IDENTIFICATION OF PAPRIKA (*Capsicum annuum* L.) GENOTYPE(S) FOR YIELD AND QUALITY CHARACTERS

by

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(2010-12-101)

THESIS

Submitted in partial fulfillment of the

requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF OLERICULTURE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

2012

DECLARATION

I hereby declare that this thesis entitled **"Identification of paprika (*Capsicum annuum* L.) genotype(s) for yield and quality characters"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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ACKNOWLEDGEMENT

I bow my head before God Almighty for all the bountiful blessings he has showered on me at each and every moment without which this study would never have seen light.

I wish to express my deep sense of gratitude and indebtedness to

Dr. I. Sreelathakumary, Professor, Department of Olericulture, Chairperson of the advisory committee. for her note worthy guidance, creative suggestions and sustained interest. I am indebted to my major advisor for her constant encouragement, timely advice and friendly approach during the course of study as well as investigation and in the execution of this thesis.

Dr. M. Abdul Vahab, Professor and Head, Department of Olericulture, for his continuous and timely advice, constructive criticisms and guidance at all the stage of research work.

Dr. V. A. Celine, Professor, Department of Olericulture for her valuable suggestions and critical evaluation during the course of this work.

Dr. C. R. Sudharmai Devi, Professor Department of Soil Science and Agricultural Chemistry, for her guidance and suggestions rendered to me in formulating the thesis.

Mr. C. E. Ajith Kumar, Junior Programmer of Department of Agricultural Extension for helping me in getting the data analysed .

I sincerely thank the facilities rendered by the library of College of Agriculture Vellayani.

Bismi and Aneesh for their co-operation and sincere efforts for the successful completion of my research work.

Teaching and Non teaching staff of the Department of Olericulture and labourers for their co-operation and sincere efforts for the successful completion of my research work.

Staff of the Department of Soil Science and Chemistry who assisted me to complete my analysis work.

My classmate Sivakumar V for the co-operation and support during the course of study.

My dear friends Shruthi. K. Soman and Sneha Elizabeth Varghese for their love, inspiration and support which is always unforgettable.

My batchmates Divya, Asha, Subitha, Soniya and others. My heartfelt thanks to my best friends who has always for me as a friend, loving support, confidence, moral support and so much more.

My seniors Kranthi, Divya, Resmi, Anju, Kavitha, Mariya, Shameena, Siji for their support and guidance.

My juniors Shruthi, Divya and Robida for their love, timely help, support and co-operation during the course of study.

I am most indebted to my loving father and mother for their affection, constant encouragement, moral support and blessings that have enabled me to compute this work without which I would not have completed this research. Words fail to express my deep sense of gratitude to my lovely sister Parvathy. My heartfelt thanks to Dileep, Dileesh, Karthika, Harikrishnan, Haripriya and all family members for their affection and encouragement.

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DEDICATED TO ... MY FAMILY

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LIST OF ABREVIATIONS

%	-	per cent
µg	-	microgram
CD	-	Critical difference
Cm	-	centimeter
DAT	-	Days After Transplanting
et al	-	And others
Fig.	-	Figure
g	-	gram
GA	-	Genetic Advance
GCV	-	Genotypic Coefficient of Variation
h	-	hour
H^2	-	Heritability
ha	-	hectare
I.U	-	International Unit
IPGRI	-	International Plant Genetic Resources Institute
KAU	-	Kerala Agricultural University

kg	-	Kilogram
m	-	metre
mg	-	milligram
min	-	minutes
ml	-	millilitre
mm	-	millimeter
nm	-	nanometer
°C	-	Degree Celcius
PCV	-	Phenotypic Coefficient of Variation
s	-	seconds
SE	-	Standard error
t	-	tons
UPGMA	-	Unweighted Pair Group Method with Arithmetic Mean
Var.	-	variety

INTRODUCTION

1. INTRODUCTION

Chilli [*Capsicum annuum* (L.) (2n = 24) family Solanaceae] is an important vegetable cum spice crop rich in vitamins yielding capsaicin, oleoresin and extractable colour. It includes all the commercially important types *viz.*, red pepper, paprika, cayenne, chilli and sweet pepper.

Capsicum is derived from the Greek word 'Kapso' meaning 'to bite'. Among the five cultivated species *viz. C. annuum*, *C. frutescens*, *C. chinense*, *C. baccatum* and *C. pubescens*, most of the commercially cultivated chilli types including paprika belong to the species *C. annuum*. The origin of chilli is Mexico, with secondary centres in Guatemala and Bulgaria.

Paprika is defined in the world market as non-pungent brilliant red ground capsicum powder, derived from the dried red pods, with most of the seeds and veins removed. Paprika is the high coloured low pungent chilli. This is mainly used for its rich red colour although in fresh form it contributes a special delicate flavour (Mathew, 2008). The Hungarain word for plants in the genus *Capsicum* is 'paprika'. The Hungarian paprika may be pungent or non-pungent, depending upon the cultivar.

India is the leading producer of chilli in the world. World production is going up year after year as more consumers are falling for the flavour of the chilli (Murugan, 1998). In India chilli is grown in an area of 7.90 lakh ha with a production of 12.23 lakh tonnes and a productivity of 1.5 t/ha (Anon. 2011). The area under chilli cultivation in Kerala is 1501 ha and production is 1302 tonnes (Anon. 2012).

Value addition of spices holds a great potential for India with the global food industry increasing towards oleoresins and oils with a natural flavour. Paprika is gaining more importance in the global market because of its value added products like oleoresin, capsaicin, chilli powder etc. In India the export of these products are

increasing tremendously every year and thus contribute a major share in Indian economy.

Paprika is valued most for its colour and mildness of flavour. The market value of paprika depends largely on its red colour, both surface hue and extractable colour. The pigment content of paprika varies from 0.1 – 0.8%. The pigments comprise a mixture of closely related carotenoids such as capsorubin, capsanthin, β - carotene, zeaxanthin, violaxanthin and lutene. The most important pigments responsible for red colour are capsanthin and capsorubin. The paprika colours are not metabolised in human body and hence are an ideal natural colour additive for food items.

Oleoresin represents the total flavour of ground spice and consists of fixed oil, capsaicin, pigments, sugars and resin. Oleoresin of paprika is used to impart bright red color to meat, sausage products, sauces and to other processed foods thus making the product more acceptable and pleasing to the eye. The pungency of chilli is due to crystalline acrid volatile alkaloid capsaicin, present in the placenta of fruits. Paprika is a rich source of vitamin C. Vitamins A and E, small quantity of proteins, fat, carbohydrates and traces of minerals are also present in paprika fruits.

The main objective of paprika research involves in the development of varieties or hybrids for export as well as for domestic consumption. The major thrust area is the improvement in paprika both as a vegetable and a condiment plant. The former refers to vegetable paprika which is a green pepper used for raw consumption, in making stuffed sweet pepper dishes and for processing into canned or pickled forms. Latter is the spice paprika which deals with red high colour paprika suitable for paprika powder and oleoresins used for food seasoning and other commercial purposes. Arka Abir and Kt-Pl-19 are the released paprika varieties and Byadagi is a local paprika type mainly grown in Karnataka which has got a geographical indication rank.

Paprika can be successfully grown in Kerala. There exists considerable variability in paprika genotypes with respect to yield and quality attributes. Considering the economic importance of paprika, varietal improvement of existing strains available in different parts of the county in terms of quality and productivity assumes significance. The information on variety suitability and the extent of genetic variability will be useful for the crop improvement. The stage of harvest may vary with the purpose for which paprika fruits are used. The quality parameters vary with the harvesting stage. Information on the correct stage of maturity which yields economic level of quality attributes will be very useful for the farmers and paprika industries.

Taking into considerations of all these aspects, the present study was undertaken with the following objectives:

1. To identify superior genotype(s) of paprika based on yield, quality and pest and disease resistance.

2. To estimate the extent of available variability for important characters in paprika.

3. To study the extent of genetic divergence among the accessions and to group them based on genetic distance.

4. To estimate the role of genetic contribution in the expression of each character

5. To measure the degree and pattern of association between the characters.

6. To study the influence of harvest maturity stages on quality characters.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Capsicum annuum is the most important spice on a world scale and it includes all the commercially important types *viz.*, red pepper, paprika, cayenne, chillies and sweet pepper. Paprika is defined in the world market as non-pungent brilliant red ground capsicum powder, derived from the dried red pods, with most of the seeds and veins removed.

In the present investigation an attempt has been made to study genetic variability, heritability, genetic advance, character association, path coefficient analysis, genetic divergence in paprika and influence of harvest maturity on quality.

The literature is reviewed under the following headings.

2.1 Variability

2.2 Heritability and Genetic advance

2.3 Correlation studies

2.4 Path coefficient analysis

2.5 Selection index

2.6 Genetic divergence

2.7 Quality

2.8 Incidence of diseases

2.9 Influence of harvest maturity on quality

2.1 Variability

Variability either naturally existing or created artificially forms the basis for any crop improvement programme.

Considerable variation for several characters was reported in paprika by Anu (2001), Bini (2004), Ahmed *et al.* (2006), Sandeep (2007), Prasath *et al.* (2007), Prasath and Ponnuswami (2008), Srividya and Ponnuswami (2010) and Kumari *et al.* (2010).

Field evaluation studies of 20 paprika types revealed suitability of its cultivation in Kerala during winter months (Indira, 1994). Evaluation and subsequent selection for less pungent chilli cultures resulted in the development of a less pungent paprika selection CA 517 at Kerala Agricultural University (Indira and Rajan, 1997).

Realizing the vast potential of paprika some works were undertaken to study the variability in paprika. Korikkanthimath *et al.* (2000) reported the work undertaken by Indian Institute of Spice Research and University of Agricultural Sciences, Dharwad on the evaluation and improvement of Byadagi paprika types. The performance of improved lines Kt-Pl-19 was considered along with the suggestion for Byadagi paprika improvement. A few selections were made from Byadagi chillies at Indian Institute of Horticulture and the selection was released as Arka Abir (John, 2000).

To study the feasibility of paprika cultivation in Kerala, Anu (2001) conducted an experiment at the Indian Institute of Spices Research, Calicut, Kerala. Forty indigenous and exotic paprika genotypes collected from various sources were evaluated for their morphological and biochemical characters for three seasons. Variation in morphological and quantitative characters was reported. Genotype Paprika King was found to be superior to other types in yield and colour value followed by PBC 066, KT-Pl-8 and KT-Pl -20.

Genetic cataloguing of germplasm based on standard descriptors helps in international exchange of information in a more scientific way. Manju (2001) describes hot chilli accessions based on IPGRI descriptor and observed variability for

plant, fruit and seed characters. Sood *et al.* (2011a) characterized 25 genotypes of bell pepper for various morphological characters.

2.1.1 Morphological characters

High phenotypic and genotypic coefficient of variation for plant height in paprika was reported by Bini (2004), where as Sandeep (2007) reported the presence of low GCV and moderate PCV in Byadgi kaddi and Byadgi dabbi accessions. A wide range of variation for plant height was reported by Prasath and Ponnuswami (2008) in paprika. Kumari *et al.* (2010) obtained a phenotypic and genotypic coefficient of variation of 15.23 and 14.84 per cent respectively in a study consisting of 94 paprika accessions.

Giritammanavar (1995) reported a moderate phenotypic and genotypic coefficient of variation in paprika for primary branches. Rao (2005) revealed a low range of variation in primary branches in Byadagi genotypes. Sandeep (2007) obtained a low GCV and moderate PCV. Smitha and Basavaraj (2007), Sharma *et al.* (2009) and Singh and Singh (2011) reported high values of phenotypic and genotypic coefficients of variation in chilli.

Low phenotypic and genotypic coefficients of variation was reported for days to flowering in paprika by Giritammanavar (1995), Bini (2004), Rao (2005) and Sandeep (2007). Kumari *et al.* (2010) reported low values of 8.20 and 8.37 for genotypic and phenotypic coefficients of variation for days to flowering in paprika.

Chatterjee (2006) and Farhad *et al.* (2008) reported a low phenotypic and genotypic coefficients of variation for days to maturity in paprika. Kumari *et al.* (2010) also reported similar findings.

2.1.2 Economic characters

2.1.2.1 Fruit characters

Bini (2004) observed high phenotypic and genotypic coefficients of variation in paprika for fruit characters. Rao (2005) reported moderate values of GCV and PCV for fruit characters in Byadagi selections. High values of GCV and PCV are reported by Mishra *et al.* (2005) and Smitha and Basavaraj (2007) in chilli.

Fruit length varied from 3.97 – 13.17 cm, fruit girth from 1.25- 4.6 cm in paprika. Phenotypic and genotypic coefficients of variation of 24.37 and 22.69 for fruit length and 30.61 and 28.63 for fruit girth was recorded respectively (Kumari *et al.*, 2010).

Moderate PCV and GCV were recorded for pedicel length (Srilakshmi, 2006). Sood *et al.* (2011b) recorded a PCV and GCV of 22.31 and 22.29 for pericarp thickness in bell pepper.

Giritammanavar (1995), Bini (2004), Rao (2005) and Sandeep (2007) obtained high phenotypic and genotypic coefficients of variation for fruits per plant in paprika. Mini (2003), Patil (2007) and Singh and Yadav (2008) also reported similar results. A phenotypic and genotypic coefficient of variation of 32.82 and 32.46 per cent respectively for fruits per plant was reported by Kumari *et al.* (2010) in paprika.

Bini (2004) studied 44 paprika genotypes and observed high phenotypic and genotypic coefficients of variation for yield per plant. Other similar results were reported by Shirsat *et al.* (2007), Patil (2007) and Farhad *et al.* (2008). Kumari *et al.* (2010) observed considerable variation for the character with a range of 291.67 to 1195.5 g and 35.56 and 35.53 per cent of phenotypic and genotypic coefficients of variation respectively.

2.1.2.2 Seed characters

Sarkar *et al.* (2009) reported wide variation for seeds per fruit. Kumari *et al.* (2010) observed higher genotypic and phenotypic coefficients of variation for seeds per fruit. Seeds per fruit ranged from 21-188.33.

2.2 Heritability and genetic advance

Heritability and genetic advance are important selection parameters. The ratio of genetic variance to phenotypic variance is known as heritability. According to Hanson *et al.* (1956) heritability in broad sense is the ratio of genotypic variance to total variance in nonsegregating population.

Moderate heritability for plant height was observed by Ajjappalavara and Channagoudra (2009) in chilli. High heritability for plant height was observed by Kumari *et al.* (2010) in paprika.

Giritammanavar (1995) and Rao (2005) recorded a low heritability and genetic advance for primary branches per plant in paprika whereas high values of heritability coupled with high genetic advance (GA) as percentage of mean were obtained for primary branches per plant by Farhad *et al.* (2008) in chilli.

Low heritability and genetic advance for days to flowering were recorded by Giritammanavar (1995) in paprika. High heritability coupled with low genetic advance values for the same were recorded by Rao (2005) and Kumari *et al.* (2010).

Choudhary and Samadia (2004) and Chatterjee (2006) reported a high heritability coupled with a high genetic advance for days to maturity in chilli. Kumari *et al.* (2010) observed a high heritability coupled with low genetic advance values for days to maturity in paprika.

Giritammannavar (1995), Bini (2004) and Kumari *et al.* (2010) observed a high heritability coupled with high genetic advance for fruit girth in paprika.

Fruit weight exhibited a high heritability coupled with high genetic advance as reported by Bini (2004), Gupta *et al.* (2009), Sarkar *et al.* (2009) and Kumari *et al.* (2010).

A high value of heritability coupled with high genetic advance was observed for fruits per plant by Bini (2004), Sandeep (2007), Patil (2007), Ukkund *et al.* (2007), Patel *et al.* (2009) and Kumari *et al.* (2010).

Yield per plant registered high estimates of heritability and genetic advance as reported by Bini (2004), Sandeep (2007), Patel *et al.* (2009), Gupta *et al.* (2009), Kumari *et al.* (2010) and Sood *et al.* (2011 b) indicating a preponderance of additive gene action.

Moderate and high heritability for pedicel length was reported by Giritammannavar, (1995) and Rao (2005) respectively in paprika genotypes.

High heritability coupled with moderate genetic advance for pericarp thickness was observed by Sood *et al.* (2011b).

Kumari *et al.* (2010) revealed high heritability coupled with high genetic advance for several biometric characters including seeds per fruit.

2.3 Correlation studies

Knowledge of association between yield and its component characters and between component characters is essential for yield improvement through selection programme. The correlation coefficient analysis measures the mutual relationship between various characters and it determines the component traits on which selection can be relied upon the effect of improvement. The coefficient of correlation can vary from +1 to −1.

Acharya *et al.* (2002) reported positive and significant correlation of total fresh yield per plant with total dry yield per plant. Khader and Jose (2002) reported positive correlation of yield with fruit weight, fruits per plant , primary branches per plant, secondary branches per plant, plant height, 100 seed weight, fruit length, fruit girth and crop duration. Correlation was negative with days to flowering.

Correlation and path analyses for oleoresin yield and yield components were conducted for *C. annuum* (CA 653, Arka Lohit, Ujwala and KTPL-19), *C. chinense* (CA 640 and CA 645), *C. frutescens* (CA 671 and CA 648) and *C. baccatum* (CA 670) cultivars grown in Kerala by Mini and Vahab (2002). The days to flowering was positively associated with days to first fruit set and first harvest, and fruit yield per plant. The days to fruit set had a significant and positive association with days to first harvest and negative association with fruits per plant.

Fruit yield was positively correlated with fruits per plant, fruit length, fruit diameter, plant height, capsaicin content and colouring matter but negatively correlated with number of days of flowering (Khuranna *et al.*, 2003). Krishnakumar *et al.* (2003) also observed positive association of yield with number of primary and secondary branches, fruits per plant and other characters.

Significant positive correlation existed between days to 50% flowering and plant height and branch number, plant height and fruit number, branch number and fruit number, fruit length and flesh to seed ratio, fruit length and average fruit weight, fruit girth and pungency, flesh to seed ratio and average fruit weight and average seed weight (Ahmed *et al.*, 2006).

Fruit weight, pericarp thickness, number of seeds per fruit and 1000 seed weight showed positively significant association with fruit yield (Chatterjee *et al.*, 2007).

Emphasis should be given to the genotypes that are having more number of fruits, more width, and higher average fruit weight in the selection process due to their high positive effect on yield (Reddy *et al.*, 2008).

Jabeen *et al.* (2009) studied 25 chilli genotypes and observed that the yield per plant exhibited highly significant correlation with fruits per plant, branches per plant and height.

Fruits per plant and green fruit length showed highly positive direct effects on fruit yield per plant in a study involving 34 chilli genotypes (Chattopadhyay *et al.*, 2011).

Correlation studies conducted in 94 diverse genotypes of paprika indicated that dry fruit yield per plant showed significant and positive association with plant height, plant spread, fruits per plant, fruit girth, seeds per fruit and capsanthin content. (Kumari *et al.*, 2011).

Singh and Singh (2011) in a study of thirty diverse chilli genotypes observed significant and positive correlation of fruits per plant, yield per plant and red ripen fruit yield.

2.4 Path coefficient analysis

Certain characters might indirectly influence yield, but their correlation with yield may not be statistically significant. In such cases, path coefficient analysis is an efficient technique, which permits the separation of coefficients into components of direct and indirect effects.

Path analysis indicated that the days to flowering had a positive direct effect on oleoresin yield. The days to harvesting and fruits per plant had negative direct effects on oleoresin yield (Mini and Vahab, 2002).

Path analysis with yield as the dependent variable revealed in the study conducted by Kumar *et al.* (2003) that fruit length and fruits per plant had higher degree of direct effect, followed by fruit weight and day to fruit harvest. Dipendra and Gautam (2003) reported in their study conducted using 52 chilli genotypes that fruits per plant exerted highest positive direct effect (0.7148) on yield, followed by fruit length (0.3155) and fruit diameter (0.3138), indicating importance of these characters in yield improvement programme. Sreelathakumary and Rajamony (2003) reported that fruits per plant, fruit weight and fruit girth had positive direct effect on yield whereas fruit length had negative direct effect on yield.

Genotypic path for yield per plant revealed that fruit diameter, number of primary branches, seed weight per fruit, test weight and plant height had positive direct effect on yield in Byadgi kaddi whereas in Byadgi dabbi seeds per fruit, number of primary branches, test weight, fruit length and plant height had direct positive effect on yield (Sandeep, 2007).

Dandunayak (2008) evaluated 60 chilli genotypes and path analysis revealed that the primary branches, secondary branches per plant and fruits per plant showed positive direct effects while seeds per fruit, ascorbic acid content, leaf curl complex and capsaicin content were negatively associated with yield.

The number of fruits per plant showed significantly positive association with number of primary branches (0.7831), number of secondary branches (0.5804) and fruit diameter (0.5749) (Tembhurne *et al.*, 2008).

Path coefficient analysis of thirty diverse chilli genotypes showed highly positive direct effect of fruits per plant, fruit weight, fruit length and primary branches per plant on green fruit yield per plant (Patel *et al.*, 2009).

Path coefficient studies conducted in 94 diverse genotypes of paprika revealed that the fruits per plant exhibited highest direct positive effect (0.4498 and 0.4775) and indirect effect through other characters like weight of dry stalkless chillies per plant, seeds per fruit and capsanthin content. Characters like oleoresin content, fresh to dry fruit recovery percentage and capsaicin content had negative direct effects (Kumari *et al.*, 2011).

2.5 Selection index

Discriminant function analysis developed by Fisher (1936) gives information on the proportionate weightage to be given to a yield component. Thus, selection index was formulated to increase the efficiency of selection by taking into account the important characters contributing to yield. Further Hazel (1943) suggested that

selection based on suitable index was more efficient than individual selection for the characters.

Identification of superior accessions in chilli based on discriminant function analysis was done by Rani and Usha (1996) in *C. annuum* and Manju (2001) in hot chilli. Mini (2003) constructed selection index based on fourteen characters studied in *C. annuum* genotypes. Bini (2004) opined that Vellayani Local, EG 101 and EG 105 were superior based on selection index analysis in paprika genotypes.

2.6 Genetic divergence

The magnitude of divergence between two groups under consideration is provided by D^2 statistic developed by Mahalanobis (1928).

Thirty three genotypes studied were grouped into 11 clusters by Varalaxmi and Haribabu (1991). Out of 10 characters studied, fruits per plant, fruit weight and total yield were reported to be the chief contributors towards genetic divergence. They also found no firm relationship between genetic divergence and geographical distances.

Based on D^2 statistic, Shirsat (1994) grouped 75 genotypes of chilli into 28 clusters. Maximum diversity was observed as inter cluster distance increases. The clustering pattern also revealed that geographic diversity did not seem to have direct association with genetic diversity. A comparison of cluster means for different characters indicated considerable differences between clusters for all the characters (Gill *et al.*, 1982 and Varalakshmi and Haribabu, 1991).

Prabhudeva (2003) grouped 36 genotypes into 11 clusters with D^2 values ranging between 34.02 to 102.13. In his study, maximum contribution of characters towards diversity was fruits per plant, followed by ten fruit weight and plant height.

Senapati *et al.* (2003) grouped 20 diverse chilli genotypes studied for 11 characters into 6 clusters suggesting wide diversity between these groups and four

characters viz., fresh fruit weight, fruit girth, fruit length and fruit number per plant were the chief contributors towards genetic divergence.

44 paprika genotypes were evaluated and grouped into 9 clusters considering 16 characters, each cluster with varying number of genotypes (Bini, 2004). Manju and Sreelathakumary (2004) grouped 32 accessions of hot chilli into 6 clusters. Cluster I was the largest with 21 accessions and had the highest intra cluster distance. Among the characters, fruit per plant and yield per plant contributed maximum divergence in *C. chinense*.

Karad *et al.* (2006) grouped 40 chilli genotypes into 8 clusters and reported that D^2 value ranged from 0.1032 to 8.7702. Mubarak (2002) grouped 46 chilli genotypes into 13 clusters which showed inter cluster D^2 values ranging between 18.91 and 87.12.

Genetic diversity in the available germplasm was assessed by using D^2 statistic, 102 genotypes were grouped into 15 clusters which had high range of intercluster D^2 values (Srilakshmi, 2006). Ninety accessions were grouped into 18 clusters in Byadgi kaddi and 14 clusters in Byadgi dabbi by Sandeep (2007).

Genetic diversity in the available germplasm was assessed by using D^2 statistic. 60 genotypes were grouped in to 11 clusters which had high range of intracluster distance (Dandunayak, 2008). Dutonde *et al.* (2008) grouped 40 chilli genotypes into 7 clusters.

Kumari *et al.* (2010) grouped 94 paprika genotypes into 10 clusters which indicated considerable genetic diversity in the material studied. The largest was cluster I which comprised of 24 genotypes. The cluster distances ranged from 15789.6 (between cluster II and cluster X) to 856.7 (between cluster 1 and cluster II).

2.7 Quality

Chillies are an indispensable adjunct and a popular condiment in the world of food. Chilli enjoys a unique position in the nutritional world. Besides adding flavour it also enhances the neutraceutical value to the diet. The quality of red chilli powder and paprika products is based on visual and extractable red colour, pungency level and to a lesser degree the nutrition value (Bosland, 1999).

2.7.1 Oleoresin

Oleoresin consists of fixed oil, capsaicin, pigments, sugars and resin. Oleoresin is extracted from milled paprika using organic solvents. Oleoresin has great advantages as it is free from pathogens and microbial infections, it is a sterile extract, it is a clean product, free of physical contaminants, concentrate can be easily distributed in media such as soil or water, it has longer shelf life and is free from deterioration caused by pests or moulds.

