SCREENING OF SPICE CHILLI (*Capsicum annuum* L) GENOTYPES SUITABLE FOR KERALA

By

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(2014-12-111)

THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Screening of spice chilli (*Capsicum annuum* L) genotypes suitable for Kerala"** is a bonafide record of research 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, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Screening of spice chilli (*Capsicum annuum* L) genotypes suitable for Kerala"** is a record of research work done independently by **Nabeela. K** (2014-12-111) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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ABBREVIATIONS

cm	Centimeter
g	Gram
mm	Millimeter
ASTA	American Spice Trade Association
%	Percent

Introduction

1. INTRODUCTION

Chilli (*Capsicum* spp.) is the third most important spice crop of the world. It is originated in tropics of central and South America. The genus Capsicum, belonging to Solanaceae family, includes 30 species and among these, five are economically important. They are *Capsicum annuum* L., *C. frutescens* L., *C. chinense* Jacq., *C. pubescens* Ruiz. & Pav., and *C. baccatum*. Among these, *Capsicum annuum* is the most widely cultivated and traded species in India and known by different names as chilli, pepper, hot pepper chilli, chilli pepper, chile, sweet pepper, bell pepper and paprika. Cultivars of *C. annuum* include hot peppers with pungent fruits and sweet or bell peppers with non pungent fruits. Many types of chilli have been recorded in India, varying in shape, yield, quality and other traits.

Chilli is one of the most valuable spice crops of India having good export potential in the international market for earning foreign exchange. Globally, 1776 thousand hectares of land is estimated to be under cultivation of chillies, producing around 7182 thousand tonnes. India is the largest producer, consumer and exporter of chillies, contributing about one fourth of world production. In India, it is grown in an area of about 7.91 lakh hectares yielding about 13.76 tonnes of dry chilli annually. Chilli contributes about 33 per cent of the total spice export from India and share about 16 per cent of the world spice trade. Total chilli export of the country is 347,000 tonnes earning 351710 lakh rupees (Spices Board, 2015).

Chilli exhibits wide range of genetic diversity and is cultivated for various uses; either for marketing as green chillies in fresh form (green, red, multicolour whole fruits), processed products (sauce, paste, canned chilli, pickles *etc*.), dried 12 spice (whole and ground form) or industrial extracts (oleoresin, capsaicinoids, carotenoids). They are excellent source of antioxidants like flavonoids, carotenoids and vitamin C. Besides this, conventional nutritional food uses, spiritual, defence and ethno botanical uses are also known (Kumar *et al*, 2006). Some varieties of chillies are famous for their red colour because of the pigment capsanthin and others are known for biting pungency.

Pungency in chilli is due to capsaicin (8-methyl-N-vanillyl-6-nonenamide) and seven closely related alkyl vanillyl amides, collectively known as 'capsaicinoids'. More than 15 different alkaloids were reported in chilli fruits and among these capsaicin and dihydrocapsaicin accounts for more than 80 per cent of capsaicinoids (Bosland and Votava, 2000).

Quality of chilli fruit is judged by the purpose for which it is used. Colour in chilli is contributed approximately by 20 carotenoids and among these, capsanthin contributes about 60 per cent of total carotenoids. Chilli colourant imparts appealing colour, aesthetic flavour, aroma and has many end uses in various food, pharmaceutical and cosmetic preparations.

At present chilli is not cultivated for dry or spice purpose in Kerala and the requirement is met from nearby states of Karnataka and Andra Pradesh. There are indigenous as well as released varieties in chilli with considerable variability in morphological and biochemical parameters. Certain local types in different districts of Kerala are found to be unique in their qualities.

Several biotic and abiotic factors like climate, temperature, soil condition, pests and diseases influence growth of chilli plant or adaptation of a particular variety in a region. Soil type and climate have strong influence on quality of chilli though it is mainly a genetically controlled character. Bacterial wilt is the main problem faced in the cultivation of chilli in Kerala and identification of spice chilli types suitable for warm humid tropics of Kerala will pave way for promoting and popularizing their large scale cultivation in Kerala. Considering all these factors, the present study was proposed with the following objectives.

1) Evaluation of chilli accessions for morphological and biochemical characters.
2) Identifications of types with good processing qualities.

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Review of literature

2. REVIEW OF LITERATURE

The investigation on 'Screening of spice chilli (*Capsicum annuum* L.) genotypes suitable for Kerala' was conducted in the department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Thrissur, during 2014-2016 with the objective of identifying spice chilli genotypes suitable for Kerala. In this programme, 35 genotypes (which include released varieties and local collections) were characterized morphologically and biochemically.

The relevant literature on various aspects of the study is included in this chapter.

Genus Capsicum belonging to solanaceae family include five cultivated species and they are *Capsicum annuum* L., *C. frutescens* L., *C. chinense* Jacq., *C. pubescens* Ruiz. & Pav., and *C. baccatum.*

Capsicum annuum L. is known by various names viz., chilli, pepper, hot pepper, chilli pepper, chile, sweet pepper and paprika. It is one of the unique species because of its variant features. In India it is cultivated for vegetable purpose, as a spice, oleoresin and colour extraction (Kumar *et al.*, 2006). Sweet peppers are non pungent types and also known as bell peppers. Paprika possess high colour value with negligible pungency. Paprika oleoresin is used as natural colourant to impart deep red colour to food products. (Mathurarai *et al.*, 2010). Besides, they are the rich source of Vitamins A and C and bioactive compounds present in the fruits and are known to impart antioxidant, anti microbial, anti inflammatory, anti viral and anti cancerous properties. (Khan *et al.*, 2014). Great variability occurs for fruit size, colour, shape and biochemical characters among the species.

2.1. Morphological characterization

Throughout India, a wide variability in fruit morphology, bearing habit and crop duration was reported by Asati and Yadav (2004).

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Birds eye chilli *(Capsicum frutescens* L.) is mainly cultivated for the small pungent fruits and has a life span of 2-3 years. Fruits in the species are ovoid, oblong, cylindrical or blunt pointed and the fruit colour varies from creamish yellow to orange scarlet to blood red. Baruah and Baruah (2004) reported that in *Capsicum frutescens*, fruit length varies from 0.7cm to 2.5 cm and width from 0.3cm to 1 cm.

Diverse climatic conditions prevailing in different parts of Kerala offer great scope for commercial cultivation of a variety of chilli genotypes. Even though it is an indispensable spice in Kerala dishes, its commercial cultivation in the state is limited to certain districts namely chittoor taluks of Palakkad, some villages of Malappuram and Kasargode districts only (Indira and Gopalakrishna, 2004).

Chilli fruits have rich diversity for its size, colour, shape and quality. Fruit shape may be oval, elongated, round, distal end may be pointed, blunt or sucked and fruit surface may be wrinkled, leathery or smooth. Fruit colour varies from green, white, cream, yellow, orange, violet, blue, or nearly black. Specific adapted varieties are cultivated in most of the chilli growing tracts and there are so many cultivars traditionally grown by farmers (Kallupurackal and Ravindran, 2004).

A popular variety 'Mali mulaku' of *C. chinense* is gaining importance now a days especially in high ranges of Idukki district in Kerala. About 95 percent of fruit is exported to Maldives. It is a perennial plant growing to a height of about 1 meter or above. It's fruits are attractive, stout with broad base, shrunken and glossy in appearance. Based on the fruit colour Thomas *et al*. (2004) reported two distinct types namely red type with high content of capsanthin and yellow type which is rich in capsaicin .

Selection of desirable types always depends on large amount of variability. Generally, most of the economic characters are quantitative in nature and are highly influenced by heritable and non heritable factors (Sharma *et al*., 2009).

2.1.1. Plant characters

Variability studies was carried out in College of Horticulture, Arabahavi by Krishna *et al.* (2007) in *Capsicum annuum* and reported significant variability for plant height (40.4 - 110.4 cm) and days to 50% flowering (35 -56).

Two hundred and three accessions were evaluated at NBPGR regional station, Nainital (Verma *et al.*, 2008) and found a wide range of variability for stem colour (light green, purple and green), leaf colour (purple, light green, dark green) and corolla colour (white, yellow and purple). Among these, more than 88% accessions were green stemmed, erect with green medium sized leaves and plant height ranged from 37 to 93 cm, days to 50% flowering from 137 to 163 days and days to 50% fruiting from 144 to 168 days.

Thul *et al.* (2009) found significant variation among twenty four accessions of chilli genotypes under their study. They observed that plant height varied from 23 cm to 107 cm. Leaf length was highest (14.7 cm) for the genotype CCA 60 and lowest (3.6cm) for CCA 13. Leaf breadth varied from 1.3 cm to 8.2 cm and days to 50% flowering ranged from 116 (CCA 36) to 220 (CCA 41) days. Days to 50% fruiting were highest in CCA 16 (314 days) and lowest in CCA 36 (150 days).

Character association study was conducted by Kumar *et al.* (2010) among byadagi kaddi and KtPI-19 and the study revealed that plant height has positive correlation with dry fruit yield.

Cultivars and environment highly influence the production and productivity of chilli. In a study on evaluating the performance of various chilli genotypes under South Gujarat conditions, the genotype BCC-1 recorded the highest plant height (110.6 cm) and lowest (57.83cm) for VR-338 (Saravaiya *et al.*, 2010).

Chattopadhyay *et al.* (2011) analysed thirty four genotypes for their qualitative and quantitative parameters and found great variability for all the characters studied. Maximum number of genotypes (74%) had medium sized leaves and the predominant leaf colour was green (77%). All the genotypes had only one flower per axil.

In a study conducted at CIMAP for evaluation of genetic variability in 38 accessions of chilli, variability was observed for plant height (41 - 111 cm), days to first flowering (144 -218) and days to fruit initiation (174 - 310) (Misra *et al.*, 2011)

Umajyothi *et al.* (2011) found variation for plant height among chilli accessions with maximum values in DCL -352 (99.3 cm) and minimum in DSL-1 (73.7 cm).

Phulari (2012) studied the performance of major morphological characters among five accessions of *C. annuum* (Black short, Deonurbyadagi, Jwala, pant C-1 and Sankshwari) and one accession of *C. frutescens* (Lavangi). Minimum plant height was observed for the variety Jwala (44.86cm) and maximum for the variety Sankshwari (65.8 cm). Days to 50% flowering ranged from 47 days in Black short to 64 days in Deonurbyadagi.

A study was undertaken at IISR, Calicut to evaluate the performance of paprika and paprika alike chillies (*C. annuum*) under warm humid tropics by Shiva *et al.* (2013). Among 21 indigenous and 10 exotic collections, minimum number of days for flowering was noticed in ICDB-17 (54 days) and maximum in Kt-P1-19 variant-1 (65 days). Early flowering is a desirable character leading to early fruiting and harvest. Plant height ranged from 142.7 cm (ICDB-16) to 105.3 cm (ICDB-19) among indigenous types. Among the exotic types, maximum plant height was recorded in PBC – 171(180 cm) and minimum in Paprika King (80 cm).

A study was conducted under Kashmir conditions for genetic variability and correlation for growth and yield characters in 23 genotypes of *C. annuum* by Amit *et al.* (2014). Considerable variability was reported for all the traits examined like plant height (52.5 – 120.23 cm), days to 50% flowering (70 to 94 days) *etc.*

Naik *et al.* (2014) studied the F2 population of commercial hybrids (Bomby and Atlas) for their different quantitative characters and observed that plant height ranged from 45 cm to 224 cm.

According to Vijaya *et al.* (2014), high degree of variation was observed for plant characters like plant height (52.7 – 118.6 cm) and days to 50% flowering (49.3 – 76.3).

Maurya *et al.* (2015) reported considerable variability for mean values for characters like plant height (75.09cm), days to 50% flowering (46.67) and days to 50% ripening (87.01).

Quresh *et al.* (2015) reported considerable variability among 10 accessions for qualitative characters like leaf colour (light green to dark green), flower position (pendent to erect) and corolla colour (white to green).

2.1.2. Fruit characters

Weight of pericarp is an important quantitative character in determining the yield of chilli powder and variation in the pericarp weight and number of seeds was reported by Anu *et al.* (2002) in different genotypes.

Significant variability was observed for fruit length (5.06cm - 14.05cm), fruit girth (0.5cm - 1.39cm), number of fruits per plant (107 - 502) in a study conducted by Krishna *et al.* (2007) to evaluate variability in green chillies among eighty genotypes.

According to Singh and Sharma (2008), fruit length, fruit weight and number of fruits per plant contribute to marketable yield.

Evaluation of chilli at NBPGR regional station, Nainital revealed wide range of variability for mature fruit colour (yellow, light green, green, dark green, purple), ripe fruit colour (yellow to purple), fruit position (pendent to erect), fruit shape (elongated, round, oblate, blocky), seed colour (yellow to brown) *etc*. Fruit length ranged from 2.76 to 12.06 cm), fruit width from 0.51 to 2.77 cm, number of fruits per plant from 5.2 to 76.2, number of seeds per fruit from 25 to 130, fresh fruit weight from 1.5 to 7.5g, fruit yield per plant from 33.8 to 291g. More than 88% accessions had elongated fruits, green colour with pendent nature and ripe fruit colour was red (Verma *et al*., 2008).

In a study conducted by Jabeen *et al.* (2009), genotypic coefficients were higher than phenotypic coefficients indicating higher heritability of traits. They also found that fruit yield per plant exhibited positive correlation with number of fruits per plant, fruit weight, number of branches per plant and plant spread.

Evaluation of *C. annuum* genotypes was carried out at IIVR, Varanasi for yield and quality traits at different dates of transplanting. The study revealed change in yield and qualitative attributes due to temperature variations and concluded that genotype KA-2 is suitable for main season where as Japani long and ISC-9 for summer season for getting maximum yield (Mishra *et al*., 2009).

In a study conducted by Sharma *et al.* (2009) variability was reported for characters like days to 50% flowering (42.67 – 59.67), fruit length (5.04 - 11.57 cm), fruit girth (0.81 - 2 cm), dry fruit weight (0.48 – 1.12 g) , number of seeds per fruit (54.4 – 102.45), total number of fruits per plant (19.48 – 74.07) and dry fruit yield per plant (9.79 – 34.45).

Thul *et al.* (2009) found significant variation among twenty four accessions of chilli genotypes under their study. Fruit length varied from 0.7 cm to 7.2 cm and fruit diameter from 0.4cm to 4.2 cm. Dry fruit weight was found maximum in CCA 60 (2.7g) and lowest in 0.07 (CCF1) and number of fruits ranged from 14 to 128.

Character association study was studied by Kumar *et al.* (2010) among byadagi kaddi and KtPI-19. The study revealed that dry fruit yield has strong positive correlation with number of fruits per plant, fruit length and fruit weight. Fruit girth, number of seeds per fruits, number of branches per plant and plant 21 height have positive correlation with dry fruit yield. Days to first flowering had significant negative correlation with dry fruit yield.

Saravaiya *et al.* (2010) evaluated the performance of various chilli genotypes under South Gujarat conditions and compared with LCA 206. Fruit length was found to be maximum (19cm) for GVC-111 and minimum (9.5cm) for CCH-05-01. Highest (1.24cm) and lowest (0.83cm) values for fruit width was for BCC-1 and PC-2062 respectively. LCA-206 recorded a fruit length of 10.93cm and fruit width of 0.99 cm. High variation with respect to fruit size, weight, colour, shape and seed number was observed in their study and identified genotypes having thin pericarp, low seed content and long fruits which are good for dried chilli.

Chattopadhyay *et al.* (2011) analysed thirty four chilli genotypes for their qualitative and quantitative parameters and found great variability for all the characters studied. Eighty percentage of genotypes had long fruits and the rest had conical fruits. In most of the genotypes, fruits were pendent (91%) followed by erect types. About 65% genotypes had pointed fruits and rest of genotypes had blunt edged fruits. Predominant (85%) mature fruit colour was green and ripe fruit colour was red (62%). Earliest 50% flowering (30 days) was noticed in genotype chilli-10 and late flowering in chilli-335 (109 days). Fruit length was maximum in HP-25 (14.97 cm) and minimum in chilli-335 (2.93 cm). Fruit girth varied from 0.53cm to 2.77cm, fruit weight from 1.07g to 19.87g and dry fruit weight from 0.2g to 4.6g. Maximum (134) number of fruits was in BCCh Sel-4 and minimum (6) in HP-30. Dry fruit yield per plant ranged from 8.36g to 54.56g.

According to Kumari *et al.* (2011), weight of fruit or pericarp, number and weight of seeds are the contributing factors for yield.

In a study conducted at CIMAP, variability was observed among chilli accessions for fruit length (1.45 – 9.96 cm), fruit diameter (0.65 – 1.84 cm), fresh fruit weight (0.36 – 4.44 g) and dry fruit weight (0 .14 – 0.96 g) (Misra *et al.*, 2011). 22

In a study conducted by Umajyothi *et al.* (2011), maximum variation was observed for number of fruits per plant, fruit length and seed number per fruit and in their study LCA 353 gave maximum (315) number of fruits per plant.

Performance of major morphological characters among five accessions of *C. annuum* (Black short, Deonurbyadagi, Jwala, pant C-1 and Sankshwari) and one accession of *C. frutescens* (Lavangi) was studied by Phulari (2012) and obtained highest fruit number (146 fruits) for Lavangi variety of *C. frutescens* where as number of fruits per plant was lowest (62) for Black short. Fruit length was found to be maximum in Sankshwari (21.22 cm) and minimum (5.72) for Lavangi. Pedicel length ranged from 3.76 cm (Sankshwari) to 2.1 cm (Lavangi) and the variety Jwala recorded highest dry fruit yield (61.49g) compared to Black short (39.18g).

Prajapati *et al.* (2012) reported that yield and yield attributing characters are highly dependent on climatic conditions.

Weight of pericarp is an important trait in determining yield of paprika powder. In the study on evaluating the performance of chilli types carried out by Shiva *et al.* (2013), pericarp weight ranged from 2.4g (IMI-5) to 29.4g (SSP-1999) and seed number ranged from 45 (ICDB- 15) to 106 (ICDB-12).

High phenotypic and genotypic variations were observed for number of fruits per plant, fruit weight and dry yield in a study conducted by Amit *et al.* (2014). They reported considerable variability for all traits examined like fruit length (4.16 - 14.7 cm), fruit girth (0.88 - 2.8 cm), fruit weight (1.71 - 5.19g), fruit number per plant (66 - 198), seed number per fruit (35 - 116), and dry fruit yield/ plant (20.73 - 102.24 g). They also reported that plant height, fruit length, number of fruits per plant, fruit weight and yield can be used as the most important characters in the crop improvement programmes in chilli.

Fruit parameters like fruit length, fruit circumference, number of seeds per fruit, fruit weight and fruit yield was more in first three pickings (P1, P2, P3) 23 compared to the remaining pickings (P4, P5) in cultivated variety PKM-1 (Ananthi *et al.*, 2014).

In a study on F2 population of commercial hybrids, "Bomby and Atlas" (Naik *et al.*, 2014), fruit length was in the range of 4.9cm to 10.7 cm. Fruit diameter (3.56 cm to 9.67 cm), pedicel length (1.57cm to 7.1cm), pericarp thickness (0.23cm to 2.83cm), seed number per fruit (5 to 317) and yield (250g to 1860g) also varied in the population.

Vijaya *et al.* (2014) observed high degree of variation for fruit characters like fruit length (4.9 -14.6), fruit diameter (0.77 – 1.6cm), pericarp weight (0.28 – 0.8g), number of seeds per fruit (51.3 – 98.4), number of fruits per plant (49.63 – 186.3) and dry fruit yield per plant (26.1 – 97.3g).

Dhaliwal *et al.* (2015) reported absence of correlation of plant height with fruit yield. whereas fruit length and fruit width were positively correlated to fruit yield.

Variability in fruit characters was reported by Maurya *et al.* (2015) among twelve genotypes of chilli evaluated. Fruit length varied from 15.15 cm in Pusa Jwala to 5 cm in Jorhat local. Fruit width was maximum in Jwalamukhi (1.39cm) and minimum in Jorhat local (0.75cm). Ripe fruit colour varied from light red to red to dark red. Highest dry weight was for Pusa Jwala (1.285g) and lowest was in Jorhat Local (0.55g). Fruit yield per plant ranged from 102.15g (Jorhat Local) to 205.45g (Pusa Jwala).

Quresh *et al.* (2015) reported considerable variability among 10 accessions for morphological and yield characters. Variability was reported for qualitative characters like fruit colour (purple to dark red), fruit shape (cordated to elongated), fruit surface (sooth to wrinkled) and seed colour (light brown to brown). They also found variability for quantitative characters like plant height (33.9 - 64.5 cm), leaf length (3.7 - 10.5 cm), leaf width (1.5 - 6.4 cm), fruit length (4-10.9 cm), fruit width (1 - 6.1 cm), fruit pedicel length (1.3 - 2.5 cm), fruit weight (1.4 - 57.3 g), fruit wall thickness (0.7 - 5.1 mm) and seed number per fruit (31.7 - 243.3).

2.2. Biochemical characters

Chilli fruits consist of numerous chemicals including capsaicinoids, vitamins, fibres, proteins, carotenoids, oils and minerals. It is also used in cosmetics, medicinal and ornamental purposes (Bosland and Votava, 2000).

Pungency, antioxidant properties, vitamin C and natural pigments are the functional properties in chilli (Jagadeesh, 2000). Pungent chillies are used as spice chillies.

In international trade, paprika is the dried deep red coloured non pungent fruits of capsicum. Colour values are generally measured in ASTA units and in good varieties, ASTA values will be more than 80 units. Percentage of pungent principles varies from 0% to 1.86% in paprika, but good paprika never exceeds 0.5% of pungent principles. Best paprika are those having pungency in the range of 0% to 0.0003% (Mathew *et al.*, 2000).

Different genotypes are grown in different locations. 'Nagahari' also known as Naga Jolokia or BhutJolokia, is the hottest chilli of the world, indigenous to NE region of India and it is having 8,55,000 scoville heat units (Mathur *et al.*, 2000).

Hot chilli (*Capsicum chinense* Jacq.) is cultivated for domestic and export purposes. This species is characterized by its peculiar flavour and aroma, richness in oleoresin and pungency. Because of these traits, it has wide application in pharmaceutical and cosmetic industries (Manju and Sreelathakumary, 2002).

Patil and Jagadeesha (2002) reported that soil type and climate have strong influence on quality of chilli though it is mainly a genetically controlled character.

Capsaicinoids present in chillies gives pungency whereas carotenoids contribute colour and nutritional value (Galvez *et al.*, 2003).

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Chilli fruits are valued because of its characteristic pungency, colour and flavour. Besides it is a rich source of Vitamin A, C and E. (Kallupurakkal and Ravindran, 2004).

