients were higher than phenotypic correlation coefficients for all the characters. The path coefficient analysis revealed that mean pod weight, number of secondary branches per plant and plant height, red pod yield per plant, capsanthin content, carotene content and capsaicin content could be considered major yield components and should be given importance while exercising selection.

Abraham *et al.* (2017) conducted character correlation and path coefficient analysis study using 55 hot pepper genotypes with the objectives to assess the nature of character correlation at phenotypic and genotypic levels and direct and indirect effects of traits on yield and yield components. Path analysis revealed that the maximum direct effect on fresh fruit yield was exerted by dry weight (0.6686), average fruit length (0.2185), fruit diameter (0.2085) and average fruit number per plant (0.1444) whereas plant height (-0.0173) and stem diameter (-0.0932) depicted negative direct effect and also negative indirect effects though the magnitude is relatively low.

Maurya *et al.* (2017) conducted study on 30 chilli genotypes to elucidate the association of various growth, yield and quality traits. Path coefficient analysis revealed that the highest direct effect on fruit yield per plant was exerted by average fruit weight followed by number of fruits per plant, showing its more accountability for higher fruit yield. Therefore, it may be possible to improve fruit yield and quality by selecting the accessions on the basis of number of fruits, average fruit weight and fruit body length.

Study on genetic variability, heritability, correlation and path analysis of 63 chilli genotypes conducted by Udachappa *et al.* (2017). Path-coefficient analysis revealed that fruit set percentage and fruit weight had the highest positive direct effect on fruit yield both at genotypic and phenotypic levels and most of the fruit related traits contributed to fruit yield mainly through fruit girth and fruit weight.

Vidya *et al.* (2018) conducted experiment on twenty chilli genotypes for correlation and path analysis studies for 14 characters. Path coefficient analysis

revealed that plant spread and fruit diameter was found positive and direct effect on fruit yield per plant, while stem girth, primary branches, days to first flowering was found high negative direct effect on fruit yield per plant. Plant height and days to first harvest had negligible effect on fruit yield per plant. Fruit diameter had highest indirect effect on yield per plant through fruit length and fruit stalk length.

Shweta *et al.* (2018) studied correlation and path analysis for forty two genotypes of chilli and concluded that fruit yield per plant had positive indirect effect fruit length, fruit girth, via traits like days to 50 per cent flowering, plant height, number of secondary branches, number of fruits per plant and green fruit weight.

Manoj *et al.* (2018) studied correlation and path coefficient analysis of twenty five chilli genotypes for 15 different qualitative and quantitative characters. Path coefficient analysis revealed that the highest positive direct effect on fruit yield per plant was exerted by average fruit weight followed by fruit length, fruit pericarp thickness, number of fruits per plant, fruit breadth, number of seeds per fruit, days taken for first flowering, number of primary branches, plant height and days to first fruit harvesting, while as highest negative direct effect on fruit yield per plant was exerted by ascorbic acid content, number of branches per plant, plant stem girth and days for 50% flowering. Therefore, selection should be practiced for average fruit weight, number of fruits per plant, fruit pericarp thickness and fruit length for direct improvement of fruit yield per plant.

Chethan *et al.* (2019) the present study was conducted at AICRP, during *rabi* season. Thirty four genotypes were evaluated in a RBD with three replications. The genotypes were evaluated on the basis of 15 parameters that included growth and yield. Characters like average fresh fruit weight, number of fruits per plant, fruit girth, and average dry fruit weight were positively and significantly correlated to yield at genotypic and phenotypic level. However, significant negative correlations were found with days to initial flowering, days to 50 % flowering and leaf area. Number of fruits per plant was found to exert

maximum positive direct effect on yield followed by average fresh fruit weight, average dry fruit weight and fruit girth. Thus direct selection through the characters would be very effective in chilli improvement programme.

CHAPTER-III

MATERIAL AND METHODS

The present investigation on “**Genetic Variability, Genetic Divergence Studies for Yield and Yield Related Traits in Chilli (*Capsicum annuum* L.) Germplasm**” was carried out during *Kharif*, 2019. The details of the material used and methods adopted for this study are presented in this chapter.

3.1 EXPERIMENT LOCATION AND CLIMATE

The present experiment was carried out during *Kharif*, 2019, at ICAR-NBPGR Regional Station, Rajendranagar, Hyderabad, which is situated in semi-arid tropical zone at an altitude of 542.6 meters above mean sea level with a geographical bearing of 79°-23' East longitude and 17°-19' North latitude. The meteorological data for the period of experimentation as recorded at the meteorological observatory of Agricultural Research Institute, Rajendranagar, Hyderabad, are presented in Appendix-I.

The present investigation was carried out as “Genetic variability, genetic divergence studies for yield and yield related traits in chilli (*Capsicum annuum* L.) germplasm”.

3.2 EXPERIMENTAL MATERIALS

The experimental materials comprised of 40 (36 elite lines+4 checks), chilli genotypes obtained from ICAR-NBPGR Regional Station, Rajendranagar, Hyderabad, and evaluated for 17 quantitative and qualitative traits to identify and selected. The accession numbers of the respective genotypes with source are presented in Table 3.1

3.3 EXPERIMENTAL DESIGN

The experiment was laid out in a completely Randomized Block Design with 40 chilli accessions as treatments during *Kharif*, 2019 at ICAR-NBPGR Regional Station, Rajendranagar, Hyderabad. Each treatment was randomly replicated thrice.

3.4 CROP HUSBANDRY

3.4.1 Nursery raising

The seed was sown in the plug trays on 10th June, 2019 and the seedlings were transplanted on 17th July, 2019 to main field. Field was thoroughly ploughed thrice and levelled. The recommended dose of manures and fertilizers were incorporated at the final levelling. The seedlings were transplanted in the field adopting a spacing of 60cm x 60cm in a plot measuring 1.8 m x 2.4 m.

3.4.2 Preparation of experimental plot

The experimental field was brought to fine tilth by ploughing thrice followed by harrowing. Before final harrowing, FYM @ 15 tonnes/ha was applied with recommended fertilizer doses of 200:60:80 kg NPK/ha in the form of Urea, Single Super Phosphate and Muriate of Potash, respectively. Urea and Muriate of Potash were applied in three equal splits during the crop growth period at the time of transplanting, 30 DAT and 60 DAT, whereas single super phosphate was applied as a basal dose.

3.4.3 Transplanting and after care

Five weeks old healthy seedlings were transplanted in the main field after allotting entries randomly in each replication. Each germplasm line was grown in a plot of 1.8m×2.4m (4.32 Sq. meters), with spacing of 60×60 cm per replication. Immediately after transplanting, the field was irrigated lightly. The plots were kept free of weeds and irrigated as and when required depending on soil moisture content. Need based plant protection measures were taken up to keep the plot free from pests and diseases.

3.5 OBSERVATIONS RECORDED

The data on different parameters were recorded by selecting and tagging five plants at random in each replication. The different observations were recorded as follows:

3.5.1 Plant height (cm)

Plant height was determined by measuring the length from the ground level to the tip of the plant in centimeters at the time of final harvest.

3.5.2 Plant spread (cm)

The plant spread was measured with the help of a twine held over the plant in the direction of maximum spread of the plant.

3.5.3 Number of primary branches per plant

The total number of branches arising from the main stem of randomly selected/tagged five plants in each replication were counted and averaged to get the number of primary branches per plant at the time of final harvest.

3.5.4 Days to first flowering (DAT)

The number of days from the date of transplanting to the day when the first plants flowers was recorded and expressed as number of days taken.

3.5.5 Days to 50 % flowering (DAT)

The number of days from the date of transplanting to the date on which 50 % of the plants bear flowers was recorded and expressed as number of days taken to attain 50 percent flowering.

3.5.6 Days to first harvest (DAT)

The number of days from the date of transplanting to the date on which fruits are harvested for the first time was expressed as days to first picking.

3.5.7 Days to last harvest (DAT)

Number of days taken from the date of transplanting to last picking was recorded.

3.5.8 Fruit length (cm)

The mean length of ten random ripe fruits from each of the selected tagged plants was measured in cm from the base of the calyx to the apex of the fruits.

3.5.9 Fruit diameter (cm)

The fruits which were used for fruit length were also used for measuring the fruits diameter in centimeters at the widest point of the fruits.

3.5.10 Number of fruits per plant

The number of fruits per plant was counted at the time of each harvest and the total number of fruits from all the pickings were pooled up and recorded as number of fruits per plant.

3.5.11 Average fresh fruit weight (g)

Ten fresh riped fruits were selected at random and weighed and the mean weight was taken as fresh fruit weight of the accession.

3.5.12 Fresh fruit yield per plant (kg/plant)

Fresh fruits harvested in all the pickings were weighed and recorded as total fresh fruit yield per plant and expressed in kilo grams per plant.

3.5.13 Fresh fruit yield per hectare (kg/ha)

Ten green riped fruits were selected at random and weighed and the mean weight was taken as fresh fruit weight of the accession.

3.5.14 Estimation of ascorbic acid content (mg/100g of fruit)

The ascorbic acid content was estimated as per the procedure given by Ranganna (1986).

3.5.14.1 Reagents

1. Meta-phosphoric acid (HPO_3) 3 %: Prepared by dissolving the sticks or pellets of HPO_3 in glass distilled water.
2. Ascorbic acid standard: 100 mg of L-ascorbic acid was dissolved in 3% HPO_3 and volume was made up to 100 ml. 10 ml of this solution was diluted to 100ml with 3% HPO_3 (1 ml = 0.1 mg of ascorbic acid).
3. Dye solution: 50 mg of the sodium salt of 2, 6-dichlorophenol-indophenol was dissolved in approximately 150 ml hot glass distilled water containing 42 mg of sodium bicarbonate. Cooled and diluted with distilled water to 200 ml stored in a refrigerator and was standardized every day.

3.5.14.2 Standardization of Dye

To 5 ml of standard ascorbic acid solution, 5 ml of HPO_3 was added. Microburette was filled with the dye and was titrated until a pink colour which persisted for 15 sec. Dye factor *i. e.* mg of ascorbic acid per ml of dye was determined using the formula given by Ranganna (1986):

$$\text{Dye factor} = \frac{0.5}{\text{Titre value}}$$

Here,

0.5 means 0.5mg of ascorbic acid in 5ml of 100ppm standard ascorbic acid solution
Titre = Volume of dye used to neutralize 5ml of 100ppm standard ascorbic acid solution along with 5ml of metaphosphoric acid.

3.5.14.3 Preparation of Sample

Ten grams of grounded fruit sample was blended with 3% metaphosphoric acid (HPO_3) and volume made up to 100ml with 3% HPO_3 . The contents after shaking well were filtered through Whatman No. 1 filter paper.

3.5.14.4 Assay of extract

Ten millilitres of the HPO_3 extract of sample was titrated against 2, 6-Dichlorophenol-Indophenol standard dye up to a pink end point which persisted for at least 15 seconds. Titration was done rapidly for preliminary determination of the titre. In the next determination, most of the dye required was added and then titrated accurately. The aliquot of sample was taken such that the titre did not exceeded 3 to 5ml. The results, thus obtained were expressed in terms of milligram of ascorbic acid per 100g of sample.

3.5.14.5 Calculation

The ascorbic acid content was calculated by using the following formula:

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract} \times \text{Weight of sample taken for extraction}} \times 100$$

Here,

Titre = Volume of dye used to titrate the aliquot of extract of a given sample.

3.5.15 Chlorophyll content of green chilli (%)

For measuring total chlorophyll content, fresh green mature chillies were used. Freshly harvested mature green chillies of 100mg were taken and cut into small pieces. Cut pieces were transferred into a test tube containing 7 ml of dimethyl sulphoxide (DMSO) and heated at 65° C for 3 hours in oven. Extract was collected by discarding the fruit sample. Then volume was made up to 10 ml with DMSO. Optical density of the extract was measured at 645 and 663 in a spectrophotometer using DMSO as blank.

3.5.16 Capsanthin content (ASTA units)

The capsanthin content of fruits was measured in ASTA (American Spice Trade Association) units was determined using the procedure outlined by ASTA (1986).

3.5.16.1 Procedure:

Sieved fine chilli powder of 100mg was weighed into a volumetric flask. Acetone was added and flask was closed tightly with stopper, then contents were kept for 16h at room temperature in dark and shaken intermittently. Solution was filtered using Whatman filter paper and final volume was made up to 100ml. Absorbance of final extract was read at 460nm using acetone as blank, using UVVIS Spectrophotometer.

ASTA color units were calculated as per the formula given below:

$$\text{ASTA} = \frac{\text{Absorbance at 460nm} \times 16.4}{\text{Weight of sample in grams}}$$

3.5.17 Capsaicin content (%)

The capsaicin content of fruits was estimated by colorimetric method described by Balasubramanian *et al.* (1982).

3.5.17.1 Principle:

The phenolic group in capsaicin reduces phosphomolybdic acid to lower acids of molybdenum. The resulting component is blue in color and is read at

650nm. The color intensity is directly proportional to the concentration of capsaicin.

3.5.17.2 Chemicals:

- 0.4% sodium hydroxide.
- 3% phosphomolybdic acid.
- Dry acetone (add 25g anhydrous sodium sulphate to 500ml of acetone at least one day before use).
- Stock standard capsaicin solution (exactly 50mg capsaicin was dissolved in 50ml of 0.4% NaOH solution (1000µg/ ml)).
- Working standard (10ml of the stock standard) was diluted to 50ml with 0.4% NaOH solution (200µg/ ml)).

3.5.17.3 Procedure:

0.5g Dry chilli powder was weighed into glass-stoppard test tube; 10ml dry acetone was added into the test tube and kept overnight for extraction. Next day samples were centrifuged at 10000rpm for 10min to get clear supernatant. 1ml of the supernatant was taken into a test tube and evaporated to dryness in a hot water bath. Then, the residue was dissolved in 5ml of 0.4% of NaOH solution and 3ml of 3% phosphomolybdic acid was added. The contents were shaken and left undisturbed for 1hr. After 1hr, the solution was quickly filtered into centrifuge tubes to remove any floating debris, and then centrifuged at 5000rpm for 15min. The clear blue coloured solution was directly transferred into the cuvette and absorbance was read at 650nm along with a reagent blank, using UV-VIS Spectrophotometer.

3.5.17.4 Preparation of standard graph:

A standard graph was prepared using 0-200µg pure capsaicin. Simultaneously 0.2, 0.4, 0.6, 0.8 and 1ml of working standard solutions were taken into new test tubes and proceeded as mentioned above. Per cent capsaicin was calculated using the formula mentioned below:

$$\text{Capsaicin (\%)} = \frac{\mu\text{g capsaicin}}{1000 \times 1000} \times \frac{100}{1} \times \frac{100}{2}$$

3.6 STATISTICAL ANALYSIS

The data were subjected to the following analyses with the help of standard statistical procedures:

1. Analysis of variance for RBD
2. Multivariate analysis (D^2 statistics)
3. Coefficient of variation, heritability in broad sense (h^2) and genetic advance (GA)
4. Correlation coefficient analysis
5. Path coefficient analysis

3.6.1 Analysis of variance (ANOVA) for RBD

The data collected on 17 characters were subjected to the analysis of variance for Randomized Block Design as suggested by Panse and Sukhatme (1985). Partitioning the total variance into replications and treatments represented the expectations of the variance and the appropriate degrees of freedom in each case. The computation of analysis of variance is as follows.

The model of ANOVA used is presented below: $Y_{ij} = \mu + g_i + v_j + e_{ij}$

Where,

- | | | |
|----------|---|---|
| Y_{ij} | = | Phenotypic observation of i^{th} genotype in j^{th} replication |
| M | = | General mean |
| G_i | = | Effect of i^{th} genotype |
| V_j | = | Effect of j^{th} replication |
| V_j | = | Effect of j^{th} replication |
| E_{ij} | = | Random error |

The analysis of variance (ANOVA) was carried out for each character as indicated below:

Source	d.f.	MSS	F calculated
Replications(r)	(r-1)	Mr	Mr/Me
Genotypes(treatments) (g)	(g-1)	Mg	Mg/Me
Error(e)	(r-1) (g-1)	Me	-
Total	(rg-1)	-	-

Where,

R	=	Number of replications
G	=	Number of genotypes (treatments)
Mg	=	Mean sum of squares of genotypes (treatments)
Mr	=	Mean sum of squares of replications
Me	=	Mean sum of squares of error
Df	=	Degrees of freedom
MS	=	Mean sum of square

The significance of mean sum of squares for each character was tested against the corresponding error degrees of freedom using F-test (Fisher and Yates, 1967). The level of significance was tested at 5% and 1% using F-test.

3.7 GENETIC DIVERGENCE

3.7.1 Mahalanobis' S Generalized Distance D^2

Genetic diversity among genotypes was estimated using by Mahalanobis D^2 statistics (Mahalanobis D^2 , 1936).

3.7.2 Test of significance

Variances were calculated for all the characters and test of significance was done. Analysis of covariance for the character pairs was estimated on the basis of mean values (Panse and Sukhatme, 1985). After testing the difference between genotypes for each of the characters, a simultaneous test of significance for differences in the mean values of a number of correlated variables with regard to the pooled effect of characters was carried out using 'V' statistic, which in turn

utilizes Wilk's criterion (Wilk, 1932). The sum of squares and sum of products of error and error + variety, variance - covariance matrix were used for this purpose. The estimation of Wilk's criterion was done using the following relationship.

$$\Lambda = \frac{(E)}{(E+V)}$$

Where,

Λ = Wilk's criterion

(E) = Determinant of error matrix and

(E + V) = Determinant of error + variety matrix

The significance of Λ was tested by V (Stat)

$$V(\text{Stat}) = -m \log_e \Lambda = -n \left[\frac{P+Q+1}{2} \right] \log_e \Lambda$$

Where, $m = n - (P + Q + 1) / 2$

n = Degrees of freedom for error + genotypes at base of natural log = 2.7183

P = Number of variables or characters.(19)

Q = Number of genotypes – 1 (or d.f. for genotypes) 57

$V(\text{stat})$ is distributed as χ^2 with PQ ($1083 = 19 \times 57$) degrees of freedom.

χ^2 table value at 5 per cent level of significance is 1137.50 (approx) distributed with 1083 degrees of freedom.

3.7.3 Transformation of correlated variables

In the present model, computation of D^2 values was reduced to simple summation of the differences in mean values of various characters of the two genotypes *i. e.* $\sum d_i^2$. Therefore transformation of correlated variables into uncorrelated ones was done before working out the D^2 values. Transformation was done using pivotal condensation method.

3.7.4 Computation of D^2 values

For the given combination of i^{th} and j^{th} genotype, the mean deviation (p) variables are computed and the D^2 values were calculated as:

$$D^2_{ij} = \sum_{t=1}^p (Y_i^t - Y_j^t)^2$$

Where y_{it} = Uncorrelated mean value of the i^{th} genotype for t character

y_{jt} = Uncorrelated mean value of the j^{th} genotype for t character

D^2_{ij} = D^2 between i^{th} and j^{th} genotype

3.7.5 Testing the significance of D^2 values

The D^2 value obtained for a pair of population is taken as calculated value of χ^2 and is tested against the tabulated value of χ^2 for P degrees of freedom where P is the number of characters considered.

3.7.6 Grouping of genotypes into various clusters

The grouping of genotypes into different clusters was done using the Tocher's method as described by Rao (1952). The criterion was that the two varieties belonging to the same cluster should at least on an average show a smaller D^2 value than those belonging to different clusters.

The first step in grouping into different cluster was to arrange the genotypes in order of their relative distance from each other. For this purpose, D^2 values of all combinations of each genotype were arranged in ascending order of magnitude in a tabular form as described by Singh and Chaudhary (1977). To start with two genotypes having the closest distance from each other were considered, to which the third population having the smallest average D^2 value from the first two genotypes was added. Similarly, the next nearest fourth population was considered and this procedure was continued. At certain stage, when it was felt that after adding a particular population there was an abrupt increase in the average D^2 , that population was not considered for including in that cluster. The genotypes of the first cluster were then eliminated and the rest were treated in a similar way. This procedure was continued until all the genotypes were included into one or other cluster.

3.7.7 Intra and inter cluster distance

1. Average intra cluster distance

The average intra cluster distances were calculated by the formula given by Singh and Chaudhary (1977).

$$\text{Square of intra cluster distance} = \Sigma Di^2 / n$$

Where,

ΣDi^2 = Sum of distance between all possible combinations.

n = Number of all possible combinations

2. Average inter cluster distance

The average inter cluster distance were calculated by the formulae described by Singh and Chaudhary (1977).

$$\text{Square of inter cluster distance} = \Sigma Di^2 / n_i n_j$$

Where,

ΣDi^2 = Sum of distances between all possible combinations ($n_i n_j$) of the entries included in the cluster study.

n_i = Number of entries in cluster i

n_j = Number of entries in cluster j

3.7.8 Cluster diagram

The cluster and their mutual relationship were presented diagrammatically by using D^2 values

3.7.9 Contribution of individual characters towards genetic divergence

The character contribution towards genetic divergence was computed using the method given by Singh and Chaudhary (1977). In all the combinations, each character was ranked on the basis of $d_i = y_i^j - y_i^k$ values.

Where,

d_i = mean deviation

y_i^j = mean value of the j^{th} genotype for the i^{th} character and

y_i^k = mean value of the k^{th} genotype for the i^{th} character.

Rank 'I' is given to the highest mean difference and rank 'P' is given to the lowest mean difference.

Where,

P is the total number of characters.

Finally, the number of times that each character appeared in the first rank is computed and per cent contribution of characters towards divergence was estimated using the formula

$$\text{Percentage contribution of character } x = \frac{N \times 100}{M}$$

X = Percent contribution of character

N = Number of genotype combinations where the character was ranked first.

M = All possible combinations of number of genotypes considered.

3.8 GENETIC VARIABILITY

The variability parameters among the genotypes traits of chilli were estimated by using the following formula:

3.8.1 Genotypic and phenotypic variance

The genotypic and phenotypic variance was computed based on the expected mean sum of squares as follows.

$$\text{Genotypic variance } \sigma^2_g = \frac{M_2 - M_3}{r} + M_3$$

$$\text{Phenotypic variance} = \sigma^2_p = \sigma^2_g + \sigma^2_e$$

Where,

σ^2_g = Genotypic variance (GV)

σ^2_p = Phenotypic variance (PV)

σ^2_e = Environmental variance (EV)

3.8.2 Coefficient of variation

Genotypic and phenotypic coefficient variations were computed according to Burton and De Vane (1953) based on the estimate of genotypic and phenotypic variance as follows:

$$GCV = \frac{\sqrt{GV}}{\bar{X}} \times 100$$

$$PCV = \frac{\sqrt{PV}}{\bar{X}} \times 100$$

Where,

GCV	=	Genotypic coefficient of variation
PCV	=	Phenotypic coefficient of variation
GV	=	Genotypic variance
PV	=	Phenotypic variance
$\bar{X}$	=	General mean of character

PCV and GCV were classified as suggested by Sivasubramanian and Menon (1973) and are given below

0-10 %	:	Low
10-20 %	:	Moderate
20 % and above	:	High

3.8.3 Heritability in broad sense (h^2)

Heritability in broad sense refers to the proportion of genetic variation to the total observed variance in the population. It has been estimated as per the formula given by Allard (1960). Heritability in broad sense is the ratio of genotypic variance to the phenotypic variance and is expressed in percentage.

$$h^2(b) = \frac{\text{Genotypic variance } (\sigma^2_g)}{\text{Phenotypic variance } (\sigma^2_p)} \times 100$$

The range of heritability in broad sense was classified as suggested by Johnson *et al.* (1955).