Biochemical evaluation of twenty-three paprika genotypes by Jyothi *et al.* (2008) revealed considerable variability among the cultivars with respect to oleoresin recovery. It varied from 6.91 to 13.82 per cent. Similar results are given by Gupta *et al.* (2009) and Singh *et al.* (2009). The oleoresin content of ripe fruit varied from 8.89% to 37.00%, the maximum being in 'AC-588' and the minimum in 'BCC-12 (Chattopadhyay *et al.*, 2011).

Correlation and path analyses for oleoresin yield and yield components were conducted for chilli cultivars grown in Kerala by Mini and Vahab (2002). Genetic correlation analysis revealed that oleoresin yield was positively correlated with fruits per plant, and negatively associated with number of days to fruit set, flowering and harvesting. High heritability estimates coupled with high genetic advance was observed for capsaicin in paprika (Bini, 2004).

2.7.2 Colour

The charming colour is one of the most important attributes of red chilli and paprika. The dark green colour at immature stage and deep red colour at maturity in

chilli are important quality characters for domestic and export purposes. Basically the colouring matter of chillies is a mixture of carotenoids, yellow and red pigments, which encompass carotenes and xanthophylls. The colour is genetically controlled by four different genes (Y, C1, C2 , C1) with epistatic interaction have been reported to the development of colour in mature fruits.

Joshi *et al.* (1990) has described the colour of cultivars as red, medium, light red, orange as this information could be used for documentation of genotypes for breeding and evolving high quality paprika varieties. Approximately 20 carotenoids contribute to the colour of chilli powder. Carotenoid compounds are yellow to red pigments composed of isoprene units and are normally fat soluble colours. The major red colour in chilli comes from capsanthin and capsorubin while the yellow-orange colour is from beta-carotene and violaxanthin but chlorophyll pigments is responsible for green colour. Colour is measured spectrophotometrically in ASTA (Amerian Spice Trade Association) units or SICU (Standard International Colour Units), with 100, 000 SICU being equal to 2500 ASTA units (Bosland, 1993).

Green chillies were found to contain 2835 mg/100 g total carotenes, 1045.9 mcg/100 g, b-carotene which forms 36.9 per cent of total carotenes (Usha and Kowsalya, 2002).

Dhall and Hundall (2005) reported colour value as 190.47 ASTA unit and 81.88 ASTA units. Savita (2005) reported a variation in colour value from 85.4 to 178.2 ASTA units.

Prasath *et al.* (2007) reported that total extractable colour ranged from 32.820 to 208.56 ASTA units. Srilakshmi (2006) reported that colour value ranged from 34.02 to 241.00, the maximum value for Byadgi dabbi. Colour value exhibited positive significant association with yield.

Jyothi *et al.* (2008) observed notable variability in colour value among twenty three paprika accessions employed in a biochemical study.

Kumari *et al.* (2011) evaluated 94 paprika accessions and reported that the association of fruits per plant with quality parameters namely, capsanthin content was positive and significant.

2.7.3 Ascorbic acid

Chilli is considered to be rich source of ascorbic acid and minerals. It is the source for commercial preparation of vitamin C.

Bhagyalekshmi *et al.*, (1990) found that ascorbic acid content in green chillies varied from 84.55 to 139.96 mg per 100 g fresh fruit. Choudhary and Samadia (2004) reported that ascorbic acid content varied from 70.83 to 237.30 mg per 100 g fresh fruit.

Bini (2004) reported a high heritability and genetic advance for ascorbic acid in a study of 44 paprika accessions. Singh *et al.* (2005) observed a maximum vitamin C value of 240 mg per 100 g of fresh fruit in a study.

Dandunayak (2008) observed a range of 132.5 to 177.5 with over all mean of 153.04 for ascorbic acid content. Chattopadhyay *et al.* (2011) observed a high genetic advance for ascorbic acid.

2.7.4 Pungency

The another important typical and unique attribute of capsicum is pungency. Scoville heat units measure the heat of Capsicum powder. One part per million concentration of capsaicinoids is equal to 15 Scoville heat units. The nature of pungency has been established as a mixture of seven homologous branched – chain alkyl vanillylamides, named capsaicinoids. They often are called capsaicin after the most prevalent one, dihydrocapsaicin being the second. They are odourless, colourless and non nutrient compounds. The capsaicinoids are produced in the glands

on the placenta of the fruits (Fujiwake *et al.*, 1982). About 90 percent of capsaicin is concentrated in the placenta (Sumathykutty and Mathew, 1984).

Capsaicinoid accumulation is controlled by several factors *viz.*, age of the plant, temperature, light and nutritional status (Iwai *et al.*, 1979). Seeds are not the sources of pungency, but they occasionally absorb capsaicin because of their proximity to the placenta (Jurenitsch *et al.*, 1979).

According to Govindarajan *et al.* (1977), the group paprika contains less than 0.1% of capsaicinoids, the best grade of Spanish paprika having 0 to 0.003% and for the pungent grade, a maximum of 0.5%. But the pungency level of chillies varies from 0.1% to 1.4%. Govindarajan (1985) has reported that cultivar is the most important factor that determines the amount of capsaicinoid and the value of capsaicinoids vary from less than 0.1 per cent to over 1 per cent. Generally there is a decrease in pungency from chillies to paprika and a parallel increase in colour, pigment concentration and an increase in size and fleshy nature of pericarp.

Seasonal change had no significant effect on the pattern of capsacinoid accumulation. In *Capsicum annuum*, the ratio of capsicum to dihydrocapsaicin varies from 1.36 – 1.71 (Estrada *et al.*, 1997), while Boronat *et al.* (1999) have reported a ratio of 0.64 to 1.94.The hottest chilli pepper recorded was Habanero with a Scoville pungency of 577,000 in contrast to the sweet Italian Bell pepper with a pungency of 0 units (Bellringer, 2001). Indian scientists have recently claimed that Tezpur chilli grown in the north east has the highest Scoville units of 8,55,000.

Wilbur Scoville in 1912 developed a scale to measure the "heat levels" of chilli peppers. In the original Scoville test, a panel of volunteers would be asked to determine the dilution of the chilli pepper solution that no longer can cause burning discomfort in the mouth (Borges, 2001).

Indira (1994) classified genotypes with capsaicin in the range 1.0 – 1.5 percent as highly pungent, 0.25 – 0.75 percent as medium pungent and 0.11 – 0.25

percent as less pungent. Mini (1997) evaluated different capsicum species for capsaicin content. Boronat *et al.* (1999) reported that the ratio of capsaicin to dihydrocapsaicin varies in the range from 0.64 to 1.94. Dabrowska *et al.* (2000) reported that the content of capsaicin depends mainly on genotypes.

Dried red capsicum powder is classified into five groups based on pungency level: nonpungent or paprika (0 to 700 Scoville heat units) mildly pungent (700 to 3,000), moderately pungent (3,000 to 25,000), highly pungent (25,000 to 70,000) and very highly pungent (> 80,000 Scoville heat units). The last group is mainly the product from Asian countries.

Mathur *et al.* (2000) reported that Tezpur cultivar (*C. frutescence*) containing highest amount of capsaicin and dihydrocapsaicin (4.28 & 1.42%) contributing to pungency. Jha *et al.* (2001) reported that all the cultivars followed a uniform pattern of capsaicin accumulation with progressive fruit development.

According to Kumar *et al.* (2003) capsaicin content exhibited significant positive association with fruits per plant and negative association with fruit width, fruit length and fruit weight. Moreover capsaicin content and ascorbic acid showed strong negative association with each other. This resulted that pungency is related to more number of fruits per plant with smaller size while ascorbic acid is related with larger fruit size.

Capsaicin content showed high heritability value coupled with moderate level of genetic advance (Khurana *et al.*, 2003).

Bini (2004) observed high heritability coupled with high genetic advance or capsaicin in paprika. Fruit length had a negative correlation with capsaicin. No significant correlation was observed for capsaicin with yield. Prasath *et al.* (2007) analysed 27 chilli accessions and reported that extreme capsaicin levels are 0.10 and 1.26 %, showing a mean value of 0.36 %. Six genotypes exhibited high capsaicin per cent (>1) and low capsaicin value was seen for 3 genotypes (< 0.20). Jyothi *et al.*

(2008) observed a range of 0.256 to 0.528 for capsaicin content in different genotypes of paprika.

The capsaicin content of ripe fruit was estimated to be high with a mean value of 0.15% in chilli cultivars (Chattopadhyay *et al.*, 2011).

Breeding for quality should be the prime target to obtain high nutritional quality and minimum pungency.

2.8 Incidence of diseases

2.8.1 Bacterial wilt

Bacterial wilt caused by *Ralstonia solanacearum* is a devastating disease in tropical and subtropical regions of chilli cultivating tract. The drooping of leaves followed by wilting of the plants are the major symptoms. Vascular system discoloration and brown decay of the pith are associated symptoms.

The invasion occurs through wounds usually below the ground. High temperature and humidity accelerates the disease. It was also reported that the organism spread through irrigation water and rain water (Nair and Menon, 1983). The disease is very difficult to manage because of its wide spread, the exceptional ability of the pathogen to survive in the roots of non-host plants and in the soil, susceptibility of all the commercial cultivars and non-feasibility of chemical control.

The resistance of 53 *C. annuum* accessions to bacterial wilt was studied in Kerala (Fathima and Joseph, 2001). 15 accessions were found to be resistant. Robi (2003) studied the bacterial wilt resistance in 10 hot chilli accessions and found that one accession was resistant.

2.8.2 Leaf curl

Leaf curl disease seems to be a major bottleneck in commercial chilli cultivation. The symptoms include downward leaf curling, vein thickening, dark green colour and oval to round shaped leaves and leafy outgrowths on lower surface

of leaves. Flower and fruit production were seriously reduced. Chilli leaf curl virus or Tobacco leaf curl virus is referred to be the causal organism (Peter, 1998).

Chilli leaf curl virus is a complex disease caused by separate or combined infection of mites, thrips and viruses (Tewari, 1983 and Nawalagatti *et al.* 1999).

Robi (2003) studied leaf curl virus incidence in ten hot chilli accessions and reported that four accessions were resistant, one accession was moderately resistant and five were susceptible.

Incidence of virus exhibited positively significant association with days to 50% fruit harvest and showed negatively significant correlation with fruit length and dry matter (Gupta *et al.*, 2009).

2.9 Influence of harvest maturity on quality

2.9.1 Oleoresin

Oleoresin consists of fixed oil, capsaicin, pigments, sugars and resin.

Mini (1997) studied the influence of maturity stages on oleoresin yield and the results indicated that oleoresin yield was high when fruits were harvested at turning stage.

Mini and Vahab (2000) found significant differences among genotypes for oleoresin recovery and interaction of stage of harvest was significant for oleoresin recovery. Maximum recovery observed in winter season, harvested at full ripe, withering or turning stage. In rainy season oleoresin was high in fruits at withering stage.

A study conducted in 25 accessions of bird pepper *C. frutescens* indicated that the oleoresin content was more in red ripe stages than in mature green fruits (Sheela *et al.*, 2001). The oleoresin content ranged from 4.5 to 14.25 per cent in mature green stage to 8.75 to 24.45 per cent in red ripe stage.

The oleoresin content of chilli cultivars increased significantly with maturity stage. The per cent increase in dry chillies over ripe was ranging from 6.43 to 96.75 percent .The oleoresin content of chilli cultivars varied significantly between the cultivars, maturity stages and interaction between maturity stage and cultivars (Robi, 2003 and Khyadagi, 2009).

2.9.2 Colour

Mini (1997) opined that chilli genotypes exhibited highest color value at withering stage, moderate to full ripe stage and lowest at turning stage. Anu (2001) reported that most of the lines belonged to the high colour group (above 100 ASTA). in a study involving paprika lines. Deli *et al.* (2001) investigated carotenoid content in red paprika and found 1.3 g per 100 g of dry weight of which capsanthin constituted 37 per cent, zeaxanthin was 8 per cent, cucurbitaxanthin 'A' was 7 per cent, capsorubin constituted 3.2 per cent and b-carotene 9 percent.

The carotenoid content of chilli cultivars increased with increase in maturity stage (Robi, 2003; Khyadagi, 2009).

2.9.3 Ascorbic acid

Ahmed *et al.* (1986) analysed the ascorbic acid content in 12 different chilli genotypes and reported that it increased from green stage (98-1616 mg/100 g) to ripe stage (905-2254 mg/100 g) and further at sun drying stage (240-4550 mg/100 g).

The ascorbic acid content was highest at ripening stage of chilli (Howalder *et al.*, 1996).

Garcia *et al.* (1998) observed increase in ascorbic acid content after green mature stage and peaked at ripe fruit with 75 per cent of moisture. Robi and Sreelathakumary (2006) studied the influence of maturity stages on ascorbic acid and reported that ascorbic acid content was maximum in red ripe stage.

The water soluble ascorbic acid content of ripe chilli cultivars was higher than green and differed between cultivars (Khyadagi, 2009).

2.9.4 Capsaicin

Ahmed *et al.* (1987) tabulated the capsaicin content at three different stages *viz.*, green, ripe and sundried fruits of 12 *C. annuum* varieties. They reported that capsaicin content increased in the order green fruit, ripe fruit and sundried fruit. The capsaicin content ranged from 1.0 to 107.2 mg per 100 g fruit at ripe stage. They opined that fruit size and stage of maturity influenced the amount of capsaicinoind present in chilli fruit. The capsaicin content was found to be inversely related to fruit diameter, length and thickness.

Mini (1997) analysed nine chilli genotypes harvested during three different maturity stages *viz*, turning stage, full ripe and withering stage and observed that chilli fruits were least pungent at turning stage and the pungency showed an increasing trend as the harvesting was progressed from turning to full ripe and withering stage. But the fruits harvested at full ripe and withering stage were on par in pungency in varieties Ujjwala and Kt-Pl 19.

Estarwada *et al.* (1997) studied changes in capsaicin content with fruit development in *C. annuum* and observed that capsaicinoid increases with fruit development.

The capsaicinoid concentration of developing fruits (20 to 100 days after flowering were determined by Minami *et al.* (1998) and observed that capsaicin content was highest between 20 and 40 days after flowering.

Gnayfeed *et al.* (2001) conducted a work to investigate changes in capsaicin as a function of ripening in *C. annuum.* The results indicated that capsaicin was at a low level in mature green fruits and the onset of climacteric ripening caused their content to grow. Capsaicinoid content reached their maximum at the colour break or red stage and then decreased.

Jha *et al.* (2001) investigated the capsaicin content in developing fruits of ten *C. annuum* cultivars and recorded the highest capsaicin level at mature stage than at immature stage, intermediate stage and ripened stags in all cultivars.

The biosynthesis of capsaicin content commenced during the early phase of fruit growth. 15 days after flowering the biosynthesis was non significant and at 30 days after flowering it became significant. During the later stages of fruits growth, the capsaicin content started declining (Sathiamurty *et al.*, 2002).

Robi (2003) opined that capsaicin content in hot chilli increased from turning to withering stage.

The capsaicin content of chilli cultivars increased significantly with maturity stage. The per cent increase in ripe chilli cultivar over green stage ranged between 21.28 to 77.78 per cent. The maximum increase in capsaicin content was noticed in Byadagi Kaddi and minimum in Pusa Jwala (Khyadagi, 2009).

High heritability estimates coupled with high expected genetic advance per cent of mean was observed for capsaicin content (Gupta *et al.*, 2009).

MATERILAS AND METHODS

3. MATERIALS AND METHODS

The experiment entitled "Identification of paprika (*Capsicum annuum* L.) genotype(s) for yield and quality characters" was carried out in the Department of Olericulture, College of Agriculture, Vellayani, during 2011-2012. The experimental site is located at 8° 5' N latitude and 77° 1' E longitude at an altitude of 29.0 m above mean sea level. Predominant soil type of the experimental site is red loam belonging to Vellayani series, texturally classified as sandy clay loam. The soil pH is 5.2. The area enjoys a warm humid tropical climate.

The study consisted of the following experiments.

3.1 Variability in paprika

3.2 Influence of harvest maturity on quality

3.1 Variability in paprika

3.1.1 Experimental materials and methods

The experimental material comprised of 53 accessions of paprika collected from different parts of the country. These accessions of paprika were grown during September 2011 to March 2012, to identify superior genotypes with yield, quality and reaction towards the incidence of pests and diseases. The details of accessions and their source are given in Table 1.

Design	: RBD
Replication	: 3
Treatments	: 53 accessions
Plot size	: 4.5 m^2
Spacing	: 45 cm x 45 cm
Number of plants/ plot	: 15

Table 1. Particulars of paprika accessions used for the study and their sources

Sl. No.	Accession Number	IC No./Accession Name	Source
1	CA1	EC-354890	NBPGR, Hyderabad
2	CA 2	EC-391082	NBPGR, Hyderabad
3	CA 3	EC-391083	NBPGR, Hyderabad
4	CA 4	EC-399574	NBPGR, Hyderabad
5	CA 5	EC-596920	NBPGR, Hyderabad
6	CA 6	EC-596940	NBPGR, Hyderabad
7	CA 7	EC-599960	NBPGR, Hyderabad
8	CA 8	EC-599969	NBPGR, Hyderabad
9	CA 9	EC-599992	NBPGR, Hyderabad
10	CA 10	EC-628901	NBPGR, Hyderabad
11	CA 11	IC-255896	NBPGR, Hyderabad
12	CA 12	IC-436231	NBPGR, Hyderabad
13	CA 13	IC-570369	NBPGR, Hyderabad
14	CA1 4	IC-572481	NBPGR, Hyderabad
15	CA 15	IC-572490	NBPGR, Hyderabad
16	CA 16	Local	Kollam, Kerala
17	CA 17	Local	Dharwad, Bangalore
18	CA 18	Local	Dharwad, Bangalore
19	CA 19	Local	Dharwad, Bangalore
20	CA 20	Local	Dharwad, Bangalore
21	CA 21	Local	Dharwad, Bangalore
22	CA 22	Local	Dharwad, Bangalore
23	CA 23	Local	Dharwad, Bangalore
24	CA 24	Local	Dharwad, Bangalore
25	CA 25	Local	Dharwad, Bangalore
26	CA 26	Local	Dharwad, Bangalore

27	CA 27	Local	Dharwad, Bangalore
28	CA 28	Local	Dharwad, Bangalore
29	CA 29	Local	Dharwad, Bangalore
30	CA 30	Local	Dharwad, Bangalore
31	CA 31	Local	Dharwad, Bangalore
32	CA 32	Local	Dharwad, Bangalore
33	CA 33	Local	Dharwad, Bangalore
34	CA 34	Local	Dharwad, Bangalore
35	CA 35	Local	Dharwad, Bangalore
36	CA 36	Local	Dharwad, Bangalore
37	CA 37	Arka Abhir	IIHR, Bangalore
38	CA 38	Byadagi Local	Dharwad, Bangalore
39	CA 39	Kt-Pl-19	TNAU, Tamilnadu
40	CA 40	Local	Dharwad, Bangalore
41	CA 41	Local	Dharwad, Bangalore
42	CA 42	Local	Dharwad, Bangalore
43	CA 43	Local	Dharwad, Bangalore
44	CA 44	Local	Dharwad, Bangalore
45	CA 45	Local	Dharwad, Bangalore
46	CA 46	Local	Dharwad, Bangalore
47	CA 47	Local	Dharwad, Bangalore
48	CA 48	Local	Dharwad, Bangalore
49	CA 49	Local	Dharwad, Bangalore
50	CA 50	Local	Dharwad, Bangalore
51	CA 51	Local	Dharwad, Bangalore
52	CA 52	Local	Dharwad, Bangalore
53	CA 53	Local	Dharwad, Bangalore

The crop were raised as per package of practices recommendations of Kerala Agricultural University (KAU, 2007).

3.1.2 Biometrical observations

Five plants were randomly selected per accession per replication for recording observations and the mean worked out. For recording observations on fruit characters, five fruits were selected at random from each accession in each replication.

Observations on the following characters were recorded.

3.1.2.1 Plant characters

a. Plant height (cm)

Measured from the ground level to the tip of the plant at the time of final harvest.

b. Primary branches

Branches arising from the main stem were counted.

3.1.2.2 Flowering characters

a. Days to first flowering

Number of days from the date of transplanting to the first flowering of observational plants was recorded.

b. Node to flower

The node at which the first flower developed was observed.

c. Height of node to first flower (cm)

The height from ground level to the node to first flower was measured.

d. Days to maturity

Number of days from flowering to red ripe stage maturity of fruit was measured.

3.1.2.3 Fruit and yield characters

a. Fruit length (cm)

Distance between pedicel attachment and fruit apex.

b. Fruit girth (cm)

Measured using twine and scale at the maximum width of the fruit.

c. *Fruit weight (g)*

Average of five fruits weight.

d. Fruits per plant

Total number of fruits produced per plant was observed.

e. Yield per plant (g)

Weight of fruits harvested from each plant was recorded.

f. Pedicel length (cm)

Distance between the point of attachment of pedicel with the stem and the fruit.

g. Fruit : pedicel ratio

The ratio of fruit length and pedicel length was recorded.

h. Flesh thickness (mm)

The thickness of fruit pericarp was measured and expressed in mm.

i. Seeds per fruit

Seeds per fruit were counted in five fruits and average was taken.

j. Flesh : seed ratio

The ratio between flesh weight and seed weight of fruit was recorded.

k. Driage (%)

The driage of fruits was expressed in percentage as per the formula.

$$\text{Driage} = \frac{\text{Weight of dried fruit}}{\text{Weight of fresh fruit}} \times 100$$

3.1.2.4. Quality characters

a. Oleoresin (%)

Oleoresin in chilli was extracted in a Soxhlet's apparatus using solvent acetone (Sadasivam and Manickam, 1992).

Procedure

Chilli fruits harvested at red ripe stage were dried in a hot air oven at 50°C and powdered finely in a mixer grinder. Weighed two grams of chilli powder and packed in filter paper and placed in Soxhlet's apparatus. 200 ml of acetone was taken in the round bottom flask of the apparatus and heated in a water bath. The temperature was maintained at the boiling point of the solvent (around 60°C). After complete extraction (4 - 5hours) the solvent was evaporated to dryness.

Yield of oleoresin on dry weight basis was calculated using the formula

$$\text{Oleoresin (\%)} = \frac{\text{Weight of oleoresin}}{\text{Weight of sample}} \times 100$$

b. Colour

Red ripe chillies were dried and the stalk and seeds were removed before powdering. 0.1 g of ground chilli powder was transferred into a 250 ml Erlenmeyer flask with 100 ml isopropanol and kept overnight at room temperature. The contents

were filtered through a Whatman No. 42 filter paper. The first 10 ml was discarded and 25 ml of the filtrate was pipetted into a volumetric flask and diluted to the mark with isopropanol. The absorbance was read at 450 nm against isopropanol as blank. Standard colour solution was prepared by dissolving 0.5 mg per ml of reagent grade potassium dichromate in 1.8M sulphuric acid.

$$\text{Colour value (ASTA units)} = \frac{\text{Absorbance of sample at 450 nm x 200}}{\text{Absorbance of standard solution at 450 nm}}$$

Extractable colour in ASTA units

c. Ascorbic acid (mg per 100g fresh fruit weight)

Ascorbic acid content of fruit was estimated by 2,6-dichlorophenol indophenol dye method (Sadasivam and Manickam, 1992).

Reagents

1. Oxalic acid (4 %)

2. Ascorbic acid standard

Stock solution was prepared by dissolving 100 mg of ascorbic acid in 100 ml of four per cent oxalic acid. 10 ml of this stock solution was diluted to 100 ml with four per cent oxalic acid to get working standard solution.

3. 2, 6-dichlorophenol indophenol dye

Forty two mg sodium bicarbonate was dissolved in a small volume of distilled water. 52 mg of 2,6-dichlorophenol indophenol was added into this and made up to 200 ml with distilled water.

4. Working standard

Diluted 10 ml of stock solution to 100 ml with 4% oxalic acid. The concentration of working standard is 100 mg per ml.

Procedure

Pippeted out 5 ml of the working standard solution into a 100 ml conical flask and added 10 ml of 4% oxalic acid. Titrated it against the dye (V_1 ml). End point is the appearance of pink colour which persisted for at least 5 seconds.

Five gm of fresh fruit was extracted in four per cent oxalic acid medium, filtered the extract and volume was made upto 100 ml using oxalic acid. From this five ml of aliquat was taken, added 10 ml of four % oxalic acid and titrated as above against the dye and determined the endpoint (V_2 ml).

Ascorbic acid content of the sample was calculated using the formula

$$\text{Amount of ascorbic acid in mg / 100 g sample} = \frac{0.5 \times V_2 \times 100}{V_1 \times 5 \times \text{Weight of sample}} \times 100$$

d. Capsaicin (%)

Capsaicin content of different accessions was determined by Folin-Dennis method. The pungent principle reacts with Folin-Dennis reagent to give a blue coloured complex which is estimated colorimetrically (Mathew *et al.*, 1971).

Reagents

i) Folin-Dennis reagent

Refluxed 750 ml distilled water, 100 g sodium tungstate, 20 g phosphomoloybdic acid and 50 ml phosphoric acid for two hours. Cooled and diluted to 1000 ml with distilled water.

ii) 25% aqueous sodium carbonate solution

iii) Acetone

Procedure

The fruits harvested at red ripe stage were dried in a hot air oven at 50°C and powdered finely in a mixer grinder. 500 mg each of the sample was weighed into test

tubes. Added 10 ml of acetone to it and kept overnight. Aliquot of 1ml was pipetted into 100 ml conical flask, added 25 ml of Folin-Dennis reagent and allowed to stand for 30 minutes. Added 25 ml of freshly prepared sodium carbonate solution and shook vigorously. The volume was made upto 100 ml with distilled water and the optical density was determined after 30 minutes at 725 nm against reagent blank(1 ml acetone + 25 ml Folin Dennis reagent + 25 ml aqueous sodium carbonate solution) using a UV spectrophotometer.