Byadagi chillies grown in Dharwad district of Karnataka and Warangal Chappatta (tomato chilli) grown in Kammam and Warangal districts of Andra Pradesh are having low pungency and high colour and they are in similar quality as that of paprika types grown in Hungary and Spain. These chillies are preferred by oleoresin industries for extraction of oleoresin (Shiva *et al*., 2008).

Capsicum annuum includes pungent and non pungent types. In India, chilli is mainly used as spice, for oleoresin and colour extraction (Paprika types) and for processing or pickling. Fresh green chillies are used for culinary needs whereas dried powder is used as a spice. Paprika refers to non pungent or mild pungent fruits or its powder or oleoresin extracts. Intense colour which may be bright or deep red, free from blemishes and sun bleaching, colour stability after processing and acceptable level of pungency are the important parameters for processing. Preference for pungency varies from region to region. Colour and pungency are the most important qualities required for spice chilli. Good colour retention after drying and grinding, high dry matter content/ driage, ease of grinding are the other important qualities for using as spice. Long chillies are preferred for using as a spice. Short chillies are usually 2-7 cm long, with medium to very hot pungency, bright or dark red at mature stage. Main quality parameters for pepper spice apart from colour and pungency are fruit wall thickness, colour retention during storage, fruit size, shape and weight (Singh, 2010).

2.2.1. Capsaicin

Narayanan *et al.* (1980) reported that the pericarp contained almost all the pungency (0.1267 mg to 0.2723 mg per 100g) whereas chilli seeds contained only traces of pungency (0.005 per cent). Thain *et al.* (1980) mentioned that if the dry fruits of the genus *Capsicum* contains carotenoids of 0.4% and above, they should be called chillies and those below this level are called capsicums. The fraction of 26 pungency level in the fruit was studied by many authors such as Suzuki *et al.* (1980) and Gareilia and Alejo (1990).

Influence of storage condition on capsaicin content was studied by Laxmichand *et al.* (1990) and observed that the loss of capsaicin from open chilli samples was more (82.75%) than in sealed chilli samples (39.6%).

Capsaicin and allied constituents contributes to the hot flavour of chilli. Capsaicin is an acid amide of vanillylamine and has both nutritional and toxic effects and its action on digestive, cardiovascular, respiratory and nervous systems are well known (Caulibaly *et al.*, 1998).

Pungency is defined as sharp, piercing, stinging, biting or penetrating quality or power to excite. Capsaicinoids are group of chemical compounds responsible for their pungency and have wide use in pharmacological applications. Pungency in chilli is due to capsaicin (8-methyl-N-vanillyl-6-nonenamide) and 7 closely related alkyl vanillyl amides collectively known as capsaicinoids. More than 15 different alkaloids are found in chilli fruits and among these capsaicin and dihydrocapsaicin accounts for more than 80% of capsaicinoids (Bosland and Votava, 2000).

Cheriyan (2000) evaluated hot chilli types (*Capsicum chinense*) for their oleoresin content and reported high capsaicin content (> 1%) in all the accessions studied.

Perucka and Oleszek (2000) reported broad range of variability in capsaicinoid and pungency levels in *Capsicum annuum*.

Mathur *et al.* (2000) studied the capsaicin content of five capsicum types viz. Tezpur, Gwalior, Patna, Guntur and Kashmir and the values were 4.28%, 0.47%, 0.21%, 0.16%, and 0.18% respectively.

Perucka and Materska (2001) described capsaicin as the 9-11 carbon compounds of vanillamides of fatty acids.

Puranaik *et al.* (2001) reported that capsaicin content in chilli gradually decreased in storage and cold storage proved better compared to ambient condition in retention of capsaicin content.

Sathyamurthy *et al.* (2001) reported variability in the capsaicin content ranging from 0.511% to 0.875% among 40 accessions of *capsicum annuum.* Similiarly singh *et al.* (2003) reported variability (0.33% to 0.7%) among 59 accessions studied for their capsaicin content.

Many factors like climate, light, soil properties, temperature, moisture content in soil and fertilization during their growth and development determines the content and composition of capsaicin in the different species and cultivars of capsicum (Estrada *et al.*, 2002). It also depends on the processing and drying conditions (Titze *et al.*, 2002).

Manju and Sreelathakumary (2002) evaluated thirty two genotypes of *Capsicum chinense* for their capsaicin content and value was found to vary from 1.20% (CC 1) to 3.74% (CC 16) and in their study capsaicin content was found to be positively correlated to oleoresin content and negatively correlated with pedicel length and fruit weight.

Kumar *et al.* (2003) reported a range of 0.33 % to 0.49 % in capsaicin content in their study whereas Singh *et al.* (2003) observed a variation of 0.33% to 0.7% of capsaicin in chilli genotypes.

Umajyothi (2003) evaluated eight chilli genotypes at RARS, Lam for capsaicin content and the values ranged from 0.226% to 0.658%.

Baruah and Baruah (2004) reported that capsaicin content of *Capsicum frutescens* fruits ranges from 0.26% to 1.21% in their study.

Anon (2005) evaluated different Indian chillies from different locations for their capsaicin content. It was found that Guntur sannam, Tomato chilli, Birds eye chilli and Ramnad Mundu have capsaicin content of 0.226%, 0.17%, 0.589%, and 0.166% respectively.

Twenty three cultivars of *capsicum annuum* were evaluated by Umajyothi *et al.* (2007) for their capsaicin content and it was found to be in the range of 0.256% in cultivar SKAU-C-101 to 0.528% in BC-40-2. Capsaicin contents of LCA 334, LCA 353 and CO-4 were 0.346%, 0.323% and 0.319% respectively.

Accumulation of capsaicin in seed, pericarp and placenta of *C. annuum* fruit was studied by Pandhair and Sharma (2008). In their study, capsaicin accumulation was highest in placenta (63.9 mg/g dry weight) followed by pericarp (7.12 mg/g) and seeds (5.06 mg/g).

Capsaicin is the most pungent among the capsaicinoids and they are sparingly soluble in water and highly soluble in alcohols, fats and oils. Some of the compounds in capsaicinoid groups are Dihydrocapsaicin, Norhydrocapsaicin, Homocapsaicin and Homodihydrocapsaicin. Capsaicinoids are produced and accumulated in the epidermal cells of placenta and intercellular septum of fruits. Capsaicinoids are produced in glands of placenta during the later stages of fruit development. Seeds don't produce capsaicin but absorb capsaicin due to their placement near to placenta. Only *Capsicum* species are reported to produce capsaicinoids (Prasath and Ponnuswami, 2008).

Whole chilli fruit consists of 40% pericarp, 56% seeds and 4% stalk. Pericarp contains an inner sheath known as dissepiment in which pungency is mostly concentrated. Chilli seeds contain traces of pungency (0.005%) only (Prasath and Ponnuswamy, 2008).

Genetic variation in capsaicin content of chilli genotypes have been reported by several workers. Sanathombi and Sharma (2008) reported that genotypes from *C. annum* species have lesser capsaicin content than other *Capsicum* species.

After nine months of cold storage a loss of 47.8% capsaicin was reported by Umajyothi *et al.* (2008) where as 63% loss was observed under ambient condition of storage.

Deng *et al.* (2009) reported that *Capsicum annuum*genotypes are less pungent compared to other species of chilli.

Mishra *et al.* (2009) studied the capsaicin content in ten genotypes of *C. annuum* in different seasons (main season and off season) and reported only a negligible variation in its content in two seasons.

Pandey *et al.* (2009) observed wide variation in the capsaicin content of five cultivated species and the values were less than 0.05% in mild pungent types and 1.3% in very hot types.

Thul *et al.* (2009) evaluated twenty four genotypes of chilli for their capsaicin content and values ranged from 1.89% (CCF 3) to 0.03% (CCA 36).

Capsaicin is used in food industry and has pharmaceutical properties. Capsaicin has shown great potential as chemo preventive against cancer diseases (Oyagbemi *et al.*, 2010).

Umajyothi *et al.* (2010) evaluated 300 germplasm of chilli for capsaicin content and the values were in the range of 0.094% (GP 158) to 0.99% (GP 186).

Genus capsicum only produces the pungent principle 'capsaicin' and it is mostly located in the vesicle like sub cellular organelles of epidermal cells of placenta. Highest concentration of capsaicin is found in ovary and lower flesh (tip of fruit) and lowest in seeds. Capsaicinoids are produced by glands present in the placenta. Placenta contributes 89% of capsaicin where as 5 to 6% by pericarp and seed. Pungency varies with different varieties of same species and even among fruits of a single variety (Arora *et al.*, 2011).

Chattopadhyay *et al.* (2011) evaluated thirty four chilli genotypes for their quality parameters and observed highest capsaicin content in BCC-12 (.56%), followed by BCC-1 (0.31%) and BCC-62 (0.26%).

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Fatima *et al.* (2013) reported that *Capsicum frutescence* are more pungent compared to *Capsicum annuum* species and it is not associated with colour of fruits.

A study conducted at GKVK, Bangalore on 24 genotypes of chilli, considerable variability was observed for capsaicin content which ranged from 0.09 % - 0.38 % (Vijaya *et al.*, 2014).

2.2.2. Oleoresin

Oleoresin is the complete profile of colouring matters and pungent principles. It has many advantages over ground chilli like uniform colour and flavour distribution, elimination of contamination by microbes and it is easy to store or transport. Now a days many countries are using chilli oleoresin instead of whole chilli or ground forms. Since oleoresin represents the total flavour extract of ground spice, it has commercial applications in food, beverage and pharmaceutical industries. The food industry generally prefers to use large, highly coloured and less pungent chillies for preparation of oleoresins.

Oleoresin in general contains capsaicinoids, carotenoids, colouring principles, fatty components, proteins, vitamins *etc.*, the relative proportion of which depends on the kind of Capsicums, part used and method of extraction. Considerable variability exists among chilli cultivars with respect to oleoresin recovery. Influence of cultivars on oleoresin recovery was reported by Pradeepkumar (1990), Umajyothi, *et al* (2003 and 2007). Pradeepkumar (1990) obtained an oleoresin content of 18.7% in *Capsicum annnuum*, 27.3% in *C. frutescens* and 31.7% in *C. chinense.* F1 hybrid developed from *C. frutescens* x *C. chinense* recorded high oleoresin yield (35.37%) and 34.4% in *C. annuum* x *C. chinense.*

Pruthi (1993) analysed the oleoresin yield of 15 chilli cultivars grown in different zones of India and its content varied from 6.2 – 12.4%.

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Oleoresin recovery and storage stability in chilli genotypes was studied by Mini (1997). Mathur *et al.* (2000) studied the oleoresin content of five capsicum types viz. Tezpur, Gwalior, Patna, Guntur and Kashmir and oleoresin content was 15%, 12.5%, 19.1%, 12%, and 11% respectively.

Singh *et al.* (2001) reported that quality and quantity of oleoresins are determined by solvents used and extraction time. In his study acetone was the best solvent compared to ethyl acetate and ethyl alcohol. Oleoresin yield was maximum (16.25%) when acetone used as solvent. Oleoresin yield was higher (16.02%) under five hours of extraction compared to four hours (14.56%) of extraction.

Manju and Sreelathakumary (2002) evaluated thirty two genotypes of *Capsicum chinense* for their oleoresin content and revealed considerable variation for its content ranging from 4.92% (CC 21) to 24.25% (CC 16) with an overall mean of 12.44%.

Eight varieties of chilli evaluated by Umajyothi *et al* (2003) for oleoresin content, revealed highest oleoresin content (10.7%) in LCA 235 and lowest (7.1%) in LCA 424.

The study conducted at Punjab Agricultural University by Singh and Hundal (2004) recorded maximum oleoresin content in an accession S-2529 (17.2%) followed by MS-12 (17%) and CH-3 (17%) and minimum content was reported in Perennial (9.9%).

Umajyothi *et al.* (2007) reported considerable variability among the chilli genotypes with respect to oleoresin recovery with values ranging from 6.91% to 13.82%.

Twenty three cultivars of *Capsicum annuum* were evaluated by Umajyothi *et al.* (2008) for their capsaicin and oleoresin content. Oleoresin content was found to be in the range of 6.91% in cultivar PC-7 to 13.28% in DCL-352.

Oleoresin content of LCA 334, LCA 353 and CO-4 was 10.12%, 8.92% and 9.77% respectively.

Influence of storage condition on oleoresin content was studied by Umajyothi *et al.* (2008) and reported that LCA 206 was found to be better in retention of oleoresin after a months of storage.

Pandey *et al.* (2009) reported a variation of oleoresin from 7.2% to 17.4% among thirty accessions studied.

Considerable variability exist with respect to oleoresin yield was reported by Umajyothi *et al.* (2010).

Chattopadyay *et al.* (2011) evaluated thirty four genotypes of chilli for their qualitative characters and it was found that oleoresin yield ranged from 8.89% to 37.5% with maximum value in AC-588 and minimum in BCC-12.

Wesolowska *et al.* (2011) reported that oleoresin consists of essential oil, natural colourants, waxes, alkaloids and pharmaceutical ingredients.

Vijaya *et al.* (2014) reported variability in oleoresin content ranging from 6.25% to 15.55% among 24 chilli genotypes evaluated at GKVK, Bangalore.

2.2.3. Colour

Artificial colorants and aromatics added in various food and cosmetics are reported to be carcinogenic. As a result of these there is great demand for natural colorants. Capsantin and capsorubin are the major pigments found in chilli fruits and capsanthin contributed to 60 per cent of total pigments. Colour extracted from chilli has application in food, pharmaceutical and cosmetic industries due to its appealing colour, aesthetic flavour and aroma.

Colour of chilli is measured as extractable colour which is the official method used by the American Spice Trade Association (ASTA, 1985).

Wall *et al.* (2001) conducted a study to evaluate β-carotene and total carotenoid content of different coloured chilli and it was found that yellow cultivars contained very low level of both β-carotene and total carotenoids compared to orange coloured fruits whereas red pigmented cultivars recorded maximum content of β-carotene.

Considerable variability in colour value was reported by different authors. Anu *et al.* (2002) reported variation in the colour value (70.3 - 268.3 ASTA units) among 24 genotypes evaluated. Red colour intensity is the most important attribute of chilli considered for industrial and culinary purposes (Kim *et al.*, 2002).

Gadal *et al.* (2003) reported significant variability (56.07 – 187.70 ASTA units) among 36 genotypes evaluated. Singh *et al.* (2003) evaluated 59 accessions and in their study colour value ranged from 15.92-180 ASTA units.

Capsorubin, the red pigment, extracted from chilli fruits is used as a natural colorant in food, cosmetic and pharmaceutical industries (Thomas and Thomas, 2003).

Baruah and Baruah (2004) reported a colour value of 41.7 ASTA units in *Capsicum frutescens.*

A number of different coloured fruits are available now a days due to the presence of various phytochemicals in the form of pigments. Besides carotenoids, some amount of flavonoids (quercetin and luteolin) and other phenolic compounds which are collectively known as hydroxyl cinnamic acid derivatives are present in chilli fruits (Marin *et al.*, 2004).

Anon (2005) evaluated different Indian chillies from different locations for their colour value and was found that Guntur sannam, Tomato chilli, Birds eye chilli, Byadagi Kaddi and Ramnad Mundu have colour value of 32.11, 125.26, 41.7, 156.9 and 32.95 ASTA units respectively.

According to Prasath (2005), colour value of 27 genotypes ranged from 32.82 - 208.56 ASTA units.

ASTA values are known to differ significantly depending on the cultivar, ripening stage and presence of seed (Garcia *et al.*, 2007).

Carotenoid content increases with maturity and ripening stages and amount of carotenoids depend on cultivar, environment and maturity stages. Visual and extractable colour and pungency are the quality determining factors of paprika. Colour value is the principal criterion for assessment of quality of paprika, measured by spectrophotometric method and expressed by ASTA (American Spice Trade Association) units (Prasath and Ponnuswami, 2008).

Umajyothi *et al.* (2008) reported that drying methods influence the quality of chilli. Colour of ground chilli deteriorates when exposed to air, sunlight and moisture has great influence on colour retention in both ground and whole chillies.

Pandey *et al.* (2009) reported a colour value variation from 273.88 to 294.38 ASTA units among thirty accessions studied. He also found that colour value varies according to inherent characteristics of each cultivar and due to certain biosynthetic pathway.

Green, red, deep red, purple, orange and yellow are the common colours in chilli. Parthasarathy *et al.* (2010) reported that capsanthin and capsorubin are responsible for red colour whereas lutein, β- carotene, zeaxanthin, violaxanthin and antheraxathin for yellow and orange colour.

Approximately 20 carotenoids contribute colour to chilli powder. Carotenoids are made by isoprene units and normally they are fat soluble (Reddy, 2010). 35

Colouring matter of chillies is a mixture of carotenoids (Umajyothi *et al.*, 2010) and it is widely used to replace synthetic colour in processed foods and it is an important quality attribute in spice trade.

Colour can be determined by extractable colour and visual colour method. Extractable colour is the official method used as per ASTA. (Zaki *et al.*, 2013)

Gobinath *et al.* (2014) conducted cluster analysis (based on biochemical constituents) on twenty four indigenous collection of Bayadagi Dabbi (ICDB) chillies and grouped them into six clusters. It was found that cluster 1 (ICDB-17, 18, 16, 3) had colour value > 250 ASTA units. The second cluster had low colour value (140-173 ASTA units). The accessions (ICDB-6, 13, 4 and ICDB 23) falling under third cluster had colour value of more than 200 ASTA units. Accessions like ICDB-2, 5, 1, 14, 20, 25 and ICDB-26 were falling under fourth cluster and their colour value ranged from 184 to 200 ASTA units. Fifth cluster (ICDB-24) had low colour value and ICDB-11 and ICDB-19 falling under sixth cluster had highest colour value (> 340 ASTA units).

Vijaya *et al.* (2014) reported variability in colour value ranging from 49.2 ASTA units to 230.5 ASTA units among 24 chilli genotypes evaluated at GKVK, Bangalore.

Kim *et al.* (2016) observed that capsanthin and capsorubin are the major pigments in red coloured fruits and β- carotene in orange coloured fruits. Lutein is abundant in yellow and green paprika. They reported different carotenoid profiles in differently colored chilli fruits. Six kinds of carotenoids were found to be present in red coloured fruits and nine types in orange and yellow fruits.

Materials and methods

3. MATERIALS AND METHODS

The investigation on "Screening of spice chilli (*Capsicum annuum* L.) genotypes suitable for Kerala" was carried out at the Department of Plantation Crops and Spices, college of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala during 2014-2016.

The experimental materials and methodology of the study are presented in this chapter. The whole programme was divided into two experiments.

A) EVALUATION OF CHILLI ACCESSIONS FOR MORPHOLOGICAL CHARACTERS

3.1. MATERIALS

Materials used in this study consist of 35 accessions including indigenous types and released varieties of chilli (Table 1).

3.2. METHODS

3.2.1. DESIGN AND LAYOUT

Experiment was conducted in Randomized Block Design (RBD) with two replications. Plot size was $2m^2$ with spacing of 45cm x 45cm. Ten plants were maintained in each plot.

The seedlings were transplanted 45 days after sowing. All the management practices were done as per Package of Practices Recommendations of Kerala Agricultural University (KAU, 2011).

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Table 1: Details of chilli genotypes used in the experiment with their source.

Sl. No.	Accession No.	Name of genotype	Source
1. *Capsicum annuum*			
1	CA 1	KKM-1	Agricultural college and research station, Killikulam
2	CA 2	K-1	Agricultural experimental research station, Kovilpatti
3	CA 3	CO-4	TNAU
4	CA 4	PKM-1	Periyakulam, TNAU
5	CA 5	G3	Horticultural research station, LAM
6	CA 6	G4	Horticultural research station, LAM
7	CA 7	LCA353	Horticultural research station, LAM
8	CA 8	LCA235	Horticultural research station, LAM
9	CA 9	LCA960	Horticultural research station, LAM
10	CA 10	LCA625	Horticultural research station, LAM
11	CA 11	LCA206	Horticultural research station, LAM
12	CA 12	LCA334	Horticultural research station, LAM
13	CA 13	ArkaLohit	IIHR, Bangalore
14	CA 14	ArkaKyathi	IIHR, Bangalore
15	CA 15	ArkaHaritha	IIHR, Bangalore
16	CA 16	ArkaSuphal	IIHR, Bangalore
17	CA 17	ArkaMeghna	IIHR, Bangalore
18	CA 18	Localcollection	Kodakara, Thrissur
19	CA 19	KasiAnmol	11VR, Varanasi
20	CA 20	Utkal-Ava	OUAT, Bhubaneswar
21	CA 21	UtkalRasmi	OUAT, Bhubaneswar
22	CA 22	Local collection	Athavanad, Malappuram
23	CA 23	Local collection	Edayur, Malappuram
24	CA 24	Daritri	Private seed company
25	CA 25	Tejasvi	Private seed company
26	CA 26	Chivar	Vegetable research farm, Allahabad
27	CA 27	Local collection	Thriprayar, Thrissur
28	CA 28	Local collection	Palakkad
29	CA 29	Local collection	Athavanad, Malappuram

Plate 1: Field view

30	CA 30	Ujwala	KAU
31	CA 31	Anugraha	KAU
32	CA 32	VellayaniAthulya	KAU
2. *Capsicum chinense*			
33	CC 1	Local collection	Kodakara, Thrissur
34	CC 2	Local collection	Thriprayar, Thrissur
35	CC 3	Local collection	Mattathur, Palakkad

3.2.2. OBSERVATIONS

Five plants were randomly selected from each genotype and the observations on following quantitative and qualitative characters were recorded. Ten fruits were selected at random from each plant for observations on fruit characters and the average was worked out.

3.2.2.1. PLANT CHARACTERS

a) Plant height

Measured from ground level to tip of plants with the help of a measuring tape when plants are at 50% flowering stage and expressed in centimetre.

b) Stem colour

Recorded at full foliage stage.

c) Leaf colour

Recorded at full foliage stage.

d) Leaf length

Fully opened fourth leaf from the tip is taken for measuring leaf characters. Leaf length is measured from tip to base of leaf by using a measuring scale and expressed in centimetre.

e) Leaf breadth

Measured from the broadest point on the lamina of the leaf and expressed in centimetre

f) Petiole length

Length measured from point attachment of petiole to leaf base and expressed in centimetre

g) Pigmentation at node

Observed on the node of mature leaf.

h) Days to 50% flowering

Number of days from date of transplanting to date when 50% plants show first flower opening.

i) Corolla colour

Recorded immediately after flower opening.

j) Number of flowers per axil

Observed as average of 5 random axils at flowering stage.

k) Days to 50% fruiting

Number of days from date of transplanting to date to 50% plants showing fruit initiation.

3.2.2.2. FRUIT CHARACTERS

a) Fruit position

Recorded at mature fruit stage.