Less than 30 %	:	Low
30-60 %	:	Moderate
More than 60 %	:	High

3.8.4 Genetic advance (GA)

Genetic advance is the expected genetic gain of superior individual under certain amount of selection pressure. Genetic advance for each character was worked out by adopting the formula given by Johnson *et al.* (1955).

$$GA = K \times \sigma_p \times h^2(b)$$

where,

GA = Genetic advance.

$h^2(b)$ = Heritability in broad sense.

k = Selection differential which equal to 2.06 at 5 % intensity of selection (Lush, 1940)

σ_p = Phenotypic standard deviation

Further, the genetic advance as per cent of mean was computed by using the following formula

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

Genetic advance as per cent mean was categorized as given below as suggested by Johnson *et al.* (1955).

0- 10%	- Low
10.1-20%	- Moderate
>20.1%	- High

3.8.5 Correlation coefficient analysis

Character association refers to the association of characters *i.e.*, a change in one character brought about by a change in the other character Phenotypic and genotypic correlation coefficients between different variables were calculated by using covariance technique (Al-Jibouri *et al.*, 1958). To determine the degree of

association of characters with yield and also among the yield components, the correlation coefficients were calculated.

The phenotypic and genotypic correlations among yield and other character were computed as:

$$r_g(xy) = \frac{\text{Cov}_g(xy)}{\sqrt{\sigma_g^2(x) \cdot \sigma_g^2(y)}} \quad r_p(xy) = \frac{\text{Cov}_p(xy)}{\sqrt{\sigma_p^2(x) \cdot \sigma_p^2(y)}}$$

Where,

$r_g(xy)$, $r_p(xy)$ are the genotypic and phenotypic correlation coefficients respectively.

Cov_g , Cov_p are the genotypic and phenotypic covariance of x & y, respectively.

σ_g^2 and σ_p^2 are the genotypic and phenotypic variance of x and y, respectively.

3.8.6 Test of significance

Significance of correlation coefficients was tested by comparing phenotypic correlation coefficients with the table values (Fisher and Yates, 1967) at (n-2) degrees of freedom at 5 % and 1 % level where 'n' denotes the total number of pairs of observations used in the calculation.

3.8.7 Path coefficient analysis

The direct and indirect contribution of various characters to yield were calculated through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lee (1959). The following simultaneous equation were formed and solved for estimating various direct and indirect effects.

Path coefficients were obtained by solving the following simultaneous equations.

$$r_{ly} = P_{ly} + r_{12}P_{2y} + r_{13}P_{3y} + \dots + r_{lk}P_{ky}$$

Where,

r_{ly} = Simple correlation coefficient between x_1 and y, the dependent character

P_{ly} = Direct effect of x_1 on y, the dependent character

$r_{12}P_{2y}$ = Indirect effect of x_1 on y through x_2 .

r_{12} = Correlation coefficient between x_1 and x_2 .

$r_{1k}P_{ky}$ = Indirect effect of x_1 only through k^{th} variable.

In the same way, equations for r_{2y} , r_{3y} , r_{4y} , up to r_{ky} were obtained. The direct and indirect effects were calculated by solving the simultaneous equations. Besides the direct and indirect effects, the residual effect was computed by using the formula.

$$\text{Residual effect } (Pr_y) = 1 - R^2$$

Where, $R^2 = P_{1y}r_{1y} + P_{2y}r_{2y} + P_{3y}r_{3y} + \dots\dots\dots P_{iy}r_{iy}$

Pr_y = Residual effect

P_{1y} = Direct effect of x_1 on y .

r_{1y} = Correlation coefficient of x_1 and y

P_{2y} = Direct effect of x_2 on y

r_{2y} = Correlation coefficient of x_2 and y .

P_{3y} = Direct effect of x_3 on y

r_{3y} = Correlation coefficient of x_3 and y

P_{iy} = Direct effect of x_i on y

r_{iy} = Correlation coefficient of x_i and y

$$Pr_y = \sqrt{1 - P_{1y}r_{1y} + P_{2y}r_{2y} + \dots\dots\dots P_{ky}r_{ky}}$$

Where P_{ry} = Residual effect

P_{1y} = Direct effect of x_1 only

r_{1y} = Correlation coefficient of x_1 only

Scales for path coefficients

Values of direct (or) indirect effects	Rate (or) scale
0.00 to 0.09	Negligible
0.10 to 0.19	Low
0.20 to 0.29	Moderate
0.30 to 0.99	High
> 1.00	Very high

3D Plot

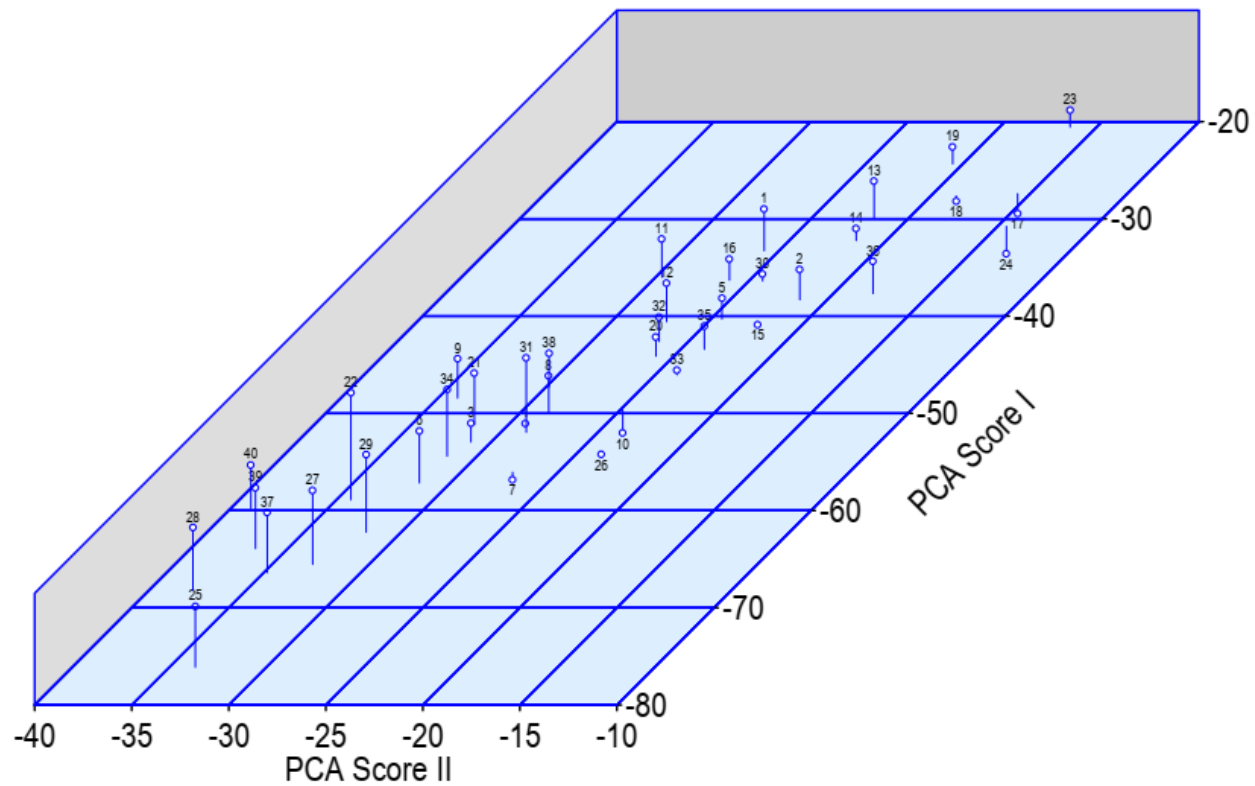


Fig 4.9: 3-Dimensional plot showing clustering pattern for divergence of 40 chilli genotypes

Table 4.1: ANOVA for 17 yield and yield attributes in 40 genotypes of chilli

S. No.	Characters	Mean Sum of Squares		
		Replications (df=2)	Treatments (df=39)	Error (df=78)
1	Plant height (cm)	33.233	578.388***	60.4
2	Plant spread (cm)	4.908	291.254***	48.42
3	Number of primary branches per plant	1.058	1.564***	0.66
4	Days to first flowering	0.525	144.614***	18.11
5	Days to 50 % flowering	2.275	165.058***	28.30
6	Days to first harvest	57.633	252.013***	69.67
7	Days to last harvest	20.008	258.084***	46.62
8	Fruit length (cm)	0.382	17.755***	0.42
9	Fruit diameter (cm)	0.077	0.397***	0.02
10	Number of fruits per plant	18.225	924.245***	72.29
11	Average fruit weight (g)	0.155	30.605***	0.82
12	Fruit yield per plant (kg/plant)	0.001	0.038***	0.01
13	Fruit yield per hectare (kg/ha)	2773408.000	95955965.165***	6023858.56
14	Ascorbic acid content (mg/100g)	0.681	1985.566***	0.29
15	Capsanthin (ASTA unit)	9.100	10773.365***	5.00
16	Capsaicin (%)	0.000	0.042***	0.00
17	Chlorophyll content of green fruits (%)	0.009	0.441***	0.00

* and ** significant at P = 0.05 and 0.01 levels, respectively

Table 4.2: Mean values of the 17 yield and yield contributing characters in 40 chilli genotypes

S. No.	Genotypes	PH	PS	NPBP	DDFF (DAT)	D50%F (DAT)	DFH (DAT)	DLH (DAT)	AFW	FL	FD	NFPP	FYPP	FYPH	ASA	CLC	CPSN	CPSI
1	EC-378630	76.67	63.66	4.66	33.33	47.33	98.33	146.33	4.46	10.53	1.26	57.00	0.254	12,700.0	68.75	2.08	128.33	0.35
2	EC-378635	92.66	62.00	4.67	22.33	33.00	80.67	128.33	4.02	8.30	1.46	31.33	0.125	6,266.6	72.70	2.17	193.33	0.28
3	EC-391083	49.67	59.33	6.00	28.00	49.33	98.33	134.66	8.85	12.60	1.13	36.00	0.318	15,900.0	89.52	2.22	255.67	0.14
4	EC-402105	104.00	57.00	4.33	42.33	54.33	100.33	142.33	4.91	11.16	1.13	19.00	0.093	4,650.0	84.36	1.78	340.00	0.25
5	EC-405253	68.33	54.33	4.33	26.33	45.00	89.33	128.66	5.38	6.50	1.50	32.00	0.172	8,583.3	78.00	1.91	201.00	0.13
6	EC-566920	78.67	64.67	4.67	31.33	35.33	77.67	120.00	6.59	9.96	1.20	53.00	0.349	17,466.6	101.91	2.12	237.33	0.37
7	EC-596940	45.66	54.33	4.00	26.33	35.33	74.66	132.66	13.30	13.70	1.86	33.00	0.439	21,933.3	77.53	1.91	297.33	0.17
8	EC-599969	56.00	71.67	3.67	35.33	47.33	94.33	138.33	7.50	11.67	1.43	49.00	0.367	18,366.6	85.26	2.07	217.33	0.37
9	EC-628901	56.33	48.66	6.00	39.00	52.33	97.66	135.33	4.23	9.76	1.00	52.00	0.220	10,983.3	92.63	2.32	238.00	0.26
10	IC-208534	84.33	74.00	6.00	26.00	46.33	89.33	156.33	8.01	11.63	1.56	43.33	0.347	17,341.6	71.02	1.73	358.67	0.21
11	IC-278055	70.67	72.33	7.00	31.33	49.33	93.00	148.00	4.57	9.46	0.86	91.33	0.417	20,833.3	68.45	1.38	166.00	0.52
12	IC-284474	74.67	58.33	5.00	31.33	47.33	90.67	146.66	2.52	7.63	0.90	32.33	0.081	4,050.0	85.68	2.24	190.33	0.17
13	IC-324215	86.33	67.33	5.00	31.33	49.33	89.67	144.66	3.08	7.13	0.93	23.66	0.073	3,643.3	63.85	2.17	138.67	0.36
14	IC-329995	84.00	63.66	4.33	35.33	49.33	91.66	128.33	2.42	7.36	0.90	29.33	0.071	3,533.3	61.57	2.06	226.33	0.22
15	IC-330193	85.67	79.33	4.33	26.33	33.00	73.33	137.33	2.53	5.80	0.96	34.67	0.088	4,383.3	68.63	1.98	328.00	0.26
16	IC-332924	95.66	58.33	5.00	38.33	49.33	94.67	139.66	3.27	7.10	0.83	64.33	0.210	10,500.0	68.96	1.85	238.33	0.33
17	IC-335340	91.33	55.67	4.00	31.33	42.33	82.00	133.33	2.65	4.60	1.06	27.33	0.072	3,610.0	39.21	2.20	309.00	0.31
18	IC-363905	93.33	87.33	5.00	26.33	42.33	88.66	138.00	2.81	6.90	0.86	28.66	0.080	4,000.0	51.89	2.00	238.00	0.19
19	IC-394731	94.00	71.33	5.33	26.66	49.33	91.66	143.33	2.31	8.70	0.90	66.33	0.153	7,666.6	48.18	1.65	188.00	0.45
20	IC-419750	102.00	68.00	5.33	38.00	47.33	93.33	144.33	3.53	6.03	1.20	52.00	0.183	9,166.6	83.26	0.78	244.33	0.26
21	IC-447065	95.33	39.67	4.33	33.33	52.33	101.67	143.66	3.75	7.16	1.13	28.00	0.105	5,233.3	102.52	1.63	202.00	0.32
22	IC-526432	75.00	65.67	4.67	31.33	42.33	84.67	138.33	3.28	5.33	1.30	58.33	0.191	9,566.6	127.32	2.19	142.00	0.49
23	IC-528876	93.00	59.66	5.00	26.33	35.33	79.67	129.66	3.29	7.76	1.03	40.33	0.132	6,616.6	45.38	2.29	127.67	0.16
24	IC-528879	95.33	69.33	4.66	26.00	45.00	92.66	151.66	4.64	4.60	1.36	35.66	0.165	8,266.7	46.84	0.38	262.00	0.19
25	IC-561614	82.33	47.66	3.66	26.33	31.33	74.66	126.66	15.03	10.93	1.86	27.00	0.406	20,283.3	129.55	2.00	227.00	0.22

Table 4.2: Mean values of the 17 yield and yield contributing characters in 40 chilli genotypes (contd...)

S. No.	Genotypes	PH	PS	NPBP	DFP (DAT)	D50%F (DAT)	DFH (DAT)	DLH (DAT)	AFW	FL	FD	NFPP	FYPP	FYPH	ASA	CLC	CPSN	CPSI
26	IC-561619	88.66	47.66	4.00	13.33	35.33	76.67	128.33	13.41	10.26	2.16	20.00	0.268	13,383.3	71.20	1.50	314.66	0.53
27	IC-561640	80.00	54.33	4.67	18.33	42.33	85.00	129.66	6.85	9.20	1.60	17.33	0.118	5,916.6	128.34	2.02	197.00	0.27
28	IC-561670	97.67	62.33	4.67	18.33	33.33	74.66	130.00	5.94	10.30	1.20	65.00	0.386	19,300.0	134.01	2.21	239.67	0.12
29	IC-561673	75.66	36.00	4.00	18.33	31.00	69.67	119.66	4.79	7.93	1.20	25.00	0.120	5,976.6	113.47	1.89	219.33	0.58
30	IC-561679	89.66	64.67	5.33	20.00	33.00	77.67	129.66	4.81	12.63	0.86	25.33	0.121	6,050.0	60.70	1.96	234.33	0.32
31	IC-561688	64.66	58.00	4.67	26.00	33.33	73.33	124.66	5.41	8.50	1.40	19.00	0.102	5,121.7	104.80	2.11	137.67	0.33
32	IC-561691	78.00	68.33	5.66	20.33	31.33	78.00	129.66	7.87	10.30	1.30	28.33	0.223	11,133.3	72.78	1.77	197.33	0.39
33	IC-561694	84.00	66.00	4.33	31.33	45.33	96.67	144.33	5.85	6.80	2.03	18.33	0.107	5,333.3	78.50	1.80	289.00	0.26
34	IC-561695	77.33	55.33	4.33	26.33	35.34	81.00	139.66	6.99	11.06	1.23	39.67	0.277	13,846.6	106.00	2.15	151.00	0.29
35	IC-561715	70.33	67.33	3.66	26.00	42.33	87.33	133.33	13.29	13.43	1.80	19.67	0.261	13,050.0	64.00	2.26	192.33	0.51
36	IC-561723	93.33	57.33	4.67	26.33	31.33	78.00	128.33	6.68	6.23	2.06	21.00	0.140	6,991.6	72.37	2.17	151.33	0.19
37	Arka Lohit	89.66	63.67	5.00	36.00	44.00	84.33	126.00	4.43	7.76	0.86	65.00	0.288	14,383.3	126.00	2.17	290.00	0.21
38	CA-960	87.67	55.00	4.33	31.33	40.33	94.67	146.66	6.04	11.40	1.00	35.33	0.213	10,650.0	89.59	1.89	195.00	0.19
39	LCA-334	87.33	65.00	5.67	42.00	53.33	101.00	156.00	6.20	9.43	1.20	65.33	0.405	20,266.6	119.63	1.80	243.00	0.35
40	Pusa Jwala	68.33	63.33	5.33	42.00	51.33	98.00	144.66	4.40	11.60	1.10	51.67	0.227	11,333.3	115.01	2.06	272.67	0.20
	Mean	81.58	61.44	4.78	29.15	42.35	86.96	136.68	5.75	8.98	1.26	39.02	0.209	10457.04	84.23	1.92	225.47	0.29
	CV	9.53	11.32	16.94	14.59	12.56	9.59	4.99	15.72	7.20	11.28	21.78	23.567	23.47	0.63	5.13	0.99	5.13
	S.Ed	6.34	5.68	0.66	3.47	4.34	6.81	5.57	0.73	0.52	0.11	6.94	0.040	2003.97	0.44	0.60	1.82	0.01
	CD (5%)	12.66	11.31	1.31	6.93	8.66	13.59	11.09	1.47	1.05	0.23	13.84	0.080	3989.62	0.87	0.11	3.64	0.02

PH - Plant height (cm), PS - Plant spread (cm), NPBP - Number of primary branches per plant, DFP - Days to first flowering, D50%F - Days to 50 percent flowering, DFH - Days to first harvest, DLH - Days to last harvest, AFW - Average fruit weight (g), FL - Fruit length (cm), FD - Fruit diameter (cm), NFPP – Number of fruits per plant, FYPP- Fruit yield per plant (kg/plant), FYPH- Fruit yield per hectare (kg/ha), ASA - Ascorbic acid (mg/100g), CLC - Chlorophyll content of green fruits (%), CPSN - Capsanthin (ASTA unit), CPSI - Capsaicin (%), DAT - Days after transplanting.

Table 4.3: Cluster wise distribution of 40 genotypes of chilli (Tocher's method)

Cluster	No. of genotypes	Genotypes
I	8	IC-561688, IC-561695, IC-447065, CA-960, EC-566920, EC-628901, EC-599969, IC-284474
II	11	EC-378630, IC-324215, IC-278055, IC-561723, EC-378635, IC-561715, IC-561691, IC-329995, IC-561679, IC-335340, EC-405253
III	1	IC-363905
IV	1	EC-391083
V	7	EC-596940, IC-561694, IC-561619, IC-330193, IC-208534 EC-402105, IC-419750,
VI	7	IC-561673, LCA-334, IC-561640, IC-561614, IC-561670, Arka Lohit, Pusa Jwala
VII	1	IC-528879
VIII	2	IC-419750, IC-528876
IX	1	IC-526432
X	1	IC-335340

Table 4.5: Mean values of clusters for 17 characters in 40 chilli genotypes (Tocher's method)

CLUSTER	Plant height (cm)	Plant spread (cm)	Number of primary branches per plant	Days to first flowering DAT	Days to 50% flowering DAT	Days to first harvest DAT	Days to last harvest DAT	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Number of fruits per plant	Fruit yield per plant (kg/plant)	Fruit yield per hectare (kg/ha)	Ascorbic acid content (mg/100g)	Capsanthin content (ASTA Units)	Capsaicin content (%)	Chlorophyll content of green fruits (%)
I	73.83	56.42	4.63	31.75	42.96	88.88	136.25	9.65	1.16	5.38	38.54	0.21	10714.79	96.05	196.08	0.29	2.07
II	82.33	63.58	4.94	28.27	41.88	87.12	135.00	9.00	1.25	5.45	38.48	0.19	9389.55	68.38	187.94	0.33	1.98
III	93.33	87.33	5.00	26.33	42.33	88.67	138.00	6.90	0.87	2.81	28.67	0.08	4000.00	51.90	238.00	0.19	2.00
IV	49.67	59.33	6.00	28.00	49.33	98.33	134.67	12.0	1.13	8.85	36.00	0.32	15900.00	89.52	255.67	0.14	2.22
V	84.90	63.76	4.62	29.10	42.43	86.33	140.81	9.34	1.56	7.37	31.48	0.22	10884.52	76.36	310.29	0.28	1.64
VI	83.00	56.05	4.71	28.76	40.95	83.90	133.95	9.60	1.29	6.81	45.19	0.28	13922.86	123.72	241.24	0.28	2.02
VII	95.33	69.33	4.67	26.00	45.00	92.67	151.67	4.60	1.37	4.64	35.67	0.17	8266.67	46.85	262.00	0.19	0.38
VIII	93.50	65.50	5.17	26.50	42.33	85.67	136.50	8.23	0.97	2.81	53.33	0.14	7141.67	46.78	157.83	0.31	1.97
IX	75.00	65.67	4.67	31.33	42.33	84.67	138.33	5.33	1.30	3.29	58.33	0.19	9566.67	127.33	142.00	0.49	2.19
X	91.33	55.67	4.00	31.33	42.33	82.00	133.33	4.60	1.07	2.65	27.33	0.07	3610.00	39.21	309.00	0.31	2.20

Table 4.4: Average intra (bold) and inter-cluster D^2 values for ten clusters in 40 chilli genotypes (Tocher's method)

Table 4.6: The nearest and farthest clusters from each cluster based on D² values in 40 chilli genotypes

Cluster No.	Nearest cluster with D² values	Farthest cluster with D² values
I	IV (603.16)	X (4910.89)
II	III (780.78)	VI (5447.72)
III	VII (325.48)	IX (8198.99)
IV	I (603.16)	VIII (4554.15)
V	IV (651.15)	IX (5395.65)
VI	IX (1317.78)	VIII (10643.73)
VII	III (325.48)	IX (9671.49)
VIII	III (886.00)	VI (10643.73)
IX	VI (1317.78)	X (11369.49)
X	III (539.56)	IX (11369.49)

Table 4.7: Percent contribution of different characters towards genetic divergence in 40 chilli genotypes