To determine the EI per cent value for pure capsaicin, a stock solution of standard capsaicin (200 µg ml^{-1}) was prepared by dissolving 20 mg in 100 ml acetone. From this a series of solutions of different concentrations were prepared and their optical density measured at 725 nm. Standard graph was prepared and calculated capsaicin content in the samples.

3.1.2.5. Reaction towards major pests and diseases.

No scoring for pests was done since there was no major pest incidence in the crop. Bacterial wilt and leaf curl virus diseases were found to be major problems during the study. Bacterial wilt was observed and the number of wilted plants were recorded. Chilli leaf curl virus was another problem and scoring based on visual observations was done. The incidence of fruit rot was negligible.

a) Bacterial wilt

Daily observation of plants was done for incidence of bacterial wilt and recorded the number of plants wilted per plot.

b) Leaf curl virus incidence The scoring was based on a scale 0 to 4 proposed by Rajamony *et al.*, (1990) in melons with slight modifications (Table 2). This was done according to the characteristic symptom of each observational plant (Plate 1).

Table 2. Scoring for chilli leaf curl virus disease

Score	Symptoms
0	No symptoms
1	Slight curling of terminal leaves
2	Curling of terminal and adjacent leaves
3	Curling and appearance of blisters on leaves
4	Severe curling and puckering of leaves, stunted appearance of plants

The individual plant score was utilized to work out the severity index or vulnerability index so as to measure the degree of resistance. The index was calculated using an equation adopted by Silbernagel and Jafri (1974) for measuring the degree of resistance in snap bean (*Phaseolus vulgaris)* to beet curly top virus and later modified by Bos (1982).

$$\text{Vulnerability index (V.I)} = \frac{0n0 + 1n1 + 2n2 + 3n3 + 4n4}{nt\,(nc-1)} \times 100$$

Where

$n_o, n_1, ---, n_4$ = number of plants in the category 0, 1, ---, 4 respectively

n_1 = total number of plants

n_c = total number of categories = 5

The genotypes were classified according to vulnerability index as

V.I	Category
0.0	Resistant(R)
1.00-25.00	Tolerant (T)

25.01-50.00	Susceptible(S)
>50.00	Highly susceptible (HS)

3.1.3 Statistical Analysis

Data recorded from experimental plants were statistically analysed. Analysis of variance and covariance were done:

a) To test significant difference among the genotypes and

b) To estimate variance components and other genetic parameters like correlation coefficients, heritability, genetic advance etc.

From the Table 3 other genetic parameters were estimated as follows.

Table 3. Analysis of Variance / Covariance for RBD

Source	Df	Observed mean square XX	Expected mean square XX	Observed mean sum of products XY	Expected mean sum of products XY	Observed mean square YY	Expected mean square YY
Block	(r-1)	B_{xx}		B_{xy}		B_{yy}	
Genotype	(v-1)	G_{xx}	$\sigma^2_{ex}+\sigma^2_{gx}$	G_{xy}	$\sigma^2_{exy}+r\sigma^2_{gxy}$	G_{yy}	$\Sigma^2_{ex}+r\sigma^2_{gx}$
Error	(v-1) (r-1)	E_{xx}	σ^2_{ex}	E_{xy}	σ^2_{exy}	E_{xy}	σ^2_{xy}
Total	v(r-1)	T_{xx}				T_{yy}	

From the above table other genetic parameters were estimated as follows:

3.1.3.1 Variance

The variance and covariance components were calculated as per the formula

:

	X	Y
Environmental variance (σ^2_e)	$\sigma^2_{ex} = E_{xx}$	$\sigma^2_{ey} = E_{yy}$
Genotypic variance (σ^2_g)	$\sigma^2_{gx} = \frac{Gxx - Exx}{r}$	$\sigma^2_{gy} = \frac{Gyy - Eyy}{r}$
Phenotypic variance (σ^2_p)	$\sigma^2_{px} = \sigma^2_{gx} + \sigma^2_{ex}$	$\sigma^2_{py} = \sigma^2_{py} + \sigma^2_{ey}$

3.1.3.2 Coefficient of variation

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

Genotypic coefficient of variability (GCV) = $\frac{\sigma gx}{\bar{X}} \times 100$

Phenotypic coefficient of variability (PCV) = $\frac{\sigma px}{\bar{X}} \times 100$

Where,

σ_{gx} - Genotypic standard deviation

σ_{px} - Phenotypic standard deviation

$\bar{x}$ - Mean of the character under study

GCV and PCV values were categorized as low, moderate and high values as suggested by Sivasubramanian and Menon (1973) which is as follows.

0-10%: Low

10-20%: Moderate

20% and above: High

3.1.3.3 Heritability

$$H^2 = \frac{\sigma 2gx}{\sigma 2px} \times 100$$

Where, H^2 is the heritability (Jain, 1982) expressed in percentage.

The range of heritability was categorized as suggested by Robinson *et al.*, (1949) as follows:

Definition	Category
0 – 30 percent	Low
31 – 60 percent	Medium
61 percent and above	High

3.1.3.4 Genetic Advance as percentage mean

Genetic advance as percentage over mean was calculated as per the formula given by Lush (1949) and Johnson *et al.*, (1955).

Genetic Advance as percentage mean

$$GA = \frac{kH2\sigma p}{\bar{X}} \times 100$$

Where, k is the standard selection differential.

K = 2.06 at 5% selection intensity (Miller *et al.*, 1958)

The range of genetic advance as per cent of mean was classified according to Johnson *et al.*, (1955).

0- 10 per cent ⟶ Low

11- 20 per cent ⟶ Moderate

> 20 per cent ⟶ High

3.1.3.5 Correlation

Phenotypic, genotypic and environmental correlation coefficients were worked out according to the procedure suggested by Singh and Choudhary (1985).

Genotypic correlation coefficient (γ_{gxy}) = $\frac{\sigma gx}{\sigma gx \, X \, \sigma gy}$

Phenotypic correlation coefficient (γ_{pxy}) = $\frac{\sigma pxy}{\sigma px \, X \, \sigma py}$

Environmental correlation coefficient (γ_{gxy}) = $\frac{\sigma egx}{\sigma ex \, X \, \sigma ey}$

3.1.3.6 Path analysis

The direct and indirect effects of yield contributing factors were estimated through path analysis technique (Wright, 1954; Dewey and Lu, 1959).

3.1.3.7 Selection Index

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

The selection index is described by the function, $I = b_1x_1 + b_2x_2 + \ldots\ldots\ldots + b_kx_k$ and the merit of a plant is described by the function, $H = a_1G_1 + a_2G_2 + \ldots\ldots\ldots + b_kG_k$ where $x_1, x_2 \ldots\ldots\ldots x_k$ are the phenotypic values and $G_1, G_2 \ldots\ldots\ldots G_k$ are the genotypic values of the plants with respect to characters, $x_1, x_2 \ldots\ldots\ldots x_k$ and

H is the genetic worth of the plant. It is assumed that the economic weight assigned to each character is equal to unity i. e., a_1, a_2.....$a_{k=1}$

The regression coefficients (b) are determined such that the correlation between H and I is maximum. The procedure will reduce to an equation of the form, $b = P^{-1}Ga$ where, P is the phenotypic variance – covariance matrix and G is the genotypic variance – covariance matrix x. Based on the 'b' estimates and the mean values for the ten characters with respect to each accession, scores were calculated and the accessions were ranked.

3.1.3.8 Mahanolobis D^2 analysis

Genetic divergence was studied using D^2 statistic. The genotypes were clustered by Tocher's method as described by Rao (1952).

3.1.3.9 Genetic cataloguing of paprika

The descriptor developed by IPGRI for *Capsicum* was used for cataloguing (Appendix I).

3.2 Influence of harvest maturity on quality

3.2.1 Experimental materials and methods

Fruits were harvested at three different stages of maturity (Plate 2) from each accession and studied quality parameters.

The experiment formed a factorial RBD with 53 accessions, three maturity stages and three replications.

The three maturity stages were:

M_1 (Turning stage) : Stage when mature fruit just starts changing its colour to intermediate stage.

M_2 (Red ripe stage) : Stage when fruit becomes fully ripe, but firm and succulent in nature.

M_3 (Withering stage) : Stage when the fully ripe fruit has become shriveled in appearance.

3.2.2 Observations

Dried fruits at three stages of maturity were powdered and evaluated for the following characters as in previous case.

a) Ascorbic acid : 2.6- dichlorophenol indophenol dye

b) Oleoresin : Soxhlet method

c) Colour : Spectrphotometric method

d) Capsaicin : Folin- Dennis method

3.2.3 Statistical analysis

The data were subjected to analysis of variance to test the significant difference among accessions and different maturity stages.

3.3 Weather parameters

Following weather parameters during the course of investigation were recorded and furnished in Appendix 2.

3.3.1 Maximum temperature (°C)

3.3.2 Rainfall (mm)

3.3.3 Relative humidity (%)

Plate 1. Plants with symptoms of leaf curl virus: Score 0, Score 1, Score 2, Score 3 and Score 4 respectively

Plate 2. Stages of harvest maturity

M_1 (Turning stage)

M_2 (Red ripe stage)

M_3 (Withering stage)

RESULTS

4. RESULTS

The experiment entitled 'Identification of paprika genotype(s) (*Capsicum annuum* L.) for yield and quality characters' was carried out in the Department of Olericulture, College of Agriculture, Vellayani during the period of 2011-2012.

Experimental data recorded during the course of investigation were subjected to statistical analysis and are presented under the following heads.

4.1 Variability in paprika

4.2 Influence of harvest maturity on quality

4.1 Variability in paprika

4.1.1 Mean performance of accessions for biometric characters

Analysis of variance revealed significant differences among the accessions of paprika for all the characters. The mean values of 53 accessions for various characters are presented in Table 4.

Plant height

There was significant difference among the accessions for plant height. It ranged from 31.5 cm to 104.69 cm with an overall mean of 69.59 cm. CA 12 was the tallest with a height of 104.69 cm. The accession CA 51 was the shortest (31.5 cm) and was on par with CA 40 (31.53 cm).

Primary branches

Primary branches per plant varied from 2 to 3.33 with an average of 2.36 . Maximum primary branches was observed in CA 41 (3.33).

Days to flowering

It ranged from 24 to 43.33 days. CA 10 was the earliest to flower (24) and was significantly different from all other accessions. CA 1 was the latest to flower (43.33).

Node to first flower

Wide variation among the accessions was observed for node to first flower. Node to first flower was lowest in CA 53 (5.67) and highest in 16.67 (CA 1).

Height of node to first flower

CA 37 had maximum height to first flowering node (37.83 cm). Minimum was noted in CA 51 (12.93 cm).

Days to maturity

The accessions varied significantly for days taken from fruit set to maturity. CA 45 was the earliest to mature, which took 23.33 days, while CA 15 was the latest (37.00).

Fruit length

Fruit length varied considerably from 2.70 cm in CA 12 to 14.17 cm in CA 33 with an overall mean of 8.56 cm.

Fruit girth

Girth of the fruits varied significantly among the accession from 3.4 cm to 8.73 cm. Maximum fruit girth was recorded in CA 24 (8.73 cm) and minimum in CA 10 (3.4 cm).

Fruit weight

The fruit weight ranged from 2.54 g to 13.43 g, the highest in CA 47 (13.43 g) and lowest in CA 12 (2.54 g).

Fruits per plant

A wide range of variation was noticed for fruits per plant. It varied from 34.67 and to 265.33. Maximum fruits were obtained from CA 12 (265.33) which was on par with CA 7 (254.67). CA 31 had the minimum fruits (34.67) which was on par with CA 39 (42.67) ad CA 51 (37.00).

Yield per plant

The highest yield was recorded in CA 6 (776.12 g) which was on par with CA 5 (770.04 g) and CA 34 (748.19 g) and the lowest yield in CA 51 (217.63 g) followed

by CA 31 (220.61 g).

Pedicel length

Pedicel length among the accessions ranged from 2.10 cm in CA 53 to 5.00 cm in CA 28.

Fruit : pedicel ratio

The ratio was highest for CA 18 (4.72) and lowest was observed in CA 12 (0.89) followed by CA 31 (0.97).

Flesh thickness

The accessions varied significantly for the flesh thickness. It ranged from 1.23 mm (CA 1) to 3.63 mm (CA 2).

Seeds per fruit

The accessions varied significantly for seeds per fruit from 55.00 to 160.33. The fruits of CA 37 had the maximum seeds (160.33) whereas CA 11 and CA 27 had the lowest number of seeds (55.00).

Flesh: seed ratio

High value for flesh: seed ratio was observed in CA 47 (4.97) and the lowest in CA 10 (1.81) which was on par with CA 12 (1.82).

Driage

Driage among the accessions varied from 18.78 % to 36.71 % which were recorded in CA 41 and CA 47 respectively.

Oleoresin

The fruits of CA 7 (18.09 per cent) had maximum oleoresin content which was on par with CA 28 (18.00 per cent) and CA 8 (8.45 per cent) recorded minimum oleoresin content

Colour

Wide variation in colour value was observed among the accessions. The fruit of CA 2 had maximum colour value (169.21 ASTA units) and was on par with CA 37

(168.37 ASTA units) whereas CA 20 recorded minimum colour value (79.55 ASTA units).

Ascorbic acid

Ascorbic acid ranged from 185.07 mg per 100 g to 82.34 mg per 100 g. The fruits of CA 38 (185.07 mg per 100 g) had highest ascorbic acid content and was on par with CA 33 (184.86 mg per 100 g) whereas CA 1 recorded minimum ascorbic acid content (73.94 mg per 100 g).

Capsaicin

CA 10 had the highest capsaicin content (0.88 per cent) and CA 34 and CA 40 recorded the lowest capsaicin content of 0.10 per cent.

Bacterial wilt

Incidence of bacterial wilt was maximum in CA 31 and CA 39 (28.58 per cent). No incidence was observed in accessions like CA 2, CA 3, CA 4, CA 5, CA 6, CA 7, CA 9, CA 10, CA 12, CA 16, CA 18, CA 24, CA 33, CA 34, CA 35 and CA 47.

Leaf curl virus incidence

The vulnerability index for leaf curl incidence ranged from 0.00 to 52.96. Maximum incidence was noticed for CA 1 (52.96) and CA 47 recorded no incidence. The reaction of accessions towards leaf curl virus incidence (Table 7) indicated that 47 accessions were tolerant and two accessions were susceptible. CA 1, CA 11 and CA 13 were highly susceptible.

4.1.2 Genetic parameters

The population mean, range, phenotypic and genotypic variances and genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for 21 characters were studied and are presented in Table 8 and Fig 1.

High phenotypic and genotypic variances were observed for characters like yield per plant, fruits per plant, plant height seeds per fruit, colour and ascorbic acid.

Table 4. Analysis of variance for 23 characters in 53 accessions of paprika (Mean sum of squares)

Source	DF	Plant height	Primary branches	Days to flowering	Node to first flower	Height of node to first flower	Days to maturity	Fruit length	Fruit girth
Replication	2	52.84	0.12	3.95	3.09	7.88	2.31	0.25	5.10
Treatment	52	721.31**	0.53**	33.78**	11.03**	75.13**	22.72**	21.65**	4.27**
Error	104	26.70	0.16	1.15	0.37	1.49	0.76	0.12	0.026

Source	DF	Fruits per plant	Yield per plant	Fruit weight	Pedicel length	Fruit: pedicel ratio	Flesh thickness	Seeds per fruit
Replication	2	18.5	974	0.11	4.52	1.2	2.5	68.81
Treatment	52	6813.60**	59346.31**	13.57**	1.33**	1.82**	0.55**	1599.73**
Error	104	29.09	849.61	0.11	1.51	3.13	1.13	21.74

Source	DF	Flesh:seed ratio	Driage	Oleoresin	Colour	Ascorbic acid	Capsaicin	Bacterial wilt	Leaf curl virus incidence
Replication	2	7.39	29.44	1.45	70	211.5	4.67	1.96	49.03
Treatment	52	1.45**	50.15**	26.06**	2247.86**	2034.54**	0.12**	151.19**	381.85**
Error	104	0.06	3.97	0.39	31.02	88.78	2.98	30.59	26.12

Table 5. Mean performance of 53 paprika accessions for biometric characters

Accessions	Plant height (cm)	Primary branches	Days to flowering	Node to first flower	Height of node to first flower (cm)	Days to Maturity	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Fruits/plant	Yield/plant (g)
CA 1	82.60	2.00	43.33	16.67	27.00	35.67	8.20	3.57	3.59	140.33	405.31
CA 2	92.40	2.67	29.00	12.00	31.57	28.67	5.57	6.58	6.11	143.67	483.43
CA 3	73.05	2.00	32.00	9.33	17.81	32.33	10.17	5.57	6.72	85.33	502.70
CA 4	71.49	2.00	29.00	8.00	17.00	29.67	9.10	6.87	6.81	110.33	502.64
CA 5	67.92	2.00	33.33	9.33	20.00	32.67	8.13	4.50	7.32	123.00	770.04
CA 6	93.35	2.00	31.33	8.00	18.83	31.33	8.43	7.33	8.90	154.33	776.12
CA 7	88.25	2.33	32.33	7.33	18.50	32.33	9.80	6.87	6.57	254.67	642.06
CA 8	61.94	2.67	35.67	7.00	16.87	34.67	10.10	6.57	6.33	149.33	714.02
CA 9	67.10	2.00	31.33	10.33	22.32	29.67	8.40	4.55	5.08	155.33	590.50
CA 10	52.07	2.00	24.00	6.00	17.50	23.67	6.14	3.40	4.27	118.33	410.86
CA 11	48.67	2.00	32.33	9.00	24.43	34.33	9.49	7.30	8.52	99.33	403.07
CA 12	104.69	2.67	34.00	7.00	24.83	30.00	2.70	4.10	2.54	265.33	427.06
CA 13	55.40	2.00	34.00	12.00	27.30	32.33	5.53	5.73	5.22	146.67	450.03
CA 14	82.40	2.00	38.67	12.00	31.17	36.33	4.73	3.63	5.89	107.67	499.36
CA 15	67.23	3.00	32.33	8.33	15.63	37.00	5.97	3.77	4.62	150.00	667.91
CA 16	89.89	3.00	34.33	8.33	17.20	32.67	10.50	5.50	6.10	118.67	636.53
CA 17	53.40	2.00	36.33	7.67	16.20	35.33	9.80	6.07	7.37	61.67	415.95
CA 18	58.93	2.33	34.67	7.33	18.67	33.67	10.03	5.83	9.03	74.67	372.03
CA 19	76.43	2.00	36.00	9.00	21.73	34.33	9.40	6.57	8.47	73.33	472.55
CA 20	81.27	2.67	36.67	10.33	26.03	30.33	11.57	6.67	8.20	59.00	384.75
CA 21	76.47	3.00	31.33	7.33	21.83	32.00	7.13	6.57	7.49	64.00	394.11
CA 22	70.27	2.00	35.00	9.33	25.50	33.00	11.83	5.57	12.37	83.67	582.20
CA 23	72.70	2.00	34.00	8.33	22.07	32.00	11.17	6.40	8.50	66.33	472.28
CA 24	68.70	2.00	30.00	6.33	20.70	30.67	10.06	8.73	7.50	59.33	336.54

CA 25	66.53	2.33	31.67	7.00	19.47	32.00	7.90	6.53	10.59	65.33	399.06
CA 26	71.50	2.33	32.33	9.33	25.50	30.33	8.70	6.33	8.17	91.67	580.36
CA 27	65.93	2.00	33.33	8.33	22.03	33.33	4.55	6.12	8.55	143.33	578.47
CA 28	78.93	2.67	35.33	9.00	25.03	34.00	11.77	6.62	8.93	46.33	346.74
CA 29	80.40	3.00	34.00	10.33	26.70	32.00	11.27	5.10	8.40	73.33	345.07
CA 30	68.83	2.00	31.00	8.00	18.13	31.33	11.37	5.83	7.88	78.00	367.33
CA 31	58.57	2.67	30.67	8.33	17.20	32.33	4.27	8.33	6.23	34.67	220.66
CA 32	65.57	2.00	33.33	7.33	15.60	30.67	6.29	6.67	8.24	57.00	313.90
CA 33	89.73	2.00	26.33	9.00	28.37	32.00	14.17	6.40	9.17	109.00	672.23
CA 34	86.13	2.33	32.33	7.67	22.87	31.33	13.60	7.40	9.89	95.67	748.19
CA 35	88.93	3.00	30.33	8.00	25.87	30.67	12.43	7.27	8.72	109.00	644.78
CA 36	82.97	3.00	29.67	8.33	21.67	29.00	11.63	6.93	8.35	85.67	591.25
CA 37	77.67	3.00	33.33	8.00	37.83	33.33	12.20	6.43	7.87	76.00	418.70
CA 38	67.75	3.00	35.00	7.67	20.67	35.00	12.53	7.24	10.30	86.67	513.63
CA 39	62.17	2.67	37.67	10.00	25.57	34.33	9.20	7.03	10.76	42.67	360.55
CA 40	31.53	2.67	34.33	8.33	22.83	30.67	5.51	7.17	7.13	45.33	262.65
CA 41	46.67	3.33	31.67	9.00	18.17	29.67	4.62	6.93	6.70	58.33	321.93
CA 42	47.70	2.00	34.00	7.67	24.43	32.67	5.80	7.60	8.10	47.33	293.92
CA 43	45.90	2.00	34.33	9.00	17.00	30.00	8.67	7.37	10.00	47.33	385.36
CA 44	49.51	2.33	29.33	9.33	16.10	27.67	8.27	7.23	11.36	92.00	467.02
CA 45	71.37	2.00	26.00	6.33	20.40	23.33	7.70	6.47	9.23	63.67	357.37
CA 46	57.87	2.00	35.33	8.33	17.90	32.67	9.27	5.30	6.02	44.00	314.21
CA 47	91.60	2.00	31.67	6.00	30.73	30.00	10.10	7.53	13.43	95.67	591.27
CA 48	79.93	2.33	34.67	6.33	22.47	32.67	6.53	6.86	9.17	65.00	340.35
CA 49	71.92	2.00	40.00	11.33	20.93	36.33	7.23	6.15	10.49	73.00	376.92
CA 50	65.11	2.33	34.00	7.00	19.53	31.67	8.00	6.17	9.68	46.67	403.38
CA 51	31.50	2.00	28.67	6.83	12.93	26.00	5.70	5.97	9.21	37.00	217.63
CA 52	60.17	3.00	30.33	6.00	17.20	30.67	5.00	7.33	10.40	72.00	395.48
CA 53	69.00	3.00	33.00	5.67	13.50	31.33	5.57	8.07	9.33	89.00	354.94
CD (5%)	8.40	0.66	1.74	0.98	1.99	1.42	0.57	0.26	0.55	8.76	47.36

Table 5 Continued

Accessions	Pedicel length (cm)	Fruit: pedicel ratio	Flesh thickness (mm)	Seeds/per fruit	Flesh: Seed ratio	Driage (%)	Oleoresin (%)	Colour (ASTA units)	Ascorbic acid (mg/100 g)	Capsaicin (%)
CA 1	3.27	2.51	1.23	128.00	3.38	31.23	10.83	125.93	73.94	0.54
CA 2	3.27	1.70	3.63	137.67	2.89	29.87	10.67	169.21	133.32	0.63
CA 3	3.67	2.78	2.70	126.33	3.65	26.37	16.63	131.12	78.61	0.57
CA 4	3.73	2.44	2.57	112.00	4.31	36.19	9.67	104.73	124.88	0.63
CA 5	4.27	1.91	2.27	105.67	3.35	25.21	15.38	84.68	110.44	0.70
CA 6	4.23	2.00	2.23	106.00	4.01	23.83	16.33	91.78	132.02	0.52
CA 7	2.90	3.41	2.40	116.67	2.83	20.90	18.09	115.38	140.45	0.49
CA 8	2.67	3.80	2.03	83.33	4.05	21.36	8.45	103.24	103.39	0.41
CA 9	4.07	2.07	2.20	151.67	3.43	22.80	11.63	110.94	130.66	0.51
CA 10	3.20	1.92	1.80	103.00	1.81	33.07	10.83	114.39	106.44	0.88
CA 11	4.53	2.10	2.43	55.00	3.39	22.57	12.76	90.84	110.02	0.40
CA 12	3.03	0.89	1.87	58.00	1.82	31.11	11.72	116.57	111.04	0.73
CA 13	2.63	2.12	2.00	98.00	3.00	24.42	10.03	97.92	101.96	0.43
CA 14	3.30	1.43	2.47	87.33	2.01	31.91	13.17	105.69	106.98	0.41
CA 15	3.53	1.69	2.40	90.33	1.86	25.83	14.81	114.37	108.60	0.46
CA 16	4.53	2.32	2.87	121.67	2.71	33.26	13.67	125.64	136.17	0.29
CA 17	3.20	3.06	2.57	142.67	3.55	26.92	12.32	149.31	110.69	0.18
CA 18	2.13	4.72	2.43	109.33	3.47	28.29	13.33	102.03	124.58	0.11
CA 19	2.87	3.28	2.10	120.00	3.20	22.18	11.17	118.68	124.20	0.11
CA 20	3.73	3.11	2.59	111.67	3.12	28.38	10.17	79.55	132.27	0.16
CA 21	4.17	1.71	2.73	98.67	3.07	27.81	16.00	96.13	114.53	0.12
CA 22	4.13	2.87	2.50	104.33	3.71	22.69	10.83	94.75	175.60	0.13
CA 23	4.57	2.45	2.87	120.00	4.10	27.61	9.00	123.07	134.75	0.15
CA 24	4.27	2.36	2.43	106.67	3.10	32.44	10.00	92.22	117.71	0.14
CA 25	3.17	2.50	1.97	100.67	3.72	28.78	16.17	86.91	130.48	0.13