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b) Mature fruit colour

Recorded at mature fruit stage.

c) Ripe fruit colour

Recorded on ripe fruits.

d) Fruit shape

Recorded at mature fruit stage.

e) Fruit length

Measured from base to tip of the fruit by using a thread and expressed in centimetre

f) Fruit width

Measured by using a vernier calliper at the middle of fruit and expressed in centimetre

g) Fruit pedicel length

Measured by using a scale and expressed in centimetre.

h) Fruit surface

Recorded at mature fruit stage.

i)Fruit weight

Weight of ripe red fruits were recorded by using an electronic balance and expressed in grams.

j) Placenta length

Length of placenta taken frombase to tip on ripe fruits and expressed in centimetre.

k) Placenta weight

Placenta separated from fruits and weight recorded by using an electronic balance and expressed in grams.

l) Number of fruits per plant

Total number of fruits produced per plant was counted.

m) Pericarp weight

Seeds and placenta removed from fruits and weight of pericarp taken by using an electronic balance and expressed in grams.

n) Pericarp thickness

Recorded from middle of fruits by using avernier calliper and expressed in millimetre.

o) Seed number

Seed number per individual fruits were counted.

p) Fruit yield per plant

Cumulative yield of all pickings at ripe fruit stage (fresh) was taken and expressed in gram.

q) Dry weight per fruit

Dry weight (g) of individual fruits taken by an electronic balance.

r) Dry fruit yield per plant

Harvested fruits from all pickings of a plant were dried in a drier and weight (g) was recorded.

s) Driage

Driage (%) is calculated as

$$\frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

t) Seed colour

Recorded at dry seed stage.

3.2.2.3. Incidence of bacterial wilt (%)

Calculated as

$$\frac{\text{Number of bacterial wilt affected plants}}{\text{Total number of plants}} \times 100$$

3.2.2.4. Other pests and diseases

Incidence of other pests and diseases were observed.

B) EVALUATION OF CHILLI ACCESSIONS FOR BIOCHEMICALCHARACTERS

Materials

Fruits harvested at red ripe stage were dried in a drier at 50° C, powdered using a grinder and sieved to get fine powder.

Methods

Biochemical analysis for estimation of capsaicin, oleoresin and colour value of each chilli genotype was done by using standard procedure as given below.

Capsaicin (%)

Capsaicin in chilli was estimated by colorimetric method (Sadasivam and Manickam, 1992).

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Procedure

- Weigh 0.5g dry chilli powder into a glass stoppered test tube or volumetric flask.
- Pipette out 10ml dry acetone into the flask and shake it for 3hr in a mechanical shaker. Let the contents settle down or centrifuge (10000rpm for 10min).
- Pipette out 1ml of the clear supernatant into a test tube and evaporate to dryness in a hot water bath.
- Dissolve the residue in 5ml of 0.4% sodium hydroxide solution.
- Add 3 ml of 3% phosphomolybdic acid.
- Shake the contents and let stand for 1hr.
- Filter the solution quickly into centrifuge tubes to remove any floating debris.
- Centrifuge at about 5000rpm for 10-15min.
- Transfer the clear blue coloured solution directly into the cuvette and read the absorbance at 650nm.
- Run a reagent blank along with the test samples.
- Prepare a standard graph using 0-200 µg capsaicin simultaneously i.e., pipette out 0.2, 0.4, 0.6, 0.8 and 1ml of working standard solution and proceed as above.

Oleoresin (%)

Oleoresin in chilli was extracted in a Soxhlet 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. Two grams of chilli powder was weighed and packed in filter paper and placed in a Soxhlet apparatus. Two hundred ml of acetone was taken in the round bottom flask of the apparatus and heated in a water 45 bath. The temperature was maintained at boiling point of solvent. After complete extraction (7 to 8 hr), the solvent was evaporated to dryness under vacuum.

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

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

Colour value (ASTA colour units)

Colour value was estimated by measuring the absorbance of alcoholic extract of chilli at 450 nm. (ASTA, 1985).

Procedure

- 100mg of finely powdered chilli sample was taken in a 250ml conical flask.
- 100ml of isopropanol was added and the flask was stoppered tightly.
- The contents were swirled and kept overnight for 16 hours at room temperature.
- The extract was cooled to room temperature and filtered through whatsman No. 12 filter paper.
- The first 10ml of the extract was discarded.
- 25ml of ensuing extract was transferred to cell and it's absorbance was measured at 450nm.

Extractable colour in ASTA units was calculated by using the following formula

$$\frac{\text{Absorbance of chilli extract at 450nm X 200}}{\text{Absorbance of potassium dichromate solution at 450nm}}$$

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Results

4. RESULTS

The investigation on 'Screening of spice chilli (*Capsicum annuum* L.) genotypes suitable for Kerala' was studied in the department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Thrissur, during 2014-2016. The results of the study are described in this chapter.

4.1. MORPHOLOGICAL CHARACTERS

4.1.1. Quantitative characters

4.1.1.1. Plant characters

Mean performance of chilli genotypes (35 numbers) for different plant and yield characters are presented in table 2 - 4.

Plant height

Plant height is a good indicator of the process of growth and development. The results of the present study implied that the differences obtained among different genotypes in relation to plant height were statistically significant. Plant height ranged from 49.2 cm to 120.25 cm. Accession CA 22 recorded maximum plant height (120.25 cm) followed by CA 28 (109.6 cm), CA 29 (103.8 cm) and CA 27 (103.02 cm). The minimum plant height (49.2 cm) was observed for accession CA 31, followed by CA 25 (54.55 cm) which was on par with CA 32 (54.85 cm) (Table 2).

Leaf length

Considerable variability was observed with regard to leaf length ranging from 3.69 to 9.81 cm (Table 2). Genotype CA 27 recorded highest leaf length (9.81 cm), followed by CA 30 (9.51 cm) whereas CA 3 recorded lowest leaf length (3.69 cm) followed by CA 8 (4.09 cm).

Leaf breadth

Distinguishable difference was observed with respect to leaf breadth among the genotypes studied (Table 2). The genotype CA 6 recorded maximum leaf breadth (4.28 cm), followed by CA 18 (3.31 cm). Minimum leaf breadth was recorded by CA 19 (1.4 cm) followed by CA 31 (1.5 cm).

Petiole length

Considerable differences were noticed for petiole length (Table 2). The highest petiole length noticed for genotype CA 30 was 3.42 cm, followed by CA 32 (3.15 cm). Lowest petiole length was noticed for CA 2 (1.03 cm), followed by CA 10 (1.09 cm); which were on par with CA 8 (1.13 cm).

Days to 50% flowering

Earliness in flowering is one of the important attribute to be included in crop improvement programme. Early flowering was noticed in CA 25 (32 days after transplanting) followed by CA 21 (34 days), CA 15 and CA 17 (36 days) which was on par with CA 27 (36.5 days). The accessions CC 1, CC 2 and CC 3 were found to be late in flowering. Genotype CC 3 took 79 days to flower which was on par with CA 16 (77 days) followed by CC 2 (72.5 days) and CA 13 (72.5 days) which was on par with CC 1 (70.00 days) (Table 2).

Days to 50% fruiting

Days to 50% fruiting after transplanting was minimum in CA 25 (37 days after transplanting), followed by CA 21 (38.5 days), CA 15 and CA 17 (41 days). CA 27 (41.5 days)was on par with it. Maximum days to 50 % fruiting were observed in CC 3 and CA 16 (83 days), followed by CC 2 (77 days) and CA 13 which was on par with CC 1 (75 days)(Table 2).

Table 2: Mean performance of chilli genotypes for different plant characters

Genotypes	Plant height (cm)	Leaf length (cm)	Leaf breadth (cm)	Petiole length (cm)	Days to 50% flowering	Days to 50% fruiting
CA 1	69.87^{g-m}	5.11^{qr}	2.05^{l-n}	1.86^{k}	54.00^{ef}	60.00^{e}
CA 2	82.85^{c-j}	4.25^{x}	1.97^{qr}	1.03^{t}	45.50^{ij}	50.50^{hi}
CA 3	71.55^{g-m}	3.69^{z}	1.97^{qr}	1.82^{k}	43.50^{jk}	47.50^{j}
CA 4	73.05^{f-m}	5.76^{l}	2.05^{l-n}	2.21^{e}	47.50^{hi}	51.00^{h}
CA 5	55.80^{k-m}	5.07^{rs}	1.96^{q-s}	2.11^{f}	37.50^{mn}	41.50^{mn}
CA 6	85.70^{b-j}	4.41^{w}	4.28^{a}	2.21^{e}	42.50^{k}	46.50^{jk}
CA 7	78.95^{c-l}	4.62^{v}	1.94^{rs}	1.57^{l}	38.00^{mn}	44.00^{k-m}
CA 8	71.10^{g-m}	4.09^{y}	1.36^{u}	1.13^{s}	39.50^{lm}	45.50^{j-l}
CA 9	73.10^{f-m}	5.06^{rs}	2.55^{g}	1.48^{n}	41.00^{kl}	47.00^{j}
CA 10	88.55^{b-i}	5.36^{m}	2.03^{m-p}	1.09^{s}	38.00^{mn}	43.00^{l-n}
CA 11	89.90^{b-h}	5.09^{qr}	2.27^{k}	1.47^{n}	41.00^{kl}	46.00^{jk}
CA 12	97.50^{a-f}	5.28^{n}	1.97^{qr}	2.09^{fg}	42.00^{kl}	47.50^{j}
CA 13	99.45^{a-e}	5.93^{ij}	2.38^{j}	2.27^{d}	72.50^{b}	77.00^{b}
CA 14	78.65^{c-l}	5.02^{st}	1.99^{o-q}	1.31^{op}	46.50^{i}	51.00^{h}
CA 15	80.70^{c-k}	5.86^{k}	1.92^{s}	2.05^{g-i}	36.00^{n-p}	41.00^{n-p}
CA 16	98.83^{a-e}	4.61^{v}	2.07^{lm}	1.19^{r}	77.50^{a}	83.00^{a}
CA 17	77.13^{e-l}	6.01^{h}	2.02^{n-p}	1.53^{lm}	36.50^{n-p}	41.00^{n-p}
CA 18	71.46^{g-m}	5.35^{m}	3.31^{b}	2.11^{f}	57.50^{d}	63.00^{d}
CA 19	63.92^{i-m}	5.90^{jk}	1.40^{u}	2.07^{f-h}	37.50^{mn}	43.00^{l-n}
CA 20	55.26^{k-m}	5.21^{op}	2.09^{l}	1.95^{j}	52.00^{fg}	56.50^{fg}
CA 21	55.25^{k-m}	5.98^{hi}	1.94^{rs}	2.01^{i}	34.00^{o-q}	38.50^{o-q}
CA 22	120.25^{a}	5.13^{q}	1.97^{qr}	1.50^{mn}	42.50^{k}	48.00^{ij}
CA 23	94.05^{b-g}	4.91^{u}	3.05^{d}	2.05^{g-i}	46.00^{ij}	51.50^{h}
CA 24	82.650^{c-j}	6.19^{g}	2.47^{hi}	2.09^{fg}	50.00^{gh}	54.50^{g}
CA 25	54.55^{l-m}	6.27^{f}	2.63^{f}	1.47^{n}	32.50^{q}	37.50^{q}
CA 26	91.680^{b-j}	5.23^{n-p}	2.44^{i}	2.03^{hi}	55.50^{de}	60.00^{e}
CA 27	103.02^{a-d}	9.81^{a}	2.52^{g}	1.57^{l}	36.50^{n-p}	41.50^{mn}
CA 28	109.60^{ab}	4.97^{t}	2.51^{gh}	2.62^{c}	52.50^{fg}	57.50^{ef}
CA 29	103.80^{a-c}	5.91^{jk}	3.19^{c}	2.04^{hi}	52.50^{fg}	58.00^{ef}
CA 30	62.35^{j-m}	9.51^{b}	2.76^{e}	3.42^{a}	62.50^{c}	68.50^{c}
CA 31	49.20^{m}	7.50^{d}	1.50^{t}	2.05^{g-i}	52.50^{fg}	57.50^{ef}
CA 32	54.85^{l-m}	7.84^{c}	2.35^{j}	3.15^{b}	51.50^{fg}	57.50^{ef}
CC 1	64.61^{h-m}	5.10^{qr}	3.07^{d}	1.51^{mn}	70.00^{b}	75.00^{b}
CC 2	75.70^{e-l}	5.23^{n-p}	2.79^{e}	1.49^{mn}	72.50^{b}	77.00^{b}
CC 3	77.89^{d-l}	6.99^{e}	3.08^{d}	1.25^{q}	79.00^{a}	83.00^{a}
CD (0.05)	25.71	0.05	0.05	0.04	2.98	2.99

4.1.1.2. Fruit characters

Data pertaining to the fruit and yield characters are presented in table 3(a) & 3(b) respectively.

Fruit length

In chilli, fruit length is an important trait influencing market value. Considerable variability was observed for fruit length among the genotypes studied. Fruit length was highest in CA 29 (12.3 cm) which was on par with CA 32 (12.03 cm) and CA 31 (11.62 cm). Lowest fruit length was observed for CC 1 (3.85 cm) which was on par with CC 3 (3.91 cm), CA 30 (3.97 cm) and CC 2 (4.0 cm) (Table 3a).

Fruit width

Fruit width was maximum (2.32 cm) in CA 23 which was on par with CC 2 (2.01 cm), CC 1 (1.98 cm) and CC 3 (1.98 cm). Lowest fruit width was observed in CA 14 (0.61 cm), followed by CA 6 (0.68 cm).

Fruit pedicel length

Highest pedicel length was found for the genotype CA 21 (4.09 cm), followed by CA 4 (3.97 cm) and lowest in CA 1 (1.14 cm)followed by CA 11 (2.31 cm).

Fruit weight

Maximum fruit weight was observed for CA 23 (13.31 g)followed by CA 29 (12.43 g) which was on par with CA 32 (11.93g). Minimum fruit weight was noticed in CA 26 (2.31 g), followed by CA 12 (2.42 g), CA 7 (2.67 g) which was on par with CA 30 (2.69 g) and CA 8 (2.82 g).

Number of fruits per plant

Considerable differences were observed for number of fruits per plant. Maximum number of fruits per plant was observed in the genotype CA 7 (45.4) which was followed by CA 22 (45.3), CA 19 (44) and CA 25(42.4). Minimum number of fruits per plant was obtained in CA 29 (11.9) which was followed by CA 24 (14.7), CA 23 (15.5), CA 2(15.6) and CA 6 (15.8).

Placenta length

Placenta length was highest in CA 29 (12.3 cm) which was on par with CA 32 (12.03 cm) and CA 31 (11.62 cm). Lowest placenta length was observed for CC 1 (3.85 cm) which was on par with CC 3 (3.91 cm), CA 30 (3.97 cm) and CC 2 (4.0 cm) (Table 3b)

Placenta weight

Significant variation for placenta weight was observed among genotypes. The genotype CA 23 recorded highest placenta weight (1.75 g) and lowest for CA 30 (0.09 g).

Pericarp weight

Distinguishable variation was recorded for pericap weight among the genotypes studied. Maximum pericarp weight was observed for CA 23 (11.01g) followed by CA 29 (9.89 g) and CA 32 (8.57 g). Pericarp weight was minimum in CA 8 (2.01g) followed by CA 30 (2.13 g).

Pericarp thickness

Considerable variability was observed for pericarp thickness. The genotype CA 23 recorded highest pericarp thickness (2.56 mm) followed by CA 29 (1.96 mm) and CC 2 (1.71 mm). CC 1 and CA 28 were on par with respect to pericarp thickness (1.57 mm and 1.54 mm respectively). Lowest pericarp thickness was observed for CA 8 (0.25 mm) followed by CA 4 (0.4mm).

Seed number per fruit

Maximum seed number per fruit was observed for CA 23 (125.8) followed by CA 29 (95.2) and CA 25 (89.9). Minimum number of seeds were observed for CC3 (17.8) followed by CC 1 (20.7), CC 2 (24.4) and CA 19 (37.00).

Fresh fruit yield per plant

Significant variation was observed for ripe fruit yield (fresh) per plant among the genotypes studied. The accession CA 32 recorded highest yielding (318.6 g) followed by CA 25 (234.16 g) which was on par with CA 22 (227.74 g) and followed by CA 23 (206.1 g). CA 26 was the lowest yielding (39.72 g) which was on par with CA 24 (42.44 g), followed by CA 21 (54.1 g) (Table 4).

Dry weight per fruit

Notable variability was observed for dry weight among the genotypes studied (Table 4). Highest dry weight per fruit was observed for CA 23 (1.96 g) followed by CA 13 (1.47 g) and CA 29 (1.4 g). Dry weight of individual fruit was lowest in CA 14 (0.3 g) followed by CA 6 (0.43 g) which was on par with CA 8 (0.45 g) and CA 30 (0.45 g).

Dry fruit yield per plant

Considerable variation was observed for dry fruit yield per plant (Table 4) and among the genotypes investigated, maximum dry yield per plant was recorded for CA 13 (47.53 g) followed by CA 16 (39.82 g) which was on par with CA 22 (39.75 g). It was followed by CA 17 (36.31 g) which was on par with CA 18 (34.95 g), CC 1 (34.78 g) and CA 32 (34.77 g). Lowest dry yield was recorded in CA 14 (5.6g) followed by CA 6 (6.92 g) and CA 2 (8.43 g). 53

Driage

Distinct variation was recorded with respect to driage and among the genotypes, CA 26 recorded maximum driage (39.51 %), followed by CA 10 (36.53 %) and CA 12 (33.6 %) (Table 4). Minimum driage was recorded in CA 14 (7.14 %) followed by CA 6 (8.7 g) and CA 32 (10.82 g).

Table 3 (a): Fruit characters of chilli genotypes

Genotypes	Fruit length (cm)	Fruit width (cm)	Pedicel length (cm)	Fruit weight (fresh) (g)	Number of fruits/plant
CA 1	5.86^{n-q}	0.89^{g-k}	1.14^{j}	3.08^{l-n}	24.80^{l}
CA 2	7.01^{j-m}	1.00^{e-j}	2.80^{c-i}	3.95^{h-j}	15.60^{r}
CA 3	5.12^{qr}	1.29^{c-f}	3.16^{a-i}	4.35^{gh}	19.80^{mn}
CA 4	9.21^{ce}	0.86^{g-k}	3.97^{ab}	4.43^{gh}	17.30^{n-r}
CA 5	6.83^{k-n}	1.00^{e-j}	3.75^{a-d}	4.10^{g-i}	17.10^{n-r}
CA 6	7.41^{h-k}	0.68^{jk}	2.73^{e-i}	5.00^{ef}	15.80^{qr}
CA 7	8.92^{ef}	1.61^{bc}	3.24^{a-i}	2.67^{n-q}	45.40^{a}
CA 8	6.29^{l-p}	1.00^{e-j}	2.80^{c-i}	2.82^{n-q}	41.90^{c}
CA 9	7.13^{j-m}	1.54^{cd}	2.50^{hi}	5.84^{d}	20.60^{m}
CA 10	8.26^{e-i}	0.90^{g-k}	3.18^{a-i}	3.18^{l-n}	20.80^{m}
CA 11	7.97^{f-j}	1.04^{e-j}	2.31^{i}	4.12^{g-i}	34.70^{ef}
CA 12	6.31^{l-p}	0.94^{f-k}	3.37^{a-h}	2.42^{o-q}	32.90^{fg}
CA 13	6.15^{m-p}	0.83^{g-k}	3.46^{a-h}	5.73^{d}	32.20^{f-h}
CA 14	7.32^{i-k}	0.61^{k}	3.08^{b-i}	4.27^{g-i}	18.90^{m-p}
CA 15	7.20^{j-l}	0.81^{h-k}	3.54^{a-g}	4.61^{fg}	33.60^{ef}
CA 16	7.91^{g-j}	1.09^{e-i}	3.11^{a-i}	5.72^{d}	30.20^{g-i}
CA 17	10.47^{b}	0.97^{e-k}	2.63^{f-i}	5.76^{d}	28.90^{ij}
CA 18	7.97^{f-j}	1.186^{d-g}	2.82^{c-i}	7.66^{c}	25.50^{kl}
CA 19	5.78^{o-q}	0.88^{g-k}	2.94^{c-i}	3.80^{i-k}	44.00^{a-c}
CA 20	4.41^{rs}	1.31^{c-e}	3.77^{a-c}	3.43^{j-l}	18.60^{m-q}
CA 21	6.58^{k-p}	0.94^{f-k}	4.09^{a}	3.35^{k-m}	16.30^{o-r}
CA 22	10.19^{bc}	0.98^{e-j}	3.14^{a-i}	5.01^{ef}	45.30^{ab}
CA 23	9.03^{de}	2.32^{a}	3.11^{a-i}	13.31^{a}	15.50^{r}
CA 24	7.47^{h-k}	0.99^{e-j}	3.08^{b-i}	2.90^{m-p}	14.70^{rs}
CA 25	9.97^{b-d}	1.13^{e-h}	2.92^{c-i}	5.52^{de}	42.40^{bc}
CA 26	8.72^{e-g}	0.73^{i-k}	3.01^{b-i}	2.31^{q}	17.10^{n-r}
CA 27	8.81^{e-g}	0.85^{g-k}	3.04^{b-i}	4.31^{g-i}	25.00^{l}
CA 28	8.31^{e-h}	1.02^{e-j}	3.48^{a-h}	4.22^{g-i}	28.00^{i-k}

CA 29	12.30^{a}	1.96^{ab}	3.62^{a-e}	12.43^{b}	11.90^{s}
CA 30	3.97^{s}	1.06^{e-i}	3.14^{a-i}	2.69^{n-q}	38.00^{d}
CA 31	11.62^{a}	0.94^{f-k}	3.08^{b-i}	3.06^{l-n}	29.60^{h-j}
CA 32	12.03^{a}	1.02^{e-j}	2.57^{g-i}	11.93^{b}	26.70^{j-l}
CC 1	3.85^{s}	1.98^{a}	2.80^{c-i}	3.47^{j-l}	35.90^{de}
CC 2	4.0^{s}	2.01^{a}	2.78^{d-i}	3.48^{j-l}	27.60^{i-l}
CC 3	3.91^{s}	1.98^{a}	3.56^{a-f}	3.42^{k-m}	21.30^{m}
CD (0.05)	0.98	0.36	0.98	0.52	2.97