S. No.	Source	Times Ranked 1st	Contribution (%)
1	Plant height	0	0
2	Plant spread	0	0
3	Number of primary branches per plant	0	0
4	Days to first flowering	0	0
5	Days to 50% flowering	0	0
6	Days to first harvest	0	0
7	Days to last harvest	0	0
8	Fruit length	1	13
9	Fruit diameter	0	0
10	Average fruit weight	0	0
11	Number of fruits per plant	0	0
12	Fruit yield per plant	2	26
13	Fruit yield per hectare	4	51
14	Ascorbic acid content	491	62.95
15	Chlorophyll content of green chili	6	77
16	Capsanthin content	258	33.08
17	Capsaicin content	18	2.31

Table 4.8: Estimates of variability, heritability and genetic advance as percent of mean for 17 characters in 40 chilli genotypes

S. No.	Characters	Range		Mean	Variance		PCV %	GCV %	h ² (%)	Genetic advance	GA as % of mean
		Minimum	Maximum		Phenotypic	Genotypic					
1	Plant height	45.66	104.00	81.58	177.10	172.64	18.71	16.10	97	29.85	36.59
2	Plant spread	36.00	87.33	61.44	89.46	80.94	18.51	14.64	90	18.78	30.57
3	No. of primary branches per plant	3.66	7.00	4.78	0.95	0.90	20.47	20.11	95	0.81	17.06
4	Days to first flowering	13.33	42.33	29.15	60.27	42.16	26.63	22.27	70	14.33	49.19
5	Days to 50% flowering	31.00	54.33	42.35	73.88	45.58	20.29	20.04	62	14.00	33.05
6	Days to first harvest	69.67	101.67	86.96	130.44	60.78	13.13	8.96	47	14.04	16.15
7	Days to last harvest	119.66	156.33	136.68	117.11	70.48	7.91	6.14	60	17.19	12.58
8	Fruit length	4.60	13.70	8.98	6.19	5.77	27.71	26.76	93	6.12	68.24
9	Fruit diameter	0.83	2.16	1.26	0.14	0.12	30.14	27.95	86	0.86	68.43
10	Average fruit weight	2.31	15.03	5.75	10.74	9.92	57.00	54.79	93	7.99	139.03
11	Number of fruits per plant	17.33	91.33	39.02	356.27	289.98	48.36	43.18	82	39.71	101.77
12	Fruit yield per plant	0.070	0.438	0.209	0.013	0.012	57.37	52.35	93	0.26	126.13
13	Fruit yield per hectare	3533.33	21933.33	10457.0	36001227.4	29977368.8	57.37	52.35	83	13189.8	126.13
14	Ascorbic acid content	39.21	134.01	84.23	662.04	661.75	30.54	30.53	99	67.89	80.60
15	Capsanthin content	127.66	358.66	225.47	3594.45	3589.45	26.59	26.57	99	158.05	70.09
16	Capsaicin content	0.12	0.58	0.29	0.01	0.01	40.66	40.33	100	0.30	105.63
17	Chlorophyll content of green chilli	0.38	2.32	1.92	0.15	0.14	20.21	19.84	94	0.98	51.46

Table 4.9: Phenotypic (P) and genotypic (G) correlation coefficients among yield and yield attributes in 40 chilli genotypes

Character		PH	PS	NPBP	DFF	D50%F	DFH	DLH	FL	FD	AFW	NFPP	FYPH	ASA	CPSN	CPSI	CLC	FYPP
PH	P	1.0000	0.0921***	-0.0334	-0.0276	-0.0415	0.0059	0.0973	-0.4273***	-0.1393	-0.3215***	-0.0126	-0.3354***	-0.1691	0.0993	-0.0411	-0.2990	-0.3354
	G	1.0000	0.1451	-0.0798	0.0004	-0.0121	0.0200	0.2019	-0.4852	-0.1942	-0.4082	-0.0387	-0.4357	-0.1993	0.1206	-0.0571	-0.3598	-0.4369
PS	P		1.0000	0.3240***	0.0954	0.0774	0.0705	0.2335*	-0.0836	-0.2198*	-0.2089 *	0.2553**	0.0502	-0.3335***	0.0732	-0.0572	-0.1153	0.0502
	G		1.0000	0.3756	0.1361	0.1872	0.2055	0.4227	-0.0947	-0.2649	-0.2957	0.3271	0.0067	-0.4203	0.0885	-0.0774	-0.1555	0.0081
NPBP	P			1.0000	0.1454	0.2248*	0.1764	0.1729	0.0263	-0.3488***	-0.2274*	0.3438***	0.1115	-0.0570	-0.0376	-0.0201	-0.1054	0.1115
	G			1.0000	0.2719	0.5117	0.5385	0.6049	0.0688	-0.5605	-0.4255	0.7776	0.2361	-0.0965	-0.0776	-0.0455	-0.2114	0.2338
DFF	P				1.0000	0.7362***	0.6396***	0.4402***	-0.0755***	-0.3254***	-0.3208***	0.2903**	0.0103	0.0701	0.0919	-0.1399	-0.0025	0.0103
	G				1.0000	0.7533	0.7977	0.4720	-0.0991	-0.4345	-0.3834	0.4638	0.0598	0.0834	0.1109	-0.1610	-0.0123	0.0594
D50%F	P					1.0000	0.8218***	0.6220***	-0.0473	-0.3148***	-0.2899 **	0.2329*	-0.0540	-0.0682	0.1152	-0.0418	-0.1664	-0.0540
	G					1.0000	1.0339	0.6859	-0.0684	-0.3986	-0.3813	0.4179	-0.0183	-0.0886	0.1468	-0.0456	-0.2075	-0.0175
DFH	P						1.0000	0.7244***	0.0079	-0.1907*	-0.2259*	0.1695	-0.0470	-0.0776	0.0399	-0.1003	-0.1916*	-0.0470
	G						1.0000	0.6958	0.0071	-0.3470	-0.3445	0.3712	-0.0037	-0.1159	0.0616	-0.1402	-0.2513	-0.0026
DLH	P							1.0000	-0.0331	-0.1606	-0.2000*	0.2508**	0.0556	-0.1553	0.1140	-0.0456	-0.3885***	0.0556
	G							1.0000	-0.0349	-0.2325	-0.2599	0.3930	0.1080	-0.2008	0.1499	-0.0453	-0.4621	0.1094
FL	P								1.0000	0.1861*	0.6078***	-0.0027	0.5380***	0.1940*	0.1018	0.0377	0.2452**	0.5380
	G								1.0000	0.1791	0.6546	0.0205	0.6242	0.2010	0.1062	0.0398	0.2524	0.6247
FD	P									1.0000	0.7016***	-0.3964***	0.2170*	0.1089	0.1048	0.0569	-0.0691	0.2170
	G									1.0000	0.7601	-0.4774	0.2601	0.1170	0.1158	0.0555	-0.0748	0.2602

Table 4.9: Phenotypic (P) and genotypic (G) correlation coefficients among yield and yield attributes in 40 chilli genotypes

Character		PH	PS	NPBP	DFP	D50%F	DFH	DLH	FL	FD	AFW	NFPP	FYPH	ASA	CPSN	CPSI	CLC	FYPP
AFW	P										1.0000	-0.2516**	0.5584***	0.2114*	0.1806*	0.0876	0.0259	0.5584
	G										1.0000	-0.2831	0.6501	0.2194	0.1880	0.0917	-0.0748	0.6509
NFPP	P											1.0000	0.5824***	0.1539	-0.0830	0.1151	-0.1116	0.5824
	G											1.0000	0.5094	0.1728	-0.0955	0.1347	-0.1239	0.5087
FYPH	P												1.0000	0.3463***	0.1252	0.0414	-0.0295	1.0000
	G												1.0000	0.3805	0.1357	0.0511	-0.0329	1.0000
ASA	P													1.0000	-0.0444	-0.0215	0.2308*	0.3463
	G													1.0000	-0.0442	-0.0214	0.2347	0.3822
CPSN	P														1.0000	-0.2085*	-0.2442**	0.1252
	G														1.0000	-0.2109	-0.2488	0.1331
CPSI	P															1.0000	-0.0996	0.0414
	G															1.0000	-0.0975	0.0507
CLC	P																1.0000	-0.0295
	G																1.0000	-0.0326
FYPP	P																	1.0000
	G																	1.0000

*Significant at 5 per cent level, **Significant at 1 per cent level

PH - Plant height (cm), PS – Plant spread (cm), NPBP - Number of primary branches per plant, DFP - Days to first flowering, D50%F - Days to 50 percent flowering, DFH - Days to first harvest, DLH - Days to last harvest, AFW - Average fruit weight (g), FL - Fruit length (cm), FD - Fruit diameter (cm), NFPP – Number of fruits per plant, FYPP - Fruit yield per plant (kg/plant), FYPH- Fruit yield per hectare (kg/ha), ASA - Ascorbic acid (mg/100g), CPSN – Capsanthin (ASTA unit), CPSI - Capsaicin (%), CLC - Chlorophyll content of green fruits (%).

Table 4.10: Phenotypic (P) and genotypic (G) path coefficients indicating direct and indirect effects of components characters on fruit yield in 40 chilli genotypes

Character	Path effect	PH	PS	NPBP	DFP	D50%F	DFH	DLH	FL	FD	AFW	NFPP	FYPH	ASA	CPSN	CPSI	CLC	Correlation coefficient
PH	P	<u>0.0007</u>	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	-0.0003	-0.0001	-0.0002	0.0000	-0.0002	-0.0001	0.0001	0.0000	-0.0002	-0.3354
	G	<u>-0.0289</u>	-0.0042	0.0023	0.0000	0.0004	-0.0006	-0.0058	0.0140	0.0056	0.0118	0.0011	0.0126	0.0058	-0.0035	0.0016	0.0104	-0.4369
PS	P	-0.0004	<u>-0.0007</u>	-0.0001	0.0001	-0.0001	-0.0002	-0.0003	0.0004	0.0002	0.0004	0.0007	0.0001	-0.0009	0.0002	-0.0002	-0.0003	0.0502
	G	-0.0017	<u>-0.0115</u>	-0.0043	-0.0016	-0.0022	-0.0024	-0.0049	0.0011	0.0030	0.0034	-0.0038	-0.0001	0.0048	-0.0010	0.0009	0.0018	0.0081
NPBP	P	0.0000	-0.0001	<u>-0.0003</u>	0.0000	-0.0001	-0.0001	-0.0001	0.0000	0.0001	0.0001	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.1115
	G	0.0092	-0.0432	<u>-0.1151</u>	-0.0313	-0.0589	-0.0620	-0.0696	-0.0079	0.0645	0.0490	-0.0895	-0.0272	0.0111	0.0089	0.0052	0.0243	0.2338
DFP	P	0.0001	-0.0002	-0.0003	<u>-0.0021</u>	-0.0015	-0.0013	-0.0009	0.0002	0.0007	0.0007	-0.0006	0.0000	-0.0001	-0.0002	0.0003	0.0000	0.0103
	G	0.0000	-0.0076	-0.0152	<u>-0.0561</u>	-0.0422	-0.0447	-0.0265	0.0056	0.0244	0.0215	-0.0260	-0.0034	-0.0047	-0.0062	0.0090	0.0007	0.0594
D50%F	P	0.0002	-0.0004	-0.0011	-0.0035	<u>-0.0048</u>	-0.0039	-0.0030	0.0002	0.0015	0.0014	-0.0011	0.0003	0.0003	-0.0006	0.0002	0.0008	-0.0540
	G	-0.0008	0.0128	0.0350	0.0516	<u>0.0685</u>	0.0708	0.0470	-0.0047	-0.0273	-0.0261	0.0286	-0.0012	-0.0061	0.0101	-0.0031	-0.0142	-0.0175
DFH	P	0.0001	0.0006	0.0016	0.0059	0.0076	<u>0.0092</u>	0.0067	0.0001	-0.0018	-0.0021	0.0016	-0.0004	-0.0007	0.0004	-0.0009	-0.0018	-0.0470
	G	-0.0010	-0.0105	-0.0274	-0.0406	-0.0526	<u>-0.0509</u>	-0.0354	-0.0004	0.0176	0.0175	-0.0189	0.0002	0.0059	-0.0031	0.0071	0.0128	-0.0026
DLH	P	-0.0004	-0.0010	-0.0007	-0.0018	-0.0025	-0.0030	<u>-0.0041</u>	0.0001	0.0007	0.0008	-0.0010	-0.0002	0.0006	-0.0005	0.0002	0.0016	0.0556
	G	0.0082	0.0171	0.0245	0.0191	0.0277	0.0281	<u>0.0404</u>	-0.0014	-0.0094	-0.0105	0.0159	0.0044	-0.0081	0.0061	-0.0018	-0.0187	0.1094
FL	P	0.0011	0.0002	-0.0001	0.0002	0.0001	0.0000	0.0001	<u>-0.0026</u>	-0.0005	-0.0016	0.0000	-0.0014	-0.0005	-0.0003	-0.0001	-0.0006	0.5380
	G	-0.0269	-0.0052	0.0038	-0.0055	-0.0038	0.0004	-0.0019	<u>0.0554</u>	0.0099	0.0363	0.0011	0.0346	0.0111	0.0059	0.0022	0.0140	0.6247
FD	P	0.0008	0.0013	0.0020	0.0019	0.0018	0.0011	0.0009	-0.0011	<u>-0.0057</u>	-0.0040	0.0023	-0.0012	-0.0006	-0.0006	-0.0003	0.0004	0.2170
	G	-0.0019	-0.0027	-0.0056	-0.0043	-0.0040	-0.0035	-0.0023	0.0018	<u>0.0100</u>	0.0076	-0.0048	0.0026	0.0012	0.0012	0.0006	-0.0007	0.2602

Table 4.10: Phenotypic (P) and genotypic (G) path coefficients indicating direct and indirect effects of components characters on fruit yield in 40 chilli genotypes (Contd...)

Character	Path effect	PH	PS	NPBP	DFF	D50%F	DFH	DLH	FL	FD	AFW	NFPP	FYPH	ASA	CPSN	CPSI	CLC	Correlation coefficient
AFW	P	0.0006	0.0004	0.0004	0.0006	0.0006	0.0004	0.0004	-0.0012	-0.0014	<u>-0.0020</u>	0.0005	-0.0011	-0.0004	-0.0004	-0.0002	-0.0001	0.5584
	G	0.0166	0.0120	0.0173	0.0156	0.0155	0.0140	0.0106	-0.0267	-0.0309	<u>-0.0407</u>	<u>0.0115</u>	-0.0265	-0.0089	-0.0077	-0.0037	-0.0008	0.6509
NFPP	P	0.0001	-0.0020	-0.0028	-0.0023	-0.0019	-0.0014	-0.0020	0.0000	0.0032	0.0020	<u>0.7424</u>	-0.0080	-0.0047	-0.0012	0.0007	-0.0009	0.5824
	G	-0.0043	0.0361	0.0859	0.0512	0.0461	0.0410	0.0434	0.0023	-0.0527	-0.0313	<u>0.1104</u>	0.0563	0.0191	-0.0105	0.0149	-0.0137	0.5087
FYPH	P	-0.3381	0.0506	0.1124	0.0104	-0.0545	-0.0474	0.0561	0.5424	0.2188	0.5629	0.5872	<u>1.0082</u>	0.3491	0.1262	0.0417	-0.0298	1.0000
	G	-0.4153	0.0064	0.2251	0.0570	-0.0174	-0.0035	0.1030	0.5949	0.2479	0.6196	0.4855	<u>0.9531</u>	0.3627	0.1294	0.0487	-0.0314	1.0000
ASA	P	-0.0004	-0.0007	-0.0001	0.0001	-0.0001	-0.0002	-0.0003	0.0004	0.0002	0.0004	0.0003	0.0007	<u>0.0021</u>	-0.0001	0.0000	0.0005	0.3463
	G	0.0016	0.0033	0.0008	-0.0007	0.0007	0.0009	0.0016	-0.0016	-0.0009	-0.0017	-0.0014	-0.0030	<u>-0.0079</u>	0.0003	0.0002	-0.0018	0.3822
CPSN	P	-0.0003	-0.0002	0.0001	-0.0002	-0.0003	-0.0001	-0.0003	-0.0003	-0.0003	-0.0005	0.0002	-0.0003	0.0001	<u>-0.0026</u>	0.0005	0.0006	0.1252
	G	-0.0011	-0.0008	0.0007	-0.0010	-0.0014	-0.0006	-0.0014	-0.0010	-0.0011	-0.0017	0.0009	-0.0013	0.0004	<u>-0.0093</u>	0.0020	0.0023	0.1331
CPSI	P	0.0000	0.0000	0.0000	-0.0001	0.0000	-0.0001	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	-0.0001	<u>0.0006</u>	-0.0001	0.0414
	G	0.0020	0.0027	0.0016	0.0057	0.0016	0.0049	0.0016	-0.0014	-0.0019	-0.0032	-0.0047	-0.0018	0.0008	0.0074	<u>-0.0351</u>	0.0034	0.0507
CLC	P	0.0005	0.0002	0.0002	0.0000	0.0003	0.0003	0.0006	-0.0004	0.0001	0.0000	0.0002	0.0000	-0.0004	0.0004	0.0002	<u>-0.0017</u>	-0.0295
	G	0.0076	0.0033	0.0044	0.0003	0.0044	0.0053	0.0097	-0.0053	0.0016	-0.0004	0.0026	0.0007	-0.0049	0.0052	0.0020	<u>-0.0210</u>	-0.0326

Phenotypic Residual effect = 0.024; Genotypic Residual effect= 1.0003; Diagonal (under lined) values indicate direct effects

PH - Plant height (cm), PS – Plant spread (cm), NPBP - Number of primary branches per plant, DFF - Days to first flowering, D50%F - Days to 50 percent flowering, DFH - Days to first harvest, DLH - Days to last harvest, AFW - Average fruit weight (g), FL - Fruit length (cm), FD - Fruit diameter (cm), NFPP – Number of fruits per plant, FYPP - Fruit yield per plant (kg/plant), FYPH- Fruit yield per hectare (kg/ha), ASA - Ascorbic acid (mg/100g), CPSN – Capsanthin (ASTA units), CPSI - Capsaicin (%), CLC - Chlorophyll content of green fruits (%).

APPENDIX-I

Monthly meteorological data recorded at ARI, Rajendranagar during June, 2019 to December, 2019.

Month	Temperature ($^{\circ}\text{C}$)		Relative Humidity (%)		Rainfall (mm)	Rainy days	Sunshine (hours)	Wind Speed (km/hr)	Evaporation (mm)
	Maximum	Minimum	Morning	Evening					
June	36.82	19.95	80.50	48.23	2.83	0.21	7.43	6.10	7.80
July	31.80	18.29	83.45	58.22	1.95	0.25	4.09	6.31	5.35
August	29.87	17.41	88.22	67.96	6.15	0.38	4.38	7.98	4.20
September	29.70	16.65	93.06	69.86	10.62	0.46	3.32	2.12	3.23
October	30.06	16.58	92.96	70.32	4.16	0.38	5.30	0.18	2.88
November	29.85	17.71	90.33	49.36	0.00	0.00	7.76	0.03	3.03
December	27.82	15.79	91.67	51.96	0.28	0.03	6.42	0.02	2.59

CHAPTER-IV

RESULTS AND DISCUSSION

The present study entitled “Genetic variability, genetic divergence studies for yield and yield related traits in chilli (*Capsicum annuum* L.) germplasm” was carried out by involving 40 genotypes of chilli during *Kharif*, 2019 at ICAR-NBPGR Regional Station, Rajendranagar, Hyderabad.

The data were collected from all these 40 genotypes for 17 characters viz., plant height (cm), plant spread (cm), number of primary branches per plant, days to first flowering (DAT), days to 50 % flowering (DAT), days to first harvest (DAT), days to last harvest (DAT), fruit length (cm), fruit diameter (cm), average fresh fruit weight (g), number of fruits per plant, fresh fruit yield per plant (kg/plant), fresh fruit yield per hectare (kg/ha), ascorbic acid content (mg/100g of fruit), chlorophyll content of green chilli (%), capsanthin content (ASTA Units) and capsaicin content (%) were subjected to statistical analysis for drawing appropriate and valid conclusions. The results of the present investigation are presented under following headings:

- 4.1 Analysis of Variance (ANOVA)
- 4.2 Mean performance of germplasm lines
- 4.3 Genetic Variability, heritability h^2 and genetic advance parameters
- 4.4 Genetic divergence (D^2 statistic)
- 4.5 Correlation coefficient analysis
- 4.6 Path coefficient analysis of variance

4.1 ANALYSIS OF VARIANCE

The data on Analysis of Variance (ANOVA) for yield and its attributing characters under study are presented in Table 4.1. The mean sum of squares for genotypes was found to be significant for all the 17 characters studied viz., plant height (cm), plant spread (cm), number of primary branches per plant, days to first flowering DAT, days to 50 % flowering DAT, days to first harvest DAT, days to last harvest DAT, fruit length (cm), fruit diameter (cm), average fresh

fruit weight (g), number of fruits per plant, fresh fruit yield per plant (kg/plant), fresh fruit yield per hectare (kg/ha), ascorbic acid content (mg/100g of fruit), chlorophyll content of green chilli (%), capsanthin content (ASTA units) and capsaicin content (%) indicated that the genotypes under investigation were different statistically from each other. Similarly mean sum of squares o of replications were also significant revealing that environmental error is eliminated. Hence, differences among genotypes are free from existing environmental influence.

4.2 MEAN PERFORMANCE OF CHILLI GENOTYPES

The mean performance of 40 genotypes of chilli with respect to various yield and yield attributes are described character wise below. Mean performance of the genotypes for 17 biometric characters and one qualitative character are presented in Table 4.2.

4.2.1 Plant height (cm)

Plant height ranged from 45.66cm to 104.00cm with a grand mean of 81.58cm. Among the genotypes, EC-402105 showed maximum plant height (104.00cm) which was statistically on par with 10 genotypes viz., IC-419750 (102.00cm), EC-378635 (92.66cm), IC-332924 (95.66cm), IC-335340 (91.33cm), IC-363905 (93.33cm), IC-394731 (94.00cm), IC-447065 (95.33cm), IC-528876 (93.00cm), IC-528879 (95.33cm) and IC-561670 (97.67cm). While the minimum height (45.66cm) recorded in EC-596940. Eleven genotypes were significantly taller than the best check Arka Lohit (89.66cm) and IC-561679 (89.66cm) recorded equal value with this check.

4.2.2 Plant spread (cm)

Plant spread ranged from 36.00cm to 87.33cm with a grand mean of 61.44cm. Among the genotypes, IC-363905 showed maximum plant spread (87.33cm) which was statistically on par with IC-330193 (79.33). While the minimum spread (36.00cm) was observed in IC-561673. Thirteen genotypes viz., EC-599969 (71.67cm), IC-208534 (74.00cm), IC-278055 (72.33cm), IC-324215 (67.33cm), IC-330193 (79.33cm), IC-363905 (87.33cm), IC-394731 (71.33cm), IC-419750 (68.00cm), IC-526432 (65.67cm), IC-528879 (69.33cm), IC-561691 (68.33cm), IC-561694 (66.00cm) and IC-561715 (67.33cm)

(87.33cm) were recorded more plant spread than the best check LCA-334 (65.00cm).