CA 26	4.47	1.95	2.17	102.33	3.19	28.99	13.67	111.77	146.34	0.15
CA 27	4.37	1.05	2.07	55.00	3.20	29.65	15.99	118.48	107.41	0.15
CA 28	5.00	2.35	2.37	108.00	3.28	29.45	18.00	131.89	85.88	0.13
CA 29	3.57	3.16	2.07	118.67	3.01	26.42	17.50	125.30	82.34	0.18
CA 30	4.00	2.84	2.40	108.67	3.07	30.47	11.49	127.09	102.10	0.18
CA 31	4.37	0.98	3.33	112.67	2.74	26.88	10.00	101.37	120.25	0.17
CA 32	4.00	1.57	2.67	98.33	2.65	24.10	10.17	114.16	121.00	0.12
CA 33	3.63	3.90	3.03	108.00	3.73	25.82	11.73	130.59	184.86	0.13
CA 34	4.57	2.98	2.93	139.00	4.21	26.03	9.98	136.45	174.44	0.10
CA 35	4.33	2.87	3.00	122.00	3.34	22.11	14.63	137.63	175.82	0.12
CA 36	4.30	2.71	3.03	139.67	4.04	27.43	11.82	120.69	162.95	0.13
CA 37	3.40	3.60	2.63	160.33	4.07	23.35	17.00	168.37	155.42	0.18
CA 38	3.37	3.73	2.80	84.33	4.23	25.76	10.33	163.35	185.07	0.11
CA 39	3.33	2.77	3.50	111.67	4.43	27.13	11.88	137.76	164.00	0.17
CA 40	2.97	1.86	2.60	131.67	3.45	21.78	11.53	119.18	88.00	0.10
CA 41	2.47	1.88	2.73	143.33	3.60	18.78	11.67	114.26	99.19	0.12
CA 42	3.87	1.50	2.37	108.67	3.10	34.84	12.25	112.47	169.25	0.12
CA 43	3.97	2.19	2.27	149.67	3.87	23.83	12.18	111.48	125.29	0.13
CA 44	3.57	2.32	2.27	79.00	4.88	21.43	13.83	96.59	134.46	0.12
CA 45	3.10	2.49	2.23	115.00	4.09	27.89	12.71	110.62	104.22	0.13
CA 46	3.07	3.02	2.20	152.67	2.21	24.21	12.28	124.17	133.86	0.25
CA 47	3.50	2.89	2.63	122.33	4.97	36.71	14.82	144.94	170.32	0.11
CA 48	3.30	1.98	2.60	99.33	3.37	24.31	10.67	124.40	123.17	0.19
CA 49	3.27	2.22	2.57	94.67	3.71	25.51	11.17	134.50	129.90	0.20
CA 50	3.00	2.67	2.67	103.00	3.48	28.37	13.49	95.94	127.40	0.19
CA 51	3.97	1.44	1.77	118.00	3.80	22.22	13.50	124.42	121.16	0.20
CA 52	2.93	1.71	2.60	134.00	3.57	27.66	15.00	139.65	129.58	0.14
CA 53	2.10	2.66	2.23	113.33	3.49	22.11	10.64	137.47	121.88	0.17
CD (5 %)	0.19	0.29	0.17	3.24	0.39	7.58	0.57	5.15	15.07	0.02

Table 6. Reaction of paprika accessions to bacterial wilt and leaf curl virus incidence

Accessions	Bacterial wilt (%)	Leaf curl virus incidence (V.I)
CA 1	9.13 (2.52)	52.96 (29.61)
CA 2	0.00 (0.00)	4.82 (0.71)
CA 3	0.00 (0.00)	19.12 (10.73)
CA 4	0.00 (0.00)	19.53 (11.18)
CA 5	0.00 (0.00)	29.60 (24.42)
CA 6	0.00 (0.00)	19.46 (11.11)
CA 7	0.00 (0.00)	18.13 (9.69)
CA 8	4.31 (0.56)	18.43 (10.00)
CA 9	0.00 (0.00)	22.55 (14.71)
CA 10	0.00 (0.00)	11.13(3.73)
CA 11	15.14 (6.83)	41.26 (52.22)
CA 12	0.00 (0.00)	14.96 (6.67)
CA 13	16.12 (7.71)	40.25 (52.21)
CA 14	21.83 (13.83)	38.56 (38.87)
CA 15	4.99 (0.760	41.47 (43.89)
CA 16	0.00 (0.00)	9.97 (3.00)
CA 17	19.12 (10.73)	21.96 (14.00)
CA 18	0.00 (0.00)	17.15 (8.70)
CA 19	14.96 (6.67)	16.77(8.33)
CA 20	15.14 (6.83)	15.72 (7.34)
CA 21	19.87 (11.57)	16.34 (7.92)
CA 22	17.83 (9.39)	21.41 (13.33)
CA 23	20.93 (12.77)	18.61 (10.19)
CA 24	0.00 (0.00)	24.84 (17.66)
CA 25	15.31 (6.98)	20.64 (12.43)
CA 26	14.12 (5.95)	21.15 (13.03)
CA 27	20.18 (11.91)	17.72 (9.27)

CA 28	20.11 (11.83)	26.81 (20.35)
CA 29	22.93 (15.19)	19.35(10.98)
CA 30	22.93 (15.19)	20.37 (12.120
CA 31	28.58 (22.90)	17.49 (9.04)
CA 32	22.86 (15.10)	19.60 (11.26)
CA 33	0.00 (0.00)	4.99 (0.76)
CA 34	0.00 (0.00)	4.99 (0.76)
CA 35	0.00 (0.00)	16.72 (8.28)
CA 36	10.15 (3.11)	22.29 (14.33)
CA 37	14.81 (6.54)	15.14 (6.83)
CA 38	16.86 (8.42)	22.65 (14.840
CA 39	28.58 (22.90)	29.41 (24.13)
CA 40	14.94 (6.65)	17.75 (9.30)
CA 41	19.96 (6.67)	14.49 (6.27)
CA 42	10.33 (3.22)	13.95 (5.82)
CA 43	9.48 (2.72)	17.62 (9.17)
CA 44	15.97 (7.58)	2.38 (18.38)
CA 45	15.05 (6.74)	26.39(19.78)
CA 46	17.15 (8.71)	16.74 (8.30)
CA 47	0.00 (0.00)	0.00 (0.00)
CA 48	14.78 (6.51)	19.52 (11.57)
CA 49	10.33 (3.22)	19.05 (10.66)
CA 50	14.71 (6.45)	21.02 (12.88)
CA 51	19.17 (10.79)	21.08 (12.94)
CA 52	21.87 (13.89)	23.19 (15.52)
CA 53	19.77 (11.44)	17.67 (9.22)
CD (5%)	5.46	7.26

(Transformed data is given in the parentheses)

Table 7. Categorization of accessions based on vulnerability index of leaf curl virus incidence

Category	Number	Accessions
Resistant	1	CA 47
Tolerant	47	CA 2, CA 3, CA 4, CA 5, CA 6, CA 7, CA 8, CA 9, CA 10, CA 12, CA 16, CA 17, CA 18, CA 19, CA 20, CA 21, CA 22, CA 23, CA 24, CA 25, CA 26, CA 27, CA 28, CA 29, CA 30, CA 31, CA 32, CA 33, CA 34, CA 35, CA 36, CA 37, CA 38, CA 39, CA 40, CA 41, CA 42, CA 43, CA 44, CA 45, CA 46, CA 48, CA 49, CA 50, CA 51, CA 52 and CA 53
Susceptible	2	CA 14 and CA15
Highly Susceptible	3	CA 1, CA 13 and CA 11

PLATE 3. Variability in fruit characters of paprika


CA 29
CA 30
CA 31
CA 32
CA 33
CA 34
CA 35
CA 36
CA 37
CA 38
CA 39
CA 40
CA 41
CA 42
CA 43
CA 44
CA 45
CA 46
CA 47
CA 48
CA 49
CA 50
CA 51
CA 52
CA 53

A close association between phenotypic and genotypic variances was noticed for fruits per plant, yield per plant, fruit length, fruit girth and capsaicin. For most of the characters genotypic variances make up the major portion of phenotypic variances, with very little effect of environment.

Fruits per plant recorded high GCV and PCV of 51.07 and 51.40 respectively followed by fruit length (31.28 and 31.55). High GCV and PCV of 30.21 and 30.86 was recorded for yield per plant. Fruit weight recorded a GCV of 26.36 and PCV of 26.69. Low GCV and PCV were recorded by days to maturity (8.53 and 8.96) and days to flowering (10.02 and 10.53). Among the quality parameters capsaicin (75.49 and 75.67) and ascorbic acid (20.99 and 22.20) also recorded high GCV and PCV. The GCV was very near to PCV for most of the characters, indicating a highly significant effect of genotype on phenotypic expression, with very little effect of environment.

4.1.3 Heritability and genetic advance

Heritability and genetic advance for different characters are presented in Table 9 and Fig 2. Most of the characters showed wide range of variation. High heritability coupled with high genetic advance was observed for most of the characters.

High heritability was observed for the characters fruits per plant (98.73) followed by fruit length (98.31), fruit girth (98.21), fruit weight (97.54), yield per plant (95.82), pedicel length (96.68), seeds per fruit (96.03), height of node to first flower (94.26). Quality parameters also recorded a high heritability *viz.*, capsaicin (99.52), colour (96.38), oleoresin content (93.68) and ascorbic acid (89.37). Moderate heritability was observed for primary branches (42.51).

Table 8 : Estimates of genetic parameters for various characters in paprika

Characters	Range	Mean	σp^2	σg^2	GCV (%)	PCV (%)
Plant height (cm)	31.5-104.69	69.59	258.24	231.54	21.87	23.09
Primary branches	2.00-3.33	2.36	0.29	0.12	14.74	22.61
Days to flowering	24.00-43.33	32.92	12.06	10.878	10.02	10.53
Node to first flower	16.67-5.67	8.49	3.92	3.55	22.21	23.32
Height to node to first flower (cm)	12.93-37.83	21.65	26.04	24.55	22.89	23.57
Days to maturity	23.33-37.00	31.73	8.082	7.319	8.53	8.96
Fruit length (cm)	2.70-14.17	8.56	7.29	7.17	31.28	31.55
Fruit girth (cm)	3.40-8.73	6.31	1.44	1.42	18.84	19.01
Fruits per plant	34.67-265.33	93.11	2290.59	2261.50	51.07	51.40
Fruit weight (g)	2.54-13.43	8.03	4.59	4.49	26.36	26.69
Yield per plant (g)	217.63-776.12	479.82	20348.51	19489.9	30.21	30.86
Pedicel length (cm)	2.10-5.00	3.60	0.46	0.44	18.42	18.73
Fruit : pedicel ratio	0.89-4.72	2.42	0.63	0.59	31.89	32.72
Flesh thickness (mm)	1.23-3.63	2.47	0.19	0.18	17.26	17.79
Seeds per fruit	55.00-160.33	111.85	547.74	525.99	20.50	20.92
Flesh : seed ratio	1.81-4.97	3.40	0.53	0.46	20.02	21.29
Driage (%)	18.78-36.71	26.96	19.36	15.39	14.66	16.44
Oleoresin (%)	8.45-18.09	12.75	6.36	5.96	19.20	19.84
Colour (ASTA units)	79.55-169.21	118.12	422.96	407.67	17.09	17.41
Ascorbic acid mg/00g)	73.94-185.07	126.87	146.56	137.67	20.99	22.20
Capsaicin (%)	0.10-0.88	0.26	0.04	0.04	75.49	75.67

High genetic advance was observed for fruits per plant (104.54), fruit length (63.91), fruit weight (53.66), fruit girth (38.49), yield per plant (58.69) and seeds per fruit (46.30). Quality parameters like capsaicin (157.69), colour value (40.83) and ascorbic acid content (51.83) also recorded a high genetic advance as per cent mean. Low genetic advance was observed for days to maturity (16.71), days to flowering (19.63) and primary branches (19.84). High heritability coupled with high genetic advance was observed for the characters like fruits per plant, fruit length, fruit weight, fruit girth, plant height, seeds per fruit, yield per plant and quality characters like capsaicin, colour and ascorbic acid. High heritability coupled with low genetic advance was observed for days to flowering and days to maturity.

4.1.4 Correlation analysis

The phenotypic, genotypic and environmental correlation coefficients were estimated for the 23 characters (Table 10, 11).

A) Phenotypic correlation

i) Correlation between yield and other characters

Yield per plant showed highest positive correlation with fruits per plant (0.5828), followed by primary branches (0.4879) and fruit length (0.3738). Other characters which showed positive correlation with yield are height of node to first flower (0.1103), pedicel length (0.2447), oleoresin (0.1590) and ascorbic acid (0.3225). Bacterial wilt and leaf curl virus showed high negative correlation with yield as -0.5639 and -0.0764 respectively.

ii) Correlation among the yield component characters

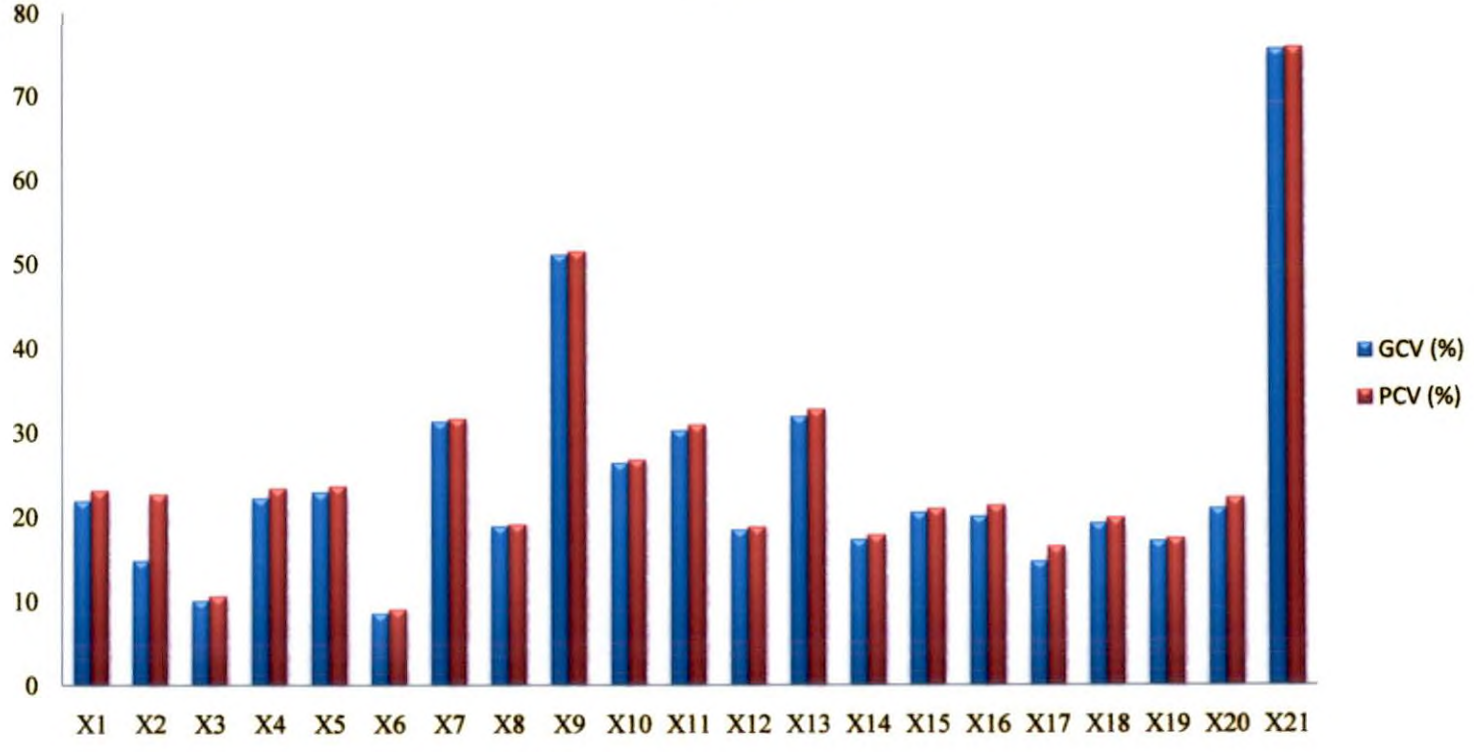
Plant height was positively correlated with flesh thickness (0.2660) and colour (0.2098).

Primary branches had high positive correlation with fruits per plant (0.4819), height of node to first flower (0.4196) and fruit length (0.3069).

Table 9 Heritability and genetic advance as per cent of mean for different characters in paprika

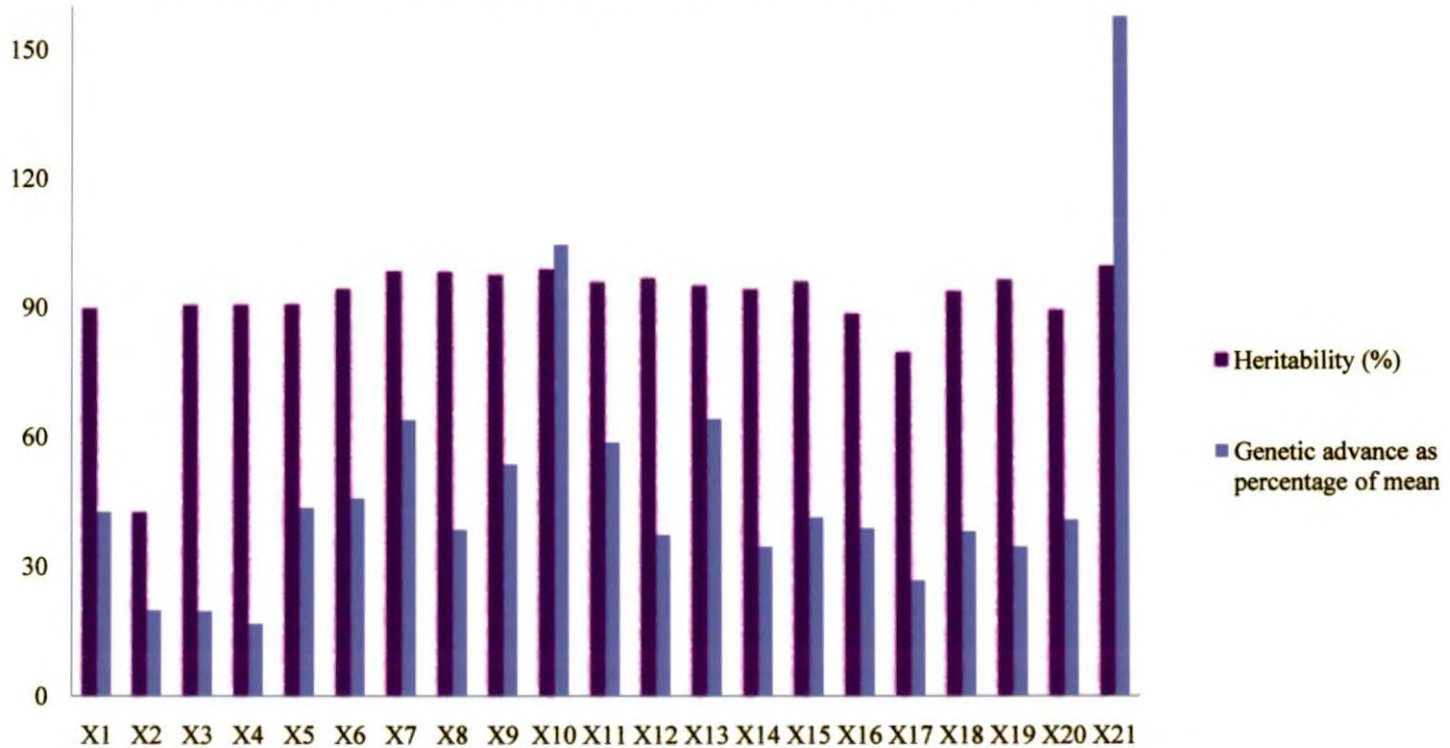
Characters	Heritability (%)	Genetic advance as percentage of mean
Plant height	89.66	42.65
Primary branches	42.51	19.84
Days to flowering	90.45	19.63
Days to maturity	90.56	16.71
Node to first flower	90.68	43.55
Height of node to first flower	94.26	45.77
Fruit length	98.31	63.91
Fruit girth	98.21	38.49
Fruit weight	97.54	53.66
Fruits per plant	98.73	104.54
Yield per plant	95.82	58.69
Pedicel length	96.68	37.31
Fruit : pedicel ratio	95.02	64.11
Flesh thickness	94.18	34.54
Seeds per fruit	96.03	41.39
Flesh : seed ratio	88.50	38.84
Driage	79.49	26.73
Oleoresin	93.68	38.16
Colour	96.38	34.57
Ascorbic acid	89.37	40.85
Capsaicin	99.52	157.69

Fig. 1. Phenotypic and genotypic coefficient of variation for different characters in paprika



X1 Plant height X2 Primary branches X3 Days to flowering X4 Node to first flower X5 Height of node to first flower
X6 Days to maturity X7 Fruit length X8 Fruit girth X9 Fruit weight X10 Fruits per plant
X11 Yield per plant X12 Pedicel length X13 Fruit: pedicel ratio X14 Flesh thickness X15 Seeds per fruit
X16 Flesh : seed ratio X17 Driage X18 Oleoresin X19 Colour X20 Ascorbic acid
X21 Capsaicin

Fig. 2 Heritability and genetic advance for different characters in paprika



X1 Plant height X2 Primary branches X3 Days to flowering X4 Node to first flower X5 Height of node to first flower
X6 Days to maturity X7 Fruit length X8 Fruit girth X9 Fruit weight X10 Fruits per plant
X11 Yield per plant X12 Pedicel length X13 Fruit: pedicel ratio X14 Flesh thickness X15 Seeds per fruit
X16 Flesh : seed ratio X17 Driage X18 Oleoresin X19 Colour X20 Ascprbic acid
X21 Capsaicin

Days to flowering had high positive correlation with days to maturity (0.7271), node to first flower (0.5125) and negative correlation with fruits per plant (-0.0373) and yield (-0.0818).

Node to first flower had positive correlation with height of node to first flower (0.4301) and days to maturity (0.3337) and negatively correlated with fruit girth (-0.3858).

Fruit length had positive correlation with yield (0.3738) and fruit pedicel ratio (0.7798), flesh : seed ratio (0.4112), ascorbic acid (0.4226) and negative correlation with driage (-0.0476).

Fruit girth showed positive correlation with fruit weight (0.5288) and ascorbic acid (0.3658) whereas it showed negative correlation with fruits per plant (-0.3908), yield (-0.1630). Fruit weight exhibited a positive correlation with fruit length (0.3348), fruit girth (0.5288) and flesh thickness (0.2525). Fruit weight had negative correlation with number of fruits (-0.4306).

Seeds per fruit exhibited a positive correlation with fruit length (0.2548). Colour had a positive correlation with flesh thickness (0.3308). Ascorbic acid exhibited a positive correlation with fruit length (0.4226), fruit girth (0.3658) and fruit weight (0.5008) and colour (0.2531).

Bacterial wilt recorded a negative correlation of -0.3959 on fruits per plant and -0.2298 on fruit length. Leaf curl virus incidence had negative correlation with fruit length (-0.1820), fruit girth (-0.2491) and fruit weight (-0.2631).

B) Genotypic correlation

i) Correlation between yield and other characters

High positive correlation was observed between yield and fruits per plant (0.5885), primary branches (0.5267), fruit length (0.3873). Yield per plant also exhibited a positive correlation with pedicel length (0.2464), fruit : pedicel ratio (0.2268) and flesh : seed ratio (0.1562). High negative correlation was found between yield and bacterial wilt (-0.6133) and leaf curl virus incidence (-0.0865).

ii) Correlation among the yield component characters

Plant height had positive correlation with fruit girth (0.2080), flesh thickness (0.4317) and colour (0.3542).

Primary branches exhibited a positive correlation with height of node to first flower (0.4617), fruit length (0.3187), fruit weight (0.5721), fruits per plant (0.5087).

Days to flowering also exhibited negative correlation with yield (-0.1014). Days to flowering had high positive correlation with days to maturity (0.7760), node to first flower (0.5334).

Node to first flower showed a positive correlation with height of node to first flower (0.4341).

Fruit length had positive correlation with fruit weight (0.3206) and ascorbic acid (0.4515).Fruit girth showed a high and positive correlation with flesh : seed ratio (0.5478) and flesh thickness (0.4640). Fruit girth and fruits per plant had a negative correlation (-0.3948).

Fruits per plant exhibited high and positive correlation with primary branches (0.5087) and a negative correlation with leaf curl virus incidence (-0.3196).

Seeds per fruit exhibited a positive correlation with fruit length (0.2633).

Bacterial wilt had a negative correlation with fruits per plant (-0.5630) and yield per plant (-0.6133).

Colour exhibited positive correlation with flesh thickness (0.3459) and strong negative correlation with leaf curl virus incidence (-0.3159).

Oleoresin exhibited positive correlation with colour (0.0375). Capsaicin had high positive correlation with fruits per plant (0.6747) and fruit weight (0.2584) and negative correlation with fruit girth (-0.5952) and fruit length (-0.2427) and ascorbic acid (-0.3546). Ascorbic acid content recorded positive correlation with flesh thickness (0.4951), fruit length (0.4515) and fruit girth (0.3873), fruit weight (0.3857) and colour (0.2614).