Table 3 (b):Fruit characters of chilli genotypes

Genotypes	Placenta length (cm)	Placenta weight (g)	Pericarp weight (g)	Pericarp thickness (mm)	Seed number/fruit
CA 1	5.86^{n-q}	0.28^{m}	2.42^{t}	1.05^{h}	67.00^{j}
CA 2	7.01^{j-m}	0.18^{uv}	3.01^{n}	1.02^{h}	83.40^{e}
CA 3	5.12^{qr}	0.27^{n}	2.85^{op}	0.94^{ij}	71.00^{hi}
CA 4	9.21^{ce}	0.38^{h}	2.63^{r}	0.40^{s}	66.90^{j}
CA 5	6.83^{k-n}	0.23^{q}	4.14^{ij}	0.72^{mn}	52.20^{q}
CA 6	7.41^{h-k}	0.29^{lm}	3.94^{k}	0.97^{i}	65.30^{jk}
CA 7	8.92^{ef}	0.18^{tu}	2.36^{u}	0.58^{r}	79.60^{f}
CA 8	6.29^{l-p}	0.15^{w}	2.01^{x}	0.25^{t}	49.00^{rs}
CA 9	7.13^{j-m}	0.48^{f}	3.76^{l}	1.46^{e}	71.00^{hi}
CA 10	8.26^{e-i}	0.42^{g}	2.76^{q}	1.28^{f}	66.70^{j}
CA 11	7.97^{f-j}	0.22^{qr}	2.41^{t}	0.91^{jk}	63.50^{kl}
CA 12	6.31^{l-p}	0.31^{jk}	2.20^{v}	0.84^{l}	75.20^{g}
CA 13	6.15^{m-p}	0.30^{kl}	5.65^{f}	0.69^{n-p}	55.30^{n}
CA 14	7.32^{i-k}	0.198^{s}	4.08^{j}	0.80^{l}	53.00^{o-q}
CA 15	7.20^{j-l}	0.19st	4.25^{hi}	0.95^{i}	47.30^{s}
CA 16	7.91^{g-j}	0.38^{h}	5.14^{g}	1.10^{g}	48.10^{rs}
CA 17	10.47^{b}	0.16^{vw}	5.97^{e}	0.68^{o-p}	82.80^{e}
CA 18	7.97^{f-j}	0.56^{c}	6.13^{d}	1.28^{f}	72.40^{h}
CA 19	5.78^{o-q}	0.13^{x}	3.53^{m}	1.05^{h}	37.00^{t}
CA 20	4.41^{rs}	0.23^{qr}	3.08^{n}	1.27^{f}	66.60^{j}
CA 21	6.58^{k-p}	0.19^{s-u}	2.14^{w}	0.67^{q}	86.60^{d}
CA 22	10.19^{bc}	0.31^{jk}	4.13^{ij}	0.88^{k}	75.90^{g}
CA 23	9.03^{de}	1.75^{a}	11.01^{a}	2.56^{a}	125.80^{a}
CA 24	7.47^{h-k}	0.22^{r}	2.28^{v}	0.95^{i}	49.50^{r}
CA 25	9.97^{b-d}	0.29^{lm}	4.36^{h}	0.70^{n-p}	89.90^{c}
CA 26	8.72^{e-g}	0.22^{r}	1.93^{x}	0.89^{k}	70.10^{i}

CA 27	8.81^{e-g}	0.57^{d}	3.05^{n}	0.96^{i}	54.70^{n-p}
CA 28	8.31^{e-h}	0.30^{kl}	4.15^{ij}	1.54^{d}	60.30^{m}
CA 29	12.30^{a}	1.17^{c}	9.89^{b}	1.96^{b}	95.20^{b}
CA 30	3.97^{s}	0.09^{y}	2.13^{w}	0.95^{i}	62.60^{l}
CA 31	11.62^{a}	0.25^{op}	2.21^{v}	0.75^{m}	47.00^{s}
CA 32	12.03^{a}	1.41^{b}	8.57^{c}	0.97^{i}	79.20^{f}
CC 1	3.85^{s}	0.32^{ij}	2.45^{t}	1.57^{d}	20.70^{v}
CC 2	4.0^{s}	0.33^{i}	2.15^{w}	1.71^{c}	24.40^{u}
CC 3	3.910^{s}	0.31^{jk}	2.53^{s}	1.46^{e}	17.80^{w}
CD (0.05)	0.98	0.01	0.13	0.04	2.00

Table 4: Yield characters of chilli genotypes

Genotypes	**Fresh fruit yield/plant (g)**	**Dry fruit weight (g)**	**Dry yield / plant (g)**	**Driage (%)**
CA 1	75.51^{m-q}	0.63^{rs}	15.71^{lm}	20.86^{h-k}
CA 2	61.78^{qr}	0.53^{u}	8.43^{n-q}	13.85^{r-u}
CA 3	85.58^{k-m}	0.76^{mn}	15.05^{lm}	17.63^{k-q}
CA 4	76.38^{m-q}	0.55^{tu}	9.68^{n-p}	12.55^{s-u}
CA 5	69.52^{m-r}	1.02^{g}	17.57^{j-l}	25.58^{fg}
CA 6	79.02^{l-q}	0.43^{v}	6.92^{o-q}	8.70^{vw}
CA 7	120.40^{hi}	0.61^{rs}	28.62^{de}	23.30^{g-i}
CA 8	117.97^{hi}	0.45^{v}	18.77^{i-k}	16.29^{m-s}
CA 9	120.18^{hi}	0.99^{gh}	20.56^{hi}	17.15^{k-r}
CA 10	66.33^{n-r}	1.12^{f}	23.01^{gh}	36.53^{ab}
CA 11	142.97^{g}	0.78^{lm}	27.21^{ef}	19.21^{j-m}
CA 12	80.43^{l-p}	0.80^{lm}	26.58^{ef}	33.60^{bc}
CA 13	184.89^{de}	1.47^{b}	47.53^{a}	26.22^{e-g}
CA 14	80.64^{l-p}	0.30^{w}	5.60^{q}	7.14^{w}
CA 15	155.87^{fg}	0.60^{st}	20.22^{h-j}	14.02^{q-u}
CA 16	170.37^{ef}	1.31^{de}	39.82^{b}	23.85^{g-i}
CA 17	168.44^{ef}	1.27^{e}	36.31^{c}	22.52^{g-j}
CA 18	195.24^{cd}	1.36^{cd}	34.95^{c}	17.81^{k-p}
CA 19	167.32^{ef}	0.66^{qr}	29.28^{de}	17.55^{k-r}
CA 20	63.43^{o-r}	0.70^{n-q}	13.21^{m}	20.78^{h-k}
CA 21	54.10^{rs}	0.61^{rs}	9.95^{n}	19.00^{j-n}
CA 22	227.74^{b}	0.87^{jk}	39.75^{b}	17.90^{k-p}
CA 23	206.10^{c}	1.96^{a}	30.63^{d}	14.89^{o-t}

CA 24	42.44^{s}	0.69^{o-q}	10.09^{n}	24.26^{gh}
CA 25	234.16^{b}	0.83^{kl}	35.29^{c}	15.36^{n-s}
CA 26	39.72^{s}	0.90^{ij}	15.48^{lm}	39.51^{a}
CA 27	107.77^{h-j}	0.98^{gh}	24.69^{fg}	23.37^{g-i}
CA 28	117.77^{hi}	1.08^{f}	30.21^{d}	25.84^{fg}
CA 29	148.14^{g}	1.40^{c}	16.77^{kl}	11.29^{tv}
CA 30	102.30^{i-k}	0.45^{v}	16.98^{kl}	16.73^{l-r}
CA 31	84.53^{k-n}	0.95^{hi}	28.17^{de}	31.88^{cd}
CA 32	318.60^{a}	1.30^{e}	34.77^{c}	10.89^{uv}
CC 1	123.97^{h}	0.97^{gh}	34.78^{c}	28.35^{d-f}
CC 2	96.18^{j-l}	0.72^{n-p}	20.01^{ij}	20.37^{i-l}
CC 3	74.15^{m-q}	0.99^{gh}	20.86^{hi}	29.75^{de}
CD (0.05)	18.29	0.06	2.86	3.75

4.1.1.3. Incidence of pest and diseases

Only bacterial wilt disease was observed in the chilli field. No other serious pest and diseases was noticed.

Bacterial wilt incidence (%)

Data on incidence of bacterial wilt disease is described in table 5 and significant variation was observed for the disease incidence among the genotypes. It was a severe problem in CA 15 (85%), followed by CA 14 (70 %) and CA 6 (50 %). Bacterial wilt was not observed (0%) in CA 4, CA 16, CA 22, CA 23, CC I, CC 2, CC 3, CA 30, CA 31 and CA 32. Low wilt incidence was noted in CA 8 (10 %), CA 27 (10 %), CA 28 (10 %), CA 18 (15 %), and CA 29 (15 %).

Table 5: Bacterial wilt disease incidence in chilli genotypes.

Genotypes	Wilt (%)
CA 1	20.00^{e-h}
CA 2	30.00^{c-g}
CA 3	35.00^{c-f}
CA 4	0.00^{h}
CA 5	45.00^{cd}
CA 6	50.00^{bc}
CA 7	30.00^{c-g}

CA 8	10.00^{gh}
CA 9	40.00^{c-e}
CA 10	40.00^{c-e}
CA 11	40.00^{c-e}
CA 12	40.00^{c-e}
CA 13	20.00^{e-h}
CA 14	70.00^{ab}
CA 15	85.00^{a}
CA 16	0.00^{h}
CA 17	50.00^{bc}
CA 18	15.00^{f-h}
CA 19	50.00^{bc}
CA 20	50.00^{bc}
CA 21	40.00^{c-e}
CA 22	0.00^{h}
CA 23	0.00^{h}
CA 24	25.00^{d-g}
CA 25	20.00^{e-h}
CA 26	45.00^{cd}
CA 27	10.00^{gh}
CA 28	10.00^{gh}
CA 29	15.00^{f-h}
CA 30	0.00^{h}
CA 31	0.00^{h}
CA 32	0.00^{h}
CC 1	0.00^{h}
CC 2	0.00^{h}
CC 3	0.00^{h}
CD (0.05)	22.94

4.1.2. Qualitative characters

4.1.2.1. Plant characters

The genotypes were characterized based on the qualitative characters and the plant characters observed are presented in table 6.

Stem colour

Distinct variation was observed with respect to stem colour among the genotypes studied. It was observed that majority of genotypes are having green stem colour. Stem colour was light green in CA 2, CC 1, CC 2, CC 3 and CA 31. It was dark green in CA 1, CA 17 and CA 29.

Leaf colour

Considerable variation was observed with respect to leaf colour among the genotypes investigated. Leaf colour ranged from light green (CA 2, CC 1, CC 2, CC 3 and CA 31) to green (CA 5, CA 10, CA 11, CA 12, CA 13, CA 18, CA 20, CA 21, CA 22, CA 24, CA 25, CA 26, CA 27, CA 28, CA 30 and CA 32) to dark green (CA 1, CA3, CA 4, CA 6, CA 7, CA 8, CA 9, CA 14, CA 15, CA 16, C A 17, CA 19, CA 23 and CA 29).

Corolla colour

No variation was observed with respect to corolla colour in the genotypes studied and it was white in all the genotypes.

Pigmentation at node

Variability was observed among genotypes with regard to pigmentation at node. No pigmentation was observed in CA 4, CA 8, CA 9, CA 10, CA 11, CA 14, CC 1, CA 24, CC 2 and CC 3. All other genotypes were showing purple pigmentation at leaf node.

Table 6: Qualitative characters of chilli genotypes.

Genotypes	Stem colour	Leaf colour	Corolla colour	Pigmentation at node
CA 1	Dark green	Dark Green	White	Present
CA 2	Light green	Light Green	White	Present
CA 3	Green	Dark Green	White	Present
CA 4	Green	Dark Green	White	Absent
CA 5	Green	Green	White	Present

CA 6	Green	Dark Green	White	Present
CA 7	Green	Dark Green	White	Present
CA 8	Green	Dark Green	White	Absent
CA 9	Green	Dark Green	White	Absent
CA 10	Green	Green	White	Absent
CA 11	Green	Green	White	Absent
CA 12	Green	Green	White	Present
CA 13	Green	Green	White	Present
CA 14	Green	Dark green	White	Absent
CA 15	Green	Dark green	White	Present
CA 16	Green	Dark green	White	Present
CA 17	Dark green	Dark green	White	Present
CA 18	Green	Green	White	Present
CA 19	Green	Dark green	White	Present
CA 20	Green	Green	White	Present
CA 21	Green	Green	White	Present
CA 22	Green	Green	White	Present
CA 23	Green	Dark green	White	Present
CA 24	Green	Green	White	Absent
CA 25	Green	Green	White	Present
CA 26	Green	Green	White	Present
CA 27	Green	Green	White	Present
CA 28	Green	Green	White	Present
CA 29	Dark green	Dark green	White	Present
CA 30	Green	Green	White	Present
CA 31	Light green	Light green	White	Present
CA 32	Green	Green	White	Present
CC 1	Light green	Light green	White	Absent
CC 2	Light green	Light green	White	Absent
CC 3	Light green	Light green	White	Absent

4.1.2.2. Fruit characters

Data pertaining to the qualitative characters of the fruit like colour, shape, position, seed colour *etc*. are presented in table 7.

Mature fruit colour

Distinct variation was observed for the mature fruit colour which varied from light green (CA1, CA 2, CA 9, CA 11, CA 12, CA 14, CC 1, CA 20, CA 22, CC 2, CC 3, CA 29, CA 31, CA 32) to green (CA 3, CA 4, CA 5, CA 7, CA 10, CA 16, CA

18, CA 21, CA 23, CA 24, CA 25, CA 26, CA 27, CA 28) and to dark green (CA 6, CA 8, CA 13, CA 15, CA 17, CA 19, CA 30).

Ripe fruit colour

Ripe fruit colour varied considerably from light red, red, and dark red. Majority of genotypes were red in colour where as some genotypes had light red fruit colour (CA 1, CA 2, CA 4, CA 7, CA 11, CA 12, CC 1, CA 22, CC 2, CC 3, CA 29, CA 31, CA 32) and dark red fruits (CA 6, CA 13, CA 19).

Fruit shape

Distinct variability was observed for fruit shape among the genotypes studied. Most of the chilli types were long fruited. It was long and tapering in CA 4, CA 7, CA 8, CA 11, CA 25, CA 26, CA 29, CA 31 and CA 32 where as long shaped fruits with blunt edge were observed in CA 9 and CA 23. In CA 5, fruit was long and curved. Genotypes CA 20, CC 1, CC 2 and CC3 recorded conical shaped fruits.

Fruit surface

Measurable variation was observed with respect to fruit surface. It was found to be varying from smooth (CA2, CA 5, CA 13, CA 15, CA 16, CA 18, CA 19, CA 20, CA 25, CA 27, CA 28, CA 29, CA 30) to semi wrinkled (CA 4, CA 8, CA 9, CA 10, CA 17, CA 21, CA 22, CA 23) and wrinkled (CA1, CA 3, CA 6, CA 7, CA 11, CA 12, CA 14, CC 1, CA 24, CC 2, CA 26, CC 3, CA 31, CA 32).

Fruit position

Most of the genotypes (80 %) recorded pendulous nature of fruit position. Some genotypes (CA 4, CC 1, CA 27 and CC 3) recorded semi pendulous nature while CA 20, CC 2 and CA 30 had erect nature of fruits.

Seed colour

Considerable variability was observed for seed colour among the genotypes investigated. Seed colour varied from light yellow (CA 8, CA 10, CA 11, CA 12, CA 13, CA 14, CA 17, CA 19, CA 24, CA 26, CA 27, CA 28) to deep yellow (CA 1, CA 2, CA 3, CA 4, CA 5, CA 6, CA 7, CA 15, CA 16, CC 1, CA 20, CA 21, CA 22, CA 23, CA 29, CA 30, CA 31, CA 32, CC 2 and CC 3) and light brown (CA 9, CA 18, CA 25). Twenty accessions (57%) recorded deep yellow seeds.

Table 7: Qualitative characters of the fruits of chilli genotypes

Genotypes	Mature fruit colour	Ripe fruit colour	Fruit shape
CA 1	Light green	Light red	Long
CA 2	Light green	Light red	Long
CA 3	Green	Red	Long
CA 4	Green	Light red	Long & tapering
CA 5	Green	Red	Long & curved
CA 6	Dark green	Dark red	Long
CA 7	Green	Light red	Long & tapering
CA 8	Dark green	Red	Long & tapering
CA 9	Light green	Red	Long, blunt edge
CA 10	Green	Red	Long
CA 11	Light green	Light red	Long, tapering
CA 12	Light green	Light red	Long
CA 13	Dark green	Dark red	Long
CA 14	Light green	Red	Long
CA 15	Dark green	Red	Long
CA 16	Green	Red	Long
CA 17	Dark green	Red	Long
CA 18	Green	Red	Very long
CA 19	Dark green	Dark red	Long
CA 20	Light green	Red	Conical
CA 21	Green	Red	Long
CA 22	Light green	Light red	Long,
CA 23	Green	Red	Long, blunt edge
CA 24	Green	Red	Long

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CA 25	Green	Red	Long and tapering
CA 26	Green	Red	Long and tapering
CA 27	Green	Red	Long
CA 28	Green	Red	Long
CA 29	Light green	Light red	Long and tapering
CA 30	Dark green	Red	Long
CA 31	Light green	Light red	Long and tapering
CA 32	Light green	Light red	Long and tapering
CC 1	Light green	Light red	Conical
CC 2	Light green	Light red	Conical
CC 3	Light green	Light red	Conical

Table 7 (Contd): Qualitative characters of the fruits of chilli genotypes

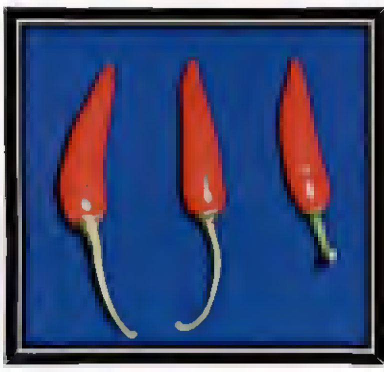
Genotypes	Fruit surface	Fruit position	Seed colour
CA 1	Wrinkled	Pendulous	Deep yellow
CA 2	Smooth	Pendulous	Deep yellow
CA 3	Wrinkled	Pendulous	Deep yellow
CA 4	Semi wrinkled	Semi pendulous	Deep yellow
CA 5	Smooth	Pendulous	Deep yellow
CA 6	Wrinkled	Pendulous	Deep yellow
CA 7	Wrinkled	Pendulous	Deep yellow
CA 8	Semi wrinkled	Pendulous	Light yellow
CA 9	Semi wrinkled	Pendulous	Light brown
CA 10	Semi wrinkled	Pendulous	Light yellow
CA 11	Wrinkled	Pendulous	Light yellow
CA 12	Wrinkled	Pendulous	Light yellow
CA 13	Smooth	Pendulous	Light yellow
CA 14	Wrinkled	Pendulous	Light yellow
CA 15	Smooth	Pendulous	Deep yellow
CA 16	Smooth	Pendulous	Deep yellow
CA 17	Semi wrinkled	Pendulous	Light yellow
CA 18	Smooth	Pendulous	Light brown
CA 19	Smooth	Pendulous	Light yellow
CA 20	Smooth	Erect	Deep yellow
CA 21	Semi wrinkled	Pendulous	Deep yellow
CA 22	Semi wrinkled	Pendulous	Deep yellow
CA 23	Semi wrinkled	Pendulous	Deep yellow

Plate 2: Variations in leaf characters

CA 23

CA 26

CA 8



CA 16

CA 31

CA 9

Plate 3: Variations in fruit characters

CA 24	Wrinkled	Pendulous	Light yellow
CA 25	Smooth	Pendulous	Light brown
CA 26	Wrinkled	Pendulous	Light yellow
CA 27	Smooth	Semi pendulous	Light yellow
CA 28	Smooth	Pendulous	Light yellow
CA 29	Smooth	Pendulous	Deep yellow
CA 30	Smooth	Erect	Deep yellow
CA 31	Wrinkled	Pendulous	Deep yellow
CA 32	Wrinkled	Pendulous	Deep yellow
CC 1	Wrinkled	Semi pendulous	Deep yellow
CC 2	Wrinkled	Erect	Deep yellow
CC 3	Wrinkled	Semi pendulous	Deep yellow

4.2. BIOCHEMICAL CHARACTERS

Now a days consumers are focussing on nutritional content and quality of the produce. Hence understanding the variations of bioactive compounds like capsaicin and oleoresin of chilli genotypes has great importance in developing better quality varieties through crop improvement programme. Data pertaining to biochemical characters like capsaicin, oleoresin and colour value studied are presented in table 8.

4.2.1. Capsaicin

Distinguishable variability was observed for capsaicin content among the genotypes studied. Capsaicin content ranged from 0.11 % to 1.09 %. Capsaicin content was more than 1 % in C. *chinense* types (CC 1, CC 2, and CC 3). The highest capsaicin content was recorded for CC 2 (1.09 %) which was on par with CC3 (1.06 %) followed by CC 1 (1.04 %). Among the *Capsicum annuum* types, CA 25 (0.95 %) and CA 16 (0.91%) recorded highest capsaicin content. The lowest capsaicin content was recorded for CA 6 (0.11%) followed by CA 26 (0.18) and CA 9 (0.20%).

4.2.2. Oleoresin

Oleoresin content was found to vary with the genotypes. The maximum content of oleoresin was observed in CC 2 (27.5 %) followed by CC 3 (25.50 %), CA 16 (25.25 %), CC 1 (24.00 %) and CA 1 (22.50 %) respectively. Minimum value for oleoresin content was recorded in CA 23 (7.50 %) followed by CA 14 (9.60 %) which was on par with CA 20 (10.00 %).

4.2.3. Colour value

Considerable variability was observed for colour value among the genotypes studied. The highest colour value was observed for CA 30 (131. 91 ASTA units) followed by CA 31 (119.47 ASTA units), CA 8 (114.84) which was on par with CA 32 (114.58). Colour value observed was lowest for CA 15 (26.07 ASTA units) which was on par with CA 25 (28.05 ASTA colour units) followed by CA 4 (36.29 ASTA Units) and CA 7 (39.27 ASTA units).