4.2.3 Number of primary branches per plant

Number of primary branches per plant ranged from 3.66 to 7.00 with a grand mean of 4.78. Among the genotypes, IC-278055 recorded maximum number of primary branches per plant (7.00). While the minimum number of primary branches per plant (3.66) were observed in EC-599969, IC-561614 and IC-561715. Four genotypes viz., EC-391083 (6.00), EC-628901 (6.00), IC-208534 (6.00) and IC-278055 (7.00) exhibited significantly higher values for number of primary branches per plant than the best check LCA-334 (5.67). Whereas IC-561691 (5.66) was on par with check LCA-334.

4.2.4 Days to first flowering (DAT)

The number of days to first flowering (DAT) ranged from 13.33 to 42.33 days with a total mean of 29.15 days. Among the genotypes, IC-561619 took minimum days to first flowering (13.33 days), while EC-402105 took maximum days to first flowering (42.33 days). Only five genotypes viz., EC-378635 (22.33 days), EC-391083 (28.00 days), IC-561673 (18.33 days), IC-561688 (26.00 days) and IC-561691 (20.33 days) were statistically earlier to first flowering when compared to check variety CA-960 (31.33 days).

4.2.5 Days to 50 % flowering (DAT)

Number of days to 50 per cent flowering (DAT) ranged from 31.00 to 54.33 days with a total mean of 42.35 days. Among the genotypes, IC-561673 took minimum days to 50 % flowering (31.00 days), while EC-402105 took maximum days to 50 % flowering (54.33 days). Fourteen genotypes viz., EC-378635 (33.00 days), EC-566920 (35.33 days), EC-596940 (35.33 days), IC-330193 (33.00 days), IC-528876 (35.33 days), IC-561614 (31.33 days), IC-561619 (35.33 days), IC-561670 (33.33 days), IC-561673 (31.00 days), IC-561679 (33.00 days), IC-561688 (33.33 days), IC-561691 (31.33 days), IC-561695 (35.34 days) and IC-561723 (31.33 days) took less number of days to 50% flowering than the better check CA-960 (40.33 days). Where only four genotypes are statistically earlier to 50% flowering when compared to check.

4.2.6 Days to first harvest (DAT)

Days to first harvest (DAT) ranged from 69.67 to 101.67 days with a grand mean of 86.96 days. Among the genotypes, IC-561673 took minimum days for first harvesting (69.67 days), while IC-447065 took maximum days for first harvesting (101.67 days). Only one genotype IC-447065 (101.67 days) took more number of days to first harvest than the best check LCA-334 (101.00 days). While 15 genotypes viz., EC-378635 (80.67 days), EC-566920 (77.67 days), EC-596940 (74.66 days), IC-330193 (73.33 days), IC-335340 (82.00 days), IC-528876 (79.67 days), IC-561614 (74.66 days), IC-561619 (76.67 days), IC-561670 (74.66 days), IC-561673 (69.67 days), IC-561679 (77.67 days), IC-561688 (73.33 days), IC-561691 (78.00 days), IC-561695 (81.00 days) and IC-561723 (78.00 days) were statistically on par with each other related to days to first harvest.

4.2.7 Days to last harvest (DAT)

Days to last harvest (DAT) ranged from 119.66 to 156.33 days with a grand mean of 136.68 days. Among the genotypes, IC-561673 took minimum days for last harvesting (119.66 days), while IC-208534 took maximum days to last harvest (156.33 days). Three genotypes viz., IC-566920 (120.00 days), IC-561688 (124.66 days) and IC-561688 (119.66 days) recorded lower values for days to last harvest than the best check Arka Lohit (126.00 days).

4.2.8 Fruit length (cm)

The trait fruit length exhibited a range of 4.60 cm to 13.70 cm with a total mean of 8.98 cm. Among the genotypes, EC-596940 showed maximum fruit length (13.70cm), while the minimum fruit length (4.60cm) was observed in IC-335340 and IC-528879. Six genotypes viz., EC-391083 (12.60cm), EC-596940 (13.70cm), EC-599969 (11.67cm), IC-208534 (11.63cm), IC-561679 (12.63cm) and IC-561715 (13.43cm) recorded significantly lengthy fruits than the best check Pusa Jwala (11.60cm).

4.2.9 Fruit diameter (cm)

The mean values for fruit diameter ranged from 0.83 cm to 2.16 cm with a total mean of 1.26 cm. Among the genotypes, IC-561619 showed maximum fruit

diameter (2.16cm), while the minimum fruit diameter (0.83cm) was observed in IC-332924. Sixteen genotypes viz., EC-378630 (1.26cm), EC-378635 (1.46cm), EC-405253 (1.50cm), EC-596940 (1.86cm), EC-599969 (1.43cm), IC-208534 (1.56cm), IC-528879 (1.36cm), IC-526432 (1.30cm), IC-561614 (1.86cm), IC-561619 (2.16cm), IC-561640 (1.60cm), IC-561688 (1.40cm), IC-561691 (1.30cm), IC-561694 (2.03cm), IC-561715 (1.80cm) and IC-561723 (2.06cm) recorded higher values for fruit diameter than the best check LCA-334 (1.20 cm). Whereas IC-561695 (1.23cm) was statistically on par with check LCA-334.

4.2.10 Average fresh fruit weight (g)

The grand mean of average fruit weight was 5.75g with a range of 2.31g to 15.03g. Among the genotypes, IC-561614 showed maximum average fresh fruit weight (15.03g), while IC-394731 had minimum average fresh fruit weight (2.31g). Eight genotypes viz., EC-391083 (8.85g), EC-596940 (13.30g), EC-599969 (7.50g), IC-208534 (8.01g), IC-561614 (15.03g), IC-561619 (13.41g), IC-561691 (7.87g) and IC-561715 (13.29g) exhibited significantly higher values for average fresh fruit weight than the best check LCA-334 (6.20g). Whereas other four genotypes EC-566920 (6.59g), IC-561640 (6.85g), IC-561695 (6.99g), and IC-561723 (6.68g) were statistically on par with check LCA-334.

4.2.11 Number of fruits per plant

Number of fruits per plant ranged from 17.33 to 91.33 with a grand mean of 39.02. Among the genotypes, IC-278055 showed maximum number of fruits per plant (91.33). While the minimum number of fruits per plant (17.33) was observed in IC-561640. Only one genotype IC-278055 (91.33) recorded higher number of fruits per plant than the best checks Arka Lohit (65.00) and LCA-334 (65.33). Whereas IC-394731 (66.33) was statistically on par with best checks Arka Lohit and LCA-334.

4.2.12 Fresh fruit yield per plant (kg/plant)

Fresh fruit yield per plant ranged from 0.071kg to 0.439kg with a total mean of 0.209kg. Among the genotypes, EC-596940 showed maximum fresh fruit yield per plant (0.439kg), while the minimum fresh fruit yield per plant (0.071kg) was observed in IC-329995. Two genotypes EC-596940 (0.439kg) and

IC-278055 (0.417kg) recorded higher fresh fruit yield per plant than the best check LCA-334 (0.405kg). Whereas IC-561614 (0.406kg) was statistically on par with the best check LCA-334.

4.2.13 Fresh fruit yield per hectare (kg/ha)

Fresh fruit yield per hectare ranged from 3533.3kg to 21933.3kg with a total mean of 10457.04kg. Among the genotypes, EC-596940 showed maximum fruit yield per hectare (21933.3kg), while the minimum fruit yield per hectare (3533.3kg) was observed in IC-329995. Three genotypes EC-596940 (21933.3kg), IC-278055 (20833.3kg) and IC-561614 (20283.3kg) recorded significantly higher values for fresh fruit yield per hectare than the best check LCA-334 (20266.6kg).

4.2.14 Ascorbic acid content (mg/100 g of fruit)

The quality character ascorbic acid content ranged from 39.21mg/100g to 134.01 mg/100g with a total mean of 84.23 mg/100g. Among the genotypes, IC-561670 showed maximum ascorbic acid content (134.01mg/100g), while the minimum ascorbic acid content (39.21mg/100g) was observed in IC-335340. Four genotypes IC-526432 (127.32mg/100g), IC-561614 (129.55mg/100g), IC-561640 (128.34mg/100g) and IC-561670 (134.01mg/100g) exhibited significantly higher values for ascorbic acid content than the best check Arka Lohit (126mg/100g).

4.2.15 Capsanthin content (ASTA units)

Capsanthin content ranged from 127.67 to 358.67 ASTA units with a grand mean of 225.47 ASTA units. Among the genotypes, IC-208534 showed maximum capsanthin content (358.67 ASTA units), while the minimum capsanthin content (127.67 ASTA units) was observed in IC-528876. Five genotypes serially EC-596940 (297.33 ASTA units), IC-208534 (358.67 ASTA units), IC-330193 (328.00 ASTA units), IC-335340 (309.00 ASTA units) and IC-561619 (314.66 ASTA units) recorded significantly higher values for capsanthin content than the best check Arka Lohit (290.00 ASTA units).

4.2.16 Capsaicin content (%)

The mean values for the quality trait capsaicin content ranged from 0.12% to 0.58% with a total mean of 0.29%. Among the genotypes, maximum capsaicin content (0.58%) was observed in IC-561673, while IC-561670 showed minimum capsaicin content (0.12%). Eleven genotypes viz., EC-378630 (0.35%), EC-566920 (0.37%), EC-599969 (0.37%), IC-278055 (0.52%), IC-324215 (0.36%), IC-394731 (0.45%), IC-526432 (0.49%), IC-561619 (0.53%), IC-561673 (0.58%), IC-561691 (0.39%) and IC-561715 (0.51%) recorded significantly higher values for capsaicin content than the best check LCA-334 (0.35%).

4.2.17 Chlorophyll content of green chilli (%)

The mean values for chlorophyll content of green chilli ranged from 0.38% to 2.32% with the grand mean value of 1.92%. Maximum chlorophyll content (2.32%) was recorded in EC-628901, whereas the minimum content of chlorophyll (0.38%) was recorded in IC-528879. Ten genotypes namely, EC-378635 (2.17%), EC-391083 (2.22%), EC-628901 (2.32%), IC-284474 (2.24%), IC-324215 (2.17%), IC-335340 (2.20%), IC-526432 (2.19%), IC-528876 (2.29%), IC-561670 (2.21%) and IC-561715 (2.26%) recorded higher chlorophyll content than the best check Arka Lohit (2.17%), and IC-561723 (2.17%) recorded equal value with this check.

4.3 GENETIC DIVERSITY

The results of quantitative assessment of genetic divergence among 40 genotypes of chilli for yield and yield contributing characters following Mahalanobis's D^2 statistic are presented below.

4.3.1 Mahalanobis's generalized distance D^2

In order to assess the genetic diversity among the 40 genotypes, D^2 statistic was carried out by following the procedure given by Rao (1952). Since all the seventeen variables were correlated, they were transformed into uncorrelated linear combinations through pivotal condensation method.

4.3.2 Grouping of genotypes into various clusters

Procedure suggested by Tocher (Rao, 1952) was used to group 40 chilli genotypes into ten clusters by treating estimated D^2 values as the square of the generalized distance. The pattern of distribution of 40 genotypes into various clusters is indicated in Table 4.3. Out of ten clusters formed, cluster II was the largest group comprising of 11 genotypes, followed by cluster I 8 genotypes, cluster V and VI with 7 genotypes each, cluster VIII with 2 genotypes, whereas clusters III, IV, VII, IX, and X are monotypic or solitary.

4.3.3 Average intra and inter cluster distances

The mean intra and inter cluster D^2 values among the 10 clusters are given in the Table 4.4. The intra cluster distance was ranged from 0.00 to 511.49. Cluster VI had the maximum D^2 value (511.49) followed by cluster I (492.82), cluster V (469.64), cluster VIII (450.90) and cluster II (450.67). No intra cluster distance was observed in clusters III, IV, VII, IX, X.

The inter cluster D^2 values of the ten clusters revealed that the highest inter cluster generalized distance (11369.49) was between cluster IX and cluster X, while, the lowest (325.48) was between cluster III and cluster VII.

The minimum inter cluster distance between cluster III and VII indicated narrow genetic diversity and the maximum between clusters IX and X followed by cluster VI and VIII indicated wider genetic diversity among the genotypes included in these groups. Selection of parents from these diverse clusters for hybridization programme would help in achieving novel recombinants.

4.3.4 Performance of characters in cluster

The cluster means for each of the 17 traits are presented in Table 4.5. From the data, it can be seen that considerable differences exist for all the traits studied.

The genotype of the cluster VII recorded highest plant height (cm) of (95.33) followed by cluster VIII (93.50), cluster III (93.33) and cluster X (91.33), while the genotype of cluster IV registered lowest plant height (49.67).

The genotype of the cluster III recorded highest plant spread (cm) of (87.33) followed by cluster VII (69.33), while the genotype of cluster X registered lowest plant spread (55.67).

The genotype of the cluster IV recorded highest number of primary branches per plant (6.00) followed by the genotype of the cluster VIII (5.17) and the genotype of the cluster III (5.0), while the genotype of the cluster X was observed to have lowest number of primary branches per plant (4.00).

Genotype grouped into cluster VII showed minimum number of days (26.00) for first flowering followed by the genotype of the cluster III (26.33) and genotype VIII (26.50), whereas the genotype of the cluster I recorded highest number of days for first flowering (31.75).

Genotype grouped into cluster VI showed minimum number of days (40.95) for 50% flowering followed by the genotype of the cluster II (41.88), whereas the genotype of the cluster IV recorded highest number of days for 50% flowering (49.33).

The number of days for first harvest was observed to be minimum (82.00) for the genotype of the cluster X followed by the genotype of the cluster VI (83.90), while the maximum number of days (98.33) has been observed by the genotype of the cluster IV.

The genotype of the cluster X recorded lower number of days (133.33) to last harvest followed by the genotype of the cluster VI (133.95), while the genotype of the cluster VII showed highest number of days for final harvest (151.67).

The genotype of the cluster IV recorded highest fruit length (cm) (12.60) followed by the genotype of the cluster I (9.65) and the genotype of the cluster VI (9.65), while the genotype of the cluster VII and genotype of the cluster X recorded lowest fruit length (4.60).

Highest fruit diameter (cm) (1.56) was recorded for the genotype of the cluster V followed by the genotype of the cluster VII (1.37), while the genotype of the cluster III showed lowest fruit diameter (0.87).

Average fresh fruit weight (g) was observed to be highest (8.85) for the genotype of the cluster IV 2 followed by the genotype of the cluster V (7.37), while the lowest average fruit weight (2.65) was recorded by the genotype of the cluster X.

The genotype of the cluster IX was recorded to have highest number of fruits per plant (58.33) followed by the genotype of the cluster VIII (53.33), whereas the genotype of the cluster X was noted to have lowest number of fruits per plant (27.33).

The genotype of the cluster IV was recorded to have highest fruit yield (kg) per plant (0.32) followed by the genotype of the cluster VI (0.28), whereas the genotype of the cluster X was noted to have lowest fresh fruit yield per plant (0.07).

The fresh fruit yield per hectare (kg/ha) was found to be highest (15900) for the genotype of the cluster IV followed by the genotype of the cluster VI (13922.86), while the genotype of the cluster X was found to have lowest fruit yield (kg/ha) per hectare (3610).

Ascorbic acid content of the fruits was found to be highest (127.33) for the genotype of the cluster IX followed by the genotype of the cluster VI (123.72), while the lowest ascorbic acid content was noted for the genotype of the cluster X (39.21).

Capsanthin content was observed to be highest (310.29) for the genotype of the cluster V followed by the genotype of the cluster X (309.00), while the lowest capsanthin content was recorded by the genotype of the cluster IX (142.020).

The genotype of the cluster IX showed highest capsaicin content (0.49) followed by the genotype of the cluster II (0.33), while the genotype of the cluster IV recorded lowest capsaicin (0.14).

Chlorophyll content of the green fruits was found to be highest (2.22) for the genotype of the cluster X followed by the genotype of the cluster IX (2.20), while the least chlorophyll content was observed by the genotype of the cluster VII (0.38).

The wide range of mean values among the clusters and the characters studied indicated the presence of wide variation among the genotypes.

4.3.5 Relative contribution of characters towards diversity

Number of times each of 17 traits appeared in first rank and its respective per cent contribution towards genetic divergence are presented in Table 4.7. The results showed that the character chlorophyll content contributed maximum (77%) towards diversity by taking six times first ranking followed by ascorbic acid content (62.95%) by 491 times, fruit yield per hectare (51%) by four times, capsanthin content (33.08%) by 258 times, fruit yield per plant (26%) by two times, fruit length (13%) by one time and capsaicin content (2.31%) by 18 times towards total diversity. In contrast, plant height, plant spread, number of primary branches per plant, days to first flowering, days to 50% flowering, days to first harvest, days to last harvest, fruit diameter, average fruit weight and number of fruits per plant did not contribute towards total diversity.

Hence, apart from selecting genotypes from the clusters which have high inter-cluster distance for hybridization, one can also think of selecting parents based on extent of genetic divergence in respect to a particular character of interest. This means, if breeder's intention is to improve fruit yield, he can select parents which are highly divergent with respect to that characters.

The choice of parents for heterosis breeding and expression of heterosis is influenced by genetic diversity of parents. Cress (1966) demonstrated that 'genetic diversity' is necessary for significant heterosis but not sufficient to guarantee the same. Several reports indicate that hybrids between genetically diverse parents manifest greater heterosis than those between more closely related parents (Ram and Panwar, 1970; Moll and Stuber, 1974 and Singh and Sharma, 1989). In fact, such a conclusion is based upon a rather restricted range of genetic diversity and may not hold over the entire range of divergence encountered in a species. In general, the level of heterosis increases with the increase in parental diversity up to a certain level and decreases with further increase in parental diversity owing to cross ability barriers. Thus maximum heterosis occurs at an optimal or intermediate level of parental diversity. Further, the occurrence of heterosis cannot be predicted on the basis of genetic divergence

alone (Matzinger and Werusman, 1958). Apart from high degree of divergence, the mean performance of genotypes and the characters with maximum contribution towards divergence should also be given due consideration.

In view of the above phenotypic diversity and mean performance of genotypes, fruit quality with good consumer preference are considered in selecting the germplasm lines as parents for heterosis breeding. Accordingly, three genetically divergent and horticulturally superior lines with optimum or intermediate level of diversity viz., EC-596940, IC-278055 and IC-561614 can be selected as parents for generating breeding material of chilli.

Genetic divergence among forty genotypes revealed that the genotypes viz., EC-402105, IC-419750, IC-561670, IC-332924, IC-447065 and IC-528879 were identified as promising genotypes for plant height and hence, these genotypes can be utilized in crop improvement programme as donor parents for improving plant height. The genotypes IC-363905, IC-330193, IC-208534, IC-278055, EC-599969 and IC-394731 are promising for improving plant spread.

Four genotypes viz., IC-278055, IC-208534, EC-628901 and EC-391083 are promising for improving number of primary branches per plant.

Six genotypes viz., IC-561619, IC-561640, IC-561670, IC-561673, IC-561679 and IC-561691 were found to be promising lines for less number of days to first flowering.

Fourteen genotypes viz., IC-561673, IC-561691, IC-561723, IC-561614, EC-378635, EC-566920, EC-596940, IC-330193, IC-528876, IC-561619, IC-561670, IC-561679, IC-561688 and IC-561695 were found to be promising lines for less number of days to 50% flowering.

Twelve genotypes IC-561673, IC-561691, IC-561723, IC-561614, EC-566920, EC-596940, IC-528876, IC-561619, IC-561670, IC-561679, IC-561688 and IC-329995 for days to first harvest. Fourteen genotypes viz., IC-561673, IC-561691, IC-561723, IC-561614, EC-566920, EC-405253, IC-528876, IC-561619, IC-561640, IC-561679, IC-561688, EC-378635, IC-329995 and Arka Lohit for days to last harvest were found to be promising.

Genotypes EC-391083, EC-596940, EC-599969, IC-208534, IC-561614, IC-561619, IC-561691 and IC-561715 for average fruit weight; EC-391083, EC-402105, EC-596940, EC-599969, IC-208534, IC-561679, IC-561695, IC-561715, CA-960 and Pusa Jwala for fruit length and EC-405253, IC-561715, IC-561723, IC-561614, EC-596940, IC-208534, IC-561619, IC-561640 and IC-561694 for fruit diameter were found to be promising genotypes.

Genotypes EC-378630, IC-278055, IC-332924, IC-394731, IC-526432, IC-561670, Arka Lohit and LCA-334 for number of fruits per plant; EC-391083, EC-566920, EC-596940, EC-599969, IC-208534, IC-278055, IC-561614, IC-561670 and LCA-334 for fruit yield per plant and EC-596940, EC-599969, IC-278055, IC-561614, IC-561670 and LCA-334 for yield per hectare can be potentially used for improving the yield.

Some genotypes, EC-566920, IC-447065, IC-526432, IC-561614, IC-561640, IC-561670, IC-561673, IC-561688, IC-561695, Arka Lohit, LCA-334 and Pusa Jwala for ascorbic acid; EC-391083, EC-402105, EC-596940, IC-208534, IC-330193, IC-335340, IC-561619, IC-561694 and Arka Lohit for capsanthin; IC-278055, IC-394731, IC-526432, IC-561619, IC-561673, IC-561715 for capsaicin and EC-378635, EC-391083, EC-566920, IC-284474, IC-335340, IC-526432, IC-561670, IC-561688, IC-561695, IC-561715, IC-561723 and Arka Lohit for chlorophyll content can be potentially used for improving the respective characters.

Hence, apart from selecting genotypes from the clusters which have high inter cluster distance for hybridization, one can also think of selecting parents based on extent of genetic divergence with respect to a particular character of interest.

4.4 GENETIC VARIABILITY

The analysis of variance in 40 chilli genotypes indicated highly significant differences among the genotypes for all the 17 quantitative characters studied, indicating the existence of adequate genetic variability among the genotypes studied. This was in accordance with the reports of Sarma and Roy (1995).

Variability helps to choose the potential genotype, since it indicates the extent of recombination for implementing effective selection. Character exhibiting highest degree of variability however cannot be identified due to the absolute variability in different characters. Therefore, PCV and GCV values were estimated. The magnitude of phenotypic and genotypic coefficients of variation has been assessed to know the real worth of the source material. Genotypic coefficient of variation would be a useful tool for the assessment of variability, since it depends upon the heritable portion of the total variability (Allard, 1960). Heritability estimates give a measure of transmission of characters from one generation to another, thus giving an idea of heritable portion of variability and enabling the plant breeder in isolating the elite genotype in the crop. Heritability coupled with genetic advance is an important selection parameter. Johnson *et al.* (1955) reported that heritability along with genetic gain is more useful than the heritability alone, in predicting the resultant effect for selecting the best individuals.

The simple measures of variability like mean, range and the major components of variability such as phenotypic and genotypic coefficients of variation (PCV and GCV), heritability in broad sense (h^2), genetic advance and genetic advance as per cent of mean are presented in Table 4.8 and Fig 4.11. All the 17 characters under study exhibited high variability as evident from the estimates of mean, range, coefficients of variation, heritability and genetic advance.