Table 10. Phenotypic correlation matrix among yield and its components

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23
X1	1.0000																						
X2	0.1047	1.0000																					
X3	-0.0102	0.0552	1.0000																				
X4	-0.0972	0.1207	0.5125**	1.0000																			
X5	0.0516	0.4196**	0.2064**	0.4301**	1.0000																		
X6	0.0396	0.1284	0.7271**	0.3337**	0.1616	1.0000																	
X7	-0.0103	0.3069**	0.0144	0.0099	0.2190	0.1422	1.0000																
X8	0.1362	-0.1273	-0.1956*	-0.3858**	-0.0941	-0.1144	0.1652*	1.0000															
X9	-0.0061	-0.0037	-0.0475	-0.3454**	0.0039	-0.0617	0.3348**	0.5288**	1.0000														
X10	-0.0127	0.4819**	-0.0373	0.1323	0.1118	0.0424	-0.1351	-0.3908**	-0.4306**	1.0000													
X11	-0.0268	0.4879**	-0.0818	0.0546	0.1103	0.1547	0.3738**	-0.1630*	-0.0039	0.5828**	1.0000												
X12	-0.1046	0.1591*	-0.1316	0.0600	0.1015	-0.0260	0.3216**	0.1198	0.1302	-0.1176	0.2447**	1.0000											
X13	0.0320	0.1615*	0.1117	-0.0559	0.1028	0.1964*	0.7798**	0.1081	0.2533**	-0.0731	0.2090**	-0.3060**	1.0000										
X14	0.2660**	0.1723*	-0.1500	-0.0888	0.1742	0.0664	0.2279**	0.4480**	0.2525**	-0.2566**	0.0659	0.1927*	-0.1626	1.0000									
X15	0.0888	-0.0486	-0.0360	0.0755	0.0646	-0.1784*	0.2548**	0.1033	-0.0443	-0.3020	-0.0868	-0.0661	-0.3060**	0.1927*	1.0000								
X16	-0.0167	-0.0888	-0.0495	-0.0829	0.0468	-0.1067	0.4112**	0.5049	0.6267**	-0.2788*	0.1380	0.0549	0.3710**	0.0884	0.2515**	1.0000							
X17	-0.1182	0.2498**	-0.0294	0.0047	0.1924	-0.0469	-0.0476	-0.1498	-0.0624	0.0148	-0.0328	0.1870*	0.2515**	-0.0035	-0.1171	-0.1626*	1.0000						
X18	0.1570	-0.2099**	0.0856	-0.0034	-0.0542	0.1249	-0.1207	0.1567	0.1077	-0.3959	-0.5639**	0.1045	-0.0160	0.1109	-0.0741	-0.2344**	-0.0060	1.0000					
X19	-0.1040	-0.1914*	0.2057**	0.3595	0.0708	0.3124**	-0.1722*	-0.2772**	-0.2867**	0.1059	-0.0764	0.0080	-0.1360	-0.2641**	-0.3274**	-0.1802*	-0.1049	0.1103	1.0000				
X20	0.1321	0.1670*	-0.0697	-0.0850	0.1099	0.0717	0.0662	-0.1062	0.1521	0.1185	0.1590*	0.1441	0.0024	0.1253	-0.0242	-0.0178	-0.0242	-0.0598	0.0206	1.0000			
X21	0.2098**	0.1971*	0.0429	0.0069	0.2645**	0.0897	0.1819*	0.0657	0.1142	-0.0290	-0.0256	-0.1154	0.2015*	0.3308**	0.0444	0.1560*	0.0444	0.0258	-0.2771**	0.0386	1.0000		
X22	0.0486	0.2255**	-0.1694*	-0.2078*	0.2364**	-0.0173	0.4226**	0.3658**	0.5008**	-0.0444	0.3225**	0.1745*	0.2928**	0.4566**	0.0236	0.3408**	0.0236	-0.1062	-0.2966**	-0.1149	0.2531**	1.0000	
X23	-0.1614	0.1924*	-0.1061	0.2257**	-0.0142	-0.0888	-0.2815**	-0.5874**	-0.6356**	0.6692**	-0.6356**	-0.0907	-0.2427**	-0.2727**	0.1685*	-0.3883**	0.1685	-0.3521**	0.2164*	-0.0023	-0.1247	-0.3348**	1.0000

X1 Plant height
X2 Primary branches
X3 Days to flowering
X4 Node to first flower
X5 Height to node to first flower
X6 Days to maturity
X7 Fruit length
X8 Fruit girth
X9 Fruit weight
X10 Fruits per plant
X11 Yield per plant
X12 Pedicel length
X13 Fruit: pedicel ratio
X14 Flesh thickness
X15 Seeds per fruit
X16 Flesh : seed ratio
X17 Driage
X18 Bacterial wilt
X19 Leaf curl virus
X20 Oleoresin
X21 Colour
X22 Ascorbic acid
X23 Capsaicin

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 11. Genotypic correlation matrix among yield and its components

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23
X1	1.0000																						
X2	0.1708*	1.0000																					
X3	-0.0218	-0.0713	1.0000																				
X4	-0.1695*	0.1278	0.5334**	1.0000																			
X5	0.0392	0.4617**	0.2045**	0.4341**	1.0000																		
X6	0.0804	0.1318	0.7760**	0.3620**	0.1837*	1.0000																	
X7	-0.0050	0.3187**	0.0193	0.0125	0.2302**	0.1543	1.0000																
X8	0.2080**	-0.1307	-0.2094**	-0.4162**	-0.1055	0.1226	0.1674*	1.0000															
X9	-0.1998*	0.5721**	-0.1122	-0.0586	-0.0417	0.0959	0.3206**	-0.1490	1.0000														
X10	-0.0110	0.5087**	-0.0422	0.1359	0.1146	0.0475	-0.1373	-0.3948**	-0.4395**	1.0000													
X11	-0.0342	0.5267**	-0.1014	0.0510	0.1150	0.1593*	0.3873**	-0.1696*	-0.0082	0.5885**	1.0000												
X12	-0.1862*	0.1782*	-0.1528*	0.0549	0.0985	-0.0329	0.3394**	0.1179	0.1334	-0.1190	0.2464**	1.0000											
X13	0.0780	0.1645*	0.1331	-0.0507	0.1155	0.2209**	0.7829**	0.1148	0.2635**	-0.0765	0.2268**	-0.2859**	1.0000										
X14	0.4317**	0.1972*	-0.1620*	-0.0829	0.1855*	0.0643	0.2349**	0.4640**	0.2633**	-0.2638**	0.0731	0.2064**	0.0881	1.0000									
X15	0.1635*	-0.0387	-0.0472	0.0818	0.0683	-0.1926*	0.2633**	0.1006	-0.0449	-0.3096**	-0.0878	-0.0713	0.2661**	0.2376**	1.0000								
X16	-0.0693	-0.0828	-0.0593	-0.0927	0.0331	-0.1131	0.4425**	0.5478**	0.6819**	-0.2939**	0.1562	0.0583	0.4040**	0.2112**	0.1953*	1.0000							
X17	-0.2688**	0.3281**	-0.0521	-0.0133	0.2224**	-0.0802	-0.0437	-0.1729*	-0.0820	0.0196	-0.0512	0.2059**	-0.1773*	-0.1689*	-0.1334	-0.1689*	1.0000						
X18	0.1430	-0.2991**	0.1496	0.0361	-0.0545	0.1709*	-0.1539	0.2339**	0.1716*	-0.5630**	-0.6133**	0.0301	-0.2338**	0.1142	-0.0839	-0.0208	-0.1702*	1.0000					
X19	-0.1858*	0.2268**	0.2463**	0.4175**	0.0854	0.3520**	-0.1944*	-0.3021**	-0.3019**	0.0576	-0.0865	0.0051	-0.2095**	-0.3196**	-0.3737**	-0.1820*	-0.1606*	0.2929**	1.0000				
X20	0.2084**	0.1810*	-0.0949	-0.0962	0.1105	0.8610**	0.0672	-0.1111	0.0275	0.0275	0.2268**	0.1502	-0.0012	-0.1270	0.0094	-0.0012	-0.0244	-0.0663	0.0444	1.0000			
X21	0.3542**	0.2132**	0.0524	0.0062	0.2757**	0.0995	0.1861**	0.0720	-0.0764	-0.0309	0.1632*	-0.1199	0.2099**	0.3459**	0.4064**	0.2099**	0.0267	-0.0340	-0.3159**	0.0375	1.0000		
X22	-0.2427**	0.2036*	-0.1090	0.2381**	-0.0153	-0.0262	0.4515**	0.3873**	0.3857**	0.5321**	-0.0304	0.1889*	0.3175**	0.4951**	0.1299	0.3175**	-0.0013	-0.1589*	-0.4263**	-0.1218	0.2614**	1.0000	
X23	0.1038	0.2536**	-0.1552	-0.2357**	0.2556**	-0.0915	-0.2856**	-0.5952**	0.2584**	0.6747**	0.3583**	-0.0911	-0.0021	-0.2824**	-0.1538	-0.2516**	0.1945*	-0.1611*	-0.2331**	-0.0021	-0.1247	-0.3546**	1.0000

X1 Plant height
X2 Primary branches
X3 Days to flowering
X4 Node to first flower
X5 Height to node to first flower
X6 Days to maturity
X7 Fruit length
X8 Fruit girth
X9 Fruit weight
X10 Fruits per plant
X11 Yield per plant
X12 Pedicel length
X13 Fruit: pedicel ratio
X14 Flesh thickness
X15 Seeds per fruit
X16 Flesh : seed ratio
X17 Driage
X18 Bacterial wilt
X19 Leaf curl virus
X20 Oleoresin
X21 Colour
X22 Ascorbic acid
X23 Capsaicin

4.1.5 Path analysis

In path coefficient analysis, the genotypic correlation coefficients among yield and its component characters were partitioned into direct and indirect contribution of each character to fruit yield (Table 12). Days to first flowering, primary branches, plant height, fruit weight, fruits per plant, bacterial wilt incidence and leaf curl virus incidence were selected for path coefficient analysis.

Fruit weight exhibited the highest positive direct effect on fruit yield (0.8543) followed by fruits per plant (0.7320), primary branches (0.1760) and plant height (0.0325) also exerted positive direct effect on the yield. Days to flowering (-0.1211) and bacterial wilt (-0.3199) exhibited negative direct effect on fruit yield.

Primary branches had genotypic correlation of 0.5267 with yield. In this, the direct effect was only 0.1760. Major portion of indirect effects was through fruit weight (0.4346).

The direct effect of plant height on yield was 0.0325 but genotypic correlation with yield was -0.0342. This character exhibited indirect effect on yield through fruits per plant (0.0056), days to flowering (0.0026) and primary branches (0.0301).

Fruit weight exhibited highest positive direct effect on fruit yield (0.8543) while the correlation was about 0.3022. Fruit weight had major indirect effect on yield through days to flowering (0.0051).

Fruits per plant had a direct effect of 0.7320 with a correlation of 0.5885. Indirect effects through fruits per plant were high signifying the importance of the character.

In the case of bacterial wilt and days to flowering the negative correlation on yield was mainly due to the negative indirect effects on fruit weight (-0.4810 and -0.0361 respectively).

The residue was 0 .5280 indicating that selected seven characters contributing the remaining forty seven per cent.

4.1.6 Selection Index

A discriminate function analysis was carried out for isolating superior genotypes.

Selection index involving characters *viz.,* plant height (X_1), days to flowering (X_3), fruit length (X_7), fruit girth (X_8), fruits per plant (X_{10}), yield per plant (X_{11}), and quality characters like oleoresin (X_{20}), Colour (X_{21}), ascorbic acid (X_{22}) and capsaicin content (X_{23}) were selected for the analysis.

The selection index, worked out in the present study is given below

$$I = 0.3405\ X_1 + 1.0119\ X_3 + 3.2688\ X_7 + -0.3995\ X_8 + 1.0989\ X_{10} + 0.9123\ X_{11} + 1.1112\ X_{20} + 0.8729\ X_{21} + 4.0496\ X_{22} + 1.0541\ X_{23}$$

The index value for each accession was determined and they were ranked. The scores obtained for the accessions based on the selection index were given in Table 1

Based on selection index including both vegetative and qualitative characters CA 34 was ranked first with an index of 3896.75 followed by CA7 (3881.287). CA6, CA 33 and CA35 obtained next three positions with indices of 3805.51, 3684.26 and 3601.68. The minimum scores were obtained for CA 51 with an index of 1681.466.

Table 12 : Direct and indirect effects of yield components of paprika

Characters	Days to flowering	Plant height	Primary branches	Fruit weight	Fruits per plant	Bacterial wilt	Leaf curl virus incidence	Total correlation
Days to flowering	-0.1211	0.0126	-0.0007	-0.0361	0.0615	-0.0747	0.0571	-0.1014
Primary branches	-0.0086	0.1760	0.0056	0.4346	-0.1448	0.1236	-0.0596	0.5267
Plant height	0.0026	0.0301	0.0325	-0.0094	0.0056	-0.0635	-0.0321	-0.0342
Fruit weight	0.0051	-0.0895	-0.0004	0.8543	-0.5513	0.1801	0.0111	0.3022
Fruits per plant	-0.0102	-0.0348	0.0003	-0.6434	0.7320	-0.0967	-0.0361	0.5885
Bacterial wilt	-0.0283	-0.0680	0.0065	-0.4810	0.2212	-0.3199	0.0562	-0.6133
Leaf curl virus incidence	-0.0360	-0.0547	-0.0054	0.0492	-0.1378	-0.0937	0.1919	-0.0865

Residue (R) = 0.5280

(Underlined figures are Direct effects)

Fig.3. Path diagram showing direct effects and correlation of yield components on total yield of paprika accessions

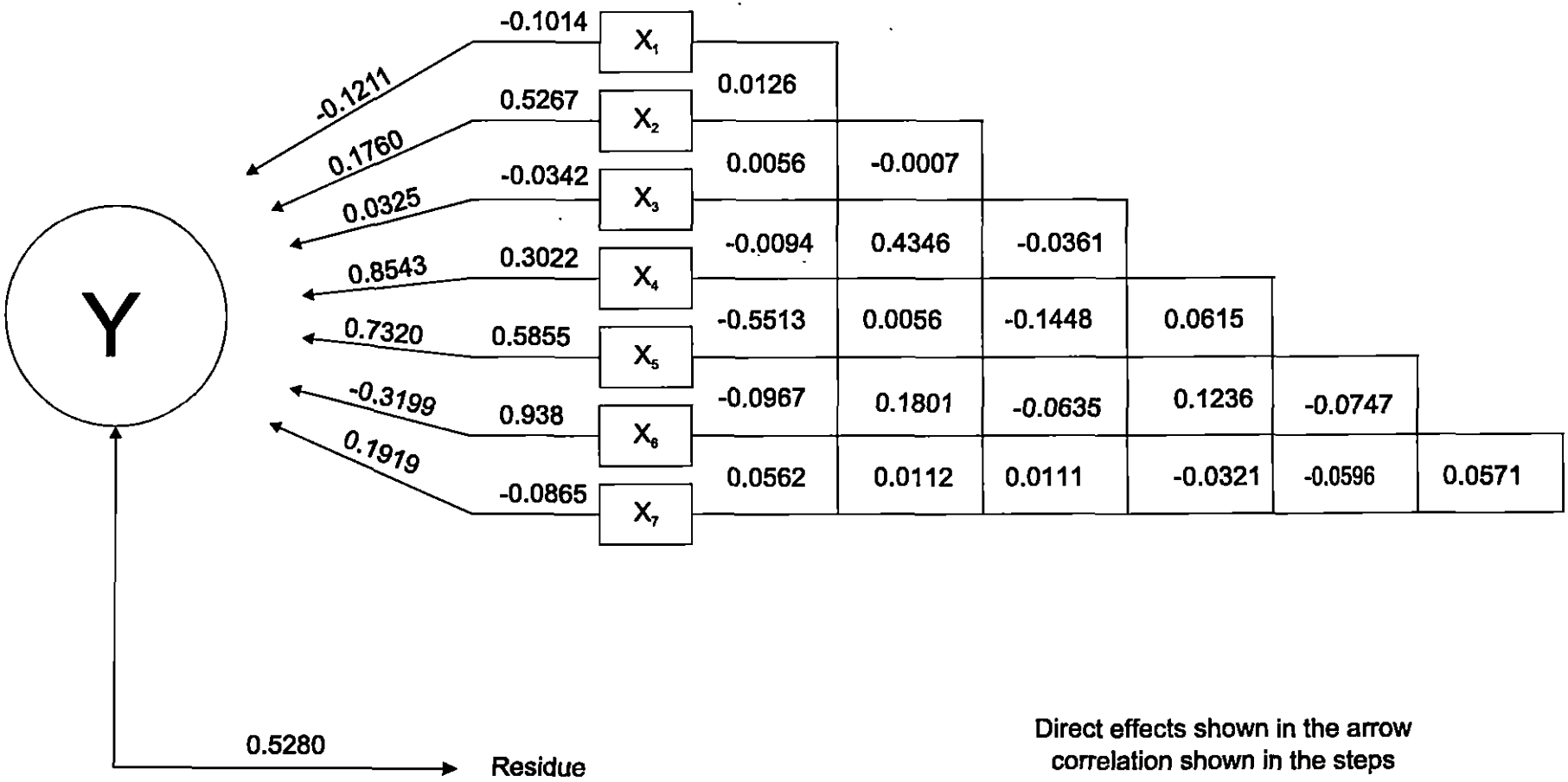


Table 13: Selection indices arranged in descending order

RANK	Accessions	Index
1	CA 34	3896.751
2	CA 7	3881.287
3	CA 6	3805.513
4	CA 33	3684.256
5	CA 35	3601.68
6	CA 5	3557.175
7	CA 8	3466.469
8	CA 16	3436.028
9	CA 47	3370.945
10	CA 15	3362.401
11	CA 9	3281.749
12	CA 36	3281.086
13	CA 12	3227.182
14	CA 38	3195.524
15	CA 22	3149.906
16	CA 27	3107.866
17	CA 2	3088.674
18	CA 26	3077.6
19	CA 37	2860.187
20	CA 4	2827.124
21	CA 14	2772.545
22	CA 3	2732.5
23	CA 23	2698.081
24	CA 13	2653.982
25	CA 19	2645.7
26	CA 44	2640.072
27	CA 1	2600.687
28	CA 10	2511.863

29	CA 11	2481.043
30	CA 17	2472.066
31	CA 52	2455.491
32	CA 49	2412.824
33	CA 39	2412.641
34	CA 53	2378.484
35	CA 30	2364.877
36	CA 21	2353.575
37	CA 25	2344.014
38	CA 50	2332.679
39	CA 20	2325.16
40	CA 18	2321.784
41	CA 29	2318.007
42	CA 48	2281.595
43	CA 43	2252.498
44	CA 28	2233.997
45	CA 45	2185.042
46	CA 46	2166.189
47	CA 32	2142.55
48	CA 42	2136.617
49	CA 24	2128.448
50	CA 41	2046.701
51	CA 40	1750.003
52	CA 31	1711.624
53	CA 51	1681.466

4.1.7 Genetic Divergence analysis

Following Mahalanobis's statistic, the 53 accessions of paprika were subjected to D^2 analysis based on twenty three characters.

The 53 accessions were grouped into four clusters (Fig. 3). The clustering pattern is furnished in Table 14. Dendrogram generated by UPGMA cluster analysis is shown in Fig 4.

Cluster I was the largest with thirty four accessions followed by cluster IV with 15 accessions and cluster II with three accessions. Cluster III had one accession only.

The cluster means for different characters are presented in Table 15 and the average intra and inter cluster distances are furnished in Table 16.

Cluster III consisted of only one accession, CA 12 which had highest fruits per plant with lowest fruit weight and fruit length. Cluster II had the minimum yield per plant (CA 31, CA 40 and CA 51).

Cluster IV included accessions with high yield per plant, fruit weight and fruit length and these accessions had highest selection index also. This cluster consisted of the top ranking accessions like CA 34, CA 7, CA 6, CA 33 and CA 35.

The average inter and intra cluster distances were estimated based on total D^2 values. The intracluster distances seen to be lower than intercluster distances. Cluster IV had the highest intracluster distance (16698.46), followed by Cluster I (12669.35), cluster II (2885.52) and cluster III (0.00).

The highest intercluster distance was observed between clusters II and IV (196265.00), followed by Clusters III and II (98833.41) and clusters I and IV (81929.80). The minimum intercluster distance was observed between clusters I and II (37963.41) indicating a close relationship among the accessions included.

Table 14. Clustering pattern of paprika accessions

Cluster number	Number of accessions	Accessions
I	34	CA 1, CA 2, CA 3, CA 4, CA 10, CA 11, CA 13, CA 14, CA 17, CA 18, CA 19, CA 20, CA 21, CA 23, CA 24, CA 25, CA 28, CA 29, CA 30, CA 32, CA 37, CA 38, CA 39, CA 41, CA 42, CA 43, CA 44, CA 45, CA 46, CA 48, CA 49, CA 50, CA 52 and CA 53
II	3	CA 31, CA 40 and CA 51
III	1	CA 12
IV	15	CA 5, CA 6, CA 7, CA 8, CA 9, CA 15, CA 16, CA 22, CA 26, CA 27, CA 33, CA 34, CA 35, CA 36 and CA 47

Table 15. Cluster means for biometric characters in paprika

Character	Cluster I	Cluster II	Cluster III	Cluster IV
Plant height (cm)	67.02	40.53	104.69	78.85
Primary branches	2.34	2.45	2.67	2.51
Days to first flowering	33.39	31.22	34.00	32.10
Days to maturity	31.84	22.01	30.00	29.47
Node to first flower	8.67	7.83	7.00	8.31
Height of node to first flower (cm)	21.70	17.65	24.83	22.13
Fruit length (cm)	8.79	5016	2.70	10.24
Fruit girth (cm)	6.37	7.16	4.10	6.18
Fruits per plant	77.43	39	2.54	121.57
Fruit weight (g)	8.15	7.92	265.33	654.4
Yield per plant (g)	386.00	233.65	427.06	7.93
Pedicel length (cm)	3.44	3.77	3.03	3.97
Fruit : pedicel ratio	2.50	1.42	0.89	2.73
Flesh thickness (mm)	2.54	3.77	1.89	2.36
Seeds per fruit	112.93	120.78	58.00	123.91
Flesh : seed ratio	3.41	3.33	1.82	3.18
Driage (%)	27.17	23.63	31.11	26.77
Oleoresin (%)	12.55	11.68	11.72	13.46
Colour (ASTA units)	119.49	114.99	116.57	116.08
Ascorbic acid (mg/100g)	117.85	109.80	111.04	143.93
Capsaicin (%)	0.60	0.16	0.73	0.29

Table 16. Average intra and inter cluster distances (D values)

Clusters	I	II	III	IV
I	12669.35			
II	37963.41	2885.52		
III	47167.61	98833.41	0.00	
IV	81929.80	196265.00	82744.48	16698.46

Diagonal elements - intracluster values

Off diagonal elements – intercluster values

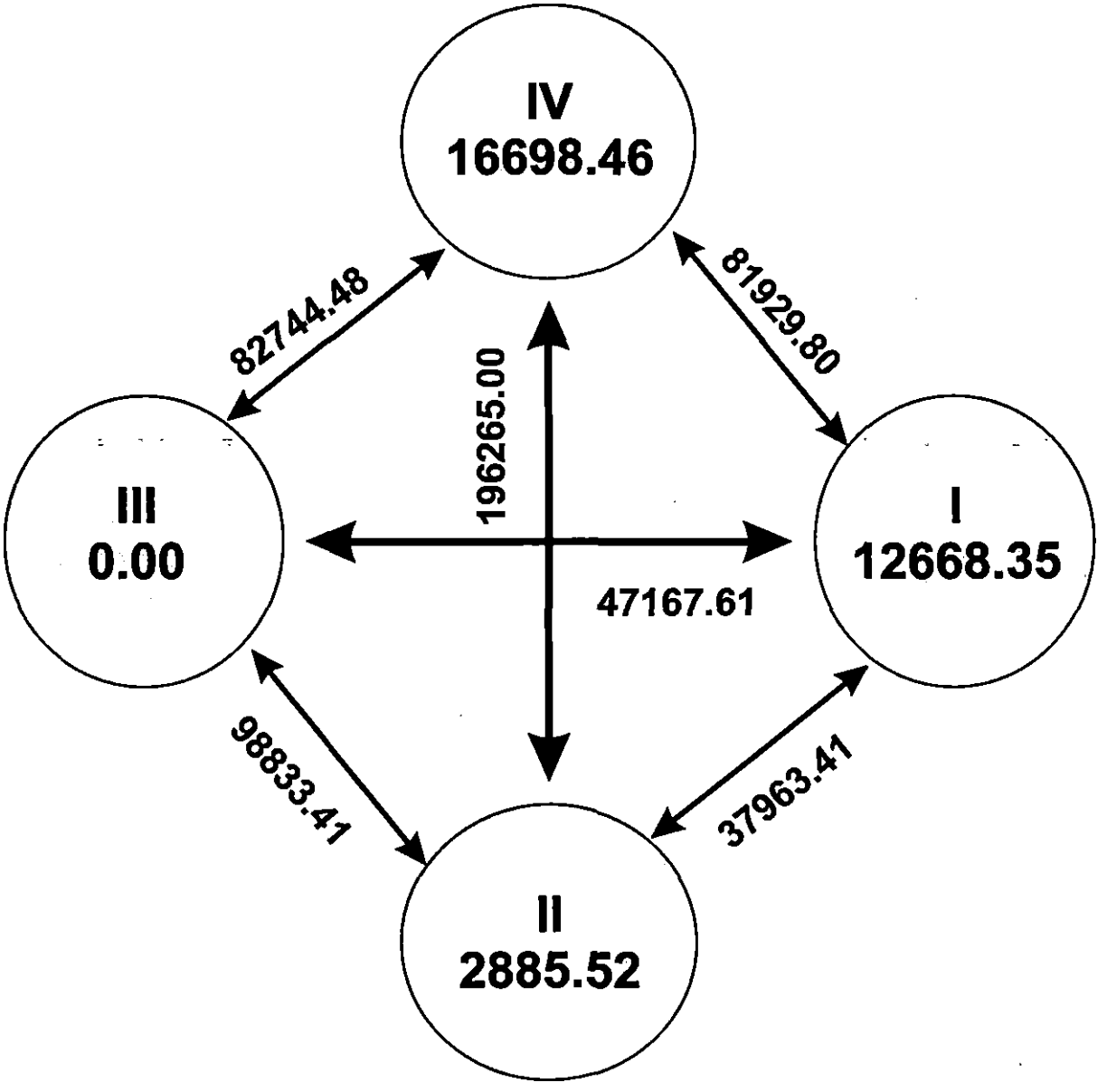
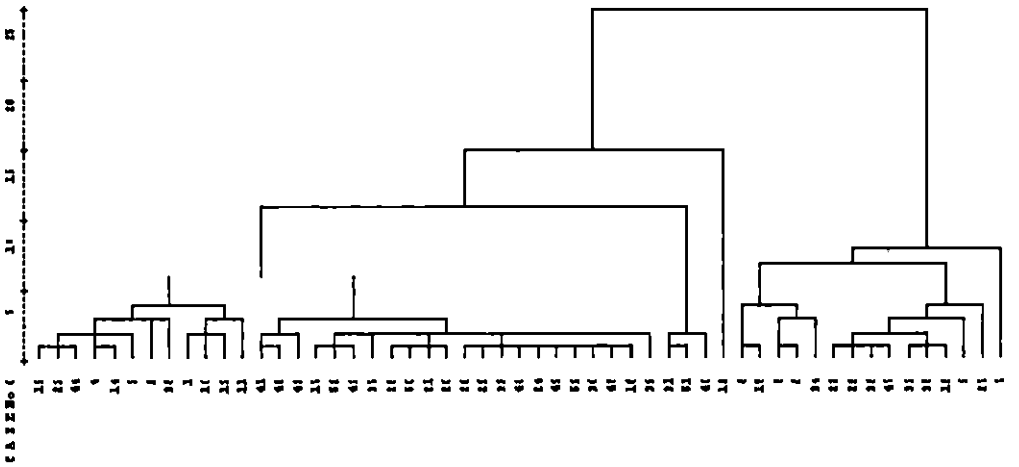


Fig. 4 Cluster Diagram

Fig 5.Dendrogram of paprika accessions constructed using UPGMA hierarchial cluster analysis



4.3 Genetic cataloguing of paprika

All the 53 accessions were described morphologically using the descriptor method developed by IPGRI. Considerable variation was noticed among the accessions for various characters (Table 20).