Table 8: Biochemical characters of chilli genotypes

Genotypes	Capsaicin (%)	Oleoresin (%)	Colour value (ASTA units)
CA 1	0.55^{e}	22.50^{b-d}	77.22^{jk}
CA 2	0.35^{fg}	20.85^{c-e}	100.29^{f}
CA 3	0.27^{g-j}	15.50^{h-k}	65.01^{mn}
CA 4	0.30^{f-i}	13.50^{j-l}	36.95
CA 5	0.39^{f}	13.75^{i-l}	110.65^{c-e}
CA 6	0.11^{k}	11.25^{l-n}	109.90^{c-e}
CA 7	0.31^{f-h}	12.97^{k-m}	39.27
CA 8	0.26^{g-j}	15.25^{h-k}	114.84^{bc}
CA 9	0.20^{i-k}	13.82^{i-l}	90.09^{gh}
CA 10	0.30^{f-h}	15.42^{h-k}	57.42^{o-q}
CA 11	0.22^{h-j}	11.50^{l-n}	106.27^{d-f}
CA 12	0.21^{h-k}	12.50^{k-n}	51.15
CA 13	0.61^{e}	20.20^{d-f}	111.22^{cd}
CA 14	0.77^{d}	9.60^{m-p}	81.84^{ij}
CA 15	0.73^{d}	16.92^{f-i}	26.07^{x}
CA 16	0.91^{c}	25.25^{ab}	86.79^{g-i}
CA 17	0.76^{d}	20.50^{de}	45.44

CA 18	0.56^{e}	16.52^{g-j}	74.91^{kl}
CA 19	0.54^{e}	13.50^{i-l}	43.56
CA 20	0.78^{d}	10.00^{m-p}	56.10
CA 21	0.36^{fg}	17.62^{e-h}	69.30^{lm}
CA 22	0.60^{e}	18.87^{e-g}	104.29^{ef}
CA 23	0.39^{f}	7.50^{op}	102.00^{f}
CA 24	0.36^{fg}	17.50^{e-h}	66.33^{mn}
CA 25	0.95^{bc}	20.02^{d-f}	28.05^{x}
CA 26	0.18^{jk}	12.50^{k-n}	73.26^{kl}
CA 27	0.56^{e}	13.80^{i-l}	88.77^{gh}
CA 28	0.22^{h-j}	13.85^{i-l}	62.37^{n-p}
CA 29	0.56^{e}	13.02^{k-m}	84.48^{hi}
CA 30	0.72^{d}	15.75^{g-k}	131.91^{a}
CA 31	0.60^{e}	13.50^{i-l}	119.47^{b}
CA 32	0.57^{e}	13.10^{k-m}	114.58^{bc}
CC 1	1.04^{ab}	24.00^{bc}	100.75^{f}
CC 2	1.09^{a}	27.50^{a}	103.36^{f}
CC 3	1.06^{a}	25.50^{ab}	91.25^{g}
CD (0.05)	0.10	3.35	6.49

4.3. CORRELATION ANALYSIS

Since yield is a complex trait, governed by a large number of component traits, it is imperative to know the interrelationships between yield and its component traits to arrive at an optimal selection index for improvement of yield. Correlation analysis was done with the characters viz., plant height, fruit length, fruit width, fruit weight, placenta length, placenta weight, number of fruits per plant, pericarp weight, pericarp thickness, dry yield, driage, capsaicin, oleoresin and colour value and the results presented in Table 9

Plant height

Plant height was not significantly correlated to any of the characters.

Fruit length

Fruit length was positively and significantly correlated with fruit weight, placenta length, placenta weight, pericarp weight and dry yield where as a significant negative correlation was observed with respect to oleoresin content.

Fruit width

Significant positive correlation was observed for fruit width with respect to fruit weight, placenta weight, pericarp weight, pericarp thickness and capsaicin content.

Fruit weight

Fruit weight was positively and significantly correlated to fruit length, fruit width, placenta length, placenta weight, pericarp weight, pericarp thickness and dry yield. Significant negative correlation was found with respect to number of fruits per plant and driage.

Placenta length

Significant positive correlation was observed between placenta length and fruit length, fruit weight, placenta weight, pericarp weight and dry yield where as significant negative correlation was found with respect to oleoresin content.

Placenta weight

Significant positive correlation was observed for placenta weight with fruit length, fruit width, fruit weight, placenta length, pericarp weight and pericarp thickness. Significant negative correlation was found with respect to number of fruits per plant, driage and oleoresin content.

Number of fruits per plant

Number of fruits per plant was significantly and positively correlated to dry yield and capsaicin content while it was negatively and significantly correlated to fruit weight, placenta weight and pericarp thickness.

Pericarp weight

Significant positive correlation was observed for pericarp weight with pericarp thickness, dry yield, fruit length, fruit width, fruit weight, placenta length and placenta weight. A significant negative correlation was found with respect to driage.

Pericarp thickness

Pericarp thickness was significantly and positively correlated to fruit width, fruit weight, placenta weight and pericarp weight. A significant negative correlation was found with respect to number of fruits per plant.

Dry yield

Significant positive correlation was observed for dry yield with respect to fruit length, fruit weight, placenta length, number of fruits per plant, pericarp weight, driage, capsaicin and oleoresin content.

Driage

Driage was significantly and positively correlated to dry yield where as it was negatively correlated with fruit weight, placenta weight and pericarp weight.

Capsaicin

Capsaicin content is positively and significantly correlated to fruit width, number of fruit per plant, dry yield and oleoresin content. No significant negative correlation was found for any other characters.

Oleoresin

Oleoresin content was positively and significantly correlated to dry yield and capsaicin content and significantly negatively correlatedwithfruit length, placenta length and weight.

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Table 9: Correlation studies for different characters in chilli genotypes

	Fruit weight	Placenta length	Placenta weight	No. of fruits/ plant	Pericarp weight	Pericarp thickness	Dry yield	Driage	Capsaicin	Oleoresin
Fruit length	0.52(**)	1.00(**)	0.45(**)		0.51(**)		0.25(*)			-0.34(**)
Fruit width	0.37(**)		0.46(**)		0.32(**)	0.70(**)			0.32(**)	
Fruit weight		0.52(**)	0.90(**)	-0.25(**)	0.96(**)	0.54(**)	0.28(*)	-0.46(**)		
Placenta length			0.45(**)		0.51(**)		0.25(*)			-0.34(**)
Placenta weight				-0.30(**)	0.84(**)	0.62(**)		-0.25(*)		-0.28(*)
No. of fruits/plant						0.33(**)	0.60(**)		0.24(*)	
Pericarp weight						0.52(**)	0.35(**)			
Dry yield								0.25(*)	0.30(*)	0.25(*)
Capsaicin										0.59(**)

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4.4. CLUSTER ANALYSIS

Cluster analysis is an appropriate method for determining the genetic diversity among the chilli genotypes that will facilitate the selection of suitable germplasm for future programmes. Cluster analysis was done based on thirteen parameters viz., plant height, fruit length, fruit width, fruit weight, placenta weight, number of fruits per plant, pericarp weight, pericarp thickness, dry yield, driage, capsaicin content, oleoresin content and colour value. Genotypes coming under each cluster is listed in table 10. Range and mean values for each character in each cluster is presented in table 11.

Table 10: Clustering pattern in chilli genotypes

Cluster 1	CA 1, CA 2, CA 3, CA 7, CA 11, CA 12, CA 14, CA 15, CA 19, CA 20, CA 21, CA 24, CA 26
Cluster 2	CA 29
Cluster 3	CA 9, CA 10, CC 1, CC 2, CC 3, CA 28
Cluster 4	CA 23
Cluster 5	CA 4, CA 5, CA 6, CA 17, CA 22, CA 25
Cluster 6	CA 8, CA 30, CA 31
Cluster 7	CA 13, CA 16, CA 18, CA 27
Cluster 8	CA 32

Based on cluster analysis, all the thirty five chilli genotypes under the study were grouped into eight clusters (Table 10). The study revealed that cluster 1 contained highest number of genotypes (13) followed by cluster 3 and 5 having six genotypes, cluster 7 having four genotypes and cluster 6 having three having genotypes. Only one genotype each was observed in cluster 2, 4 and 8.

Table 11: Range and mean values of different characters in cluster analysis of chilli genotypes

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Total mean
Plant height(cm)	55.25 - 97.5 (76.37)	103.8 (103.8)	64.61- 109.6 (87.10)	94.05 (94.05)	54- 120.25 (87.13)	49.2- 71.1 (60.15)	71.46- 103.02 (87.24)	54.85 (54.85)	81.34
Fruit length (cm)	4.41 - 8.92 (76.37)	12.3 (12.3)	3.85- 8.31 (6.08)	9.03 (9.03)	6.83- 10.47 (8.65)	3.97- 11.62 97.79)	6.15- 8.81 (7.48)	12.03 (12.03)	8.7
Fruit width (cm)	0.61- 1.61 (1.11)	1.96 (1.96)	0.9-2.01 (1.45)	2.32 (2.32)	0.68- 1.13 (0.90)	0.94- 1.06 (1)	0.83- 1.18 (1.01)	1.02 (1.02)	1.34
Fruit weight (g)	2.31- 4.35 (3.33)	12.43 (12.43)	3.18- 5.84 (9.02)	13.31 (13.31)	4.1- 5.76 (4.93)	2.69- 3.06 (2.87)	4.31- 7.6 (5.96)	11.93 (11.93)	7.97
Placenta weight (g)	0.13- 0.28 (0.20)	1.17 (1.17)	0.3-0.48 (0.39)	1.75 (1.75)	0.16- 0.38 (0.27)	0.09- 0.25 (0.17)	0.3- 0.57 (0.435)	1.41 (1.41)	0.72
No. of fruits/plant	14.7- 45.4 (30.05)	11.9 (11.9)	20.6- 35.9 (28.25)	15.5 (15.5)	15.8- 45.3 (30.55)	29.6- 41.9 (35.75)	25- 32.2 (28.6)	26.7 (26.7)	25.91
Pericarp weight (g)	1.93- 4.25 (3.09)	9.89 (9.89)	2.15- 4.15 (3.15)	11.01 (11.01)	2.63- 5.97 (4.3)	2.01- 2.21 (2.11)	3.05- 6.13 (4.59)	8.57 (8.57)	5.84
Pericarp thickness (mm)	0.58- 1.27 (0.92)	1.96 (1.96)	1.28- 1.71 (1.49)	2.56 (2.56)	0.4- 0.97 (0.68)	0.25- 0.95 (0.6)	0.69- 1.28 (0.98)	0.97 (0.97)	1.27
Dry yield (g)	5.6- 29.28 (17.44)	16.77 (16.77)	20.01- 34.78 (27.39)	30.63 (30.63)	6.92- 39.75 (23.34)	16.98- 28.17 (22.57)	24.69- 47.53 (36.11)	34.7 (34.7)	26.12
Driage (%)	7.14- 39.51 (23.32)	11.29 (11.29)	17.15- 36.53 (26.84)	14.89 (14.89)	8.7- 25.58 (17.14)	16.29- 31.88 (24.08)	17.81- 26.22 (22.02)	10.89 (10.89)	18.81
Capsaicin (%)	0.18- 0.78 (0.48)	0.56 (0.56)	0.2-1.09 (0.64)	0.39 (0.39)	0.11- 0.95 (0.53)	0.26- 0.72 (0.49)	0.56- 0.91 (0.73)	0.57 (0.57)	0.55
Oleoresin (%)	9.6- 22.5 (16.05)	13.02 (13.02)	13-27 (20)	7.5 (7.5)	11.25- 20.02 (15.64)	13.5- 15.75 (14.62)	13.8- 25.25 (14.62)	13.1 (13.1)	17.37
Colour value (ASTA units)	26.07- 100.29 (63.18)	84.48 (84.48)	57.42- 103.36 (80.36)	102 (102)	28.05- 110.65 (69.35)	114.84- 131.91 (123.3)	74.91- 111.22 (93.06)	114.58 (114.5 8)	91.3

Cluster 1 contained 37.1 per cent of the total genotypes and the average values of genotypes in this cluster for plant height was less than 100 cm. Fruit length, fruit width, placenta weight, pericarp weight, and fruit weight was low while number of fruits per plant was high. Dry yield was lowest while driage was highest. Colour value was lowest where as acceptable value for oleoresin and capsaicin were obtained in this cluster. Thirteen accessions are coming under cluster 1 and among these CA 19 got high dry yield (29.28g) where as high capsaicin content was observed in CA 20 (0.78 %)

Cluster 2 was distinct from other clusters. CA 29 is the only genotype coming under in this cluster and it recorded highest fruit length and lowest number of fruits per plant. The average values for fruit length was found to be higher (12.3 cm) than the mean of all genotypes (8.7 cm). This cluster recorded second highest values for fruit width, fruit weight, pericarp weight and pericarp thickness compared to cluster 3. Capsaicin and colour value were higher in this cluster.

Cluster 3 include 17.1 per cent of the total genotypes and all these genotypes belong to *C. chinense* species. Fruit length ranged from 3.8 cm - 8.3 cm and fruit width was very high in this cluster. Highest capsaicin content (0.2 % to 1.09 %) and oleoresin content (13 % to 27 %) was observed in this cluster and the colour value was moderate to high. Driage and dry yield values were acceptable and higher than the grant mean values for these characters.

CA 23 is the only genotype coming under cluster 4 and this cluster is independent from others having highest fruit width (2.32 cm), fruit weight (13.31 g), placenta weight (1.75 g), pericarp weight (11.01g) and pericarp thickness (2.56 g). It was found good in dry yield also. Capsaicin and oleoresin contents were low while colour value was more than 100 ASTA units.

Six genotypes coming under cluster 5 recorded highest plant height, medium to high fruit length and fruit width. Fruit weight and placenta weight were low whereas number of fruits per plant was high in this cluster. Pericarp weight and pericarp thickness were acceptable but lower than the total mean values. Content of capsaicin, oleoresin and colour value were high in this cluster.

Genotypes (CA 8, CA 30 and CA 31) classified in cluster 6 accounted for 17.7 per cent of the total genotypes and were lowest in plant height (49.2 cm to 71.1 cm). Genotypes in this cluster had low fruit weight (2.69g to 3.06 g), lowest placenta weight (0.09g to 0.25 g) and pericarp thickness (0.25 mm to 0.95 mm) where as number of fruits per plant was high in this cluster. The capsaicin content was high and oleoresin content was medium. All the genotypes in this cluster recorded very high colour value (above 100 ASTA units) ranging from 114. 84 ASTA units to 131.91 ASTA colour units.

Four genotypes are coming under cluster 7 accounting for 11.4 per cent of the total genotypes. High values for plant height, fruit length, fruit width, number of fruits per plant, medium pericarp weight and pericarp thickness, highest dry yield (47.53 g), medium to high capsaicin (0.56 % to 0.91 %), oleoresin (13.8 % to 25.25 %) and colour value (74.91 ASTA units to 111.22 ASTA units) were recorded in the genotypes belonging to this cluster.

Cluster 8 was distinct from other clusters with only one genotype (CA 32), recording lowest plant height (54.85 cm), higher fruit length (12.03 cm), fruit width (1.02 cm), fruit weight (11.93 g), placenta weight (1.41 g), pericarp weight (8.57 g) and dry yield (43.7g). Capsaicin content and oleoresin contents were low where as colour value was good (114.58 ASTA units).

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Discussion

5. DISCUSSION

Chilli (*Capsicum annuum* L) is an important commercial crop of India valued for its spicy fruits with characteristic flavour and colour. Wide variability is reported for its morphological and biochemical characters. Pungency and colour is exploited in pharmaceutical, oleoresin and food industries. Green chillies are rich sources of vitamin C content and hence it is highly nutritional.

The morphological and biochemical characters are highly dependent on genotypes and environmental factors. The significant G X E interaction influences the plant growth and yield characters. (Dhaliwal *et al.*, 2015). In Kerala, chilli is cultivated almost throughout the year, but seasons have great influence on both morphological and biochemical characters.

The present investigation was carried out with the objective of finding morphological and biochemical variability in chilli and for identifying spice chilli genotypes suitable for Kerala.

The knowledge about the variability in a crop species is of great importance as it paves the way for an effective selection. Genotypic variability along with environmental effects cumulatively contributes to the resultant variability in a population.

In the present study, analysis of variation (ANOVA) revealed significant differences among the thirty five genotypes for plant and fruit characters (qualitative and quantitative) viz., plant height (cm), stem colour, leaf colour, leaf length and breadth (cm), petiole length (cm), pigmentation at node , days to 50% flowering, corolla colour, days to 50% fruiting, fruit colour, fruit shape, fruit length and width (cm), fruit pedicel length (cm), fruit weight (g), placenta length and weight (g), number of fruits per plant, pericarp weight and thickness (mm), number of seeds per fruit, yield per plant (g), driage (%), seed colour, incidence of bacterial wilt (%) *etc*. Variation was also observed for biochemical characters like capsaicin (%), oleoresin (%) and colour value (ASTA value). Genetic variability play a pivotal role in its economic utilizations, and characters with high range of variation have a better scope of improvement through selection.

Correlation analysis provides the information on the nature and extent of relationship between the different pairs of characters studied. Correlation analysis was done with the characters *viz.*, plant height, fruit length, width and weight, placenta length and weight, number of fruits per plant, pericarp weight and thickness, dry yield, driage, capsaicin, oleoresin and colour value.

5.1. Morphological characterization

High range of variation was observed for all the characters studied. The characters showing wide range of variation provide ample scope for selecting desired types. Plant height is an important growth parameter which varies with genotypes and with present context, it ranged from 49.2 cm to 120.25 cm. Among the thirty five genotypes analysed, CA 22 recorded maximum plant height (120.25 cm) which was followed by CA 28 (109.6 cm), CA 29 (103.8 cm) and CA 27 (103.02 cm) (Figure 1). The minimum plant height was recorded for CA 31 (49.2 cm). Four genotypes were taller (CA 22, CA 28, CA 29 and CA 27) having plant height of more than one meter and this contrast may be a genotypic characteristic. Phulari (2012) reported that most of the genotypes in their study were having less than one meter plant height and our findings are also in confirmatory with his findings. The present study revealed the absence of significant positive correlation between plant height and yield, which supports the findings of Dhaliwal *et al.* (2015), whereas Kumari *et al.* (2011) reported significant positive correlation between plant height and fruit yield. These differences may be due to the differences in the genotypes included in the study. In the present study, most of the genotypes (82.85%) showed more than 60 cm plant height. Plant height was not significantly correlated to the rest of the characters studied.

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Fruit length, width and weight are the important yield contributing characters and also decide consumer acceptability. Generally fruits of medium to long, slender types are preferred and such types are suitable for spice chilli purposes. Extra large fruits are undesirable because of lower productivity, irregular fruit shape and quality.

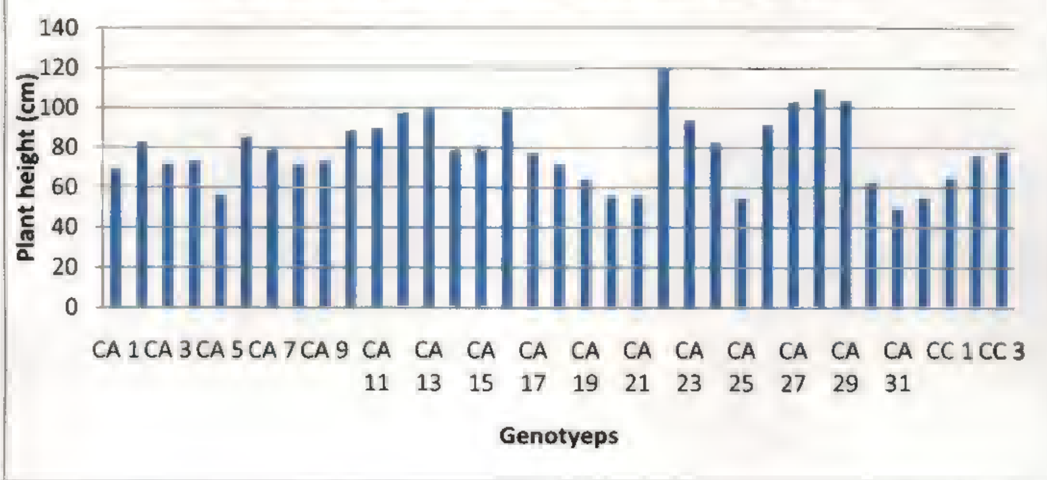
Considerable variation was observed for fruit length, breadth and weight. It is observed from the present investigation that, among the *Capsicum annuum* CA 29 had the highest fruit length measuring to 12.30 cm (Figure 2) while lowest fruit length is recorded in CA 30 (3.97). Fruits of *Capsicum chinense* are generally short compared to *Capsicum annuum* with lowest in CC 1(3.85 cm). Twenty seven genotypes recorded more than 6 cm fruit length and three genotypes (CA 29, CA 31 and CA 32) are extra long with a fruit length of more than 11 cm. Krishna *et al.* (2007), Verma *et al.* (2008) and Phulari (2012) also observed varietal variation in fruit length in chilli accessions. Very long fruits are not desirable for spice chilli purpose because of low consumer demand. Accessions like CA 4, CA 7, CA 10, CA 17, CA 22, CA 23, CA 25, CA 26, CA 27 and CA 28 were having medium long fruits and hence suitable for spice chilli purpose.

Fruit length was positively and significantly correlated to fruit weight, placenta length and weight, pericarp weight and yield. The positive correlation of fruit length with fruit yield was also reported by Dhaliwal *et al.* (2015)and Kumari *et al.* (2011). Fruit length was negatively and not significantly correlated with fruit width, number of fruits per plant, pericarp thickness and driage. Thus it is clear that those genotypes producing long fruits may produce less number of fruits per plant hence yield is low. It was supported by the findings of Kumar *et al.* (2003). The genotype CA 29 produced longest fruit (12.3 cm) but it was not the highest yielder due to less number of fruits per plant (11.9). Hence it can be concluded that fruit length, fruit weight and number of fruits per plant are the highly contributing parameters for total yield.

The range of variation for fruit width is 0.61 cm in CA 14 to 2.32 cm in CA 23 (Figure 3). Such variations were reported by Krishna *et al* (2007) and Verma *et al.* (2008) indicating varietal variation in fruit breadth. Generally fruits of *Capsicum chinense* are wider than *Capsicum annuum*. Five genotypes namely CA 23, CA 29, CC 1,CC 2 and CC 3 recorded a fruit width of more than 1.9 cm. Maximum fruit width observed in the local genotype CA 23 (2.32 cm) contributed to its highest individual fruit weight, placenta weight, pericarp weight, pericarp thickness and dry weight. But it doesn't contribute to yield because of negative correlation of fruit width with number of fruits. According to sherma *et al.* (2009), small fruit size is associated with more number of fruits and reverse is the relationship in large sized accessions.

Correlation studies revealed that fruit width is positively and significantly correlated to fruit weight, placenta weight, pericarp weight and pericarp thickness. Fruit width and yield were not correlated, whereas significant negative correlation was observed between fruit width and length. This is against the findings of Kumar *et al.* (2010) who found a significant positive correlation between fruit length and width. Negative correlation observed in this study may be due to the variations in the genotypes included in the study.