4.4.1 Plant height (cm)

High phenotypic and genotypic variances (177.10 and 172.64, respectively) coupled with moderate PCV and GCV of 18.71% and 16.10% respectively were recorded. This trait showed high heritability (97%), high genetic advance (29.85) and high GA as percent of mean (36.59).

The PCV and GCV values were high for plant height suggesting high genetic variability for this trait in the genotypes under study. High heritability coupled with high genetic advance as per cent of mean was observed for this trait which indicated the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement of

plant height through simple selection procedures. These results are in line with the findings of Sharma *et al.* (2010), Suryakumari *et al.* (2010) and Datta and Das (2013) in chilli.

4.4.2 Plant spread (cm)

Plant spread showed high phenotypic and genotypic variance (89.46 and 80.94 respectively) and recorded moderate PCV (18.51%) and GCV (14.64%) respectively. This trait showed high heritability (90%), moderate genetic advance (18.78) and high GA as percent of mean (30.57).

4.4.3 Number of primary branches per plant

Number of primary branches per plant showed very low phenotypic and genotypic variances (0.95 and 0.90, respectively) with high PCV (20.47%), high GCV (20.11%), high heritability (95%), but low genetic advance (0.81) and moderate GA as per cent of mean (17.06). The results are comparable with findings of Amit *et al.* (2014).

High PCV and GCV were recorded for number of branches per plant indicating the existence of wider genetic variability for this trait in the genotypes under study. High heritability coupled with high genetic advance as per cent of mean was observed for this trait indicating the predominance of additive gene action and offers the best possibility of improvement of trait through simple selection.

4.4.4 Days to first flowering (DAT)

High phenotypic variance (60.27) and high genotypic variances (42.16) were recorded in chilli genotypes with high PCV and GCV of 26.63% and 22.27% respectively. This trait showed high heritability (70%), moderate genetic advance (14.33) and high GA as per cent of mean (49.19). Moderate PCV and GCV estimates for this trait indicated moderate variability and influence of environment on the trait. High heritability coupled with high genetic advance as per cent of mean was observed for this trait which indicated the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement of plant height through simple selection

procedures. These results are comparable with the findings of Priyanka and Naidu (2015).

4.4.5 Days to 50% flowering (DAT)

High phenotypic variance (73.88) and high genotypic variances (45.58) coupled with high PCV and high GCV of 20.29% and 20.04% respectively were recorded. This trait showed high heritability (62%), moderate genetic advance (14.00) and high GA as per cent of mean (33.05).

Moderate PCV and GCV estimates for this trait indicated moderate variability and influence of environment on the trait. High heritability coupled with high genetic advance as per cent of mean was observed for this trait which indicated the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement of plant height through simple selection procedures. These results are in line with the findings of Priyanka and Naidu (2015).

4.4.6 Days to first harvest (DAT)

High phenotypic (130.44) and genotypic variances (60.78), moderate PCV (13.13%) and low GCV (8.96%) were recorded for days to first harvest. High heritability (47%), moderate genetic advance (14.04) and GA as percent of mean (16.15) were also observed.

The PCV and GCV values were low for this trait indicating narrow range of variability for this trait. High heritability coupled with moderate genetic advance as percent of mean was observed for this trait indicating non additive gene action. Similar studies are conducted by Manoj *et al.* (2018) and Hasanuzzaman *et al.* (2012), Anita *et al.* (2017) on the same parameter.

4.4.7 Days to last harvest (DAT)

High phenotypic (117.11) and genotypic (70.48) variances, low PCV (7.91%) and GCV (6.14%) were observed for days to last harvest. High heritability (60%), moderate genetic advance (17.19) and moderate GA as percent of mean (12.58) were observed.

The PCV and GCV values were low for this trait indicating narrow range of variability for this trait. High heritability coupled with moderate genetic advance as percent of mean was observed for this trait indicating non additive gene action.

4.4.8 Fruit length (cm)

With regard to fruit length, low phenotypic and genotypic variances (6.19 and 5.77 respectively) with high PCV (27.71%) and GCV (26.76%), high heritability (93%), low genetic advance (6.12) and high GA as per cent mean (68.24) were recorded.

High PCV and GCV were recorded for fruit length indicating the existence of wider genetic variability for this trait in the genotypes under study. High heritability coupled with high genetic advance as per cent of mean was observed for this trait indicates the predominance of additive gene action. The results are comparable with Amit *et al.* (2014) and Pandiyaraj *et al.* (2017).

4.4.9 Fruit diameter (cm)

Fruit diameter recorded low phenotypic and genotypic variances (0.14 and 0.12, respectively) with high PCV (30.14%), high GCV (27.95%), high heritability (86%), low genetic advance (0.86) and high GA as per cent of mean (68.43).

High PCV and GCV were recorded for fruit diameter indicating the existence of wider genetic variability for this trait in the genotypes under study. High heritability coupled with high genetic advance as per cent of mean was observed for this trait. These results are in agreement with the findings of Ibrahim *et al.* (2001), Suryakumari *et al.* (2010) and Amit *et al.* (2014) in chilli.

4.4.10 Average fresh fruit weight (g)

Moderate phenotypic (10.74) and low genotypic (9.92) variances, high PCV (57.00%) and GCV (54.79%) for average fresh fruit weight were recorded. High heritability (93%), low genetic advance (7.99) and high GA as per cent of mean (139.03) were also recorded.

High PCV and GCV were observed for fresh fruit weight indicating the existence of wider genetic variability for this trait in the genotypes under study. High heritability coupled with high genetic advance as per cent of mean was also observed for this trait. These results are in conformity with the findings of Sharma *et al.* (2010), Amit *et al.* (2014) and Syed *et al.* (2017) in chilli.

4.4.11 Number of fruits per plant

Number of fruits per plant exhibited very high phenotypic (356.27) and genotypic (289.98) variances, high PCV (48.36%), high GCV (43.18%), high heritability (82%), high genetic advance (39.71) and high GA as per cent of mean (101.77) were recorded.

The PCV and GCV values were moderate for number of fruits per plant, suggested moderate range of genetic variability and considerable influence of environment in the expression of the trait. High heritability coupled with high genetic advance as per cent of mean was observed for this trait indicates the predominance of additive gene action. Results are in tune with findings of Krishnamurthy *et al.* (2013).

4.4.12 Fresh fruit yield per plant (kg/plant)

Very low phenotypic (0.013) and genotypic (0.012) variances were registered for fresh fruit yield per plant with high PCV (57.37%), high GCV (52.35%), high heritability (93%), low genetic advance (0.26) and high GA as per cent of mean (126.13).

The estimates of both GCV and PCV were high for fresh fruit yield per plant that indicates wider genetic variability. High heritability coupled with high genetic advance as per cent of mean was observed for this trait. These results are in agreement with the findings of Sharma *et al.* (2010), Suryakumari *et al.* (2010), Datta and Das (2013) and Amit *et al.* (2014) in chilli.

4.4.13 Fresh fruit yield per hectare (kg/ha)

High phenotypic (36001227.4) and genotypic (29977368.8) variances with high PCV (57.37%), high GCV (52.35%), high heritability (83%), high

genetic advance (13189.8) and high GA as per cent of mean (126.13) were registered for fresh fruit yield per hectare.

High PCV and GCV were observed for fresh fruit yield per hectare indicating the existence of wider genetic variability for this traits in the genotypes under study. High heritability coupled with high genetic advance as per cent of mean was observed for this trait. These results are in conformity with the findings of Udachappa *et al.* (2017).

4.4.14 Ascorbic acid content (mg/100g of fruit)

Ascorbic acid content exhibited very high phenotypic (662.04) and genotypic (661.75) variances, high PCV (30.54%) and GCV (30.53%), high heritability (99%), high genetic advance (67.89) and high GA as per cent of mean (80.60).

High PCV and GCV were observed for ascorbic acid content indicating the existence of wider genetic variability for this trait in the genotypes under study. High heritability coupled with high genetic advance as per cent of mean was also observed for this trait that indicating predominance of additive gene action. These results are in conformity with the findings of Sharma *et al.* (2010) and Udachappa *et al.* (2017) in chilli.

4.4.15 Capsanthin content (ASTA units)

Capsanthin content exhibited very high phenotypic (3594.45) and genotypic (3589.45) variances, high PCV (26.59%) and GCV (26.57%), high heritability (99%), high genetic advance (158.05) and high GA as per cent of mean (70.09).

Moderate PCV and GCV estimates for this trait indicated moderate variability and influence of environment on the trait. High heritability coupled with high genetic advance as per cent of mean was also observed for this trait indicating predominance of additive gene action. These results are in conformity with the findings of Mallikarjun *et al.* (2003a) and Suryakumari *et al.* (2010) in chilli.

4.4.16 Capsaicin content (%)

Capsaicin content exhibited very low phenotypic (0.01) and genotypic (0.01) variances, high PCV (40.66%), high GCV (40.33%), high heritability (100%), low genetic advance (0.30) and high GA as per cent of mean (105.63).

High PCV and GCV were observed for capsaicin content indicating the existence of wider genetic variability for this trait in the genotypes under study.

High heritability coupled with high genetic advance as per cent of mean was also observed for this trait indicating predominance of additive gene action. High heritability and high genetic advance as per cent mean for capsaicin content are also reported by Suryakumari *et al.* (2010) and Datta and Das (2013) in chilli.

4.4.17 Chlorophyll content (%)

Low phenotypic (0.15) and genotypic (0.14) variances, high PCV (20.21%), moderate GCV (19.84%), high heritability (94%), low genetic advance (0.98) and high GA as percent of mean (51.46) estimates were recorded for the trait chlorophyll content of fruit.

High PCV and GCV were observed for chlorophyll content indicating the existence of wider genetic variability for this trait in the genotypes under study. High heritability coupled with high genetic advance as per cent of mean was also observed for this trait indicating predominance of additive gene action. Similar studies are conducted by Dixita *et al.* (2015), Smitha and Basavaraja (2006b).

The study revealed that PCV was higher than the corresponding GCV for all the characters indicating that all characters have interacted with environment to some degree. High PCV and GCV were recorded for number of primary branches per plant, days to first flowering, days to 50% flowering, fruit length, fruit diameter, average fruit weight, number of fruits per plant, fruit yield per plant, fruit yield per hectare, ascorbic acid content, capsanthin content, capsaicin content and chlorophyll content indicating the existence of wider genetic variability for these traits in the genotypes under study. On the other side, PCV and GCV estimates were moderate for the traits plant height, plant spread and days to first harvest. Only one character days to last harvest were found with low variability suggesting narrow range of genetic variability for these traits.

High heritability coupled with high genetic advance as per cent of mean indicated operation of additive gene action which was observed in characters viz., plant height, plant spread, days to first flowering, days to 50% flowering, fruit length, fruit diameter, average fruit weight, number of fruits per plant, fruit yield per hectare, ascorbic acid content, capsanthin content, capsaicin content and chlorophyll content. Hence, directional selection for these traits in genetically diverse material could be effective for desired genetic improvement. Moderate genetic advance as per cent of mean with high or moderate heritability suggests the action of both additive and non-additive genes there by favorable influence of environment in the expression of the traits. The same was reported in case of number of primary branches per plant, days to first harvest and days to last harvest. Moderate heritability coupled with low genetic advance as per cent of mean indicates the influence of non-additive gene action and considerable influence of environment on the expression of these traits, which didn't observed in any case.

Hence, the breeder should adopt suitable breeding methodology to utilize both additive and non-additive gene effects simultaneously, since varietal and hybrid development will go a long way in the breeding programme especially in case of chilli.

In general, the range of variation was wide for plant height, number of primary branches per plant, fruit yield per plant, fruit yield per hectare, average fruit weight, ascorbic acid content, oleoresin content, capsaicin content and chlorophyll content. This is in accordance with the reports of Arya and Saini (1977), Deshpande and Anand (1988), Amarchandra *et al.* (1990), Giritammannavar (1995), Bhatt and Deepak (1996), Kohli and Chatterjee (2000), Ramesh (2001), Geleta and Labuschagne (2004), Mini and Khader (2004), Sood *et al.* (2006), Smitha and Basavaraja (2006b), Singh and Yadav (2008), Misra *et al.* (2011) and Dixita *et al.* (2015).

4.5 CORRELATION COEFFICIENT ANALYSIS

The phenotypic (P) and genotypic (G) correlation coefficients were worked out for 17 characters in chilli and the data is presented in Table 4.9. In general, it was observed that genotypic correlation coefficients were higher than

that of phenotypic correlation coefficients. This could be interpreted on the basis that there was a strong inherent genotypic relationship between the characters studied, but their phenotypic expression was impeded by the influence of environmental factors.

4.5.1 Plant height (cm)

Plant height showed positive and significant correlations with plant spread (0.0921P, 0.1451G) at both phenotypic and genotypic levels. Negative and significant correlations has been observed with fruit length (-0.4273P, -0.4852G), average fruit weight (-0.3215P, -0.4082G) and fruit yield per hectare (-0.3354P, -0.4357G) at both phenotypic and genotypic levels.

4.5.2 Plant spread (cm)

Plant spread exhibited positive and significant correlations with plant height (0.0921P, 0.1451G), number of branches per plant (0.3240P, 0.3756G), days to last harvest (0.2335P, 0.4227G) and number of fruits per plant (0.2553P, 0.3271G) at both phenotypic and genotypic levels. Negative and significant correlations were observed with fruit diameter (-0.2198P, -0.2649G), average fruit weight (-0.2089P, -0.2957G) and ascorbic acid (-0.3335P, -0.4203G) at both phenotypic and genotypic levels.

4.5.3 Number of primary branches per plant

Number of primary branches per plant showed positive and significant correlations with plant spread (0.3240P, 0.3756G), days to 50% flowering (0.2248P, 0.5117G) and number of fruits per plant (0.3438P, 0.7776G) at both phenotypic and genotypic levels respectively. Number of primary branches per plant recorded negative and significant correlations with fruit diameter (-0.3488P, 0.5605G) and average fruit weight (-0.2274P, -0.4255G) at both phenotypic and genotypic levels, respectively.

4.5.4 Days to first flowering (DAT)

Days to first flowering showed positive and significant correlations with days to 50% flowering (0.7362P, 0.7533G), days to first harvest (0.6396P, 0.7977G), days to last harvest (0.4402P, 0.4720G) and number of fruits per plant

(0.2903P, 0.4638G) at both phenotypic and genotypic levels. Days to first harvest recorded negative and significant correlations with fruit length (-0.0755P, -0.0991G), fruit diameter (-0.3254P, -0.4345G) and average fruit weight (-0.3208P, -0.3834G) at both phenotypic levels, respectively.

4.5.5 Days to 50% flowering (DAT)

Days to 50 percent flowering showed positive and significant correlations with number of primary branches per plant (0.2248P, 0.5117G), days to first flowering (0.7362P, 0.7533G), days to first harvest (0.8218P, 1.0339G), days to last harvest (0.6220P, 0.6859G) and number of fruits per plant (0.2329P, 0.4179G) at both phenotypic and genotypic levels and showed negative and significant correlations with fruit diameter (-0.3148P, -0.3986G) and average fruit weight (-0.2899P, -0.3813G) at both phenotypic and genotypic levels.

4.5.6 Days to first harvest (DAT)

Days to first harvest showed positive and significant correlations with days to first flowering (0.6396P, 0.7977G), days to 50% flowering (0.8218P, 1.0339G) and days to last harvest (0.7244P, 0.6958G) at both phenotypic and genotypic levels and showed negative and significant correlations with fruit diameter (-0.1907P, -0.3470G), average fruit weight (-0.2259P, -0.3445G) and chlorophyll content (-0.1916P, -0.2513G) at both phenotypic and genotypic levels, respectively.

4.5.7 Days to last harvest (DAT)

Days to last harvest showed positive and significant correlations with plant spread (0.2335P, 0.4227G), days to first flowering (0.4402P, 0.4720G), days to 50% flowering (0.6220P, 0.6859G), days to first harvest (0.7244P, 0.6958G) and number of fruits per plant (0.2508P, 0.3930G) at both phenotypic and genotypic levels and showed negative and significant correlations with average fruit weight (-0.2000P, -0.2599G) and chlorophyll content (-0.3885P, -0.4621G) at both phenotypic and genotypic levels.

4.5.8 Fruit length (cm)

Fruit length showed positive and significant correlations with fruit diameter (0.1861P, 0.1791G), average fruit weight (0.6078P, 0.6546G), fruit yield per hectare (0.5380P, 0.6242G), ascorbic acid (0.1940P, 0.2010G) and chlorophyll (0.2452P, 0.2524G) at both phenotypic and genotypic levels and showed negative and significant correlations with plant height (-0.4273P, -0.4852G) and days to first flowering (-0.0755P, -0.0991G) at both phenotypic and genotypic levels, respectively.

4.5.9 Fruit diameter (cm)

Fruit diameter showed positive and significant correlations with fruit length (0.1861P, 0.1791G), average fruit weight (0.7016P, 0.7601G) and fruit yield per hectare (0.2170P, 0.2601G) at both phenotypic and genotypic levels, respectively and showed significantly negative correlations with plant spread (-0.2198P, -0.2649G), number of primary branches (-0.3488P, -0.5605G), days to first flowering (-0.3254P, -0.4345G), days to 50% flowering (-0.3148P, -0.3986G), days to first harvest (-0.1907P, 0.3470G) and number of fruits per plant (-0.3964P, -0.4774G) at both phenotypic and genotypic levels, respectively.

4.5.10 Average fresh fruit weight (g)

Average fresh fruit weight showed positive and significant correlations with fruit length (0.6078P, 0.6546G), fruit diameter (0.7016P, 0.7601G), fruit yield per hectare (0.5584P, 0.6501G), ascorbic acid (0.2114P, 0.2194G) and capsanthin (0.1806P, 1880G) at both phenotypic and genotypic levels. It showed significantly negative correlations with plant height (-0.3215P, -0.4082G), plant spread (-0.2089P, 0.2957G), number of primary branches per plant (-0.2274P, -0.4255G), days to first flowering (-0.3208P, -0.3834G), days to 50% flowering (-0.2899P, -0.3813G), days to first harvest (-0.2259P, -0.3445G), days to last harvest (-0.2000P, 0.2599G) and number of fruits per plant (-0.2516P, -0.2831G) at both phenotypic and genotypic levels, respectively.

4.5.11 Number of fruits per plant

This character exhibited significant and positive correlations with plant spread (0.2553P, 0.3271G), number of primary branches per plant (0.3438P, 0.7776G), days to first flowering (0.2903P, 0.4638G), days to 50% flowering (0.2329P, 0.4179G), days to last harvest (0.2508P, 0.3930G) and fruit yield per hectare (0.5824P, 0.5094G) at both phenotypic and genotypic levels. However, it showed negative and significant correlations with fruit diameter (-0.3964P, -0.4774G) and average fruit weight (-0.2516P, -0.2831G) at both phenotypic and genotypic levels, respectively.

4.5.12 Fresh fruit yield per hectare (kg/ha)

Fresh fruit yield per hectare showed positive and significant correlations with fruit length (0.5380P, 0.6242G), fruit diameter (0.2170P, 0.2601G), average fruit weight (0.5584P, 0.6501G), number of fruits per plant (0.5824P, 0.5094G) and ascorbic acid (0.3463P, 0.3805G) at both phenotypic and genotypic levels. This character also exhibited negative and significant correlations with plant height (-0.3354P, -0.4357G) at both phenotypic and genotypic levels, respectively.

4.5.13 Ascorbic acid content (mg/100g of fruit)

Ascorbic acid exhibited positive and significant correlations with fruit length (0.1940P, 0.2010G), average fruit weight (0.2114P, 0.2194G), fruit yield per hectare (0.3463P, 0.3805G) and chlorophyll (0.2308P, 0.2347G) at both phenotypic and genotypic levels, respectively and plant spread (-0.3335P, -0.4203G) showed negative and significant correlations with this character at both phenotypic and genotypic levels, respectively.

4.5.14 Capsanthin content (ASTA units)

Capsanthin content showed positive and significant correlations with average fruit weight (0.1806P, 0.1880G) at both phenotypic and genotypic levels. While capsaicin content (-0.2085P, -0.2109G) and chlorophyll content (-0.2442P, -0.2488G) showed negative and significant correlations with this character at both phenotypic and genotypic levels, respectively.

4.5.15 Capsaicin content (%)

Capsaicin content didn't show any positive or negative significant correlations with any other characters. It showed negative and significant correlations with capsanthin (-0.2085P, -0.2109G) at both phenotypic and genotypic levels, respectively.

4.5.16 Chlorophyll content (%)

Chlorophyll content showed positive and significant correlations with fruit length (0.2452P, 0.2524G) and ascorbic acid content (0.2308P, 0.2347G) at both phenotypic and genotypic levels, respectively and showed negative and significant correlations with days to first harvest (-0.1916P, -0.2513G), days to last harvest (-0.3885P, -0.4621G) and capsanthin content (-0.2442P, -0.2488G) at both phenotypic and genotypic levels, respectively.

4.5.17 Fresh fruit yield per plant (kg/plant)

Fruit yield per plant showed positive but not significant correlations with plant spread, number of primary branches per plant, days to first flowering, days to last harvest, fruit length, fruit diameter, average fruit weight, number of fruits per plant, fruit yield per hectare, ascorbic acid content, capsanthin content and capsaicin content at both phenotypic and genotypic levels.

Sharma *et al.* (2010), Singh and Singh (2011), Krishnamurthy *et al.* (2013) and Amit *et al.* (2014) reported parallel character association with number of fruits per plant and fruit length. Nazir *et al.* (2005) showed similar association with fruit pedicel length and average fruit weight. Priyanka and Mishra (2014) showed similar association with, days to 50% flowering, days to first harvest, fruit length and number of branches per plant. Ajjapplavara *et al.* (2009) showed similar results with days to 50 percent flowering and days to fruit set. Anita *et al.* (2017) reported similar results with ascorbic acid content and average fruit weight. A significant positive correlation of economic traits like fruit length, fruit weight and yield was recorded suggesting that selection for these characters would lead to improvement in yield by Smitha and Basavaraja (2006b). Similar studies on correlation are conducted by Warade *et al.* (1996a) and Maneet *et al.* (2015).

The results on character association indicated positive, though not significant association of fruit yield per plant with plant height, plant spread, number of primary branches per plant, days to first flowering, days to 50% flowering, days to first harvest, days to last harvest, fruit length, fruit diameter, average fruit weight, number of fruits per plant, fruit yield per hectare, ascorbic acid content, capsanthin content, capsaicin content and chlorophyll content which indicated that the adequate knowledge of interrelationship between fruit yield per plant and its components creates ample scope in the improvement of yield by improving these characters as they are highly correlated.

4.6 PATH COEFFICIENT ANALYSIS

Path analysis was carried out at phenotypic and genotypic levels considering fruit yield as dependent variable and its attributes viz., plant height (cm), plant spread (cm), number of primary branches per plant, days to first flowering (DAT), days to 50% flowering (DAT), days to first harvest (DAT), days to last harvest (DAT), fruit length (cm), fruit diameter (cm), average fresh fruit weight (g), number of fruits per plant, fresh fruit yield per plant (kg/plant), fresh fruit yield per hectare (kg/ha), ascorbic acid content (mg/100g), capsanthin content (ASTA units), capsaicin content (%) and chlorophyll content (%) as independent variables as independent variables.