The accessions had green to purple cotyledon. Plant growth habit was either erect or compact.

Fruit colour varied from green to purple during maturity stages and red to deep red during ripening stage. Fruit shape also showed considerable variation.

4.2 INFLUENCE OF HARVEST MATURITY ON QUALITY

Varietal performance based on different maturity stages with respect to quality characters are presented in Table 18, 19 and 20 and Figures 5, 6, 7, 8 and 9.

4.2.1 Oleoresin (%)

At turning stage CA 25 (15.67 per cent) had maximum oleoresin which was on par with CA 29 (15.50 per cent) followed by CA 27 (14.97 per cent) and CA 28 (14.83 per cent). CA 8 had the minimum oleoresin content (7.34 per cent).

The fruits of CA 7 (18.09 per cent) had maximum oleoresin content which was on par with CA 28 (18.00 per cent) when harvested at full ripe stage, whereas CA 8 (8.45 per cent) recorded minimum oleoresin content at this stage.

When fruits were harvested at withering stage CA 5 had highest oleoresin content 21.13 per cent which was on par with CA 6 (20.83 per cent) followed by CA 7 (19.40 per cent), CA 29 (19.10 per cent). CA 23 had the lowest content (9.83 per cent).

Oleoresin content increased as the age of the fruit increased. The maximum oleoresin content was recorded when fruits were harvested at withering stage. The

interaction of genotypes with maturity stage was also significant. Considering genotypes with maturity stages, CA 5 had highest oleoresin content (21.13 per cent) when harvested at withering stage.

4.2.2 Colour

When fruits were harvested at turning stage (M1) CA 38 recorded maximum colour content (137.06) which was on par with CA 34 (134.67), CA 2 (133.96) and CA 37 (132.50) and CA 5 recorded minimum (60.69).

The fruits of CA 2 had maximum colour value (169.21 ASTA units) which was on par with CA 37 (168.37 ASTA units) followed by CA 38 (163.35 ASTA units) when harvested at full ripe stage. The accession CA 20 recorded minimum colour value (79.55 ASTA units) at this stage.

When fruits harvested at withering stage CA 37 (200.32 ASTA units) had highest value for colour and was on par with CA 34 (198.48 ASTA units) followed by CA 38 (193.60 ASTA units). CA 20 had the lowest content (86.84 ASTA units).

Similar to other quality parameters colour value also increased as the age increased and recorded maximum colour value at withering stage. Considering genotypes in relation to maturity stage CA 37 recorded the maximum colour value at withering stage.

4.2.3 Ascorbic acid

At turning stage CA 38 (162.27) had maximum ascorbic acid followed by CA 33 (160.37) and CA 22 (160.31). CA 29 (52.72) recorded the lowest ascorbic acid.

The fruits of CA 38 (185.07) had highest ascorbic acid content when harvested at full ripe stage and was on par with CA 33 (184.86). The accession CA 1 recorded minimum ascorbic acid content (73.94) at this stage.

When fruits harvested at withering stage CA 22 had highest ascorbic acid content (174.86) and CA 1 had the lowest content (67.47).

Interaction between genotypes and maturity stages were significant. Ascorbic acid increased from turning stage to red ripe stage and then declined in the withering stage. Maximum ascorbic acid content was observed in CA 38 (185.07) at red ripe stage.

4.2.4. Capsaicin (%)

When fruits were harvested at turning stage (M1) CA 10 recorded maximum capsaicin content (0.71) and CA 38 recorded minimum (0.08 per cent) which was on par with CA 40 (0.09 per cent) and CA 47 (0.1 per cent).

At full ripe stage (M2), CA 10 had the highest capsaicin content (0.88) and CA 34 and CA 40 recorded the lowest capsaicin content of 0.10.

When harvesting was done at withering stage CA 10 recorded maximum capsaicin content of 0.99 and CA 34 had the lowest capsaicin content (0.10).

Capsaicin content increased as the age of the fruit increased and it was maximum in withering stage among the three different maturity stages. The interaction of genotypes with maturity stage was significant. Considering genotypes in relation to maturity stages, capsaicin was maximum in CA 10 at withering stage and minimum for CA 38 at turning stage.

4.3 Weather parameters

The weather parameters during the crop period are presented in Appendix II.

Table 17. Genetic catalouging in paprika accessions

Accessions	Hypocotyl colour	Stem pubescence	Leaf colour	Stem colour	Plant growth habi	Number of flowers per axil	Flower position	Corolla color	Filament colour	Calyx pigmentation
CA 1	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 2	Green	Sparse	Light green	Green	Compact	One	Intermediate	Light green	White	Absent
CA 3	Green	Sparse	Light green	Green	Compact	Two	Intermediate	Light green	White	Absent
CA 4	Green	Sparse	Light green	Green	Erect	One	Erect	Light green	White	Absent
CA 5	Green	Sparse	Light green	Green	Erect	Two	Pendant	Light green	White	Absent
CA 6	Green	Sparse	Light green	Green	Erect	Two	Intermediate	Light green	White	Absent
CA 7	Green	Sparse	Light green	Green	Erect	One	Pendant	Light green	White	Absent
CA 8	Green	Sparse	Light green	Green	Erect	One	Pendant	Light green	White	Absent
CA 9	Green	Sparse	Light green	Green	Erect	One	Pendant	Light green	White	Absent
CA 10	Green	Sparse	Light green	Green	Erect	One	Pendant	Light green	White	Absent
CA 11	Green	Intermediate	Light green	Green	Erect	Two	Pendant	Light green	White	Absent
CA 12	Purple	Sparse	Purple	Purple	Erect	Two	Erect	Purple	Light purple	Absent
CA 13	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 14	Green	Sparse	Light green	Green	Erect	One	Pendant	Light green	White	Absent
CA 15	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 16	Green	Sparse	Green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 17	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 18	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 19	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 20	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 21	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 22	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 23	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 24	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 25	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent

CA 26	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 27	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 28	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 29	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 30	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 31	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 32	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 33	Green	Sparse	Light green	Green	Erect	One	Pendant	Light green	White	Absent
CA 34	Green	Sparse	Light green	Green	Compact	One	Pendant	Light green	White	Absent
CA 35	Green	Sparse	Light green	Green	Compact	One	Pendant	Light green	White	Absent
CA 36	Green	Sparse	Light green	Green	Compact	One	Pendant	Light green	White	Absent
CA 37	Green	Sparse	Light green	Green	Erect	One	Pendant	Light green	White	Absent
CA 38	Green	Sparse	Light green	Green	Erect	One	Pendant	Light green	White	Absent
CA 39	Green	Sparse	Light green	Green	Erect	One	Pendant	Light green	White	Absent
CA 40	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 41	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 42	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 43	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 44	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 45	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 46	Green	Sparse	Light green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 47	Green	Intermediate	Green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 48	Green	Sparse	Green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 49	Green	Sparse	Green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 50	Green	Sparse	Green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 51	Green	Sparse	Green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 52	Green	Sparse	Green	Green	Erect	One	Intermediate	Light green	White	Absent
CA 53	Green	Sparse	Green	Green	Erect	One	Intermediate	Light green	White	Absent

Table 8 Continued

Accessions	Anthocyanin spots or strips	Fruit colour at immature stage	Fruit colour at mature stage	Fruit shape	Fruit shape at pedicel attachment	Fruit shape at blossom end	Fruit surface	Seed colour
CA 1	Absent	Green	Red	Elongate	Acute	Pointed	emi wrinkled	Straw
CA 2	Absent	Green	Dark red	Rriangular	Truncate	Pointed	Smooth	Straw
CA 3	Absent	Green	Red	Elongate	Obtuse	Pointed	Wrinkled	Straw
CA 4	Absent	Green	Red	Elongate	Acute	Pointed	Smooth	Straw
CA 5	Absent	Green	Red	Elongate	Acute	Pointed	Smooth	Straw
CA 6	Absent	Green	Red	Elongate	Acute	Pointed	Smooth	Straw
CA 7	Absent	Green	Red	Elongate	Acute	Pointed	Smooth	Straw
CA 8	Absent	Green	Red	Elongate	Acute	Pointed	Semi wrinkled	Straw
CA 9	Absent	Green	Red	Elongate	Acute	Pointed	Semi wrinkled	Straw
CA 10	Absent	Green	Red	Elongate	Acute	Pointed	Semi wrinkled	Straw
CA 11	Absent	Green	Red	Elongate	Acute	Pointed	Semi wrinkled	Straw
CA 12	Present	Purple	Dark red	Campanulate	Obtuse	Blunt	smooth	Straw
CA 13	Absent	Green	Red	Elongate	Truncate	Pointed	Semi wrinkled	Straw
CA 14	Absent	Green	Red	Elongate	Obtuse	Pointed	Semi wrinkled	Straw
CA 15	Absent	Green	Red	Elongate	Obtuse	Pointed	Semi wrinkled	Straw
CA 16	Absent	Green	Red	Elongate	Obtuse	Pointed	Semi wrinkled	Straw
CA 17	Absent	Green	Red	Elongate	Obtuse	Pointed	Semi wrinkled	Straw
CA 18	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 19	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 20	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 21	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 22	Absent	Green	Red	Elongate	Acute	Pointed	Smooth	Straw
CA 23	Absent	Green	Red	Elongate	Acute	Pointed	Smooth	Straw
CA 24	Absent	Green	Red	Elongate	Acute	Pointed	Smooth	Straw

CA 25	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 26	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 27	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 28	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 29	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 30	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 31	Absent	Green	Red	Elongate	Lobate	Blunt	semi wrinkled	Straw
CA 32	Absent	Green	Dark red	Elongate	Obtuse	Pointed	semi wrinkled	Straw
CA 33	Absent	Green	Dark red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 34	Absent	Green	Dark red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 35	Absent	Green	Dark red	Elongate	Obtuse	Blunt	Smooth	Straw
CA 36	Absent	Green	Dark red	Elongate	Obtuse	Pointed	Semi wrinkled	Straw
CA 37	Absent	Green	Dark red	Elongate	Obtuse	Pointed	Semi wrinkled	Straw
CA 38	Absent	Green	Dark red	Elongate	Obtuse	Blunt	Semi wrinkled	Straw
CA 39	Absent	Green	Red	Campanulate	Obtuse	Blunt	Smooth	Straw
CA 40	Absent	Green	Red	Campanulate	Cordate	Blunt	Smooth	Straw
CA 41	Absent	Green	Red	Elongate	Cordate	Pointed	Smooth	Straw
CA 42	Absent	Green	Red	Elongate	Truncate	Pointed	Smooth	Straw
CA 43	Absent	Green	Red	Elongate	Truncate	Pointed	Semi wrinkled	Straw
CA 44	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 45	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 46	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 47	Absent	Green	Red	Elongate	Truncate	Blunt	Smooth	Straw
CA 48	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 49	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 50	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 51	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 52	Absent	Green	Red	Elongate	Obtuse	Pointed	Smooth	Straw
CA 53	Absent	Green	Red	Elongate	Obtuse	Blunt	Smooth	Straw

Table 18. Analysis of variance for quality characters over harvest maturity

Source	Degrees of freedom	Oleoresin	Colour	Ascorbic acid	Capsaicin
Genotype	52	48.43**	3552.35**	5405.04**	0.36**
Maturity stage	2	552.14**	75517.5**	9606.75**	0.13**
Interaction(Genotype X Maturity)	104	4.75**	186.59**	203.66**	2.11**
Error	316	0.39	31.02	88.78	2.98

Table 19. Mean performance of paprika accessions for oleoresin and colour over maturity stages

Accessions	Oleoresin (%)			Colour (ASTA units)		
	M1	M2	M3	M1	M2	M3
CA 1	8.83	10.83	11.67	116.58	125.93	144.25
CA 2	10.00	10.67	13.14	121.25	169.21	176.41
CA 3	10.00	16.63	20.76	133.96	131.12	153.72
CA 4	8.64	9.67	10.17	65.38	104.73	123.54
CA 5	11.83	15.38	21.13	60.69	84.68	115.00
CA 6	13.20	16.33	20.83	75.16	91.78	110.61
CA 7	12.06	18.09	19.40	99.68	115.38	144.94
CA 8	7.34	8.45	11.17	80.15	103.24	127.63
CA 9	10.62	11.63	14.13	100.96	110.94	142.58
CA 10	8.23	10.83	11.23	93.03	114.39	142.25
CA 11	8.59	12.76	15.46	75.48	90.84	145.16
CA 12	10.56	11.72	19.75	97.44	116.57	146.13
CA 13	8.24	10.03	12.31	85.71	97.92	121.59
CA 14	11.39	13.17	14.67	78.60	105.69	124.63
CA 15	13.83	14.81	17.08	93.40	114.37	130.62
CA 16	12.33	13.67	14.50	101.64	125.64	158.56
CA 17	8.99	12.32	14.22	123.79	149.31	168.91
CA 18	11.83	13.33	14.63	82.76	102.03	117.39
CA 19	10.17	11.17	11.68	104.10	118.68	123.77
CA 20	9.83	10.17	12.00	61.05	79.55	86.84
CA 21	14.82	16.00	18.50	77.02	96.13	119.28
CA 22	9.83	10.83	10.67	77.33	94.75	125.93
CA 23	8.86	9.00	9.83	109.21	123.07	140.69
CA 24	9.01	10.00	10.83	76.77	92.22	104.67
CA 25	15.67	16.17	17.92	69.64	86.91	98.53
CA 26	11.67	13.67	14.77	98.39	111.77	131.81
CA 27	14.97	15.99	16.42	107.12	118.48	146.70
CA 28	14.83	18.00	19.03	101.01	131.89	157.46
CA 29	15.50	17.50	19.10	109.76	125.30	161.30
CA 30	10.19	11.49	13.69	103.49	127.09	147.51
CA 31	9.19	10.00	11.15	88.57	101.37	127.13

CA 32	10.00	10.17	12.20	94.81	114.16	146.59
CA 33	10.17	11.73	13.82	109.22	130.59	161.26
CA 34	8.91	9.98	12.61	134.67	136.45	198.48
CA 35	10.96	14.63	17.80	118.11	137.63	170.58
CA 36	8.17	11.82	15.17	106.41	120.69	162.32
CA 37	12.83	17.00	18.92	132.50	168.37	200.32
CA 38	8.31	10.33	16.45	137.06	163.35	193.60
CA 39	10.66	11.88	13.04	109.28	137.76	157.24
CA 40	10.33	11.53	12.31	104.17	119.18	146.78
CA 41	9.83	11.67	12.15	101.67	114.26	155.17
CA 42	11.20	12.25	14.02	96.17	112.47	139.44
CA 43	10.33	12.18	12.34	111.72	111.48	134.35
CA 44	10.37	13.83	15.16	78.19	96.59	125.40
CA 45	11.33	12.71	14.16	107.71	110.62	117.44
CA 46	10.17	12.28	13.32	99.78	124.17	150.50
CA 47	13.83	14.82	16.17	110.27	144.94	169.18
CA 48	9.73	10.67	11.00	103.08	124.40	142.52
CA 49	10.17	11.17	12.67	100.59	134.50	138.38
CA 50	11.32	13.49	13.89	79.11	95.94	122.12
CA 51	11.83	13.50	14.67	111.54	124.42	135.80
CA 52	12.83	15.00	15.33	118.61	139.65	160.02
CA 53	9.83	10.64	12.67	105.19	137.47	151.09

	Oleoresin		Colour	
	CD (0.05 values)	SE values	CD (0.05 values)	SE values
Genotype	0.58	0.21	5.15	1.86
Maturity	0.14	4.97	1.22	0.44
Interaction	1.00	0.36	8.91	3.22

Table 20. Mean performance of paprika accessions for ascorbic acid and capsaicin over maturity stages

Accessions	Ascorbic acid (mg/100 g)			Capsaicin (%)		
	M1	M2	M3	M1	M2	M3
CA 1	63.35	73.94	67.47	0.50	0.54	0.58
CA 2	125.33	133.32	126.63	0.62	0.63	0.64
CA 3	74.39	78.61	75.99	0.58	0.57	0.62
CA 4	120.36	124.88	130.08	0.58	0.63	0.64
CA 5	100.00	110.44	116.96	0.66	0.70	0.72
CA 6	122.19	132.02	128.47	0.45	0.52	0.55
CA 7	124.73	140.45	134.92	0.46	0.49	0.60
CA 8	99.21	103.39	101.32	0.38	0.41	0.49
CA 9	117.46	130.66	123.90	0.50	0.51	0.60
CA 10	92.35	106.44	105.24	0.71	0.88	0.99
CA 11	99.66	110.02	108.16	0.36	0.40	0.47
CA 12	104.33	111.04	108.74	0.65	0.73	0.81
CA 13	95.26	101.96	101.23	0.38	0.43	0.54
CA 14	100.30	106.98	103.78	0.35	0.41	0.46
CA 15	100.77	108.60	105.31	0.40	0.46	0.53
CA 16	130.28	136.17	131.79	0.25	0.29	0.35
CA 17	100.20	110.69	103.82	0.15	0.18	0.21
CA 18	114.91	124.58	121.28	0.11	0.11	0.13
CA 19	115.08	124.20	124.86	0.12	0.11	0.14
CA 20	124.65	132.27	146.31	0.15	0.16	0.19
CA 21	113.83	114.53	114.09	0.12	0.12	0.13
CA 22	160.31	175.60	174.86	0.12	0.13	0.13
CA 23	112.52	134.75	129.88	0.14	0.15	0.19
CA 24	113.41	117.71	115.96	0.12	0.14	0.16
CA 25	125.24	130.48	128.41	0.13	0.13	0.17
CA 26	132.35	146.34	146.26	0.14	0.15	0.17
CA 27	99.70	107.41	100.15	0.12	0.15	0.17
CA 28	106.94	85.88	111.50	0.12	0.13	0.14
CA 29	52.72	82.34	75.27	0.16	0.18	0.18

CA 30	100.15	102.10	100.62	0.13	0.18	0.20
CA 31	103.05	120.25	109.24	0.14	0.17	0.17
CA 32	107.65	121.00	114.74	0.12	0.12	0.13
CA 33	160.37	184.86	122.43	0.11	0.13	0.13
CA 34	145.15	174.44	171.56	0.11	0.10	0.10
CA 35	151.85	175.82	168.22	0.11	0.12	0.12
CA 36	139.32	162.95	151.94	0.13	0.13	0.14
CA 37	125.42	155.42	135.26	0.14	0.18	0.23
CA 38	162.27	185.07	168.93	0.08	0.11	0.11
CA 39	148.30	164.00	161.44	0.14	0.17	0.19
CA 40	67.67	88.00	108.40	0.09	0.10	0.15
CA 41	88.03	99.19	100.16	0.11	0.12	0.15
CA 42	117.17	169.25	169.26	0.11	0.12	0.14
CA 43	91.38	125.29	121.67	0.11	0.13	0.17
CA 44	109.26	134.46	131.59	0.11	0.12	0.15
CA 45	77.00	104.22	99.10	0.12	0.13	0.15
CA 46	113.07	133.86	126.42	0.22	0.25	0.25
CA 47	141.32	170.32	162.27	0.10	0.11	0.11
CA 48	101.74	123.17	116.78	0.19	0.19	0.21
CA 49	103.85	129.90	128.00	0.19	0.20	0.20
CA 50	109.94	127.40	123.29	0.18	0.19	0.20
CA 51	108.43	121.16	113.88	0.18	0.20	0.21
CA 52	118.07	129.58	130.67	0.12	0.14	0.16
CA 53	102.83	121.88	117.63	0.16	0.17	0.18

	Ascorbic acid		Capsaicin	
	CD (0.05 values)	SE values	CD (0.05 values)	SE values
Genotype	8.71	3.14	0.02	0.06
Maturity	2.07	0.75	0.04	0.01
Interaction	15.08	5.44	8.91	3.22