Figure 1: Plant height of different chilli genotypes



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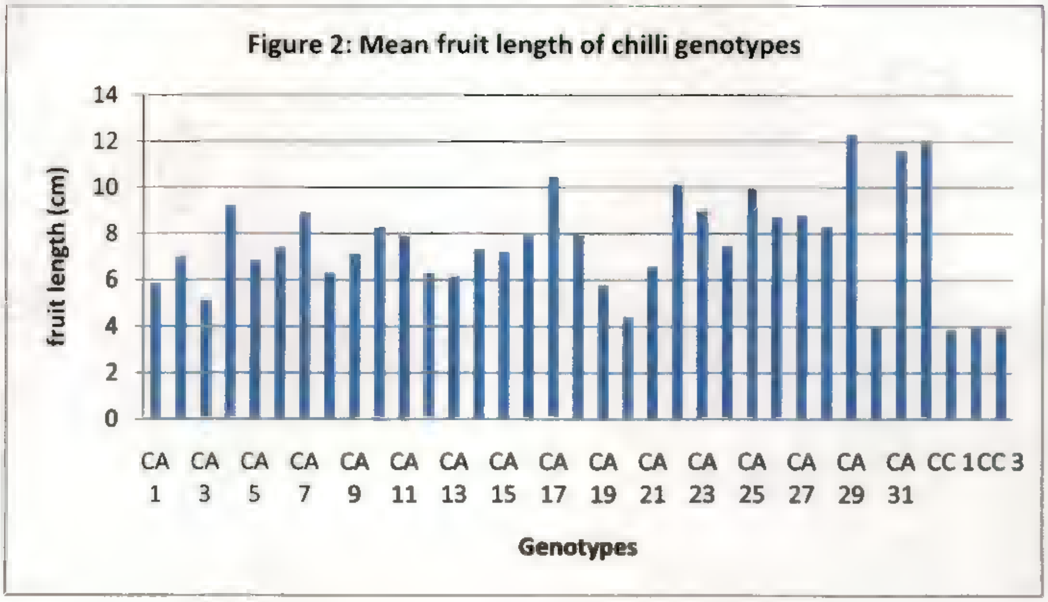

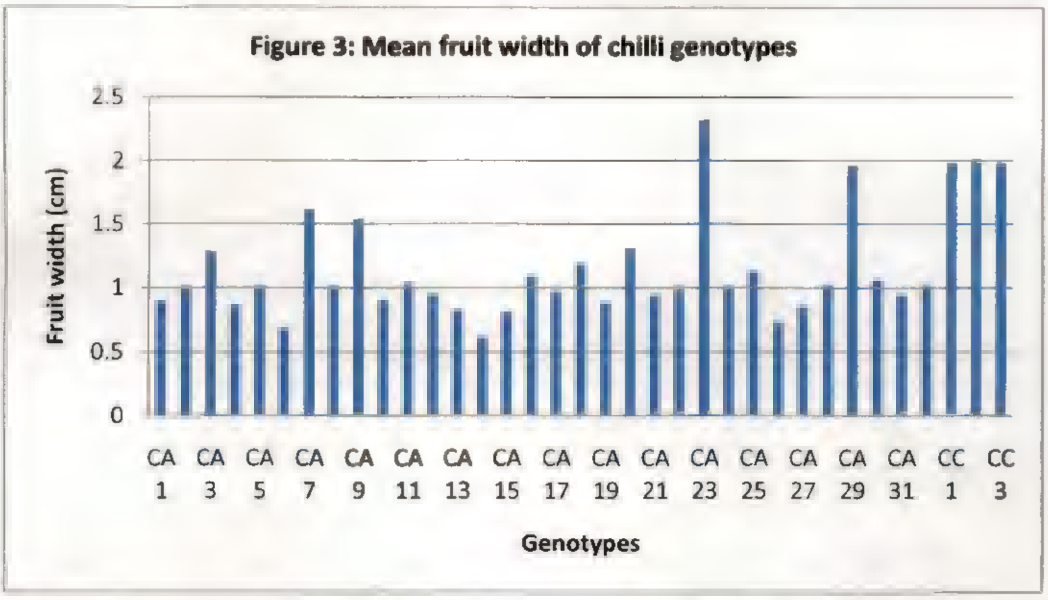

Fruit weight (Fresh)

Large variation in fruit weight, shape, and number is noticed in chilli. Fruit weight is an important economic parameter in chilli contributing to its total yield. In total, individual fruit weight was found varying from 2.31g to 13.31 g. Based on fruit weight, three genotypes (CA 23, CA 29 and CA 32) performed better (more than 10g per fruit) (Figure 4).Varietal variation in fresh weight of fruits was also reported by Chattopadhyay *et al.* (2011) and Misra (2011). CA 23 is a local accession which is having highest fruit weight (13.31g) followed by CA 29 (12.43

g) and CA 32 (11.93g). High fruit weight in CA 23is due to its long fruits, highest fruit width, placenta weight, pericarp wight and pericarp thickness. But CA 23 was not the highest yielder. The significant negative correlation of fruit weight with number of fruits per plant asserts this phenomenon. Hence it is clear that small fruit size is associated with more number of fruits and similar results are also reported by Phulari (2012).

Correlation analysis revealed that fruit weight is positively and significantly correlated to fruit length, fruit width, placenta length, placenta weight, pericarp weight, pericarp thickness, dry yield and significantly negatively correlated with number of fruits per plant, driage and oleoresin content.

Placenta weight

Placenta weight varied from 0.09 g to 1.75 g. CA 23, a local genotype recorded highest placenta weight (Figure 5). Highest placenta weight in CA 23 contributes to its highest fruit weight. Correlation analysis indicated significant and positive correlation of placenta weight with fruit length, fruit width, fruit weight, placenta length, pericarp weight and pericarp thickness and a significant negative correlation with number of fruits per plant, driage, and oleoresin content.

Number of fruits per plant

Number of fruits per plant is an important economic character in chilli. It is highly dependent on genotypic, environmental and soil conditions. Significant variation (14.7 to 45.4) was observed among the genotypes studied (Figure 6). Such genotypic variation was also reported by Krishna *et al.* (2007), Verma *et al.* (2008) and Sherma *et al.* (2009) for this character. Correlation studies revealed that number of fruits per plant is positively correlated to dry yield, indicating that fruit number per plant is the primary contributor for yield in chilli. Similar results were reported by Manju and Sreelathakumary (2002). Negative correlation with plant height indicates the possibility for more number of fruits per plant in those genotypes with reduced plant height. Number of fruits per plant was negatively correlated to fruit length, fruit width, fruit weight, placenta length, placenta weight, pericarp weight and pericarp thickness. This observation is supported by the findings of Sherma *et al.* (2009) and Kumar *et al.* (2003) and according to them small fruit size is associated with more number of fruits with reverse relationship in large sized fruit chilli types. Our observation is in agreement with this finding. While considering number of fruits per plant as one of the important yield contributing parameter, CA 7 was found promising (45.4).But it was not the highest yielder due to its low fruit weight. CA 22 was the second highest in number of fruits per plant (45.3) followed by CA 19 (44) and CA 25(42.4). CA 22 possessing high number of fruits per plant coupled with high yield can be considered as a superior genotype in terms of all economic traits.

Seed number

Less seeded fruits will be soft with poor shelf life and transportability besides adversely affecting pungency. Among the *Capsicum annuum* maximum number of seeds per fruit was observed for CA 23 (125.8) followed by CA 29 (95.2) and CA 25 (89.9) and minimum number in CA 19 (37.00). Generally *Capsicum chinense* recorded less number of seeds per fruit with minimum in CC3 (17.8) followed by CC 1 (20.7) and CC 2 (24.4) (Figure 7).

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Figure 4: Mean fruit weight of chilli genotypes

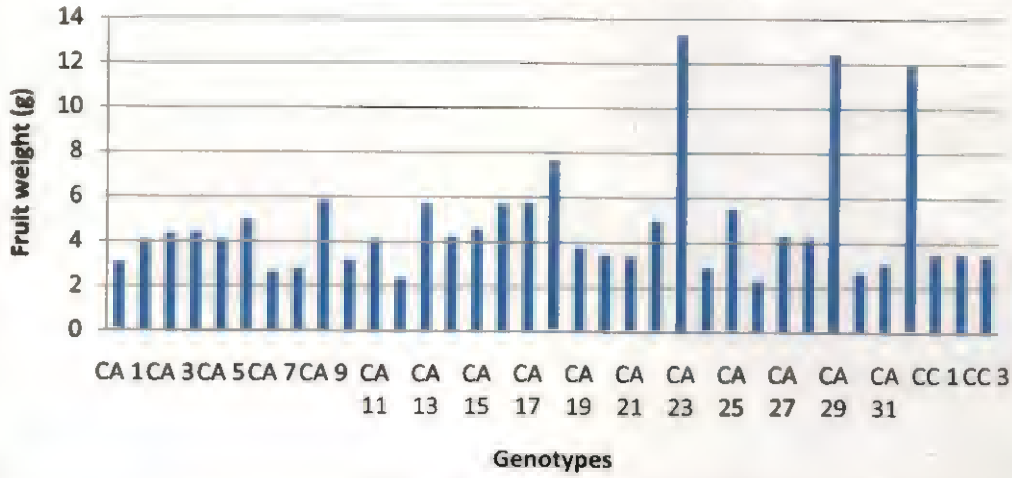


Figure 5: Mean placenta weight of chilli genotypes

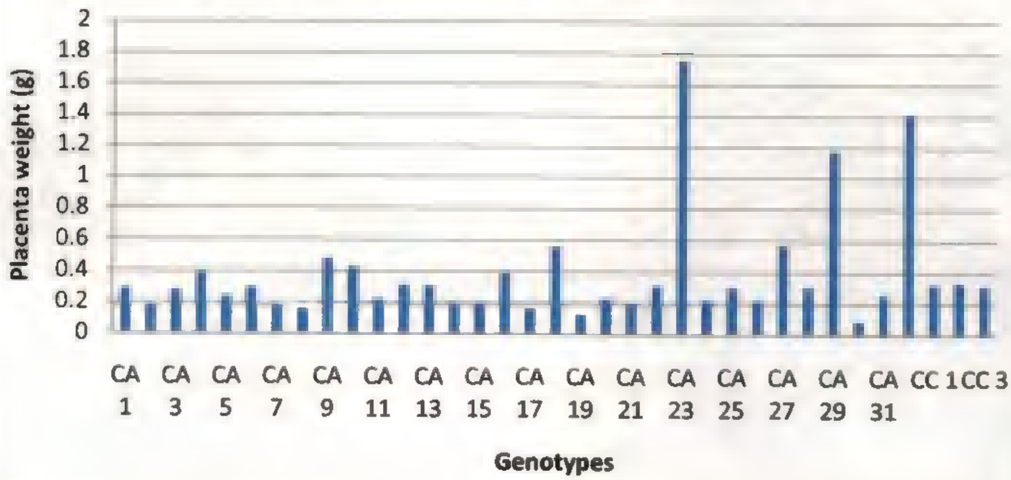


Figure 6: Mean number of fruits per plant in different chilli genotypes

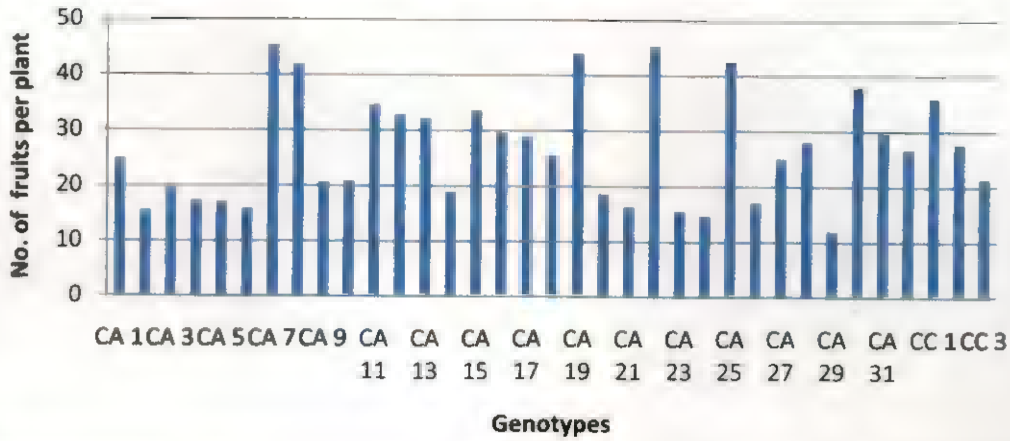
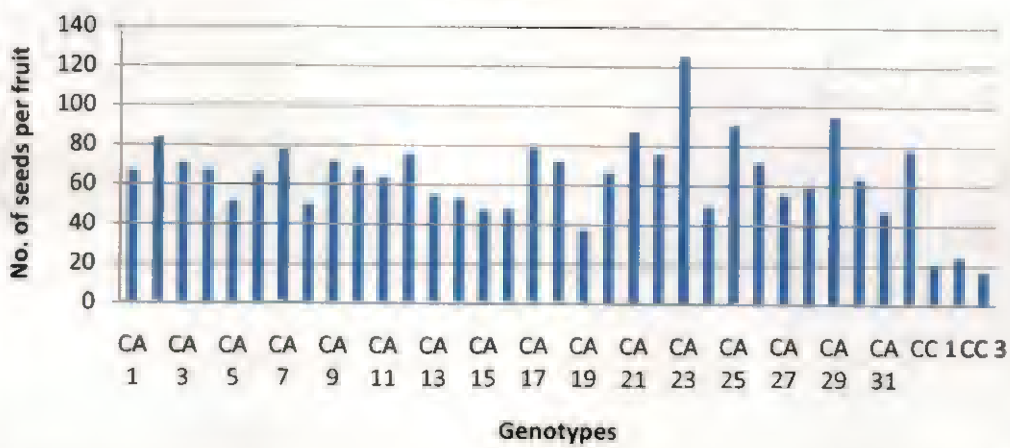


Figure 7 : Mean number of seeds per fruit in different chilli genotypes



Pericarp weight

Pericarp weight varied from 2.01 g (CA 8) to 11.01g (CA 23) (Figure 8). The variation in the pericarp weight mostly depends on fruit characters. High fruit width and pericarp thickness contributes to high pericarp weight. The highest pericarp weight in CA 23 is due to its highest fruit width, fruit length, placenta weight and pericarp thickness. Such variations were also reported by Kumari *et al.* (2011), shiva *et al.* (2013). High Pericarp weight is not a desirable character for spice chilli because it will take more time for drying. Correlation analysis revealed that pericarp weight is significantly and positively correlated to fruit length, fruit width, fruit weight, placenta length, placenta weight, pericarp thickness and dry yield, while driage and number of fruits per plant are negatively correlated. Pericarp weight has great influence on driage as it reduces driage due to its increased fresh weight. Correlation analysis revealed a significant negative correlation of pericarp weight with driage. Hence the driage will be maximum for those genotypes having low pericarp weight as observed in CA 26.

Pericarp thickness

Pericarp thickness varied from 0.25 mm (CA 8) to 2.56 mm. Accession CA 23 recorded highest pericarp thickness (2.56 mm) followed by CA 29 (1.96 mm) and CC 2 (1.71 mm)(Figure 9). Pericarp thickness contributes to pericarp weight, placenta weight, fruit weight and fruit yield. Correlation analysis revealed significant positive correlation of pericarp weight with fruit width, fruit weight, placenta weight and pericarp weight. Negative correlation was obtained between pericarp thickness and driage. Those genotypes having higher driage is found to possess low fresh weight as seen in CA 26. Genotypes having thin pericarp, low seed content and strong spike are suitable for dry chilli (Saravaiya *et al.*, 2010)

Dry yield per plant

Yield is a complex character that depends on a number of parameters and high yield is an important objective in any crop improvement programme. The difference in yield among different genotypes is attributed to difference in their genetic makeup. In the present investigation, dry chilli yield ranged from 5.6 g to 47.53 g (Figure 10). Such large variations in dry chilli yield were also reported by Vijaya *et al.* (2014), Khurana *et al.* (2003) and Shantthanu *et al.* (2005). Ten genotypes (28.5 %) recorded a yield of more than 30g per plant. Maximum dry yield per plant was recorded for CA 13 (47.53 g), followed by CA 16 (39.82 g) with the dry yield of CA 22 (39.75 g), on par with CA 16. Highest yield recorded in CA 13 was 179.91 per cent higher than that of the KAU released variety 'Ujwala'. Dry yield per plant established a strong significant positive correlation with yield contributing parameters viz., fruit length, fruit weight, placenta length, number of fruits per plant and pericarp weight indicating the usefulness of these traits for improving fruit yield. Among the various component traits, number of fruits per plant and pericarp weight contributed more towards dry fruit yield. Similar results have been reported in chillies by Raghavan (2007) and Kumar *et al.* (2010) who had observed significant positive correlation of various yield contributing traits with fruit yield. The characters fruit width, placenta weight and thickness were not correlated at all with yield. Even though CA 7 had maximum number of fruits per plant it was not the best yielder due to its low fruit weight. The highest dry yield per plant noticed in CA 13 (47.53g), due to its higher individual fruit weight and in contrast to the lowest dry yield in CA 14 (5.6g) is due to low dry fruit weight. Dry fruit weight mostly depends upon the total dry matter content of fruits.

Figure 8: Mean pericarp weight of chilli genotypes

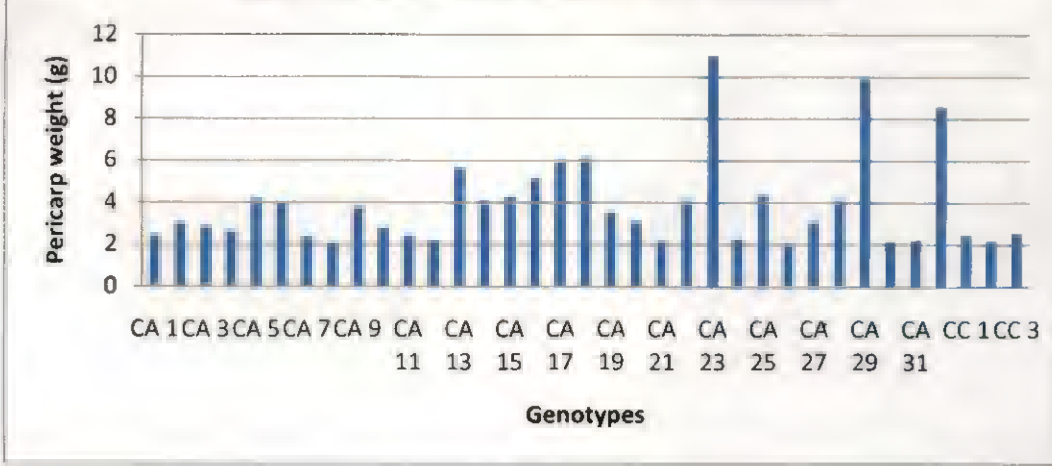


Figure 9: Mean pericarp thickness of chilli genotypes

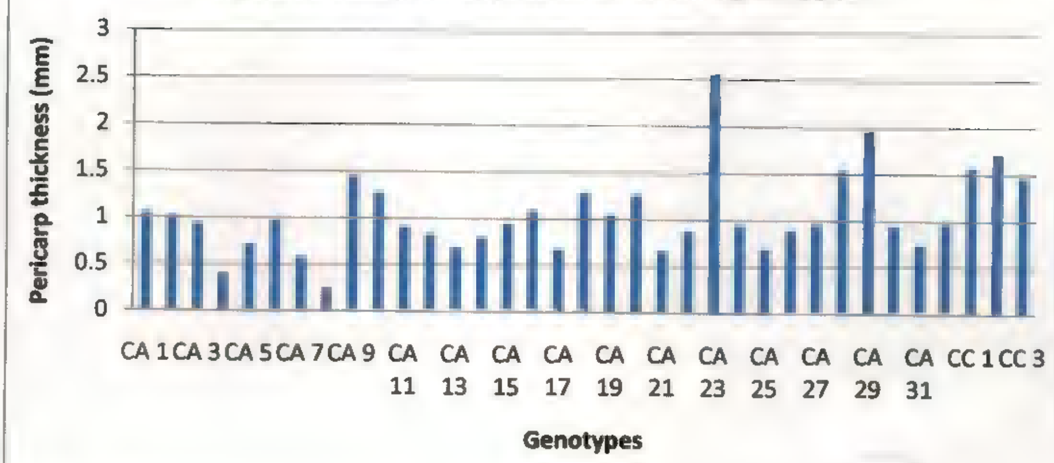
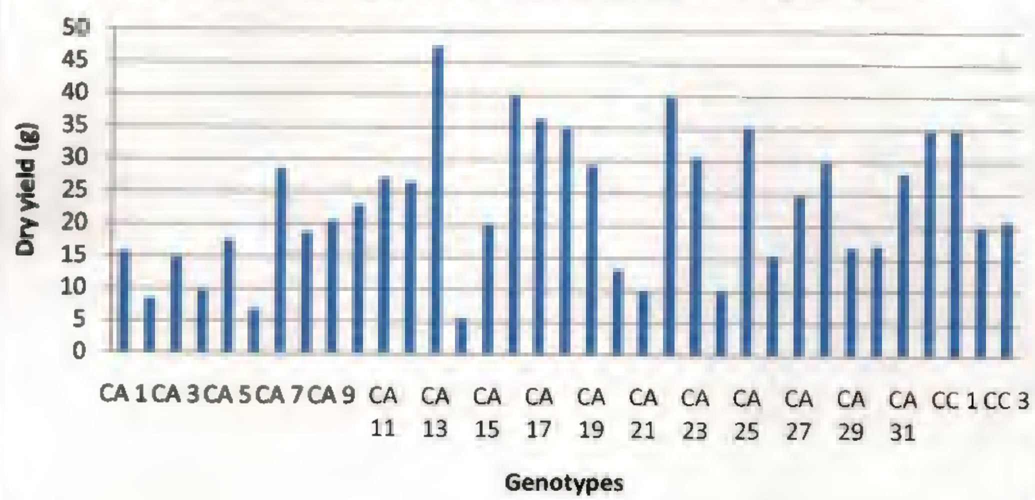


Figure 10: Mean dry yield per plant of different chilli genotypes



Driage

Driage is an important parameter for spice chilli purpose. Driage ranged from 7.14 % to 39.51 % (Figure 11). Among the genotypes, CA 26 recorded maximum driage (39.51 %) followed by CA 10 (36.53 %) and CA 12 (33.6 %). The highest driage in CA 26, due to its low fruit weight. Driage was found to be negatively and significantly correlated to fruit weight, placenta weight and pericarp weight.