Each component has two path actions viz., direct effect on yield and indirect effect through components which are not revealed by correlation studies.

The estimates of direct and indirect effects of the seventeen yield related characters on fruit yield per plant are presented in Table 4.10.

Direct and indirect effects

4.6.1 Plant height (cm)

Plant height showed negligible and positive direct effect (0.0007P) at phenotypic level and negligible and negative direct effect (-0.0289G) at genotypic level on fruit yield per plant.

4.6.2 Plant spread (cm)

This trait showed negligible and negative direct effect at both phenotypic and genotypic levels (-0.0007P, -0.0115G) on fruit yield per plant.

4.6.3 Number of primary branches per plant

Number of primary branches per plant showed negligible and negative direct effect (-0.0003P) at phenotypic level and low and negative direct effect (-0.1151G) at genotypic level on fruit yield per plant.

4.6.4 Days to first flowering (DAT)

This character recorded, negligible and negative direct effect (-0.0021P, -0.0561G) at both phenotypic and genotypic levels on fruit yield per plant.

4.6.5 Days to 50 % flowering (DAT)

Days to 50% flowering showed negligible and negative direct effect (-0.0048P) at phenotypic level and negligible and positive direct effect (0.0685G) on fruit yield per plant at genotypic level.

4.6.6 Days to first harvest (DAT)

Days to first harvest showed negligible and positive direct effect (0.0092P) at phenotypic level and negligible and negative direct effect (-0.0509G) at genotypic level on fruit yield per plant.

4.6.7 Days to last harvest (DAT)

Days to last harvest showed negligible and negative direct effect (-0.0041P) at phenotypic level and negligible and positive direct effect (0.0404G) at genotypic level, respectively on fruit yield per plant.

4.6.8 Fruit length (cm)

Fruit length showed negligible and negative direct effect (-0.0026P) at phenotypic level and negligible and positive direct effect (0.0554G) at genotypic level, respectively on fruit yield per plant.

4.6.9 Fruit diameter (cm)

Fruit diameter showed negligible and negative direct effect (-0.0057P) at phenotypic level and negligible and positive direct effect (0.0100G) at genotypic level, respectively on fruit yield per plant.

4.6.10 Average fresh fruit weight (g)

Average fruit weight showed negligible and negative direct effect (-0.0020P, -0.0407G) on fruit yield per plant at both phenotypic and genotypic levels, respectively.

4.6.11 Number of fruits per plant

This character showed high positive direct effect (0.7424P) at phenotypic level and low positive direct effect (0.1104G) at genotypic level, respectively on fruit yield per plant.

4.6.12 Fresh fruit yield per hectare (kg/ha)

This character showed very high positive direct effects (1.0082P) at phenotypic level and high positive direct effects (0.9531G) on fruit yield per plant at genotypic level, respectively.

4.6.13 Ascorbic acid content (mg/100g fruit)

Ascorbic acid showed negligible and positive direct effect (0.0021P) at phenotypic level and negligible and negative direct effect (-0.0079G) at genotypic level, respectively on fruit yield per plant.

4.6.14 Capsanthin content (ASTA units)

Capsanthin content showed negligible and negative direct effect (-0.0026P, -0.0093G) on fruit yield per plant at both phenotypic and genotypic levels, respectively.

4.6.15 Capsaicin content (%)

Capsaicin content showed negligible and positive direct effect (0.0006P) at phenotypic level and negligible and negative direct effect (-0.0351G) at genotypic level, respectively on fruit yield per plant.

4.6.16 Chlorophyll content of green chilli (%)

Chlorophyll content showed negligible and negative direct effect (-0.0017P, -0.0210G) on fruit yield per plant at both phenotypic and genotypic levels, respectively.

Although correlation coefficients indicate the nature of association among the characters, path analysis splits the correlation coefficients into measures of direct and indirect effects, thus providing an understanding on the direct and indirect contribution of each character towards yield.

Path coefficient analysis showed that the number of fruits per plant and fruit yield per hectare showed positive direct effect at both phenotypic and genotypic levels on fruit yield per plant. Days to 50% flowering, days to last harvest, fruit length and fruit diameter showed positive direct effect at genotypic level on fruit yield per plant.

Similar results are reported in chilli by Bhat (1981), Choudary and Das (1998), Legesse *et al.* (1999), Giritammannavar and Patil (2006), Krishnamurthy *et al.*, (2013), Maneet *et al.* (2015), Shiva *et al.* (2015), Maurya *et al.* (2017), Mamtha *et al.* (2017) and Manoj *et al.* (2018). It clearly indicates that direct selection based on these characters would be effective for increasing the yield.

The residual factor determines how best the causal factors account for the variability of the dependent factor, the fresh fruit yield per plant in this case. The residual effects are 0.024 and 1.0003, which were of low magnitude at phenotypic and high magnitude at genotypic levels, respectively.

Table 4.11: List of promising genotypes compared to best check variety

S. No.	Parameter	Best genotypes	Check variety
1	Plant height (cm)	EC-402105 (104.00cm) IC-419750 (102.00cm) IC-561670 (97.67cm) IC-528879 (95.33cm)	Arka Lohit (89.66cm)
2	Plant spread (cm)	IC-363905 (87.33cm) IC-330193 (79.33cm) IC-208534 (74.00cm) IC-526432 (65.67cm)	LCA-334 (65.00cm)
3	Number of primary branches per plant	IC-278055 (7.00) EC-391083 (6.00) EC-628901 (6.00) IC-208534 (6.00)	LCA-334 (5.67)
4	Days to first flowering (DAT)	EC-391083 (28.00 days) EC-405253 (26.33 days) EC-596940 (26.33 days) IC-208534 (26.00 days) IC-330193 (26.33 days)	CA-960 (31.33 days)
5	Days to 50% flowering (DAT)	EC-596940 (35.33 days) IC-561695 (35.34 days) IC-330193 (33.00 days) IC-561691 (31.33 days)	CA-960 (40.33 days)
6	Days to first harvest (DAT)	EC-378635 (80.67 days) EC-566920 (77.67 days) EC-596940 (74.66 days) IC-330193 (73.33 days)	Arka Lohit (84.33 days)
7	Days to last harvest (DAT)	IC-561673 (124.66 days) IC-566920 (120.00 days) IC-561688 (119.66 days)	Arka Lohit (126.00 days)
8	Average fruit weight (g)	IC-561614 (15.03g) EC-596940 (13.30g) IC-561619 (13.41g) IC-561715 (13.29g)	LCA-334 (6.20g)
9	Fruit length (cm)	EC-596940 (13.70cm) IC-561679 (12.63cm) EC-391083 (12.60cm) EC-599969 (11.67cm)	Pusa Jwala (11.60cm).
10	Fruit diameter (cm)	IC-561619 (2.16cm) IC-561723 (2.06cm) IC-561694 (2.03cm) EC-596940 (1.86cm)	LCA-334 (1.20 cm)

DAT-Days after transplanting

Table 4.11: List of promising genotypes compared to best check variety (contd...)

S. No.	Parameter	Best genotypes	Check variety
11	Number of fruits per plant	IC-278055 (91.33), IC-394731 (66.33) IC-561670 (65.00)	LCA-334 (65.33)
12	Fruit yield per plant (kg/plant)	EC-596940 (0.439kg) IC-278055 (0.417kg) IC-561614 (0.406kg)	LCA-334 (0.405kg).
13	Fruit yield per hectare (kg/ha)	EC-596940 (21933.3kg) IC-278055 (20833.3kg) IC-561614 (20283.3kg)	LCA-334 (20266.6kg).
14	Ascorbic acid content (mg/100g)	IC-561670 (134.01mg/100g) IC-561614 (129.55mg/100g) IC-561640 (128.34mg/100g) IC-526432 (127.32mg/100g)	Arka Lohit (126mg/100g).
15	Capsaicin content (%)	IC-561673 (0.58%) IC-561619 (0.53%) IC-561715 (0.51%) IC-526432 (0.49%) IC-394731 (0.45%) IC-561691 (0.39%)	LCA-334 (0.35%)
16	Capsanthin (ASTA units)	IC-208534 (358.67 ASTA units) IC-330193 (328.00 ASTA units) IC-561619 (314.66 ASTA units) IC-335340 (309.00 ASTA units) EC-596940 (297.33 ASTA units)	Arka Lohit (290.00 ASTA units)
17	Chlorophyll content of green fruits (%)	EC-628901 (2.32%) IC-528876 (2.29%) IC-561715 (2.26%) IC-284474 (2.24%) IC-335340 (2.20%) IC-526432 (2.19%)	Arka Lohit (2.17%).

DAT-Days after transplanting

**Table 3.1: List of germplasm lines of chilli (*Capsicum annuum* L.)
selected for present study**

S. No.	Genotypes	Source
1.	EC-378630	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
2.	EC-378635	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
3.	EC-391083	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
4.	EC-402105	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
5.	EC-405253	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
6.	EC-566920	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
7.	EC-596940	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
8.	EC-599969	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
9.	EC-628901	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
10.	IC-208534	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
11.	IC-278055	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
12.	IC-284474	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
13.	IC-324215	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
14.	IC-329995	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
15.	IC-330193	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
16.	IC-332924	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
17.	IC-335340	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
18.	IC-363905	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
19.	IC-394731	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
20.	IC-419750	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30

**Table 3.1: List of germplasm lines of chilli (*Capsicum annuum* L.)
selected for present study continued.,**

Sl. No.	Genotypes	Source
21.	IC-447065	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
22.	IC-526432	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
23.	IC-528876	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
24.	IC-528879	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
25.	IC-561614	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
26.	IC-561619	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
27.	IC-561640	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
28.	IC-561670	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
29.	IC-561673	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
30.	IC-561679	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
31.	IC-561688	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
32.	IC-561691	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
33.	IC-561694	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
34.	IC-561695	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
35.	IC-561715	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
36.	IC-561723	ICAR-NBPGR Regional Station Rajendranagar, Hyderabad-30
37.	Arka Lohit	IIRH, Indian Institute of Horticultural Research, Banglore
38.	CA-960	HRS, Lam Farm, Guntur
39.	LCA-334	HRS, Lam Farm, Guntur
40.	Pusa Jwala	IARI, Indian Agricultural Research Institute, New Delhi

Plate 4.1: Phenotypic diversity in fruits of chilli germplasm



EC-378630



EC-378635



EC-391083



EC-402105



EC-405253



EC-566920

Plate 4.1: Phenotypic diversity in fruits of chilli germplasm continued.,



EC-566940



EC-599969



EC-628901



IC-208534



IC-278055



IC-284474

Plate 4.1: Phenotypic diversity in fruits of chilli germplasm continued.,



IC-324215



IC-329995



IC-330193



IC-332924



IC-335340



IC-363905

Plate 4.1: Phenotypic diversity in fruits of chilli germplasm continued.,



IC-394731



IC-419750



IC-447065



IC-526432



IC-528876



IC-528879

Plate 4.1: Phenotypic diversity in fruits of chilli germplasm continued.,



IC-561614



IC-561619



IC-561640



IC-561670



IC-561673



IC-561679

Plate 4.1: Phenotypic diversity in fruits of chilli germplasm continued.,



IC-561688



IC-561691



IC-561694



IC-561695



IC-561715



IC-561723

Plate 4.1: Phenotypic diversity in fruits of chilli germplasm continued.,



Arka Lohit



CA-960



LCA-334



Pusa Jwala



Plate 3.2: General view of the experimental plot

Clustering by Tocher's method

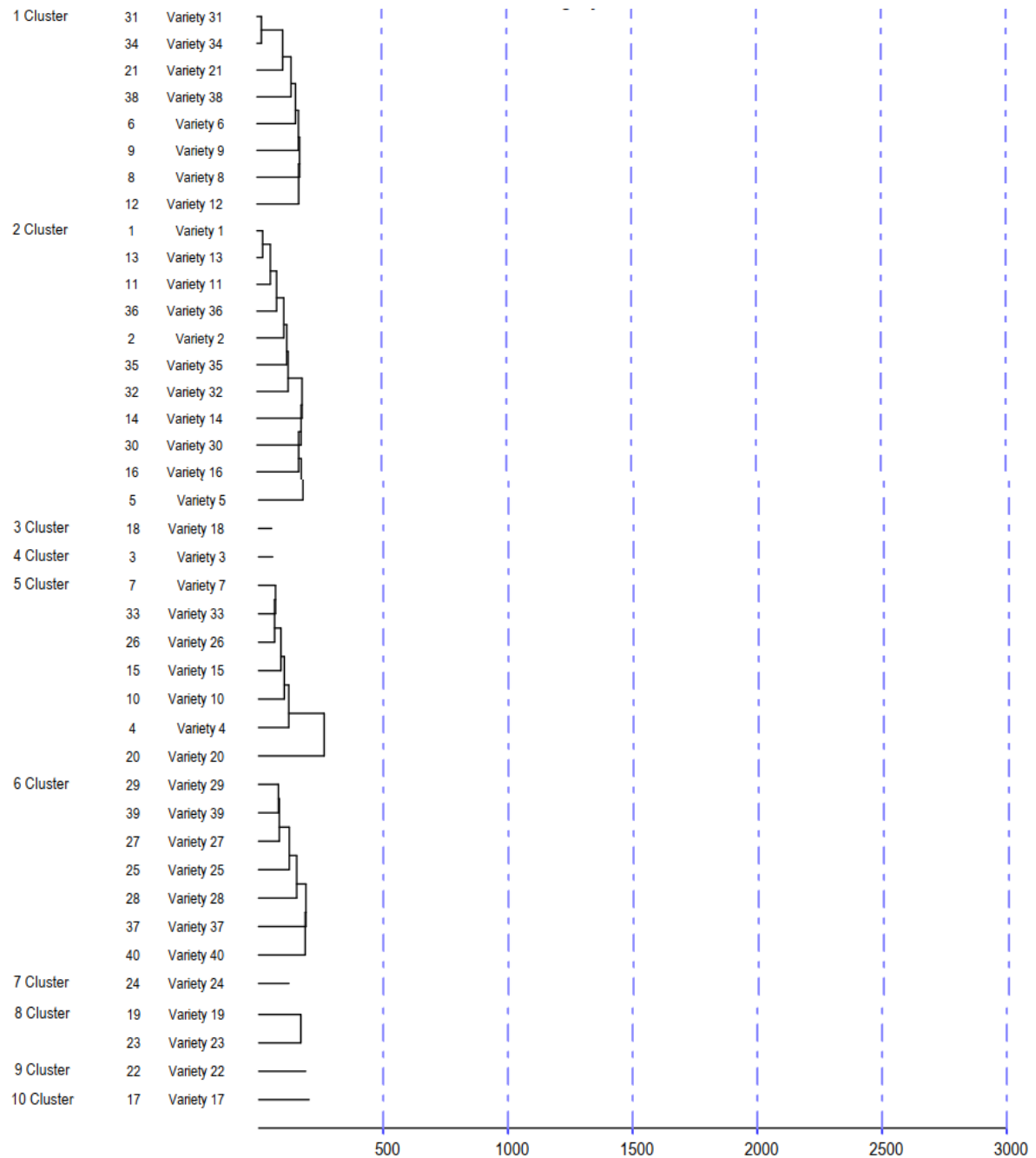
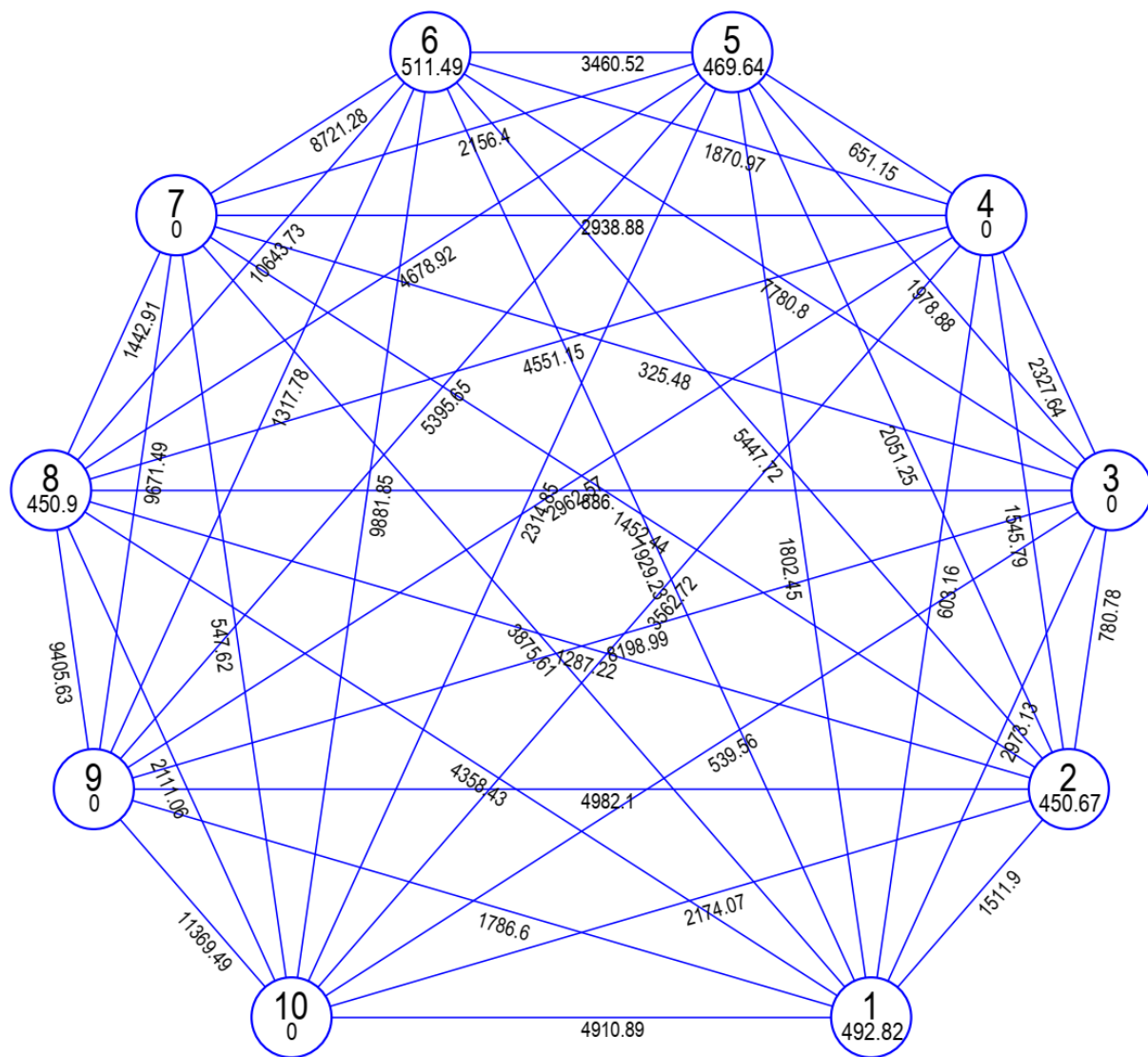


Fig 4.8: Dendrogram showing clustering pattern for divergence of 40 chilli genotypes

Variety 1: EC-378630	Variety 9: EC-628901	Variety 17: IC-335340	Variety 25: IC-561614	Variety 33: IC-561694
Variety 2: EC-378635	Variety 10: IC-208534	Variety 18: IC-363905	Variety 26: IC-561619	Variety 34: IC-561695
Variety 3: EC-391083	Variety 11: IC-278055	Variety 19: IC-394731	Variety 27: IC-561640	Variety 35: IC-561715
Variety 4: EC-402105	Variety 12: IC-284474	Variety 20: IC-419750	Variety 28: IC-561670	Variety 36: IC-561723
Variety 5: EC-405253	Variety 13: IC-324215	Variety 21: IC-447065	Variety 29: IC-561673	Variety 37: Arka Lohit
Variety 6: EC-566920	Variety 14: IC-329995	Variety 22: IC-526432	Variety 30: IC-561679	Variety 38: CA-960
Variety 7: EC-596940	Variety 15: IC-330193	Variety 23: IC-528876	Variety 31: IC-561688	Variety 39: LCA-334
Variety 8: EC-599969	Variety 16: IC-332924	Variety 24: IC-528879	Variety 32: IC-561691	Variety 40: Pusa Jwala

Tocher's Method



Mahalanobis Euclidean Disatnce (Not to the Scale)

Fig 4.10: Cluster diagram showing the average intra and inter-cluster D^2 values of 40 chilli genotypes

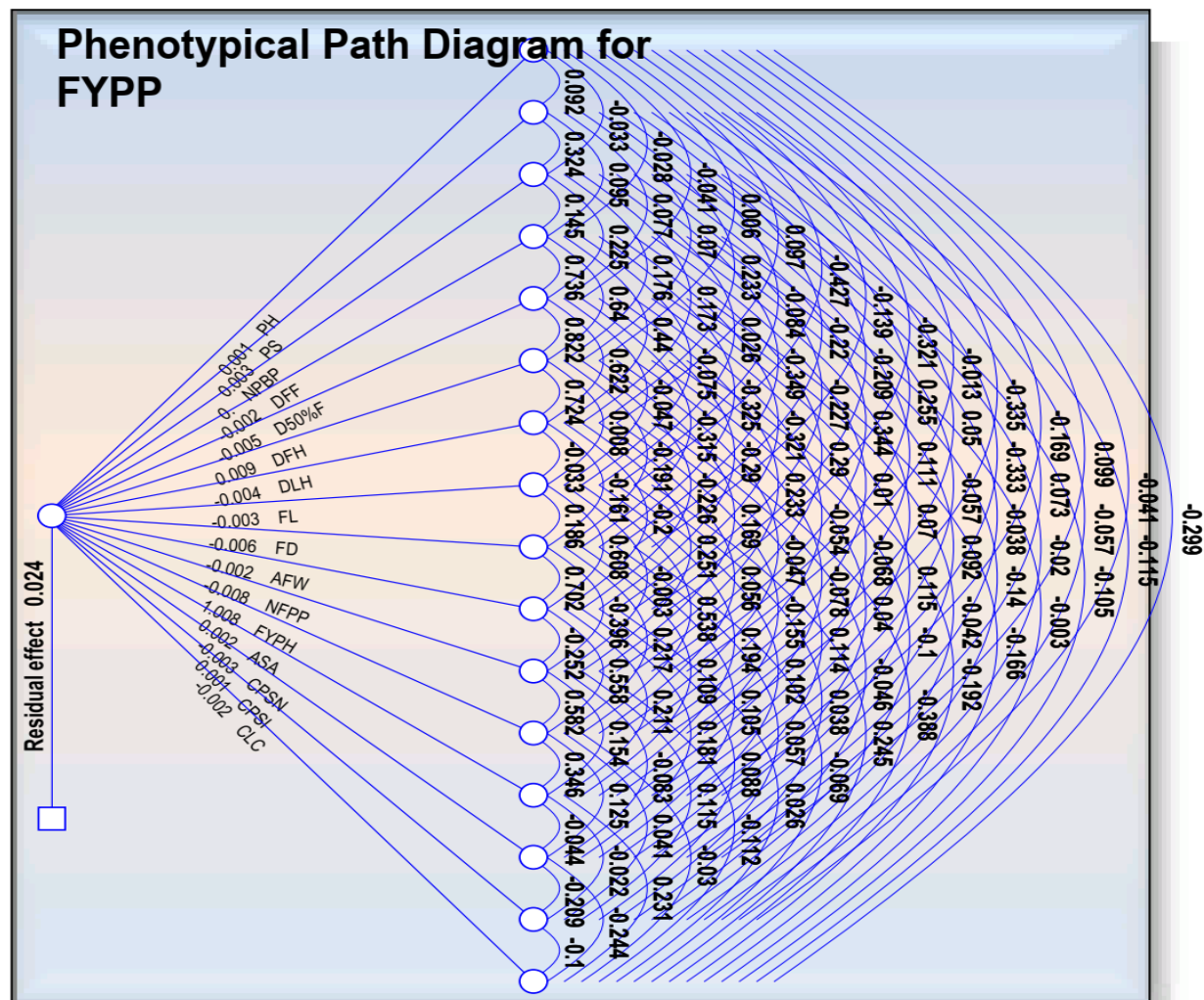


Fig 4.12: Phenotypic path diagram representing direct and indirect effect for fruit yield in chilli

PH - Plant height (cm), PS - Plant spread (cm), NPBP - Number of primary branches per plant, DFF - Days to first flowering, D50%F - Days to 50 percent flowering, DFH - Days to first harvest, DLH - Days to last harvest, AFW - Average fruit weight (g), FL - Fruit length (cm), FD - Fruit diameter (cm), NF/P - Number of fruits per plant, FY/P- Fruit yield per plant (kg/plant), FY/H- Fruit yield per hectare (kg/ha), ASA - Ascorbic acid (mg/100g), CLC - Chlorophyll content of green fruits (%), CPSN - Capsanthin (ASTA unit), CPSI - Capsaicin (%). Chlorophyll content of green fruits (%).