Fig. 6 Mean performance of accessions for oleoresin over maturity stages

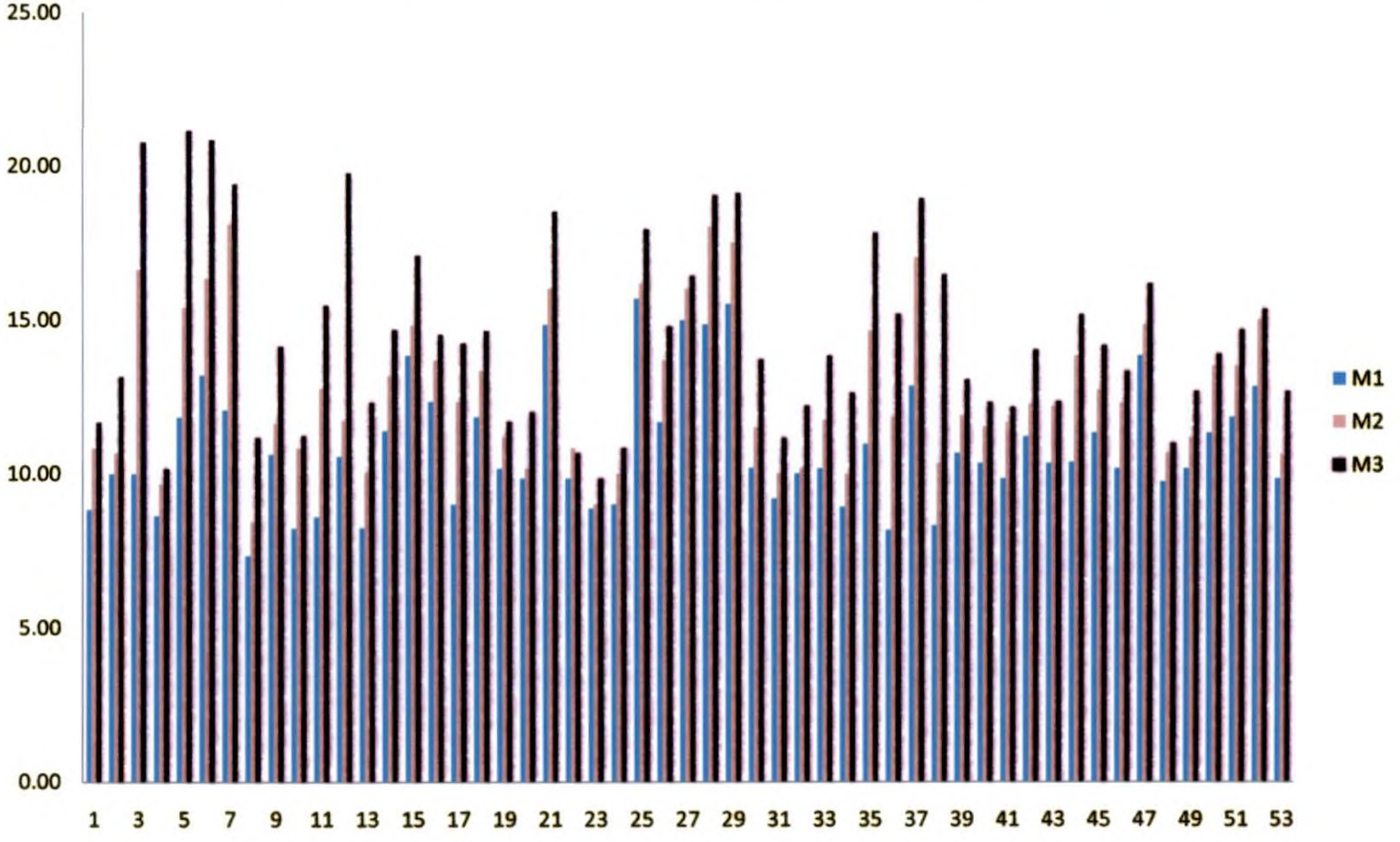


Fig. 7 Mean performance of accessions for colour over maturity stages

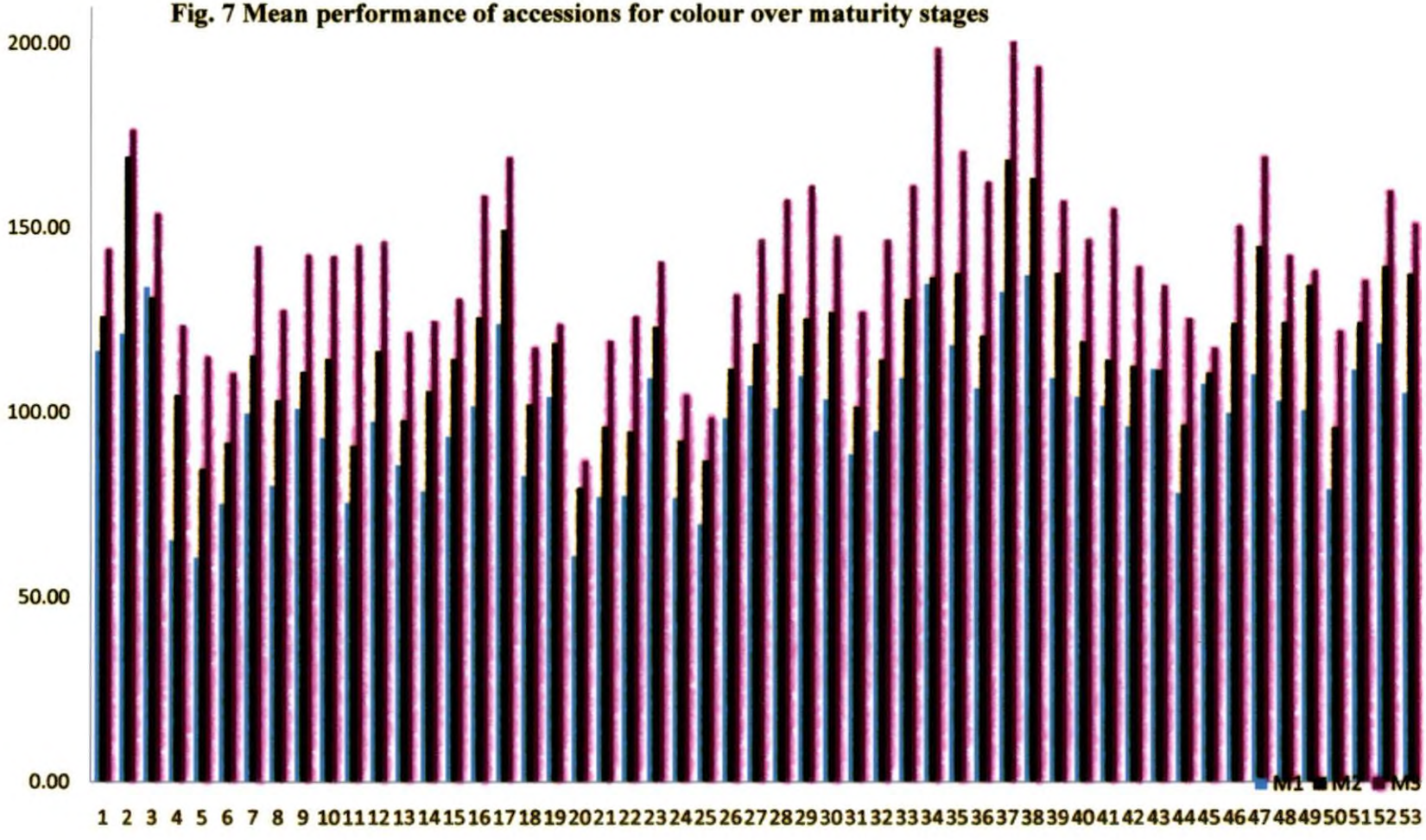


Fig 8. Mean performance of accessions for ascorbic acid over maturity stages

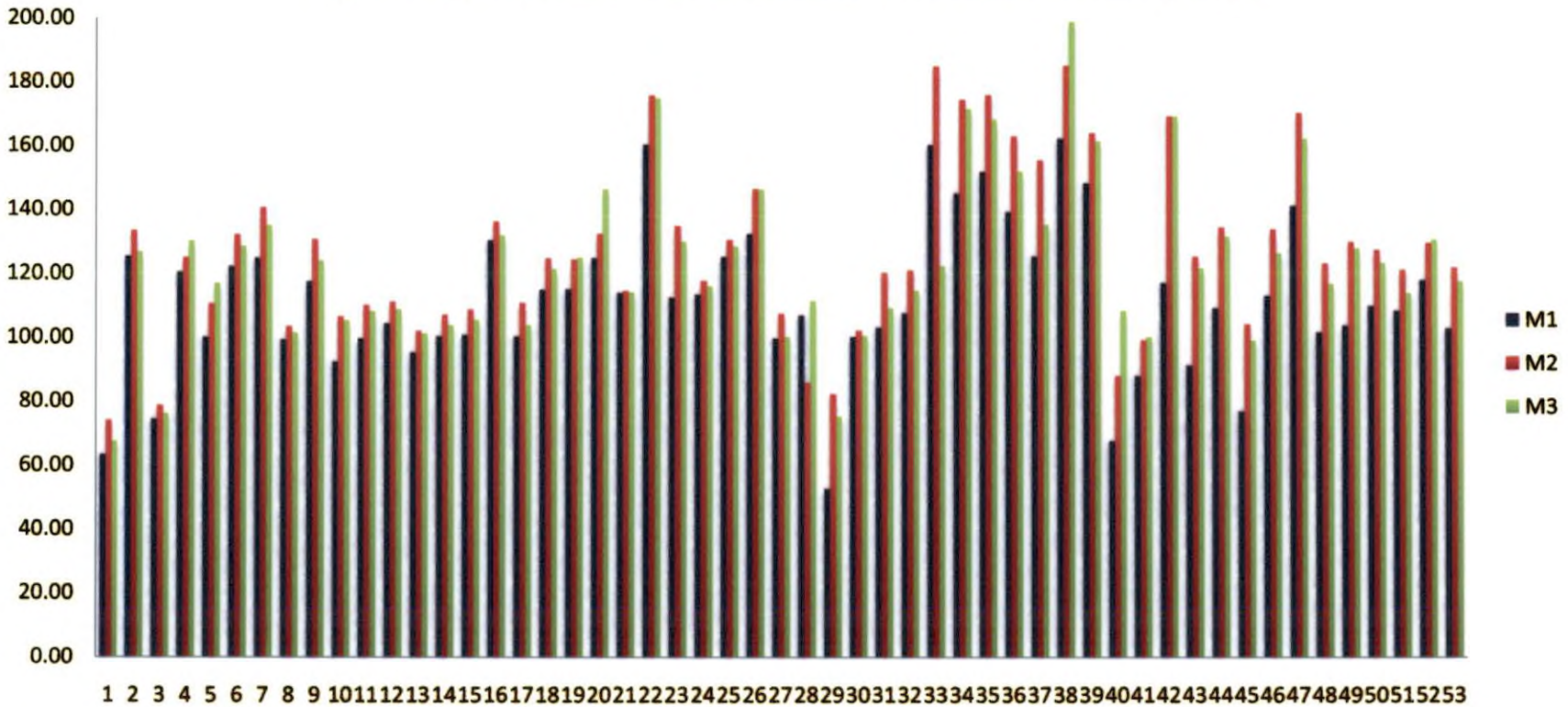
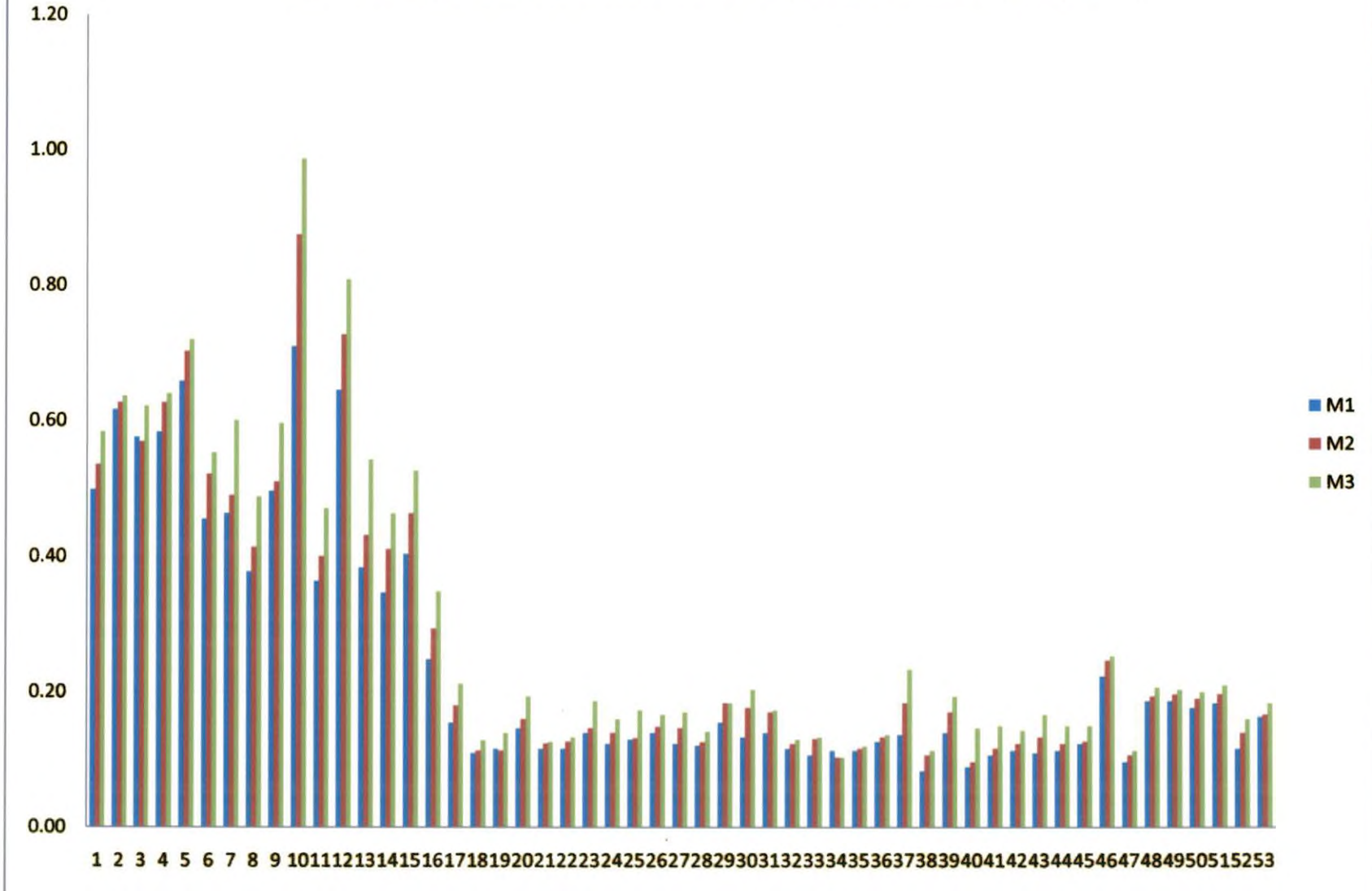
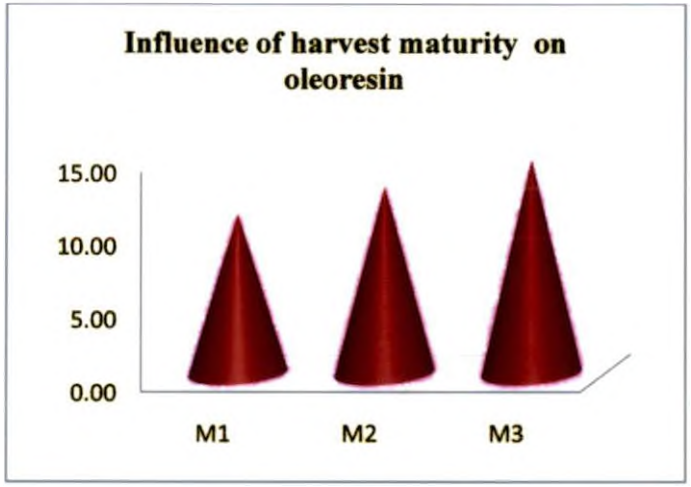
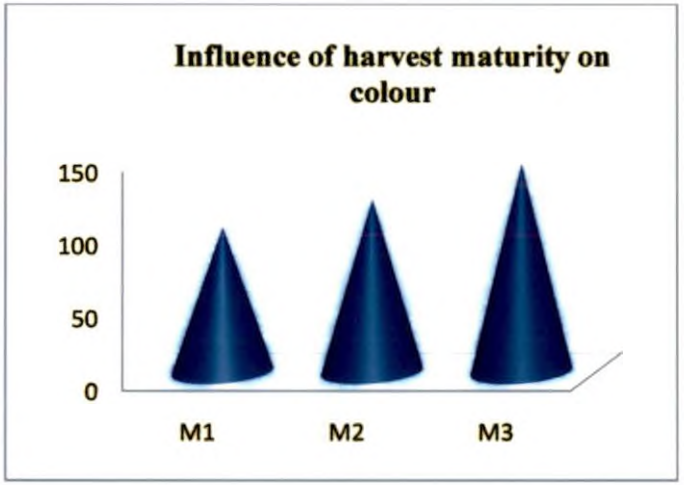
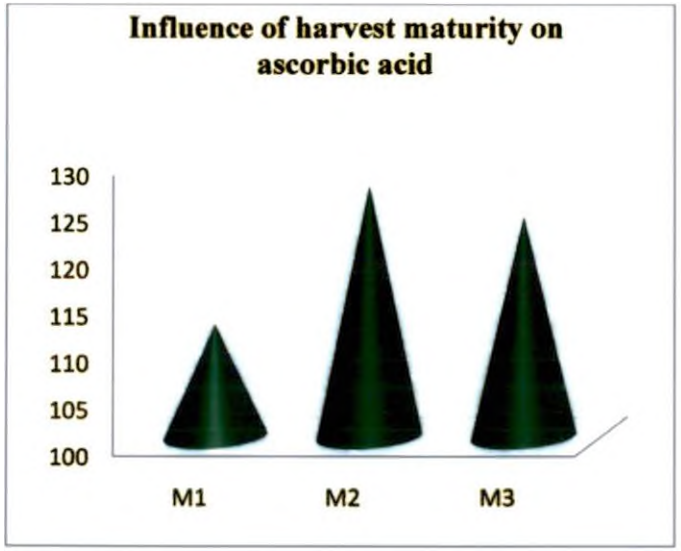


Fig. 9 Mean performance of accessions for capsaicin over maturity stages.









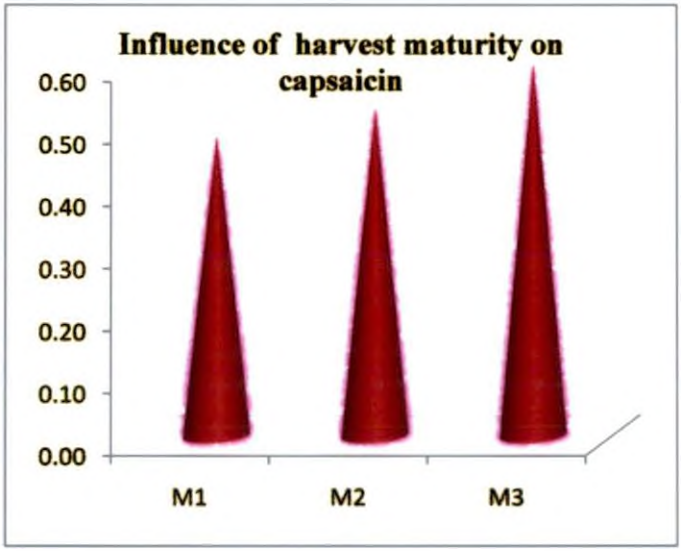


Fig 10. Influence of harvest maturity on different quality characters

Plate 4. CA 34- Accession ranked first based on selection index

Plate 5. CA 6- Accession with highest yield

Plate 6. CA 12 Accession with maximum number of fruits

Plate 7. CA 38 - Accession with maximum ascorbic acid content at red ripe stage

Plate 8. CA 37 – Accession with maximum colour content at withering stage

Plate 9. CA 10 – Accession with maximum capsaicin content at withering stage

Plate 10. CA 5 – Accession with maximum oleoresin content at withering stage

DISCUSSION

5. DISCUSSION

The genus *Capsicum* is renowned for its affluence in diversity with respect to pungency, colour and other characters. Paprika is gaining momentum in the international scenario for its high colour and low pungency. It is an ideal source for the extraction of oleoresin. Oleoresin is swiftly gaining momentum in the export market as a proxy for chilli powder. Paprika is an exceptional source of brilliant red colour. The natural red colour from paprika can be used for colouring food products. Green fruits of paprika are quite rich in ascorbic acid.

Inspite of the economic importance and great demand for high quality oleoresin and colour in the international market, very little efforts have been made in the country to make it a remunerative enterprise. Sustainable efforts are required for genetic amelioration of the crop to develop improved as well as high yielding varieties with desirable adjustments between yield and quality parameters.

Investigations were conducted at Department of Olericulture, College of Agriculture, Vellayani to study the variability in paprika accessions for yield and quality and to identify suitable genotypes. The study was carried out in two experiments *viz.*,

5.1. Variability in paprika

5.2. Influence of harvest maturity on quality

The experimental results are discussed under different headings.

5.1 Variability in paprika

5.1.1 Mean performance of accessions

An insight into the magnitude of variability present in a crop species is of utmost importance as it provides a basis for effective selection. The observed

variability in the population is the sum total of the variations that arise due to genotype and environmental effects. Hence knowledge on the nature and magnitude of genetic variation contributing to gain under selection is vital.

The present study revealed highly significant differences among the 53 accessions of paprika for all the characters *viz.*, plant height, primary branches, days to flowering, node to first flower, height of node to first flower days to maturity, fruit length, fruit girth, fruit weight, fruits per plant, yield per plant, pedicel length, fruit: pedicel ratio, flesh thickness, seeds per fruit, flesh: seed ratio, driage, incidence of bacterial wilt, leaf curl virus, oleoresin, colour, ascorbic acid and capsaicin. Such variation indicated the scope for improving the population for these characters as accounted earlier by Bini (2004), Ahmed *et al.* (2006) and Kumari *et al.* (2011) in paprika.

5.1.1.1 Growth and yield characters

Ample variability was observed for vegetative characters as obvious from the wide range obtained for plant height. Among the accessions evaluated CA 12 was the tallest. Considerable variability was reported by Bini (2004) and Kumari *et al.* (2010) in paprika. Primary branches per plant registered a low range of variation compared to other characters as reported by Giritammanavar (1995) and Rao (2005) in paprika.

The accession CA 10 was the earliest to flower (24 days). In the present study the days to flowering ranged from 24.00 - 43.33. Days to maturity recorded a narrow range of variation. Most of the accessions attained fruit maturity around 31 days after fruit set. Kumari *et al.* (2010) reported a similar range for days to maturity in paprika.

Among the 53 accessions maximum fruit weight was observed in CA 47 (13.43 g). Both fruit length and fruit girth contributed to fruit weight in CA 47. Other accessions with better fruit weight were CA 22 and CA 44. In the present study fruit length ranged from 2.7 - 14.17 cm and fruit girth ranged from 3.40 - 8.73 cm

suggesting ample variability and scope for improvement of fruit size in paprika as reported by Bini (2004) and Kumari *et al.* (2010).

High variability was observed for fruits per plant and yield per plant among the accessions. Fruits per plant were maximum in CA 12 followed by CA 7. Yield per plant was highest in CA 6. Other accessions with better fruit yield were CA 5, CA 33, CA 34 and CA 7. The high yield in CA 6, CA 5 and CA 7 may be attributed to the high fruits per plant, fruit length, fruit girth and fruit weight. CA 33 and CA 34 were characterized by high fruit weight, fruit length and fruit girth. These accessions also recorded high value for plant height. This supports the fact that yield is a complex trait and it is the ultimate expression of many component characters. Similar high variability for yield was reported by Giritammanavar (1995), Bini (2004), Rao (2005), Sandeep (2007) and Kumari *et al.* (2010).

Pedicel length in the current study ranged from 2.10 to 5.00 cm. In paprika fruits with short pedicel is desirable. Such results were earlier reported by Manju (2000). Fruit : pedicel ratio showed a range from 0.89 to 4.72.

Seeds per fruit exhibited a range from 55.00 – 160.33. Wide variation in seeds per fruit was reported by Bini (2004) in paprika. Flesh : seed ratio showed a range between 1.81 – 4.97. Driage per cent exhibited a range of 18.78 – 36.71 in the present study. Similar variation was observed by Kumari *et al.* (2010) in paprika.

Bacterial wilt caused by *Ralstonia solanacearum* has become a major bottle neck in successful cultivation of paprika in Kerala. The present investigation resulted in the identification of sixteen accessions without bacterial wilt incidence.

The vulnerability index for leaf curl incidence ranged from 0.00 to 52.96. No incidence was noticed for CA 47 (0.00) and maximum for CA 1. The reaction of accessions towards leaf curl virus incidence indicated that 47 accessions were tolerant and two accessions were susceptible. CA 1, CA 11 and CA 13 were highly

susceptible. Robi (2003) studied the incidence of bacterial wilt and leaf curl virus in chilli and obtained similar results.

CA 33, CA 34, CA 35 and CA 47 recorded less incidence of both diseases and hence can be successfully used in further crop improvement programme.

5.1.1.2 Quality characters

In the case of paprika quality parameters hold significant importance as the economic value of the crop is directly linked with the superior quality parameters.

In the present study, different accessions showed variation in quality characters like colour, oleoresin, capsaicin and ascorbic acid content.

Oleoresin represents the total flavour extract of ground spice and consists of fixed oil, capsaicin, pigments, sugars and resin. They are now being extensively used in processed foods and pharmaceutical products (Bajaj, 1986). The present study unraveled considerable variation among the accessions of paprika for oleoresin content. Maximum oleoresin content was observed in CA 7 (18.09 per cent) and was on par with CA 28 (18.00 per cent) followed by CA 29 and CA 37. Similar variation in oleoresin content was reported by Bini (2004), Prasath *et al.* (2007) and Jyothi *et al.* (2008) in paprika and Chattopadhyay *et al.* (2011) in chilli.

High pungent oleoresin obtained from CA 7, CA 6 and CA 5 can be used in the pharmaceutical and cosmetic industries where high pungency and high colour are desired. The low pungency oleoresin obtained from CA 28, CA 29 and CA 37 can be of high value in preparation of processed foods making the product more acceptable and pleasing to the eye and for export where low pungency and high colour are desirable traits.

Paprika colourant, which imparts appealing colour, aesthetic flavour and aroma, has many end uses in various food, pharmaceutical and cosmetic preparations. The indiscriminate use of synthetic colours for the food colouring has several harmful

effects. This has resulted in huge demand for chilli and paprika oleoresin with high colourant and mild pungency as natural colour. There is a great demand for natural paprika fruit colour which is used in processed foods replacing synthetic colour. In the present study considerable variation among the accessions was observed for colour. CA 2 recorded a high colour value with pungency and CA 37 recorded a high colour with low pungency. High colour obtained from the accession CA 2 can be of great value in the pharmaceutical and cosmetic industry where high colour and pungency are desirable. High colour and low pungent extract from CA 37 can be of great value in processing industries. CA 34 (Local, Dharwad) and CA 38 (Byadagi) also recorded better value for colour. Similar results were reported by Bini (2004), Prasath *et al.* (2007), Jyothi *et al.* (2008) in paprika and Srilakshmi (2006) in chilli.

Paprika is an excellent source of Vitamin C. The nutritive value of paprika is largely determined by the content of ascorbic acid. Significant variation in ascorbic acid among the accessions was noticed in the current study. CA 38 recorded maximum ascorbic acid content (185.07 mg per 100g). C 38, CA 33, CA 34 and CA 35 were found to be excellent sources of ascorbic acid and they are suitable for vegetable purpose. Such wider variation was reported by Manju (2001), Bini (2004), Choudhary and Samadia (2004), Shirsat *et al.* (2007) and Dandunayak (2008).

Capsaicin, the pungent principle in chilli is considered to be an important quality character. There existed a wide variation among the accessions for capsaicin content. This variability could be due to the presence of gene modifying factors for pungency, the ratio of placental tissue to seed and pericarp. CA 10 recorded the highest capsaicin content (0.88 per cent). CA 34 and CA 40 had the minimum capsaicin content (0.10 per cent).

The present study revealed that 16 accessions can be grouped as medium pungent (0.25-0.75) and the remaining 37 accessions as low pungent (< 0.25). The medium pungent accessions are valued for their pungency and for the manufacture of high pungent oleoresin. CA 10 recorded the maximum capsaicin content. CA 3, CA

4, CA 5, CA 6 and CA 7 had medium pungency coupled with better fruit and yield characters. Less pungent paprika accessions were CA 34, CA 18, CA 19, CA 33, CA 35, CA 40 and can be used for low pungent oleoresin. Varietal variation in capsaicin content in paprika was reported by Bini (2004), Prasath *et al.* (2007) and Jyothi *et al.* (2008) in paprika and Kumar *et al.* (2003), Srilakshmi (2006) and Chattopadhyay *et al.* (2011) in chilli.

5.1.2 Coefficient of variation

The magnitude of variability present in a population is of utmost importance as it provides the basis for effective selection. Since the observed variability in a population is the sum of variation arising due to the genotypic and environmental effects, knowledge on the nature and magnitude of genetic variation contributing to gain under selection is essential. The PCV and GCV are the components used to measure the variability present in a population.