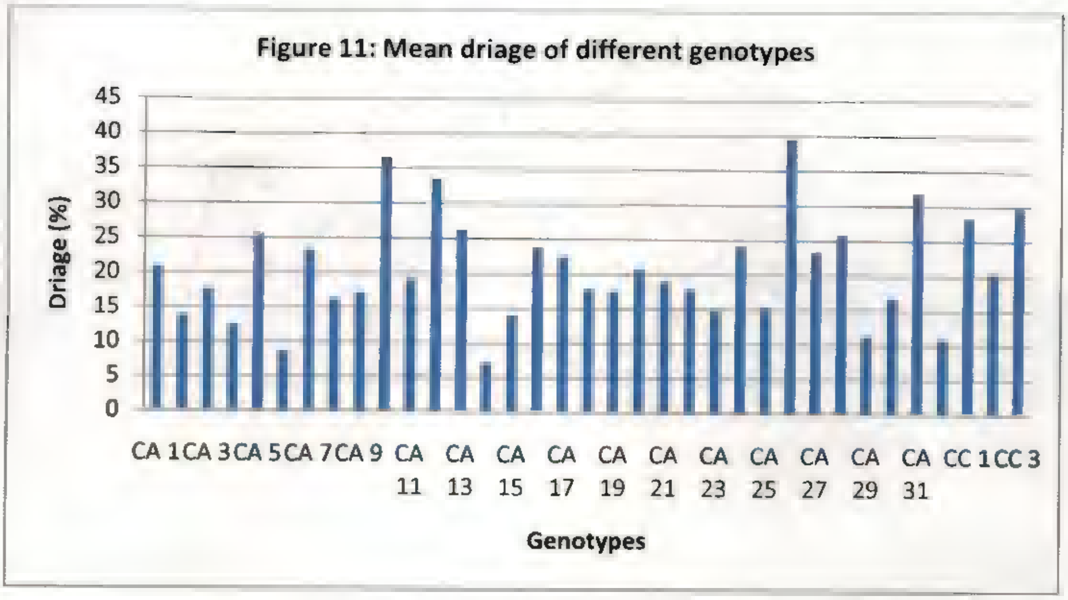


Figure 11: Mean driage of different genotypes

Qualitative characters

Chilli genotypes are characterized based on qualitative characters. (Table 12). Majority of the genotype showed green stem (77%) followed by light green (14.2%) and dark green (8.5%) stem colour. Leaf colour was green in 45 % percent of genotypes and rest of the types showed dark green (40%) and light green leaf colour (14.2 %). Manju and Sreelathakumary (2002) reported that in 90 per cent cases in their study leaf colour was green. Pigmentation at node was present in most of genotypes and absent in 11 accessions (31.4%). All the genotype had white corolla. Mature fruit colour ranged from light green to dark green and only 20 percent genotypes had dark green fruit colour at mature stage. Ripe fruit colour ranged from red, light red and dark red. Most of the genotypes had long fruits except four which had conical shaped fruits (11.4%). Based on fruit position, genotypes could be grouped in to erect, semi pendulous and pendulous. Most of the genotypes produced (80%) pendulous fruits where as only three genotypes (8.5%) produced erect fruits. Surface of mature fruit was smooth (37.1%), semi wrinkled (22.8%) and wrinkled (40%). High variability for morphological characters in chilli was reported by Sreelathakumary (2000) which was similar with the present study.

Table 12: Characterization of chilli germplasm based on qualitative characters

Character	Type	Number of genotype	Frequency (%)
Stem colour	Green	27	77.14
	light green	5	14.28
	Dark green	3	8.57
Leaf colour	Green	16	45.71
	light green	5	14.28
	Dark green	14	40
Pigmentation at node	Present	24	68.57
	Absent	11	31.42
Mature fruit colour	Light green	14	40
	Dark green	7	20
	green	14	40
Ripe fruit colour	Light red	13	37.14
	Red	19	54.28
	Dark red	3	8.57
Fruit shape	Long	18	51.42
	Long and tapering	9	25.71
	Long and curved	1	2.85
	Very long	1	2.85
	Long and blunt edged	2	5.71
	Conical	4	11.42
Fruit surface	Wrinkled	14	40
	Semi wrinkled	8	22.85
	Smooth	13	37.14

Fruit position	Pendulous	28	80
	Semi pendulous	4	11.42
	Erect	3	8.57
Seed colour	Deep yellow	20	57.14
	Light yellow	12	34.28
	Light brown	3	8.57

5.2. Biochemical characterization

Capsaicin

The important quality traits in chilli are colour, flavour and pungency and quality parameters depend upon their end use. For flavouring and colouring of foods, chillies should be rich in colour and flavour but mild in pungency. However for oleoresin extraction, they must be highly pungent and have less of red colour. (Pruthi, 1998).

Pungency is the most important quality attribute for spice chilli purpose. The hot flavour of chilli (Pungency) is caused by capsaicin and allied chemical constituents. Pungency is defined as sharp, piercing, stinging, biting or penetrating quality or power to excite. Pungency in chilli is due to capsaicin (8-methyl-N-vanillyl-6-nonenamide) and seven closely related alkyl vanillyl amides collectively known as capsaicinoids which have wide use in pharmacological applications. It has both nutritional and toxic effects and its action on digestive, cardiovascular, respiratory and nervous system are well known. More than 15 different alkaloids are found in chilli fruits and among these, capsaicin and dihydrocapsaicin accounts for more than 80% of capsaicinoids (Bosland and Votava, 2000).

Considerable variability exists among different genotypes for capsaicin content. Capsaicin content among the accessions ranged from 0.11 % - 1.09 % (Figure 12). This difference in capsaicin content is due to the total capsaicinoid content, the ratio of different capsaicinoids, cultivars, and environmental factors like climate, light, soil, moisture content of soil (Estrada *et al*, 2002). A number of authors reported a broad range of variation in capsaicin content and pungency levels in *Capsicum* viz. Kumar *et al.* (2003), Singh *et al.* (2003) and Pandey *et al.* (2009). This variation may be due to presence of gene modifying factors for pungency and ratio of placental tissue to seed and pericarp (Sreelathakumary (2000) and Manju and Sreelathakumary (2002)]. Kumar *et al.* (2006) reported that the degree of pungency varies widely with the genotypes from less than 0.05 percent in mildly pungent types to 1.3 per cent in the hottest chillies. Accumulation of capsaicin in different parts of fruits was studied by Pandhair and Sharma (2008) and found that a major amount of capsaicin (63.96%) is present in placenta followed by pericarp (7.12%) and seeds (5.06%). The higher content of capsaicin in placenta is due to synthesis and accumulation of capsaicinoids in the secretory organs of placenta and inter locular septum of fruits. In the present study, among the *Capsicum annuum* types, CA 25 (0.95 %) and CA 16 (0.91%) recorded highest capsaicin content. The lowest capsaicin content was recorded for CA 6 (0.11%) followed by CA 26 (0.18) and CA 9 (0.20%). Among the *Capsicum chinense* types, the highest capsaicin content was recorded for CC 2 (1.09 %) which was on par with CC3 (1.06 %) followed by CC 1 (1.04 %). The data of the present study indicates presence of higher capsaicin content in *C. chinense* than *C. annuum* which is in agreement with the report of several authors who indicated that genotypes from *C. annuum* species have lesser capsaicin content than other species. (Mathur *et al.* (2000), Antonious and Jarret (2006) and Sanathombi and Sharma (2008)]. From the current investigation it is observed that genotypes of *Capsicum chinense* can be used for extraction of capsaicin due to its higher content. This is supported by findings of Manju and Sreelathakumary (2002) who reported more than 1 % capsaicin in all the *Capsicum chinense* types evaluated in their study.

Correlation analysis revealed that capsaicin content is positively and significantly correlated to fruit width, number of fruit per plant, dry yield and oleoresin content. Those genotypes identified for high capsaicin content (CC 1, CC 2 and CC 3) can be used for capsaicin extraction finds use in pharmaceutical industry. But for spice chilli purpose, mild pungent types are preferred.

Oleoresin

Oleoresin represents complete extract of total flavour, colouring matters and pungent principles and it consists of essential oil, natural colourants, waxes, alkaloids *etc*. It has many advantages over ground chilli like uniform colour and flavour distribution, elimination of contamination by microbes and more over it is easy to store and transport. Now a days, many countries are using chilli oleoresin instead of whole chilli or ground forms. It is widely used in food and pharmaceutical industries (Singh *et al*., 2001). From *Capsicum* species different types of oleoresins are produced. Highly pungent oleoresin is used in pharmaceutical industry while high colouring matter oleoresin is utilized in colouring the food stuffs. Notable variability was observed with regard to oleoresin content among the genotypes investigated. Oleoresin content among thirty five accessions varied from 7.5 % to 27.5 % (Figure 13) and such variation was also reported by Mathur *et al.* (2000), Manju and sreelathakumary (2002), Umajyothi *et al.* (2007), Pandey *et al.* (2009) and Chattopadyay *et al.* (2011). The maximum content of oleoresin for *Capsicum annuum* types CA 16 (25.25 %) and CA 1 (22.50 %) recorded highest oleoresin content and for *Capsicum chinense* types, the maximum content of oleoresin was observed in CC 2 (27.5 %) followed by CC 3 (25.50 %), CC 1 (24.00 %) respectively. The minimum content of oleoresin was observed in CA 23 (7.50 %) followed by CA 14 (9.60 %) which was on par with CA 20 (10.00 %). High oleoresin content is a quality attribute for considering as spice chilli type.

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Correlation studies revealed that oleoresin content is positively and significantly correlated to dry yield and capsaicin content while significant negative correlation was found with respect to fruit length, placenta length and placenta weight. Generally oleoresin content in *capsicum chinense* was higher than *capsicum annuum* genotypes. This is due to availability of high dry weight per individual fruits which is supported by findings of Manju and Sreelathakumary (2002).

Colour value

Indiscriminate use of synthetic colours for food colouring has several harmful effects and they are reported to be carcinogenic. This necessitated focus towards natural colours for food colouring and development of high colour chilli varieties. The red pigment extracted from chilli fruits has many end uses as a natural colorant in many food, cosmetic and pharmaceutical industries (Thomas and Thomas, 2003). Green, red, deep red, purple, orange and yellow are the common colours in chilli. Capsanthin and capsorubin are the major pigments in red coloured fruits where as β- carotene in orange coloured fruits (Deli *et al.*, 2001). Lutein is abundant in yellow and green paprika. Differently coloured chilli fruits have different carotenoid profiles. Six kinds of carotenoids are present in red coloured fruits and nine types in orange and yellow fruits. Hence carotenoid profile of red coloured types are simpler compared to orange and yellow types (Kim *et al.*, 2016).

Colour of chilli is measured as extractable colour which is the official method used by the American Spice Trade Association (ASTA, 1985). In the present study, colour value ranged from 26.07 ASTA units (CA 15) to 131.91 ASTA units (CA 30) (Figure 14). Such large colour variations were also reported by Anu *et al.* (2002), Gadal *et al.* (2003), Singh *et al.* (2003), Prasath *et al.* (2005), Pandey *et al.* (2009) and Vijaya *et al.* (2014). This variation is due to the genotypic character of the accessions studied, total carotenoid content and the ratio among the different carotenoides. Colour value was not significantly correlated with any of the characters studied which implies that colour is highly dependent on genotypic factors.

Figure 12: Capsaicin content in different chilli genotypes

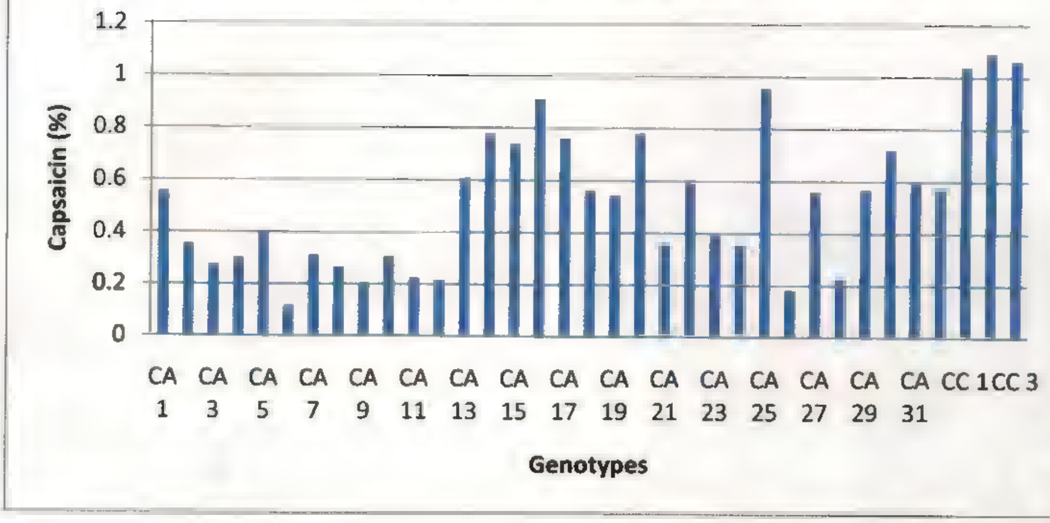
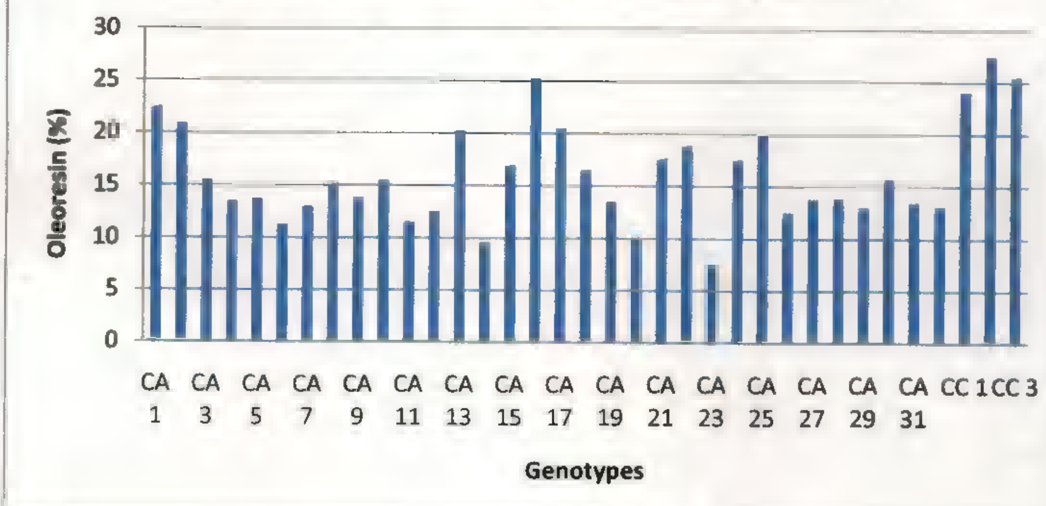


Figure 13: Oleoresin content in different chilli genotypes



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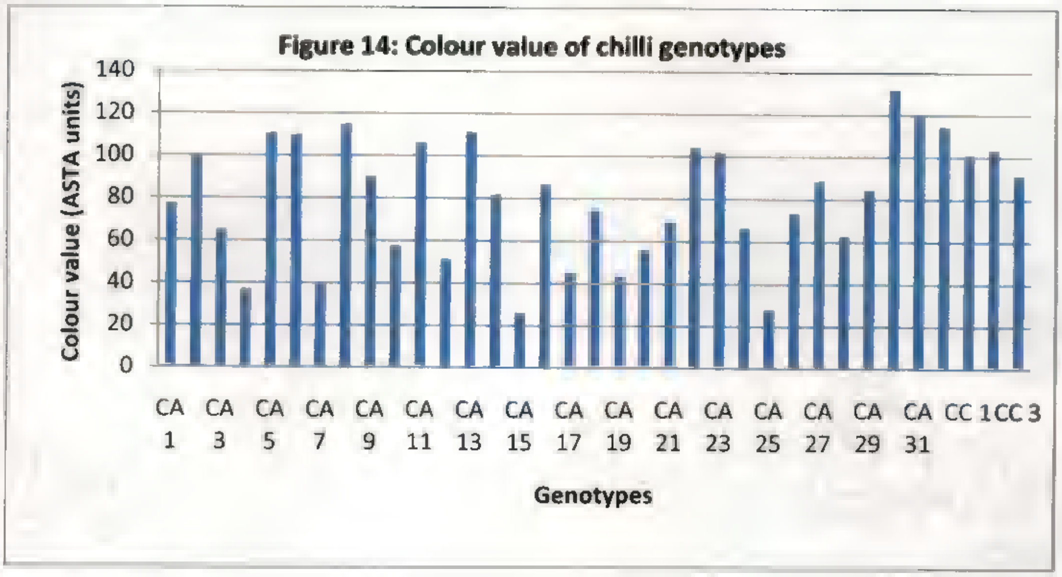

5.3. Characterization of chilli genotypes based on biochemical characters

Based on biochemical characters, chilli genotypes are grouped into low, medium and high and genotypes coming under each group is presented in table 13. Capsaicin content was low (< 0.3%) in 16 genotypes, medium (<0.5 – 1%) in 16 genotypes and high (>1%) in 3 genotypes. Oleoresin content was low (<15%) in 17 genotypes, medium (15 – 25%) in 15 genotypes and high (>25%) in 3 genotypes. Most of the genotypes having high capsaicin and oleoresin content belong to *C. chinense* species. Colour value was low (<50 ASTA units) in 6 genotypes, medium (50 -100 ASTA units) in 16 genotypes and and high (> 100 ASTA units) in 13 genotypes. Our study indicated the availability of genotypes possessing desirable quality characteristics namely CC 2 and CC 3 (*C. chinense*) for high capsaicin and oleoresin contents. Among *C. annuum* species CA 16 having high oleoresin content and breeders can make use them in the production of varieties with outstanding quality attributes. 96

Table 13: Characterization of chilli genotypes based on biochemical characters

Characters	Type	No. of genotypes	Frequency (%)	Genotypes in each group
Capsaicin (%)	Below 0.5 (Low)	16	45.71	CA 2, CA 3, CA 4, CA 5, CA 6, CA 7, CA 8, CA 9, CA 10, CA 11, CA 12, CA 21, CA 23, CA 24, CA 26, CA 28.
	0.5 to 1 (Medium)	16	45.71	CA 1, CA 13, CA 14, CA 15, CA 16, CA 17, CA 18, CA 19, CA 20, CA 22, CA 25, CA 27, CA 29, CA 30, CA 31, CA 32.
	Above 1.0 (High)	3	8.5	CC 1, CC 2, CC 3.
Oleoresin (%)	Below 15 (Low)	17	48.57	CA 4, CA 5, CA 6, CA 7, CA 9, CA 11, CA 12, CA 14, CA 19, CA 20, CA 23, CA 26, CA 27, CA 28, CA 29, CA 31, CA 32.
	15 to 25 (Medium)	15	42.85	CA 1, CA 2, CA 3, CA 8, CA 10, CA 13, CA 15, CA 17, CA 18, CC 1, CA 21, CA 22, CA

				24, CA 25, CA 30.
	Above 25 (High)	3	8.5	CA 16, CC 2, CC 3.
Colour value (ASTA units)	Below 50 (Low)	6	17.14	CA 4, CA 7, CA 15, CA 17, CA 19, CA 25.
	50 to 100 (Medium)	16	45.71	CA 1, CA 3, CA 9, CA 10, CA 12, CA 14, CA 16, CA 18, CA 20, CA 12, CA 14, CA 16, CA 18, CA 20, CA 24, CA 26, CA 27, CC 3, CA 28, CA 29.
	Above 100 (High)	13	37.14	CA 2, CA 5, CA 6, CA 8, CA 11, CA 13, CC 1, CA 22, CA 23, CC 2, CA 30, CA 31, CA 32.

5.4. Cluster analysis

Cluster analysis was found to be useful for finding high yielding chilli genotypes and many reports indicate (Misra *et al.*, 2004 and Yatung, 2014) the presence of high genetic divergence among chilli genotypes in their respective experiments.

On the basis of cluster analysis, all the 35 chilli genotypes were grouped in to eight clusters. Based on the cluster mean value it was observed that CA 32 in cluster 8 exhibited lowest plant height (54.85 cm) while CA 29 in the cluster 2 exhibited highest plant height (103.8 cm).

Maximum mean number of fruits per plant observed in cluster 6 (35.75) and minimum number of fruits in cluster 2 (11.9). Mean value for dry yield was highest in cluster 7 (36.11) and lowest in cluster 2 (16.77). Capsaicin and oleoresin contents were highest (Higher than total mean) in cluster 8 (0.735 and 39. 05% respectively) and lowest in cluster 4 (0. 39% and 7.5% respectively).

Genotypes grouped in to same cluster presumably diverge very little from one another other. Crop improvement is made through generating variability in desired traits followed by selection. In hybridisation programme, selection of parents is an important criteria and crossing programme should be conducted with parents belonging to different clusters.

5.5. Incidence of bacterial wilt disease

Bacterial wilt was the major disease observed during the cultivation. Considerable variability was observed for bacterial wilt incidence ranging from 0 % to 85 % (Figure 15). Most of the released varieties were wilt prone while most of the local genotypes were tolerant to bacterial wilt as seen in CA 22, CA 23, CC 1, CC 2 and CC 3. Among the released varieties, CA 4, CA 16, CA 30, CA 31 and CA 32 were found tolerant to bacterial wilt. The highest wilt incidence (85%) was observed in accession CA 15 followed by CA 14 (70%). The disease is favoured by warm and wet climatic conditions during the crop period.

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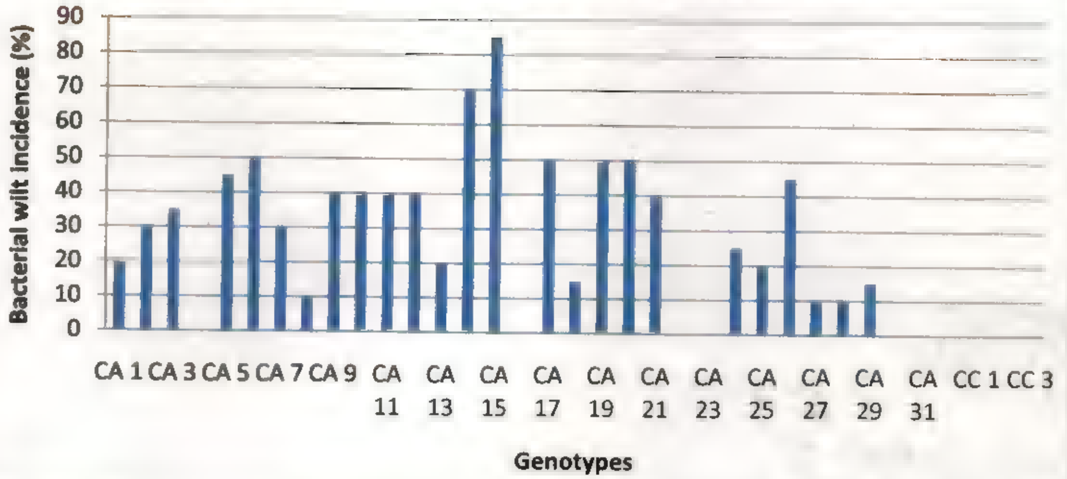
Figure 15: Incidence of bacterial wilt in chilli genotypes



There are certain quality attributes to consider a genotype as spice chilli *viz.* Medium fruit length, thin pericarp, low seed number, high fruit yield, high driage, medium pungency and oleoresin content, high colour value and disease resistance. By considering all these traits we identified certain genotypes suitable for spice chilli purpose (Table 14). Similarly we identified certain genotypes suitable for green chilli (Table 15) and genotypes with industrial value (Table 16).