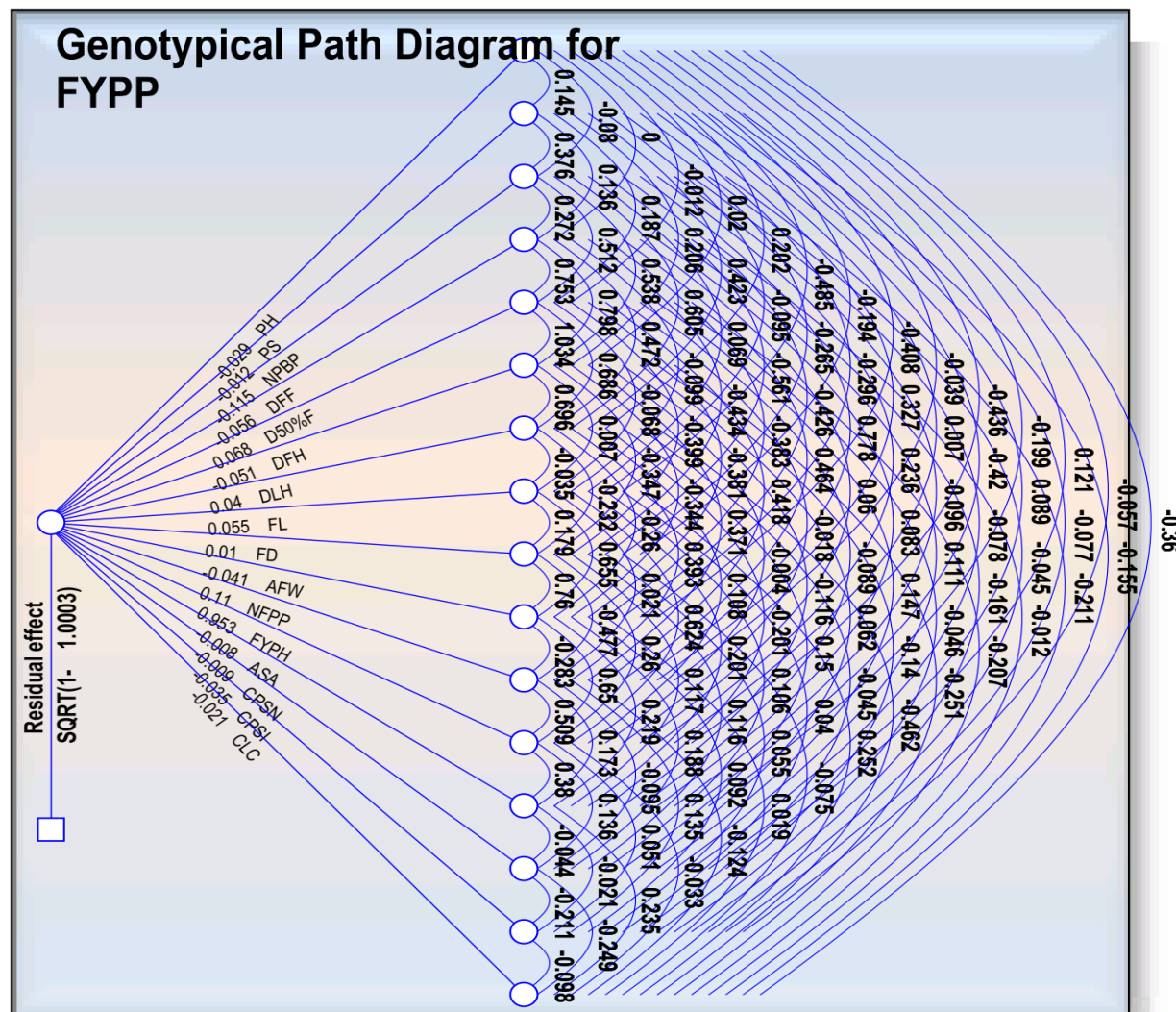


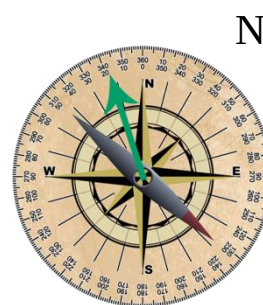
Fig 4.13: Genotypic path diagram representing direct and indirect effects for fruit yield in chilli

PH - Plant height (cm), PS - Plant spread (cm), NPBP - Number of primary branches per plant, DFF - Days to first flowering, D50%F - Days to 50 percent flowering, DFH - Days to first harvest, DLH - Days to last harvest, AFW - Average fruit weight (g), FL - Fruit length (cm), FD - Fruit diameter (cm), NF/P - Number of fruits per plant, FY/P- Fruit yield per plant (kg/plant), FY/H- Fruit yield per hectare (kg/ha), ASA - Ascorbic acid (mg/100g), CLC - Chlorophyll content of green fruits (%), CPSN - Capsanthin (ASTA unit), CPSI - Capsaicin (%). Chlorophyll content of green fruits (%).

T ₁	T ₂₁
T ₂	T ₂₂
T ₃	T ₂₃
T ₄	T ₂₄
T ₅	T ₂₅
T ₆	T ₂₆
T ₇	T ₂₇
T ₈	T ₂₈
T ₉	T ₂₉
T ₁₀	T ₃₀
T ₁₁	T ₃₁
T ₁₂	T ₃₂
T ₁₃	T ₃₃
T ₁₄	T ₃₄
T ₁₅	T ₃₅
T ₁₆	T ₃₆
T ₁₇	T ₃₇
T ₁₈	T ₃₈
T ₁₉	T ₃₉
T ₂₀	T ₄₀
Rep-I	

T ₁₀	T ₁₄
T ₁₉	T ₄₀
T ₈	T ₃₈
T ₃₇	T ₃₆
T ₆	T ₃₉
T ₂₅	T ₇
T ₄	T ₃₅
T ₂	T ₃₀
T ₁	T ₁₁
T ₂₀	T ₃₂
T ₉	T ₃₄
T ₁₇	T ₃₃
T ₁₅	T ₂₃
T ₁₈	T ₂₉
T ₁₆	T ₂₄
T ₂₂	T ₂₈
T ₁₃	T ₅
T ₁₂	T ₂₇
T ₃₁	T ₂₆
T ₂₁	T ₃
Rep-II	

T ₄₀	T ₂₀
T ₃₉	T ₁₉
T ₃₈	T ₁₈
T ₃₇	T ₁₇
T ₃₆	T ₁₆
T ₃₅	T ₁₅
T ₃₄	T ₁₄
T ₃₃	T ₁₃
T ₃₂	T ₁₂
T ₃₁	T ₁₁
T ₃₀	T ₁₀
T ₂₉	T ₉
T ₂₈	T ₈
T ₂₇	T ₇
T ₂₆	T ₆
T ₂₅	T ₅
T ₂₄	T ₄
T ₂₃	T ₃
T ₂₂	T ₂
T ₂₁	T ₁
Rep-III	