In the current study high values of PCV and GCV were observed for fruits per plant, yield per plant, fruit length, fruit weight and capsaicin. This indicated greater extent of variability that could be ascribed to genotype and consequently more scope for their improvement through selection.

The lowest GCV and PCV were exhibited by days to maturity followed by days to flowering indicating low variability which limits the scope for further improvement through selection. Similar result was obtained by Bini (2004) for days to flowering and Chatterjee, (2006) and Kumari *et al.* (2010) for both characters.

The GCV was very near to PCV for most of the characters, indicating a highly significant effect of genotype on phenotypic expression, with very little effect of environment. So the selection can be very well based on the phenotypic values. Such a closer PCV and GCV for different characters were earlier reported by Bini (2004). The phenotypic coefficient of variation (PCV) in general, was higher than genotypic coefficient of variation (GCV) for all the traits, but the differences were very narrow

indicating low environmental influence on the expression and are suggestive of the heritable nature. Similar results were reported by Chatterjee (2006) in chilli and Kumari *et al.* (2008) in paprika.

From the foregoing discussions, it is clear that the characters *viz.*, fruit weight, fruit length, fruits per plant and yield per plant offer good scope for selection in paprika.

5.1.3 Heritability and Genetic Advance

The total variability existing in a population is the sum total of heritable and non heritable components and it is necessary to portion these components, since the magnitude of heritable variability is an important aspect of genetic constitution of breeding material. A high value of heritability indicates that the phenotype of that trait strongly reflects its genotype. Heritability is a parameter of tremendous significance to the breeders as its magnitude indicates the reliability with which a genotype can be recognized through its phenotypic expression.

High values of heritability were observed for most of the characters studied. Moderate heritability was observed for primary branches per plant.

Heritability was high for fruit characters like fruit length, fruit girth, fruit weight, fruits per plant and yield per plant. Similar findings were also reported by Bini (2004), Sandeep (2007) and Kumari *et al.* (2008) in paprika.

Quality characters like oleoresin, colour, ascorbic acid and capsaicin also exhibited high heritability. Bini, (2004) and Kumari *et al.* (2010) reported high heritability for quality characters. High heritability estimates indicate the presence of large number of fixable additive factors and hence these traits can be improved by selection.

High genetic advance was noticed for most of the characters like fruits per plant, yield per plant, fruit weight, fruit length, fruit girth, plant height and capsaicin.

Primary branches, days to flowering and days to maturity exhibited moderate genetic advance as supported by Choudhary and Samadia, (2004) and Chatterjee, (2006).

Environment has least influence for the characters with high heritability and there could be greater correspondence between phenotypes and breeding value while selecting individuals. High heritability estimates indicate the effectiveness of selection based on good phenotypic performance but does not necessarily mean high genetic gain for the particular character. Johnson (1955) pointed out that high heritability along with high genetic advance would be useful than heritability values alone in predicting the resultant effect of selecting the genotype.

The present investigation revealed high heritability coupled with high genetic advance for the characters like fruit weight, fruits per plant and yield per plant and quality characters like capsaicin, colour and ascorbic acid indicating the presence of additive gene action.

High heritability coupled with low genetic advance attributable to non- additive gene action was noticed for days to flowering and days to maturity indicating that these characters are controlled by nonadditive genes and improvement through selection for these characters will not be very much effective (Choudhary & Samadia , 2004; Chatterjee, 2006; and Kumari *et al*..2010). It is an indicative of dominant gene action suggesting the possibility of genetic improvement through hybridization.

On the basis of present study it can be concluded that simultaneous selection based on multiple characters having high estimates of heritability coupled with genetic advance may be of appreciable use in the crop.

5.1.4 Correlation Studies

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. Correlation provides information on the nature and extent of relationship between all pairs of characters.

In the present study, fruits per plant, fruit length and primary branches showed high and positive phenotypic and genotypic correlation with fruit yield.

Positive genotypic correlation of yield with fruits per plant was in line with the results reported by Dandunayak (2008), Farhad *et al.* (2008), Patel *et al.* (2009), Gupta *et al.* (2009), Jabeen *et al.* (2009), Kumari *et al.* (2011), Chattopadhyay *et al.* (2011) and Singh and Singh (2011).

Srilakshmi (2006), Thembhurne *et al.* (2008), Patel *et al.* (2009), Kumar *et al.* (2010), Chattopadhyay *et al.* (2011) reported that fruit length was positively correlated with yield per plant.

Positive correlation of yield with primary branches was in line with the results reported by Krishnakumar *et al.* (2003), Ahmed *et al.* (2006), Srilakshmi (2006), Dhandunayak (2008), Patel *et al.* (2009) and Jabeen *et al.* (2009).

Days to flowering had a significant and positive correlation with days to maturity and negative correlation with fruits per plant as reported by Mini and Vahab (2002) and Kumari *et al.* (2010).

Capsaicin exhibited a negative correlation with fruit characters like fruit length and fruit girth at both phenotypic and genotypic levels. It had a strong positive correlation with fruits per plant. This indicates that pungency is related to more number of fruits per plant with smaller size which is in agreement with the result of Kumari *et al.* (2011).

In general, magnitude of genotypic correlation coefficients was higher than the corresponding phenotypic correlation coefficients for the characters positively correlated with yield indicating low environmental influence on these characters.

Positive and high phenotypic and genotypic correlation of fruit yield per plant with fruits per plant implies that selection for this character would lead to simultaneous improvement of yield in paprika. The other characters that can be taken

into consideration for indirect selection for yield include fruit length and primary branches.

5.1.5 Path analysis

The path analysis helps in partitioning the genotypic correlation coefficient into direct and indirect effects of the component characters on the yield on the basis of which improvement programmes can be devised effectively. If the correlation between yield and any of its components is due to the direct effect, it reflects a true relation between them and selection can be practiced for such a character in order to improve yield. But if the correlation is mainly due to indirect effect of the character another component trait, the breeder has to select the latter trait through which the indirect effect is exerted.

Plant height, primary branches, days to first flowering, fruit weight, fruits per plant, bacterial wilt incidence and leaf curl virus incidence were selected for path coefficient analysis. Fruit weight exhibited the highest positive direct effect on fruit yield followed by fruits per plant indicating the importance of these characters in yield improvement programme. Plant height and primary branches also exerted positive direct effect on the yield.

Days to flowering and bacterial wilt exhibited negative direct effect on fruit yield. Indirect effects through fruits per plant were high signifying the importance of the character.

The high direct effect of fruit weight on yield is in accordance with earlier findings of Sreelathakumary and Rajamony (2004), Jabeen *et al.* (2009), Patel *et al.* (2009) and Sarkar *et al.* (2009).

The high and positive direct effect of fruits per plant on yield observed in this study is supported by Kumar *et al.* (2003), Srelathakumary and Rajamony (2004), Srilakshmi (2006), Dhandunayak (2008), Kumari *et al.* (2008), Jabeen *et al.* (2009), Patel *et al.* (2009) and Sarkar *et al.* (2009).

Positive direct effect of plant height on yield was reported by Choudhary and Samadia (2004) and Rao (2005). The positive direct effect of primary branches on yield was accounted by Srilakshmi (2006).

The residue was 0.5280 indicating that the selected seven characters contributing the remaining forty seven per cent. The result goes in parallel with the study of Dandhunayak (2008) and Kumari *et al.* (2008).

Fruits per plant, fruit weight, plant height and primary branches can be identified as major characters contributing towards yield directly and indirectly and selection based on these characters are effective in developing high yielding paprika varieties. Thus an ideal plant type should have higher values for these traits. Similar results have been reported by Khader and Jose (2002).

5.1.6 Selection index

Selection index provides the information on yield components and thus aids in the indirect selection for the improvement of yield. It involves the discriminant function analysis which is meant for the improvement for isolating superior genotypes based on the phenotypic and genotypic correlations.

Bini (2004) identified superior genotypes in paprika based on discriminant function analysis. Identification of superior accessions in chilli based on discriminant function analysis was done by Rani and Usha (1996) in *C. annuum* and Manju (2000) in hot chilli. Mini (2003) constructed selection index based on fourteen characters studied in *C. annuum* genotypes.

Based on selection index including both quantitative and qualitative characters CA 34 was ranked first with an index of 3896.75 followed by CA 7 (3881.287) in this study. CA 6, CA 33 and CA 35 obtained next three positions with indices of 3805.51, 3684.26 and 3601.68. These accessions with high yield, quality and disease resistance may be recommended as elite types after refinement and multilocation trials.

5.1.7 Genetic divergence analysis

One of the present techniques of measuring genetic divergence is by Mahalanobis's D^2 statistic. This technique measures the force of differentiation at the intracluster and intercluster levels and thus provides a reasonable basis for selection of genetically divergent parents in breeding programmes. Genetic divergence in chilli was assessed by Sreelathakumary and Rajamony (2004), Bini (2004) and Kumari *et al.* (2010).

The 53 accessions of paprika were subjected to D^2 analysis based on all the characters studied. They were grouped into four clusters on the basis of relative magnitude of D^2 values. The greater the distance between two clusters, greater is the divergence between the accessions belonging to the two clusters and vice versa. Cluster I had the maximum number of accessions (34), followed by cluster IV (15), and cluster II (3). Cluster III had only one accession.

Considering the cluster means for various characters clusters IV was superior and cluster II was generally poor, whereas cluster I was intermediate. Intercrossing among accessions with better mean performance for various characters will be effectual for further crop improvement in paprika.

In the present study maximum divergence was observed between clusters II and IV as shown by their high intercluster distance. The minimum intercluster distance observed between the clusters I and II indicated a close relationship among the accessions.

The intracluster distance was maximum for cluster IV. The present study makes it clear that the clusters III and IV may be used as base materials for hybridization with selected accessions from cluster I to obtain desirable segregants with high yielding potential.

5.1.8 Genetic cataloguing

Genetic cataloguing based on standard descriptors helps to easily describe the morphological features of a genotype and thus helps exchange of information about new accessions in a clear way.

Fifty three paprika accessions upon cataloguing showed distinct variation among each other with respect to vegetative, inflorescence, fruit and seed characters. The accessions had either erect or compact growth habits with green to purple stem and leaves. Fruit colour and shape showed wide variation among the accessions. There are reports on high variability for morphological characters in *C. annuum* (Indira, 1994), *C. frutescens* (Sheela *et al.*, 1998) and *C. chinense* (Manju, 2001).

Genetic cataloguing of germplasm based on standard descriptors helps in international exchange of information in a more scientific way. This also helps in locating some accessions with specific morphological characters which can be used for crop improvement.

5.2 Influence of harvest maturity on quality

The influence of three harvest stages on quality parameters like oleoresin, colour, ascorbic acid and capsaicin was studied. Three harvest maturity stages studied were turning stage, red ripe and withering stage. The analysis of variance showed that genotype x maturity interaction was significant for all the quality parameters.

Maximum oleoresin content was recorded when fruits were harvested at withering stage. CA 5 had highest oleoresin content (21.13 per cent) which was on par with CA 6 (20.83 per cent) when fruits were harvested at withering stage. The interaction of genotypes with maturity stage was also significant. Oleoresin content was increased as the age of the fruit increased. This is in agreement with Sheela *et al.* (2001) who reported that oleoresin content was more in red ripe fruits of *C. frutescens* than in mature green fruits. Mini and Vahab (2002) reported that oleoresin recovery was higher in fruits of *Capsicum spp* at withering stage than at red ripe and

turning stage. Robi (2003) observed the same trend in a study consisting of 10 accessions of *C. chinense*. Khyadagi (2009) also reported the similar results. Oleoresin consists of fixed oil, capsaicin, pigments, sugars and resin and as fruits mature these contents also increase.

CA 37 (200.32) had highest value for colour and was on par with CA 34 (198.48) when fruits harvested at withering stage. Similar to other quality parameters colour value also increased as the age increased and recorded maximum colour value at withering stage. This is in agreement with the studies of Mini (1997), Robi (2003) and Khyadagi (2009). Colour change in chilli occurs as a result of chlorophyll degradation and a considerable increase in the carotenoid contents. The deepening of the chilli colour at withering stage was ascribed to drying which is accomplished by the subsequent formation of colouring matter.

The fruits of CA 38 had highest ascorbic acid content when harvested at full ripe stage and was on par with CA 33. Ascorbic acid increased from turning stage to red ripe stage and then declined in the withering stage. This result is in agreement with Ahmed *et al.* (1986), Khadi *et al.* (1987), Garcia *et al.* (1998), Lalithakumari *et al.* (1999), Robi (2003) and Khyadagi (2009). The ripe fruits had more ascorbic acid content. When the drying of the fruits commences, ascorbic acid content declines due to biochemical changes occurring during the drying process.

Among the accessions CA 10 recorded maximum capsaicin content irrespective of the maturity stages and obtained maximum value at withering stage. CA 38 had the lowest capsaicin content when harvesting was done at re ripe stage. Capsaicin content increased as the age of the fruit increased and it was maximum in withering stage among the three different maturity stages. Ahmed *et al.* (1987) reported that the capsaicinoids content increased with fruit maturation in relation to increase in dry matter content. Other studies of Estarwada *et al.* (2000), Robi (2003) and Khyadagi (2009) also support the result obtained. Capsaicin is synthesized and accumulated in capsaicinoids secreting organs in placenta. The site of the capsaicin synthesis and

total capsaicin content are under genetic control. As the fruit matures, placenta also become mature and moisture content of fruit may be reduced as compared to turning stage and thus the percentage of capsaicin increased. With the attainment of maturity, accumulation of capsaicinoids gradually increases that result in the highest concentration of capsaicin in later stages.

Thus the fruits left in the plant for withering had high oleoresin, colour and pungency, but low in ascorbic acid. This indicates the importance of delayed harvest in paprika for oleoresin, colour and capsaicin production. This is relevant with respect to the commercial value of paprika for these characters. The nutritive value depends on ascorbic acid content which is maximum in red ripe stage projecting that the red fruits can be utilized for vegetable purpose for getting more vitamins.

The present investigation on 53 paprika accessions showed wide variation for almost all the characters studied. High heritability coupled with high genetic advance was observed for most of the characters studied. Correlation and path analysis revealed that fruits per plant is the primary yield components. The high yielding accessions CA 5, CA 6, CA 7 with high colour value and pungency and CA 34, CA 33, CA 35 with high colour and low pungency were found to be promising and they may be used for further improvement programmes.

SUMMARY

6. SUMMARY

The study entitled "Identification of paprika genotype(s) (*Capsicum annuum* L.) for yield and quality characters" was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during the period 2011-2012.

The study envisaged assessment of genetic variability in paprika and to study the influence of harvest maturity on quality parameters.

The experiment material consisted of 53 paprika accessions collected from different parts of the country. The experiment was laid out in a randomized block design with three replications. To study the influence of harvest maturity on quality, fruits were harvested at three different stages *viz.*, turning, red ripe and withering stages.

The study revealed significant difference among the accessions for all the characters *viz.*, plant height, primary branches, days to flowering, node to first flower, height of node to first flower, fruit length, fruit girth, fruit weight, fruits per plant and yield per plant, pedicel length, fruit: pedicel ratio, flesh thickness, seeds per fruit, flesh: seed ratio, driage, bacterial wilt, leaf curl virus incidence and quality characters like oleoresin, colour, ascorbic acid and capsaicin indicating sufficient diversity among the accessions.

The highest yield was observed in CA 6 (776.12 g) followed by CA 5 (EC-596920) and CA 34 (Local, Dharwad). Among the accessions CA 12 was the tallest (104.69 cm) with maximum fruits per plant (265.33). Fruit weight was highest in CA 47 (13.43 g). CA 10 was the earliest to flower (24 days) with minimum fruit girth (3.4 cm). Fruit length was highest in CA 33 (14.17 cm).

Among the quality parameters studied oleoresin was maximum in CA 7 (18.09 per cent), colour value in CA 2 (169.21 ASTA units), ascorbic acid in CA 38 (185.07 mg per 100g) and capsaicin in CA 10 (0.88 per cent).

Bacterial wilt and leaf curl virus incidence in the accessions were studied.

High values of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were recorded for fruits per plant, fruit length, yield per plant, fruit weight and capsaicin. The lowest GCV and PCV were recorded for days to flowering and days to maturity.

Heritability was high for fruit characters like fruit length, fruit girth, fruit weight, fruits per plant and yield. High heritability coupled with high genetic advance were recorded for the characters like fruits per plant, fruit length, fruit girth, fruit weight, yield per plant, plant height. All the quality parameters like oleoresin, colour, ascorbic acid and capsaicin exhibited high heritability coupled with high genetic advance.

Correlation studies revealed that at both phenotypic and genotypic levels characters like fruits per plant, fruit length and primary branches had significant and positive correlation with yield.

Path coefficient analysis indicated that fruit weight exerted maximum positive direct effect on yield followed by fruits per plant, plant height and primary branches. Indirect effects through fruits per plant were highly signifying the importance of this character.

A selection index was worked out for isolating superior genotypes using ten characters *viz.*, plant height, days to flowering, fruit length, fruit girth, fruits per plant, yield per plant, oleoresin, colour, ascorbic acid and capsaicin. Based on the selection index scores obtained CA 34 (Local, Dharwad) was ranked first followed by CA 7 (EC-599960), CA 6 (EC-596940), CA 33 (Local, Dharwad) and CA 35 (Local, Dharwad).

The 53 accessions were grouped into four clusters based on Mahalanobis D^2 analysis. Cluster I was the largest with 34 accessions, followed by cluster IV with 15 accessions and cluster II with three accessions. Cluster III had only one accession. In the present study maximum divergence was observed between clusters II and IV as shown by their high intercluster distance. The minimum intercluster distance observed between the clusters I and II indicated a close relationship among the accessions.

The accessions were genetically catalogued based on the descriptor list for *Capsicum*. The result revealed distinct variations among the accessions for vegetative, inflorescence, fruit, seed and quality characters.

The influence of harvest maturity on quality parameters showed that CA 5 had the highest oleoresin content (21.13 per cent) when harvested at withering stage. Ascorbic acid was high in CA 38 (185.07 mg per 100g) at red ripe stage. CA 37 recorded the maximum colour values when harvested at withering stage (200.32 ASTA units). Capsaicin content was maximum in CA 10 and lowest in CA 38. Oleoresin, colour and capsaicin increased with the age of the fruit, ie these characters were found to increase from turning stage to withering stage. Ascorbic acid increased from turning stage to red ripe stage and then declined in the withering stage.

Comparison among the accessions for various biometric characters revealed CA 34, CA 7, CA 6, CA 33 and CA 35 as promising based on their superiority in yield, quality and disease resistance. These may be used for further crop improvement. The present investigation has enlarged the vision and lead to the understanding of the performance of paprika accessions. The information generated will be useful in selecting high yielding varieties suited for Kerala conditions.

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IDENTIFICATION OF PAPRIKA (*Capsicum annuum* L.) GENOTYPE(S) FOR YIELD AND QUALITY CHARACTERS

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(2010-12-101)

Abstract of the

thesis submitted in partial fulfillment of the

requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF OLERICULTURE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

2012

ABSTRACT

The experiment entitled "Identification of paprika (*Capsicum annuum* L.) genotype(s) for yield and quality characters" was conducted at the Department of Olericultue, College of Agriculture, Vellayani, during the period 2011-2012. The study envisaged assessment of genetic variability in paprika and to study the influence of harvest maturity on quality parameters.

Fifty three accessions of paprika were collected from different parts of country and grown in the field in RBD with three replications. The analysis of variance revealed highly significant differences among the 53 accessions of paprika for all the characters studied *viz.*, plant height, primary branches, days to flowering, days to maturity, node to first flower, height of node to first flower, fruit length, fruit girth, fruit weight, fruits per plant, yield per plant, pedicel length, fruit: pedicel ratio, flesh thickness, seeds per fruit, flesh: seed ratio, driage, oleoresin, colour, ascorbic acid, capsaicin, bacterial wilt and leaf curl virus incidence.

Among the accessions CA 6 recorded highest yield per plant (776.12 g) and CA 12 recorded maximum number of fruits (265.33). Fruit weight was highest in CA 47 (13.43 g).

High phenotypic coefficient of variation and genotypic coefficient of variation were observed for yield per plant, fruits per plant, fruit weight and capsaicin. High heritability and high genetic advance also observed for these characters.

The path analysis revealed that fruit weight, fruits per plant, plant height and primary branches had direct effect on yield per plant. Correlation and path analysis revealed that fruits per plant is the primary component as evident from the positive correlation as well as high direct and indirect effect on yield.

Maximum oleoresin content was observed in CA 7 followed by CA 29 and CA 37. CA 2 recorded a high color value with pungency and CA 37 recorded a high

colour with low pungency. CA 38 recorded maximum ascorbic acid content. CA 34 and CA 40 had the minimum pungency and CA 10 recorded the maximum pungency.

Bacterial wilt and leaf curl virus incidence among the 53 accessions were studied. CA 33, CA 34, CA 35 and CA 47 recorded less incidence of both diseases.

Based on Mahalanobis D^2 analysis the current genotypes were grouped into four clusters. Cluster I was the largest with 34 accessions, followed by cluster IV with 15 accessions and cluster II with three accessions. Cluster III had only one accession. In the present study maximum divergence was observed between clusters II and IV as shown by their high intercluster distance. The minimum intercluster distance observed between the clusters I and II indicated a close relationship among the accessions.

Based on selection index including both quantitative and qualitative characters CA 34 (Local, Dharwad) was ranked first followed by CA 7, CA 6, CA 33 and CA 35.

The accessions were genetically catalogued and the result revealed distinct variations among the accessions for vegetative, inflorescence, fruit, seed and quality characters.

Quality characters showed significant differences among the accessions and harvest maturity stages. Oleoresin, colour and capsaicin content in the paprika fruits were found to increase as the age of the fruits increased. Ascorbic acid content in the fruits increased from turning stage to red ripe and then declined.

On the basis of the present study the high yielding accessions can be grouped into low pungent and pungent paprika. Among the low pungent, high yielding accessions CA 34, CA 33 and CA 35 recorded high colour value also. CA 6 and CA 7 are promising high yielding pungent paprika accessions. These accessions can be utilized for further crop improvement programmes.

Appendices

Appendix I.

Descriptor for the morphological cataloguing of paprika accessions used for the study

1. Vegetative characters	
1.1 Hypocotyl colour	- White/ Green /purple
2. Stem pubescence	- Sparse/intermediate/dense
3. Leaf colour	- Light green/ green/ dark green/ light purple/purple
4. Leaf shape	- Deltoid/ovate/lanceolate/ Elong-deltoid
5. Stem colour	- Green/ green with purple stripes/ purple
6. Nodal anthocyanin	- Green/ light purple/ purple/ dark purple
7. Plant growth habit	- Prostrate/ intermediate/ erect
8. Stem length	- Height to first bifurcation
2. Inflorescence characters	
2.1. Number of flowers per axil	- One/ two/ three or more
2. Flower position	- Pendant/ Intermediate/ erect
3. Corolla colour	- White/ light yellow/ yellow green/ purple
4. Corolla spot	- Absent/ present
5. Corolla shape	- Rotate/ campanulate
6. Anther colour	- White/ yellow/ pale blue/ blue/ purple
7. Filament colour	- White/ yellow/ green/ blue/ light purple/ purple
8. Stigma exertion	- Inserted/ same level/ exerted
9. Calyx pigmentation	- Absent / present

10. Calyx margin	- Entire/ Intermediate/ dentate
11. Calyx annular constriction	- Absent/ present
3. Fruit and seed characters	
3.1 Anthocyanin spots or stripes	- Absent / present
2. Fruit colour at immature stage	- White/ yellow/ green/ orange/ purple/ deep purple
3. Fruit colour at mature stage	- White/ lemon yellow/ orange yellow/ orange/ light red/ red/ dark red/purple
4. Fruit shape	- Elongate/ almost round/ triangular/camapnulate/ blocky
5. Fruit shape at pedicel attachment	- Acute/ obtuse/ truncate/ cordate/ lobate
6. Neck at base of fruit	- Absent/ present
7. Fruit shape at blossom end	- Pointed/ blunt/ sunken/ sunken and pointed
8. Fruit cross sectional corrugation	- Slightly corrugated/ intermediate/ corrugated
9. Fruit surface	- Smooth/Semi wrinkled/Wrinkled
10.Number of locules	- Two/ Three (as percentage of each category)
10. Seed colour	- Straw/ brown/ black

Appendix – II

Weather parameters during the experimental period

(September 2011-March 2012)

Standard weeks	Maximum temperature (^{0}C)	Relative Humidity (%)	Rainfall (mm)
35	29.40	87.40	86.50
36	29.90	83.40	18.00
37	30.00	85.20	84.50
38	30.20	85.20	0.50
39	30.10	79.40	0.00
40	31.10	76.40	0.50
41	31.60	75.80	0.00
42	31.40	80.00	23.50
43	29.60	87.00	19.00
44	29.20	88.50	48.00
45	31.00	80.20	41.50
46	31.10	81.60	0.00
47	30.10	81.40	8.20
48	29.20	88.90	91.00
49	30.70	80.60	0.50
50	31.00	82.60	17.00
51	30.50	76.40	5.00
52	29.30	82.80	36.00
1	30.20	86.60	6.00
2	30.40	86.90	0.00
3	30.40	86.20	1.80
4	30.90	84.80	0.00
5	32.40	73.90	0.00
6	33.70	79.30	0.00
7	34.10	76.40	0.00
8	31.90	75.70	0.00
9	31.90	78.80	0.00
10	31.30	78.20	3.50
11	31.00	81.70	9.50
12	31.90	81.20	0.00
13	32.10	76.50	9.00
14	32.70	76.90	0.00
15	32.70	78.10	8.00
16	32.90	80.45	13.50
17	30.80	82.00	67.40