Table 14: Spice chilli genotypes identified from the study

Genotypes	Fruit length (cm)	Pericarp thickness (mm)	Dry yield (g)	Driage (%)	Capsaicin (%)	Oleoresin (%)	Colour value (ASTA units)	Bacterial wilt (%)
CA 13	6.15	0.69	47.53	26.22	0.61	20.20	111.22	20
CA 16	7.91	1.10	39.82	23.85	0.91	25.25	86.79	0
CA 22	10.19	0.88	39.75	17.9	0.6	18.87	104.29	0
CA 25	9.97	0.7	35.29	15.36	0.95	20.02	28.05	20
CA 27	8.81	0.96	24.86	23.37	0.56	13.80	88.77	10
CA 28	8.31	1.54	30.21	25.84	0.22	13.85	62.37	10

Table 15: Chilli genotypes suitable for green chilli purpose

Genotypes	Fruit length (cm)	Fresh yield (g)	Capsaicin (%)	Bacterial wilt (%)
CA 3	5.12	85.58	0.27	35
CA 7	8.92	120.4	0.31	30
CA 8	6.29	117.97	0.26	10
CA 9	7.13	120.18	0.2	40
CA 10	8.26	66.3	0.3	40
CA 11	7.97	142.97	0.22	40
CA 12	6.31	80.43	0.21	40
CA 23	9.03	206.1	0.39	0

Table 16: Chilli genotypes having industrial value

Genotypes	Capsaicin (%)	Oleoresin (%)	Colour value (ASTA units)	Dry yield (g)
CA 16	0.91	25.25	86.79	39.82
CA 25	0.95	20.2	28.05	35.29
CC 1	1.04	24	100.75	34.78
CC 2	1.09	27.5	103.36	20.01
CC 3	1.06	25.5	91.25	20.86

CA 13

CA 22

CA 16

CA 25

CA 27

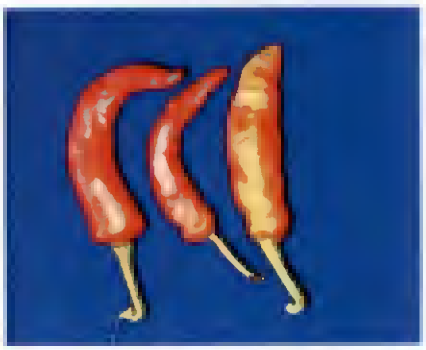
CA 28

Plate 4: Spice chilli genotypes identified from the study

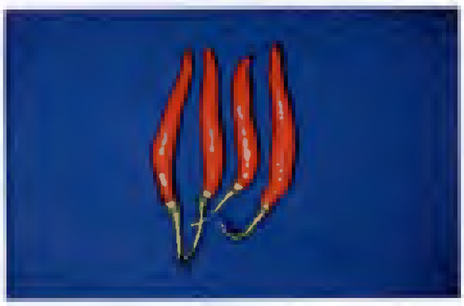
CA 3

CA 7

CA 8



CA 9



CA 10

CA 11

CA 12

CA 23

Plate 5: Genotypes suitable for green chilli purpose

CA 16

CA 25

CC 2

Plate 6: Genotypes having industrial value

Summary

6. SUMMARY

The investigation on 'Screening of spice chilli (*Capsicum annuum* L.) genotypes suitable for Kerala' was studied in the department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Thrissur, during 2014-2016. The summary of the study are given in this chapter.

1. Morphological and biochemical characters depend highly on the genotypes included in the study
2. In the present study, analysis of variation (ANOVA) revealed significant differences among the thirty five genotypes for plant and fruit characters (qualitative and quantitative) *viz.*, plant height (cm), stem colour, leaf colour, leaf length and breadth (cm), petiole length (cm), pigmentation at node, days to 50% flowering, corolla colour, days to 50% fruiting, fruit colour, fruit shape, fruit length and width (cm), fruit pedicel length (cm), fruit weight (g), placenta length and weight (g), number of fruits per plant, pericarp weight and thickness (mm), number of seeds per fruit, yield per plant (g), driage (%), seed colour, incidence of bacterial wilt (%) *etc.* variations were also observed for biochemical characters like capsaicin (%), oleoresin (%) and colour value (ASTA value).
3. Among the genotypes, CA 22, CA 27, CA 28 and CA 29 were found taller (>100 cm) and CA 31 was found to be the shortest with a plant height <50 cm. Negative correlation was observed between plant height and other characters.
4. Majority of genotypes (77.14%) were green in stem colour though light green and dark green stems were observed.
5. Leaf colour was green in majority of genotypes (45.71%) whereas some genotypes showed light green (14.28%) and dark green (40%) leaf colour.
6. Maximum leaf length was recorded in CA 27(9.81 cm) and minimum in CA 3 (3.69 cm). 106

7. Highest leaf width was recorded in CA 6 (4.28 cm) and lowest in CA 19 (1.4 cm).
8. Genotypes like CA 30 and CA 32 were highest in petiole length (> 3 cm) and CA 2 and CA 10 were lowest in petiole length (<1.1 cm)
9. No variation was observed for corolla colour. All the genotypes were white with regard to corolla colour.
10. Among the genotypes studied, 68.57 per cent showed pigmentation at node.
11. Genotypes like CA 25 and CA 21 were early in flowering (<35 days) and fruiting (<40 days) whereas CC 1, CC 2, CC3 were late in flowering (>70 days) and fruiting (>75 days).
12. Fruit characters varied highly among the genotypes studied. Mature fruit colour varied from light green (40%) to green (40%) to dark green (20%).
13. Ripe fruits were red in colour in majority of genotypes (54.28%) whereas some genotypes recorded light red (37.14%) and dark red (8.57%) coloured ripe fruits.
14. Fruit shape varied *viz.* Long, long and tapering, long and curved, long and blunt edged, very long and conical.
15. Fruit surface varied from smooth (37.14%) to semi wrinkled (22.85%) and wrinkled (40%)
16. Most of the genotypes (80%) recorded pendulous nature of fruit position and some recorded semi pendulous (11.42%) and erect (8.57%) nature of fruit position.
17. Fruit pedicel length was highest in CA 21 (4.01 cm) and lowest in CA 1 (1.14).
18. Fruit length varied from 3.85 cm (CC 1) to 12.3 cm (CA 29). Genotypes like CA 29, CA 31 and CA 32 were extra long (>11 cm). Fruit length was positively and significantly correlated with fruit weight, placenta length, pericarp weight and yield. Generally fruits of *Capsicum chinense* were shorter compared to *C. annuum.*

19. Five genotypes namely CA 23, CA 29, CC 1, CC 2 and CA 3 recorded a fruit width of more than 1.9 cm whereas minimum fruit width was observed in CA 14 (0.61 cm). Correlation studies revealed that fruit width contributed positively and significantly contributed to fruit weight, placenta weight, pericarp weight and pericarp thickness whereas no significant correlation was found between fruit width and yield.
20. Among the thirty five genotypes studied, individual fresh fruit weight varied from 2.31g to 13.31 g and three genotypes(CA 23, CA 29 and CA 32) performed better (>10g per fruit).Correlation analysis revealed positive and significant correlation of fruit weight to fruit length, fruit width, placenta length, placenta weight, pericarp weight, pericarp thickness, dry yield and a significant negative correlation with respect to number of fruits per plant, driage and oleoresin content.
21. Seed colour varied from deep yellow (57.14%) to light yellow (34.28%) and light brown (8.57%)
22. Placenta length varied from 3.85 cm (CC 1) to 12.3 cm (CA 29). Genotypes like CA 29, CA 31 and CA 32 recorded extra long placenta length (>11 cm).
23. Placenta weight varied from 0.09 g to 1.75 g and CA 23 recorded highest placenta weight. Correlation analysis indicated significant and positive correlation of placenta weight with fruit length, fruit width, fruit weight, placenta length, pericarp weight and pericarp thickness, whereas number of fruits, driage and oleoresin content were significantly and negatively correlated
24. Number of fruits per plant is an important economic character and more than forty fruits per plant were observed in CA 7, CA 22, CA 19 and CA 25. Minimum number of fruits was observed in CA 29 and CA 24 (less than fifteen fruits per plant). Correlation studies revealed positive correlation between number of fruits and yield indicating that fruit number is the primary contributor for yield in chilli. Number of fruits was found negatively correlated to plant height, fruit length, fruit width, fruit

weight, placenta length, placenta weight, pericarp weight and pericarp thickness. Negative correlation with plant height indicates the possibility for more number of fruits per plant in those genotypes with reduced plant height.

25. Pericarp weight varied from 2.01 g (CA 8) to 11.01g (CA 23). The variation in the pericarp weight mostly depends on fruit characters. High fruit width and pericarp thickness contributes to highest pericarp weight. Correlation analysis revealed that pericarp weight is significantly and positively correlated to fruit length, fruit width, fruit weight, placenta length, placenta weight, pericarp thickness, dry yield, while driage and number of fruits per plant are negatively correlated. Pericarp weight is positively correlated with capsaicin content and colour value (though not significant).
26. Pericarp thickness varied from 0.25 mm (CA 8) to 2.56 mm. Correlation analysis revealed significant positive correlation of pericarp weight with fruit width, fruit weight and placenta weight. Positive correlation was observed with capsaicin, oleoresin and colour value (though not significantly) and negative correlation with pericarp thickness and driage.
27. Maximum seed number per fruit was observed in accession CA 23 (125.8) followed by CA 29 (95.2) and CA 25 (89.9) and minimum in CC 3 (17.8) followed by CC 1 (20.7) and CC 2 (24.4).
28. Dry weight per fruit varied from 0.3 g (CA 14) to 1.96 g (CA 23). Genotypes namely CA 23, CA 13 and CA 29 recorded highest individual dry weight (>1.4g).
29. Yield per plant is an important objective in any crop improvement programme. Fruit length, fruit width, fruit weight and number of fruits highly contributed to total yield per plant. In the present investigation, fresh yield per plant ranged from 39.72 g (CA 26) to 318. 6 g (CA 32) and dry yield per plant ranged from 5.6 g (CA 14) to 47.53g (CA 13). Dry yield per plant established a strong significant positive correlation with yield contributing parameters *viz.*, fruit length, fruit weight, placenta

length, number of fruits per plant and pericarp weight indicating the usefulness of these characters for improving fruit yield.

30. Among the genotypes studied, CA 26 recorded maximum driage (39.51 %) followed by CA 10 (36.53 %) and CA 12 (33.6 %) and accession CA 14 recorded minimum driage (7.14 g).
31. Bacterial wilt was the major disease observed in field and considerable variability was recorded for the disease incidence ranging from 0 % to 85 %. Most of the released varieties were wilt prone while most of the local genotypes were resistant to bacterial wilt as seen in CC 1, CA 22, CA 23, CC 2 and CC 3. The highest wilt incidence (85%) was observed in CA 15 followed by CA 14 (70%).
32. Considerable variability exists among different genotypes for capsaicin content. In the present study, the highest capsaicin content was recorded for CC 2 (1.09 %) which was on par with CC3 (1.06 %) followed by CC 1 (1.04 %), CA 25 (0.95 %) and CA 16 (0.91%) respectively. The lowest capsaicin content was recorded for CA 6 (0.11%) followed by CA 26 (0.18%) and CA 9 (0.20%) respectively. From the current investigation it is observed that capsaicin content of *Capsicum chinensis* are higher compared to *capsicum annuum.* Correlation analysis revealed that capsaicin content is positively and significantly correlated to fruit width, number of fruit per plant, dry yield and oleoresin content.
33. Oleoresin represents complete extract of total flavour, colouring matters and pungent principles and it consists of essential oil, natural colourants, waxes, alkaloids *etc*. The maximum content of oleoresin was observed in CC 2 (27.5 %) followed by CC 3 (25.50 %), CA 16 (25.25 %), CC 1 (24.00 %) and CA 1 (22.50 %). Content of oleoresin was minimum in CA 23 (7.50 %) followed by CA 14 (9.60 %). Correlation studies revealed that positive and significant correlation of oleoresin with dry yield and capsaicin content while significant negative correlation was found with respect to fruit length, placenta length and placenta weight.

34. In the present study colour value ranged from 26.07 (CA 15) to 131.91 ASTA units (CA 31). It was not significantly correlated with any of the characters studied which implies that colour is highly dependent on genotypic factors. Genotypes *viz.*, CA 31,CA 30, CA 8,CA 32, CA 2, CA 5, CA 6, CA 11, CA 13, CC 1, CC 22, CC 23 and CC 2 obtained a colour value of more than 100 ASTA units.

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Appendices

NBPGR descriptor for chilli (*Capsicum* spp)

1. Life cycle

    1 Annual
    2 Biennial
    3 Perennial

2. Stem colour

    To be recorded at full foliage stage
    1 Green
    2 Green with purple stripes
    3 Purple
    99 Others (Specify in the 'Remarks' descriptor)

3. Plant height (cm)

    To be recorded as average of 5-10 random plants when the first fruit in 50% of the plants began to ripe

    Quantitative

4. Plant canopy width (cm)

    To be recorded simultaneously with height
    Quantitative

5. Plant growth habit

    To be recorded at fruit maturity (see figure on page 46)
    3 Prostrate
    5 Intermediate
    7 Erect
    99 Others (Specify in the 'Remarks' descriptor)

6. Branching habit

    To be recorded when plants have ceased its growth
    3 Sparse
    5 Intermediate
    7 Dense

99 Others (Specify in the 'Remarks' descriptor)

7. Leaf size

To be recorded at full foliage stage
3 Small
5 Medium
7 Large
99 Others (Specify in the 'Remarks' descriptor)

8. Leaf shape

To be recorded at full foliage stage (see figure on page 49)
1 Deltoid
2 Ovate
3 Lanceolate
99 Others (Specify in the 'Remarks' descriptor)

9. Leaf margin

To be recorded at full foliage stage

1 Entire
2 Undulate
3 Ciliate
99 Others (Specify in the 'Remarks' descriptor)

10. Leaf colour

To be recorded at full foliage stage
1 Green
2 Dark green
3 Purple
99 Others (Specify in the 'Remarks' descriptor)

11. Leaf pubescence

To be observed on the youngest mature leaf
0 Absent
3 Sparse
5 Intermediate
7 Dense
99 Others (Specify in the 'Remarks' descriptor)

12. Pigmentation at node
To be observed on the youngest mature leaf
0 Absent
1 Present
13. Days to 50% flowering
To be recorded _as number of days from date of transplanting to date when at least 50% plants show first flower open
Quantitative
14. Number of flowers per axil

To be observed as average of 5-10 random axils at flowering stage
1One
2 Two
3 Three or more
99 Others (Specify in the 'Remarks' descriptor)

15. Corolla colour

To be recorded immediately after blooming
1 White
2 Yellow
3 Purple
99 Others (Specify in the 'Remarks' descriptor)

16. Days to 50% fruiting

To be recorded as number of days from the date of transplanting to the date when at least 50% plants bear fruiting
Quantitative

17. Mature fruit colour

To be recorded at mature fruit stage
1 White
2 Yellow
3 Green
4 Orange
5 Purple
6 Deep purple
7 Black
99 Others (Specify in the 'Remarks' descriptor)
21. Ripe fruit colour

To be recorded on ripe fruits
1 White
2 Lemon yellow
3 Pale orange yellow
4 Orange yellow
5 Pale orange
6 Orange
7 Light red
8 Red
9 Dark red
10 Brown
11 Purple
12 Black
99 Others (Specify in the 'Remarks' descriptor)

18. Fruit shape

To be recorded at mature fruit stage
1 Long
2 Very long
3 Tapering
4 Conical
5 Oval
99 Others (Specify in the 'Remarks' descriptor)
23. Fruit length (cm)
To be recorded as average of 5-10 random fruits
Quantitative

19. Fruit width (cm)

To be recorded as average of same 5-10 fruits
Quantitative
25. Fruit position
To be recorded at mature fruit stage
3 Pendent
5 Semi pendent
7 Erect
99 Others (Specify in the 'Remarks' descriptor

20. Fruit pedicel length (cm)

(3)

To be recorded as average of same 5~ 10 fruits at marketable stage
Quantitative

21. Fruit surface

To be recorded at mature fruit stage
1 Smooth
2 Semi wrinkled
3 Wrinkled
99 Others (Specify in the 'Remarks' descriptor)

22. Fruit yield per plant (g)

To be recorded as average of cumulative yield of all pickings at mature green fruit stage of same 5-10 plants
Quantitative

23. Fruit weight (g)

To be calculated on the basis of fruit yield and number of fruits per plant
Quantitative

24. Seed colour

To be recorded at dry seed stage
1 Light yellow -
2 Deep yellow
3 Brown
4 Black
99 Others (Specify in the 'Remarks' descriptor)

25. Number of seeds per fruit

To be recorded as average number 5-10 'random fruits at ripen stage
Quantitative

26. Biotic stress susceptibility

Specify the infestation or infection using any 1-9 scale.
Note: For Additional information as common name(s) of disease(s)/pest(s) and casual organism(s) may be appended in the Biotic notes descriptor.
1 Very low or no visible sign of susceptibility
3 Low
5 Intermediate
7 High
9 Very high

SCREENING OF SPICE CHILLI (*Capsicum annuum* L) GENOTYPES SUITABLE FOR KERALA

By

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(2014-12-111)

ABSTRACT OF THE THESIS

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ABSTRACT

Chilli (*Capsicum* spp.) is the third most important spice crop of the world. Among the five cultivated species, *Capsicum annuum* is the most widely cultivated and traded species in India. Chilli exhibits wide range of genetic diversity and cultivated for various uses either for marketing as green chillies in fresh form (green, red, multicolour whole fruits), processed products (sauce, paste, canned chilli, pickles *etc*.), dried spice (whole and ground form) or industrial extracts (oleoresin, capsaicinoids, carotenoids). At present chilli is not cultivated for dry or spice purpose in Kerala and our requirement is met from nearby states of Karnataka and Andhra Pradesh.

Bacterial wilt is the main problem faced in the cultivation of chilli in Kerala and already proven high yielding varieties may not be suitable to Kerala conditions. Identification of spice chilli types suitable for warm humid tropics of Kerala will pave way for promoting and popularizing their large scale cultivation in Kerala. In this context, the present study entitled "Screening of spice chilli (*Capsicum annuum*L.) genotypes suitable for Kerala" was under taken with the objectives of evaluation of chilli accessions for morphological characters and biochemical characters and identifications of types with processing qualities that can be used as spice chilli.

Materials used in this study consist of 35 genotypes including indigenous types and released varieties of chilli. In the morphological characterization twenty quantitative and ten qualitative characters were recorded from two replications. Fruits of all the genotypes were subjected to biochemical analysis of capsaicin content, oleoresin content and colour value and wide variability was observed for both morphological and biochemical characters.

Among the genotypes CA 22, CA 27, CA 28 and CA 29 were found taller (more than 100 cm) and CA 31 was the shortest with a plant height of less than 50 cm, CA 27 had highest leaf length and CA 6 recorded highest leaf breadth. Genotypes like CA 25 and CA 21 were early in flowering (less than 35 days) and fruiting (less than 40 days) whereas CC 1, CC 2 and CC3 were late in flowering (more than 70 days) and fruiting (more than 75 days).Distinct variation was observed for fruit characters *viz* fruit length (3.9 cm – 12.3 cm), fruit width (0.61cm - 2.32 cm), fruit weight (2.31 g – 13.31 g), number of fruits per plant (11.9 – 45.4), dry yield per plant (5.6g - 47.53 g) *etc.*Three genotypes (CA 23, CA 29 and CA 32) performed better with individual fruit weight of more than 10g.Number of fruits per plant is an important economic character and more than forty fruits per plant were observed in CA 7, CA 22, CA 19 and CA 25. In the present investigation, fresh yield per plant ranged from 39.72 g (CA 26) to 318. 6 g (CA 32) and dry yield per plant ranged from 5.6 g (CA 14) to 47.53g (CA 13). Among the genotypes, CA 26 recorded maximum driage (39.51 %) and minimum driage was recorded in CA 14 (7.14 %). High driage (more than 30%) was obtained in CA 26, CA 10, CA 12 and CA 31. Considerable variability was observed with respect to qualitative characters like leaf colour (light green to dark green), mature fruit colour (light green to dark green), ripe fruit colour (light red to dark red), fruit shape (elongated and tapering to conical), fruit surface (smooth to wrinkled) and seed colour (light yellow to dark yellow) where as no variability was observed for corolla colour. Bacterial wilt was the major disease observed in field and considerable variability was recorded for the disease incidence ranging from 0 % to 85 %. Most of the released varieties were wilt prone except KAU varieties while most of the local genotypes were tolerant to bacterial wilt as seen in CA 22, CA 23, CC 1, CC 2 and CC 3. The highest wilt incidence (85%) was observed in CA 15 followed by CA 14 (70%).Biochemical analysis revealed that CA 25 (0.95%) and CA 16 (0.91%) were highly pungent among *Capsicum annnuum*typeswhere asamong *Capsicumchinense* types, the highest capsaicin content was recorded for CC 2 (1.09 %). CA 16,CA 1, CC 2 and CC 3 had high oleoresin recovery (more than 25%) whereas CA 31, CA 30, CA 8 and CA 32 recorded high colour value (more than 100 ASTA units).

Correlation and clustering analysis was done between fruit and yield contributing characters. Correlation analysis indicated that fruit weight was significantly and positively contributed to fruit length and width, placenta length and weight pericarp weight and thickness and dry yield.It is revealed that fruit weight and number of fruits per plant are the important yield contributing parameters.

Cluster analysis is an appropriate method for determining the genetic diversity. Based on cluster analysis, all the thirty five chilli genotypes under the study were grouped into eight clusters with significant variation among the clusters and within clusters for different character studied. Cluster 2, cluster 4 and cluster 8 were distinct from other clusters.

Based on the study, a few genotypes were found promising as spice chilli (CA 13, CA 16, CA 22, CA 25, CA 27 and CA 28), vegetable chilli (CA 3, CA 7, CA 8, CA 9, CA 10, VA 11, CA 12, and CA 23) and for industrial purpose (CA 16, CA 25, CC 1, CC 2 and CC 3).