Design: RBD

Number of Treatment: 40

Number of Replication: 3

Plot size: 1.8cm x 2.4cm

Spacing: 60 x 60 cm

Plate 3.1: Layout of the experimental plot of chilli

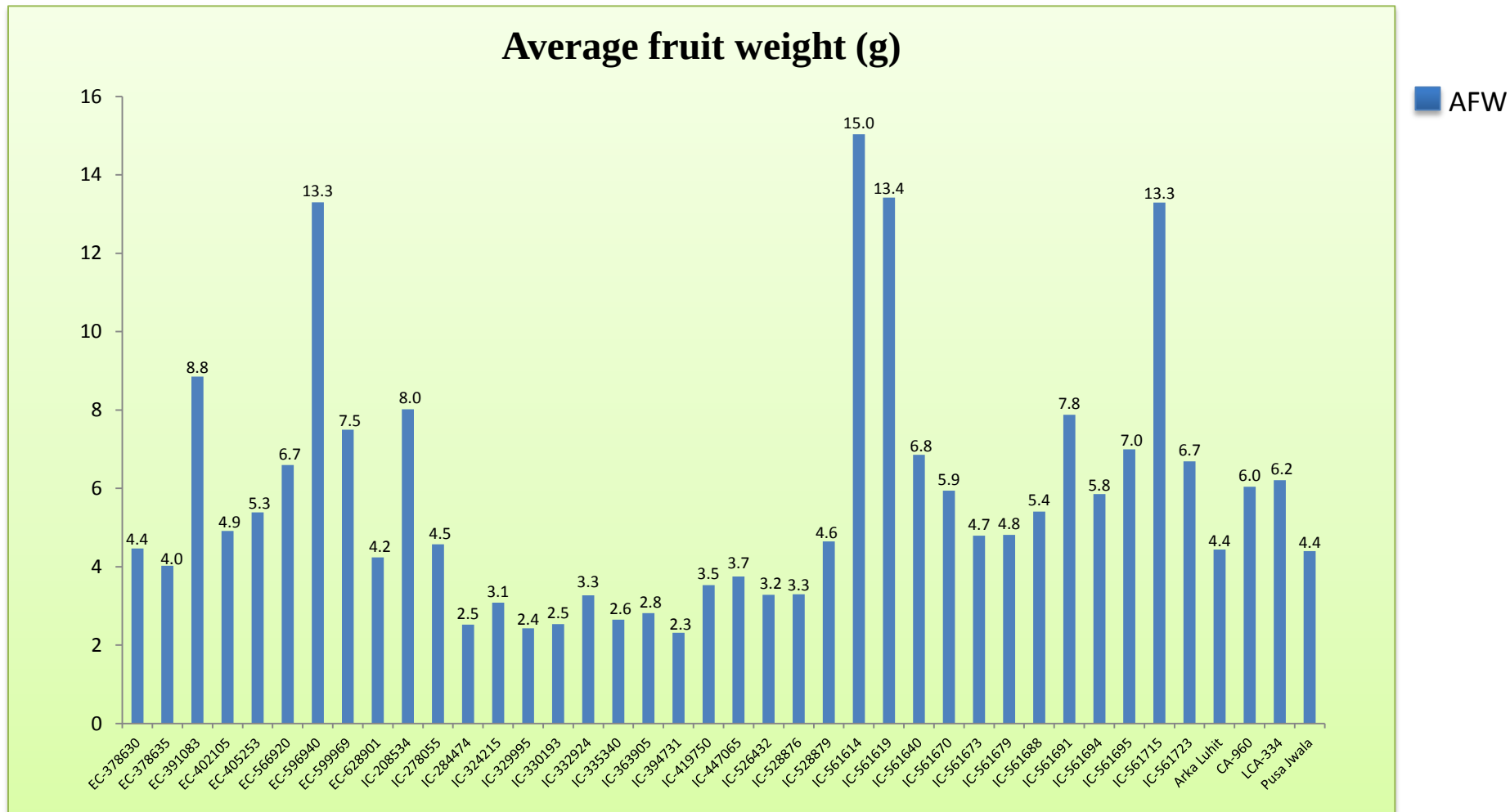


Fig 4.1: Average fresh fruit weight of 40 chilli genotypes

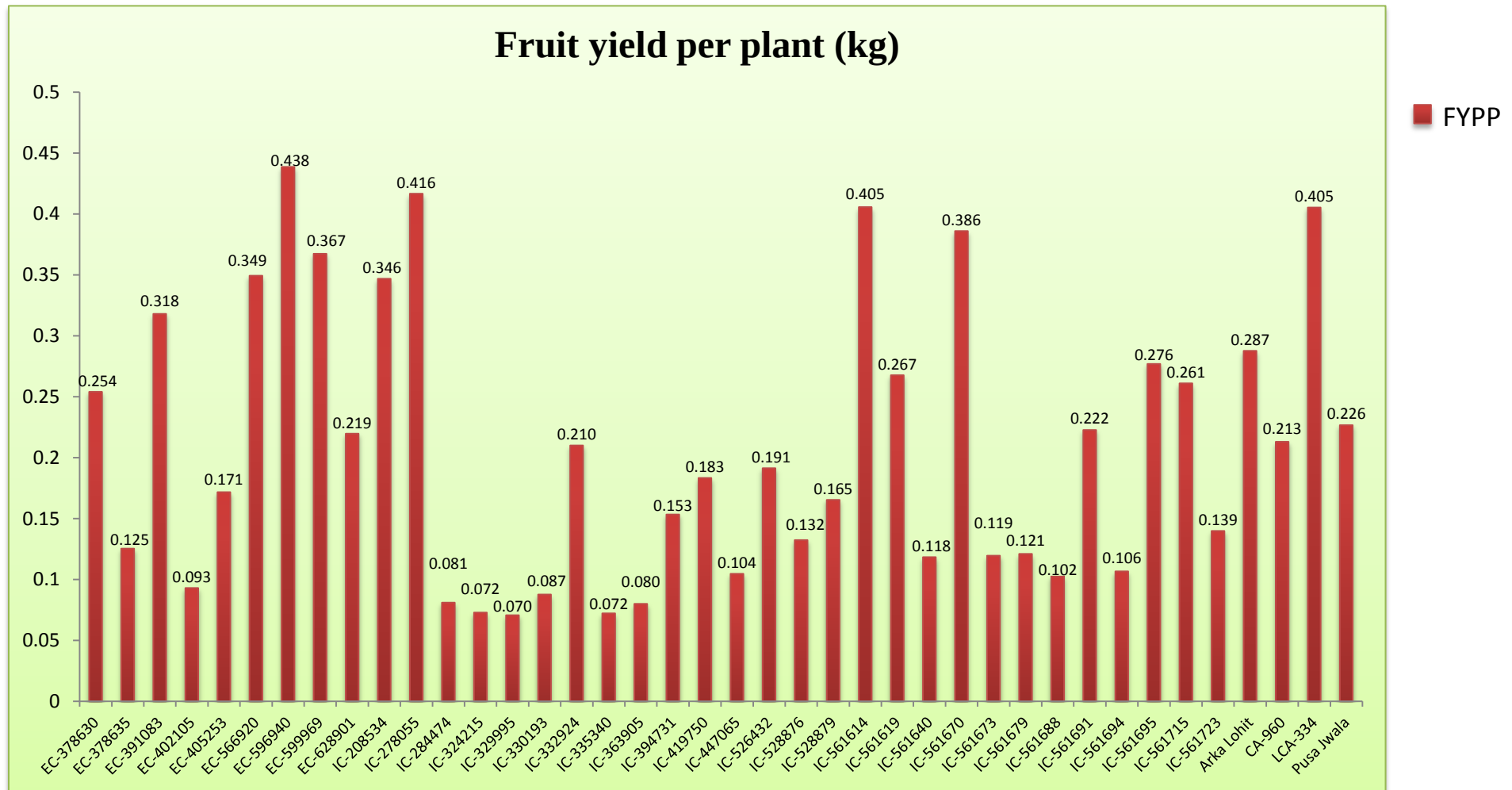


Fig 4.2: Fresh fruit yield per plant of 40 chilli genotypes

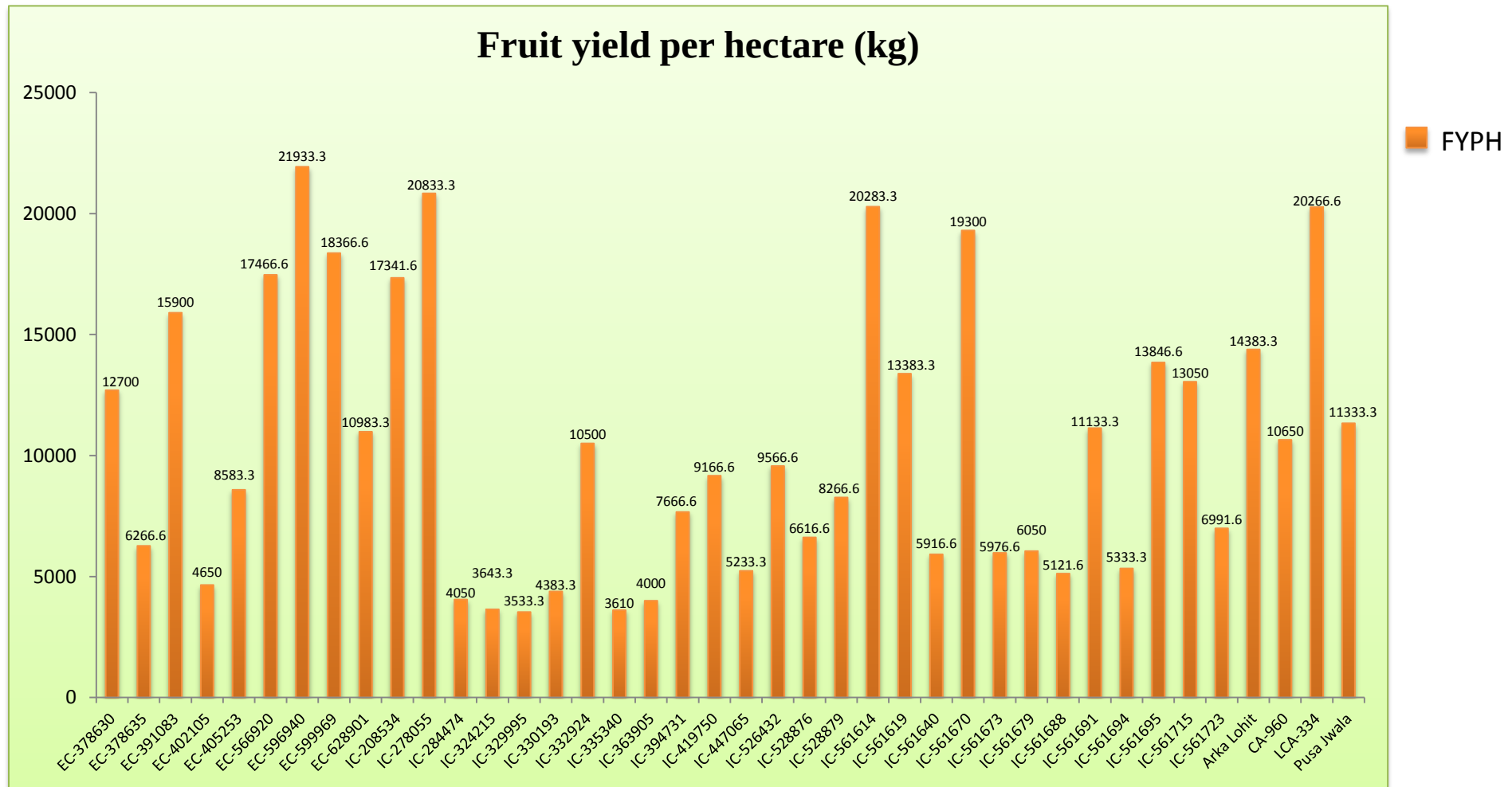


Fig 4.3: Fresh fruit yield per hectare of 40 chilli genotypes

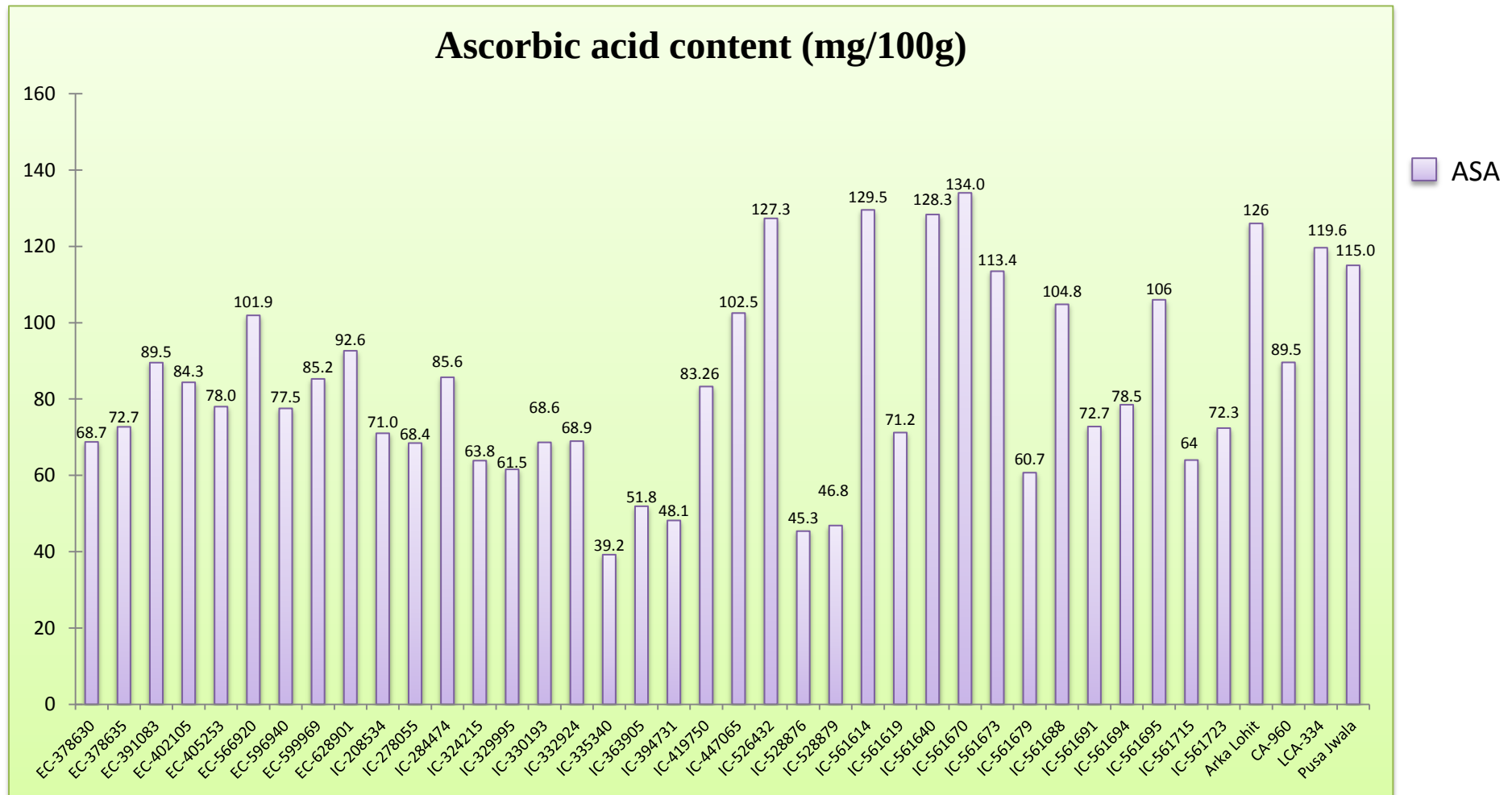


Fig 4.4: Ascorbic acid content of 40 chilli genotypes

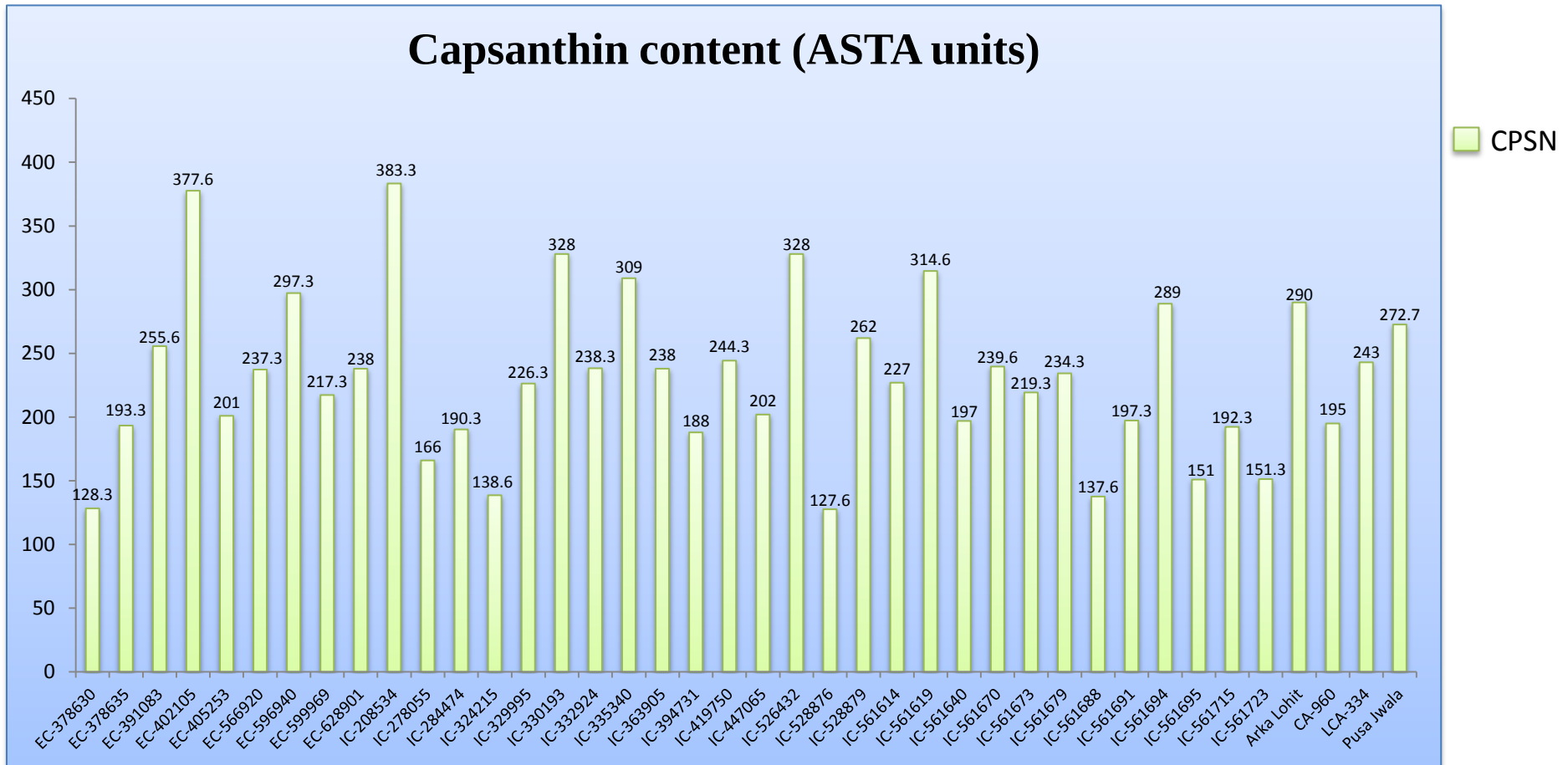


Fig 4.5: Capsanthin content of 40 chilli genotypes

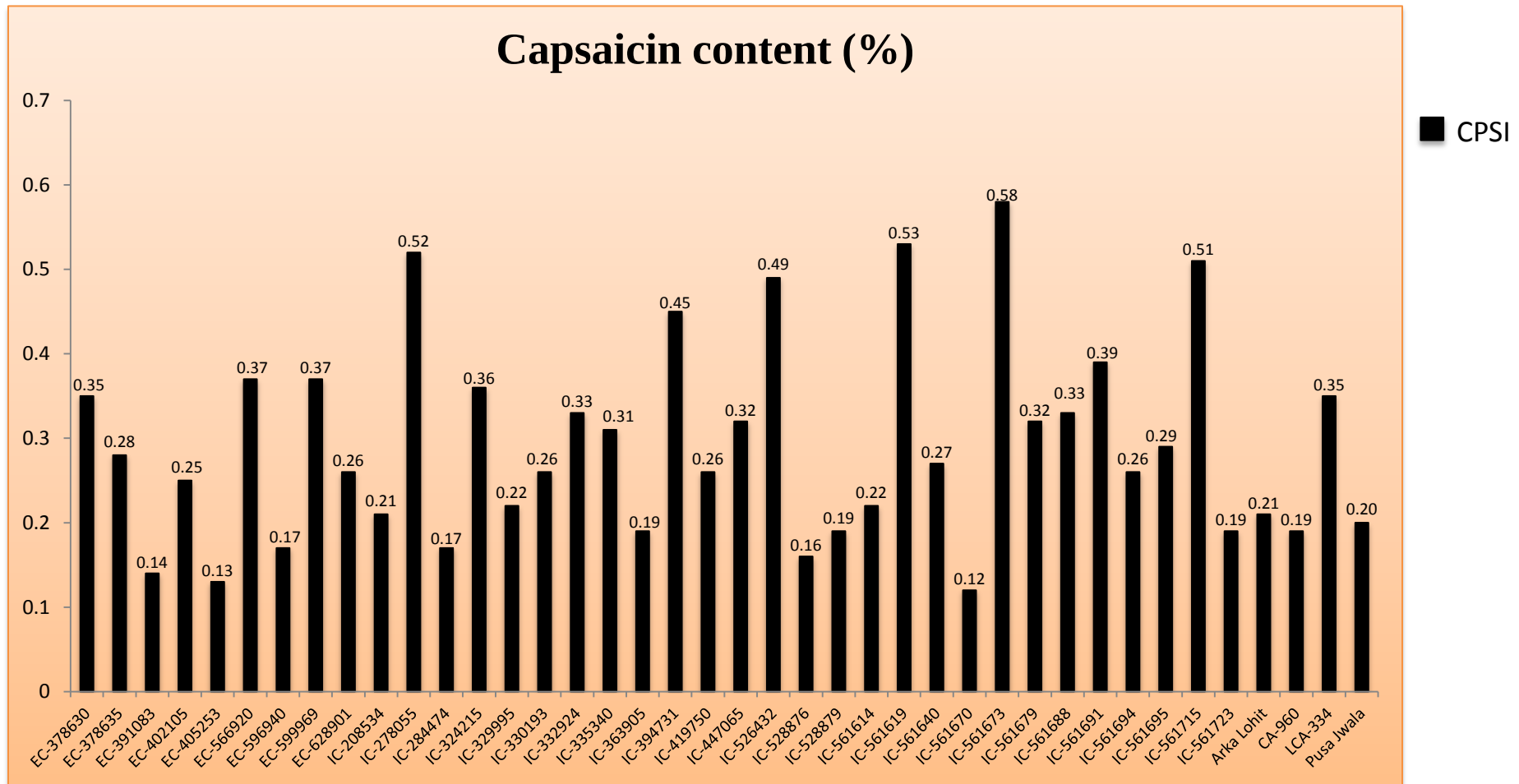


Fig 4.6: Capsaicin content of 40 chilli genotypes

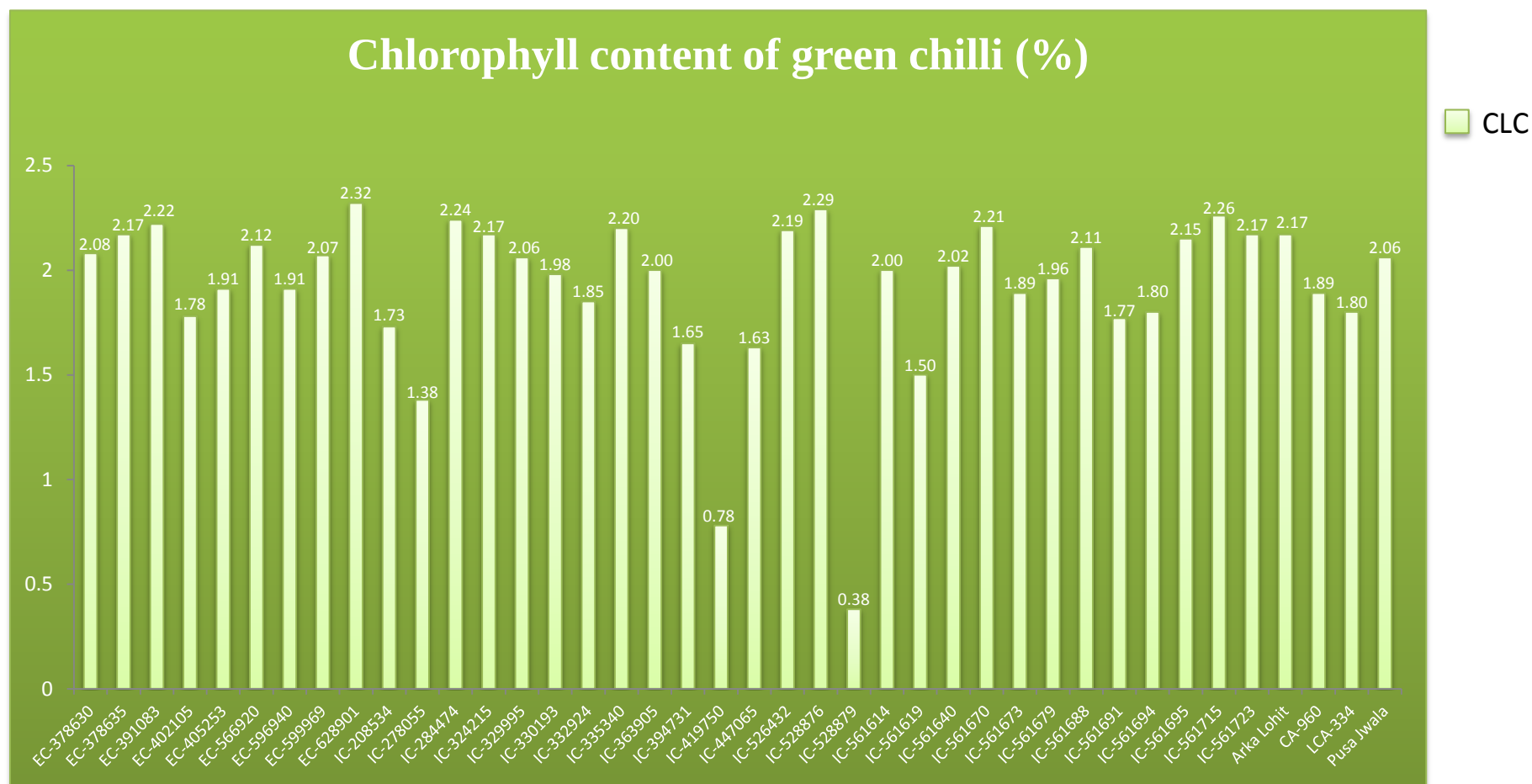


Fig 4.7: Chlorophyll content of 40 chilli genotypes

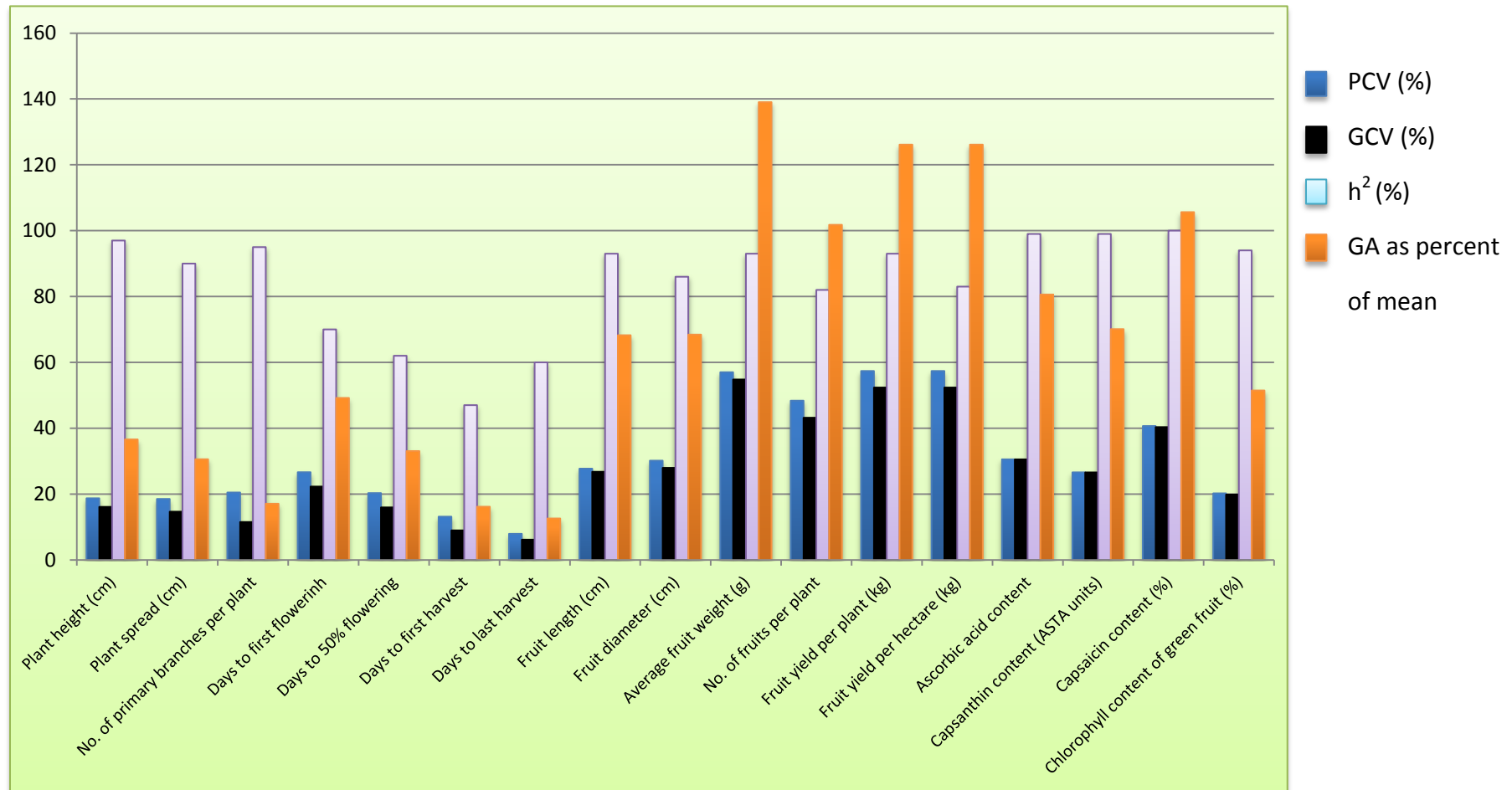


Fig 4.11: Estimation of variability, heritability and genetic advance as percent of mean for 17 characters in 40 chilli genotypes

CHAPTER-VI

SUMMARY AND CONCLUSIONS

The present investigation entitled “Genetic variability, genetic divergence studies for yield and yield related traits in chilli (*Capsicum annum* L.) germplasm” was carried out by involving 40 genotypes of chilli (*Capsicum annum* L.) during *Kharif*, 2019 at ICAR-NBPGR Regional station, Rajendranagar, Hyderabad, with the objective to study the nature and magnitude of genetic diversity available in the germplasm so as to select genetically divergent and horticulturally superior genotypes as parents for heterosis breeding to exploit hybrid vigour and combining ability.

The germplasm consisting of 40 lines were evaluated in a Randomized Block Design with three replications during *Kharif*, 2019 for genetic variability and diversity studies. The mean data was recorded for 17 characters viz., plant height (cm), plant spread (cm), number of primary branches per plant, days to first flowering (DAT), days to 50% flowering (DAT), days to first harvest (DAT), days to last harvest (DAT), fruit length (cm), fruit diameter (cm), number of fruits per plant, average fresh fruit weight (g), fresh fruit yield per plant (kg/plant), fresh fruit yield per hectare (kg/ha), ascorbic acid content (mg/100g of fruit), capsanthin content (ASTA units), capsaicin content (%), chlorophyll content of green chilli (%). Analysis of variance (ANOVA) of RBD revealed that the genotypes differed significantly for all the 17 characters.

The result of mean performance of forty genotypes for seventeen characters revealed that the genotype EC-596940 was superior for yield and yield contributing characters *i.e.*, average fresh fruit weight (13.3g), fresh fruit yield per plant (0.439kg) and fresh fruit yield per hectare (21933.3kg). The genotype IC-561619 was found to be early for days to first flowering (13.33 days). The genotype IC-561673 was found superior to be early harvesting, days to first harvest (69.67 days) and days to last harvest (119.66 days). Genotype IC-561670 was found superior for ascorbic acid content (134.01mg/100g). High capsanthin content (358.67ASTA units) in genotype IC-208534 and high chlorophyll

content (2.32%) in genotype EC-628901 were found. Genotype IC-561673 was found superior for capsaicin content (0.58%) over other entries and checks.

Mahalanobis D^2 statistics revealed that considerable genetic diversity exists within and among the ten clusters. The characters chlorophyll content, ascorbic acid content and fruit yield per hectare were the major characters that contributed towards divergence. The inter cluster D^2 values of the ten clusters revealed that the highest inter cluster generalized distance (11369.49) was between cluster IX and cluster X, while, the lowest (325.48) was between cluster III and cluster VII. The clusters showing high genetic divergence could be effectively utilized in heterosis breeding programme.

Variability studies revealed that PCV was higher than the corresponding GCV for all the characters indicating that all characters have interacted with environment to some degree. High PCV and GCV were recorded for number of primary branches per plant, days to first flowering, days to 50% flowering, fruit length, fruit diameter, average fruit weight, number of fruits per plant, fruit yield per plant, fruit yield per hectare, ascorbic acid content, capsanthin content, capsaicin content and chlorophyll content indicating the existence of wider genetic variability for these traits in the genotypes under study. On the other side, PCV and GCV estimates were moderate for the traits plant height, plant spread and days to first harvest. Only one character days to last harvest was found with low variability suggesting narrow range of genetic variability for these traits.

High heritability coupled with high genetic advance as per cent of mean indicated operation of additive gene action which was observed in characters viz., plant height, plant spread, days to first flowering, days to 50% flowering, fruit length, fruit diameter, average fruit weight, number of fruits per plant, fruit yield per hectare, ascorbic acid content, capsanthin content, capsaicin content and chlorophyll content. Hence, directional selection for these traits in genetically diverse material could be effective for desired genetic improvement. Moderate genetic advance as per cent of mean with high or moderate heritability suggests the action of both additive and non-additive genes there by favorable influence of environment in the expression of the traits. The same was reported in case of number of primary branches per plant, days to first harvest and days to last

harvest. Moderate heritability coupled with low genetic advance as per cent of mean indicates the influence of non-additive gene action and considerable influence of environment on the expression of these traits, which didn't observed in any case.

The results on character association indicated positive, though not significant association of fruit yield per plant with plant height, plant spread, number of primary branches per plant, days to first flowering, days to 50% flowering, days to first harvest, days to last harvest, fruit length, fruit diameter, average fruit weight, number of fruits per plant, fruit yield per hectare, ascorbic acid content, capsanthin content, capsaicin content and chlorophyll content which indicated that the adequate knowledge of interrelationship between fruit yield per plant and its components creates ample scope in the improvement of yield by improving these characters as they are highly correlated.

Path coefficient analysis showed that the number of fruits per plant and fruit yield per hectare showed positive direct effect at both phenotypic and genotypic levels on fruit yield per plant. Showed positive direct effect at phenotypic level in plant height, days to first harvest, ascorbic acid and capsaicin content. Days to 50% flowering, days to last harvest, fruit length and fruit diameter showed positive direct effect at genotypic level on fruit yield per plant. It clearly indicated that direct selection based on these characters would be effective for an increase in yield.

From the present investigation, high yielding genotypes viz., EC-596940, IC-278055 and IC-561614 may be released as varieties for commercial cultivation after multi-location trials.

Early genotypes IC-561673, IC-561688, IC-561670, EC-596940, IC-330193 and IC-561614 may be used in breeding programmes for developing early maturing varieties.

Genotypes IC-561670, IC-561614, EC-628901, IC-528876, IC-208534, EC-402105, IC-561673 and IC-561619 were best for quality parameters. Hence, these genotypes can be released for commercial cultivation after multi-location trials over seasons.

Future line of work

On the practical standpoint from the results obtained, future thrust can be laid on the following aspects of chilli crop improvement programmes.

Considering the mean performance, three superior genotypes for fruit yield viz., EC-596940 (21933.3kg), IC-278055 (20833.3kg) and IC-561614 (20283.3kg) can be released as pure lines or varieties after evaluating in multi-location trials for their use in further hybridization programme.

The genotypes with superior quality traits viz., IC-561670 for ascorbic acid (134.01mg/100g), IC-208534 for capsanthin content (358.67 ASTA units) and IC-561673 for capsaicin (0.58%) can be included in pedigree selection for further improvement.

The genotype IC-561673 was found to be early as observed from the characters days to 50% flowering, days to first harvest and days to last harvest.

Extensive breeding work to improve the genotypes producing stable capsanthin to the extent of more than 150 ASTA units and extensive breeding work to improve the yield of chilli.

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*Originals not seen.